Arreh Jain
Wayzata High School
Plymouth, Minnesota, USA
India, Renewable Energy

Solar, Wind or Biomass Powered Storages - A Renewable Energy Approach to Solving World Hunger Crisis

The democratic republic of India is considered the seventh- largest country by area and the second highest by population in the world, with a total area of approximately 2,042,610 miles and a total population of about 1.4 billion (O'Neill 2021). It accounts for 17.7% of the total world population (Worldometer 2022). 65% of India's population resides in rural areas, while a mere 35% is based in urban settings (World Bank 2022). Surrounded by the Arabian Sea, the Bay of Bengal, and the Indian Ocean in the south, India shares its borders with six other countries in the north. It runs on a parliamentary system of government, where the federal legislative branch consists of the President and the Rajya Sabha (Council of States) as the upper house, and the Lok Sabha (House of the People) serves as the lower house.

Dwellings in India, typically low-rise apartment buildings, high-terraced houses, and slums (Teoalida 2021), vary a lot across geographical regions and differ significantly from urban to rural regions. A couple of decades ago, rural households used to be majorly earthen houses, but their numbers have been on the decline (Kulshreshtha et al. 2020). While urban area houses are mostly made of brick, stone, and concrete. Additionally, rural areas boast of bigger family sizes with multiple generations living together, including extended families too, but they have been shrinking lately (Mitra et al. 2009). Whereas in an urban setting the typical family size has been low for many decades due to nuclear families, and that too continues to diminish (Scroope 2018) (Nooreyezdan 2018) (Thakur 2008) (Kulshreshtha et al. 2020) (Haub and Sharma 2008). A conventional meal in a household consists of legumes, beans, lentils, grains, and vegetables. Fruits and milk may not be consumed in very poor households (TNN 2020). Most people do not eat proper meals. The whole-day meals are dependent on the income levels and typically include either skipping breakfast or eating small portions of a meal. India's food security crisis is mostly impacting the people living in dense slums and remote areas.

Furthermore, the typical gross annual wage for the agricultural occupation in rural India is INR 90,000 (~USD 1,200) (Labour Bureau 2022) (Xavier Estupiñan et al. 2020). Besides, 5% of the Indian population, which is over 85 million and growing, does not have access to clean water, food, and overall sanitation. Electricity consumption is limited, and roads and local markets are polluted and dirty. This results in an obstacle to the growth and health of people and their nourishment (Agarwal 2016). Lack of education and job opportunities in rural areas have further added to the problems (TNN 2020). The poor living conditions are due to multiple reasons including inflation in the prices of the commodities, the growing poverty rates, and poor construction standards. Overall, 50% of households are considered in very poor conditions (Population Reference Bureau 2008). The World Bank has been working to improve conditions and has made significant progress however, many continue to live in poor conditions.

"India is an agrarian economy with half of its labor market representing agriculture-related sectors that play an important role in Indian economics, politics, and society. Agriculture and related sectors such as forestry and fisheries account for 19.9% of the country's GDP" (Davey 2021). According to World Bank, around 60.3% of India's land area is agricultural land (The World Bank 2021), helping it become "the world's largest producer of milk, pulses, and jute, and ranks as the second largest producer of rice, wheat, sugarcane, groundnut, vegetables, fruit, and cotton (Mishra 2021). It is also one of the leading producers of spices, fish, poultry, livestock, and plantation crops. Worth $2.1 trillion, India is the world's third-largest economy after the US and China" (FAO 2021).

Despite all these resources, the farmers of India have to strive to attain sustainable income for a modest lifestyle. Depending on the type of farmer, whether they are smallholder, sharecropper, tenant farmer, peasant, hired farm hand, dirt farmer, etc., the cause of their distress may differ resulting in varied financial issues, for which they take loans. Smaller farmers endure the consequences of lack of tools, technology and labour, low storage space, black marketing, etc. Many enterpreneurs have brought in solutions to some of these issues and even the Indian government has taken many steps to support the farmers, including setting up regional rural banks or scheduled commercial government banks (Gramin Banks). Regardless, the farmers committing suicide has been a persistent issue for many decades as they are unable to repay the meager loan amounts due to financial difficulties. Recent farmers' protests brought more infrastructure and pricing issues to the forefront (BBC 2021). The Indian farmers protested to secure their rights for fair pricing of crops and restricted / supervised the role of the middlemen, who otherwise would have manipulated prices to their personal benefits only.

