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Carbon Dioxide Emissions Laden Economic Development, Will It Go Away Making Room For Sustainable Development?

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Abstract— *In the backdrop of the existence of a sustainable limit to the anthropogenic carbon dioxide emissions, the options that are generally believed to be available for reducing the anthropogenic CO_2 emissions into the atmosphere, while maintaining a 'business-as-usual'-styled energy consumption, is reviewed. It is shown that even though technological potential exits for reducing the anthropogenic CO_2 emissions into the atmosphere, the current approach of almost all the countries, inclusive of the high-income economies, is to depend on carbon dioxide emitting fossil fuels to increase their per capita incomes, and thereby to reach high ranks in the UNDP defined human development index. With the view of offering an alternative development path to the emissions laden development path practiced by the World in general today, an 'Emissions Responsible Human Development Index'(EmRHDI) is introduced in this paper. The top ten countries in this new EmRHDI rank, which lie in the range of 46 to 93 in the HDI 2003 rank, are shown to have CO_2 emissions well below the sustainable limit, the life index above 0.75 and the educational attainment index above 0.83, despite their GDP per capita being only about quarter of the GDP per capita of the high-income economies.*

Keywords—**Carbon dioxide emissions, economic development, GDP per capita, emissions responsible human development index, sustainable limit to emissions.**

1. INTRODUCTION

On July 25, 1997 the United States Senate unanimously passed the Byrd-Hagel Resolution [1], which stated that the United States should not be a signatory to any Protocol on Climate Change to be negotiated in Kyoto in December 1997. The resolution further stated that signing any such Protocol 'would result in serious harm to the economy of the United States'. On November 01, 2005 Prime Minister Tony Blair of Britain told "The blunt truth about the policies of climate change is that no country will want to sacrifice its economy in order to meet this challenge" [2].

These words are testimony for the emissions, in particular the carbon dioxide emissions, laden economical development that the world is unable to forsake despite the looming threats of the dreadful consequences of carbon dioxide emissions induced climate change [3]-[5]. For instance, even though Canada has ratified the Kyoto Protocol making a commitment to reduce its emissions 6% below its 1990 level during 2008 to 2012, its emissions in 2003 were about 24% above the 1990 levels [6].

A good part of the trillion tonnes (= 10^{15} kg) of anthropogenic CO_2 emitted into the atmosphere since the Industrial Revolution [7] remains in the atmosphere as CO_2 since the carbon balance has been greatly upset by the excessive burning of fossil fuels [8]. As a consequence the atmospheric CO_2 concentration has risen since the Industrial Revolution [9]-[10]. The steep increase experienced by the atmospheric CO_2 concentration during the last three decades (see Fig.1), which quantifies a rate of 1.5 parts per million by volume (ppmv) per year has become a matter of grave concern for the World that is already facing the consequences of the emissions induced climate change.

The limit to anthropogenic CO_2 emissions and the time limit we have in reducing the emissions to be able to avert ecosystems breakdown are briefly presented in Section 2. The options that are generally believed to be available for reducing the anthropogenic CO_2 emissions into the atmosphere are critically reviewed in Section 3. The role of population in emissions is assessed in Section 4.

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The strong dependence of economic and human development on the emissions is quantitatively exposed in Section 5, which also introduces an Emissions Responsible Human Development Index that could be used to pressurize the countries to deviate from their emissions laden development paths. Section 6 concludes.

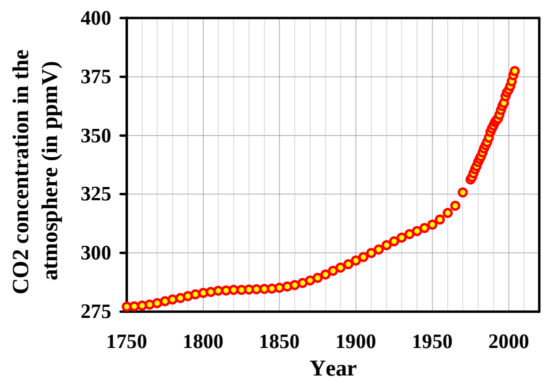

Fig.1. Atmospheric CO_2 concentrations since 1750 [9]-[10].

2. LIMIT TO EMISSIONS

The presence of carbon dioxide and other greenhouse gases in the atmosphere are responsible for the rise of the global average surface temperature by 0.6°C over the 20th century [3]. Warming of the globe, even though by a small amount such as 0.6°C over the past century, has changed the global climate in such a manner that the world has already started to experience the dire consequences of climate change (see [3]-[5]). The World Wide Fund for Nature has identified a rate of change of 0.01°C per decade as a probable threshold level for many plant, tree and animal species [11]. It also states that a 1°C warming will have significant negative impacts on many ecosystems, and a 2°C warming will undoubtedly have severe negative impacts and cause irreversible alterations in our planet's natural habitats, resulting in ecosystem breakdown and loss of biodiversity [12].

Intergovernmental Panel on Climate Change (IPCC) estimated the relationship between the atmospheric CO_2 concentration and the increase in the global average surface temperature, and noted that if the atmospheric CO_2 concentration is increased to 550 ppmv, which is twice the pre-industrial concentration, then the global average surface temperature will be increased by a value that lies in the range of 1.5^oC to 4.5^oC [13], depending on the overall responsiveness of the climate to radioactive forcing (that is, the amount of additional energy trapped or reflected by the greenhouse gases that humans have added to the atmosphere).

If we take the 'business as usual" scenario, the upper estimate of 4.5^oC is reached at 550 ppmv. This means that the world will experience a 2^oC temperature rise at 400 ppmv [5], which is only about 24 ppmv above last year's atmospheric CO_2 concentration [10]. At the present rate of increase of 1.5 ppmv carbon dioxide per year in the atmosphere, this limit will be reached in 2020, that is just 15 years from today.

