OPTIMIZE Immunization systems and technologies for tomorrow

PATH World Health Organization

EVIDENCE BRIEF SERIES

Green supply chains: a glimpse into the future?

This document discusses the rationale for introducing net-zero energy systems into vaccine supply chains and describes the experiences and lessons learned in a demonstration project in Tunisia. Opportunities and challenges are presented and evidence is provided for national and global readers involved in immunization supply chains who may be considering a similar intervention.

THE NEED FOR CLEAN, RENEWABLE ENERGY FOR VACCINE SUPPLY CHAINS

Maintaining the vaccine cold chain from manufacturer to populations in need is vital for immunization programs and is especially challenging in low-resource settings. The process requires keeping vaccines cool in storage as well as during transport throughout the supply chain, from national storage facilities all the way to remote health centers, a process which typically consumes large amounts of nonrenewable energy. The supply chain also consumes energy for heating during colder months, lighting, air conditioning for products that need storage below 25 degrees Celsius, and for running a networked and computerized logistics management information systems.

Transport systems, which usually rely on fossil fuels, also contribute to inefficiencies in the supply chain through problems such as vehicle breakdown or insufficient funds to buy fuel. This can result in delayed or missed vaccine deliveries to clinics and health centers, which means lost time and money for health care providers and families.

"Yes, [solar energy] is advantageous and economical for operating cars, warehouses, and refrigerators. I would like it to be generalized to the entire hospital."

Driver, Regional Public Health Authority

One approach to reducing the cost of supply chains and minimizing reliance on conventional energy sources is to reduce energy consumption, substitute renewable energy sources where possible, and offset the use of nonrenewables by selling excess energy from renewable sources to the grid. The importance of a more reliable and less energy-dependent supply chain is acknowledged by the Government of Tunisia, as it is in many other countries, in the form of declared national policy and capital grants for grid-linked green energy systems in the private and public sectors.

Reducing energy consumption and switching to renewable energy sources can reduce costs and contribute to improved performance of the vaccine supply chain. Photo: WHO/Aya Kouamé

TECHNOLOGIES FOR ACHIEVING NET-ZERO ENERGY USE

Like other regions worldwide, developing countries are experiencing increasing energy needs—along with escalating costs—and at the same time are struggling with the impacts of climate change. Many of these countries have abundant renewable energy resources, such as solar energy, wind power, geothermal energy, and biomass. Solar energy produced by photovoltaic panels is an especially attractive option in many areas of Africa. In addition, electric vehicles are an alternative to diesel- or petrol-powered cars or motorbikes, as they may cost less to operate and their energy consumption can be offset by electricity produced by solar panels.

Optimize demonstration project in Tunisia

Between 2009 and 2012, project Optimize, a collaboration between the World Health Organization (WHO) and PATH, worked in Tunisia with the Ministry of Health to introduce innovations in the supply chain that could help the national immunization program meet the demands of larger and more expensive immunization programs. In the Kasserine region, projects were carried out at regional and district levels to demonstrate an environmentally friendly vaccine distribution system that could offset energy consumed from the grid with solar energy produced by photovoltaic panels. In addition, the project worked to reduce the carbon footprint of the system by replacing diesel- and petrol-fueled vehicles with electric vehicles.

Background and energy audit

Although Tunisia's immunization program is very successful, the logistical challenges of introducing new and expensive vaccines are placing significant pressure on the existing supply chain system design. Vaccines are moved from a central government pharmacy warehouse to a separate government-run vaccine store and then transported to 24 regional stores on a monthly basis. From the regional level, supplies enter an irregular transportation system, where the lack of funding to maintain vehicles and pay for fuel can compromise vaccine availability at health centers. Most regional stores are furnished with cold chain equipment such as medical refrigerators designed for storing vaccines, but district stores and health centers usually must manage with domestic refrigerators, which often do not stay within the temperature range required for vaccines.

A baseline energy audit in the Kasserine region and in Foussana district revealed several sources of inefficient fossil fuel use including poorly insulated buildings, old refrigerators, desktop computers, and incandescent and fluorescent light bulbs. In addition, petrol- and diesel-powered vehicles consumed a significant amount of high-carbon fuel. According to the audit, the estimated annual energy cost at the Kasserine regional store was approximately US$1,800 and at the Foussana facility US$800.

As shown in Figure 1, transporting vaccines and medicines accounted for 42 percent of the regional energy cost and 51 percent of district costs. Heating, air conditioning, and refrigeration contributed an average of 41 percent, with the poor environmental performance of buildings responsible for a good portion of these costs.

Figure 1. Energy use at regional and district levels in Tunisia.

