

Excess power at cellphone towers to sustain cold chain for COVID-19 and other vaccines in off-the-grid rural areas in India

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Vaccines are the only currently available effective means to protect people from COVID-19 and reach herd immunity that restricts further spread of the disease. Vaccines require to be maintained in a cold chain which needs continuous electric power. While even the cities and large townships in the Indian power grid suffer from frequent power outages, a large number of areas are out of the grid and do not have the benefits of electric power. The poor and agrarian communities living in these areas need to be provided with vaccines as much as the urban populations that are being currently served. There are cellphone towers everywhere now, even in the off-grid areas. These towers have excess power which can be harnessed to run the cold chain in the off-grid places, as is being done in some African countries and Myanmar. The background, need and modalities for using power from the cellphone towers to run the vaccine cold chain in the off-grid areas, in the interests of rendering social justice, are discussed in this article.

Keywords: Cellphone towers, COVID-19 pandemic, herd immunity, off-grid areas, smart villages, vaccine cold chain.

Microbial pathogens and vaccines

PATHOGENIC bacteria and viruses cause major diseases and mortality across the globe. As validated by the SARS-CoV-2 virus, the global community is vulnerable to devastating pandemics. Until safe, effective and inexpensive therapeutics are available for a wide variety of viral infections, natural or vaccine-induced immunity coupled with non-pharmacologic interventions are the most promising approaches to control pathogenic bacteria and viruses.

Vaccines in current use

There are vaccines against such bacterial diseases as diphtheria, tetanus, cholera, typhoid, tuberculosis, etc.¹. Vaccines have also been effective for viral infections, including hepatitis-B, measles, polio, rotavirus, rubella and smallpox². Many of these vaccines are included in the child immunization programmes of the Government of India (GoI), administered via the oral, nasal or intramuscular routes.

Objective and impact of vaccinations

The objective of vaccinations is to protect an individual from contracting the disease and to control its spread in a community. Vaccines prevent millions of deaths annually, of children under the age of five and the many millions of cases of devastating illnesses from vaccine-preventable diseases in children and adults, among the world's most vulnerable populations in the poor and developing countries, more particularly in the rural areas.

The impact of vaccination on individuals is immediate in terms of reduced morbidity and mortality. It also provides a significant and broad secondary impact by empowering primary healthcare-givers (most often women), improving local community economics, and improving efficiency and reducing costs associated with healthcare delivery.

According to available data, in 73 low- and middle-income countries, vaccinations given between 2001 and 2020 are estimated to avert over 20 million deaths from vaccine-preventable diseases and save US\$ 350 billion in treatment costs³. Over the lifetime of vaccinated individuals, the same vaccinations save an estimated US\$ 5 billion in treatment costs. The broader economic and social value of these vaccinations is estimated to be US\$ 820 billion (ref. 3).

The global scientific community has extensive experience in designing, manufacturing, administering and monitoring vaccine therapy. Vaccines are amongst the

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most effective means to fight and eradicate infectious diseases. The safety of vaccines has been well demonstrated by millions of successful vaccinations administered for decades to children and adults. A small percentage of recipients of any vaccine may suffer some side effects, but this is not worse than the side effects of any other mode of disease treatment. The overwhelming balance of benefits greatly supports vaccine therapy.

Vaccines for COVID-19

Non-pharmaceutical interventions like wearing a mask, social distancing, avoiding large and crowded indoor spaces, careful personal hygiene, use of hand sanitizers and now the COVID-19 vaccine are the best means of protecting people the world over from the COVID-19 pandemic. The year-long pandemic makes vaccines to control COVID-19 both urgent and essential to save the world population from further morbidity and mortality. There are over 50 COVID-19 vaccine candidates in different stages of clinical trials in different parts of the world⁴. In India two of them, 'covishield' manufactured by the Serum Institute of India, Pune, in collaboration with AstraZeneca and Oxford University, UK, and 'covaxin' manufactured by Bharath Biotech International, Hyderabad, were permitted by GoI to be used in the vaccination schedules in the country and are being administered from 16 January 2021.

