OPTIMIZE

Tunisia

Report

OPTIMIZE Immunization systems and technologies for tomorrow

PATH World Health Organization

This report was commissioned by Optimize: Immunization Systems and Technologies for Tomorrow, a collaboration between the World Health Organization (WHO) and PATH. The report was authored by team members from WHO.

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OPTIMIZE

Tunisia
Report

An evaluation of demonstration projects conducted through a collaboration between the Ministry of Health and project Optimize to explore innovations in the Tunisian vaccine supply chain

April 2013

CONTENTS

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- The Tunisian Ministry of Public Health
- The Department of Basic Health Care
- The Sousse, Monastir, Mahdia, Kairouan, and Kasserine Regional Departments of Basic Health Care
- The Central Pharmacy of Tunisia
- The Department of Serums, Vaccines, and Biological Products
- The Department of Pharmacy and Medicines
- The National Agency for the Sanitary and Environmental Control of Products
- The Ministry of Industry and Technology
- Solar Energy Systems
- The Center for Technical Studies and Maintenance
- The National Agency for Energy Conservation
- The Computer Center of the Ministry of Public Health
- The Tunisian Company of Electricity and Gas
- The Japan International Cooperation Agency
- The United Nations Children's Fund

ACRONYMS

The following acronyms are used in this document.

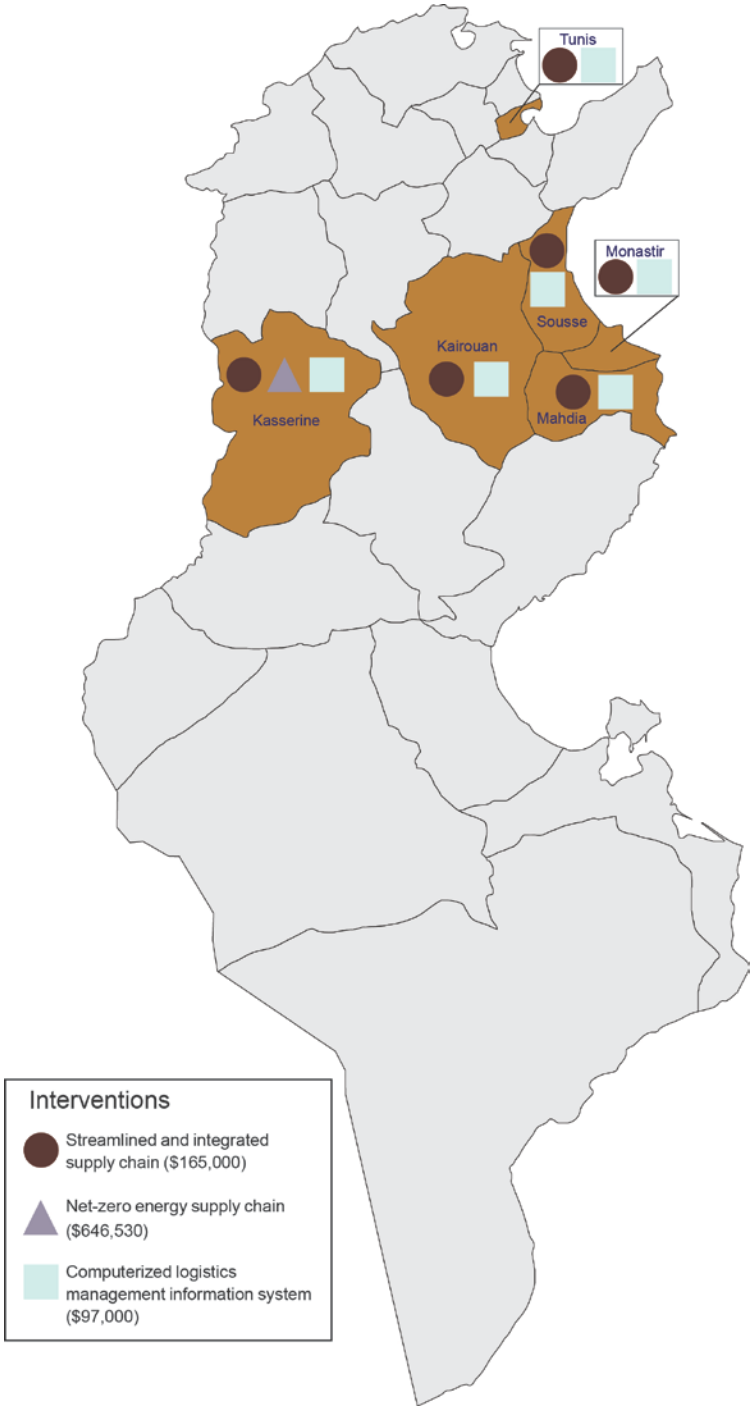
ANCSEP	National Agency for the Sanitary and Environmental Control of Products
ANME	National Agency for Energy Conservation
BCG	bacillus Calmette-Guérin
CETIME	Ministry of Industry and Technology
CIMSP	Computer Center of the Ministry of Public Health
CRT	controlled room-temperature storage
DRSSB	Regional DSSB
DSSB	Department of Basic Health Care
EPI	Expanded Programme on Immunization
EVM	Effective Vaccine Management
Hep B	hepatitis B
HPV	human papillomavirus
IT	information technology
kWp	kilowatt peak
LED	light-emitting diode
LMIS	logistics management information system
MOH	Ministry of Health
MOU	memorandum of understanding
MSP	Ministry of Public Health
NIP	National Immunization Program
PATH	Program for Appropriate Technology in Health
PCM	phase-change material
PCT	Central Pharmacy of Tunisia
PQS	performance, quality, and safety
SOP	standard operating procedure
TSHP	temperature-sensitive health products
UNICEF	United Nations Children’s Fund

VVM	vaccine vial monitor
WHO	World Health Organization
wVSSM	web-based Vaccination Supplies Stock Management

MAP OF OPTIMIZE INTERVENTIONS

The locations of the three Optimize demonstration projects described in this report are shown on the following map of Tunisia. The total Optimize investment cost for each demonstration over three years is provided in parentheses.

Figure 1. Locations of Optimize demonstration projects in Tunisia



1. INTRODUCTION

1.1. Overview

This report presents the results and findings of demonstration projects undertaken in Tunisia as part of a partnership between project Optimize and the Tunisian Ministry of Health (MOH).

Between 2009 and 2012, Optimize collaborated with the MOH to demonstrate innovations in the supply chain that can help the national immunization program meet the demands of an increasingly large and costly portfolio of vaccines. This report describes three demonstration projects undertaken in Tunisia as part of the collaboration:

1. Streamlined and integrated supply chain—demonstrating the benefits of streamlining the vaccine supply chain and integrating it with the distribution of other health commodities.
2. Net-zero energy supply chain—demonstrating an environmentally friendly vaccine supply chain at subnational levels using solar energy to achieve zero net energy consumption.
3. Computerized logistics management information system (LMIS)—demonstrating a computerized LMIS that can track and trace vaccines in real time throughout the supply chain, mitigating the risk of overstocking, expiry, and vaccine wastage.

1.2. About project Optimize

Project Optimize, a five-year partnership between the World Health Organization (WHO) and PATH, was established to identify ways in which supply chains can be optimized to meet the demands of an increasingly large and costly portfolio of vaccines.

Optimize worked directly with national governments and other institutions to identify problems in the supply chain and test innovative solutions. We also worked with vaccine manufacturers and policymakers to help ensure that new products and policies enable supply chain systems to function effectively. The goal is to help define an ideal vaccine supply chain that can be used to develop stronger, more adaptable, and more efficient logistics systems, extending the reach of lifesaving health technologies to people around the world.

For more information, please visit these Optimize websites:

PATH: www.path.org/projects/project-optimize
WHO: www.who.int/immunization_delivery/optimize

1.3. Finding more information

In 2013, Optimize is publishing comprehensive information on the demonstration projects and other initiatives it has been involved in. To view a full list of the resources that Optimize has published to document its work in Tunisia, please refer to the Tunisia resources pages that are available on both PATH and WHO websites:

PATH: www.path.org/projects/project-optimize-resources-country.php#tunisia
WHO: www.who.int/immunization_delivery/optimize/tunisia

These documents, as well as detailed information on other innovations relating to vaccine supply and logistics systems, are also available on the TechNet-21.org website:

www.technet-21.org

1.4. Contact details

Table 1 provides the details of companies and people who can be contacted about the interventions described in this report.

Table 1. Intervention contact details

Subject	Contact details
Streamlined and integrated supply chain	Patrick Lydon Technical officer, WHO Geneva lydonp@who.int
Net-zero energy supply chain	John Lloyd Consultant john.lloyd1945@gmail.com
Computerized LMIS	Ramzi Ouhichi Optimize national project manager, WHO Tunisia ouhichir@who.int

Abbreviations: LMIS = logistics management information system; WHO = World Health Organization.

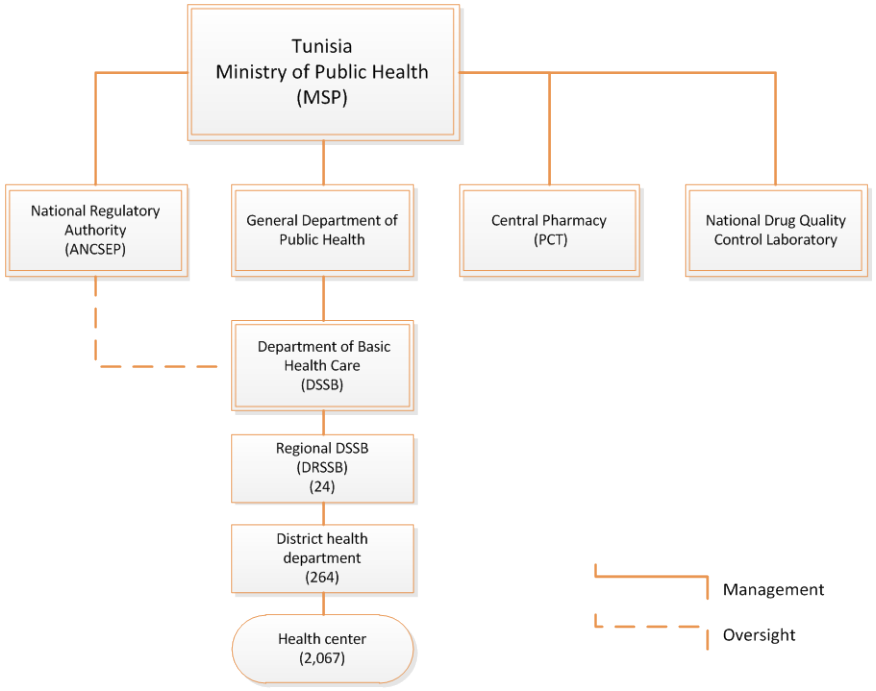
For all other questions, please contact Ramzi Ouhichi, Optimize national project manager, based in WHO Tunisia country office (ouhichir@who.int).

2. TUNISIA IN CONTEXT

2.1. The national immunization programme

Tunisia's national immunization programme is overseen by the Department of Basic Health Care (DSSB), the primary health care unit of the Ministry of Public Health (MSP). However, Tunisia's semi-autonomous national medical store, the Central Pharmacy of Tunisia (PCT) imports all vaccines and pharmaceuticals into the country on behalf of the MSP. Although the Expanded Programme on Immunization (EPI) unit of the DSSB provides a vaccine demand forecast and funding to the PCT, the PCT actually completes the procurement on their behalf and receives and stores all imported vaccines in the PCT national vaccine store. The administrative structure of the national immunization programme in Tunisia is shown in Figure 2.

Figure 2. The administrative structure of the national immunization programme in Tunisia



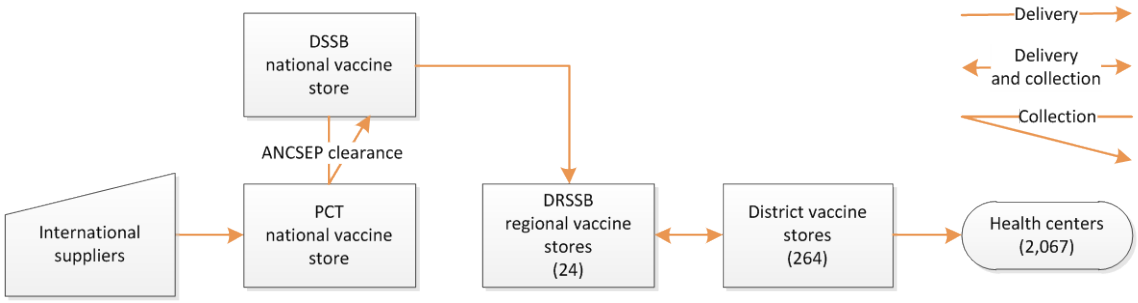
Once vaccines arrive at the PCT, they are quarantined for quality control testing by the National Drug Quality Control Laboratory of the national regulatory authority—the National Agency for the Sanitary and Environmental Control of Products (ANCSEP). ANCSEP is responsible for the lot release of imported vaccines based on the results from the National Drug Quality Control Laboratory. Once the vaccines are released by ANCSEP, they can be collected by the DSSB from the PCT national vaccine store and transported to the DSSB-managed national vaccine store for vaccine used in public health programmes.

2.2. The vaccine supply chain

In Tunisia, several public- and private-sector health supply chains operate in parallel. This often leads to duplication of effort, inefficiencies in processes, and higher operating costs for the health system. Even within the government-run national immunization program (NIP), the supply chain system is fragmented across various entities handling vaccines and related supplies.

Once vaccines arrive in Tunisia, they are transferred to the PCT national vaccine store and usually remain there for at least a month until they have been cleared by ANCSEP. According to a scheduled plan, the DSSB transports vaccines used by the NIP to the DSSB national vaccine store (Figure 3).

Figure 3. The vaccine supply chain in Tunisia



Abbreviations: ANCSEP = National Agency for the Sanitary and Environmental Control of Products; DSSB = Department of Basic Health Care; DRSSB = Regional DSSB; PCT = Central Pharmacy of Tunisia.

In practice, this means that vaccines are moved from a state-of-the-art PCT warehouse to a suboptimal storage facility located on the ground floor of the MSP building. This vaccine store serves as a transit depot for small quantities of vaccines before they are transported on a monthly basis to each of the 24 regional stores operated by regional DSSBs (DRSSBs).

From the regional level, an irregular and unplanned transportation system occurs, which varies between a system of distribution in some regions (from the level above to the level below) to ad-hoc collection-based distribution approaches in others (from the level below to the level above). Because of the weak transportation system, the ad-hoc collection-based system prevails for the 264 district stores and 2,067 health centers in Tunisia. For the most part, district stores have to collect their vaccines from the regional store, and health centers need to collect their vaccines from the district store.

Most regional stores are equipped with cold chain equipment (such as medical refrigerators designed for storing vaccines) required to keep vaccines cool at all times. On the other hand, district stores and health centers are equipped with domestic refrigerators that are not adapted for storing vaccines, which places them at risk of excessive heat or freezing.

The vaccine supply chain in Tunisia is managed using an unreliable paper-based logistics management information system (LMIS) to track stock and consumption. The paper-based system does not allow the exchange of real-time data needed for accurate vaccine forecasting,

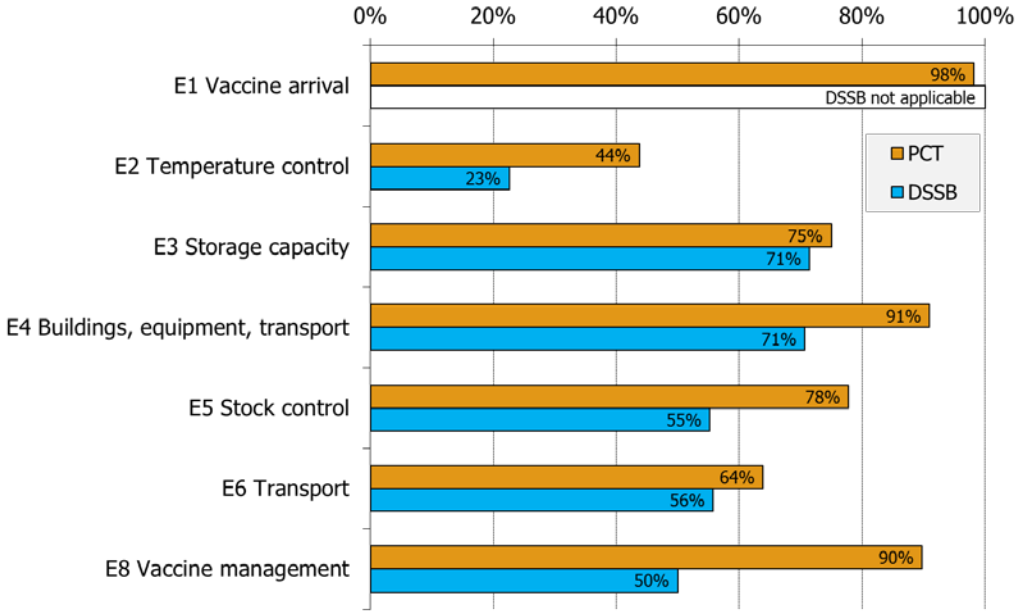
stock management, and order status information to ensure that the right quantities are distributed to the right place at the right time. The paper-based LMIS thus increases the risks of poor forecasting of needs, inaccurate quantification of orders leading to overstocking, expiry, and high vaccine wastage at lower levels of the supply chain. Likewise, the system leads to management inefficiencies, reporting duplications, high reporting workload, data inaccuracy, and delays in reporting and monitoring.

2.3. EVM assessment

Before beginning any demonstration projects, Optimize conducted an Effective Vaccine Management (EVM) assessment in 2010 to evaluate the vaccine supply chain in Tunisia. The assessment measures supply chain performance in nine categories, with a target score of 80 percent for each. The assessment was conducted at a sample of sites, and included the national vaccine stores (PCT and DSSB), 9 regional stores, 17 district stores, and 14 health centers.

For the PCT national store, the EVM assessment scores were generally very good (Figure 4). For vaccine arrival procedures (E1), vaccine management (E8), and building, equipment, and transport (E4), the scores exceeded the 80-percent target score. For other criteria, scores were typically close to 80 percent, except for temperature monitoring (E2) which scored only 44 percent, mainly due to a lack of official standard operating procedures (SOPs). Separate temperature monitoring of the cold rooms at the PCT national store revealed that 100 percent of the continuous measurements maintained vaccines within recommended ranges, with the average temperature between 4.5°C and 5.5°C.

Figure 4. 2010 EVM assessment scores for the PCT and DSSB national stores



Abbreviations: DSSB = Department of Basic Health Care; EVM = Effective Vaccine Management; PCT = Central Pharmacy of Tunisia.

For the segments of the vaccine supply chain managed by the DSSB, EVM assessment scores were generally quite weak, with no categories meeting the 80-percent target. The criteria that scored the lowest were temperature control (E2, 23 percent), vaccine management (E8, 50 percent), stock control (E5, 55 percent), and transport (E6, 56 percent).

The main conclusion from the EVM assessment was that the PCT is a much stronger node in the supply chain than the DSSB. The overall score across all criteria was 75 percent for the PCT and 57 percent for the DSSB.