Regional

	42%	*Transport*
	41%	*Heating, air conditioning, refrigeration*
	17%	*Other*

District

	51%	*Transport*
	41%	*Heating, air conditioning, refrigeration*
	8%	*Other*

Interventions: Reducing consumption, introducing renewable energy, and decreasing the carbon footprint

The baseline audit suggested several interventions that could reduce total energy consumption; those that were implemented are shown in Table 1. In addition, the vaccine and medicine stores in Foussana district were moved to the new hospital so that all vaccines and other temperature-sensitive medicines were integrated into a single supply chain network to benefit from the net-zero energy system.

Since transportation accounted for almost half of the energy consumed in the supply chain, electric vehicles were chosen to make vaccine deliveries. Vehicles were selected on the assumptions that they would cost less than conventional vehicles to operate per kilometer and that their energy consumption would be compensated by solar power, thus reducing carbon emissions. Fiat Micro-vett Fiorino vehicles were selected because of their capacity for personnel and supplies and because their daily autonomy (kilometers travelled on a full charge) would be sufficient to make pre-planned supply trips via optimized circuits to all receiving stores each supply period. They would not deliver to destinations that were too steep or rough or exceed the limits of their stated operating autonomy.

Table 1. Interventions to reduce energy consumption.

Category	Baseline (2010)	Optimize intervention (2012)
Refrigeration	Domestic refrigerators (energy class 4 and 5)	Domestic refrigerators (energy class 2 and 3)
Transport	Petrol/diesel four-wheel-drive vehicles	Electric vehicles (4)
Computing	Desktop computers	Laptop computers
Lighting	Fluorescent tubes and incandescent lamps	Light-emitting diode (LED)-based tubes and lamps

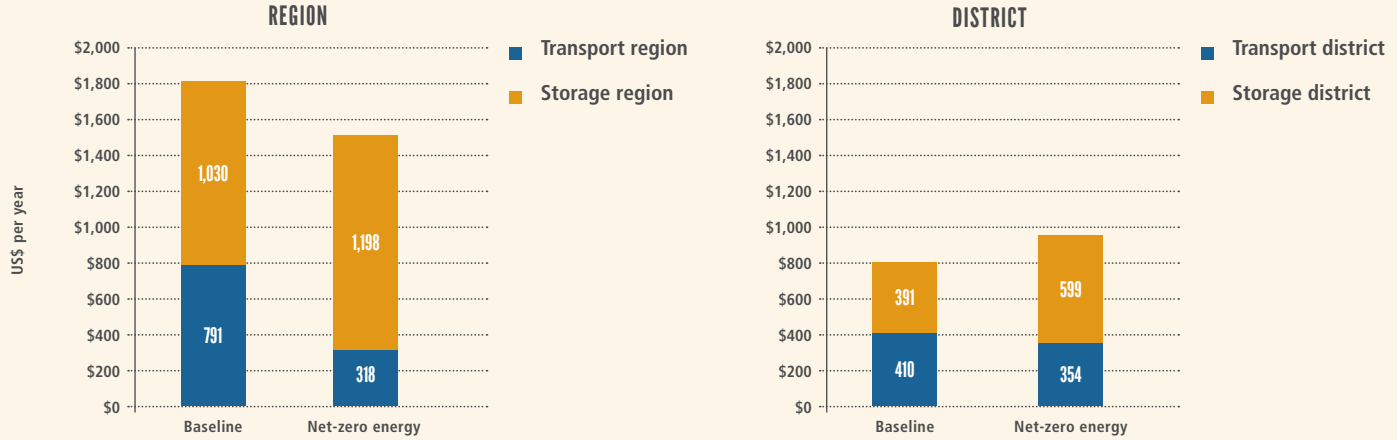
In addition to reducing consumption, the project began generating solar electricity to offset the energy consumption of the distribution system. Photovoltaic modules were installed on the rooftops of the consolidated vaccine and medical supplies stores at the regional level in Kasserine and in three districts, with surplus production fed into the electrical grid and used to provide a deduction in the overall electricity bill for the regional-level facilities. To evaluate the impact of these interventions, energy consumption at each electrical outlet and solar electricity production at each solar module array were monitored using a web-based data-collection system.

Impact of reducing energy consumption

Compared with the baseline, the annual energy cost for storage and transport using the net-zero energy system was reduced by 17 percent at the regional level. In the Foussana district, while the cost of transport went down by 14 percent, storage cost increased by 53 percent due to the more intensive use of air conditioning in the new, combined store for vaccines and medicines (Figure 2). Significant reductions were achieved by changing the lighting technology to LEDs. Energy consumption was reduced from 283 kWh per month at the baseline to 93 kWh per month with the net-zero energy system.