Herd immunity

The term 'herd immunity' refers to the minimum percentage of people within a community who need to be immune to a disease in order to prevent its further spread^{5,6}. This is reached by prior infection that has spread throughout the community, or through mass vaccination. The importance of vaccinations lies in the fact that they not only protect individuals from infection, but also protect the community from further spread of the disease by imparting mass immunity, and preventing protracted morbidity and mortality caused by infection.

Ro (R zero or R naught) reflects the average number of people an infected person can infect in turn, contributing to the spread of infection during the course of his/her disease^{5,6}. R stands for the basic reproductive rate of an organism. Ro is one of the means to gauge the infectivity of a pathogen; it varies from one pathogen to another. Ro and herd immunity are related and herd immunity is approximately calculated using the formula $(1 - 1/Ro) \times 100$.

The rate of spread of a disease is also dependent on the mode of transmission, incubation period, and environmental conditions such as temperature and humidity, which vary among pathogens even when Ro is the same. It also depends on the behaviour of the infected individuals, such as not appropriately sanitizing his/her hands, not

wearing a mask or not maintaining social distance. For example, a person with chickenpox may infect 3.23–26.3 people, a person with measles can infect between 13 and 16 people, and a person with polio can infect between 10 and 15 persons⁶. The Ro potential of COVID-19 can be as high as 5.7, indicating that one infected person can potentially transmit the disease to 5–6 people⁷. This is almost double that of earlier estimates. With Ro 5.7, at least 80% of the population needs to be immune to COVID-19, either by prior infection or immunization, to consider a community to have achieved herd immunity for this disease⁷. All the communities in a place would not gain herd immunity at the same time. In view of these considerations, the World Health Organization's generalization that 'a country's safety from an epidemic or a pandemic is palpable when about 70 per cent of its population is immune to the disease'⁸, may be a lower bound.

Cold chain

In order to maintain their purity and efficacy, vaccines must be maintained at low (cold) temperatures from the time of manufacture to the time they are administered. The temperature range is usually 2°–8°C, but varies from one vaccine to another. For example, the COVID-19 vaccines from Pfizer and Biontech require to be maintained at –70°C, while that of Moderna at –20°C. This essential temperature controlled supply chain is called the 'cold chain'⁹. A robust cold chain is critical for maintaining the integrity of not only the vaccines, but also many medicines, blood products, clinical trial agents and clinical samples. A cold chain is also essential for several food products the world over, run often at much lower temperatures than required for vaccines and medicinal products.

Annually, millions of doses of vaccines and essential medicines become ineffective and unusable because of the failure of the cold chain. The cold chain problem is even larger than the childhood vaccine distribution problem faced by poor people in the developing countries. The dire need for maintaining cold chains has become much more acute now, with the responsibility to store millions of doses of COVID-19 vaccines in the cold chain, in every part of every country in the world. The problem is much more daunting in low- and middle-income countries.

Over time, the cold chain infrastructure has become an industry in itself in the developed countries, with diverse electrical, electronic and other devices being continuously designed and manufactured. Beside the health facility refrigerators (more sophisticated than the domestic refrigerators) and deep freezers of different dimensions and temperature capabilities, there are refrigerators with sensors which monitor outside and inside temperature and retain the set cold temperature level for extended periods of time in the event of power failure. The hard truth is that

the entire cold chain maintenance essentially depends on electric power.

Rural electric power supply in developing countries

In developing countries, even cities and large townships experience frequent and prolonged outages of grid power, often coupled with simultaneous failure of auxiliary power supply as well. A large number of village and small town settings are either off the power grid or do not get any assured power supply.

The World Bank's Independent Evaluation Group stated that one billion people have chronically inadequate or unreliable power supply in developing countries¹⁰. According to report of the International Energy Agency (IEA), an additional 1.2 billion people in developing countries remained without access to electricity¹¹. Of this 1.2 billion, just over a half live in sub-Saharan Africa. Most of the remainder are in the developing countries in Asia, with India accounting for around half of the Asian total¹².

How many villages are there in India?