2.4. Challenges and opportunities

2.4.1. Supply chain network design

The current vaccine supply chain in Tunisia suffers from bottlenecks at various points that lead to considerable inefficiencies in vaccine management. The system is struggling to manage existing vaccines and is ill-equipped to accommodate the planned introduction of new vaccines—pneumococcal, rotavirus, and human papillomavirus (HPV) vaccine are all expected to be introduced before 2020.

Aside from being an unnecessary step in the supply chain (and a weak node, as indicated by the EVM assessment conducted by Optimize in 2010), the DSSB-run national vaccine store has reached its limit in terms of storage capacity and effectiveness. Because of its lack of storage space, vaccines need to be distributed to regional stores on a monthly basis. The need to frequently decentralize stock from national to regional levels is both costly on transportation and a risk to vaccines being transported in non-refrigerated vehicles using basic Styrofoam boxes. Given the irregularities in vaccine stock flows, the DSSB policy is for regional stores to keep a minimum of one month’s buffer stock. In other words, at the start of a re-supply period, regional stores can be keeping up to two months of vaccine in stock. This leads to a serious risk of vaccine wastage through both expiry (holding too much stock relative to consumption) and equipment failure. Moreover, the multiplicity of vertical health commodity supply chains operating in parallel often lead to duplication of effort, inefficiencies in processes, and higher operating costs for the health system.

A re-think of the supply chain network provides an opportunity to address the bottlenecks in the current system, streamline the network design, and strengthen the integration of the vaccine supply chain with those of other health commodities. Rather than improving the DSSB-run vaccine supply chain, which would involve significant investment when storage capacity already exists within the PCT, leveraging the strengths of the PCT in a redesign of the supply chain network may offer the best prospect of achieving these goals. (According to the EVM assessment findings discussed in section 2.3, the PCT is stronger in supply chain management than the DSSB.)

2.4.2. Ad-hoc vaccine distribution systems

At sub-national level, vaccine distribution in Tunisia employs a mixture of informal delivery and collection systems, which is inefficient and can lead to an irregular supply of vaccines further down the system. Due to the lack of dedicated vehicles for vaccine deliveries, regional vaccine stores are unable to distribute vaccines down the supply chain. Instead, district stores that are also not equipped with a dedicated vehicle must find alternative ways to collect their monthly orders of vaccines at the regional store. Likewise, health centers collect their vaccines from the district store.

In practice, an opportunistic, improvised system of collection and delivery is observed. For example, a district store vehicle may be travelling to the region for an unrelated reason and so will use the opportunity to collect their vaccines, or a regional store vehicle may conduct a visit to the district store and take advantage of that trip to collect the district's order of vaccines. In the end, the distribution of vaccines occurs in a rather ad-hoc and opportunistic fashion that is unplanned and uncoordinated. Because of this, the risk of vaccine stockouts is high, which often leads to emergency orders of vaccines that need to be responded to by the regional vaccine stores, who are not equipped with a dedicated vehicle to respond to these needs in a timely fashion.

Given this challenge, the opportunity presents itself in Tunisia to demonstrate efficiency gains from planned, regular, and one-directional distribution of vaccines down the chain (from region to district to health center). There are several advantages of such a delivery-based vaccine distribution system over a collection-based or hybrid system. First, a reliable schedule is most easily and effectively provided by the supplying store, which has the budget and supervision staff to ensure reliability. Second, the supplying store can more effectively maintain high quality standards for the cold chain during transport to receiving stores.

2.4.3. Energy supply

At lower levels of the supply chain, the energy needed for maintaining the cold chain and storing vaccines and supplies comes from fossil fuels, which are costly and polluting. The energy supply to run the cold chain is also unreliable, with frequent power-cuts and power-surges compromising the ability of the system to keep vaccines at the correct temperature ranges at all times. In addition, transportation of vaccines and supplies is a weak link because of the lack of operational budgets to maintain vehicles in good working order and to pay for fuel and petrol to run them. As such, the transport of vaccines is irregular and can compromise the ability of the supply chain to ensure vaccine availability at all levels.

These energy supply problems can be overcome by transitioning to renewable energy sources, which are priorities for the Tunisian government. Existing renewable energy technologies have great potential for saving energy and ensuring a more reliable and green supply chain system for vaccines.

2.4.4. Stock control

A major challenge in managing a vaccine supply chain is the need for centralized, timely, and accurate data to effectively manage vaccine stock. Without this information (such as data on doses procured, doses distributed, doses administered, remaining stock, and wastage rates), it is difficult to determine the necessary quantities of vaccines to order or how to manage their distribution. The ability to track and trace vaccines along an information-driven supply chain can mitigate the risks of under-stocking (leading to stockouts and missed opportunities to vaccinate children) or overstocking (leading to wasting vaccines from expiry).

Tunisia has the opportunity to transition from paper-based information management systems to electronic logistics management information systems that can increase the efficiency of the vaccine supply chain. This is becoming increasingly apparent as Internet and mobile technologies become ever more widespread in Tunisia.

3. STREAMLINED AND INTEGRATED SUPPLY CHAIN

3.1. Goal

The goal of the demonstration project was to increase the efficiency and effectiveness of vaccine, supply, storage, distribution, and stock management by streamlining and integrating the vaccine supply chain.

- Streamlining the vaccine supply chain by demonstrating an alternative supply chain network design that avoids unnecessary or inefficient steps.
- Integrating the distribution of vaccines with those of other time- and temperature-sensitive health products (TSHPs) to reduce the number of supply chains working in parallel.

Such system transformations have the potential to improve the performance of the vaccine supply chain, lower overall costs, increase the agility and responsiveness of the system, and strengthen its ability to absorb new, large-volume, higher-cost vaccines and temperature-sensitive pharmaceutical products.

3.2. System overview

Two integration models were implemented at different levels of the supply chain network:

1. At the national to regional level.
2. At the regional to health center level in five regions (Sousse, Monastir, Mahdia, Kairouan, and Kasserine).

In addition, a delivery-based distribution model was established to demonstrate gains from planned, regular, and one-directional distribution of vaccines down the chain (from region to district to health center).

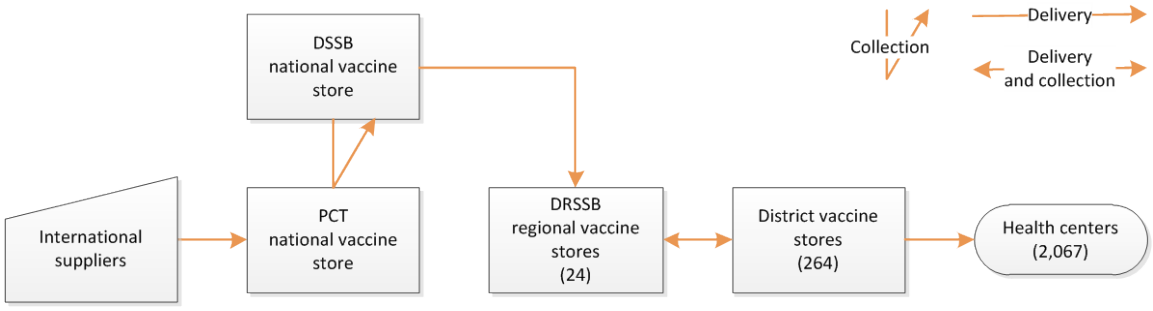
3.2.1. National to regional level

For parts of the supply chain from national to regional level, a segmented approach to integration was selected. Between these levels, products with similar temperature characteristics (needing to be kept at temperatures between 2°C and 8°C at all times) were to be stored and transported together.

Responsibility for transporting vaccines from the national to the regional level was transferred from the DSSB to the PCT. The PCT took responsibility for transporting both vaccines and other TSHPs to its five PCT inter-regional stores before distribution to DRSSBs.

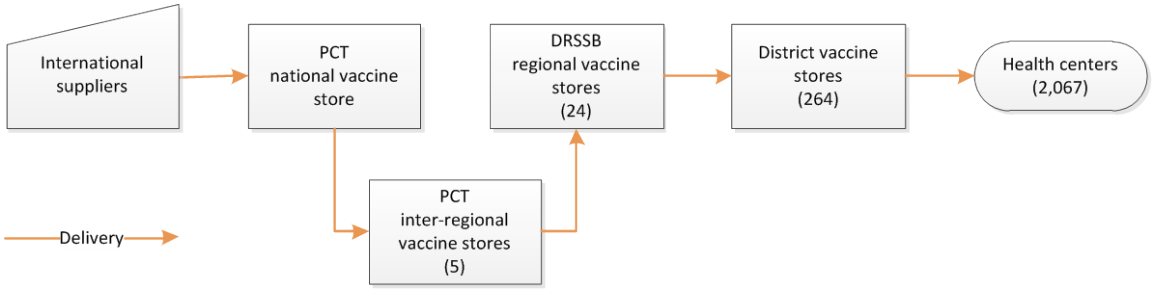
The baseline vaccine supply chain in Tunisia is shown in Figure 5, while Figure 6 shows the new system.

Figure 5. The baseline vaccine supply chain in Tunisia



Abbreviations: DSSB = Department of Basic Health Care; DRSSB = Regional DSSB; PCT = Central Pharmacy of Tunisia.

Figure 6. Streamlined vaccine supply chain in Tunisia



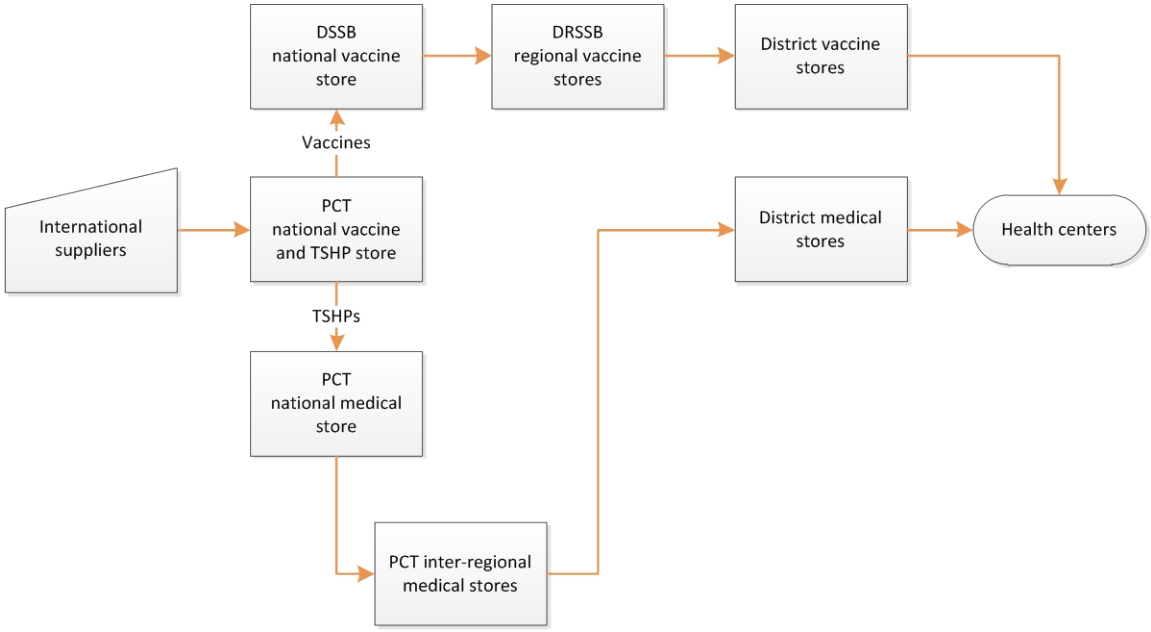
Abbreviations: DSSB = Department of Basic Health Care; DRSSB = Regional DSSB; PCT = Central Pharmacy of Tunisia.

3.2.2. Regional to health center level

At regional to service-delivery level, a full approach to integration was implemented. This involved consolidating regional and district stores for vaccines, drugs, and temperature-sensitive products. Vaccines, TSHPs and all other pharmaceutical products were to be warehoused together and transported in the same delivery circuit from the regional to health center level. Deliveries were to be made from the regional store to district stores and from district stores to health centers, grouped in convenient transportation circuits by efficient route planning. (A “green” supply chain system was tested in conjunction with the supply chain integration. This is described in chapter 4.)

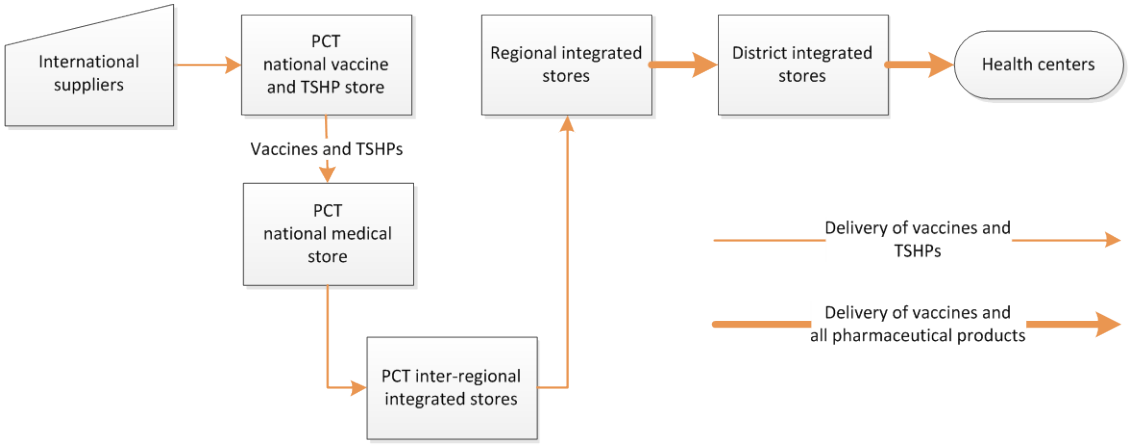
The existing supply chain for vaccines and TSHPs is shown in Figure 7, while the new system is shown in Figure 8.

Figure 7. Parallel supply chain for vaccines and TSHPs at baseline



Abbreviations: DSSB = Department of Basic Health Care; DRSSB = Regional DSSB; PCT = Central Pharmacy of Tunisia; TSHPs = temperature-sensitive health products.

Figure 8. Integrated demonstration supply chain for vaccines, TSHPs and pharmaceutical products*



Abbreviations: PCT = Central Pharmacy of Tunisia; TSHPs = temperature-sensitive health products.
* Pharmaceutical products are supplied by the PCT national store to regional integrated stores through an additional vertical supply chain not represented in this diagram.

At subregional levels, integration went beyond the physical integration of health products and included elements of service delivery and supervision. For example, the vehicle used to transport vaccines and health products also transported staff for supervisory visits to health centers.

Physical integration occurred in storage points in Kasserine and in the three districts of Foussana, Feriana, and Hassi El Frid. It was difficult, however, to create a meaningful indicator to capture the fact that vaccines and pharmaceuticals were stored closer together. In Foussana district,

integration took the form of construction (funded by the district) to create a vaccine and drug store side by side.

3.2.3. Delivery-based distribution

Deliveries were grouped into transportation circuits (from the regional store to district stores and from district stores to health centers) based on efficient route planning so that each circuit would serve the maximum number of health facilities within the autonomy of the dedicated vaccine delivery vehicles (see section 4.3.1).

The features and expected benefits of the new delivery-based system over the existing ad-hoc system are described in Table 2.

Table 2. Comparative features of existing and delivery-based distribution system

Ad-hoc system	Delivery-based system	Benefits of the change
Mixed collection and delivery	Delivery only	More controllable by managers
Ad-hoc timing of trips, on demand, and when transport is available	Preplanned delivery trips respecting supply interval	Known and trusted delivery dates simplifies stock management
Shared use of vehicles, no priority, opportunistic choice of transport	Vehicle dedicated to execute planned delivery trips	Vehicle availability better when dedicated; control better when higher-level store manages transport
Individual facilities arranged their collections or deliveries	Preplanned delivery ‘circuits’ to multiple receiving stores	Circuits result in shorter distances, less cost
Supervision trips not combined with supply trips	Supervision trips systematically combined with supply trips	Supervision of remaining stock and alarms raises quality, accuracy, and response to failures

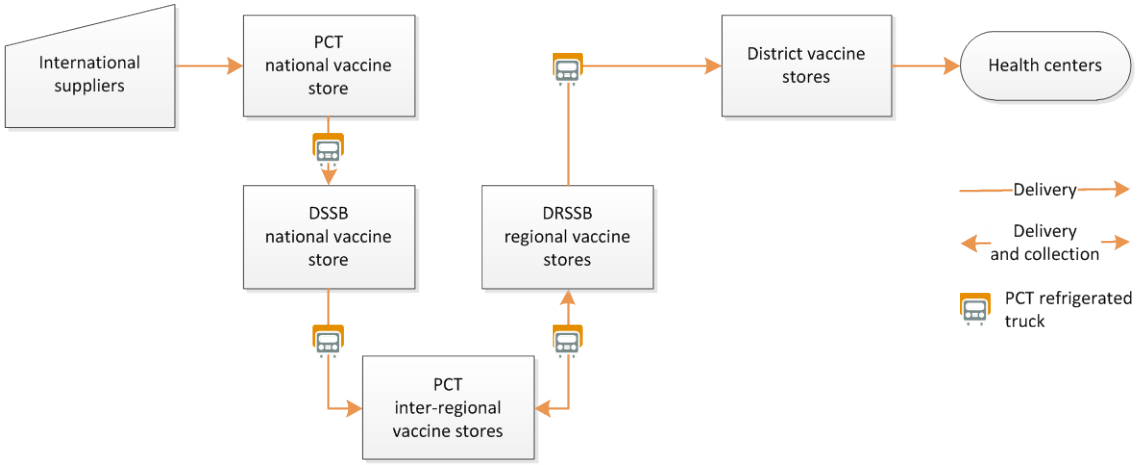
3.3. The emergence of hybrid systems

Unexpected vaccine supply and procurement issues encountered during 2012 led to national-level stockouts of certain vaccines. These events disrupted the implementation of the demonstration as originally designed. Instead, two hybrid systems emerged. These are described below.

3.3.1. Hybrid supply system A

From April to November 2012, hybrid system A was used in 14 percent of cases (Figure 9).

Figure 9. Hybrid supply system A



Abbreviations: DSSB = Department of Basic Health Care; DRSSB = Regional DSSB; PCT = Central Pharmacy of Tunisia; TSHPs = temperature-sensitive health products.

