The Two Worlds We Inhabit:

The Top 4 Billion (T4B) and the Bottom 3 Billion (B3B)

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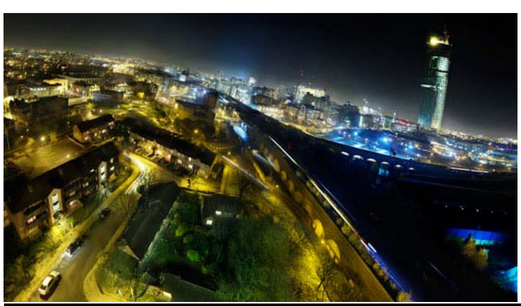
The nexus between population, energy, development, environment, and human well-being has to be understood, both conceptually and empirically, for making practical advances into the sustainability issue. Scientific studies of this nexus must recognize that there are two separate but co-dependent worlds or planets: The bottom 3 billion, (B3B) live in a world with minimal access to fossil fuels; and the top 4 billion live in T4B, a world with seemingly inexhaustible supply of affordable fossil fuels. Consumption of fossil fuels by the T4B has created the biggest threat to sustainability for both T4B and B3B, which is the planetary-scale warming of unprecedented magnitudes that will be witnessed during this century. Destruction of local habitats and ecosystems (forests) by B3B is also a threat affecting both worlds. Much of the emphasis of economists, political scientists, and global leaders interested in mitigating climate change is on decarbonizing the economy and reducing the per-capita carbon foot print … issues that are of relevance to T4B. Here I make the case for an equal emphasis on enabling sustainable and clean energy (mix of biomass, solar, and fossil) access for the B3B to avoid amplifying the global warming that is already set into motion. In order to avoid unsustainable climate changes in the coming decades, the decarbonization of the T4B economy as well as the provision of modern energy access to B3B must begin now.



T4B: *DOWNLOADED FROM THE WEB*

B3B; *PHOTO TAKEN BY RAMANATHAN*

<u>Preamble:</u> A fateful chartered flight over the Eastern Himalayas with Dr. Klaus Töpfer set me on the current path of enquiry into the fundamentals of the sustainability issue. The flight took place on March 25, 2001 onboard a small aircraft operated by Buddha Tourist Airlines of Nepal. He was then the Executive Director of UNEP. We got off the aircraft after a momentous 'sight-seeing' trip. The view on the north side had breath-taking views of Mount Everest, but I was directing Klaus' attention to the south side—to the widespread brown clouds shrouding the more modest Himalayan mountain ranges bordering Nepal. I knew, with the juxtaposition of Mount Everest on the one side and the vast brown clouds on the other, that we had Prof. Töpfer's full attention on the problem. Nevertheless, a big surprise awaited me when disembarked the aircraft, got into the waiting car, and settled into the back seat. Before it started, he turned towards me, held my hand firmly, and said: "I am going to do my best to address this problem." A day earlier on March 24th, the two of us met with my colleagues, Drs. Paul Crutzen based in Germany and A.P. Mitra of India. We all flew in from different parts of the world to meet with Klaus at Kathmandu and persuade him to start a major UNEP initiative on the brown clouds problem. He did not need any persuasion.

True to his word, Klaus started the Atmospheric Brown Clouds (ABCs) project and appointed Paul Crutzen and I as Co-Chairmen in 2002. The team included scientists from China, Germany, India, Italy, Japan, Korea, Maldives, Sweden, Thailand, and USA. Klaus' successor, Achim Steiner, continued the program with equal vigor and interest. After six years of intense field experiments and modeling studies, we released a regional assessment report in 2008, focusing on the impacts of air pollution on health, water, agriculture, and the climate of Asia. The report was the first of its kind and had a big impact. Its main conclusion was: ABCs threaten the health and the water- and agriculture-security of Asia. ABCs were linked with millions of deaths outdoors, melting of glaciers, and disruption of the monsoon. This report, UNEP-2008, which I chaired set me on a path beyond scientific enquiry, for it convinced me that we have to get rid of these pollutants for no other reason than saving millions of lives and slowing the rapid retreat of the Himalayan/Tibetan glaciers.

