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# Sustainability: The Big Challenge

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**Abstract**

Reducing greenhouse gas emissions, especially carbon-dioxide emissions, has been an agenda adopted by organizations, governments, businesses and citizens alike all over the world over the last few decades. Energy efficiency, energy conservation and renewable or alternative energy sources to lower in greenhouse gas emissions has been the most popular approach taken by various organizations, governments and individuals to reduce their carbon footprint. Being energy efficient and reducing energy consumption has not only started making business sense but increases reliability and availability of infrastructure. Introducing an environmentally friendly energy source provides a certain level of energy security by reducing dependence on depleting fossil fuel energy sources and purely by diversifying the approach of diversity in the utilization of energy sources (energy mix). However, when looking at the penetration of energy efficiency into the world's built environment and the much needed decrease in reliance on fossil fuel sources for driving energy, there is a definite challenge in that it does not seem to get the priority that it requires to arrest the exponential increase in carbon emissions causing climate change. This paper presents the impact of greenhouse gas emissions together with its role in climate change and highlights the key factors to sustain the change in direction towards energy efficiency and minimization of the use of fossil fuel-based energy sources towards energy security. The result of application of the approach presented will be a reduction in carbon emissions through changing technologies, markets, legislation, personnel and resource availability

**Keywords:** Energy efficiency, energy security, developing countries, sustainability

## I. INTRODUCTION

The challenge of climate change needs to be contextualized for it to be given the priority it requires to ensure that its potential effects do not become a reality in the near future. Climate change threatens the delicate balance in the earth's biosphere to sustain biological life and thus the survival of the human species as we know it.

The conditions required for the viability of are summarized by [1] as follows: "Liquid water is the common ecological requirement for earth life. Temperature on an exoplanet is the first parameter to consider both because of its influence on liquid water and because it can be directly estimated from orbital and climate models of exoplanetary systems. Life needs some water, but deserts show that even a little can be enough. Only a small amount of light from the central star is required to provide for photosynthesis. Some nitrogen must be present for life and the presence of oxygen would be a good indicator of photosynthesis and possibly complex life" [1]. An essential component to life as we know it is temperature. The term "climate change" is used in reference to the upsetting of this delicate temperature balance which is the main reason for the focus on reducing our impact on climate change.

The earth's average temperature has been experiencing anomalies threatening the sustainability of life as we know it. Fig. 1 shows that since 1980 we have been experiencing an increase in temperature without any signs of a recovery. The earth's temperature is regulated by the presence of greenhouse gases in its atmospheric layer. The increase in the earth's temperature can be accounted for by an increase in concentration of greenhouse gases in the earth's atmosphere earlier in earth's history. Fig. 2 shows the corresponding increase in carbon dioxide ($CO_2$) emissions.

On earth, an atmosphere containing naturally occurring amounts of greenhouse gases causes air temperature near the surface to be warmer by about 33 °C (59 °F) than it would be in their absence [2]. Without the earth's atmosphere, the earth's average temperature would be well below the freezing temperature of water [3]. The major greenhouse gases are water vapor, which causes about 36 % to 70 % of the greenhouse effect; $CO_2$, which causes 9 % to 26 %; methane (CH4), which causes 4 % to 9 %; and ozone ($O_3$), which causes 3 % to 7 % [4][5][6].

"Carbon dioxide ($CO_2$) is known as a greenhouse gas (GHG)—a gas that absorbs and emits thermal radiation, creating the 'greenhouse effect'. Along with other greenhouse gases, such as nitrous oxide and methane, $CO_2$ is important in sustaining a habitable temperature for the planet: if there were absolutely no GHGs, our planet would simply be too cold. It has been estimated that without these gases, the average surface temperature of the Earth would be about -18 degrees Celsius." [12]

"Since the Industrial Revolution, however, energy-driven consumption of fossil fuels has led to a rapid increase in $CO_2$ emissions, disrupting the global carbon cycle and leading to a planetary warming impact. Global warming and a changing climate have a range of potential ecological, physical and health impacts, including extreme weather events (such as floods, droughts, storms, and heatwaves); sea-level rise; altered

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crop growth; and disrupted water systems." [12]

To ensure that we are addressing the cause of climate change, it is essential that we are aware of which of the greenhouses gas or gases are responsible for this and then look for which activities are contributing to the unnatural increase in concentration. Fig. 3 shows the history of concentrations of greenhouse gas emissions in the atmosphere. Fig. 4 shows the global warming potential (GWP) of each greenhouse gas relative to carbon-dioxide. From these figures one can see that $CO_2$ has increased at a rate exceeding those of the other greenhouse gases, indicating the likelihood of gas being the cause of the increase in global temperature. Now that we have established that the release of $CO_2$ is responsible for the temperature increase through global warming, it is the next step to investigate the cause of the increase in $CO_2$.

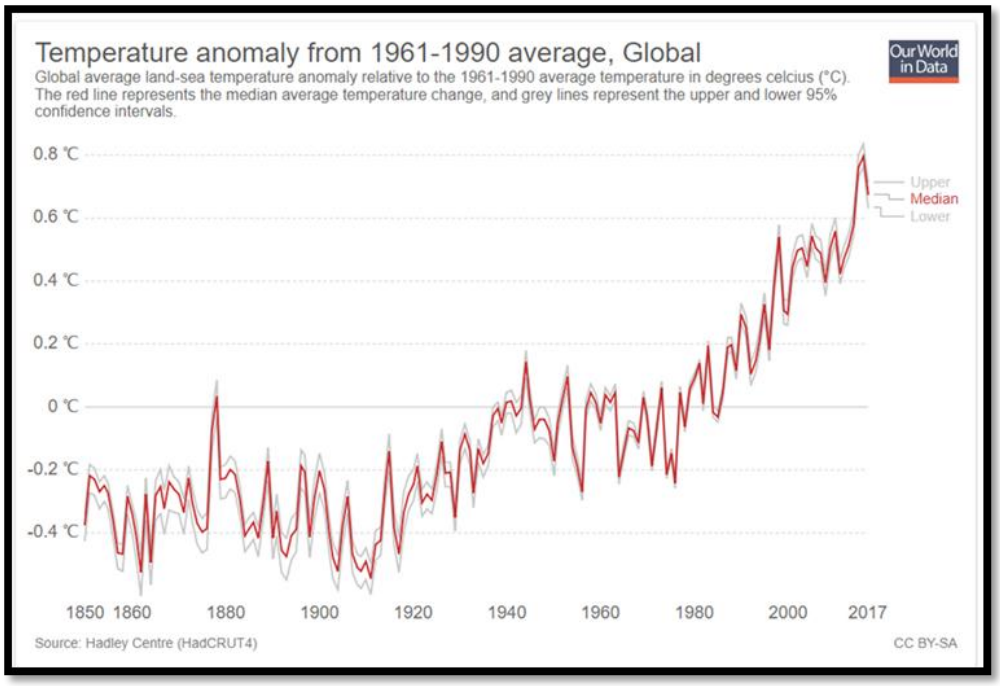


**Fig. 1.** Earth's temperature anomaly over time [12]

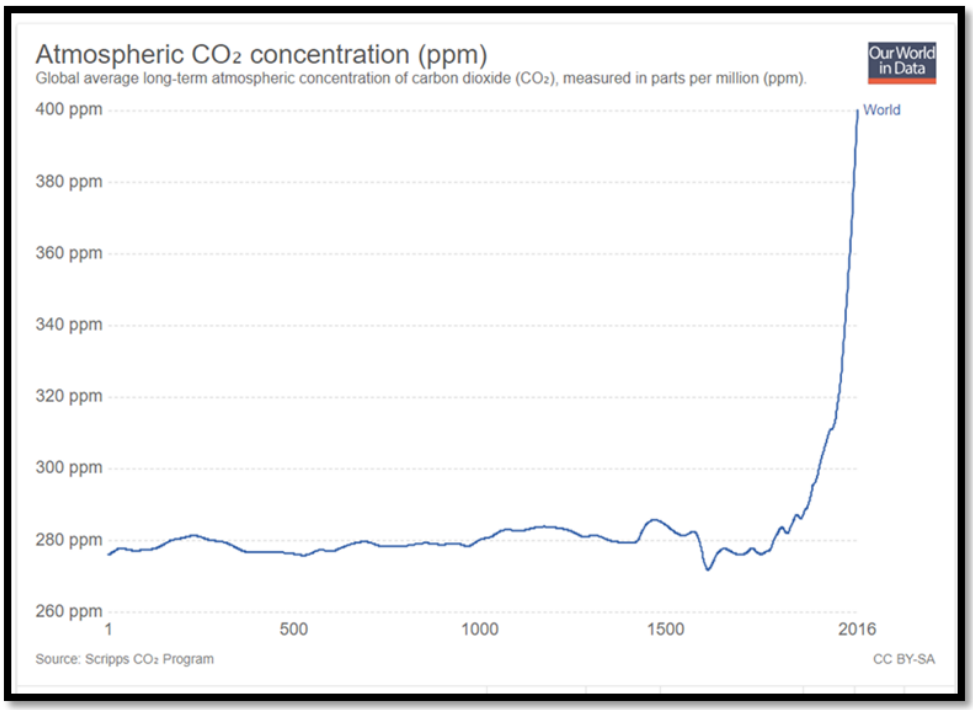


**Fig. 2.** Increase in concentration of $CO_2$ in the atmosphere [12]

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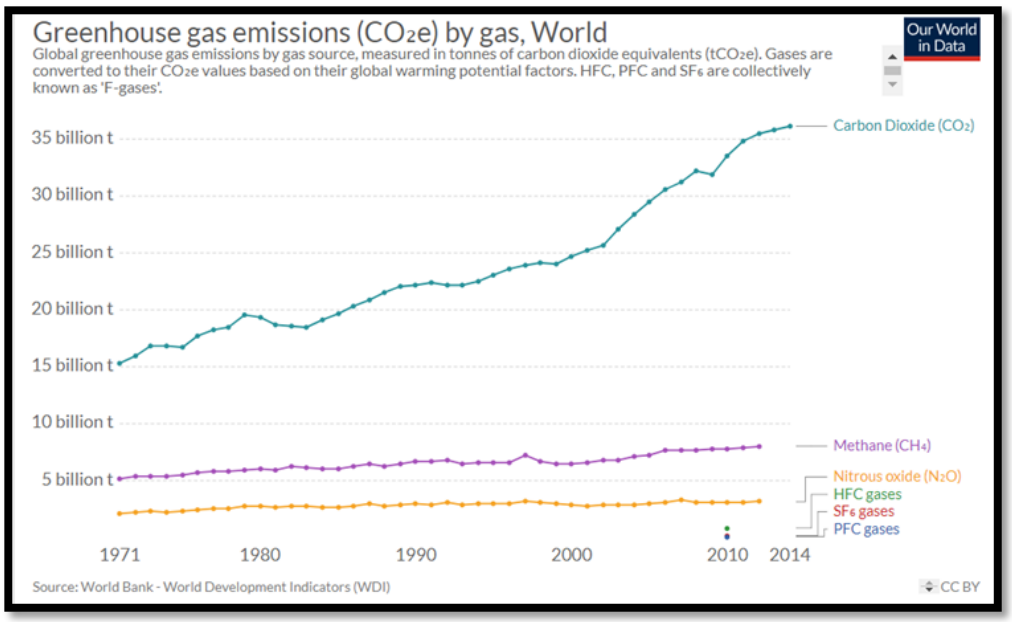