There is no parity on the number of villages in India, among the reports put out by different departments of the Government¹³. According to the 2017 report of the Integrated Management Information System, Ministry of Drinking Water and Sanitation, GoI, the count is 608,662. Whereas the Mahatma Gandhi National Rural Employment Guarantee Programme, GoI, estimates the number of villages in India to be one million. There are 597,800 villages marked on Government maps and 10,871 unmapped villages, totalling 608,671 (ref. 13). People living in these places are at a greater risk of not getting the vaccines for want of cold-chain facilities. Establishing and maintaining the cold chain in these places is a daunting challenge, particularly due to shortage or total lack of electric power.

Power supply to Indian villages

The Open Government Data Platform of India claims that 97.7% of villages in the country are electrified¹⁴. The electricity access data of IEA indicate that in 2014, rural electrification in India was 74% against 96% in urban areas¹¹. Most rural electrification programmes implemented by the government focus on village-level targets, such as schools, health centres, Panchayat offices, etc. A village is considered to be electrified if (a) basic infrastructure like distribution transformers and power lines are provided in a locality (even if it is without power flow for years), and (b) electricity is provided to at least 10% of households in the village¹⁴. The reason for the great

disparities between Government data and ground realities lies in here.

D'Cunha¹⁵ mentions that the Government distribution companies are the weakest link in the power sector value chain and that in about 18,452 targeted villages, 90% of the households have no electricity. There are many more such targeted village groups and the power supply is erratic in almost all villages. Reliable and continuous power supply to all the villages in India is a distant dream.

Samanth *et al.*¹⁶ emphasized that while electrical power and/or an alternative source of energy is crucial for maintenance the cold chain, in rural India 90% of local health centres suffer from frequent power failures and only 45% of these have a back-up generator.

Energize the Chain

In the face of this challenging problem, the solution afforded by the non-profit organization 'Energize the Chain' (EtC), offers hope. A brain child of one of us (H.R.), EtC has developed a system to harness the excess energy available at remote cellphone towers, to provide electricity, data and communications necessary to maintain and monitor the cold chain in the off-grid and/or 'no power' locations^{17,18}.

Cellphone towers

Cellphone towers are designed to be tall to keep the antennae (dish, loop or rod) aloft all surrounding high-rise structures, to receive and transmit digital signals, without disruption. The term 'tower power' refers to the electricity that cellphone towers need to run electronic equipment for successful wireless communication, mostly through cellphones.

Nowadays, cellphone towers are found everywhere. In urban and large townships the cellphone companies generally use grid power. However, to prevent signal failure from power outages, they also maintain auxiliary power-generation equipment near the towers, such as solar power generators, wind power generators, electro-chemical fuel cells or internal combustion engines driven by oil fuel or gas. In order to prevent signal weakening or failure, it is ensured that the tower sites have excess power to sustain communications for several days in case of grid and/or auxiliary power failure or other problems.

The area of coverage by cellphones is far greater than the grid power area serviced by public, private or joint enterprises, in many countries. According to the International Telecommunications Union, Geneva, Switzerland in October 2019 there were over 8.3 billion cellphone subscriptions, a little more than even the global population¹⁹. Further, developing countries experienced the most dramatic growth in cellphone use, reaching around 80%. Now, nearly a couple years later, it could actually be a lot more than 8.3 billion.

Power from cellphone towers

The greater presence of cellphone towers, with excess power, even in off-grid areas, assures that cold chains can be maintained without interruption by harnessing this power. The solution provided by EtC ensures an economically and technologically sustainable energy infrastructure for effective transportation and storage of vaccines and essential medicines in the cold chain. As mobile-phone coverage blankets the globe, and is ever expanding, drawing energy from telecommunications towers to sustain the rural cold chains would continue to be feasible in the future as well.