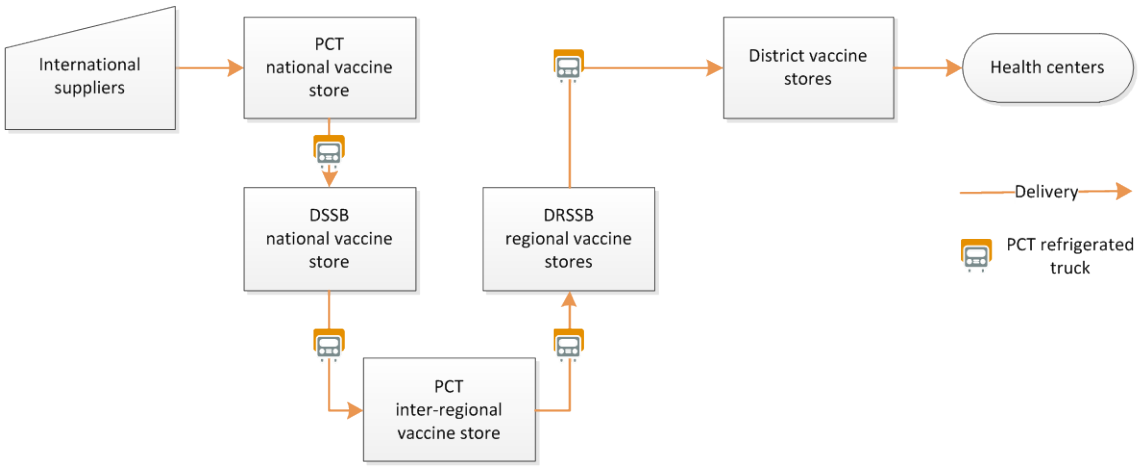
Hybrid system A functions as follows:

1. The DSSB national vaccine store in Tunis estimates that it has enough vaccine in stock to cover the monthly orders of the five regions of the demonstration project. Instead of using the vaccines for the five regions that are stored at the PCT national vaccine store, the DSSB store draws down on its own stocks and requests that the PCT refrigerated truck collect vaccines at the DSSB store.
2. Vaccines are transported from the DSSB vaccine store in Tunis to the PCT inter-regional vaccine store (Sousse) and kept there for a few days before being dispatched to the five regions.

3.3.2. Hybrid supply system B

From April to November 2012, hybrid system B was used in 86 percent of cases (Figure 10).

Figure 10. Hybrid supply system B



Abbreviations: DSSB = Department of Basic Health Care; DRSSB = Regional DSSB; PCT = Central Pharmacy of Tunisia; TSHPs = temperature-sensitive health products.

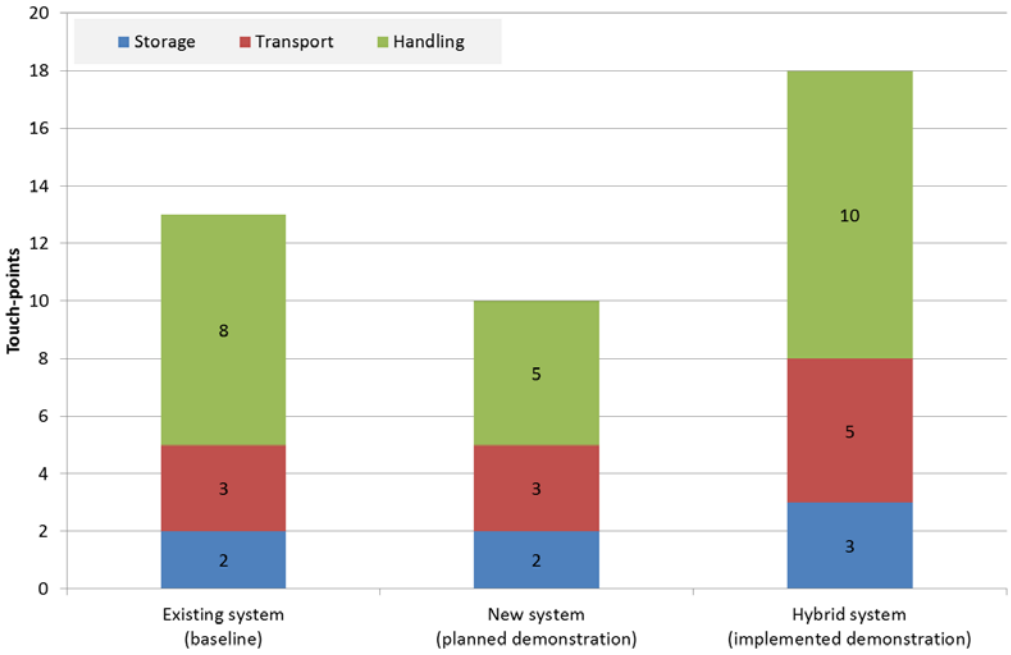
Hybrid system B functions as follows:

1. The DSSB national vaccine store in Tunis estimates that it has enough of certain vaccines in stock to cover only a portion of the monthly orders from the five regions of the demonstration project.
2. Vaccines without enough stock available in the DSSB national vaccine store are taken from the PCT national vaccine store and loaded onto the PCT refrigerated truck.
3. The PCT refrigerated truck collects the remaining vaccines at the DSSB national vaccine store.
4. The truck travels from the DSSB national vaccine store in Tunis to the PCT inter-regional vaccine store (Sousse) and is cross-docked for a few days before being dispatched to the five regions.

3.3.3. Impact of the hybrid systems

Rather than streamlining the network design by reducing vaccine touch-points, the hybrid systems introduced additional touch-points to the existing system. Each of these additional touch-points represents a vaccine handling and temperature risk, or break in the cold chain. The impact on touch-points is illustrated in Figure 11.

Figure 11. Comparison of vaccine touch-points in existing, new, and hybrid systems



The vaccine ordering system was also significantly complicated, with the hybrid system leading to a very cumbersome process at national level. This was contrary to the potential benefits that could have come from a streamlined supply chain system.

3.4. Implementation

Table 3 describes the project timeline and major milestones.

Table 3. Supply chain integration timeline

Year	Month	Milestone
2011	May	Memorandum of understanding signed by directors of the DSSB, CEO of the PCT, and WHO representative.
		Final standard operating procedures signed by directors of the DSSB and the CEO of the PCT.
	October	New cold room installed at PCT inter-regional store in Sousse and refrigerated truck and van purchased.
	November	Training of staff at PCT inter-regional store completed.
	December	National project advisory committee meeting held.

Year	Month	Milestone
2012	April	Demonstration period begun. (Although the launch was originally scheduled for January 2012, this was delayed to address concerns related to the new cold room in Sousse.)

Abbreviations: CEO = Chief Executive Officer; DSSB = Department of Basic Health Care; PCT = Central Pharmacy of Tunisia; WHO = World Health Organization.

3.5. Results

The impact of the intervention was measured by:

- Comparing the baseline and endline EVM assessment results.
- Comparing vaccine stock flow in 2010 and 2012.
- Analyzing the quality of temperature control during storage and transport.
- Comparing supply chain costs in 2010 and 2012.
- Analyzing the degree of supply chain integration at regional and lower levels.
- Analyzing the extent and impact of delivery-based vaccine distribution.

Each impact is analyzed in the following sections.

3.5.1. Comparison of baseline and endline EVM assessment results

National level

Optimize conducted the EVM assessment in four locations:

- The DSSB national vaccine store in Tunis.
- The PCT national vaccine store in Tunis.
- The PCT inter-regional store in Sousse.
- A sample of DRSSB regional stores.

An EVM assessment was conducted before the demonstration began (a baseline measurement in 2010, except for the PCT inter-regional store in Sousse, which did not then exist) and after a period of demonstration (endline in 2012). To simplify the analysis, the nine EVM criteria were grouped into four components: procurement, storage, handling, and transport.

Analysis of the EVM assessment results by location and level highlight significant improvements from baseline to endline for the DSSB national store in Tunis (Table 4).

Table 4. Overall EVM assessment scores for baseline and endline[a]

Level	Location	Baseline (2010)	Endline (2012)	Change
National	DSSB	51%	73%	22%
	PCT	75%	79%	4%
Inter-regional	PCT Sousse	N/A	63%	N/A
Regional	DRSSB Sousse	60%	64%	5%
	DRSSB Kasserine	45%	64%	19%
	DRSSB Kairouan	52%	59%	7%

Abbreviations: DSSB = Department of Basic Health Care; DRSSB = Regional DSSB; EVM = Effective Vaccine Management; PCT = Central Pharmacy of Tunisia.

a. The EVM in 2010 did not assess the regions of Monastir and Mahdia.

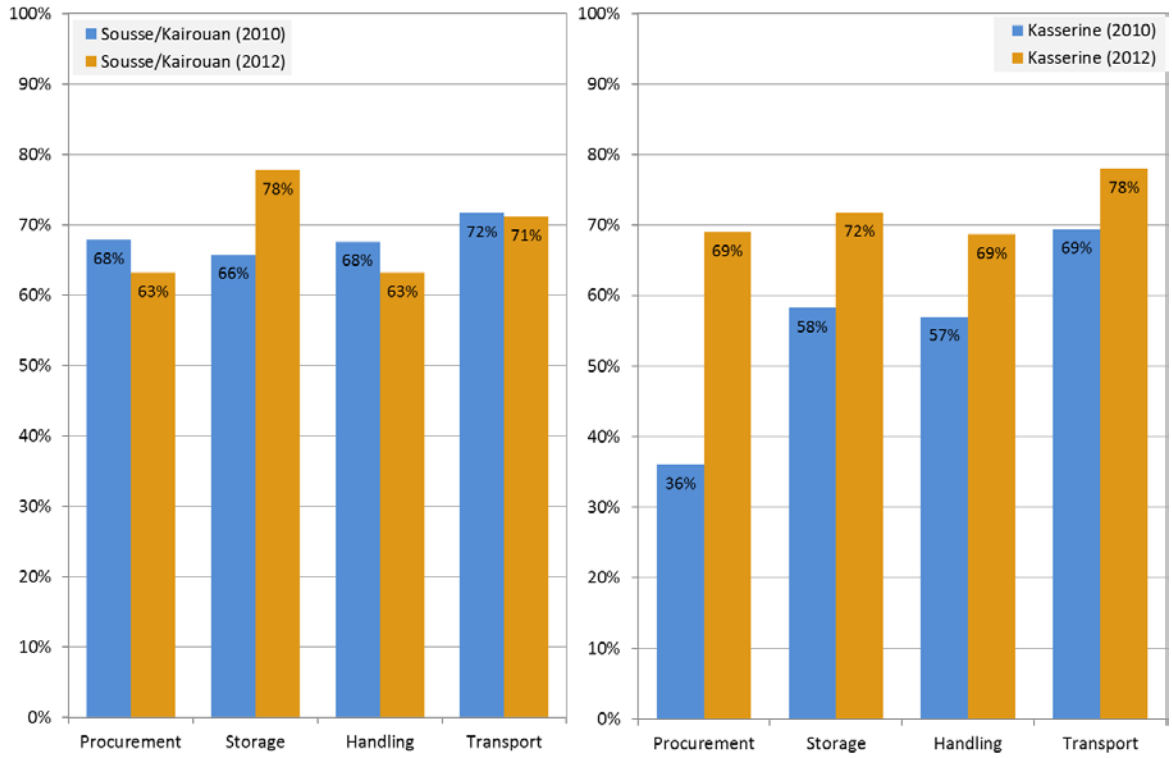
The improvements to the DSSB national store were found in all aspects of vaccine management. Some of the improvement could be due to support for the use of temperature-monitoring devices and the web-based Vaccination Supplies Stock Management (wVSSM) system and related vaccine management training. Likewise, the development of SOPs for the demonstration project provided an opportunity to revisit and strengthen procedures at the primary store. Finally, the DSSB purchased refrigerated trucks for transporting vaccines, and this improved the EVM assessment scores related to vaccine distribution.

The PCT national vaccine store showed modest overall improvement from baseline to endline. However, the EVM assessment scores associated with procurement declined between 2010 and 2012, which might be linked to national vaccine stockouts that occurred in 2012 (refer to section 3.8.2 for more information on this). Scores related to vaccine handling also decreased. It is difficult to ascribe these performance declines between 2010 and 2012 to the demonstration, as the demonstration has not operated for a sufficient length of time to stabilize and resolve initial disruptions. It is likely, for example, that turnover of key staff after the Arab Spring and a corresponding loss of expertise and skills may have contributed to these declines. Improvements in transport could be due in part to support for a refrigerated truck and the streamlined system for delivering vaccines from the PCT store in Tunis to the PCT store in Sousse. The overall EVM assessment score for the PCT inter-regional store in Sousse was only 63 percent (Table 4), reflecting the challenges encountered when implementing this demonstration project (see “Challenges” on page 32).

Regional level

Figure 12 shows the baseline and endline EVM assessment scores at regional levels.

Figure 12. Baseline and endline EVM assessment scores at regional levels in pilot demonstration areas



Some EVM assessment scores improved in the demonstration areas. Improvements in Kasserine were more pronounced than those in other areas and reflected the demonstration's focus on this region. (In the four other regions—Sousse, Mahdia, Monastir, and Kairouan—the interventions were limited to supporting the use of a temperature-monitoring system using temperature loggers and of wVSSM.)

It is not possible to attribute any of the observed improvements to project Optimize, and we cannot conclude that the demonstration project improved vaccine management relative to the existing system managed by the DSSB. The most important conclusion that can be drawn is that the interventions did not disrupt effective vaccine management in the pilot areas.

3.5.2. Vaccine stock flows

The Optimize team assessed vaccine stock flow measures to look for potential changes in supply chain performance as a result the demonstration. We used the Stock Flow Assessment Tool[1] to

[1] This is a Microsoft Excel–based tool that generates an annual stock balance chart and calculates multiple indicators related to stock flow, based on stock movement records contained in vaccine stock cards. The Stock Flow Assessment Tool was previously called the Vaccine Stock Tool (VST).

retrospectively analyze stock movements over 12 months at various storage points and to calculate key indicators. The three indicators selected for this analysis are described in Table 5.

Table 5. Vaccine stock flow indicators

Indicator	Description
Average days in stock	A measure of the speed of vaccine supply. An average of 25 days in stock is a rough benchmark for a system with monthly distribution.
Stock turnover	A measure of the speed of vaccine distribution. Directly related to average days in stock (an average of 12 turnovers per year is a rough benchmark for a system with monthly distribution).
Days out of stock	A measure of the number of days within a year during which a particular vaccine had zero stock. This is a proxy measure for a stockout even though a few days out of stock may not be synonymous with a stockout. A facility should always have a buffer stock on hand. Any value above zero for this indicator is an indication of poor vaccine stock control.

Overall, stock flows worsened in the five demonstration regions between 2010 and 2012. The average number of days in stock for three tracer vaccines rose significantly, suggesting that vaccines were not flowing through the system as rapidly in 2012 as in 2010 (Table 6). This increases the risk that vaccines will reach their expiry date and discard state before reaching the point of use.

Table 6. Average days in stock for three tracer vaccines in 2010 and 2012 in demonstration regions

Region	Polio		Measles		Hep B/pentavalent	
	2010	2012	2010	2012	2010	2012
Sousse	24	50	25	146	15	41
Mahdia	32	75	39	103	39	59
Monastir	67	51	41	73	15	37
Kairouan	35	193	35	125	193	70
Kasserine	27	70	31	98	23	84
Average	**37**	**88**	**34**	**109**	**57**	**58**

Abbreviation: Hep B = hepatitis B.

There was also a corresponding decline in stock turnover. Kasserine had stockouts in 2012 for polio and pentavalent vaccines that led to more than two weeks without these vaccines (Table 7).

Table 7. Days out of stock for three tracer vaccines in 2010 and 2012 in demonstration regions

	Polio		Measles		Hep B/pentavalent	
	2010	**2012**	**2010**	**2012**	**2010**	**2012**
Sousse	0	4	0	0	5	0
Mahdia	3	0	6	0	0	0
Monastir	0	0	2	0	17	0
Kairouan	0	0	0	0	0	0
Kasserine	0	13	0	0	0	16
Average	**1**	**3**	**2**	**0**	**4**	**3**
Total	**3**	**17**	**8**	**0**	**22**	**16**

Abbreviation: Hep B = hepatitis B.

Table 8 shows the proportion of time at baseline and endline that vaccine stock in each region was below minimum recommended levels. The reasons for the poorer performance in Kasserine are unclear.

Table 8. Time that vaccine stock was below minimum recommended levels in demonstration regions

	% of days stocks were below minimum levels		% of days with zero stock	
	2010	**2012**	**2010**	**2012**
Kasserine	7	6	0	4
Other 4 regions (average)	12	3	2	0

In summary, although the speed at which vaccines travel through the supply chain declined from baseline to endline, the availability of vaccines improved, except in Kasserine (Table 8).

The relationship between changes in supply chain performance and the demonstration project is uncertain. The overall context of vaccine supply in Tunisia (in particular, the 2012 national-level vaccine stockout) makes the interpretation of findings extremely difficult. In other words, it is not possible to definitively link lower performance in the supply chain between 2010 and 2012 with the demonstration.

3.5.3. Vaccine temperature control

Table 9 shows key temperature indicators for vaccine storage in DSSB and PCT vaccine stores in 2010 and 2012. LogTag® temperature data loggers monitored temperatures at selected times during vaccine storage and transportation.

Table 9. Temperature data in DSSB and PCT vaccine stores in 2010 and 2012

Year	Reading	DSSB national vaccine store		PCT	
				National vaccine store	Sousse
		BCG and measles	Other EPI vaccines	All vaccines	All vaccines
2010	Average temp. (°C)	0.6	4.3	4.5	-
	Min. temp. (°C)	-1.9°C	3.2°C	3.4°C	-
	Max. temp. (°C)	4.1°C	8.5°C	9.1°C	-
	% within 2°C to 8°C	22%	99%	98%	-
2012	Average temp. (°C)	-	-	-	3.8°C
	Min. temp. (°C)	-	-	-	-2.2°C
	Max. temp. (°C)	-	-	-	27.0°C
	% within 2°C to 8°C	-	-	-	82%

Abbreviations: BCG = bacillus Calmette-Guérin; DSSB = Department of Basic Health Care; EPI = Expanded Programme on Immunization; PCT = Central Pharmacy of Tunisia.

For the 2010 data, the most meaningful comparison is between temperature control at the DSSB national vaccine store and that in at the PCT national vaccine store because a primary aim of the demonstration was to strengthen the PCT system. One cold room at the DSSB store was malfunctioning during the temperature monitoring in 2010, and only 22 percent of the 15-minute temperature readings were within the recommended range. From the perspective of equipment performance, these results should favor the PCT store over the DSSB store. However, because our focus was on whether the vaccines were exposed to inadequate temperatures, the results at the DSSB store are acceptable because this cold room contained only lyophilized vaccines that are not freeze-sensitive (measles and BCG). In the other DSSB cold room, 99 percent of the data logger readings were in the recommended range, compared with 98 percent of the readings at the PCT store.

It is also instructive to compare temperature control in 2012 at the PCT store in Sousse (the new store built for the demonstration project) with that in the DSSB cold rooms in Tunis in 2010. At

the PCT store, only 82 percent of the readings were within the recommended temperature range, and great variations in temperature were seen. This compares with 99 percent of readings being in the recommended range for storage of "other EPI vaccines" at the DSSB store.

Table 10 shows temperatures recorded during vaccine transport in 2010 and 2012. The team evaluated three main transportation circuits, which were the monthly circuits that include the five demonstration regions. Special considerations related to delivery circuits 1 and 3 warrant mentioning and affect the interpretation of findings. For instance, in 2010 the vaccines for Kasserine would leave the DSSB vaccine store in Tunis and pass through a delivery circuit that includes four locations: Kasserine, Gafsa, Tozeur, and Sidi Bouzid. In 2012, the vaccines for Kasserine would leave the PCT inter-regional store in Sousse and pass through a delivery circuit that includes Kairouan and Kasserine. Although both circuits brought vaccines to Kasserine, they were different in terms of the starting point, number of locations in the journey, and other factors.