**Fig. 3.** Global greenhouse gas emissions by gas source [12]

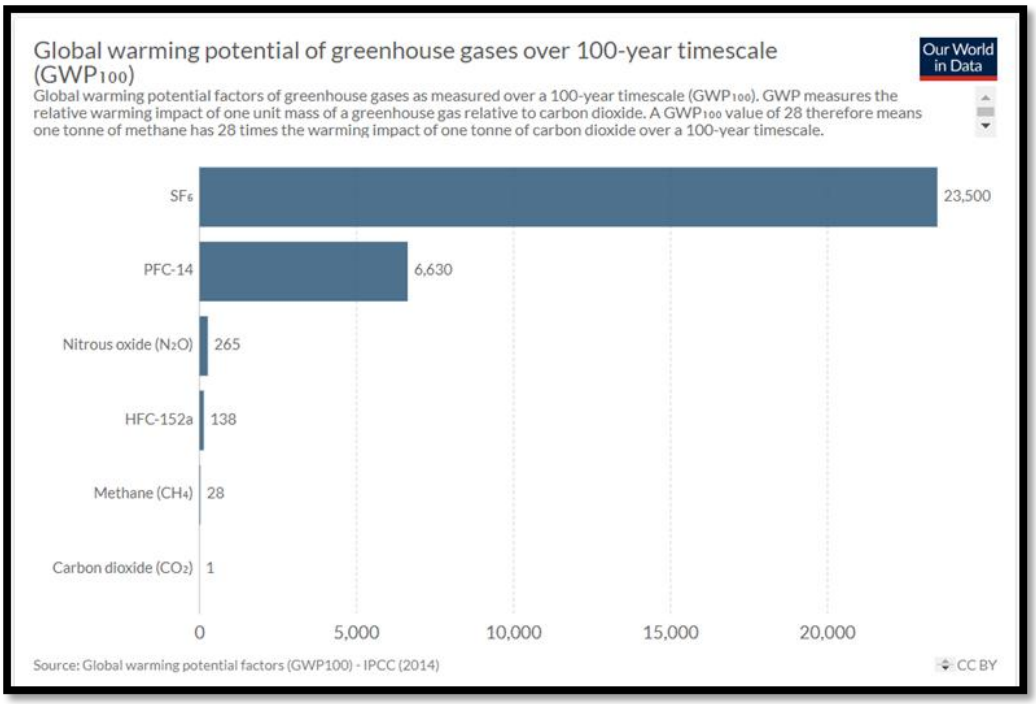


**Fig. 4.** Global warming potential of greenhouse gases relative to carbon-dioxide [12]

Human activity since the industrial revolution has increased the amount of greenhouse gases in the atmosphere, leading to increased radiative forcing from $CO_2$, methane, tropospheric ozone, CFCs, and nitrous oxide. According to work published in 2007, the concentrations of $CO_2$ and methane have increased by 36 % and 148 % respectively since 1750 [7]. These levels are much higher than at any time during the last 800 000 years, the period for which reliable data has been extracted from ice cores [8][9][10][11]. Less direct geological evidence indicates that $CO_2$ values higher than this were last seen about 20 million years ago. From Fig. 3, one observes the change in $CO_2$ levels and methane levels from 1971 to 2014.

The industrial revolutions experienced in our known history of civilization can be pictorially seen in Fig. 5. In the pre-industrial era natural power (wind, water, draft), animal and human muscle power were used for the manufacturing of goods for human consumption. The need for convenience coupled with key discoveries of energy sources and technologies started the industrial revolution. Over time this "created energy" became more intense and created greater efficiencies in that more human activity was possible per unit of energy available.

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This journey, however, has led to the disruption of the natural balance of the fundamental parameters for earth life to sustainably sustain itself.

With the birth of the industrial revolution competitiveness in survival moved from physical conquering (or overpowering through physical force) and colonization to trading and negotiations of relative worth of goods and services. Figure 6 shows the description of the constituent parts of business sustainability. "Business sustainability is often defined as managing the triple bottom line - a process by which companies manage their financial, social and environmental risks, obligations and opportunities. These three impacts are sometimes referred to as profits, people and planet." [14].

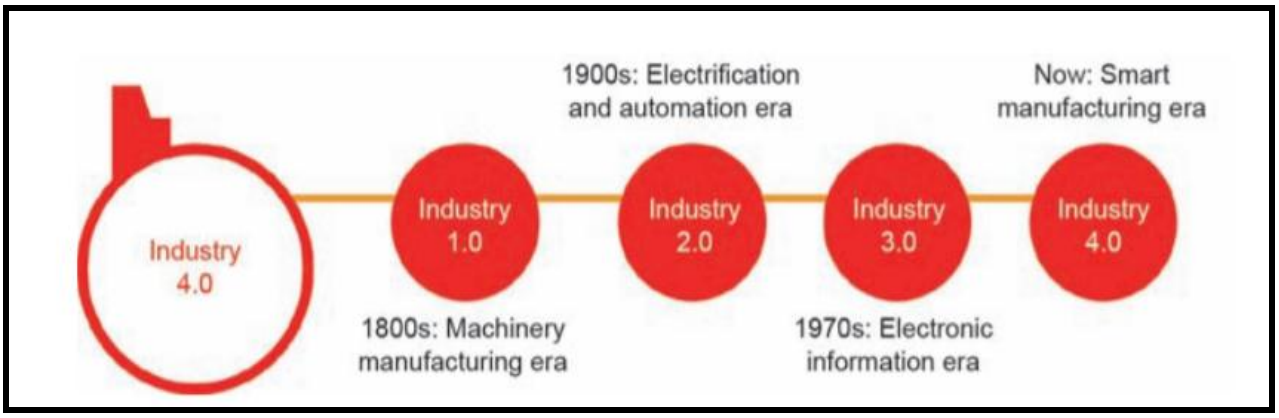


**Fig. 5.** Four stages of the industrial revolution [13]

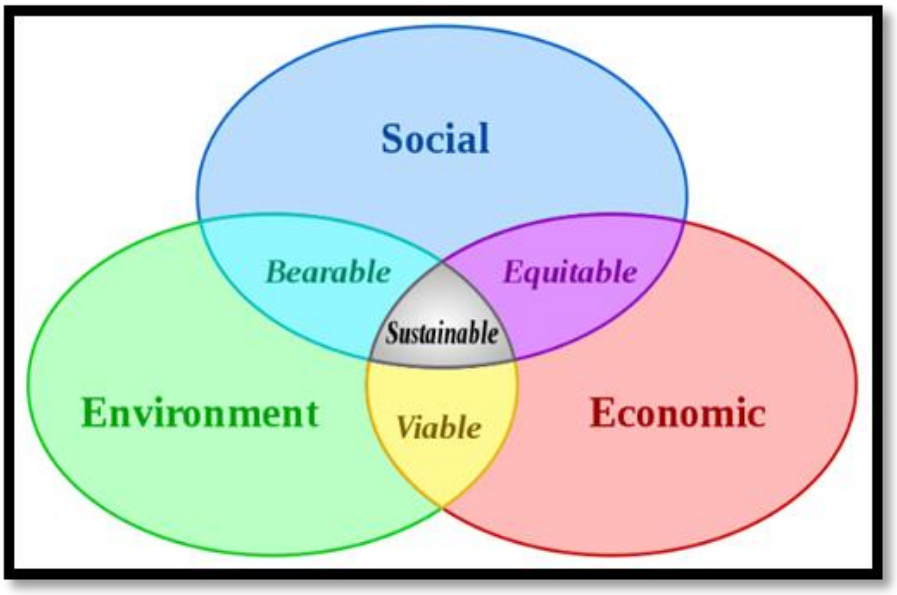


**Fig. 6.** Venn diagram – elements of business sustainability [15]

## II. DEFINING SUSTAINABILITY

The heart of sustainable development and business sustainability requires the sustainability in each dimension of economic, social and environmental factors to merge on common ground and operate in the "sustainable" zone as can be seen in Figure 6. Currently, the majority of the world's countries, policies, strategies and legislation favor trade and investment to enable their citizens and inhabitants to have a competitive advantage without much consideration for the constraints of the natural resources that make trade and investment possible.

The current business sustainability mesh works such that the economic wheel is designed to serve the social dimension of human needs and desires while environmental considerations have a low priority. Recently there has been an increasing awareness of the sustainability of human society hinging on the precise balance of the ecological environment.

The distribution of the earth's natural resources to the human species for their survival, convenience and competitive advantage is regulated by the created human financial economy where trading power is at the heart of the economy. Prior to civilization, colonization and physical force on existing

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inhabitants were used to secure resource abundant land which would enable goods and services and consequently competitive advantage as can be seen with the first and second world wars. With the scientific discoveries that led to the birth of technology, trading power became the new competitive advantage as war that resulted in physical death of the opposition was not an effective way to gain economic advantage. This adaptation of the human species was a shift in their method of sustaining their social and economic status. The following three sections will investigate the key factors at play in the environmental, social and economic dimensions.

### *A. Environmental factors*

Environmental science is the study of the interaction between natural and human systems. Humans use the land, water elements and energy for their needs, survival and convenience, in the process causing pollution and resulting in the acceleration of climate change (Fig. 7).