Even if we are to consider the optimistic view of carbon dioxide emissions stabilizing below 550 ppmv by the year 2100 without the premature 2^0C temperature rise, we must limit the net global anthropogenic CO_2 emissions to about 7 to 8 gigatonnes (i.e. 10^{12} kg) of carbon per year [14]. (The net anthropogenic CO_2 emissions includes emissions from land-use change in addition to those stemming from fossil fuel combustion and cement production.) With the assumption that each of the average 7.5 billion people on the planet over the next 50 years is allocated equal share of net carbon emissions, Graedel et al. [15] concluded that the global sustainable limiting rate of the net anthropogenic carbon dioxide emissions is roughly 1 tonne of carbon equivalents per person per year.

Of the net anthropogenic emissions for 146 countries in 2000, calculated using the data available in [16] and plotted in Fig.2, only 63 countries have per capita CO_2 emissions below the sustainable limiting rate of 1 tonne of carbon equivalents per person per year. Another 37 countries have net emissions in the range of 1 to 2 tonnes of carbon. The rest, 46 countries including many high-income economies, has emissions in the range of 2 to 10 tonnes of carbon. The net anthropogenic CO2 emissions of Guyana, Qatar and Belize in 2000 have been estimated to be 13.1, 16.5 and 25.2 tonnes of carbon equivalents per person per year, respectively.

Table 1 shows the top 20 countries in the Human Development Index (HDI) 2000 ranking [17], as well as in the latest HDI 2003 ranking [18] with their respective net anthropogenic CO_2 emissions in 2000 [16]. The HDI 2003 are given within the bracket in column 1. The anthropogenic emissions, excluding the emissions from land use change, is given in column 4. It could be seen in Table 1 that the net emissions of Norway, ranked 1 in the HDI 2000 as well as 2003 scales, is twice the sustainable limit. Australia and the United States who declined to ratify the Kyoto Protocol have net emissions 5 times the sustainable limit.

Even countries like Austria, Iceland and New Zealand, even though their electric power mix is rich in hydroelectric power, emit more than twice the sustainable limit. Sweden and Switzerland meet more than 90% of their electricity demand using hydro and nuclear electricity, but emit 50% more carbon dioxide than what the sustainable limit allows. Also Belgium and France, who are heavy consumers of nuclear energy, emit more than the sustainable limit. Japan and Finland, who use substantial amount of nuclear electric power, still emit more than 2.5 times the sustainable limit.

It is to be note that all the 20 countries listed in Table 1 have GDP per capita above 20,000 PPP US$ in 2000. Despite their high incomes, rather because of their high incomes, these countries have remained top CO2 emitting countries as well. It is shown in Section 5 that when the UNDP defined Human Development Index is made sensitive to CO_2 emissions, none of the countries listed in Table 1 survives the top 20 rank.

It is also to be noted in Table 1 that adding the emissions from land-use change does not appreciably change the per capita emissions values listed in column 4. Even when the net global anthropogenic emissions are considered, IPCC 1996 [14] reports that 0.2 tonnes of carbon per capita comes from land use change and 1.1 tonnes per capita comes from the other sources. Besides, Richard Houghton [19] of the Woods Hole Research Center, from where the emissions estimates from land-use change originates, states that Indonesia and Brazil together account for nearly 50% of the global land-use flux of carbon, and another 13 countries account for another 40%. The national estimates of land-use flux of carbon are also subjected to huge uncertainties according to Houghton. For the reasons stated above, and owing to the lack of national land-use flux data after 2000, we ignore the emissions from land-use changes from the CO_2 emissions figures that are used in the sections that follow.

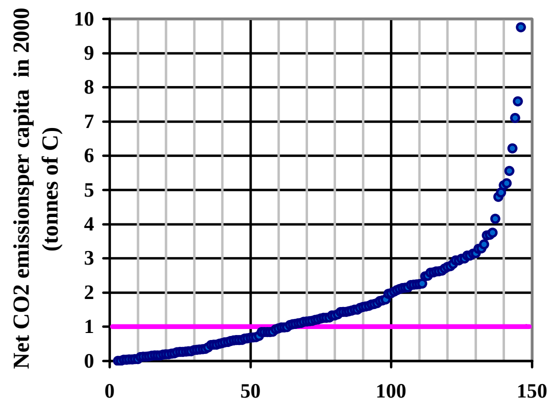

Fig.2. Net Anthropogenic per capita CO_2 Emissions of 146 countries in 2000 [16].

Table 1. Carbon Dioxide Emissions per capita of the First Twenty Countries in the HDI 2000 Rank.

HDI 2000 (2003) rank	Country	Net anthropogenic CO_2 emissions per capita (tonnes of C) 2000	Anthropogenic CO_2 emissions per capita (tonnes of C) 2000
1 (1)	Norway	1.9	2.2
2 (6)	Sweden	1.5	1.5
3 (5)	Canada	5.2	4.6
4 (9)	Belgium		3.3
5 (3)	Australia	4.8	4.7
6 (10)	United States	5.1	5.5
7 (2)	Iceland		2.2
8 (12)	Netherlands	3.0	3.0
9 (11)	Japan	2.6	2.6
10 (13)	Finland	2.9	3.0
11 (7)	Switzerland	1.6	1.6
12 (16)	France	1.6	1.7
13 (15)	United Kingdom	2.6	2.6
14 (14)	Denmark	2.6	2.6
15 (17)	Austria	2.1	2.2
16 (4)	Luxembourg		5.3
17 (20)	Germany	2.8	2.8
18 (8)	Ireland	2.9	3.1
19 (19)	New Zealand	2.6	2.4
20 (18)	Italy	2.1	2.1