A year earlier, the IPCC released its AR4 report. Using the data in that report on greenhouse forcing and climate sensitivity, my post-doctoral colleague Yan Feng and I came to an alarming conclusion, which was published in the Proceedings of the National Academy of Sciences (PNAS) in 2008 (Ramanathan and Feng, 2008)We showed that the manmade greenhouse blanket, comprising CO_2 and several non-CO_2 gases, was already thick enough to warm the planet by as much as 2.4°C (1.2°C to 3.6°C). It merited a commentary by Schellnhuber (2008) in the same issue of PNAS, titled: *Global warming: Stop worrying and start panicking*. My entry into the non-CO_2 warming pollutants began in 1975, when I identified (Ramanathan, 1975) the super-greenhouse effects of a class of halocarbons, chloro-fluoro-carbons (CFCs), then known as *Freons*.

Two corollaries from the PNAS-2008 study led me to study the short-lived climate pollutants (SLCPs), which are basically non-CO_2 warming pollutants with lifetimes of a decade or less:

First, the cooling effect of aerosols from air pollution (in brown clouds) has masked the 2.4°C greenhouse warming thus far and kept the planet from experiencing it. Once the air pollution is cleaned up, the planet will warm rapidly beyond 2 Celsius. But not all air pollutants cause cooling. Ozone gas and particles of black carbon lead to warming; in fact, that same year, I teamed up with Greg Carmichael (also with the ABC project) to conclude that black carbon was the second-largest contributor to global warming. However, contemporary air-pollution laws were targeting sulfates, mainly from coal combustion. Sulfates were one of the major cooling aerosols. If he had viewed both air pollution and climate change with one lens, we would have cut black carbon and ozone at the same time we were cutting down sulfates from coal combustion. *Second*, if the greenhouse blanket has already committed the planet to a warming in excess of 2C, the only way to reduce the committed warming is to thin that blanket; but, because of the long lifetimes of CO_2 (of the order of century and longer), cutting down emissions of CO_2 (which we must do) can only prevent it from thickening more; but not thin it. We therefore need to target climate warming gases and particles that are short lived, in addition to targeting CO_2..

Teaming up with my student Xu, we published (Ramanathan and Xu, 2010) a hybrid climate mitigation strategy in PNAS in 2010 that will stabilize CO_2 at 440ppm to limit long-term warming and mitigate emission of four SLCPs (methane, black carbon, HFCs, and ozone precursors in addition to methane) to limit near-term (mid-century) warming. The important point is that mitigation of SLCPs did not require development of new technologies but rather the maximum use of available technologies, as recommended by IIASA (International Institute for Applied Systems Analysis). The surprising findings were that limiting SLCPs reduced near-term (until 2050) warming by about half, and that the mitigation of CO_2 and SLCPs together was sufficient to limit global warming to within 2°C until the end of this century. UNEP, under Dr. Steiner's leadership, took up the proposal and formed an international committee that released a report in 2011, basically supporting the Ramanathan-Xu (RX) hybrid mitigation strategy of CO_2 and SLCPs. This report was followed by the formation of the Climate and Clean Air Coalition which, as of this writing, has been joined by 30 countries and several NGOs.