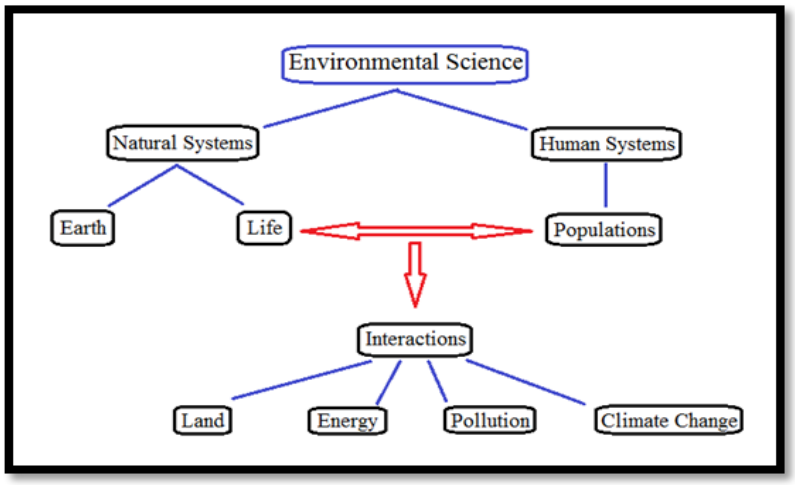


**Fig. 7.** Environmental Science: the interaction between Natural and Human Systems

Humans, purely by their presence, leave an environmental footprint on this planet, and industrialization increases this environmental impact as they manipulate the environment to suit their needs. Scientists over the years have developed what we call "planetary boundaries" that allow us to benchmark the impact of our existence and activities on a scale that compares the key planetary parameters that regulate life as we know it to before the significant impact of human existence and how far away we are from significantly altering the current planetary life (Fig. 8).

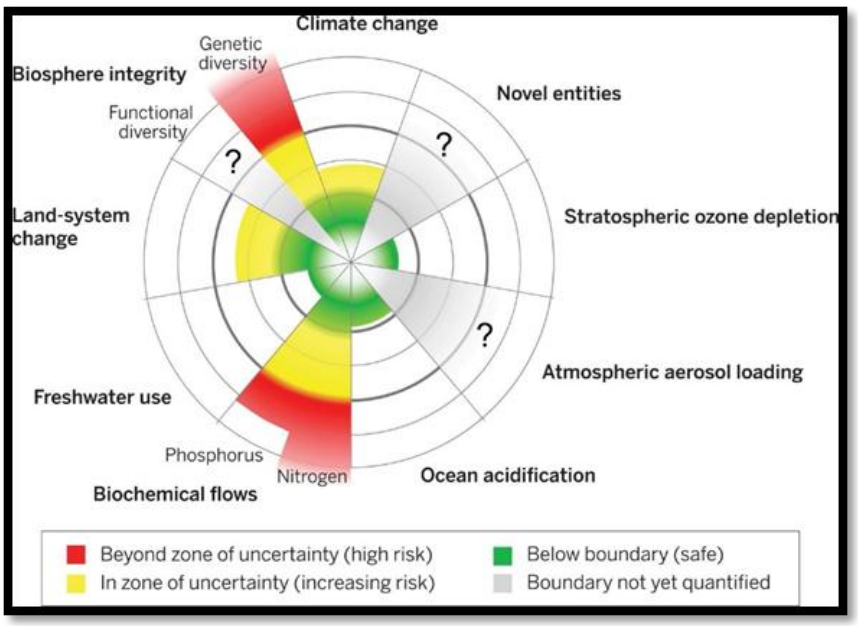


**Fig. 8.** Current status of the control variables for seven of the planetary boundaries [16]

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The planetary boundaries framework defines a safe operating space for humanity based on the intrinsic biophysical processes that regulate the stability of the earth system [16]. As can be seen in Fig. 8, there are nine planetary boundaries which, if altered for a period of time, will cause our planet to change compared to how we know it now. These nine boundaries, climate change, novel entities, stratospheric ozone depletion, atmospheric aerosol loading, ocean acidification, biochemical flows, freshwater use, land system change, biosphere integrity have close interactions with each other in that a change in one planetary boundary will automatically mean changes in another planetary boundary. Fig. 9 shows the interactions between the biosphere and the nine planetary boundaries.

An analysis of the many interactions among the boundaries suggests that the parameters of climate change and biosphere integrity are highly integrated, emergent system-level phenomena that are connected to all the other planetary boundaries. They operate at the level of the whole earth system and have co-evolved for nearly 4 billion years. They are regulated by the other boundaries and, on the other hand, provide the planetary-level overarching systems within which the other boundary processes operate. Furthermore, large changes in the climate or in biosphere integrity would likely, on their own, push the earth system out of the holocene state. The Holocene state refers to the current geological state that the earth finds itself in. Transitions between time periods in earth history have often been delineated by substantial shifts in climate, the biosphere, or both [16].

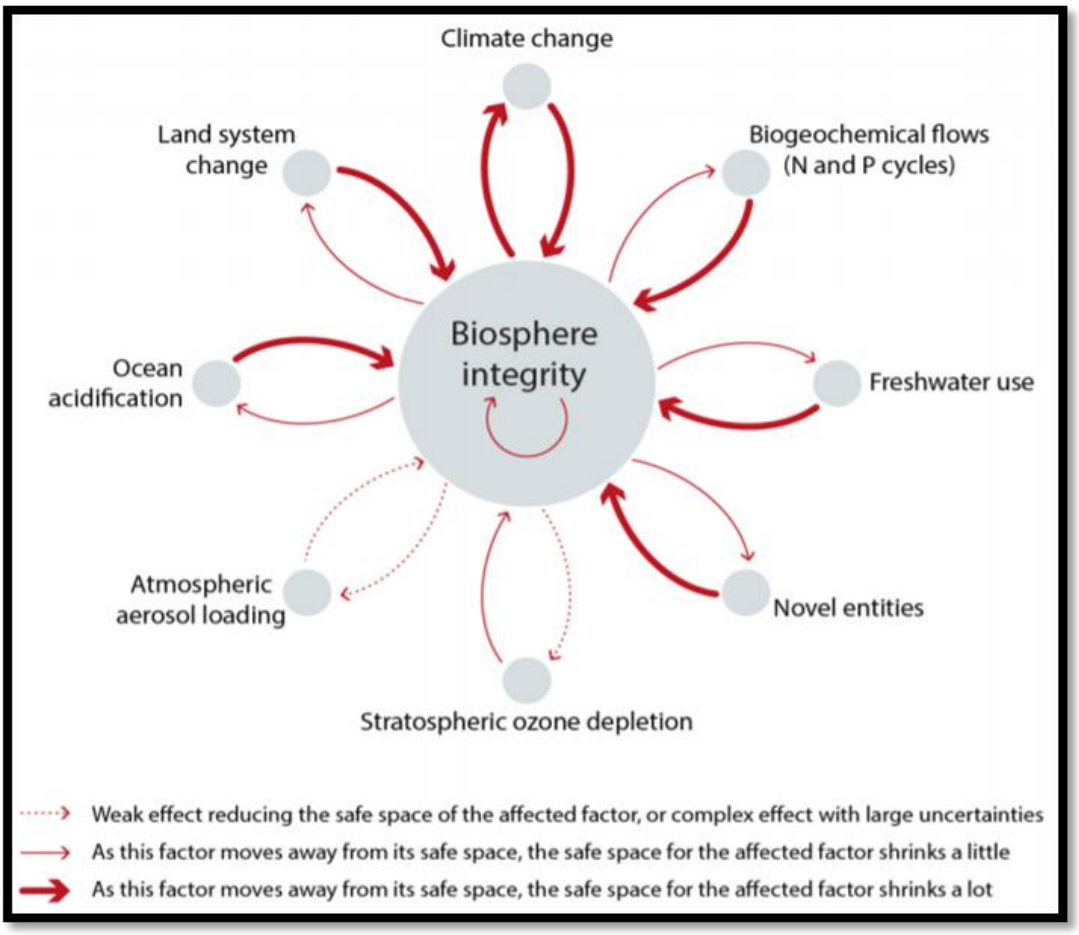


**Fig. 9.** The interaction between the biosphere integrity planetary boundary and other planetary boundaries [16]

One can see from Fig. 9 that the interaction with the planetary boundary of the biosphere integrity is linked directly with six other planetary boundaries the strongest of which is climate change, in both directions, i.e. climate change causes biosphere change and biosphere change causes climate change.

The key variable influencing climate change is generally expressed as a maximum concentration of $CO_2$ in the atmosphere of 350 ppm, a value that would likely preserve the climate in a Holocene-like state. Atmospheric $CO_2$ concentrations currently exceed 400 ppm. As an alternative boundary to 350 ppm, one can use the 2 °C temperature stabilisation goal emphasised in the Paris Agreement. [17] The Paris Agreement proposed to keep the increase in global average temperature to below 2 °C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 °C above pre-industrial levels.

The other variable causing climate change is the increase in top-of-atmosphere radiative forcing of +1.0 W/m$^2$ relative to

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preindustrial levels. Radiative forcing or climate forcing is the difference between insolation (sunlight) absorbed by the earth and energy radiated back to space. There are other greenhouse gases that have global warming potential, however, the one most prevalent in terms of human activity and increase over the past century is $CO_2$ Fig. 2 and Fig. 3). The increase in $CO_2$ emissions in earth's atmosphere is due to the combustion of fuels from which the human species derive energy to drive their machinery, produce goods and commute across the planet.

*B. Social Factors*

The dictionary definition relates the term 'social factors' is "human society, the interaction of the individual and the group, or the welfare of human beings as members of society" [18]. A social construction is built around serving human needs and wants and these are characterized in Maslow's hierarchy of needs as depicted in Figure 10.

