Diffusing Bomb of Energy Scarcity

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From the time modern humans evolved, a few million years ago, the human population on earth has grown from nought to 1.6 billion. Thanks to the contributing factors including increased birth rate, decline in the death rate, fertility rate, morality rate, life expectancy and better health care standards because of which the population shot up to 7 billion in less than 100 years. In accordance with the demographics, the world population is approximately 7.5 billion at present and is estimated to rocket up to 11.2 billion by 2100.

This uninhibited increase in the population is one of the most pressing environmental concerns that have aggravated issues like depletion in earth's resources. This effect of depletion in the resources has further led to loss of biodiversity as we humans have stripped every nook and corner of the earth for its resources. A report by *World Resources Forum* shows that we have nearly extracted 40 billion tons of resources from earth. The imparity in the biodiversity has given rise to increased greenhouse gases mostly CO_2. In 20th century, where the world encountered ~5-fold increase in population, it witnessed ~14-fold increase in CO_2 emissions. The world releases 40 billion tons of CO_2 annually.

As India's rapid growth continues, we will see a 20-fold increase in carbon emissions. This pattern would repeat from Africa and other nations that are rapidly modernising. This comprises 2/3rd population of earth increasing emissions by 20 tons. That's a 12-time increase in CO_2. This would breach greenhouse safety levels and could cause a runaway reaction that'd be detrimental to

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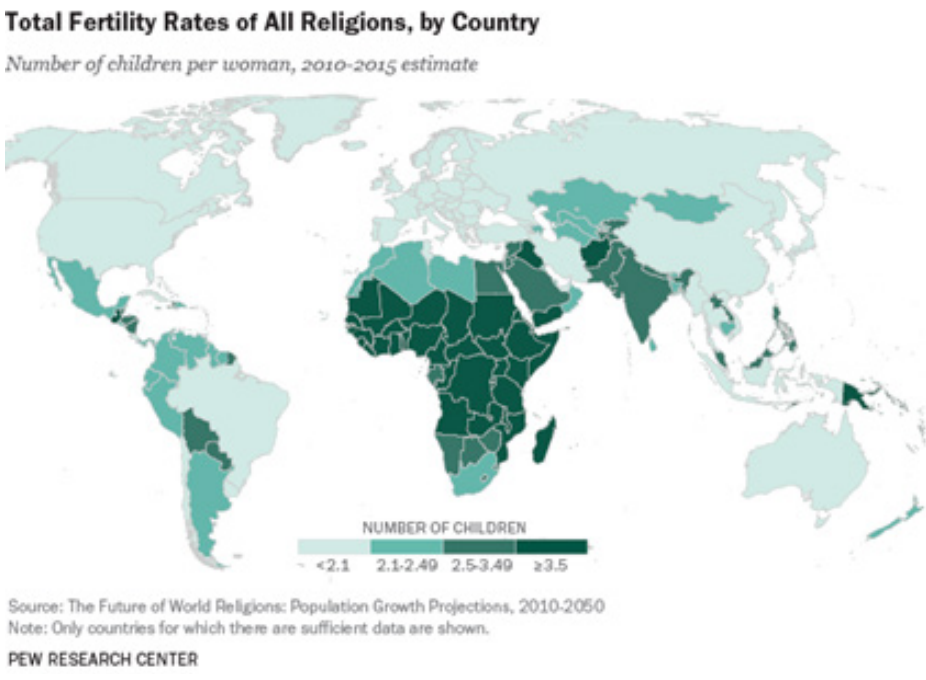
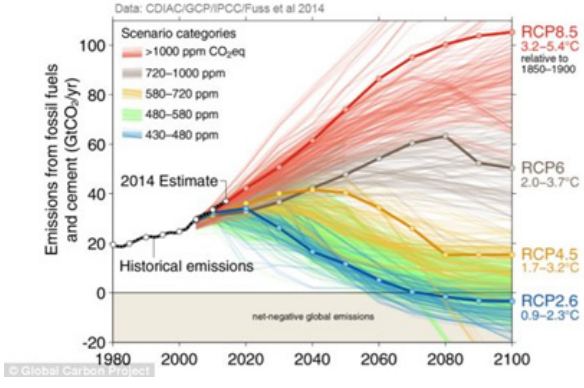
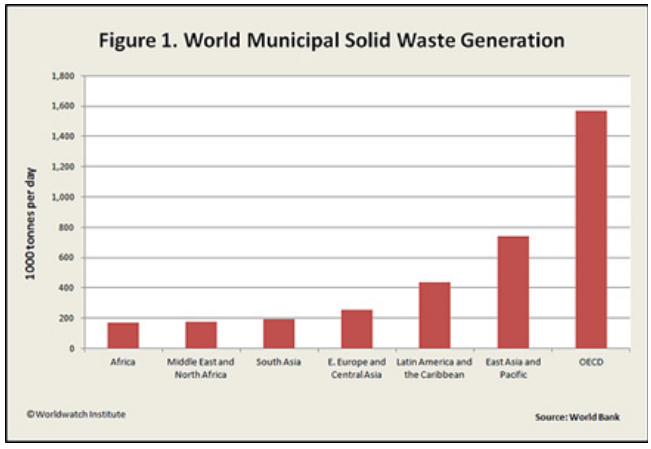


life on earth eventually resulting in climate change. Drastic global climate changes exacerbate and amplify the risk of life; it is simply suicidal! The increased temperature levels have resulted in rising sea levels, droughts, flooding and heavy precipitation. The statistics says that every year the world is experiencing at least 400 extreme events due to climate change. From 2017, roughly 41 million people have been severely affected by floods and more than 150 million people live below sea level threatening almost quarter of the entire population.