Because transport accounted for about half of total energy costs, the majority of savings was achieved through the use of electric vehicles, which replaced four-wheel-drive diesel and petrol vehicles on almost all delivery circuits for medicine and vaccine distribution. The savings would appear even greater if cost savings for regular maintenance and servicing such as oil changes were included.

Figure 2. Energy consumption expressed as cost at baseline and during net-zero energy intervention.



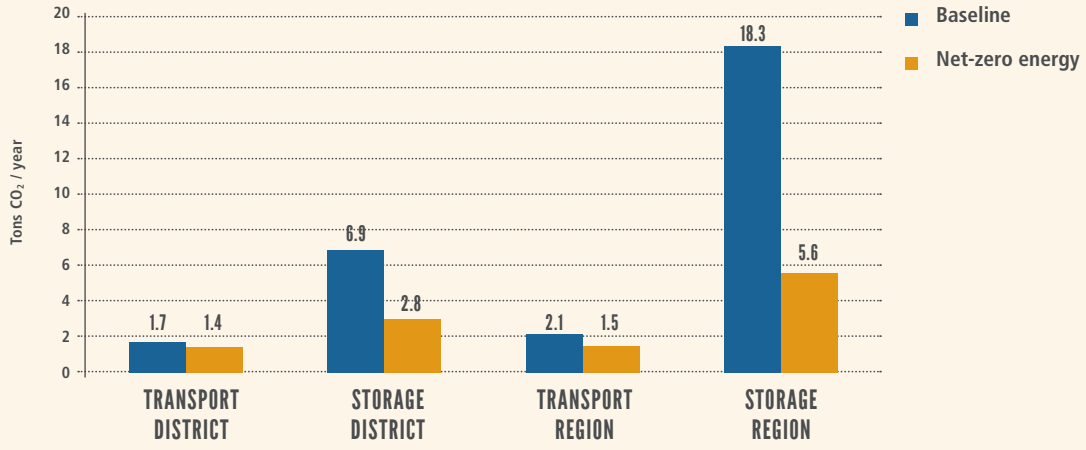
Achieving net-zero energy with solar electricity

The maximum energy generated by the photovoltaic arrays at the regional and district levels was 15.84 kW at Kasserine and 7.26 kW at each district. At the regional level, production consistently exceeded consumption, while at the district level, production exceeded consumption for 9 of 12 months. That said, the combined energy balance for the 12-month project period was positive by 10,900 kWh, about one-third of total production. The Optimize demonstration project thus met its goal of achieving net-zero energy by producing more energy than consumed for vaccine storage and transport.

As all energy consumption is offset by solar energy in the net-zero energy system, the total savings generated each year would be the baseline values of US$1,821 for the regional store and US$800 at a district store, using the Foussana district as a surrogate for all district stores. If these savings are projected nationally, they would amount to about 10 percent of the value of vaccines used in Tunisia in 2012.

The net-zero energy interventions also succeeded in reducing the carbon footprint of the supply chain; the project reduced emissions by 29 percent for transport and 68 percent for storage at the regional level. At the district level, the reductions were 18 percent and 59 percent respectively (Figure 3).

Figure 3. Impact of intervention on annual release of carbon dioxide at the regional and district levels.



Cost of interventions

Approximately US$646,500 was spent to implement the net-zero energy supply chain system, with most of the direct expenditures (US$302,000; 47 percent) related to the electric vehicles and their overhead, such as customs, insurance, and maintenance. Procurement and installation of the solar panels at the four sites accounted for 35 percent (US$228,000) of costs, and the remainder was used on equipment for other aspects of the project (e.g., refrigerators, cold boxes, ice packs) and training.

"There are advantages [to using solar energy] in terms of equipment; it has helped reduce consumption and save energy and money that can be used for something else — it has saved gasoline and oil, through the means of transport."

Nurse, Regional Public Health Authority, rural area

Challenges

As with any newly implemented technology, the introduction of photovoltaic panels and electric vehicles saw a number of challenges. In one district, one-third of the solar panels were was not connected correctly and did not produce electricity for some time. Installation took longer than planned, and faulty or incorrectly installed electrical connections caused system overload and power outages. Configuring the web-based monitoring system for analyzing the net-zero energy data was also more difficult than anticipated.

The cost of buying and maintaining the electric vehicles was high, although these costs should fall over the next few years. Managers and implementers also had concerns about the performance of electric vehicles on rough rural roads and in winter conditions. Vehicle breakdowns caused project delays at two sites, and some implementers reported that they went back to using their previous delivery systems.

In spite of the challenges, among nine implementers and managers interviewed about the project, eight said the intervention should continue.