Now, I am ready to describe what led me to the 'Two Worlds' approach to sustainability. I realized that the science behind the Ramanathan and Xu's hybrid mitigation strategy was not part of the lexicon of mainstream climate change community. It became clear to me that it has to be demonstrated via real-world trials or experiments. In addition, data published by various groups pointed to biomass burning in traditional cooking stoves as a major source of black carbon concentrations in the brown clouds. I saw this as a great opportunity to address not only a climate change problem but also a vexing problem faced by the millions of poor in South Asia. After all, I witnessed how my grandmother suffered with the traditional mud stoves, burning dung and firewood in our ancestral village of Eraharam in South India, about 200 km south of the famous city Chennai (Madras). This realization gave birth to Project Surya in 2007 under the ABC program of UNEP(www.projectsurya.org). Teaming up with The Energy Resources Institute of India and Nexleaf Analytics of USA (both NGOs), we started field studies in northern Indian villages to replace the mud stoves with improved stoves and document their impact on human health and air pollution. The two major outcomes so far are the development of cell-phones for collecting vast amounts of data from individual homes (Nithya Ramanathan et al, 2011), and identification of the forced-draft biomass cooking stove as the most effective way to reduce black carbon and CO_2 emissions (Kar et al, 2012). Five years into this program, in early 2013, I spent eight weeks living in villages in India (my grandmother's village in the south and other villages in central and north India). In between, I would seek some reprieve from the harsh, almost brutal living conditions by retreating into nearby cities with air-conditioned rooms and cars to ward off the oppressive tropical heat. It was then that I discovered the two worlds we live in. I had no inkling, during that March 2001 flight with Klaus Töpfer, that it would ultimately lead me through various unusual but exciting pathways to discover the two worlds we inhabit.

Setting the Stage: Let us start with an overly simplistic view of how humans interact with the environment and the earth system (Figure 1).

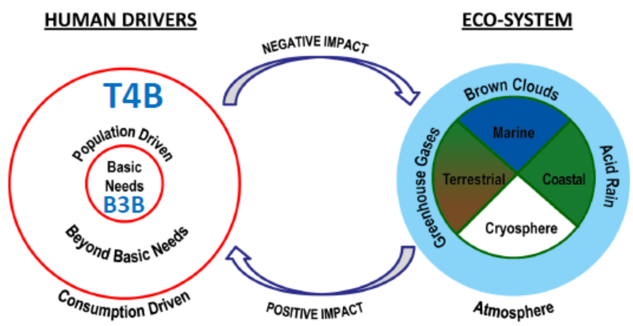


Figure 1: Schematic of Human-Environment interaction. The B3B live in the smaller inner circle and the T4B in the bigger outer circle. The area of each circle qualitatively reflect the magnitude of resource consumption. (Reproduced from Ramanathan, 2010).

Homo sapiens began as an integral part of the ecosystem, i.e., as an internal component. In other words, *Homo sapiens* and the ecosystem constituted a closed system, with the incoming solar energy as the sole external driver. Sometime during the last millennia, humans evolved into an external driver, leaving behind enormous unrecyclable waste either in the atmosphere or in the land–ocean–cryosphere system. The atmosphere alone contains about 1000 billion tonnes of manmade CO_2, widespread brown clouds of toxic SO_2, CO, NOx, ozone, black carbon, hundreds of organic compounds and acids, depleted ozone layer, etc. Similar waste and destruction of the ecosystem have been chronicled elsewhere and need no repetition here (e.g., Schellnhuber, Crutzen, Clark et al.2003). It is this period that was named the Anthropocene by Crutzen.

The Two Worlds We Inhabit: Referring back to Figure 1, there are two basic human drivers of change: population and consumption. Human well-being is dependent on ecosystem services that meet basic human needs: Food, water, shelter, health. The ecosystem stress resulting from meeting those basic needs is basically driven by the scale of human population. All other activities that fall outside are, for lack of a better term, referred to as ‘beyond basic needs.’ This category must include development that is critical for evolution of human species (e.g., transportation, information technology, refrigeration, space exploration, recreational activities, etc.). The environmental stresses that result from meeting 'beyond basic needs' are driven more by consumption than population growth. I will give examples of this later.