EtC's strategy

EtC had a challenging time in developing public-private partnership strategies with cellphone companies, Ministries of Health and local universities, in some developing countries, to ensure access to energy, connectivity and data needed to expand the vaccine cold chain to neglected areas. EtC envisions that the use of power from cellphone towers will lead to a developing world with universal access to effective vaccines, and end the senseless deaths from diseases preventable by full schedule of immunizations. EtC's confidence is bolstered by the following pioneering successes:

- (a) EtC has rebuilt and extended its work in Zimbabwe with 'Econet Wireless', which is their first and steadfast partner, continuing to support EtC's work in that country.
- (b) EtC's team launched installations in Myanmar and is extending its work to the eastern districts of that country.
- (c) EtC has completed a baseline survey in Bangladesh with its partner 'Footsteps, Bangladesh', an NGO, and plans to initially cover the Mymen Singh district, and to subsequently cover that entire country.
- (d) In Ghana, EtC is reanalysing the original sites in Upper East, Upper West and Volta in collaboration with its partners American Tower, USAID and Kwame Nkrumah University of Science and Technology, to support distribution of COVID-19 vaccines.
- (e) Negotiations with partners are in progress in Zambia, Nigeria and Guinea Conakry, and EtC hopes to work in these places in the next quarter.

The wireless technologies are being constantly evaluated by EtC to enhance the overall goals of improving its efficiency particularly in the developing world. Novel delivery technologies, including the use of autonomous vehicles are under consideration. Using vertical take-off and landing (VtOL) drones carrying insulated packets of

vaccines from tower power-supported clinics, to those in areas without cellphone towers, in North and Northeast India, is a viable option.

India needs to deploy tower power to augment its cold chain capabilities

People in India's off-grid villages and small townships, where majority of the agrarian community resides, need urgent attention of the State and Central Governments, to provide them with reliable cold chain facilities, particularly in the COVID-19 vaccine scenario. The cold chain capabilities of India, projected in the media, are grossly inadequate for the country's needs even in the immediate future and they do not at all address the needs of the off-grid areas. It is time that all off-grid and remote areas appear prominently in GoI's COVID-19 vaccination schedules. India would do well to take advantage of the use of tower power. The present tower power capacities can be easily enlarged, where needed.

Modalities of deploying tower power

The way that power from cellphone towers is used depends upon (a) the place (b) its distance from the major vaccine distribution centre, (c) the kind of different cold devices in use, (d) the size of the population of the area, and (e) the ambient temperature and humidity. The use of household refrigerators which combine both deep freezing and refrigerating capabilities is discouraged as they are poorly regulated and hardly maintained²⁰. Medical-grade cold equipment such as refrigerators, freezers and cold boxes, with precise sensors for temperature and humidity control are already available. All of these can be maintained on voltage-regulated tower power.

The anonymous reviewer of this article suggested the use of flasks that are designed to keep the contents at set temperature levels for several days without the need for constant connection to power supply. Three or four models of such passive vaccine-storage devices that keep the contents in the cold chain for 30 days are under development. Bill Gates named one such model as 'super thermos' and supported its development²¹. This flask which is in an advanced trial phase, can keep the internal temperature between 0°C and 30°C from 30 to 60 days. It senses the outside and inside temperatures and relative humidity of an area, which affect the storage period. Using the same insulation technology as in a spacecraft, this flask protects the contents from temperatures higher than that stipulated. The device has sensors and SMS capabilities to communicate with a monitoring centre to keep track of (a) the location of the flask and (b) interior and exterior temperatures and their duration. It can also report lapses in maintenance protocols. With portability as a distinct advantage, it can contain about 200–300 doses of a vaccine

and is ideally suitable in places with population between 5,000 and 15,000.

These flasks can be recharged conveniently in large numbers from the tower power. Places within 2–3 km from a tower can be organized into ‘vaccination clusters’ to share data and facilities. While advanced portable devices that run on tower power would help India immensely in conducting the present COVID-19 vaccination drives, they would be useful in the future in widely and effectively running the scenario involving dozens of other vaccines.

‘Smart villages’

For some years now, there have been several efforts to conceptualize and strategize development of ‘Smart Villages’ in developing countries^{12,14,22}, with the aim to explore access to energy as an entry point for rural development. They have identified sustainable electric power to the villages as the ‘golden thread that connects economic growth, increased social equity and an environment that allows the world to thrive’, as emphasized by the UN Secretary General²². While it would take a long time to realize this vision, harnessing the tower power to energize the cold chain in off grid villages will be a step in the direction of developing ‘Smart Villages’ in India.

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