3. ENERGY WITHOUT EMISSIONS, A MYTH OR A REALITY?

Since fossil fuels have been accounting for a major part of the total commercial energy consumed, 86% in 2003 [20], the larger the amount of commercial energy consumed, the greater is the CO_2 emissions. North America's share of the global energy consumption was 28% in 2003, and indeed it was responsible for 27% of the global CO_2 emissions in 2003. These figures were, 28.5% and 32.5%, respectively, for the Asia-Pacific region. Whereas, Africa accounted for only 3% of the global energy consumption in 2003, and its share of the global CO_2 emissions was only about 4%. Fig.3 clearly demonstrates how closely the CO_2 emissions (stemming from fossil fuel consumption and cement production) is tied to the energy consumption in any part of the world, economically prosperous or not; technologically advanced or not, even in the year 2003, which is 6 years after opening the Kyoto Protocol for signature.

One obvious way to stabilise the atmospheric carbon dioxide is, therefore, to considerably reduce the use of fossil fuels in meeting our energy requirements, in favour of the increase use of non-CO_2 emitting sources of energy. How realistic is such a proposal? Fig.4 shows that the global percentage share of hydroelectric power consumption has only been about 6% over the past 35 years. This figure also shows that the nuclear electric power consumption underwent a rapid rise during for fifteen years or so since 1970, and then slowed down. It is of interest to observe in Fig.4 that the percentage shares of both hydroelectric and nuclear electric powers have been experiencing a slight reduction since 2000.

Any intended increase in these modes of electric power, however, faces strong objections from the public nowadays for reasons such as those listed in popular magazines [22]-[23] as well as in professional Briefing Papers [24]. Eric Duchemin, a consultant for the IPCC, says that the green image of hydropower as an alternative to fossil fuels is false [25]. IPCC will include, in its next round of discussion in 2006, emissions from artificially flooded regions during its first 10 years in calculating each country's carbon budget. The International Energy Agency has forecasted in 2004 that investment on new nuclear power plants will be limited because of concerns about safety, security and radioactive waste management [26].

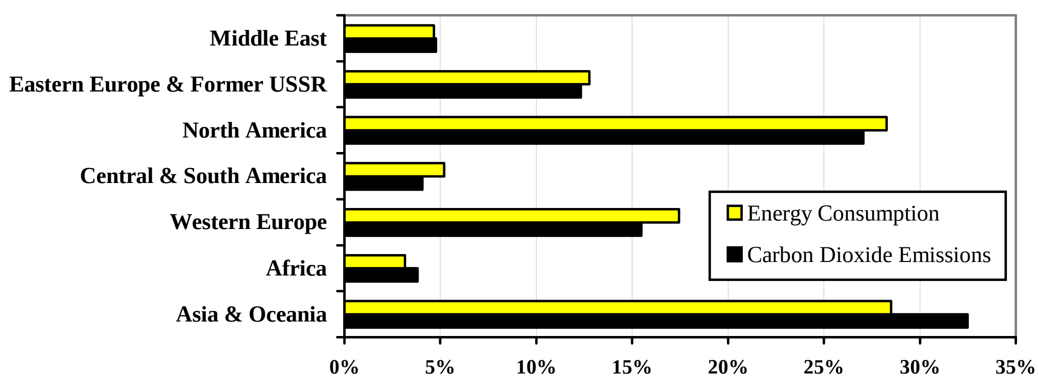

Fig.3. Percentage Shares of Energy Consumption and Carbon Dioxide Emissions in 2003 on Regional Basis [20].

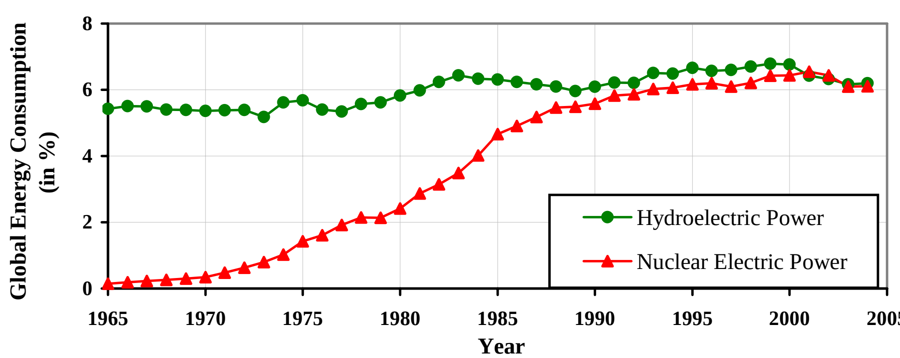

Fig.4. Percentage Shares of Hydro and Nuclear Electric Power in Global Energy Consumption [21].

Another alternative to CO_2 emitting fossil fuels is the renewable sources of energy, namely geothermal, solar, wind, and wood and waste. How sound is this alternative? The percentage of electric power consumption from these renewable energy sources was a minuscule 0.9% of the global primary energy consumption even in the year 2003 [20]. European Union, for example, has planned to achieve a 11.1% target of electricity production from renewable energy sources (exclusive of the hydroelectric power) in 2010 thus reaching the global target of 12% of the total energy consumption met by the renewable energy sources (inclusive of hydroelectric power) in 2010 [27],[28].