The usual categories, such as 'developed' and 'developing' nations, are not that helpful in the current context. Many hundreds of millions living in developing nations have living standards and carbon footprints comparable (at least in the last decade) to those in the industrialized nations such the USA and Western Europe. The categorization of all human drivers into two developmental areas (population and consumption) is an overly simplistic way of describing an incredibly complex pattern of human intervention with the Earth's life-support systems; but the thesis developed here does not depend on the number of categories.

The B3B Perspective: Approximately 3 billion human beings are still struggling to meet their basic needs and they live in the inner world, B3B, shown in Figure 1; about 1.2 billion lack electricity even for lighting; about 2.7 billion earn less than $2/day and burn solid biomass (firewood, dung, and crop waste) for cooking and home heating with rudimentary mud stoves. From personal experience, I can say the food tastes genuine and delicious—particularly if it is cooked by your grandmother and served hot from the burning stove, with the flames not only keeping the food warm but also your face, hands, and feet on a cold morning. But the delicious food comes at an enormous cost. About 3 million (mainly women and children) die each year from inhalation of the toxic pollutants (carbon monoxide, volatile organic compounds/VOCs, black carbon, organic acids, etc.) contained in the flames. My grandmother was not part of this statistic—in part because our house (not a hut) was well ventilated. But I did not realize then that the ventilated smoke is transported thousands of kilometers in a week or less, and contributes to air pollution in distant cities (the world of T4B).

***The Co-Dependence of B3B and T4B*:** The two worlds are co-dependent. The indoor biomass smoke, when transported outdoors, additionally kills more than 1 million people annually (both T4B and B3B are victims), bringing the premature mortality from indoor air pollution to 4 million. It is also transported vertically, contributing to the 3-kilometer-thick ABCs prevalent over much of Asia. In regions such as South Asia, 30% to 60% of the black carbon (soot) in ABCs derives from smoke produced by biomass cooking/heating. The rest is from fossil fuels burned by the T4B population living in the region. The black carbon solar absorption directly heats the elevated air of the Himalayas and when it is deposited on the ice/snow of the mountains (by snowfall) reduces its reflectivity and enhances melting The combined warming of the air and land surface by black carbon is a major threat to the stability of the Himalayan/Tibetan glaciers that feed famous rivers such as the Indus and the Ganges in South Asia, and the Yangtze and the Mekong in East Asia. The other destabilizing influence on glaciers is global warming caused by greenhouse gases (largely emitted by T4B in the developed nations).

The T4B Perspective: Now let us discuss from the T4B perspective. The most vivid and also most vexing example of unsustainable growth is the human impact on climate change … likely the most potent and catastrophic sustainability issue we now face. There is rancorous exchange between developing and developed nations about who is responsible for global warming. The developing nations point out that about 70% of the CO_2 in the atmosphere was dumped by about 30% of the global population in developed nations. The developed nations respond, in turn, that as the developing nations industrialize using fossil fuels, their emissions in the coming decades will far exceed levels that can trigger dangerous climate changes and mass extinction of species.

Much of the world's focus with respect to mitigation of climate change is on the T4B consumption problem. We are now dumping about 36 billion tons (Gt for giga tons) of CO_2 annually. We need to reduce this to 18 billion tons (50% reduction) by 2050, for us to have any chance of limiting global warming below 2.5 Celsius; and to zero or even negative emissions (sequestering excess CO_2 from the air) by 2100. The per-capita emission of CO_2 by the B3B is less than 1t/year and the total B3B annual CO_2 emission is less than 2 Gt. The global average per-capita fossil CO_2 emission is about 4.5 t/yr; US per capita is 18.5t/yr. We hope that the B3B catch up with the living standards of the T4B; but if they achieve this by climbing up the fossil ladder to the global average per-capita CO_2 emission of 4.5 t/yr by 2050, the emissions of the B3B will increase to 14B t/yr. For us to still meet our goals of limiting CO_2 emission to 18 Gt/yr by 2050, the emission by the T4B has to come down from 34Gt (now) to about 6Gt by 2050 … a reduction of 80% in 35 years! Clearly, it is to our (i.e., T4B) own advantage to help the B3B climb on the cleaner renewable energy ladder and not on the fossil ladder. Under some scenarios, global population is projected to reach about 9 billion during this century, and it is a good guess that most of the additional 2 billion population will be among the B3B: the B3B will, during this century, morph into the B5B.