Low profitability for the larger proportion of farmers, makes agriculture a non-sought after profession, leading to manpower drainage towards cities. India has seen a rapid urbanization trend in the last few decades, which has led to loss of labor in agricultural regions and made "cities more susceptible to natural and human-made disasters (floods, droughts, and pollution). . . . Climate change will affect food security and water access in areas that are already currently vulnerable (e.g., megacities)" (Knorr et al. 2018). The Indian government has implemented various programs and policies to make food available at subsidized rates through Public Distribution Systems, but still, many are unable to avail the benefits due to multiple reasons. Marginalized populations, minorities, and indigenous and tribal communities suffer food shortages due to their "habitation in remote difficult terrains and practice of subsistence farming" (Upadhyay and Palanivel 2011). Food wastage hurts the environment as well, "if food goes to the landfill and rots, it produces methane—a greenhouse gas even more potent than carbon dioxide thus leading to more greenhouse effect" (Fight climate change by preventing food waste 2016).

Continuous research and various endeavors are being pursued to eliminate hunger throughout the world, and while awareness is being raised via various programs that are targeted at small, medium, and large-scale food cultivators, food insecurity continues to grow with the rising global population. This can be attributed to lack of education and knowledge about remediation techniques, improper or no planning, and a lack of proper coordination and infrastructure, more prominently seen in the less developed or developing nations. According to World Hunger Facts, chronic hunger and malnourishment are the worst in Asia, Africa, and Latin America (The Hunger Project 2021). 690 million people are chronically undernourished (Action Against Hunger 2021). This is a continuation of a multi-year increase in hungry people around the world — a trend largely attributed to climate change, economic inequality, and conflict. 99% of the world's undernourished people (F.A.O. 2021) live in mid- and low-income countries and roughly one in nine people go hungry every single day (The Hunger Project 2021). Malnutrition is still the leading cause of death in the world (Team B 2020). However, this percentage varies between countries. 14.5 % of India's population - around 200 million people - are malnourished (IFBN 2020). These numbers have only increased owing to the ongoing COVID-19 pandemic and the financial crises caused by it. Even in the US, a developed country, 30-40% of Americans currently face food insecurity (Pangetsu 2020).

Remarkably, it is assumed that more than enough food is produced around the world to feed the global population—but according to the UN World Hunger Report as many as 811 million people still go hungry (Action Against Hunger 2021). Although the good news is that a 10% reduction in global food loss would result in an 11% decrease in hunger, and a 4% decrease in child malnutrition worldwide (Distler et al. 2016). There are a variety of causes limiting global food yield, ranging from soil quality, improper use of fertile land, extreme climatic conditions, food contamination, crop spoilage due to insects, pest infestation, and diseases, and inadequate and improper storage of produced food, making it difficult to isolate the root cause. Each of these factors costs the global economy billions of dollars annually (Raza et

al. 2019) (Morris 2011) (Garbach et al. 2014) (F.A.O. 2019). From the facts and numbers reported by various organizations, I could infer that the trends seem to be worsening due to contributing factors and growing problems such as extreme climatic conditions, global warming, growing amounts of uncultivated/arid land due to lack of water, repeated droughts leading to losses in supplies and resources, poverty and lack of resources leading to malpractices.

One of the major factors contributing to the shortage of food supply is the wastage of food right at the source i.e., farms (land and aquatic), and at every step before the produce is made available to the consumer in both raw and processed forms. Due to the wide variety of problems, there is no single solution that can remediate the shortcomings. Eliminating hunger involves both analyzing these multitudes of problems and creating numerous cost-effective and environment-friendly solutions. Food security, as defined by the World Food Programme, involves three components: food availability, food accessibility, and food utilization. All three of these parts together need to be fulfilled to ensure food security. When considering food availability, one problem that is often not emphasized or is easily overlooked, which impacts the quantity of the food available, is the storage of the harvested crops or animal products and safe transportation of the same to the sites where these are processed and packaged before being sold in the market to wholesale distributors and other vendors. As per FAO, “approximately US$14 billion (more than ₹1 lakh crore) worth of food is wasted in India every year. More than 40% of the produced food gets spoiled even before it reaches the consumers” (Pinto et al 2019).

Reasons for wastage: Logistics and infrastructure are deemed to be the root cause of the Indian agricultural wastage issue. The food changes many hands on its way from farms to tables, including improper storage, handling, and transportation exposing it to multiple temperature changes due to varying and extreme climatic conditions. Cold storage infrastructure remains woefully inadequate and poorly distributed in India (Pinto et al. 2019) (Shrivastava 2021).