Table 10. Temperatures during vaccine delivery circuits, 2010 and 2012

Delivery	Reading	Circuit 1	Circuit 2	Circuit 3
DSSB vaccine delivery circuits (2010)[d]	Average temp. (°C)	-1.5	4.1	3.1
	Minimum temp. (°C)	-3.3	3.2	2.4
	Maximum temp (°C)	5.0	6.1	5.3
	% within 2°C to 8°C	16%	100%	100%
PCT vaccine delivery circuits (2012)[e]	Average temp. (°C)	5.6	5.2	6.2
	Minimum temp. (°C)	-2.4	-1.4	3.3
	Maximum temp (°C)	12.3	16.7	11.1
	% within 2°C to 8°C	85%	64%	83%

Abbreviations: DSSB = Department of Basic Health Care; PCT = Central Pharmacy of Tunisia.

The overall findings on temperatures during vaccine transport suggest that the new system demonstrated lower performance than the existing system. Among the DSSB vaccine delivery circuits in 2010, two had top marks for keeping vaccines in the correct temperature ranges (100 percent of data-logger observations within the recommended temperature range). In the third circuit however, only 16 percent of the observations were within the recommended range, and the average temperature was below the freezing point.

For the PCT vaccine delivery circuits in 2012, the results are rather weak. Although the average temperature was within the recommended temperature range in all three circuits, important temperature fluctuations were seen in the minimum and maximum temperature readings.

Overall, it appears that the new demonstration system showed poorer performance than the existing system in maintaining proper temperatures during storage and transport. It is worth noting, however, that important technical problems with setting up the new cold chain system contributed to the poor temperature regulation during storage in 2012. When the PCT cold room in Sousse was functioning correctly, the temperature performance would surpass that of the existing system through the DSSB.

Significant improvements in temperature storage occurred in PCT vaccine delivery circuits over the demonstration period. Table 11 shows steady improvement during the demonstration in maintaining vaccines in the correct temperature ranges during transport. For all delivery circuits managed by the PCT, the proportion of temperature observations between 2°C and 8°C increased from 67 percent in the second quarter of 2012 to 98 percent in the fourth quarter of 2012.

Table 11. Ability to keep vaccines in the correct temperature range in PCT delivery circuits, 2012

PCT delivery circuit	% of temperature observations between 2°C and 8°C			
	Q2	Q3	Q4	Q2–Q4
Tunis-Sousse	75	85	100	87
Sousse-Sousse	78	100	100	90
Sousse-Monastir	68	100	100	92
Sousse-Mahdia	72	97	100	89
Sousse-Kairouan	53	54	93	69
Sousse-Kasserine	61	58	97	75
Overall	**67**	**75**	**98**	**82**

Abbreviations: PCT = Central Pharmacy of Tunisia.

3.5.4. Supply chain costs

Optimize also assessed supply chain performance from an economic perspective, even though cost reductions were not a main objective of the demonstration. We had assumed the new system design would increase costs because of the need for additional investments to conduct the demonstration. It was important to analyze any increases in costs in relation to benefits.

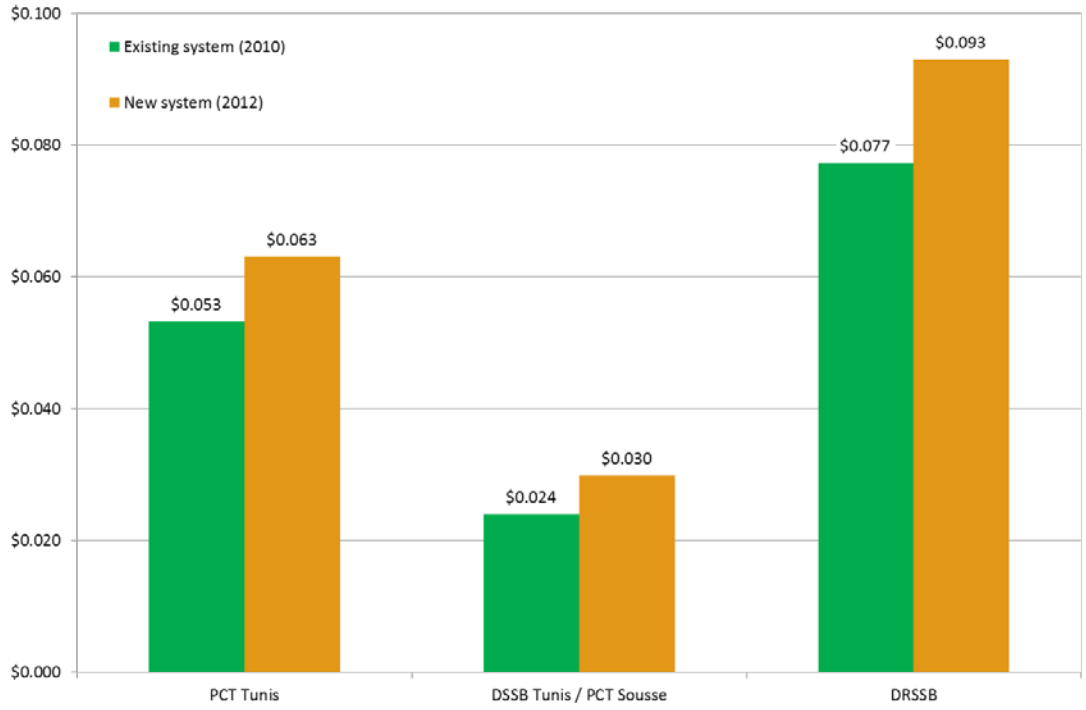
The team developed a specific supply chain costing approach and used it to calculate key costing indicators. The indicator of choice is the supply chain cost per dose of vaccine delivered. This

corresponds to the cost of storing and transporting vaccine from one storage point to another (including the cost of human resources and storage sites).

Figure 13 shows the cost per dose for the existing system (2010) and the new system (2012).[2] The costs at the DRSSB or regional level are essentially the combined cost per dose of the PCT Tunis and either the DSSB Tunis or the PCT Sousse, depending on the system. The cost per dose at the DRSSB level indicates the average supply chain cost of delivering a dose of vaccine from the national level to regional levels.

As expected, the cost of the new supply chain system was more than the existing system. The supply chain cost to get a dose of vaccine from the primary store to a regional vaccine depot was a little more than US$0.09 per dose in the new system, compared with a little less than $0.08 per dose in the existing system. About 80 percent of the costs are for storage (cold chain equipment, infrastructure, human resources), and the remaining costs are for transport (vehicles and transportation costs).

Figure 13. Supply chain cost per dose with existing (2010) and new (2012) systems



Abbreviations: DSSB = Department of Basic Health Care; DRSSB = Regional DSSB; PCT = Central Pharmacy of Tunisia.

[2] Note that this analysis did not estimate the cost per dose for the hybrid system that was actually implemented. This would be too complex to estimate given that all storage points are used and only a portion of orders are taken from the PCT Tunis and the DSSB Tunis, complicating the denominator to use (and thus how to attribute costs to different storage points). It is likely that the cost per dose delivered in the hybrid system is the highest of the three systems given that, in effect, it is a system that adds storage points and transport legs.

At first glance, the slight cost difference between the two systems at the DRSSB level seems negligible. Over the course of a year for the five concerned regions, however, this difference amounts to an extra $14,061.

Although the cost data do not support changing systems based on current needs, it is important to bear the following in mind:

- The existing system has reached its limits and will be incapable of absorbing the increase in vaccine volume expected when Tunisia introduces pneumococcal, rotavirus, and HPV vaccines before 2020. Fixing the existing system will require significantly higher investments than the new system and will result in a higher cost per dose relative to the new system.
- The cost per dose of the new system will drop over time with amortization of the investments made for the project and once new vaccines are introduced.
- The cost-per-dose estimates for the old and new system do not take into account the efficiency gains from supply chain integration and the fact that vaccines and other temperature-sensitive health products were stored and transported together in the new system. Given the lack of data, it was not possible to include the cost efficiency from integration.

Table 12 shows that the volume and value of vaccines may increase more than five-fold by 2020.

Table 12. Expected increase in volume and value of vaccines with the introduction of pneumococcal, rotavirus, and human papillomavirus (HPV) vaccines by 2020

	Capacity assumptions	Volume (liters)		Factor of increase
		2012	2020	2012–2020
National	6 months + 25% buffer	15,432	78,442	x 5.1
Regional[a]	3 months + 25% buffer	409	2,334	x 5.7
District[b]	2 months + 25% buffer	31	54	x 1.7
National vaccine value ($ million per year)		$2.49	$12.79	x 5.1

a. Based on Kasserine.

b. Based on Foussana district in Kasserine.

The expected five-fold increase in volume at national and regional level is mainly due to the predicted increase in vaccine quantities (which will be more bulky), as well as the preference of the DSSB to store vaccines in tertiary packaging in future.

The existing system at the DSSB is just able to cope with the current volume of vaccines. Any large increase in storage volume will require significant investments in cold rooms. Because this expansion is not possible in the current location, a new building will likely be required, and these future investments will significantly increase the cost per dose delivered. Although the new proposed system is marginally more expensive in terms of cost per dose, it is likely to be less expensive once Tunisia introduces new vaccines.

3.5.5. Supply chain integration

The degree of integration in the supply chain between the regional level and health centers was measured during transportation. Drivers recorded in special logbooks detailed information on the purpose of their journeys. The purpose of a journey was defined by the driver as relating to one or more of the following:

1. Vaccines and supplies.
2. Drugs and pharmaceuticals.
3. Service delivery.
4. Supervision.

Trips that were out of scope (not related to our demonstration) were excluded from the analysis. Analyzing the logbook information, trips were classified according to four levels of integration:

Level 1: Vaccines only.

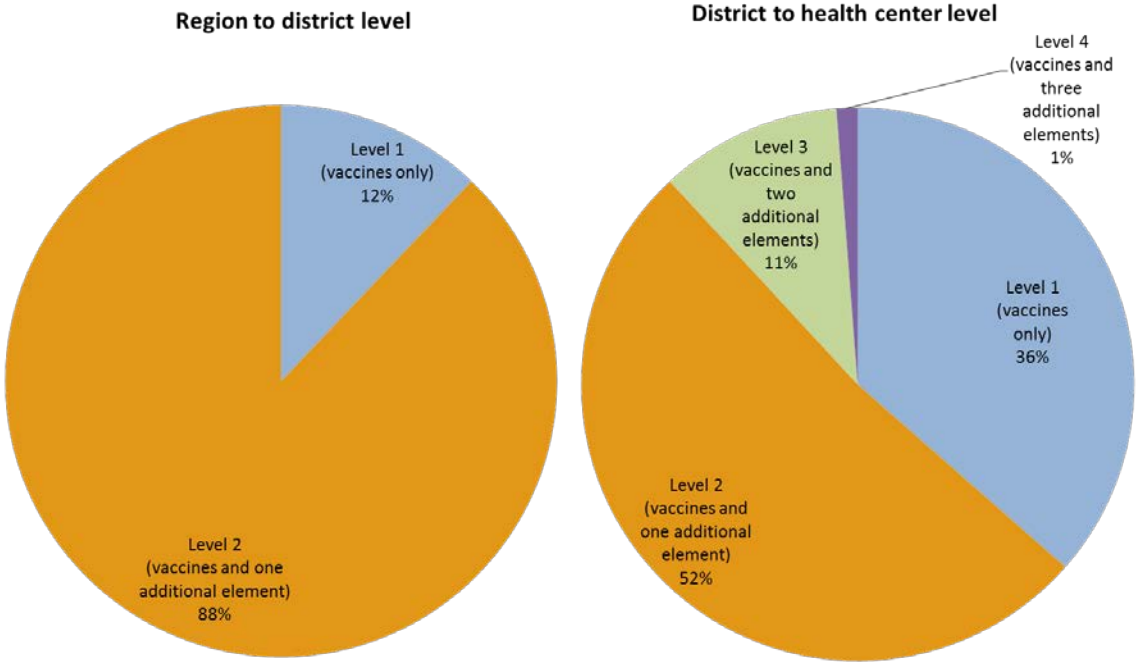
Level 2: Vaccines and one additional element.

Level 3: Vaccines and two additional elements.

Level 4: Vaccines and three additional elements.

Figure 14 shows the results of the analysis. At the regional level (distribution from region to district), 88 percent of the journeys were classified as level 2 and primarily involved deliveries of vaccines and other health commodities.

Figure 14. Levels of supply chain integration during deliveries at regional and district levels



Journeys classified as level 1 were often associated with emergency orders or delays in receiving vaccines from the national level. The level of integration does not exceed level 2 from region to district because supervision is conducted through monthly meetings at regional level (district workers come to the regional store for supervisory meetings) and no service delivery is conducted at regional level. It is therefore unsurprising that from region to district the level of integration does not exceed 2.

From the district to the health center level, there was greater variety in the levels of integration. Although most trips (52 percent) were categorized as level 2, a high proportion (36 percent) was made solely for transporting vaccines. This could be due to national vaccine supply constraints and delays in getting vaccines to Kasserine, which would have caused more vaccine-specific deliveries from Kasserine to the districts and from the districts to the corresponding health centers. Deliveries coded as level 3 or 4 represented 12 percent of the total. This shows that at subregional levels, it is possible for a vehicle to go out with an integrated package of health products and services.

To verify that the intervention had not adversely affected effective vaccine management, the team evaluated the baseline and endline EVM assessment scores at district and health center levels. In the three districts that implemented integration, the team found that EVM assessment scores improved between 2010 and 2012, while at the health center level (represented by one health center in each of the three districts), EVM assessment scores appeared to decline slightly. Overall, EVM assessment scores in demonstration locations did not decline significantly and for the most part, increased.

The overall findings on integration show that it was impossible in the lifetime of the project to demonstrate segmented integration between the national and regional levels. Results in the Kasserine region, however, show that it is possible for a vehicle at the regional level to go out on delivery circuits with more than just vaccines. Physical integration of vaccines, TSHPs, other health commodities, and supplies is a feasible solution that may bring important efficiencies to the supply chain system.

At the district level, the project showed that it is possible for delivery circuits to encompass an integrated package of health products and services (service delivery and supervision). EVM assessment at the regional- and district-level sites found that integration did not hinder effective vaccine management.

3.5.6. Delivery-based distribution

The impact of switching from an ad-hoc to a scheduled, predictable, and planned delivery-based distribution system was measured by analyzing:

- Frequency of deliveries according to schedule.
- Effect on vaccine stock flow.
- Distances traveled to distribute vaccines.

Frequency of deliveries according to schedule

Using a combination of data, it was possible to determine whether vaccine deliveries were made according to the predefined schedule stipulated in the standard operating procedure developed for the demonstration. Three sources of data were used: the delivery schedule, the driver's logbook,[3] and global positioning system journey tracking data downloaded from the four delivery vehicles. Triangulating these sets of information enabled the team to calculate the proportion of deliveries that were made according to plan. In other words, was the delivery made on the date it was scheduled in the planner and to the correct destinations? The results are presented in Table 13 and suggest that, for the most part, the demonstration was correctly implemented.

Table 13. Percentage of subnational vaccine deliveries made according to schedule and plan, 2012

	Q1	Q2	Q3	Q4
Kasserine region to districts	63	67	67	81
Foussana district to health centers	93	80	33	57
Hassi El Frid district to health centers	100	100	100	100
Feriana district to health centers	85	89	100	100

By the fourth quarter of 2012, 81 percent of planned deliveries to districts from the regional level were made according to plan, and all planned deliveries to health centers from the districts of Feriana and Hassi El Frid were made according to plan. That the regional level did not reach 100 percent is primarily due to the national supply issues for vaccines (with no vaccines, there was no need for the region to deliver).

Effect on vaccine stock flow

Table 14 and Table 15 compare key vaccine stock indicators for three tracer vaccines between 2010 (baseline) and 2012 to gauge whether vaccine flows improved as a result of planned deliveries. Note that Foussana had to be excluded due to missing 2010 baseline data.

[3] Drivers dedicates to the electric vehicles were provided with a specific logbook to track every single journey made during 2012. The information in the logbook included destination (start and stop points), purpose of the journey, odometer readings, and time measures (time of departure and arrival).

Table 14. Average days in stock at baseline (2010) and during intervention (2012)

Location	Polio		Measles		Hep B/penta.	
	2010	2012	2010	2012	2010	2012
Kasserine (region)	27	70	31	98	23	84
Feriana (district)	50	27	56	48	40	40
Hassi El Frid (district)	84	14	115	27	93	20
District average	**67**	**21**	**86**	**38**	**67**	**30**

Abbreviations: Hep B = hepatitis B; penta. = pentavalent.

Table 15. Stock turnover in days at baseline (2010) and during intervention (2012)

Location	Polio		Measles		Hep B/penta.	
	2010	2012	2010	2012	2010	2012
Kasserine (region)	14	5	12	4	16	4
Feriana (district)	7	14	7	8	9	9
Hassi El Frid (district)	4	27	3	14	4	18
District average	**6**	**21**	**5**	**11**	**7**	**14**

Abbreviations: Hep B = hepatitis B; penta. = pentavalent.

Overall, the average number of days that vaccines were in stock increased at regional level and dropped at district level. Conversely, stock turnover dropped at regional level and increased at district level. Both of these trends show improvements in vaccine stock flows at district level but not at regional level. That said, the regional level was the main level impacted by the national stockout of vaccines in 2012 and suffered from not being able to manage its stocks effectively. Given that there were enough vaccines in the system at lower levels of the supply chain, the delivery-based distribution system ensured that vaccines were supplied on time subregionally.

3.6. Acceptability and feasibility

An assessment[4] of the acceptability and feasibility of the first demonstration project was conducted to explore the perceptions of stakeholders engaged in its development and implementation. The assessment took place from October to November 2012 in Tunis, Kasserine, and regional posts and used qualitative methods, including focus groups and interviews. For more

[4] This assessment was deemed "non-research" in accordance with PATH's Research Determination Committee policies.

information about the methodology, please see Appendix A. The findings presented in this section reflect opinions gathered during 15 semi-directed interviews with managers/ decision-makers (7) and implementers/executors (8).

3.6.1. Factors of acceptability

Respondents were asked whether the intervention for the first demonstration project was appropriate and acceptable. Responses for appropriateness were simply phrased appropriate or inappropriate, whereas responses for acceptability were based on a five-point scale: very acceptable, acceptable, undecided, unacceptable, or very unacceptable. Most respondents found the intervention appropriate (13/15) and acceptable (10/15) or very acceptable (3/15). Two respondents (both at the managerial level) considered the intervention unacceptable and inappropriate.

Respondents indicated that the intervention improved the quality of the immunization program and increased efficiency. Although they reported a workload increase associated with the intervention, the change was not regarded as unwelcome or unacceptable.

Respondents indicated that their perceptions changed over time as the intervention was implemented. One respondent noted:

> *At the beginning, the project was completely unacceptable. I even considered it a waste of time. We already had vaccine coverage between 90 percent and 95 percent, so I was wondering what this project would bring to us. When we saw the details, such as rigorous management, correct stock estimate, prevention of stock shortage, my vision changed.*

Another respondent said he found the intervention acceptable because of the effects on stock management, vaccine transport, and stock wastage.