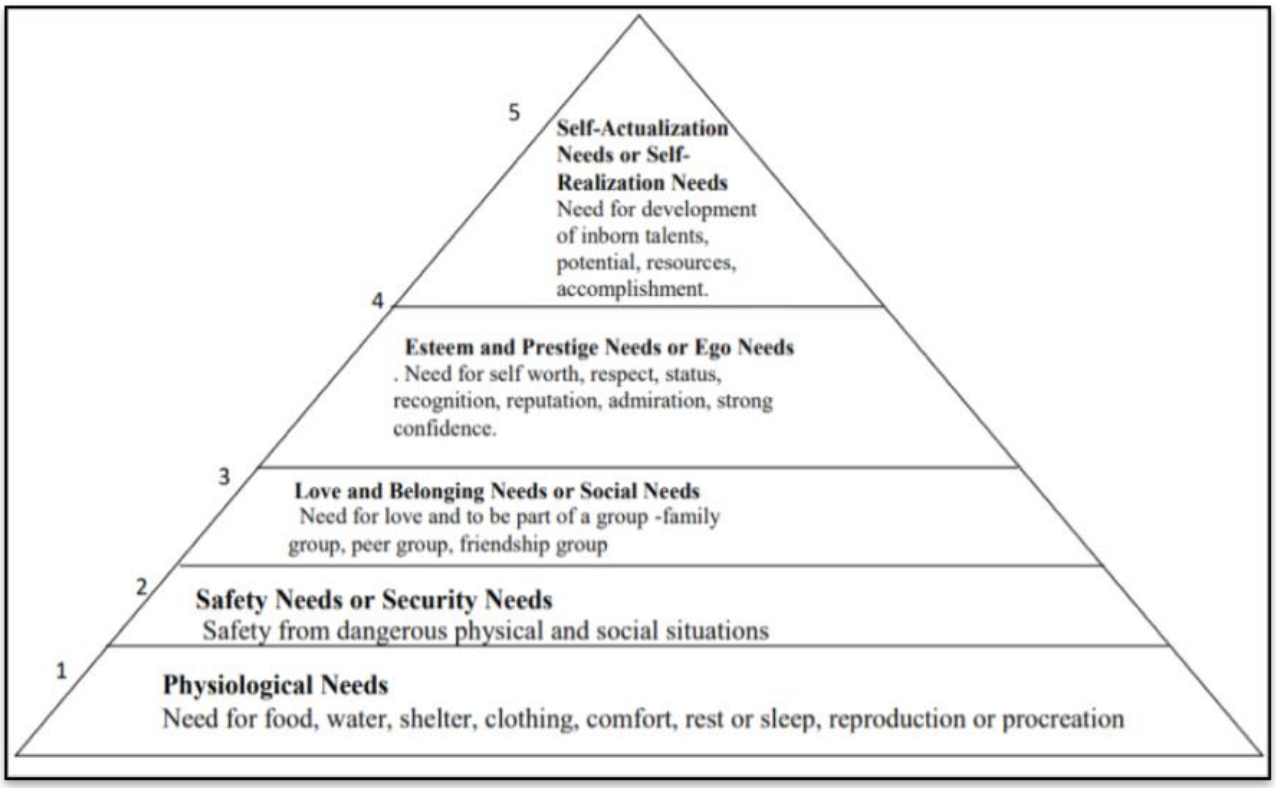


**Figure 10:** Abraham Maslow's hierarchy of needs [19]

There are several descriptive definitions of what social sustainability entails. Social sustainability can be described as equity in resource distribution, which, from a livelihood perspective, is regarded as the capacity of the human species not only to get access to but also to maintain an adequate and decent livelihood. There are two dimensions of the definition of social sustainability, namely the proactive approach that indicates the capabilities of adapting to, exploiting and creating change and ensuring continuity (positive dimension). The reactive dimension highlights the coping ability to deal with shocks and stresses (negative dimension) [20].

Social sustainability can be visualized as the improvement of living conditions for people and future generations and the quality of governance of the development process. The social pillar of sustainable development can thus be seen as including both procedural aspects and substantive aspects. The procedural aspects include the role of democratic representation, participation, and deliberation and the substantive aspects focus on "what" is to be done (i.e., the social goals of sustainable development). The procedural aspects include the "how" or the means to achieve these goals. Procedures cannot be static but should always include a temporal dimension. Aspects overlap, and it is also not always easy to distinguish between substantive and procedural issues as they may reinforce one another. For example, by achieving certain social sustainability goals such as providing opportunities for learning or improving the participatory capacities of local civil societies, one is simultaneously improving opportunities for actors to take part in sustainability projects and planning [21]. Social sustainability is all about human welfare including quality of life, social justice, social cohesion, cultural diversity, democratic rights, gender issues, human rights, participation, social capital development and human capability [22]. Fig. 11 shows the factors that are involved with social sustainability as described above.

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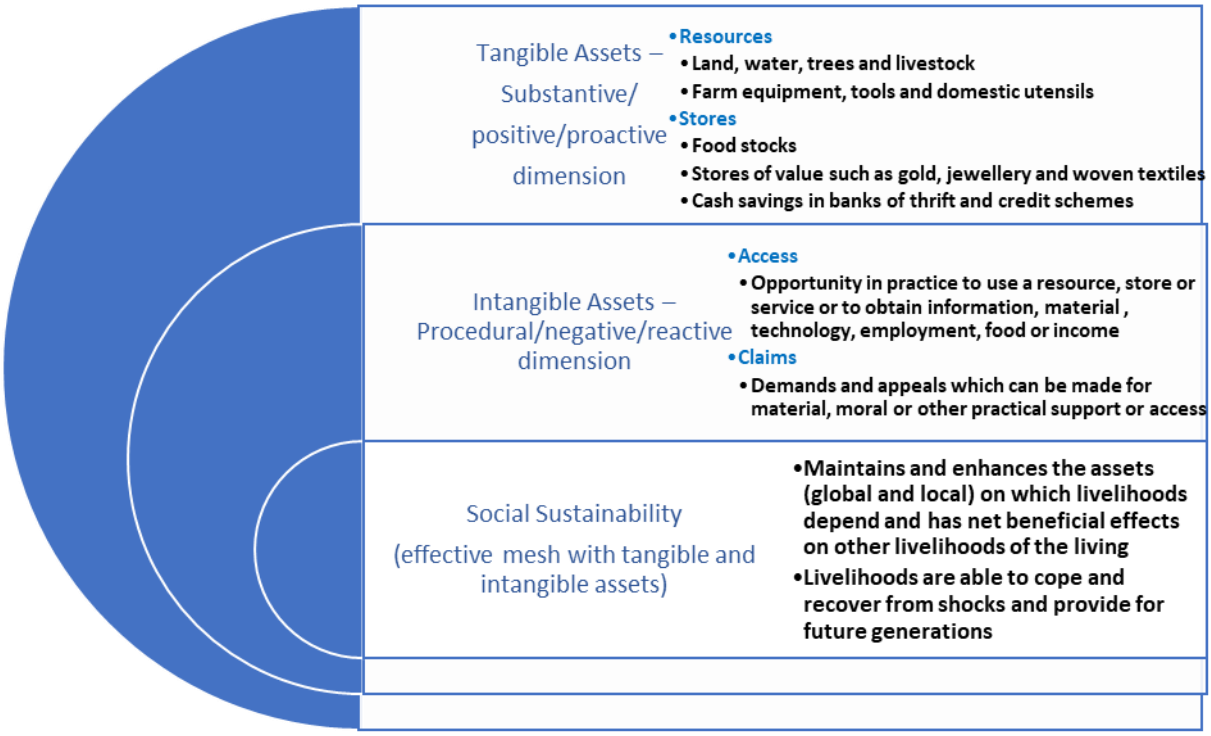


**Fig. 11.** Social factors and their sustainability, adapted from understanding of [20-22]

Out of these tangible and intangible assets people construct and contrive a living, using physical labor, skills, knowledge, and creativity. Capabilities, equity and sustainability combine in the concept of sustainable livelihoods. A livelihood fundamentally is a means of gaining a living. Capabilities are both an end and means of livelihood: a livelihood provides the support for the enhancement and exercise of capabilities (an end); and capabilities (a means) enable a livelihood to be acquired. Equity is both an end and a means: the minimum definition of equity must include adequate and decent livelihoods for all (an end); and equity in assets and access are preconditions (means) for gaining adequate and decent livelihoods. Sustainability, too, is both end and means: sustainable stewardship of resources is a value (or end) in itself and provides conditions (a means) for livelihoods to be sustained for future generations [20].

### *C. Economic Factors*

"Economics is the study of how societies use scarce resources to produce valuable commodities and distribute them among different people" [23]. Each country can be seen as having natural resources and skilled personnel which can be used to build their economy. The economic factors in a country include accessibility of natural resources, power and energy resources, capital accumulation, technological resources, available labor force, transportation and communications, education and training. Natural resources may be trees, soil, water, minerals, coal, oil and anything else naturally occurring within a country. Natural resources have the potential to develop countries through creation of jobs and increasing wealth through sales or trading. The value of the natural resources depends on the international interest in the natural resources. The process of converting economic inputs – capital, labor, and various forms of energy such as oil, coal etc. – into economic outputs such as manufactured goods and services can be expressed using an equation called production function.

Production is the heart of the economy which is the manufacture of goods and enabling of services. There are four factors that make production possible, i.e. capital, land, labor and entrepreneurship. These factors give the ability to satisfy needs and start the circulation of income (enable trade). Microeconomics is the study of basic elements in the market (microeconomy) that includes households, firms, buyers and sellers. The dynamics of demand and supply, optimal production, finance and the stock market and strategies that are involved with competition for customers and resources is called game theory. Macroeconomics is the study of the entire economy (macroeconomy) that includes the aggregation of production, consumption, saving and investment and the issues affecting it which includes the resources (labor, capital, land), inflation, exchange rates, economic growth and the public policies that address these issues. Fig. 12 is a pictorial representation of the micro and macroeconomy.