Second crucial factor that is directly interconnected with the exuberant increase in the population is enormous production of waste. A report from *World Bank Group* on waste management shows that world currently produces ~3 billion tons of municipal solid waste every day and the total household wastes accounts to ~1.5 billion tons every day. India produces approximately 60 million tons of waste every year calculated at 0.7 kg per capita per day. On gross, 77% of this waste is dumped without proper disposal and other 23% is processed by using landfills. The landfills disposal method uses soil bacteria to decompose the waste and produce manure. But often, these landfills produce tons of



methane gas. Methane is a deadly greenhouse gas with global warming effects several times higher than CO_2. This encourages zero-waste products; a process equivalent to the way resources are reprocessed in the nature.



Another paramount factor that is closely knit with the increase in population is "*Energy Demand*". Energy is at the spearhead of the global agenda and at the pedantic heart of almost every developmental, economic and environmental issue. An intricate association endures between a country's economic growth and energy consumption. It is pronounced that a sustained and convenient supply of energy is a prime requirement for a tenable society. In accordance with BP's statistical review of world energy, in 2017 world's gross primary energy consumption was 13.6 billion tons of oil equivalent with an annual growth rate of 1.5%. India stands fourth amongst the major energy consumers in the world. In 2017, India's average primary energy consumption increased to 0.75 billion tons of oil equivalent, contributing to 5.6% of the total world's primary energy consumption.

At present, majority of global energy needs are met by burning of fossil fuels. As the humankind has fallen heads down for fossil fuels, the menace it has caused has affected the world irrevocably. A world steered by fossil fuel has led to the forefront factor like: energy scarcity. The ideology of scarcity spreads over the entire civilisation; indeed basic idea of any movement has ever hung on the understanding that nothing lasts forever. Crude oil reserves are diminishing at the rate of 4 billion tons every year. At this rate of consumption, world will run out of crude oil deposits by 2050. As a result of macroeconomic expansion, India has become one of the fastest growing energy markets and a study predicts India to be second largest contributor towards the global energy demands by 2035 accounting to 20% increase in energy consumption and demand. Considering this growth trend, the effective conversion of the fossil fuels into lucrative energy lags much behind the ever-increasing demands.Global ingress to productive energy is still one of the major areas to beperemptory hit for a sustainable future. It is imperious to prioritise and address this cardinal without any further delays. One of the crucial factors allied with energy sustainability is effective and judicious management of available energy resources and an indispensable segment of efficient management of existing energy resources is; energy storage. This redefines the energy scarcity problem to energy storage problem thus intensifying the requirement of developing a cost-effective and clean energy storage device. The development of novel ESDs not only facilitates the energy storage but also helps in alleviating the dependency on fossil fuels. It also contributes to grid energy storage thus elevating the use of renewable sources. The best method of storing energy currently is to use batteries.

The tagline is obvious: "The more energy we need, the more energy we find." Despite continuous handwringing about the shortage of energy, the world has now started to relook and reconsider the renewable sources to satisfy its demands. Thus, a novel energy storage technology is of utmost important as it plays a crucial role in supplying a buoyant, clean and low-carbon energy supply by extending its hands in enabling the reliance on green, clean and renewable sources of energy. It is foreseen that the cost of generation of energy from renewable sources to reduce. Hence, for the judicious use of these sources and integrating them to the regions with a bleak grid infrastructure necessitates new energy storage. In the report "*Energy storage trends and opportunities in emerging markets*", prognosticate that worldwide demand for energy storage to shoot up to ~40% in a decade in order to meet the energy requirements.

Our work focuses on reducing the problem of waste management by incorporating its use in fabricating effective storage devices: supercapacitors and thus alleviating energy storage problem. In our research, we are finding alternate uses of bio-waste. One of the discoveries is that when bio-waste materials are heated in an inert atmosphere, it produces a unique allotrope of carbon called Carbon Nano Spheres (CNS). Carbon precursors are preferred for the electrodes because of its availability, low cost, pore volume distribution and good surface area. CNSarespherical nanoparticles with a diameter of ~50nm. They have a good surface area and exhibit excellent electrical properties. These properties make them ideal candidates for ESDs.Supercapacitors made from CNS synthesised from bio-wastes are devices that can charge rapidly and release energy as and when needed. They have a much longer life than batteries. They can thus store more charge and provide energy for a long duration. The main requirements for fabrication of the supercapacitors are novel precursors and advanced configurations. One of the prime criteria in choosing the precursor is surface area and pore size.

CNS is synthesised from bio-waste precursor by heating the same in an inert atmosphere at a constant heating rate. Electrodes made from CNS synthesised from bio-waste make for a perfect material for supercapacitor electrodes due to their large surface area, excellent electrical properties, life cycle and stability. Templated porous CNS has a combination of micropore, mesopore and macropore sizes with a neat tailored hierarchical structure making it an apt material for the electrodes of the supercapacitor. By developing electrodes from bio-waste materials, these "cells" can be sustainable, environmentally friendly and biodegradable. Supercapacitors made of bio-waste materials have both balanced energy and power density making it an apt for energy storage devices.

Table 1: Performance supercapacitor fabricated in our lab.

Bio-waste	Specific capacitance (F/g)	Electrolyte	Cycle life
Coconut fibre	236	1.0 M KOH	>10,000
Coconut stick	208	1.0 M KOH	>10,000
Coconut leaves	116	1.0 M KOH	>10,000
Lablab Purpureus seeds	300	1.0 M KOH	>10,000

The future is electrifying!!Novel energy storage plays a vital part in meeting the prudent objectives of the world. A potential driver of the energy storage demand is the use of renewable energy for clean energy mandates. Thus, supercapacitors made of bio-waste materials would be a perfect bomb diffuser for both disposal of waste and energy storage.

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