> *Before, we were not sure of the correct storage of vaccines, but now there is a good control of vaccines from the economic point of view and also for transport. In addition, there is good management of orders and stocks of vaccines, and therefore less waste. All these are advantages.*

When asked whether the intervention should continue, 13 of 15 respondents replied positively. Nine respondents felt the intervention should continue permanently.[5]

3.6.2. Factors of unacceptability

Although most participants found the intervention acceptable, they still identified factors of unacceptability. These included challenges in the collaboration between the DSSB and PCT, the limited intervention area, and the tenuous future of the intervention without the support of Optimize. The challenges in the collaboration included communication issues between the DSSB

[5] Three respondents thought the intervention should be continued for five to ten years, one thought it should be continued less than five years, and two thought it needed more evaluation before deciding how long it should be continued.

and PCT, with Optimize serving as a go-between. For one respondent, continuing the intervention will depend on improving collaboration and other factors:

> *The project offers solutions for the future. For the future, the project may be valid, but it must first be a prerequisite that you must first solve supply problems, generalize the computerization system and make it functional, and improve communication between the PCT and the DSSB.*

3.6.3. Factors of feasibility

Most respondents (12/15) felt the intervention was feasible, and one found it very feasible.[6] Factors related to the feasibility of the intervention included the availability of equipment needed for integration (such as cold rooms and refrigerated trucks). Additional factors of feasibility included the support of the Optimize team and the willingness of the DSSB and PCT to participate in this intervention. According to one regional-level respondent, the perception of feasibility changed after initial challenges were overcome:

> *The willingness already exists at the PCT to integrate [the supply chain], and there is a real interest in public health. Feasibility was not easy at first. We had to convince all stakeholders that the objective is to move forward and improve things. It was hard to get to this stage of the project. There were barriers and blocking elements due to changes in different directions.*

3.6.4. Factors of unfeasibility

The planned discontinuation of support from Optimize was seen as a factor that would make the intervention unfeasible. Respondents also noted other factors, such as continuing issues with the collaboration between the DSSB and the PCT, staff turnover, and the need to train new staff on the system. The lack of long-term support from Optimize caused one respondent to say:

> *If the project stops, I can't continue to manage vaccines properly. I am saying the truth.*

3.7. Cost

Approximately $165,000 was spent in implementing the demonstration. About half of the direct expenditures were to construct a new cold room for the PCT regional store in Sousse. Purchasing two refrigerated vehicles accounted for 46 percent of the costs. The remaining spending was related to developing the memorandum of understanding (MOU) and SOPs for the demonstration and providing training related to temperature monitoring and vaccine management. The main source of funding was project Optimize, although 7 percent of overall expenditures were financed by the PCT. Table 16 presents details on the direct costs of the demonstration project.

[6] One respondent was undecided, and one found the intervention unfeasible.

Table 16. Costs of the demonstration project by component and funding source[a]

Category	Cost component	Expenditures ($)	(%)	Funding source
Cold chain		**$79,882**	**49%**	
	Cold room	$71,500	44%	Optimize
	Freezing room	$3,192	2%	Optimize
	Chest freezer	$455	< 1%	Optimize
	Cold room installation fees	$4,680	3%	Optimize
	Cold room clothes (jackets)	$55	< 1%	Optimize
Vehicles		**$76,150**	**46%**	
	Refrigerated truck (Iveco type 35C15H + Thermo King V200)	$39,734	24%	Optimize
	Refrigerated van (Mitsubishi type L200 + ColdTeq)	$24,308	15%	Optimize
	Vehicle taxes (duty), registration and insurance	$11,441	7%	PCT
	GPS tracking system for both vehicles	$668	< 1%	Optimize
Activities		**$8,217**	**5%**	
	Development of SOPs (including consultants and review meetings)	$6,637	4%	Optimize
	Training activities (including on vaccine management)	$1,580	1%	Optimize
Total		**$164,249**	**100%**	

Abbreviations: GPS = global positioning system; PCT = Central Pharmacy of Tunisia; SOP = standard operating procedure.

a. Indirect costs incurred by the PCT for staff time, salaries, and fuel costs for vehicles are excluded.

3.8. Challenges encountered

3.8.1. Delays in agreeing on details of the demonstration

Although the broad strokes of the demonstration project were defined in the overarching project proposal that was signed on January 22, 2010, by the Minster of Health, the detail and scope had

to be agreed on by both parties. Throughout 2010, the Optimize team and local stakeholders conducted intense discussions and negotiations on implementation details. Key challenges that arose prior to project implementation are outlined below.

Delays in getting both sides to agree on the specifics of the demonstration led the international Optimize team to consider aborting their efforts. These delays were compounded by the Arab Spring events of January 2011 and related fears and risks of project setbacks even if the demonstration were to begin. In February 2011, Optimize staff organized a visit to Tunisia to make a decision with local stakeholders on whether to proceed. The outcome of this meeting was an agreement to halt the demonstration if certain deliverables (the MOU and SOPs) were not achieved by key dates. Although the schedule did slip, the eagerness, motivation, and willingness of local stakeholders to make it work persuaded the team to proceed with the demonstration.

Another delay occurred as a result of incorrect installation of cold chain equipment at the PCT inter-regional store in Sousse. Although the demonstration was launched on December 7, 2011, to formally begin in January 2012, the installed cold room was not initially keeping temperatures in the recommended ranges. The DSSB expressed legitimate concerns about the reliability of the cold room installations at the store in Sousse and asked for proof of temperature stability in the cold room over one month before beginning the demonstration. After several setbacks and visits by a technician, the demonstration started on April 19, 2012.

3.8.2. Obstacles to efficient vaccine distribution

For a variety of reasons related to procurements and delays in vaccine lot release, Tunisia experienced national-level vaccine stockouts over the course of 2012 for polio, measles, and pentavalent vaccine (these were the three tracer vaccines used by Optimize as part of its monitoring framework).

Compounding the issue of vaccine stockouts were delays related to the laboratory testing, quality control, and vaccine lot release processes required by ANCSEP. The regulatory system in Tunisia is cumbersome, and it can take several months between the time vaccines arrive in Tunisia and when batches are released. The delay reduces the vaccines' validity before expiry, and some batches were released with substantial heat exposure, as reflected in vaccine vial monitor (VVM) status (

Table 17).

Table 17. Shortest validity before expiry and VVM status of three tracer vaccines, 2012

	Shortest validity of vaccine batch released by ANCSEP	Number of batches released by ANCSEP with VVM at Stage 1 and Stage 2 status	
Vaccine	**Months before expiry**	**VVM status Stage 1**	**VVM status Stage 2**
Pentavalent	10	2	2
Polio	3	1	3
Measles	5	0	4

Abbreviations: ANCSEP: National Agency for the Sanitary and Environmental Control of Products; VVM = vaccine vial monitor.

3.8.3. Hybrid systems implemented

Implementation of the demonstration was hindered by ongoing fears at the DSSB of running out of stock of certain vaccines (see section 3.8.1), as well as a reduced time frame to use released vaccines (see section 3.8.2). Nevertheless, there was enough stock subnationally to ensure uninterrupted vaccination services. Because of these issues, the new supply network designed for the demonstration was never fully implemented. Instead, two hybrid systems emerged. The impact of these systems is described in section 3.3.

3.9. Lessons learned

The main lessons learned from this project relate to process implementation. Any intervention that requires fundamental change in the system and in roles and responsibilities of partners and stakeholders will likely be challenging to initiate and take a long time to implement. It took nearly two years for the DSSB and the PCT to agree on broad principles for the streamlining and integration demonstration and the rules of engagement. This required intense meetings and negotiations to align stakeholders' understandings and objectives. Actual operationalization of the project was relatively easy.

Key actions for making progress included the following:

- Conducting baseline assessments to gather evidence-based information on the strengths and weakness of the vaccine supply chain system. The EVM assessment was extremely useful to stimulate discussion on the need for system changes.
- Getting an agreement signed by major stakeholders to provide the glue for collaboration and broad rules for engagement. This was done through a formal MOU between the director of the DSSB, the CEO of the PCT, and WHO.
- Developing a comprehensive set of SOPs that articulates each process and task and specific roles, responsibilities, and accountabilities.
- Establishing the right process for review, validation, and formal endorsement of the SOPs as a key operational document for the MOU.

- Establishing the right process to document decisions being made and keeping track of issues and concerns to address.

New approaches to explore for future projects include the following:

- Conducting more extensive baseline assessments. The EVM assessment was extremely useful but provided an insufficient diagnosis for discussing system changes such as streamlining and integration.
- Conducting a stakeholder mapping exercise before beginning discussions to identify and understand key positions, concerns, and tensions. This mapping should be done at all levels of concern (national and subnational).
- Engaging advocacy and communications expertise from the outset to develop materials to advocate for the ideas being proposed and to communicate clearly about the work.

Overall, a general lesson is that planning for work of this nature should allow a significant amount of time for up-front activities to lay the groundwork before actual assessment can begin.

3.10. Scaling up

The future of this demonstration is uncertain, as are plans for scaling up this effort.

Positive findings from the acceptability and feasibility assessment provide support for extending the work. The majority of people interviewed said the project was relevant for Tunisia and found the system change acceptable or very acceptable. Interviewees said acceptability was good because of perceptions that the project would strengthen temperature control during vaccine storage and transport and improve and streamline planning. The same proportion of respondents felt that the intervention was feasible despite some increases in workload for staff.

Overall, almost everyone interviewed said the intervention should continue and even be expanded based on the belief that the new system design improves the vaccine supply chain, increases efficiency, and lowers overall costs to the health system. A quote from a regional immunization manager summarizes the overall sense that this work should continue: “This intervention should be continued on a permanent basis because this procedure has many advantages. The work has become more efficient, with more rigorous inventory management and control of the cold chain as well as modernization of the vaccination program.”

Unfortunately, the delays encountered in beginning the demonstration combined with the overall context of national vaccine shortages meant that several key aspects of the demonstration design were not executed and fully tested. Also, the hybrid systems that were implemented actually made the supply chain more cumbersome. Discussions with national stakeholders indicate that more implementation time and additional monitoring and evaluation are required before a decision can be made about scaling up the project.

In principle, most national and subnational stakeholders have bought into the benefits of the new system and its relevance for the future. In addition, the PCT is willing to scale up the system to

other inter-regional stores provided the DSSB is also willing to scale up the system. The bottlenecks and challenges include:

- Resolving upstream vaccine procurement challenges. No matter what supply system design is implemented in Tunisia, the system will not perform well if procurement is unable to safeguard enough national stocks of vaccines and timely release from ANCSEP.
- Strengthening trust between the DSSB and the PCT for improved collaboration. Mistrust between these entities has plagued the intervention. In some respects, the intervention worked because the Optimize project manager in Tunisia bridged communication gaps.

The demonstration will continue in the pilot areas until the second quarter of 2013 before government authorities decide whether to discontinue the demonstration or scale it up.

3.11. Conclusion

This demonstration experienced serious challenges in trying to make major system changes during the Arab Spring in Tunisia, when many elements of public services were in a state of flux. It is commendable that local partners and stakeholders continued to be engaged, committed, and willing to give the experiment a try despite a very difficult political climate.

On the concept of streamlining and integration, the team made small steps toward a big idea and gained important insights for future efforts. Although we can conceptualize the benefits of streamlining and integration in Tunisia (and some benefits were shown), it is too soon to evaluate the full impact of the demonstration.

The future of this work is Tunisia is uncertain. Any continuation will hinge on the commitment of the DSSB and PCT to make it work and to be convinced it is the right way forward.

From the perspective of project Optimize, the idea continues to have merit even though we were unable to fully show a positive impact. We believe the new system proposed has the best potential for meeting future needs, although this will require a major overhaul of the cold chain infrastructure, which will be costly.

The pressure on the system that will come from introducing more vaccines will force Tunisia to make major changes in the vaccine supply system. It is no longer a matter of “if” but rather “when” these changes will occur.

4. NET-ZERO ENERGY SUPPLY CHAIN

4.1. Goal

The goal of the project was to demonstrate at regional, district, and health center levels an environmentally friendly vaccine distribution system that met three objectives:

1. Net-zero energy—offsetting the energy consumed with solar energy produced by photovoltaic panels.
2. Preventing vaccine freezing—preventing the accidental freezing of vaccines during transport.
3. Temperature monitoring—ensuring that required temperatures for vaccine storage are maintained at all times.

4.2. Rationale

4.2.1. Net-zero energy

The vaccine supply chain depends on energy to support its transport, refrigerated storage, air-conditioning, heating, lighting, and information system needs. Like other countries, Tunisia depends on nonrenewable energy sources that are increasingly costly and environmentally polluting. Recognizing this challenge, the Tunisian government is investigating ways to reduce energy consumption, increase the proportion of energy obtained from renewable sources, and thereby reduce carbon emissions.

Net-zero energy, in the context of the vaccine supply chain, describes a system that offsets the nonrenewable energy consumed by transporting and storing vaccines and medicines against the production of renewable solar electricity. This balance of grid and solar electricity eliminates the electricity bill for transport and storage. The result is a net saving that is used to amortize the cost of solar electricity generation over the first few years of the life of the system. In addition, the level of energy consumption is minimized and the carbon footprint of the supply chain is substantially reduced.

A net-zero energy vaccine supply chain can reduce energy consumption, eliminate energy costs (once amortization is complete), and minimize environmental pollution.

4.2.2. Preventing freezing during transport

Many vaccines are at a higher risk of being damaged by freezing than by heat exposure during transport, according to reports on the incidence of freezing in vaccine distribution systems in a

number of countries.[7] Freezing is often caused by deep-frozen icepacks packed in close proximity to vaccines in cold boxes.

Before the start of the demonstration project, vaccines in the Kasserine region were transported in plastic polyvinylchloride (PVC) "picnic" boxes purchased from Tunisia's leisure market. These boxes were used in a variety of ways:

- Brought to the supplying store already loaded with prefrozen icepacks.
- Exchanged at the supplying store for a box loaded with icepacks to collect vaccines.
- Loaded with icepacks and vaccines by supplying store and delivered.

The standard WHO procedure of preconditioning the icepacks by removing them from the freezer and allowing them to warm up to 0°C should have been practiced. Monitoring data from 2011 suggest that compliance with this procedure was inadequate.

4.2.3. Temperature monitoring

Like many countries, Tunisia depends on locally assembled refrigeration equipment for the storage and transport of vaccines. These domestic and commercial appliances are designed for food conservation, however, and do not perform as consistently as equipment manufactured to meet WHO norms for vaccine storage. Fluctuations in temperature within these appliances result in loss of potency in vaccine and, subsequently, vaccine that fails to protect children.[8]

Most refrigerators used for vaccine storage, as well as carriers and boxes used to transport vaccine, are domestic products available at low prices in Tunisia. Previously, the extent of problems associated with these products was unknown because temperatures were not systematically monitored or analyzed. Baseline studies carried out by project Optimize in 2010 and the systematic logging of temperatures since January 2011 revealed a high rate of cold chain failures due to faulty equipment or improper practices. These failures not only result in unprotected children but also waste resources. By 2020, the average health center refrigerator will store about $7,500 worth of vaccine, up fivefold from today's value.

WHO publishes norms and performance specifications[9] for refrigerators suitable for vaccine storage, as well as a catalog of equipment that meets these specifications. Almost all of the equipment listed is specially designed or significantly modified for vaccine storage. None of these models is manufactured in Tunisia. Eventually, Tunisia will need to address its equipment problems, either through appropriate modification of locally assembled equipment or international procurement. In the absence of high-quality, purpose-designed refrigeration equipment, vaccine cold chain failures can be reduced by improving systematic temperature

[7] Nelson C. *Evidence of Vaccine Freezing in the Cold Chain: Literature Review*. Seattle: PATH; March 2003.
[8] McColloster PJ. US vaccine refrigeration guidelines: loose links in the cold chain. *Human Vaccines*. 2011;7(5):574–575. McColloster P, Vallbona C. Graphic-output temperature data loggers for monitoring vaccine refrigeration: implications for pertussis. *American Journal of Public Health*. 2011;101(1):46–47.
[9] WHO Performance, Quality and Safety (PQS) standards: Prequalified devices and equipment. Available at: http://apps.who.int/immunization_standards/vaccine_quality/pqs_catalogue/categorylist.aspx?cat_type=device.

monitoring in health facilities, rigorous vaccine handling procedures, and performance evaluation.

4.3. System overview

The demonstration project was implemented in four demonstration sites (the Kasserine regional store and three districts in the region) and consisted of three interconnected interventions:

- Net-zero energy
- Preventing freezing during transport
- Temperature monitoring

4.3.1. Net-zero energy

The net-zero energy system was powered by photovoltaic panels that generate electricity from solar radiation during the day and the electrical grid for electricity used during the night. Over the year, the difference between the solar electricity generated and the electricity consumed during the storage and transport of vaccines and medicines was measured. For the net-zero energy system to be successful, the difference should be zero or positive. If positive, the surplus renewable energy is credited to the Tunisian Company of Electricity and Gas. If negative, the electricity bill is paid by the Tunisian Ministry of Health.

To achieve net-zero energy most effectively, power consumption must be minimized by using more economical technologies (such as electric vehicles) and by increasing the passive thermal efficiency of buildings and transport containers. At the beginning of the demonstration project, Optimize conducted a baseline energy audit for all selected health facilities and stores. This determined the energy requirements that would inform the design of the net-zero energy system.

The net-zero energy system was designed to provide the energy required to store and transport vaccines and medicines. This was accomplished as follows:

1. Conducting an analysis of the baseline energy burden. On-site energy consumption was audited, energy-efficient modifications were identified, and renewable energy potential was assessed.
2. Reducing energy consumption. Efficiency measures were introduced at each site to reduce the energy needed to run the supply chain system (refer to Table 18 for a full list).
3. Generating solar electricity to offset the energy consumption of the distribution system. Photovoltaic panels were installed on the rooftops of regional stores, district stores, and health centers and used to provide electricity. Surplus production from the solar panels was fed into the electrical grid and sold to the national electricity supplier.
4. Replacing the diesel-powered, four-wheel-drive vehicles used to deliver vaccines and medicines with electric vehicles.

To evaluate the project, energy consumption at each electrical outlet and solar electricity production at each solar module array was monitored. Solar radiation and ambient temperatures

were also recorded at each site. The data were periodically and automatically uploaded to a web-based monitoring system to enable site performance data analysis in real time.

Table 18 lists the interventions that were made to reduce energy consumption.

Table 18. Interventions conducted by Optimize to reduce energy consumption

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

Abbreviations: LED = light-emitting diode.

Two additional categories of equipment—air-conditioning and space heating—were included in energy consumption calculations, but were not changed between the baseline and intervention stages.

Using electric vehicles to deliver vaccines

Electric vehicles were chosen to make the vaccine deliveries. The vehicles were selected for procurement on the basis that they would cost less than conventional vehicles to run (per 100 km) and that their energy consumption would be compensated by solar power, thus reducing carbon emissions. Fiat Micro-vett Fiorino vehicles, supplied by European concessionaires Monaco Newteon, were selected on the basis that their capacity was sufficient to transport:

- A driver, supervisor, and public health nurse
- Vaccine packed in cold boxes sufficient for the supply period
- Temperature-sensitive medicines
- Syringes and other dry supplies

They were also selected on the basis that 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 operating autonomy.