Transition from B3B to M5B: My proposal is for the T4B to help the B3B to morph into the M5B … the middle world of 5 billion with modern but sustainable energy access and aspirations of well-being similar to those in T4B. The basic energy needs for the B3B are: cooking, lighting, and heating. Such energy access is crucial to lift the 3 billion out of energy poverty as well as monetary poverty. It is for this reason that the United Nations initiated the Universal Energy Access Program in 2012. Technologies are available off-the-shelf to provide access to clean, renewable energy without increasing their CO_2 emissions. Two examples are given to justify this claim:

1) The biomass used for cooking leads to deforestation equal to the emission of 1 billion tons of CO_2; and another 1 to 2 billion tons of non-CO2 warming pollutants (black carbon, methane, and ozone). The smoke from the cooking kills over 4 million annually. It is the second- to third-largest source of outdoor air pollution; destroys millions of tons of crops; exacerbates the melting of Himalayan/Tibetan glaciers; weakens the monsoon; deforestation combined with monsoon disruption depletes water availability; and worse, women have to walk about 1 to 2 hours per day to collect firewood. Project Surya (www.projectsurya.org) has demonstrated that

improved forced-draft biomass cooking stoves can drastically reduce emissions of black carbon, CO_2, and other pollutants (Kar et al, 2012). But there are huge problems related to the adoption of new technology—the lack of: good business models; supply chains; infrastructure; user-friendly technologies; and understanding of the choices the B3B population make with respect to technologies—all of which hinder scale-up. 2) The second example is electricity. Distributed solar photovoltaic micro-grids can provide electricity for lighting and small-scale industry, replacing highly polluting (and expensive) kerosene lamps and diesel generators.

Environmental economists from the IIASA (Austria) (Pachauri et al. 2013) have estimated the B3B energy access market (or cost) to be about 65 to 86 billion dollars (US dollars) per year. What does society stand to gain by solving this energy access problem?

i) Saving 4 million lives (the majority among women and children) lost to air pollution each year; ii) Reducing poverty and improving quality of life among rural women and children; iii) Mitigation of 1 billion tons of CO_2 per year and of the short-lived climate pollutants (black carbon, tropospheric ozone, methane); iv) Saving tens of millions of tons of crops lost to air pollution; v) Slowing the melting of the Himalayan/Tibetan glaciers; vi) Providing energy access to farmers for improving agriculture output; vii) Avoiding massive emissions of CO_2 by the B3B, which could result if they climb on the fossil ladder instead of the renewable energy ladder.

Proposal for a Way Forward: We need to develop and demonstrate a scalable model for providing clean energy access to the B3B. Towards this objective, I suggest conducting a pilot project with a million homes in a contiguous location, with the goal of providing sustainable access to clean and renewable energy; and documenting the impact on air pollution, health, climate mitigation, local economy, and human well-being. The terms 'scalable' and 'sustainable' refer to both natural resources and to economics. The inclusion of 'economics as criteria' precludes donation (giving-away) of the energy access. It requires sustainable business models, a value chain, and a supply chain. If the pilot can be conducted in one contiguous location, we can capture the pollution-hole created by the intervention, via a combination of mass-scale in-situ data collection (using cell-phone-based sensors; see N. Ramanathan et al. in) and high-resolution satellite data (resolution of few tens of meters). Imagine how impressive that will be to show to the rest of the world. A project of such massive scope should include partnerships between natural and social scientists, technology innovators, entrepreneurs, industry, and civil society.

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