The reason for the World's inability to effect significant development in the use of renewable sources of energy (exclusive of the large-scale hydroelectric power) even in 2010 as a step towards reducing the CO_2 emissions stemming from power generation lies primarily in the lack of immediate financial benefits for such initiatives. It is very likely that the liberalized profit-oriented energy markets would see switching from coal to natural gas as a neat solution to reducing CO_2 emissions from power generation, since the emissions from natural gas is about half the emissions from coal [29].

Moreover, tapping large amount of energy from the wind and the sun requires vast areas to harness wind and solar energy. Offshore wind farms are seen as a way out of the limitations placed by onshore land requirements. However, an offshore facility costs up to 40 % more than onshore [30]. The suitability of such sources of energy, which may not be available continuously, to provide base-load electricity without dependable backup power supply systems still remains an economically unresolved problem [30]-[32].

A major hurdle to the extensive use of wind, solar and geothermal energy is the difficulty in transporting the electricity produced by these means from the production sites, determined by the precise locations of these energy sources, to the consumers, sometimes crossing over large extent of land. The massive costs involved in the construction of such facilities and the mammoth-scale infrastructures already in place to support the global fossil fuel based economy have negative impacts on the growth of a renewable energy rich energy mix [33]-[35]. Grid integration and administrative barriers remain obstacles to a greater presence of renewable energy sources in electricity production than what it is today even in the European Union [36].

The fuel cell, which is the founding stone for the much celebrated hydrogen economy of the future, in which hydrogen combines with oxygen at moderate temperatures to provide the electricity required, lets out H_2O, not CO_2 [37],[38]. The water vapour, the effluent from fuel cell facilities, is indeed a greenhouse gas. In the comments of Saudi Arabia, received by the IPCC Secretariat on April 02, 2003 for IPCC's Fourth Assessment Report due for completion in 2007, it has been pointed out that water vapour is responsible for about 88% of the absorption of infrared radiation from the earth in the 4 to 60 micron wavelength, but the Third Assessment Report did not list water vapour as a greenhouse gas. It is of relevance to note here that carbon dioxide was not regarded as a pollutant in any sense until the late 1980s [39]. Moreover, as for the technological projections into the near future, most commercial fuel cells will initially derive their hydrogen from the old-fashioned fossil fuels [37],[38],[40]. This process lets out nothing but CO_2.

A great amount of carbon dioxide from the atmosphere is absorbed by forests acting as carbon sinks. Forests, natural and planted stands of trees, covered about 3861 million hectare in 2000, which was about 30% of the total land area available [41]. This forest cover was, of course, inadequate to convert the excess carbon dioxide in the atmosphere into oxygen. What is worse, deforestation still goes on. The global rate of net deforestation was as high as 9 million hectare per year in 2000 [41]. One factor that contributes and will continue to contribute towards the destruction of virgin forest is the oil-palm plantations which are today the cheapest source of biodiesel. Ironically enough, biodiesel from palm oil is considered one of the renewable energy sources.

In a recent research work [42], it was estimated that the annual atmospheric CO_2 accumulation in US, even after taking into account the carbon sink effects of the forests and other terrestrial components in US, is in the order of 0.8 to 1.1 gigatonnes of carbon equivalent. Moreover, even though it is true that forests in fact act as very efficient carbon sinks for atmospheric carbon dioxide [42],[43], as they have been for millions of years now, the possible use of forests as carbon sinks as a substitute for curbing the emissions stemming from the burning of fossil fuels is indeed questionable.

In two of the recent research works [44],[45] carried out with a variety of pine trees (*Pinus taeda*) planted in an atmosphere containing elevated CO_2 concentrations, it was observed that the trees grew faster for only three years and then the growth rate fell back to normal values, because of factors such as the limited amount of nitrogen in the ground [44]. The expected increased rate of atmospheric CO_2 absorption by the trees in an atmosphere with elevated CO_2 concentration therefore did not materialise. Besides, it was estimated that the leaves took up about half the amount of atmospheric carbon absorbed by the trees. And, once the leaves fell from the trees, the carbon contained in the leaves returned to the atmosphere within a very short period of time [45].

Injecting CO_2 captured from large point sources, such as fossil fuel energy facilities, natural gas production, synthetic fuel plants and fossil fuel-based hydrogen production plants, into abandoned oil and gas fields, unmineable coal beds, deep saline formations, ocean water column, and onto deep seafloor for storage is a process known carbon (dioxide) capture and storage (CSS), and it is seen as an effective way of keeping CO_2 out of the atmosphere. In recent reports on CCS prepared for the Australian and UK governments [32],[46], it has been explicitly stated that storing CO_2 in ocean may be highly unlikely owing to its potential impact on marine ecosystems.

These reports suggest that storage of CO2 in geological formations is the most viable method, as has been proven in the Weyburn enhanced oil recovery project of Canada and in the Sleipner natural gas production process. However, the reports further state, issues such as establishing the characteristics of successful storage structures, understanding the potential for large releases of CO_2 into the atmosphere resulting from movements of the earth's crust, integration and scale-up of CSS technology needed for routine application to large-scale power generation, and environmental impacts and safety, would require significant research and demonstration.

Besides, the IPCC Special Report on Carbon Dioxide Capture and Storage [47] released in September 2005 states that a power plant equipped with CCS would need roughly 10-40% more energy than a plant of equivalent output without CCS, and therefore generation of 10-40% more CO_2 emissions and other pollutants. This report also states that the actual implementation of CCS is likely to be lower than the economic potential due to factors such as environmental impacts, risks of leakage and the lack of clear legal framework or public acceptance. It is also stated in these reports that the current market conditions do not favour CCS. In concluding, [32] states that 'CCS technologies are not projected to economic until around 2015, but by 2050 are projected to account for over a third of the cumulative abatement of global CO2 emissions'.