4.3.2. Preventing freezing during transport

Optimize conducted several interventions to help prevent accidental freezing of vaccine. The following systems and technologies were demonstrated:

- Phase-change material (PCM) packs

- Dometic RCW 27 cold boxes with PCM packs
- Temperature monitoring during transport

PCM packs to cool vaccines

The purpose of this intervention was to eliminate the risk of freezing vaccine during transport. PCMs change state from a liquid to a solid and back again at temperatures above zero degrees Celsius. They replace water ice in packs designed to cool vaccines in transport. By switching from water ice packs to packs containing PCMs, the risk of accidental freezing is eliminated (if the PCM conditioning process is respected). When frozen at -20°C in a freezer, water-ice packs are capable of freezing 7 to 10 percent of the vaccine load, unless an elaborate procedure of pre-conditioning is followed. PCM packs, on the other hand, solidify in a refrigerator at positive temperatures and at these temperatures are incapable of freezing vaccine.

Because the Optimize system of vaccine distribution was delivery-based, the supplying stores in all cases took the responsibility to prepare the PCM packs and then to pack and transport the vaccine to the stores designated for each delivery trip. To do so, it was necessary to use dedicated refrigerators for processing the PCM packs and not to store them with vaccines. The reason is that PCM packs solidify at 4°C but to complete the process in a full set of cool packs overnight, the refrigerator has to be set to run at 2°C. At temperatures above 2°C, the packs do solidify, but very slowly.

Dometic RCW 27 cold boxes with PCM packs

Two RCW 27 cold boxes were provided to transport vaccine from the Kasserine regional store to the districts and one RCW 27 cold box was provided to each district store for deliveries to health centers. The Dometic RCW 27 cold box, compared to the long-established RCW 25 model it is based on, is larger (27 liters versus 19 liters) and is cooled by PCM packs in contact with a separator plate. The “cold-life” of the RCW 27 is more than 24 hours at an ambient temperature of 43°C.

Temperature monitoring during transport

Each RCW 27 cold box was equipped with LogTag TRID 30/7 recording devices that were configured to read temperatures at five-minute intervals. The timing of each delivery circuit and each receipt of vaccine by the destination stores was verified and synchronized with LogTag data by manual analysis of satellite tracking (GEOTAB™) devices fitted to each vehicle and by checking the driver’s vehicle logbook. Improved monitoring of temperatures provided information needed to improve temperature control practices.

4.3.3. Temperature monitoring

In the absence of high-quality, purpose-designed refrigeration equipment, Optimize sought to reduce vaccine cold chain failures by improving systematic temperature monitoring in health facilities, rigorous vaccine handling procedures, and performance evaluation.

Optimize began by evaluating the baseline performance of vaccine storage, both in the field and in the laboratory.

- In the field: the team evaluated the Kasserine regional store, four district stores, and 25 health centers within the four districts.
- In the laboratory: the team tested four models of domestic refrigerators commonly used in Tunisia's health system.

Based on this evaluation, Optimize then revised and upgraded various temperature monitoring devices and procedures. The full list of interventions is provided in Table 19.

Table 19. Optimize temperature monitoring interventions

Location	Facility	Temperature monitoring intervention
Sousse	Inter-regional PCT store	Multi-channel, computer-based temperature recording system
Sousse, Monastir, Kairouan, Kasserine	Regional stores	LogTag 30/7 TRED temperature recorders in each refrigerator
Feriana, Foussana, Kasserine city, Hassi El Frid	District stores	LogTag 30/7 TRED temperature recorders in each refrigerator
Feriana, Foussana, Kasserine city, Hassi El Frid	Health centers (10 to 14 in each district)	LogTag 30/7 TRED temperature recorders in each refrigerator

Abbreviation: PCT = Central Pharmacy of Tunisia.

The recording device used throughout the system, known as LogTag, automatically records temperatures at 15-minute intervals, stores 30 days of records for visual review, and keeps a daily record of any alarms (these are visible for the previous 30 days). Alarms are activated by the following two conditions:

- Temperatures less than -0.5°C for more than 60 minutes consecutively.
- Temperatures greater than 8.0°C for more than 10 hours consecutively.

The LogTag can be mounted on the outside of the refrigerator and has a temperature sensor that is situated close to the vaccine load.

According to the SOP[10] that was prepared for the new temperature monitoring system, the LogTag devices are read at least twice a day, once in the morning and once in the evening, similar to the previous practice used for thermometer reading. If visual alarms are displayed, the health worker or storekeeper seeks out the cause, takes corrective action, and completes a line item on the monthly alarm report. Thirty-day recordings are downloaded during monthly visits by the supervisor and sent via email to Tunis, where monthly temperature reports are compiled for each district and the region of Kasserine. The report ranks storage facilities by their performance (green bars indicated temperatures at 2°C to 8°C), lists alarm occurrences, and shows the performance trend over time.

4.4. Implementation

This section describes how the project was implemented. Table 20 describes the project timeline and major milestones.

Table 20. Supply chain integration timeline

Year	Month	Milestone
2010	March	Demonstration sites selected.
	June	Local contractors selected.
	December	Vaccine and pharmaceutical stores consolidated: • Kasserine region: vaccine and pharmaceutical stores already in same building (no action). • Foussana district: vaccine and pharmaceutical stores consolidated in new building. • Feriana district: vaccine store moved into the same building as the pharmaceutical store. • Hassi El Frid: vaccine store moved into new store near hospital pharmacy.
		Baseline assessments conducted (energy audits, laboratory testing of cold chain equipment, research on electric vehicle specifications).
2011	September	Solar panels procured and installed.
		Electric vehicles procured and installed.
		SOPs developed.
		Monitoring systems developed.

[10] *Manuel de Procédures (MdP) pour la Surveillance de la Temperature*, Project Optimize, July 29, 2011.

Year	Month	Milestone
	December	Training in SOPs and monitoring systems conducted.
2012	January	First interim project review.
	June	Second interim project review.
	September	Third interim project review.
2013	March	Final Steering Committee meeting.

Abbreviations: SOP = standard operating procedure.

4.5. Results—Net-zero energy

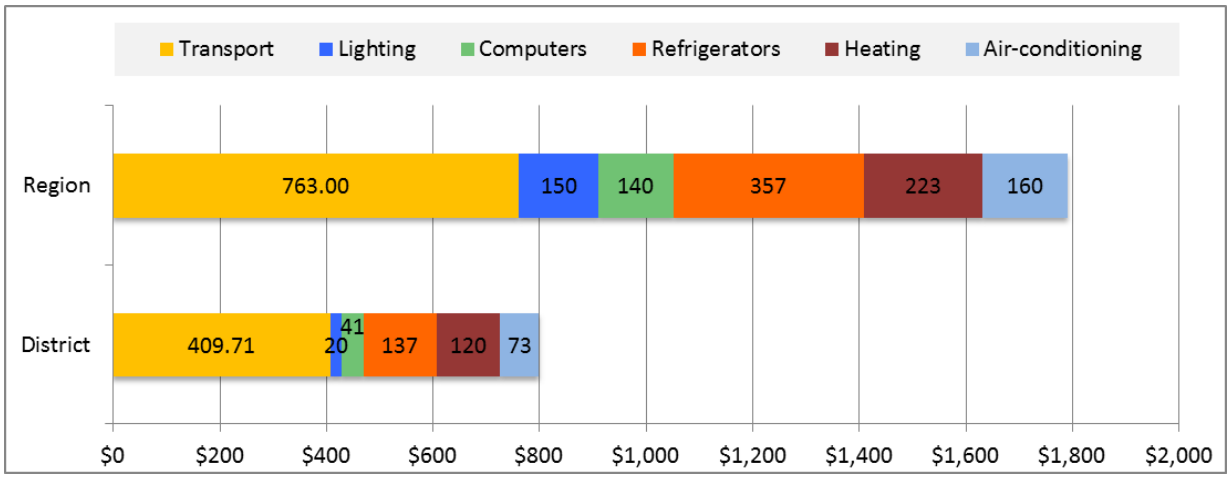
4.5.1. Analysis of the baseline energy burden

In January 2010, the project team audited energy consumption for five categories of equipment:

- Transport: The health facilities used only petrol- and diesel-powered vehicles.
- Lighting: Facilities used fluorescent tubes and incandescent lamps of 23 to 60 watts.
- Computer equipment: Desktop personal computers and printers were used in regional offices and medicine stores.
- Refrigerators: Domestic-type refrigerators were used for vaccine storage; more than 30 percent were estimated to be more than ten years old.
- Heating and air-conditioning: Some stores had heating and/or air-conditioning to provide a degree of comfort in old, poorly insulated buildings with poorly fitting windows and doors.

On the basis of the audit, the team estimated the annual energy cost of operating the distribution system at the regional level (Kasserine regional store) and district level (Foussana district store). The estimated costs were divided into six categories (Figure 15).

Figure 15. Estimated baseline annual energy costs (2010) for storage and transport of vaccines in Kasserine regional store and Foussana district store, in US$

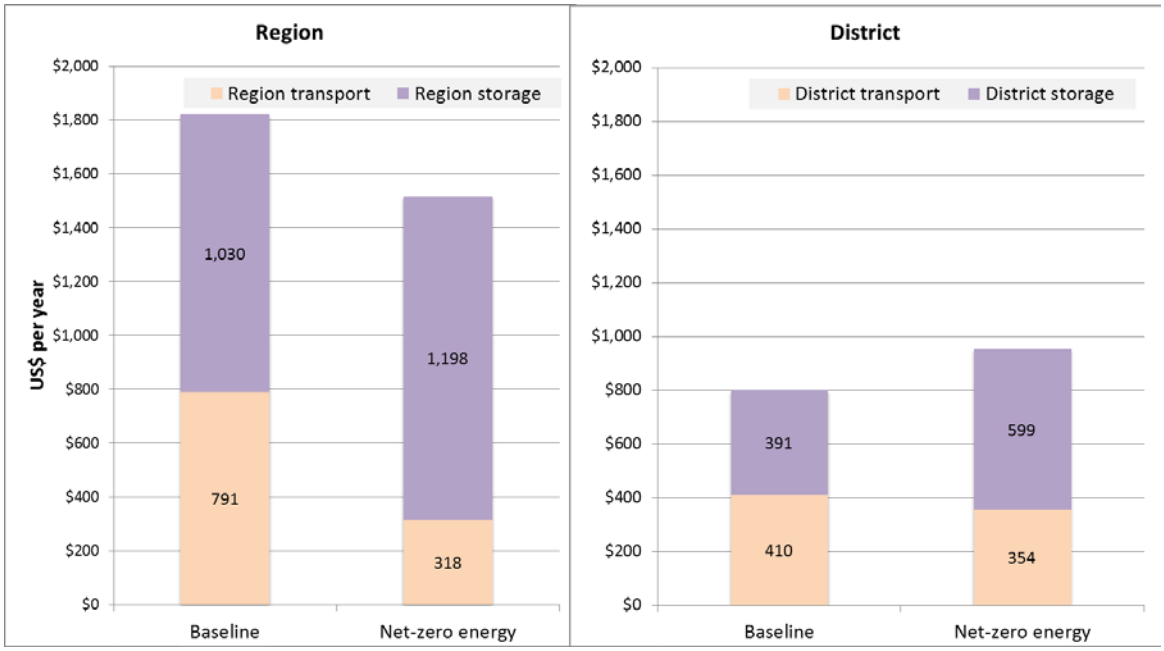


The energy costs to transport vaccines and medicines at the district ($409) and regional ($763) levels are, respectively, 51 percent and 42 percent of total energy costs. Heating, air-conditioning, and refrigeration together are also an important part of the cost (41 percent total on average). The poor environmental performance of the buildings increases these costs.

4.5.2. Impact of reducing energy consumption

Energy consumption was monitored using the same six categories. Figure 16 shows the annual consumption of energy in terms of cost at the Kasserine regional store and the Foussana district store, before and during the Optimize project.

Figure 16. Energy consumption expressed as cost at baseline and during net-zero energy intervention, 2012



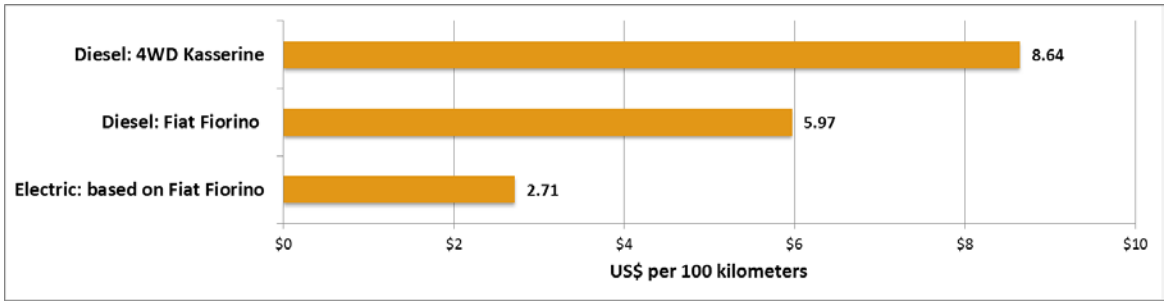
Compared to the baseline, the combined annual energy consumption[11] for storage and transport using the net-zero energy system was reduced by 17 percent at the regional level and by 19 percent at the district level. Significant reductions were also achieved by changing the lighting technology to light-emitting diodes (LEDs). Energy consumption was reduced from 283 kWh per month at the baseline to 93 kWh per month with the net-zero energy system.

However, most of the reduction in consumption was due to the electrification of transport. The energy consumption for storage actually increased in the project period by 53 percent due to the more intensive use of air-conditioning in the new, combined store for vaccines and medicines. 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 $1,821 for the regional store and $800 for the 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.

Because transport accounts for about half of total energy costs, the majority of savings were achieved through the use of electric vehicles, which were substituted for four-wheel-drive diesel and petrol vehicles on almost all delivery circuits for medicine and vaccine distribution. A few health centers were located on roads that were unsuitable for electric vehicles, so four-wheel-drive vehicles were still used in these circumstances. Figure 17, which depicts the energy costs per 100 km for various types of vehicles, shows that electric vehicles have the lowest energy costs by far. The difference would be even greater if costs of engine oil and routine service were included.

[11] Energy consumption is expressed as energy cost to unify the cost of fuel for transport in the baseline with electricity consumption.

Figure 17. Energy cost of electric vehicles in comparison to diesel vehicles



Electric vehicles have a daily autonomy (maximum kilometers per charge) that is limited to the capacity of their battery bank. Normally, the vehicles are recharged from the grid during the night. The region used 32 percent of the electric vehicles' maximum autonomy of 145 km for all purposes. The district vehicles were utilized within a range of 29 to 57 percent of their autonomy of 100 km.

4.5.3. Achieving net-zero energy with solar electricity

Solar photovoltaic panels were installed on the roofs of medicine and vaccine stores at the regional directorate at Kasserine and in three districts. The maximum energy generated by these photovoltaic arrays was 15.84 kW at Kasserine and 7.26 kW at each district, reflecting the different levels of energy consumption at regional and district levels.[12] During October 2012, the National Agency for Energy Conservation (ANME)—the agency responsible for regulating and supervising the Tunisian government grant for renewable energy projects—conducted an internal quality audit of energy production at the four Optimize demonstration sites. Their report has not yet been shared but a verbal statement was made that the ANME judged that the quality of the installation met national standards and the report commended the standard of the installations.

Figure 18 compares the region's energy production to its monthly consumption, while Figure 19 does the same at the district level.

[12] Kasserine has 15.84 kilowatt peak (kWp) of solar (72 modules x 220 watts, wired 12 in series by 6 in parallel input to three of the SMA SMC [Mini Central] 5000 grid tied inverters). The districts all have 7.26 kWp of solar (33 modules x 220 watts, wired 11 in series by 3 in parallel feeding into three of the SMA SB 25000 [Sunny Boy] grid tied inverters).

Figure 18. Monthly energy production and consumption at regional level, 2012

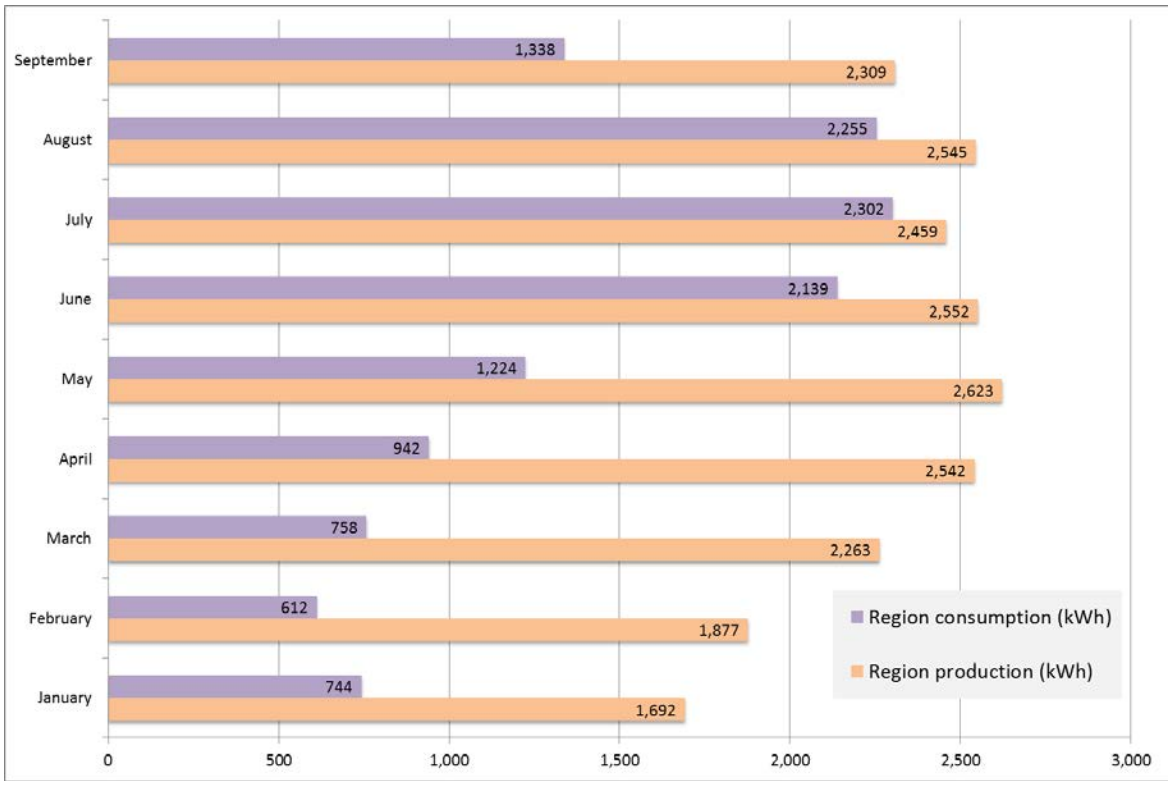
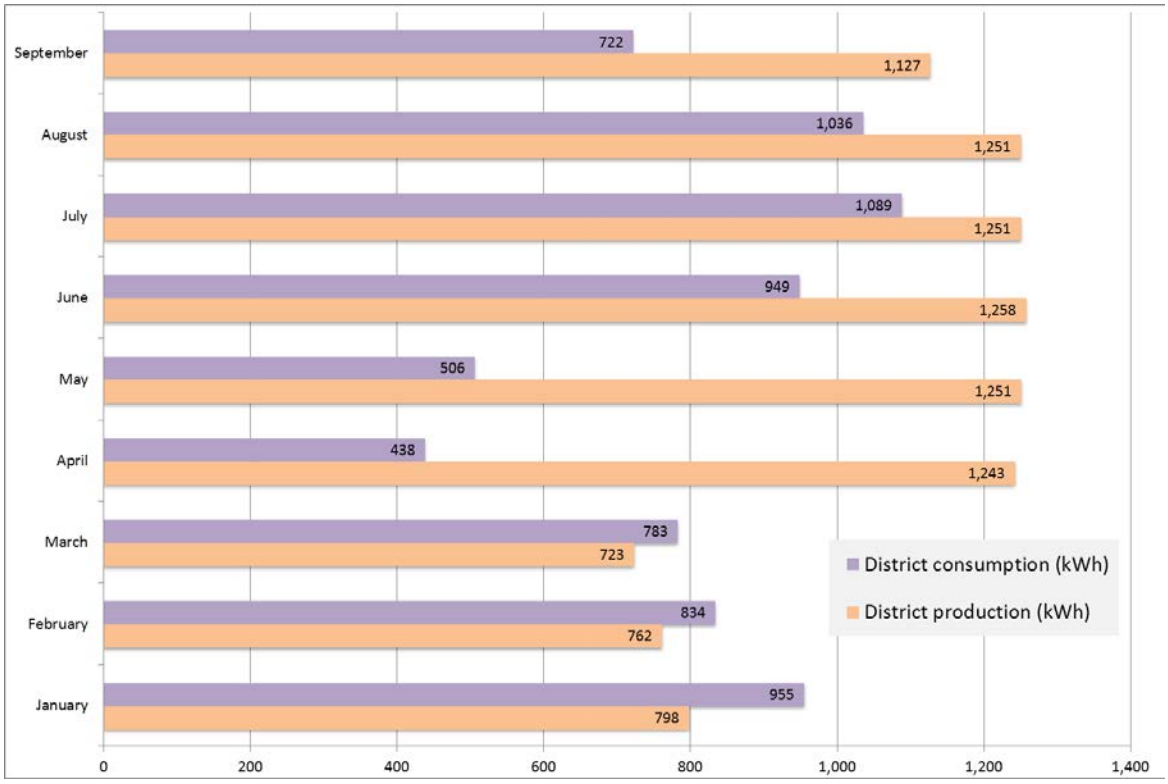


Figure 19 compares energy production at the district level to its monthly energy consumption. At this level, production consistently exceeded consumption, especially from January to May.