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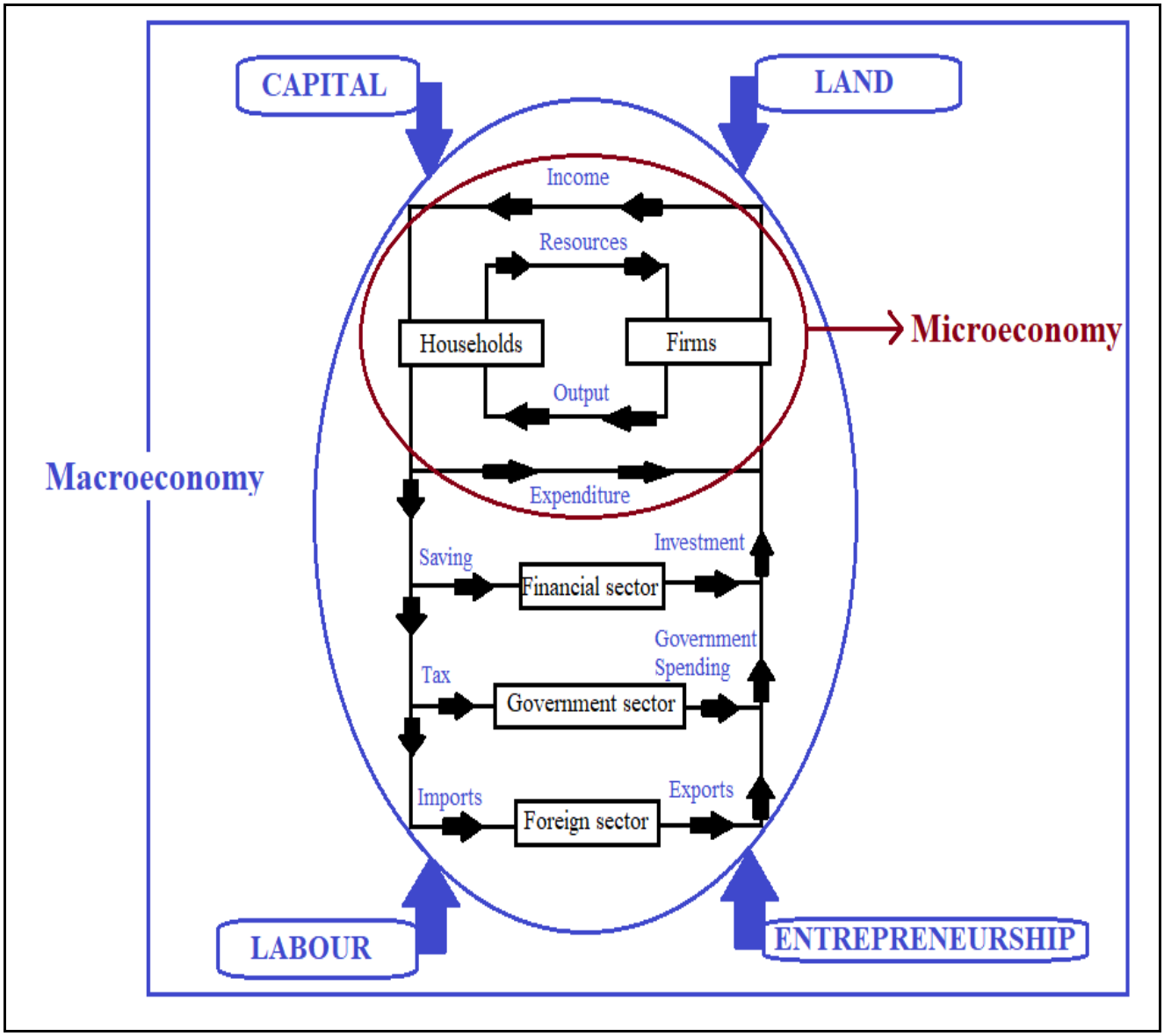


**Fig. 12.** Schematic of aspects in the economic dimension (the flow of money)

Production being at the heart of the economy involves the conversion and hence manipulation of natural resources. To manipulate natural resources, one requires energy, hence energy and its resources are key to production. The combination of technology and innovation provides the design basis upon which resources are manipulated into something useful and fit for purpose.

## III. THE IMBALANCE IN THE CURRENT INTENDED SUSTAINABILITY MESH

There is clearly an imbalance in the business sustainability mesh. The imbalance in the environmental dimension can be seen by the results in the previous sections regarding the environmental, social and economic dimensions. The environmental dimension imbalance can also be seen in section IIA. The inequality across the world that can be seen in Fig. 13, Fig. 14 and Fig. 15 and is an indication of the imbalance in the economic dimension which also implies inequitable distribution in resources such as food, shelter due to the trading power being which is able to distribute these resources being imbalanced. The imbalance compromises business sustainability and if it wants to achieve sustainability again, the three dimensions need to be contextualized to the prevailing conditions. Inequality which gives rise to poverty and other social challenges are characteristic of developing countries who have yet to effectively manipulate their natural capital to achieve adequate economic growth and distribution of wealth. Access to a secure supply of energy is key in manipulation of resources for production and creation of wealth as well as for livelihoods to improve.

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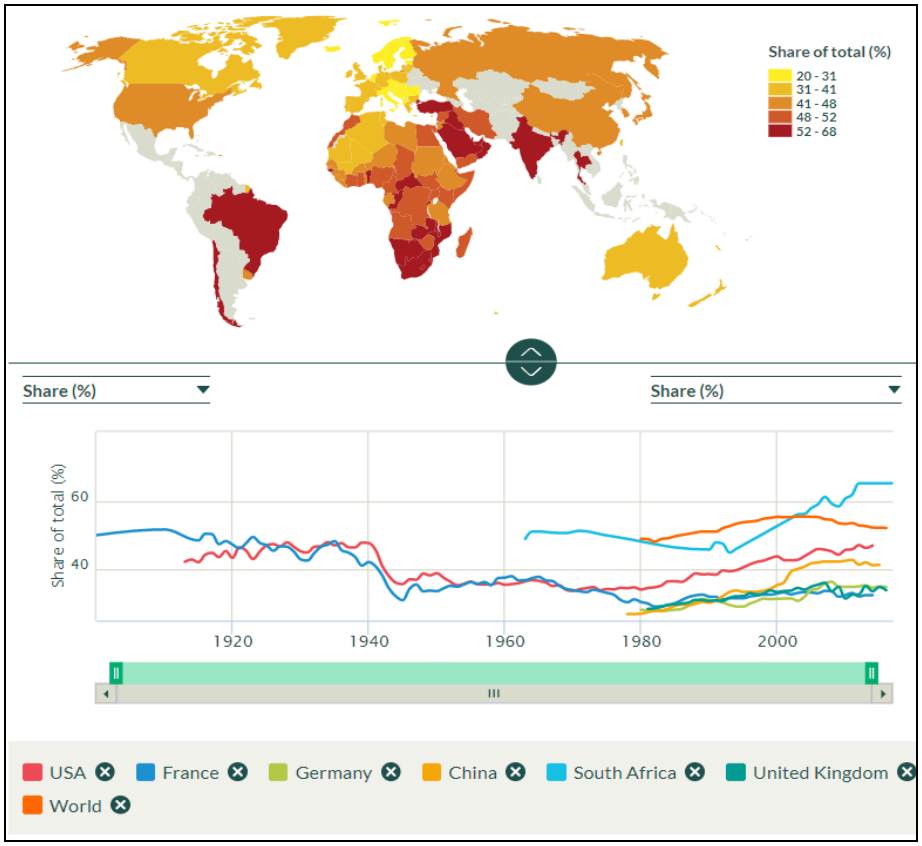


**Fig. 13.** Top 10 % national income share [24]

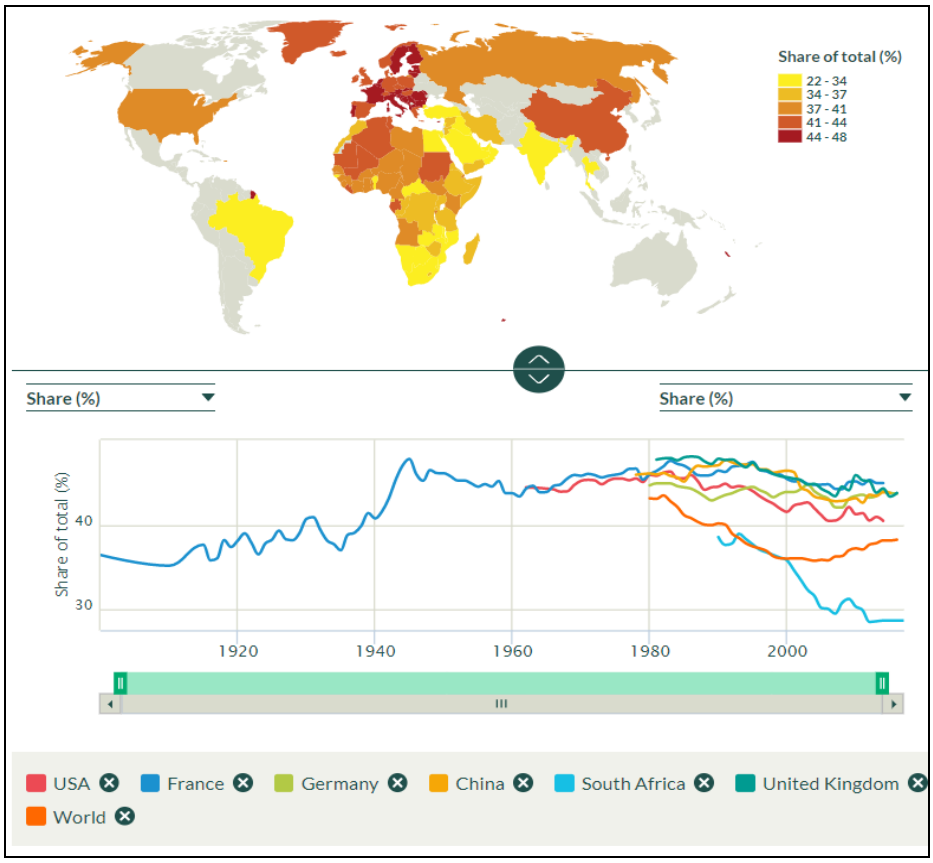


**Fig. 14.** Middle 40 % national income share [24]

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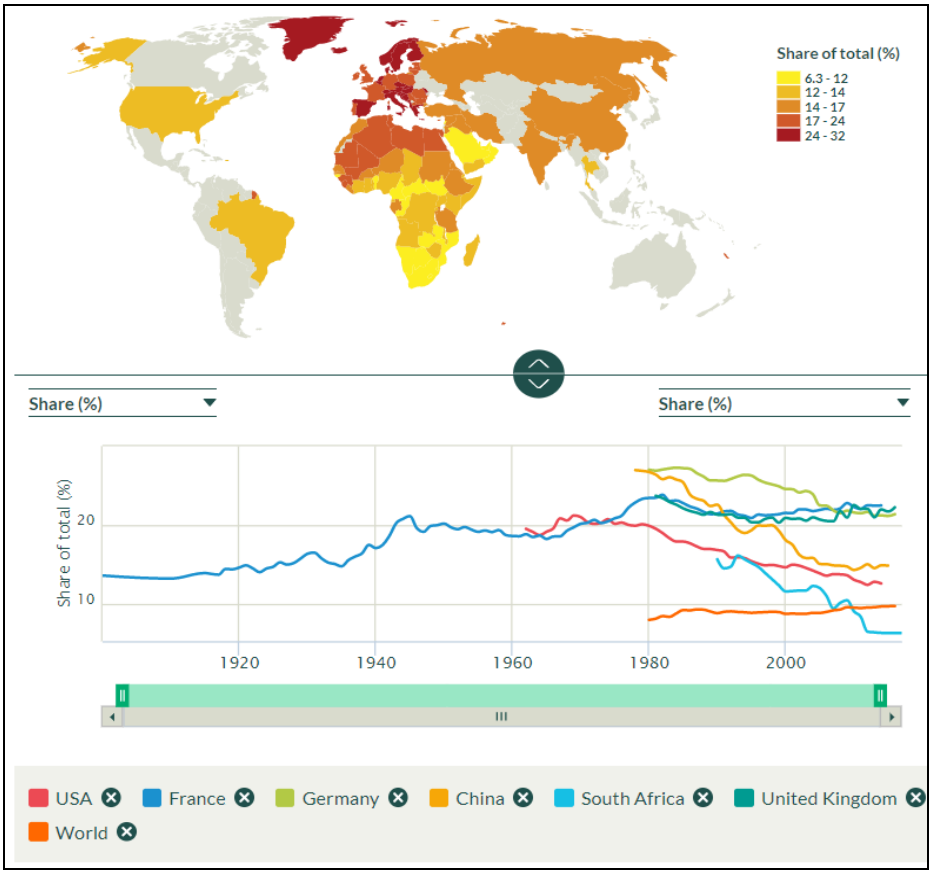