This paper focuses on this very issue of food wastage and proposes a few methods to solve it. I propose to provide sustainability through technology, minimizing damage to harvested crops from extreme weather conditions by making use of the abundance of natural solar energy, wind power, and biomass, bringing moments that matter for the farmers and providing ways to enhance food security. For preventing wastage of farm and animal harvest, the use of on-site solar-powered or wind-powered, or biomass powered temperature-controlled storage (Silos, Storage Hubs, or facilities) and transportation vehicles, provides methods, systems, and an apparatus for reduction of food wastage. Naturally available and cultivated farm, animal, and sea produce needs extra care to be saved from the impacts of bacteria, fungus, weeds, pests, and other climatic conditions, not only during cultivation but also post harvesting of the same. The produce needs proper storage facilities that would prevent it from getting spoilt due to the above factors, of which climatic conditions like high temperature are one of the environmental factors that need the most attention. The renewable energy approach to solving world hunger, combines numerous stakeholders, to ensure maximum success when implementing renewable energy sources throughout India. Farm-produce (vegetables and grains); animal and poultry products (meat and eggs), dairy products (milk and cheese), and non-food products (wool, mohair, cashmere, and leather), etc.; seafood products from wild fisheries and species farmed in the ocean (mariculture), are excellent candidates that would benefit from this solution.

This idea for sourcing electricity from renewable resources can be extended to the field of animal husbandry to provide eco-friendly and suitable temperature-controlled shelter for the animals that are raised for meat, fiber, milk, or other products. This would improve the quality of day-to-day care, including the application of technology in selective breeding and the raising of livestock right at the farm, and not stay restricted to the labs and cities. The application of this concept is highly warranted due to the rising prices of fossil fuels which have discouraged technological growth in rural areas.

The major energy demands associated with temperature-controlled food storage are for heating and cooling processes, depending on the climatic conditions. Heating is usually provided by burning fossil fuels (coal, diesel, fuel oil, wood fuel, liquefied petroleum, and liquefied natural gas) which increase carbon dioxide (CO_2) emissions or using electric heaters, which consume even more primary energy. There is a small expansion for the use of greenhouses to be used in food production, where a similar use of renewable energy has proven to save cost and addresses the rising energy cost issue. Solar-Powered Cold Storage "could also help local farmers increase their income: with up to 80% of the food in the developing world provided by small farms" (Bartoleschi 2012) innovations like these could significantly support the development of global markets.

Solar Power

The Sun is the most abundant source of energy for Earth. Naturally available solar energy falls on the surface of the Earth at the rate of 120 petawatts, which means that the amount of energy received from the Sun in just one day can satisfy the whole world's energy demand for more than 20 years. As far as renewable energy sources are concerned, solar energy is [the] most abundant and is available directly or indirectly. Therefore, there is a large amount of solar energy available for thermal applications" (Acosta-Silva et al. 2019).

While most people may often associate the image of farmers and ranchers with a profession requiring a lot of manual labor and hard work in the fields and exposure to extreme climatic conditions, however, the farmers do not always just have to produce food that we eat. In developed nations like the US, Canada, Australia, and some countries in Europe, many farmers are able to use the technology at their disposal and collaborate with the Energy Utility companies for developing innovative renewable energy projects on their land like Solar farms or Solar gardens. Thus, they can generate electricity, be self-sufficient for their needs, and also meet the electricity demand of neighboring households and still be connected to the Energy Utility company to feed the surplus to the electric grid (Aman et al. 2017). This concept is known as Distributed Energy Resources (DER) (Ontario's power system 2021) and the associated technology is also being introduced as case studies to developing countries like India.

DERs allow switching between renewable and conventional sources of energy, helping mitigate the risks of irregular supply. Energy saving measures and renewable energy producing facilities can decrease energy costs, and provide additional income for farmers, ranchers, and rural businesses. Increased use of renewable energy instead of traditional sources, also reduces dependence on foreign energy sources and as such, can help farmers mitigate the impacts of climate change. Moreover, the introduction of high-yielding plant varieties and mechanized crop production practices have led to increased energy consumption in the agricultural sector around the world. The government of India is supporting the uptake of DERs to help meet and beat the surge in energy demand. Although their initial focus was on large-scale renewable energy projects, they have set up goals and have undertaken significant measures to promote the installation of rooftop solar (RTS) panels to produce ~40 gigawatts of electricity, the adoption of electric vehicles (EVs), and energy-efficient appliances. These measures will help improve energy security, reduce land use strains, better strengthen the national grid, improve air quality and reduce user costs (Poudineh 2021) (Kuiper & Garg 2021).