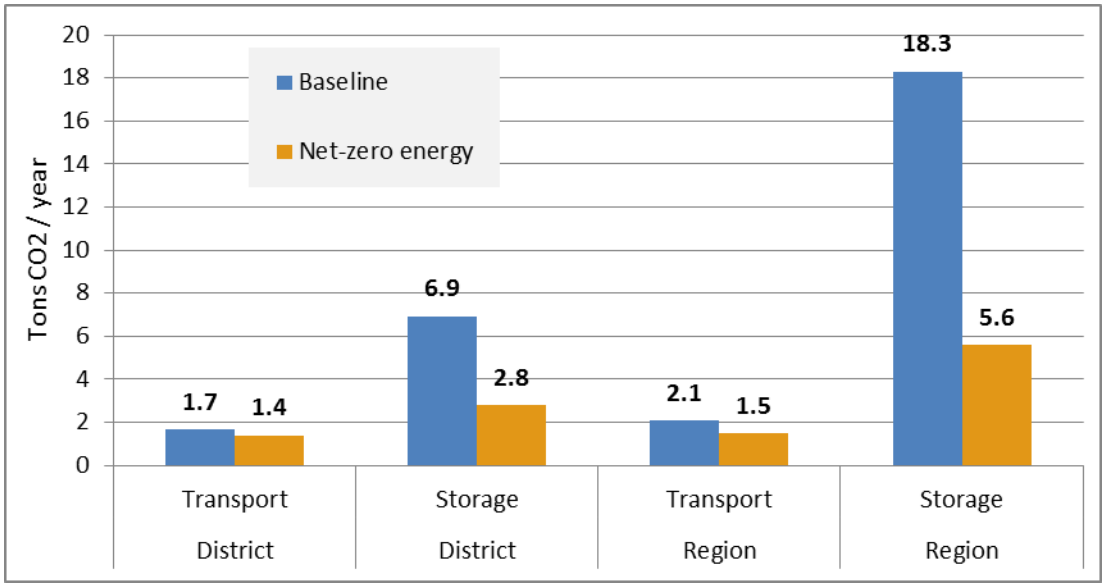
Figure 19. Monthly energy production and consumption at district level, 2012



At the district level, production exceeded consumption for most months, with the exceptions being January through March. The overall energy balance for the project period was positive (10,901.2 kWh). The Optimize demonstration project thus met its goal of achieving net-zero energy—producing more energy than consumed for vaccine storage and transport.

The strategy of the net-zero energy project was to minimize the consumption of electrical energy and fuels, then to generate sufficient renewable energy to offset the residual consumption of electricity, including the energy transformed from fuel to electricity, by the use of electric vehicles. Figure 20 evaluates the effects of these two steps on the release of carbon to the atmosphere.

Figure 20. Impact of intervention on annual release of carbon dioxide to the atmosphere at the regional and district level

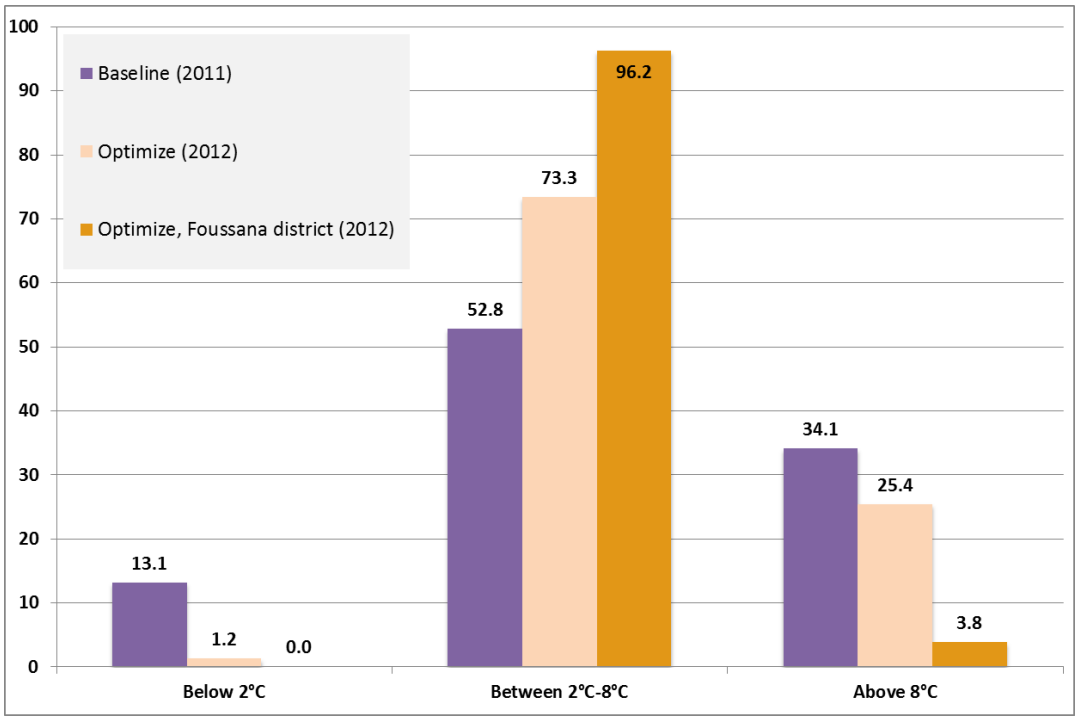


Relative to the baseline, the project reduced emissions for storage (69 percent) and for transport (29 percent) at regional level. At the district level, the project reduced emissions for storage (59.8 percent) and transport (16.7 percent).

4.6. Results—Preventing freezing during transport

Figure 21 shows temperatures recorded during vaccine transport at the baseline and after the intervention.

Figure 21. Percentage of time in different temperature ranges during vaccine transportation from district stores to health centers at baseline (2011[13]) and during demonstration (January to June 2012)



The incidence of exposure to temperatures below 2°C fell significantly (from 13.1 to 1.2 percent) between August 2011 and January to June 2012, when the Optimize system was introduced. However, in spite of this improvement some low temperature exposure remained. This is because incorrect procedures persisted at some stores in January and February 2012, and also because a faulty refrigerator used to freeze the PCMs caused temperatures to reach -20°C.

In the district with the best performance (Foussana), the percentage of transport time at 2°C to 8°C reached almost 100 percent, demonstrating the level of performance that can be achieved.

Despite the new technologies and procedures of this intervention, exposure to temperatures over 8°C persisted in some districts because PCM packs heat up more quickly than icepacks.[14] However, this degree of exposure (between 8°C and 20°C) is not considered a risk to the vaccines because transport duration is so short.

[13] Baseline (2011) vaccine distribution trips monitored at districts: Hassi El Frid (179 readings taken between July–September), Feriana (335 readings taken between September–November), Foussana (26 readings taken in June).
[14] PCM packs have a lower latent-heat capacity than water.

4.7. Results—Temperature monitoring

4.7.1. Evaluating the baseline performance of vaccine storage

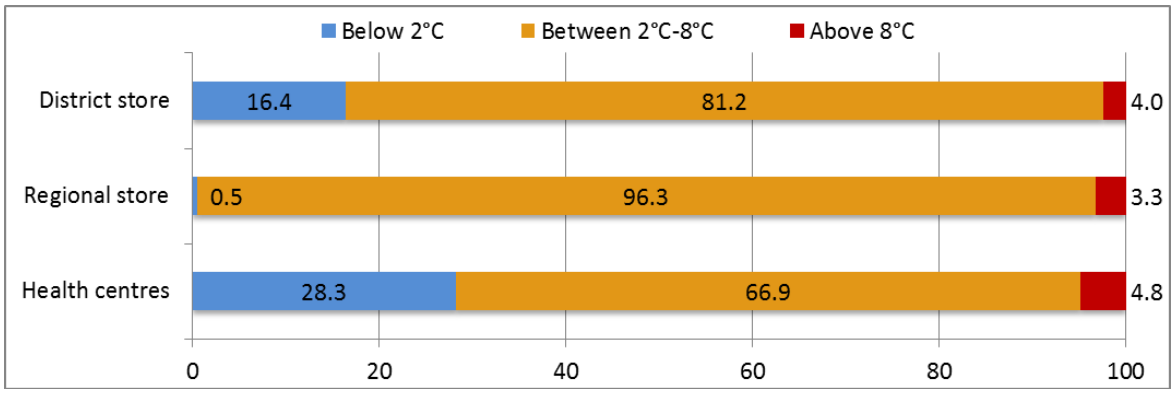
Optimize evaluated the baseline performance of refrigerators used to store vaccines in two ways.

- In the field: from January to February 2012, we evaluated the Kasserine regional store, four district stores, and 25 health centers within the four districts.
- In the laboratory: from October 2011 to February 2012, we tested four models of domestic refrigerators commonly used in Tunisia's health system.[15]

Field evaluation of refrigerator performance

Figure 22 shows the amount of time that vaccine refrigerators in the Kasserine regional store, four district stores, and 25 health centers remained below, within, or above the 2°C to 8°C range. The percentage of time in each temperature range was determined from LogTag temperature readings at 15-minute intervals.

Figure 22. Percentage of time in different temperature ranges of vaccine refrigerators during the baseline assessment, by level (January to February 2012)

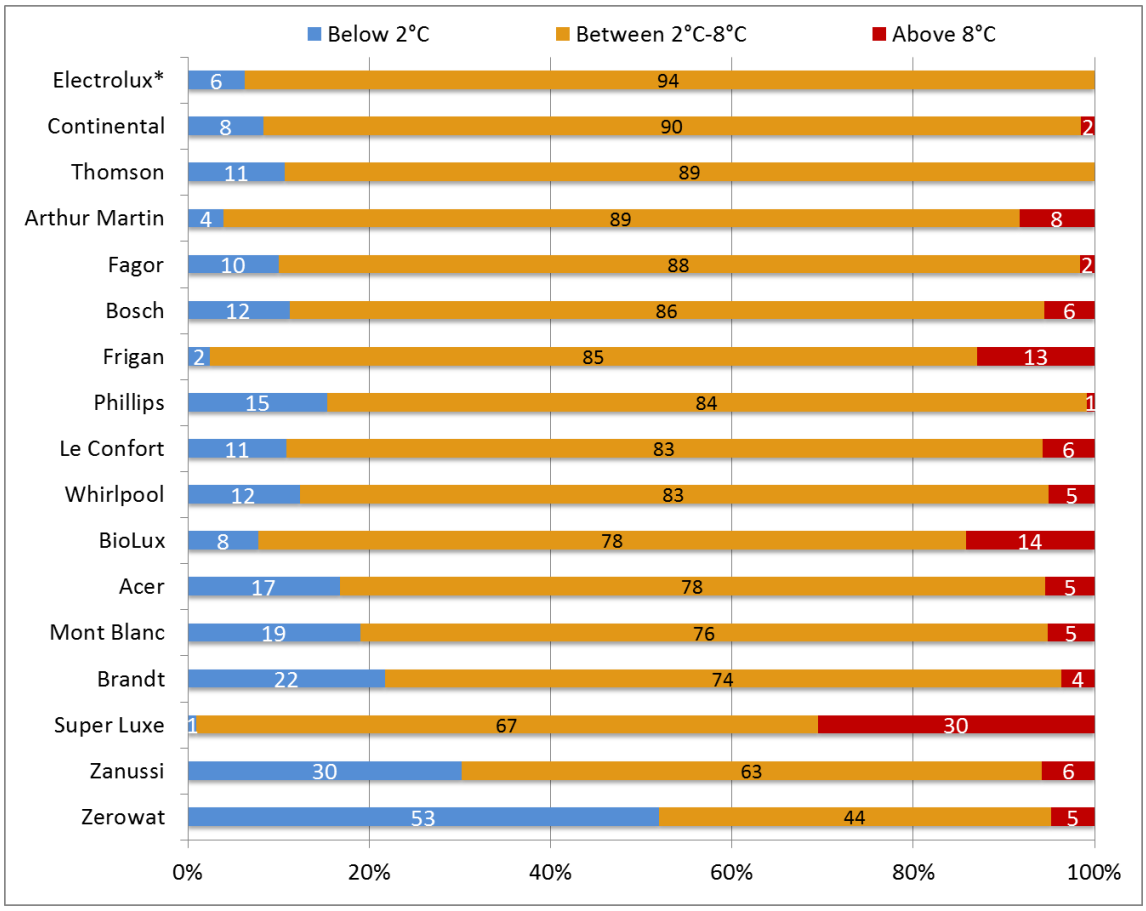


Storage temperatures were found to be frequently out of range, particularly at health center level (33.1 percent). During the baseline assessment, 97 percent of alarm events occurred in health centers (333 cold alarms and 27 hot alarms).

Figure 23 shows the amount of time that vaccine refrigerators at health centers and district stores remained below, within, or above the 2°C to 8°C range, classified by manufacturer.

[15] *Essais de Performances des Refrigerateurs, Congelateurs Combines Selon le Protocole d'Essai de Type Independent – PQS a 32C et a +43C*. Tunis: CETIME Laboratories; 2012.

Figure 23. Percentage of time in different temperature ranges of vaccine refrigerators (January to June 2012), classified by manufacturer

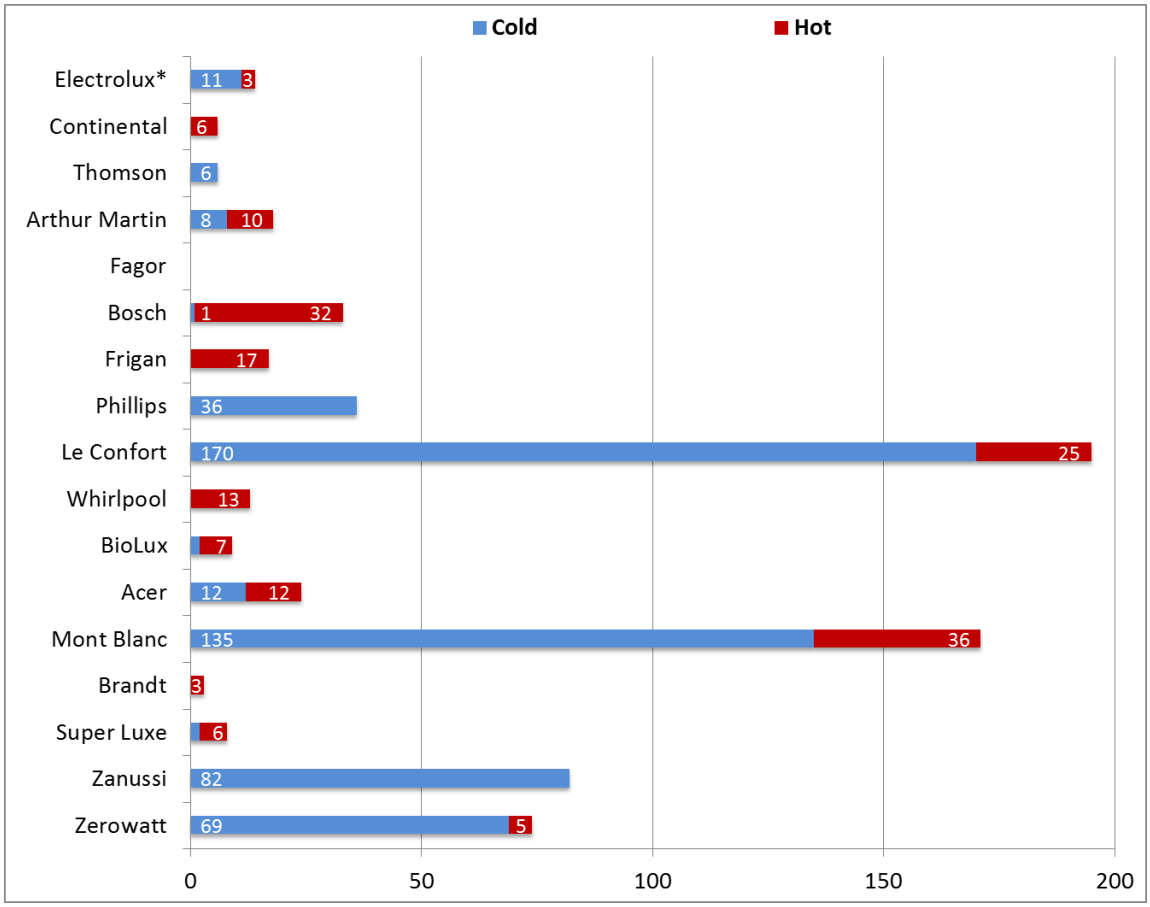


* WHO-prequalified or equivalent refrigerator.

The domestic models, which are generally installed in health centers and district stores, performed the worst. (Note that only the Electrolux models are WHO-prequalified or equivalent specialized models for storing biologicals; all other models are domestic types.)

Incidents of freezing alarms and incorrect storage temperatures were concentrated among seven domestic models (Figure 24).

Figure 24. Number of temperature alarms that occurred during baseline assessment, classified by manufacturer (January to June 2012)



* WHO-prequalified or equivalent refrigerator.