**Fig. 15.** Bottom 50 % national income share

There are various reasons for the imbalance in the business sustainability mesh. The World Wars I and II which involved military force used for subjugating countries and their citizens for reasons of racism, owning resources that a country possesses, fraud and corruption, etc. played a role in creating inequitable conditions amongst humans, based on race, gender, ethnic groups, religious sects, or wealth hierarchy. The subsequent post-World Wars economies were built with various strategies and underlying themes in mind which differed from country to country over the years, resulting in the inequality we see today with the differences of trading power (or inequality gap) between the most wealthy to the least wealthy being significantly large. One can observe that these are topics in focus of government policies today and other mechanisms adopted to bring about equality, economic freedom, in countries that are most affected. The topic of this paper is the sustainable reduction of carbon emissions through energy efficiency and energy security such that the planetary boundaries are kept within limits for now and future generations. The journey of sustaining energy efficiency and energy security has the potential as per its pivotal role in all three dimensions of economic, environmental and social to allow the achievement of a common ground for existence in the sustainable zone as depicted in Fig. 6. Successfully integrating energy efficiency and energy security within the existing framework of social, economic and environmental factors will result in the creation of new markets with the potential of positively impacting economic growth, which has the potential for decreasing the economic inequality gap and meeting the human needs in the social dimension.

## IV. ACHIEVING SUSTAINABILITY

The definition of sustainability is captured in the 1987 Brundtland Report and has been the basis upon which many sustainable development plans have been built. “Humanity has the ability to make development sustainable to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs” [25]. In the United Nations publication entitled, “Transforming our world: 2030 Agenda for Sustainable Development”, 17 goals (Sustainable Development Goals or SDGs) were highlighted in order of priority and focus. The first six goals focused on eradicating poverty, hunger, and focus on education, health and well-being, achieving gender equality and providing clean water and sanitation. The remaining goals focus on environmental sustainability and the growing of the financial economy. The order of priority of the goals tells the story of the imbalance we currently see in the sustainability mesh and what is the focus of governments and businesses from a fundamental perspective. The priorities of these goals show where effort, financial support, education and funding, will be allocated from a strategic point of view.

If humanity at the outset designed and implemented an economic system around environmentally sustainable

parameters, our social tastes and needs would have evolved around these factors and the three dimensions of social, economic and environmental would have been sustainable. Carbon emissions and its effect on climate change would not be an issue at this point in the existence of the human species. In order to implement such a designed system, there is a need to have a fundamental understanding of how all three dimensions work together. Knowledge of our planet, its environment and ecosystems have increased significantly over time. When industrialization began, the knowledge of the environment was limited, the planet's resources was seemingly inexhaustible by the human species. As knowledge of the planet's ecosystems delicate balance increased, coupled with the awareness of the exponential increase in human population numbers, the perception that the planet and its resources are inexhaustible by the human species changed and this awareness gave birth to sustainability and the definitions of the famous 1987 Brundtland report.

Today there are new challenges being faced by the human species and the Brundtland definition of sustainability and its application must be interpreted and applied to meet these challenges should humanity want to achieve sustainability of our planet and of the human species as we know it. The economic dimension was designed to extract and convert an infinite amount of resources to stimulate trade and investment as well as create wealth for humans. With this, human population grew exponentially and demand for resources and hence on the environment increased to a tipping point where planetary boundaries are being threatened. This being the new challenge, the environmental dimension can no longer be perceived as limitless. There are still many things to be uncovered about our environment and its delicate balance, hence the achievement of a sustainable mesh between social, environmental and economic is progressive. Unfortunately, the results of the evolution of the three dimensions over the years (when the earth was seen as inexhaustible), has created a very rigid and delicate financial economy that has allowed the human species to thrive in terms of population numbers due to the conveniences that came with industrialization. These two factors have created a time lag between when we have knowledge of our adverse impact on our planet to seeing the necessary change required, even though we may have resolved to do this at a policy level.

The business sustainability mesh should be progressive and agile due to our knowledge of the planet being progressive. The characteristics of a progressive business sustainability mesh (Fig. 5) is that it should respond to imbalances as they arise. However, our current response is that when results of the imbalance materializes in all dimensions, there is a tendency to prioritize short term wellness of the human species, i.e. prioritize needs in the social dimension (Fig. 10, level 1 of the pyramid) and those elements in the economic dimension that support the needs in the social dimension. Prioritizing a single dimension further perpetuates the imbalance as there must be a sacrificial dimension. In this case, our planet's natural ecosystems in the environmental dimension is the sacrificial dimension. Fig. 16 depicts this mindset.

There is a need to evolve the human business sustainability mesh as seen in Fig. 6 so as to reach sustainability. The following objectives towards achieving sustainability, unbiased to any one of the three dimensions (social, economic and environmental) need to be incorporated in the human species way of life:

- Maintain the delicate balance of planetary boundaries within restricted limits
- Ensure that human needs and requirements are met within planetary boundaries
- Ensure that the economic models that thrive on the current environmental resources are transitioned to maintain limits within planetary boundaries

The fourth industrial revolution coupled with the various new market entrants from energy efficiency and clean energy sources have converged and have the potential to address the imbalance in the business sustainability mesh, particularly in developing countries, while fulfilling its purpose of reducing carbon emissions. In fact, by fulfilling its purpose in addressing climate change within the existing business sustainability mesh, the potential of bringing about fulfilment in other dimensions will result in significant progress towards a balanced business sustainability mesh. Fig. 17 shows the culmination of the key factors in each dimension being met in the solution of energy efficiency and energy security, to meet living in what Kate Raworth calls the "Safe and Just Space" for humanity.

This leveraging of energy efficiency and clean energy for creating new market entrants in developing countries will address the following biases currently prevalent in the business sustainability mesh:

- Considering just the social and economic dimensions in the quest for being equitable, where resources are distributed equally to humans, eradicating poverty, social inequality and raise the standard of living.
- Considering just the social and environmental dimensions in the quest for making human life bearable by humans adjusting their lifestyle such that they consider the environment, contributing to a healthier environment and well-being.
- Considering just the economic and environmental dimensions in the quest for being viable by striving to meet economic growth and development with consideration for the environmental effects

The achievement of the above highlighted objectives and addressing of biases will achieve the mindset shift from the mindset depicted in Fig. 16 to the desired mindset captured in Fig. 18. We will no longer be serving our needs first and then considering the environment but will consider first what our environment can sustain within planetary boundaries and then use it innovatively such that our needs are met.

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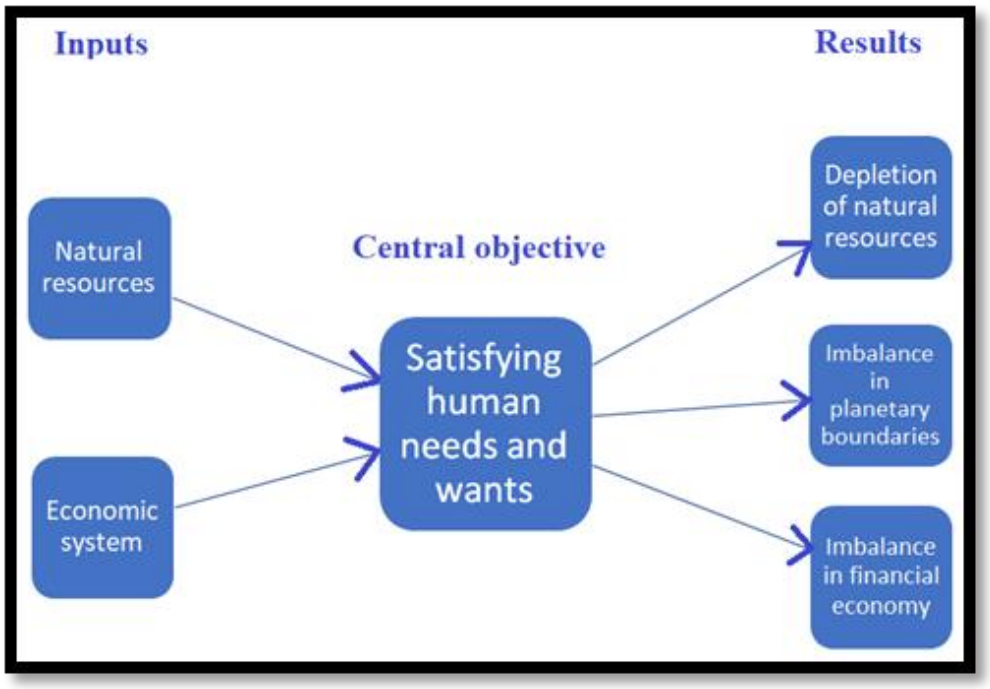