Wind Power

Wind energy is a phenomenon associated with the movement of air masses from high atmospheric pressure areas to adjacent low-pressure areas, with velocities proportional to the pressure gradient. During the daytime, the air masses over the oceans, seas, and lakes remain cool compared to neighboring masses located over land areas. In developed nations, wind power is becoming a reliable and now established technology that can produce electricity at a cost that is competitive with coal and alternative energy sources such as nuclear. While the variable nature of wind makes it difficult for electricity generated from

wind energy to fully displace other electricity sources and offshore wind energy tends to be more expensive, and a major challenge for expanding this technology lies in cutting its costs (The future of offshore wind is big-literally 2021). Hence my proposal can be cost-effective to harvest wind energy and use it for local consumption. Grid integration with DER coupled with wind forecasting solutions, may still be more effective as compared to conventional sources, and help combat the lack of electricity in rural areas.

Biomass

Biomass is a type of fuel that is burned directly to generate electricity. It is also known as biofuel, which includes biological raw materials including wood logs, thermally/chemically altered solid end products, like torrefied pellets or briquettes, etc. (Swain 2014). Biomass usually comes from fast-growing woods and grass that are cultivated for the sole purpose of being used as fuel. Although agricultural, household and industrial wastes may also be used. "In Australia and Latin America sugar cane pulp, known as bagasse, is burned as a valuable energy source as a by-product of the sugar production. Unfortunately, the energy content of all of these fuels is only about half as much as coal [as] the energy content is also dependent on the moisture content of the biomass". Such fuels are renewable energy sources that do not further global warming while utilizing the solar energy captured by photosynthesis for electrical power generation. "By 2030 biomass-fueled electricity production is projected to triple and provide 2% of the world total, . . . as a result of government policies to promote renewables" (Woodbank 2020).

With the hope that such solutions for solving food hunger that leverages renewable sources of energy, and when combined with other similar solutions both with statewide and nationwide efforts, for example, solar power greenhouses, Megawatt utility-scale solar facilities, etc., would offer integrated implementation patterns. Such solutions require collaborations by different domains and can also be improved continually to offer good quality electricity from renewable sources while reducing the carbon footprint. They can be enhanced by strategically engaging with the local communities to reduce food wastage and encouraging progressive policies and incentives that meet common objectives to make food available for all. The learnings from these efforts will then lead to better environmental policies, procedures, and controls, assuring risk mitigation and continual legal compliance with federal and state air, water, and waste regulations in both the food and energy sector and a step towards sustainability management systems.

While there will be some initial cost towards the silos and transportation vehicles, which would depend on the quality of the materials used, ease of access to the raw/construction material, construction at a cooperative level by a group of farmers, supported with subsidies from the government may further help to contain the cost. A portable cold chain room that accommodates 5-6 metric tons of produce, can cost around INR 1,210,000 (approximately ~USD 18,058). With transportation cost of max. INR 60,000 to INR70,000 (approximately ~USD 1,000) according to the location, an installation cost of INR 20,000 – INR 30,000 (approximately ~USD 400) based on site condition and location. Operations and maintenance cost of INR 150,000 (approximately ~USD 2,000) moderated by the Ministry of New & Renewable Energy (MNRE). Brings the total cost without subsidy to INR 1,460,000 + taxes. The total cost with subsidy would be INR 1,000,000 + taxes as the government offers INR 250,000 per ton subsidy, subject to a maximum subsidy amount of INR 450,000. These costs would be considerably reduced with large-scale production and cost-sharing models, supported by farmers' unions, and local state and central governments. They are expected to cover their costs within two years of installation (Engineering for Change 2022).

The choice of renewable energy would depend on the local climate where the solution is needed, as the climate varies regionally. Mostly, solar-powered storage systems may work pan-India, other renewable sources like wind, water, or biomass can be leveraged depending on the resource availability. Similar to the public storage facilities in the US, one of the models that may work fine is making these storage

facilities available to poor farmers for rental, thus they would not need to incur the maintenance cost throughout the year but would use the facility on a pay-as-you-go or need basis i.e., when the crops are harvested and stocked before those are sold to the open markets or wholesalers.

When implemented diligently, the climate-controlled storage houses and transportation vehicles can improve food security in India by reducing up to 30% wastage of perishable produce in India. Given the financial insufficiency and status of most of the farmers in India, while the government aided/funded projects to build climate-controlled storage facilities would be the way to go, individuals can help promote the idea and do further research that would help in the reduction of cost of implementation.

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