4. THE ROLE OF POPULATION IN EMISSIONS

Since Thomas Malthus essay on population in 1798 [35], the world has been concerned about the negative impacts of population growth upon the resources of the World. So much so that population control has been seen as a panacea for almost every earthly ills. When it comes to energy consumption related CO_2 emissions, population control does not help much, since population does not correlate well with the energy consumption.

For example, in 2003, the United States with only 4.6% of the world population consumed nearly a quarter of the total primary energy utilised by the world [20]. In the same year, China with 20.6% of the global population accounted for only 10.8% of the global primary energy consumption [20]. Putting it in another way, there were 765 vehicles and 484 passenger cars per 1000 people in the United States in 1996, and only 8 vehicles and 3 passenger cars per 1000 people in China [41]. The above facts clearly demonstrate that the energy consumption and the resulting emissions in today's world do not depend on the size of the population.

Regional distributions of the global CO_2 emissions, GDP and the world population presented in Fig.5 consolidate the above fact. Nearly 47.5% of the emissions in 1997 was accounted for by high income economies, but its population was only about 15% of the world population. Total emissions of low income economies, which include India and Indonesia, was as low as 10.5% despite their population being 40%. It is however revealing to observe in Fig.5 that the percentage shares of emissions correlate better with the percentage shares of GDP than with that of population.

Fig.6. provides further evidence to the close relationship between emissions and economical development for 10 countries from the Southeast Asian and Pacific regions. Singapore, Australia and South Korea, despite their differences in locations, culture, population sizes and resource availability, follow very similar emissions versus development path. The remaining 7 countries, except China, are also set out to follow that same path as Singapore, Australia and South Korea. It is therefore obvious that population control need not necessarily result in emissions reductions, whereas controlling the GDP, that is the economical development, would certainly reduce the emissions. It is however a very controversial stand to take in view of the 'perceived' positive role played by economical development in human development as demonstrated in Section 5.

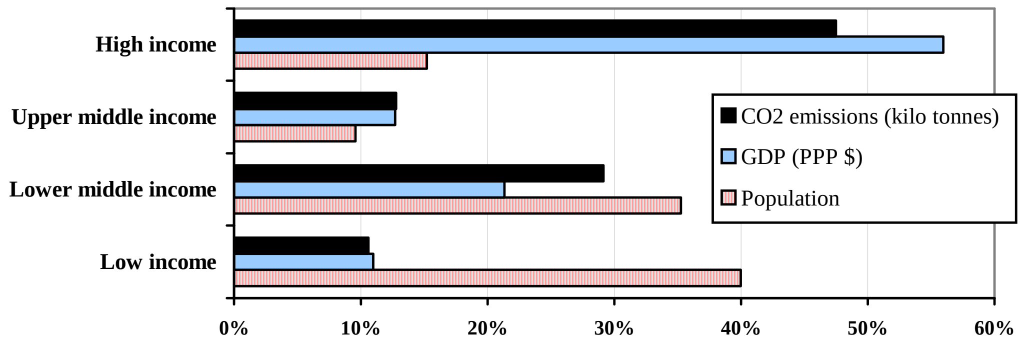

Fig.5. Percentage Shares of Global Carbon Dioxide Emissions, GDP and Population in 1997 of the income groups [41].

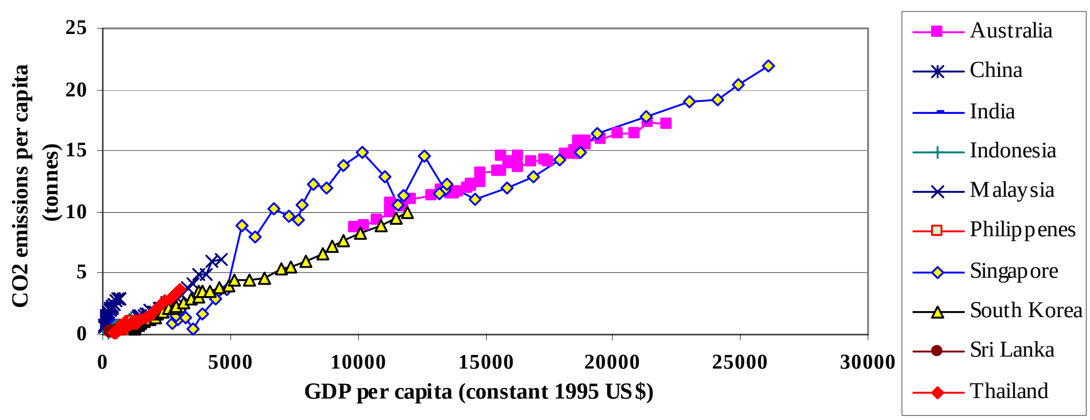

Fig.6. Dependence of Carbon Dioxide Emissions and Economical Development for 10 Southeast Asian and Pacific countries [41].

5. EMISSIONS AND HUMAN DEVELOPMENT

Economic development is vital for the humanity to better their lives. The average well-being of people living in a country is traditionally measured by the UNDP defined Human Development Index which gives equal weight to the GDP per capita (in Purchasing Power Parity $), life expectancy and educational attainment [18]. Therefore, one may conclude that HDI is neutral on the environment and social equity, which have been identified as two of the three pillars of sustainable development.

The fact is, as can be seen in Fig.7, HDI and GDPI[f], which is a measure of the average economic development in a country, have very similar relationship with the per capita emissions. Higher the emissions, higher are the indices HDI and GDPI. It is therefore I conclude that the UNDP defined HDI implicitly encourages per capita carbon dioxide emissions in a country, since the economic development is emissions intensive.