**Fig. 16.** 'As is' mindset of our current "sustainability" development focus

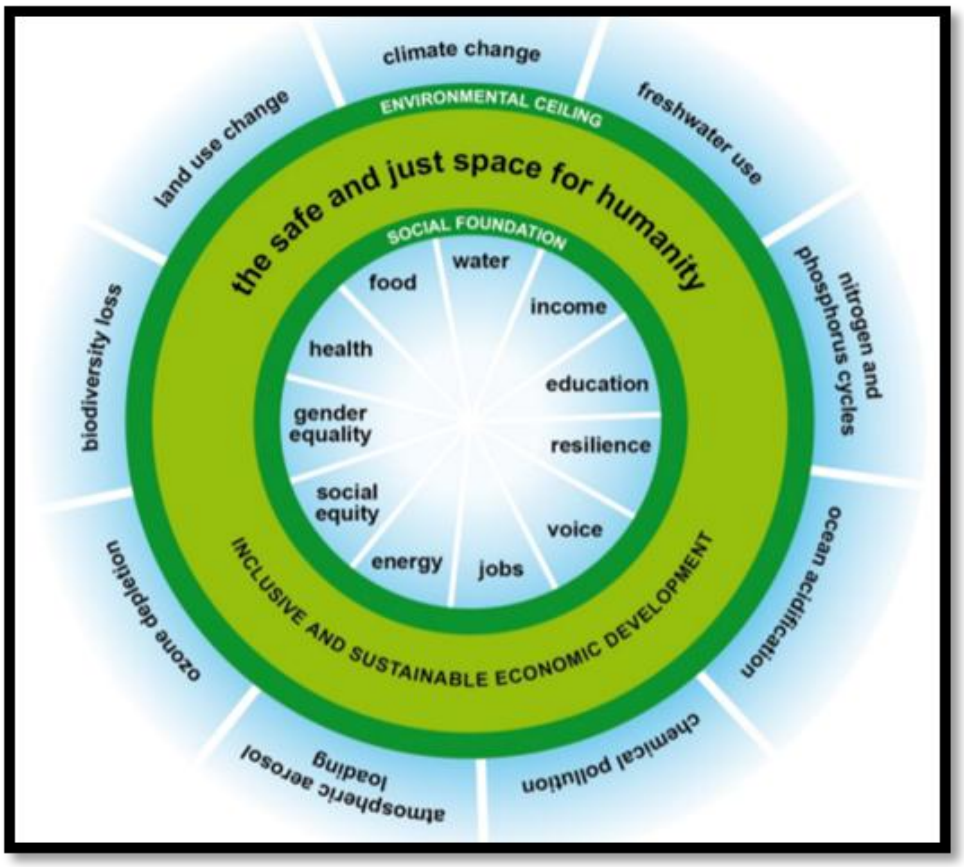


**Fig. 17.** A safe and just space for humanity to thrive in [26]

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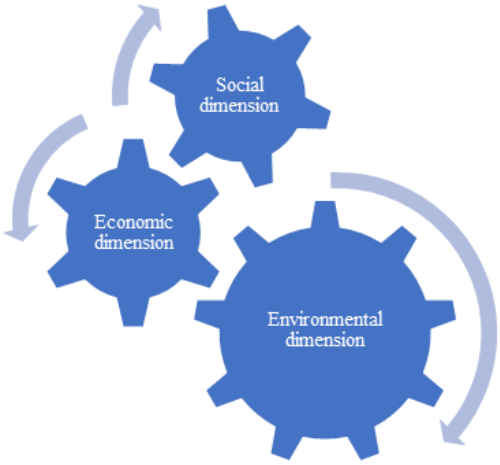


**Fig. 18.** The desired mindset ("To be" mindset)

To create the "to be" mindset as shown in Fig. 17 would have been easier if we had the knowledge we have now about our planet before industrialization and applied it then, however, we find ourselves in an existing economic system with established product markets and flow of money, satisfying the existing host of human needs and wants that we have become accustomed to. The challenge to achieve sustained energy efficiency and energy security requires a deep knowledge of how to motivate targeted objectives within the financial economy and organizations such that energy efficiency and energy security shifts offer a better solution as well as how to innovate in a way that will lead to new ways of satisfying the desires currently being satisfied by the industry.

Motivating the targeted objectives highlighted for sustained energy efficiency and energy security will require action via the social and economic levers of technology and innovation which will have the effect of transforming the market, opening the circulation of money to developing economies. This solution sustains the environmental planetary boundaries and has a "knock-on" effect in terms of potential to turn the dial of social imbalances through the stimulation of the economy by new entrants in the market. New entrants are market participants that have recently entered a market or industry sector [27].

New entrants in the market come via innovation and technological break throughs. New entrants have the effect of creating potential for "resetting the dial" to allow those in the bottom 50 % national income share (Fig. 15) to have access to a greater share of the national income, thus in a position to satisfy the needs as in Abraham Maslow's hierarchy of needs (Fig. 10). Technology is the application of knowledge to the world that allows people to affect their environment by controlling or changing it. Technological change is improvement in the art of making products or developing processes. Technological products are something that human create using the application of knowledge to improve a person's life, environment or society. A technological process is a means to make and improve products and services.

The rapid pace of technological developments played a key role in previous industrial revolutions [28]. Every industrial revolution brought with it benefits and challenges to the socioeconomic status of the countries that have engaged in such transformation. For instance, Great Britain led the first industrial revolution with the invention of the commercial steam engine, which revolutionized communication and transportation and led to many other industrial developments. In the second industrial revolution, the United States was primarily in the lead, with the telephone revolutionizing communication. In the third industrial revolution, the internet was the key factor and succeeded because it was conceived as a public infrastructure technology rather than a proprietary technology [29]. The industrial revolution history and synopsis is depicted in Fig. 5.

Industry 4.0 is not an exception to the previous eras of industries and is expected to bring immense benefits and many challenges. Social challenges are mainly the risk of cybercrime due to increased connectivity, and job losses due to the automation of large segments of operations in many industries. Technological and business-driven innovative solutions are not going to be enough. Innovation in its broadest sense is the key solution, in particular social innovation. The same drive to innovate technologies to increase productivity can also be utilized to improve the welfare and social needs of the world population [28].

Many innovations tackle social problems or meet social needs, but only for social innovation is the distribution of financial and social value tilted toward society as a whole. A social innovation is a novel solution to a social problem that is more effective, efficient, sustainable, or just than existing solutions and for which the value created accrues primarily to society as a whole rather than private individuals. A social innovation can be a product, production process, or technology (much like innovation in general), but it can also be a principle, an idea, a piece of legislation, a social movement, an intervention, or some combination of all of them. Indeed, many of the best recognized social innovations, such as microfinance, are combinations of a number of these elements [30]. Technological and social innovation are key drivers in providing sustainable solutions that meet the three key criteria of sustainability and can act as an assessment mechanism to

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any related developments of Industry 4.0, as shown in Fig. 19 [28].

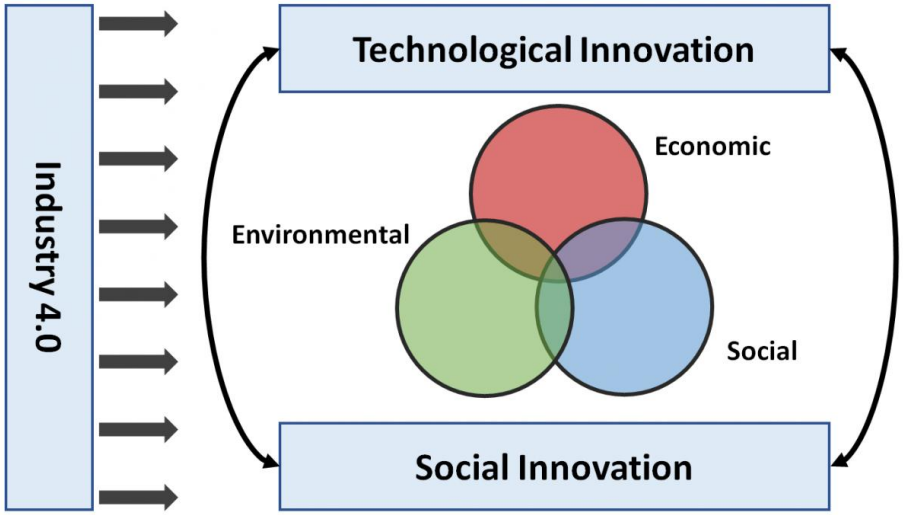


**Figure 19:** A framework to safeguard the potential of a sustainable Industry 4.0 [28]

Energy is a fuel source enabling the economy. The earth's natural capital is the available material for production. Technology and innovation are the transforming tools. Funds are the bargaining mechanism and people are the designers. The real challenge to sustainability is in achieving the paradigm shifts required in an existing economy with established drivers, existing societal expectations and requirements that humans have become accustomed to with the earth supplying the seemingly unending demand for materials. As can be seen with SDGs, sustainability of the earth's natural resources is not a priority focus, neither are the SDGs structured to eliminate the biases that may occur in the sustainability mesh highlighted earlier. Human needs are unending and the more that they are satisfied, the more the human species thrive in population growth and the greater the demand on earth's resources. One can see how the industrial revolutions timeline, the timeline of the planet's increase in temperature (and $CO_2$ levels) and the timeline of the population growth corroborates. Compare Fig. 1, Fig. 2 and Fig. 5 with Fig. 20.

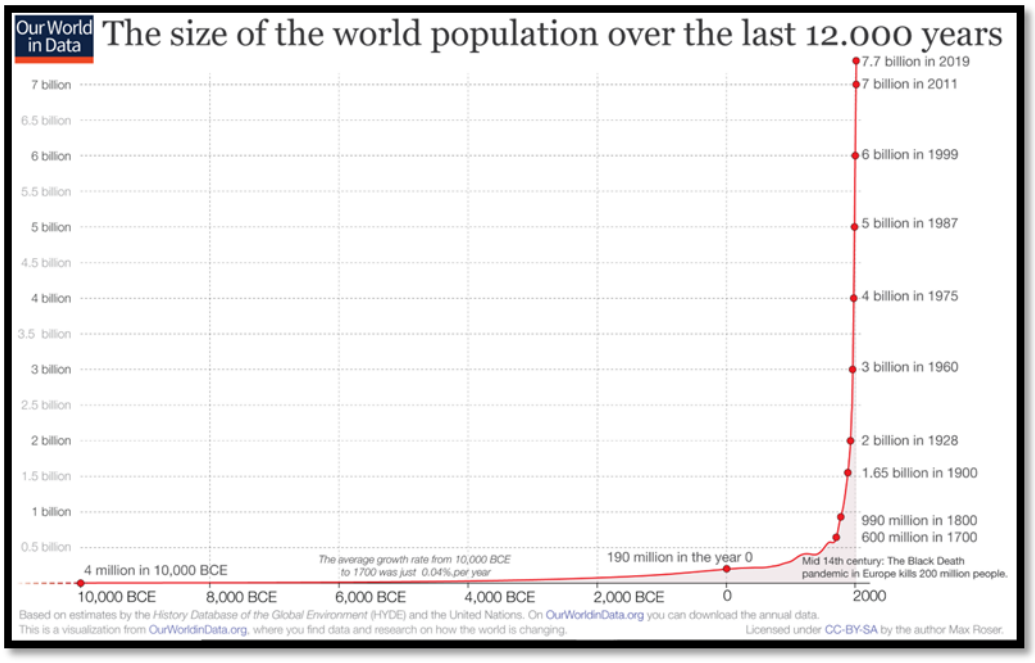


**Fig. 20.** Population growth over the last 12 000 years [31]

There are countries in the world where inequality, poverty and unemployment are not as bad as others. These countries have more developed economies than others and there is a distinction between countries that are 'developed' and countries that are 'developing'. The Human Development Index (HDI) is an index that measures key dimensions of human development considering three main factors, life expectancy, access to education and standard of living as measured by the gross national income per capita adjusted for the price level of that country [32]. Countries that are classified as developing have a poor Human Development Index (HDI) and thus will have opportunity for development of their economy and other related factors such as infrastructure, health care systems, etc.