Key lessons

- Net-zero energy is feasible in Tunisia and other locations with a similar climate; that is, they can use solar energy to produce enough cost-free energy for the entire supply chain system, including the storage and transport of vaccines with electric vehicles. Significant reduction of carbon emissions can also be achieved in this way.
- Without accounting for the amortization of the equipment (solar panels and electric vehicles), the energy savings in the supply chain can be significant. This translates to recurrent cost savings for storing and transporting vaccines.
- If amortization of equipment at today's prices is included over ten years, the value proposition loses its appeal. The amortization of the cost of solar panels offsets any savings, and the system is not cost beneficial. The capital cost of solar electricity generation is decreasing, however, and the same downward trend is expected for electric vehicles. By 2020, the economic picture may look more favorable.
- The value proposition will also improve if the structure and insulation of existing buildings are improved or, ideally, if more thermally efficient warehouses are built.

The future of reduced-cost, environmentally friendly vaccine supply chains

The cost of greener supply chains is expected to fall significantly over the next several years. The Optimize cost for solar panels was particularly high because monitoring instrumentation and maintenance services were included. Without such extra services, the panels would have cost US$87,000.[a] Industry experts predict that by 2020 a solar array that produces the same amount of energy could cost around US$25,000.[b]

a. Based on $4.59/Wp direct current (DC)—217 kWp DC commercial rooftop benchmark, 2010 United States PV system prices (cash purchase, before subsidy, and considering reported target installer operating overhead and profit margins).

b. Based on price targets for 2020 set under the United States Department of Energy's SunShot Initiative: $1.99/Wp DC—217 kWp DC commercial rooftop (SunShot target: $1.25/Wp DC)

Future electric vehicle costs are uncertain. At the start of the project, the Fiat Micro-vett Fiorino was one of few electric utility vehicles available on the European market, at a cost of US$64,000. The market is growing rapidly, however, and current trade information lists 16 models of utility vans and half-cabs, ranging in capacity from 2 to 12 cubic meters, that cost US$14,000 to US$55,000. If the cost of electric vehicles falls to one-third of today's levels by 2020, the overall cost of net-zero energy interventions would be around US$106,692, less than one-sixth of today's costs, and the baseline energy cost savings of net-zero energy would be approximately US$4,222 per year. When amortized over the life of the equipment (10 years), the annual repayment would be about US$10,700, bringing the intervention closer to cost neutrality. Although the introduction of electric vehicles is not practical today, it will become increasingly economical as an alternative to diesel-powered vehicles by 2020.

Electric vehicles were fueled by energy generated from solar panels installed at regional and district stores. Photo: WHO/Ramzi Ouhichi

Most components of net-zero energy would be practical and economical to fully implement in regions with climates and conditions similar to that of Tunisia in the future, possibly after 2020. However, implementation may take place sooner if done progressively, as suggested in Table 2.

Table 2. Implementing net-zero energy practices.

Time frame	Intervention	Task
Present to 2015	Perform energy audits of vaccine and medicine stores; reduce consumption	Implement improvements to building insulation, lighting, refrigeration, and informatics equipment.
		Critically assess the choice of district vehicles and refrigeration equipment.
		Integrate the delivery of vaccines and medicines and establish a standard delivery circuit system.
2015 to 2020	Link solar photovoltaic energy production to the grid	Conduct study of requirements and create phased plan to establish a network of net-zero energy stores.
		Begin with large, primary, high-value vaccine stores at central and regional levels.
		Progressively extend to districts.
2020 and beyond	Switch from fuel-powered to electric-powered vehicles	Conduct study of the electric vehicle market (including hybrids), facilities for maintenance in country, and requirements for the supply chain.
		Plan for phased introduction, beginning with small-scale pilot introduction.

Conclusion

The capacity of Tunisia's vaccine distribution system and the value of vaccines handled are predicted to increase up to fivefold by 2020, a change that will occur across many developing countries. The expansion of the volume of vaccines also means that the environmental impact will increase because of the need to store and transport them via the cold chain. This prediction should encourage efforts to safeguard these expensive and lifesaving vaccines—and the people who need them—with an affordable and reliable supply chain, and one that strives to protect the environment. Such efforts will align with the United Nations Sustainable Energy for All initiative that was launched in 2011 with three inter-linked objectives to be achieved by 2030: 1) ensure universal access to modern energy services; 2) double the global rate of improvements in energy efficiency; 3) double the share of renewable energy in the global energy mix.

Project Optimize has been the first to test a net-zero energy system in the immunization field. Results have shown that the energy cost of storage and transport of vaccines and medicines can be offset by generating and crediting electricity from solar electricity production to the grid. The experience suggests that the supply system can begin to be more efficient, reliable, and environmentally acceptable, as well as less expensive, in the next five to ten years.

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FINDING MORE INFORMATION

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