There is , therefore, a pressing need to correct the HDI to discourage countries from adopting the path of the CO_2 emissions intensive economic development. Such attempts have already been made by Vega et al. [48] and Shanthini [49]. Vega defined an Environmental Behaviour Index for CO_2 emissions as

$$EBI = 1 - CO_2 pc / 60$$

where CO_2pc stands for per capita CO_2 emissions in tonnes of CO_2, and 60 is taken as the maximum tonnes of CO_2 per capita that any country could ever emit. Vega et al. then determined the harmonic mean of the EBI and GDPI in their attempt to penalize countries with high emissions. The GDPI so modified was used

[f]GDPI = ln(40,000/GDP per capita in PPP $) / ln(40,000/100) is the index measuring the level of GDP per capita of a country, and it contributes towards one third of the HDI.

in place of the GDPI of the UNDP defined HDI. They named this index as pollution sensitive human development index (HDPI).

Shanthini on the other hand introduced an Environmental Responsibility Index for CO_2 emissions as

$$ERI = \ln(30 / CO_2\,pc) / \ln(30 / 0.1)$$

where she considered 30 as the maximum tonnes of CO_2 emissions and set the ERI to zero for countries with emissions greater than 30 tonnes of CO_2 per capita. She incorporated the ERI as the fourth component in modifying the UNDP defined HDI, and thus introducing the Environmentally Responsible HDI based on CO_2 emissions, abbreviated ERHDI_CO_2.

Fig.8 compares EBI and ERI, and also shows the new index, named Emissions Responsibility Index (abbreviated EmFI) defined as,

$$EmRI = \frac{8 * 0.5^3}{(CO_2\,pc/(44/12))^2 + 4 * 0.5^2}$$

where 44/12 is the per capita emissions sustainability limit of 1 tonne of C [15] converted to its equivalent in tonnes of CO_2.

Fig.8 shows, owing to the linear nature of the EBI, the value it takes at a particular per capita CO_2 emissions is sensitive to the maximum value of per capita emissions used in defining EBI. Besides, owing to the use of 60 tonnes of CO2 per capita as the maximum reachable per capita emissions in EBI by Vega et al [48], the EBI limits itself in the range of 1 to 0.5 for almost all countries including countries having per capita emissions as high as 30 tonnes of CO_2. Nevertheless, EBI takes high values, as it should be, for countries with low per capita emissions. The index ERI, on the other hand, takes low values for high emissions, as it should be, but it also takes unreasonably low values even for countries with very low emissions, such as for emissions in the range of 1 to 2 tonnes of CO_2 per capita (see Fig.8 and Fig.9).

It was therefore the need for introducing the index EmRI, which takes values higher than ERI in the low emissions range and takes values much lower than EBI for high emissions range. Besides, the nature of EmRI is such that it is naturally limited between one and zero. Moreover, the shape of EmRI is independent of the maximum value of the emissions. I have chosen the EmRI in such a manner that it takes the value of 0.5 when the per capita emissions crosses its sustainable limit of 1 tonne of C (or 3.67 tonnes of CO_2).

Using the EmRI, I modified the UNDP defined HDI by defining an Emissions Responsible Human Development Index, abbreviated EmRHDI. Following the approach adopted by Vega et al. [48], EmRHDI is defined as follows:

$$EmRHDI_{vegastyle} = \frac{LI + EI + GDPI_{EmRI}}{3}$$

where

$$GDPI_{EmRI} = \left[\frac{0.5}{GDPI} + \frac{0.5}{EmRI}\right]^{-1}$$

Following the approach adopted by Shanthini [49], EmRHDI is defined as follows:

$$EmRHDI_{shanthinistyle} = \frac{LI + EI + GDPI + EmRI}{4}$$

The major difference between the two approaches is that Shanthini [49] considers that a country taking responsibility to cutting down its emissions must be given equal weight as increasing its citizens' health, education and access to material wealth. In the vegastyle EmRHDI, it is the environmental irresponsibility in raising the GDP per capita is accounted for, still giving the emissions penalized GDP per capita index to contribute towards one third towards the HDI.

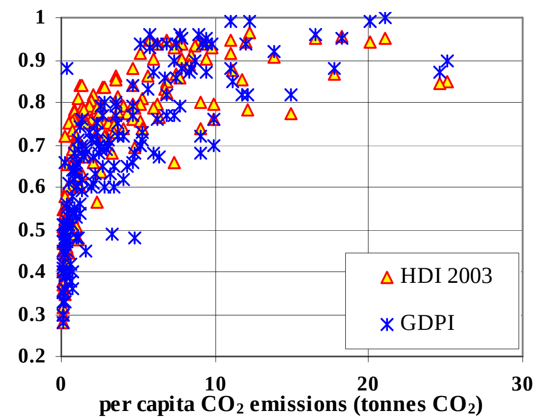

Fig.7. HDI and GDPI in 2003 versus the per capita CO_2 emissions [18].

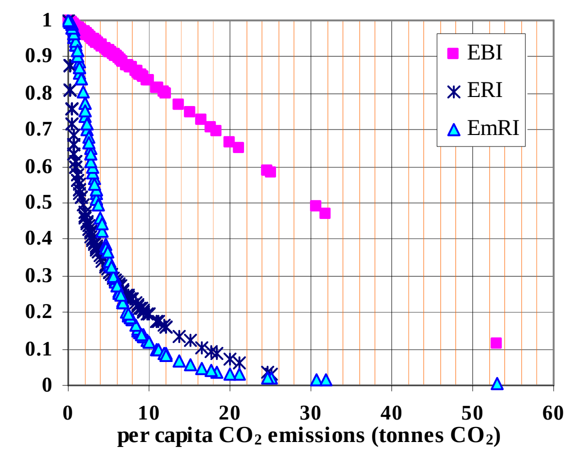

Fig.8. Indices measuring the Environmental Responsibility of a country with respect to CO_2 Emissions.