Energy plays a key role in enabling development. Leveraging on developing countries' need for achieving a better livelihood and the need for access to a secure supply of energy to enable a better livelihood will be pivotal in shifting the paradigm towards development that meets in the sustainable zone of the social, economic and environmental spheres of the business sustainability mesh. It is imperative that this opportunity be used. Failing to use this opportunity will result in accelerating climate change in order to meet the developing world's needs.

Given their extensive experience with older technologies, leading nations may have no incentive to adopt new ideas, especially those new ideas that do not initially seem to produce an improvement. Developing nations, however, have less experience; the new techniques offer them an opportunity to use their lower wages to break into the market. If the new techniques eventually prove to be more productive than the old, there is a reversal of leadership [33]. Using technological breakthroughs of the fourth industrial revolution, the developing world should engineer a built environment that is in harmony with nature, mitigating the effects of climate change while securing access to sustainable sources that are renewable. This will produce new market entrants; these new market entrants must be economically competitive to be sustained and also be fit for purpose competing with the products that they are trying to replace because of their contribution to the acceleration of climate change.

Energy efficiency and the need for energy security in developing countries need to be viewed differently from just being an environmentally sustainable initiative in order to be sustained as a focus of the human species. This is evident in the focus of the Sustainable Development Goals (SDGs) being on serving humans immediate needs first. The first five SDGs are eradicating poverty, hunger, focus on education, health and well-being, achieving gender equality. These need to be viewed in context of the opportunity that energy efficiency and energy security offer to fulfil these goals. New market entrants can potentially be created in the form of innovative market solutions and products to enable energy efficiency and energy security, and job opportunities for those specializing in energy efficiency and alternative energy technologies. These market entrants will find a place in the less developed countries and will serve to better their HDIs.

As organizations see the business case in energy efficiency and as alternative energy grid parity is met, the demand for reliable alternative solutions for energy supply based on sound engineering and science principles arise. This will feed the demand for new and revised educational programmes, creating more jobs and giving developing countries an opportunity to get a market share in energy supply. The realized profits of energy efficiency and business security offered by alternative energy supply, together with the positive public image of an environmentally responsible organization, will put pressure on all organizations to follow suite in order to remain relevant and competitive. From this point, the flow of money will gain momentum as per the depiction in Fig. 12. Pressure will be on the ruling or governing body of the country to be seen as promoting environmental sustainability and the knowledge gained on planetary boundaries will take the form of government policies. This will lead to maintaining the planetary boundaries as outlined in Fig. 9.

The solution that will ensure that sustainable energy efficiency and energy security will be established in the business sustainability mesh is as follows:

**Step 1**: Technologically innovate for energy efficiency and security of energy supply in a way that:

- Is designed to save costs and be a better commercial alternative
- Creates new opportunities for jobs
- Gradually creates a market for new products and solutions that support local participation
- Appeals to the convictions of the population at large, creating a campaign for itself

**Step 2**: Ensure that energy efficiency and energy security (a mix of alternative energy solutions) are focused on eradicating poverty, hunger and other priority focuses of most countries in the developing world as per the SDGs

**Step 3**: Ensure that energy efficiency and energy security create new markets that support local economic growth

**Step 4**: Being now established as an operational cost saving, energy efficient practices and energy security approaches be entrenched into organizational strategies and way of conducting business

**Step 5**: Being now established as a tool to improve the HDIs of developing countries, they form part of government policies

The above five steps show the creation of the affinity that energy efficiency and energy security will have to fit into the business sustainability mesh (Fig. 22).

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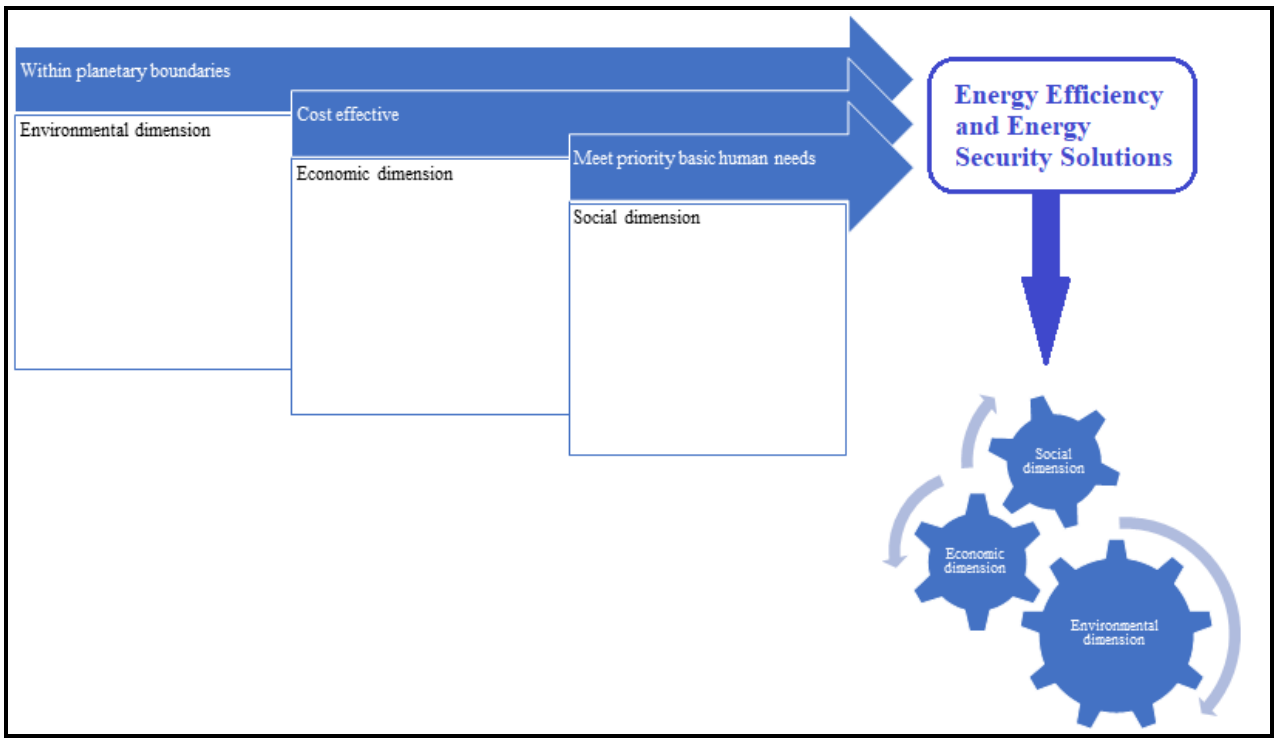


**Fig. 21.** Natural affinity of energy efficiency and energy security to the business sustainability mesh

Many countries and businesses tend to approach energy efficiency and energy security from Step 5 and expect to get to Step 1. This is the key reason that energy efficiency and energy security have a shallow penetration and slow-moving pace into and sometimes stagnate in developing countries. They are punted as "the right thing to do" instead of showing value that addresses the fundamental needs of society.

There is an interdependency of developing countries economic growth and improvement of HDIs and the role of energy efficiency and energy security. Energy efficiency and energy security is key to enabling economic growth and improvement of HDIs. Similarly, in order for energy efficiency and energy security to be sustained, it must be established as a tool of economic growth and improvement of HDIs.

## V. CONCLUSION

For the sustainability of our planet to be realized, we need to give much consideration to keeping within the planetary boundary of climate change, focusing our effort on the carbon footprint of the sources we derive our energy from. For sustainability of human livelihoods, the manipulation of resources for human use and its access must be evolved such that it allows our survival and supports our way of life without hindering the planetary boundaries that maintain the biosphere integrity. The manipulation of resources for human use is achieved with the use of energy sources, whether these be in the form of heat, electricity or others. These energy sources must be carefully chosen, and the methods chosen to derive energy from the energy source for meeting our needs must be designed to reduce impacts on planetary boundaries. Energy efficiency and energy security must be woven into the fabric of social factors for it to be sustained. Access to energy is key to production and thus economic growth. Energy combined with technology and innovation makes production possible. The requirement that energy is used efficiently, and $CO_2$ emissions are reduced from energy sources must be integrated into the economic framework already established to ensure that there is a sustained reduction in carbon emissions. This means energy efficiency and clean energy sources must make business sense and offer competitive advantage for it to be chosen over traditional and established energy sources and energy consumption methodologies.

If the developing world seeks to make good their HDI through the old and long-established technologies and ways, there is lack of acknowledgment of the climate change dilemma and the perpetuation of the economic imbalances and this will result in a worsening of their HDIs. The motivation for reduction in carbon emissions through energy efficiency and secure, clean energy sources must be through established means of the built environment, i.e. the social and economic factors, and must have adequate penetration into the engineering of the built environment, into organizations' ways of working, be economically competitive and meet fit for purpose requirements with added advantages over its competitors.

The sustainable solution for ensuring that energy efficiency and energy security has lasting and established penetration in developing countries is the solution that can achieve sustainability in all three spheres of the environmental, economic and social constructs. By addressing the priority social concerns and make for an attractive economic alternative, it will be sustained through changing markets, technologies, legislation, personnel and resource availability.

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