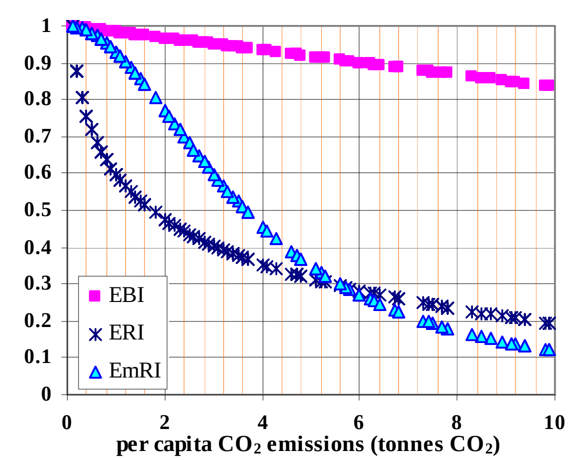

Fig.9. The information provided in Fig.8. magnified for per capita CO_2 Emissions in the range of 0 to 10.

The EmRHDI of vegastyle and shanthinistyle are compared to each other and to the UNDP defined HDI in Fig.10. The most important feature of the EmRHDIs is that each of them reaches a maximum value in the vicinity of the sustainable limit for emissions per capita. Any further increase in the per capita emissions reduces the Emissions Responsible Human Development Index. Unlike the UNDP defined HDI, which is insensitive to the level of CO_2 emissions in a country (see Fig.10), the EmRHDI defined in this paper has the capacity to appraise the ecological cost of human development.

Table 2 shows the EmRHDI ranks of the top twenty HDI 2003 countries. Owing to their high emissions (column 4 of Table 2), none of the twenty countries survive the top twenty ranks in the EmRHDI scales of both shanthini style and vega style. It is important to note that even Luxembourg, with the staggering value of GDP per capita at 62298 PPP$ in 2003, was unable or not willing to invest on technologies available to reduce CO_2 emissions into the atmosphere (presented in Section 3). The latest estimate of Luxembourg's emissions into the atmosphere by fossil fuel burning and cement manufacturing was 5.8 times the sustainable limit (see Table 2). United States and Australia, which claim that the solution to cutting down CO_2 emissions into the atmosphere must come from the technology and not from the Kyoto-type emissions reduction schemes, continue to emit more than 5 times the sustainable limit calculated by Graedel and Klee et al. (15), which is 1 tonne of carbon equivalent per capita.

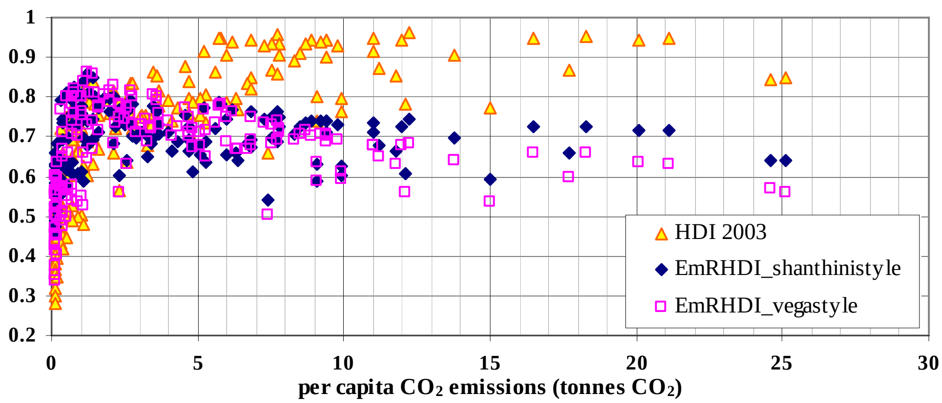

Fig.10. Emissions Responsible Human Development Indices compared with the UNDP defined HDI.

Table 2. The Ranks of the Top Twenty HDI 2003 Countries in the EmRHDI Scale.

Country	HDI 2003 rank	per capita GDP in PPP US$ 2003	per capita CO2 emissions in tonnes CO_2 (in tonnes C) 2002	EmRHDI_ shanthinistyle rank	EmRHDI_ vegastyle rank
Norway	1	37670	12.2 (3.3)	44	89
Iceland	2	31243	7.7 (2.1)	33	45
Australia	3	29632	18.3 (5.0)	65	102
Luxembourg	4	62298	21.1 (5.8)	71	115
Canada	5	30677	16.5 (4.5)	67	103
Sweden	6	26750	5.8 (1.6)	21	24
Switzerland	7	30552	5.7 (1.6)	19	25
Ireland	8	37738	11 (3.0)	56	94
Belgium	9	28335	6.8 (1.9)	32	41
United States	10	37562	20.1 (5.5)	72	113
Japan	11	27967	9.4 (2.6)	50	73
Netherlands	12	29371	9.4 (2.6)	50	77
Finland	13	27619	12 (3.3)	63	93
Denmark	14	31465	8.9 (2.4)	48	76
United Kingdom	15	27147	9.2 (2.5)	52	74
France	16	27677	6.2 (1.7)	27	33
Austria	17	30094	7.8 (2.1)	41	60
Italy	18	27119	7.5 (2.0)	40	56
New Zealand	19	22582	8.7 (2.4)	55	64
Germany	20	27756	9.8 (2.7)	59	83

Table 3 shows the top ten EmRHDI countries, all of them fall in the range of 46 to 93 in the HDI 2003 rank, but have per capita emissions well below the sustainable limit. What is very appealing to note is that the life index of these ten countries are above 0.75 and the educational attainment index are above 0.83, despite their relatively low GDP per capita in comparison to the GDP per capita achievements of the top twenty HDI 2003 countries (see Table 2).

The top ten countries of the EmRHDI scale therefore reveal the important fact that, while economical development is laden by CO_2 emissions, human development need not to be so. My recommendation is that the World must adopt EmRHDI in place of the HDI, to rank the countries on their achievement on human development goal, rather responsible human development goal. Such approach has the capacity to pressurise the countries to deviate from their emissions-laden development paths, and to seek for alternative development paths to provide their citizens with truly better standard of living.

Table 3. The Top Ten EmRHDI countries along with the UNDP defined Life Index and Educational Attainment Index.

Country	HDI 2003 rank	per capita GDP in PPP US$ 2003	per capita CO2 emissions in tonnes CO_2 (tonnes C) 2002	EmRHDI_ shanthinistyle rank	EmRHDI_ vegastyle rank	Life Index	Educational attainment index
Uruguay	46	8280	1.2 (0.3)	1	1	0.84	0.94
Costa Rica	47	9606	1.4 (0.4)	2	2	0.89	0.87
Latvia	48	10270	2.7 (0.7)	18	7	0.78	0.96
Cuba	52	..	2.1 (0.6)	12	4	0.87	0.91
Tonga	54	6992	1.1 (0.3)	3	3	0.79	0.93
Panama	56	6854	2 (0.6)	14	6	0.83	0.88
Colombia	69	6702	1.3 (0.4)	7	9	0.79	0.86
Dominica	70	5448	1.5 (0.4)	11	10	0.84	0.84
Albania	72	4584	0.8 (0.2)	4	5	0.81	0.89
Samoa (Western)	74	5854	0.8 (0.2)	5	8	0.75	0.89
Peru	79	5260	1 (0.3)	10	17	0.75	0.88
Philippines	84	4321	0.9 (0.3)	9	14	0.76	0.89
Paraguay	88	4684	0.7 (0.2)	8	19	0.77	0.86
Sri Lanka	93	3778	0.5 (0.2)	6	16	0.82	0.83

6. CONCLUSION

Mother Earth is heating up towards a perilous end owing to the colossal amount of carbon dioxide emitted into the atmosphere. The primary reason for all these emissions is the gigantic amount of global energy consumption, which is required to sponsor the reckless development activities undertaken by both the rich and poor nations alike to increase the economical prosperity of the respective nation. Development, we argue, is imperative if we are to raise the 'standard of living' of all people. By 'standard of living', we mean a life with abundance that sure strains the resources on Mother Earth and causes irrecoverable harm to her.

When we understood that Earth would not be able to sustain an uncontrolled population growth, we took immediate action. We have launched a worldwide programme on population control, and have been implementing it in the nook and corner of the globe. We believed, and still want to believe, that controlling population by itself would save the planet Earth from overexploitation of its resources by human, and from the resulting crisis situations faced by the entire globe. Now that we know what we believed in is not true when it comes to the increasing carbon dioxide emissions stemming from energy consumption, and the resulting rise in atmospheric carbon dioxide concentration, isn't it necessary to look for the real cause of increasing global energy consumption, and try to combat it?

Despite all the academic knowledge that has been accumulated over the years on renewable energy sources, they have their limitations when it comes to replacing the relatively cheaper energy from fossil fuels. The unavailability of an economically viable technology on any one of the renewable sources of energy (except for the large scale hydro electric power which has been exploited beyond its ecologically secure capacity in many countries) to address today's energy crisis is evident in Sri Lanka's proposed coal power project amidst very strong opposition from the public.

Even the international aid agencies, such as the International Monetary Fund, the World Bank, and the Asian Development Bank, do not think that they should put their money on renewable sources of energy to meet Sri Lanka's growing energy demands. So as for now, the worst CO_2 emitting fuel coal with its proven technology and low cost production facilities are recommended as the energy source for economically developing countries such as ours, for which environmental considerations remain a luxury. It is of immense importance to note that the current approach of the super-rich economies are also to depend on CO_2 emitting fossil fuels to increase their per capita incomes towards economic prosperity.

What is worst is that the UNDP defined Human Development Index ranks the countries with carbon dioxide emissions way above the sustainable limit as countries with top grade human development. Such an approach to measuring the human development in a country would also encourage the other aspiring countries to go ahead in the proven CO_2 emissions laden development path to increase their GDP per capita, which accounts for one third of the UNDP defined human development measure.

An alternative to the UNDP defined HDI is the Emissions Responsible Human Development Index (EmRHDI) proposed in this paper, which is proven to have the capacity to make the human development to be CO_2 emissions responsible. It is done in view of the pressing danger of ecosystems breakdown and its dreadful consequences. My recommendation is that the World must adopt the EmRHDI in place of the HDI, to rank the countries on their achievement on the emissions responsible human development goal. Such approach has the capacity to pressurise the countries to deviate from their emissions-laden development paths, and to seek for alternative development paths to provide their citizens with truly better standard of living.

According to Greek Mythology, the supreme Greek God Zeus seemed to have foreseen the fate that would fall upon Mankind if men were permitted to experience the comforts, and indulge in the luxuries, that the use of energy would provide them. Zeus told Prometheus [50], when he breathed life into the men made out of clay by Prometheus, "You may give men such gifts as are suitable, but you must not give them fire – for that belongs to the Immortals. If you disobey me in this matter, your fate shall be terrible." Despite the wisdom and the ingenuity of the human race, will it eventually be proven that Zeus was right when he forbade fire to us, the mortals?

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