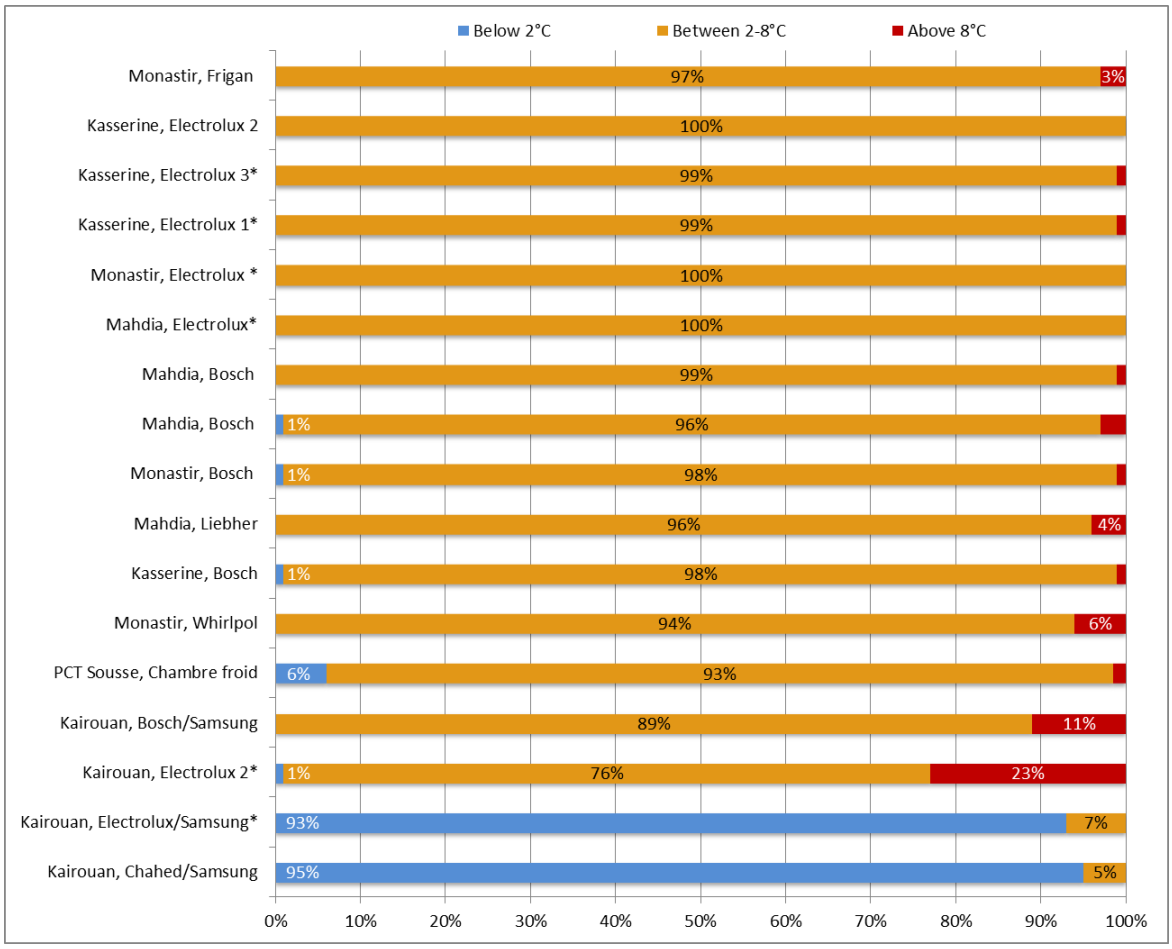
Although failing to adjust the thermostat during hot or cold weather is one cause of poor performance, failures are usually caused by domestic refrigerator performance problems such as:

- When the ambient temperature is high (above 43°C), the compressor of the domestic refrigerator is forced to run continuously, often with inadequate ventilation, and under these conditions has a limited working life.
- Low-quality, mechanical thermostats fail progressively, causing a widening of the operating temperature range until it habitually exceeds the required range.
- Cabinet insulation is insufficient, causing a rapid rise in temperature during power outages.

Examples of these failures, which can be seen throughout the temperature plots produced by the temperature-recording devices, often correlate to the model and age of equipment in the cold chain. But increasingly the newer models are failing more frequently than their older equivalents.

Figure 25 shows the performance of refrigerators in regional stores, which are more likely to have equipment that meets WHO standards. Chahed, Whirlpoool, Liebher, and Bosch are domestic models, and the Electrolux models are pharmaceutical or WHO-prequalified products.

Figure 25. Percentage of time in different temperature ranges of vaccine refrigerators in regional stores (January to June 2012)



* Domestic refrigerator.

Very few alarm events were recorded in regional stores, with one notable exception. Kairouan experienced repeated and lengthy periods of freezing. This is described in more detail in section 4.6.

Laboratory testing of domestic refrigerator models

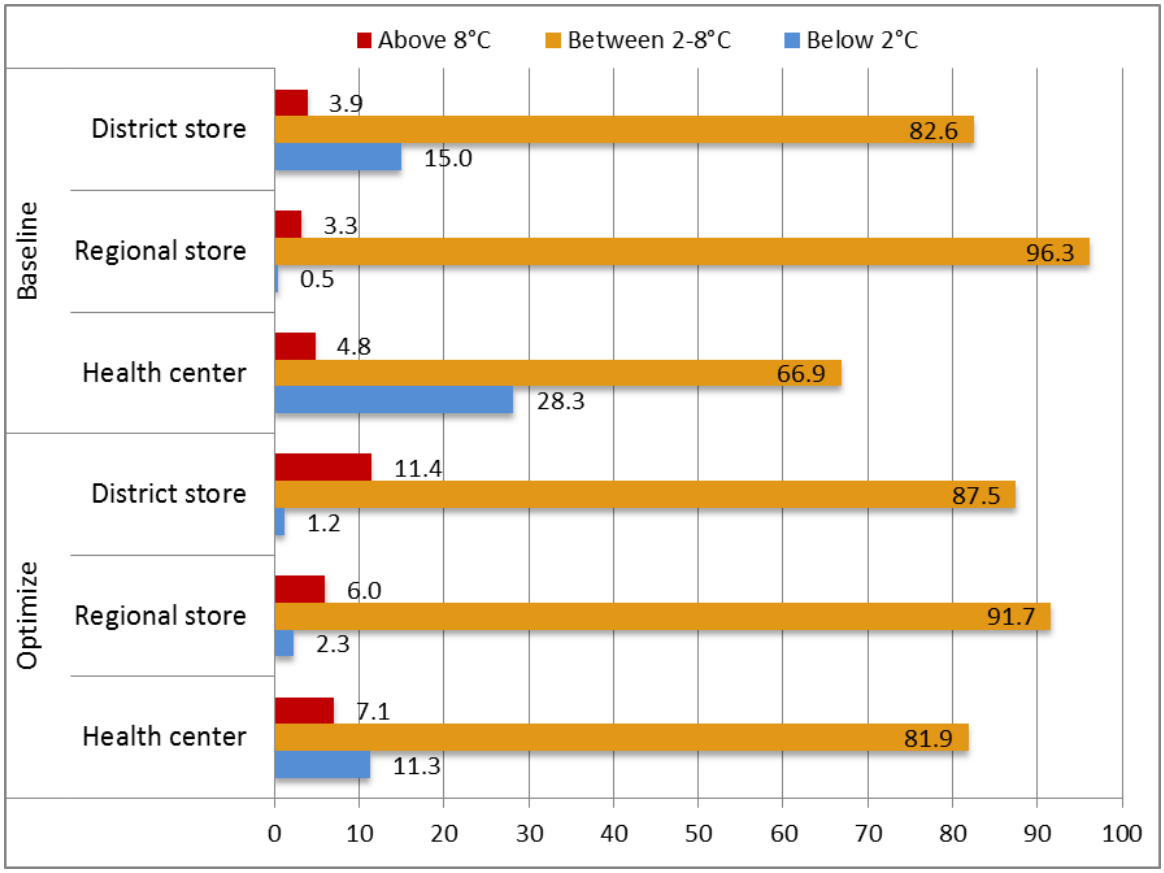
In November 2011, the government selected four models of domestic refrigerators for testing. Project Optimize contracted the Ministry of Industry and Technology (CETIME) laboratory to evaluate the suitability of the models for vaccine storage. CETIME already tests all refrigerator models in Tunisia under a government initiative to raise energy conservation standards by assigning and publishing an energy consumption classification system.

The laboratory reports on the four refrigerators were summarized in an Optimize discussion paper.[16] The testing revealed a number of weaknesses in the performance of all models in ambient test temperatures of 32°C and 43°C. The Bosch KDN36X03/04 performed the best and is closest to meeting WHO requirements. The tests at 43°C included an assessment of a configuration using water-filled or PCM packs around the inner perimeters of the refrigerator to create a thermal barrier around the vaccine load, which was found to help stabilize temperatures and provide a longer hold-over period[17] during electrical outages.

4.7.2. Impact of temperature-monitoring interventions

To assess the effect of temperature-monitoring interventions, the team compared temperature records at the baseline with those after the intervention (Figure 26).

Figure 26. Percentage of time in different temperature ranges of vaccine refrigerators at baseline (January to February 2012) and after intervention (March to October 2012)



[16] PATH, WHO. *Domestic Refrigerators for Vaccine Storage in Tunisia: Conclusion and Recommendations*. Seattle: PATH, WHO; 2012.

[17] According to WHO/PQS, "hold-over" means the time in hours during which all points in the vaccine compartment remain between +2°C and +10°C, at the maximum ambient temperature of the temperature zone for which the appliance is rated, after the fuel supply has been switched off.

After the intervention, the amount of time that refrigerators remained between 2°C to 8°C increased in the district store (by 4.9 percent) and in health centers (by 15 percent). The time that health center refrigerators dropped below 2°C decreased by 17 percent after the intervention.

We can also compare the frequency of alarms at the baseline and after the intervention (Table 21).

Table 21. Frequency of temperature alarms at baseline (January to February 2012) and during intervention (March to October 2012)

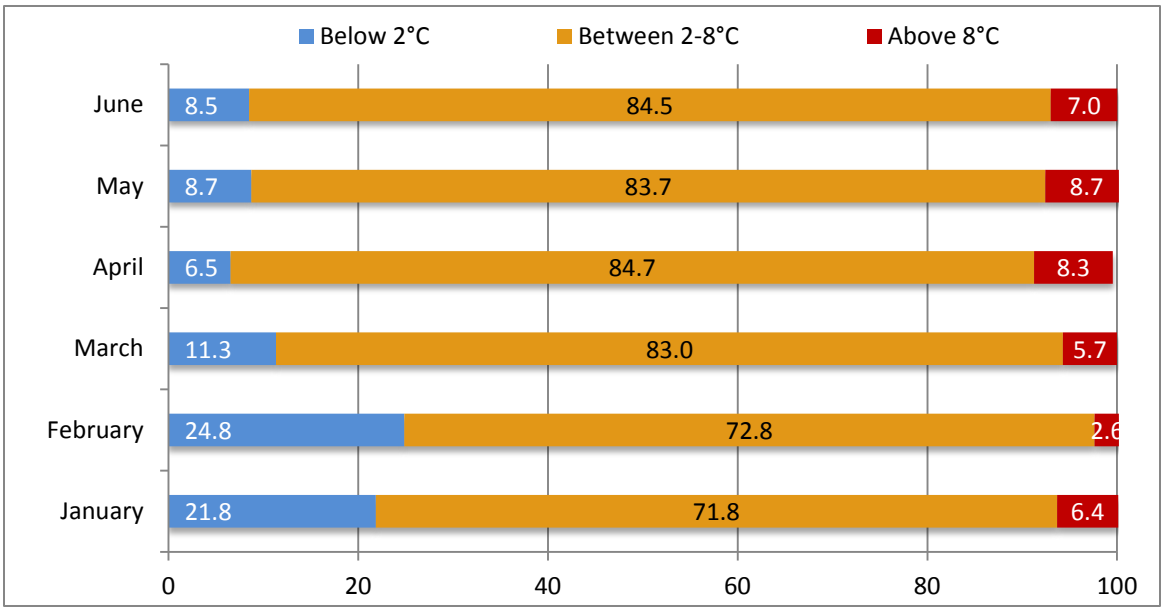
Level	Alarms (cold)		Alarms (hot)	
	Baseline	Optimize	Baseline	Optimize
District stores	2	0	6	20
Regional stores	0	23	2	0
Health centers	333	199	27	79

This shows a decrease of 34 percent in the number of cold alarms in health centers after the intervention. The rise in the number of heat alarms in district stores during the intervention period was due to the persistent and repeated failure (12 alarms) of a Bosch refrigerator in Foussana. This was replaced in April.

The best performing refrigerators were at regional stores that are usually provided with pharmaceutical refrigerators that are performance, quality, and safety (PQS) prequalified or meet WHO guidelines.

Figure 27 shows monthly trends in alarm incidence and the percentage of time within the 2°C to 8°C range at all vaccine stores in Kasserine region.

Figure 27. Monthly trends in the percentage of time in different temperature ranges of vaccine refrigerators at all vaccine stores (January to June 2012)



Temperature monitoring interventions made a strong impact on vaccine handling by recording and drawing attention to anomalies and failures of equipment performance. The first-line response to this new information was by health workers and storekeepers responsible for vaccine storage. The second-line response was by the regional and central DSSB management—for example:

- The reports triggered the purchase of 40 more refrigerators for the region during the first quarter of 2012.[18] Nonetheless, when the refrigerators were equally distributed to each area as decided by the DSSB, they were insufficient to eliminate persistent failures.
- In the coldest month, one half of the freeze alarms were caused by two refrigerators of the same model (Le Confort) and age (1981 to 1985) that were failing. They were subsequently replaced.
- Temperature alarms following power outages (due to a failure of voltage control by the Tunisian Company of Electricity and Gas) resulted in the transfer of vaccines to areas with more reliable electricity.
- "Wandering" temperatures were corrected by adjusting the thermostat, although not always in a timely fashion. (Internal temperatures "wander" and are rarely stable in domestic refrigerators because the mass of vaccines is low, thermal insulation is inadequate, and, unless adjusted, thermostats cannot compensate fully for ambient temperature changes.)

[18] In 2009, there were 2,069 refrigerators in health centers in Tunisia, normally requiring 10 percent replacement per year and therefore equivalent to a requirement of around 200 refrigerators for the country. However, only 110 refrigerators were replaced in 2010, so a procurement of 40 refrigerators for a single region in 2012 is higher than the usual level of replacement.

One common occurrence that did not result in an effective response was sudden rises in storage temperature due to power cuts lasting several hours. An appropriate response to the problem has been documented by the laboratory finding in favor of using water-filled packs to surround the vaccine load in refrigerators that are subject to power cuts. However, the policy has not yet been adopted nationally.

4.8. Acceptability and feasibility

4.8.1. Factors of acceptability

Nine participants (one manager and eight implementers) were interviewed regarding the acceptability and feasibility of the net-zero energy supply chain demonstration. All participants reported that the intervention was appropriate, and all but one felt the intervention was acceptable or very acceptable. One implementer was undecided about the acceptability of the intervention, five respondents (one manager, four implementers) rated the intervention acceptable, and three respondents rated the intervention very acceptable.

Respondents reported positive feedback on various aspects of the intervention, including the PCM packs, the implementation of electric vehicles, the installation of solar panels, the use of LogTag temperature monitoring devices, and the offset of energy consumption. Improved temperature monitoring and improved quality of the immunization system were among the factors of acceptability most often cited by respondents. Respondents reported that the accessibility of the electric vehicles not only increased the efficiency of vaccine delivery but also vaccine safety during the delivery process. A regional-level respondent explained:

> *Vaccines began to arrive in an organized manner, on time, at an appropriate temperature, and with good conditions of transport. The new method is more organized than the old method where the vaccines came to us through any means. Now it is a special car that delivers vaccines. We are more confident now. We are working with a better method.*

An urban nurse described why she feels the intervention is acceptable.

> *The vaccine arrives in good condition in a specific car. Also, with the LogTag, the vaccine is well-guarded. We can know the power cuts. Before, this went unnoticed. Now I can guarantee the vaccine gets to children in good condition. From the regional warehouse to the child, it is monitored and controlled.*

The temperature monitoring using the LogTag device was perceived as a positive aspect that contributed to the project's acceptability. A health center respondent explained why the LogTag device made such a difference in his work:

> *…especially the cold chain with the LogTag, which I find the best thing in the project.…This LogTag records everything. Over time, with changes in temperature, either we vaccinate with an unsafe vaccine or we throw away the vaccine with a huge loss…The recorder enables us continuous monitoring of temperature. We systematically realize electricity breakdowns. Before, you did not realize power cuts and freezing. Especially freezing we could not realize, especially in the winter. Sometimes it can*

> *happen, especially on weekends…and we can notice that only on Monday morning, and we were not sure what to make of the vaccine. Now the nurse knows what he has to do, and we give the child a safe vaccine.*

When asked if the intervention should continue, eight of nine interviewees responded positively. Six thought it should be continued permanently, and two thought it should be continued for five to ten years.

4.8.2. Factors of unacceptability

Unacceptable factors included challenges in using the electric vehicles and issues related to the solar panels. Respondents had many concerns about the use of the electric vehicles, their performance on rough rural roads and in winter conditions, and the ongoing maintenance and cost. Respondents worried about the sustainability of the cost of the vehicles, both in scale-up and in ongoing repairs. Because of vehicle breakdowns, some implementers reported that they went back to using their previous delivery systems, and others had given up on the idea of using electric vehicles altogether. A health unit chief in a rural area said, “Electric cars are not appropriate in our country because we do not have the skills to repair their failures.”

4.8.3. Factors of feasibility

All but one respondent said the interventions were feasible or very feasible, and the remaining respondent was undecided on this issue. The main factors cited regarding feasibility were the supply of necessary equipment, such as the vehicles and the LogTags. Another factor was the motivation and acceptance of the staff involved. One respondent explained:

> *The interest in using new technologies has become palpable and appreciated by staff. They now know that these new technologies have a positive impact on health programs, and the risk that staff do not accept or do not adhere to these technologies is not real. New things motivate staff.*

4.8.4. Factors of unfeasibility

As mentioned previously, respondents had concerns about the cost and ongoing maintenance of new equipment, such as the electric cars and solar panels. Respondents also reported challenges they had experienced with new equipment malfunctioning and difficulties with repairs. In referring to solar panels and electric vehicles, one respondent said, “I think cost hinders feasibility.”

Despite the challenges, the response was positive overall, with respondents reporting high levels of acceptability and feasibility for the interventions.

4.9. Cost

Table 22 lists the various costs associated with the demonstration project.

Table 22. Costs of the demonstration project by component and funding source*

Cost category	Component	Cost ($)	Cost (%)	Funding
Cold Chain		**$28,482**	**4.4%**	
	Refrigerators (for CETIME testing)	$2,142	0.3%	Optimize
	RCW 27 cold boxes	$4,894	0.8%	Optimize
	Engel MT45F-G3DM	$2,498	0.4%	Optimize
	Engel MT80F-U1	$2,700	0.4%	Optimize
	PCM ice packs (4°C and 5°C)	$3,283	0.5%	Optimize
	Transport and customs	$1,043	0.2%	Optimize
	Temperature monitoring system (LogTags)	$4,566	0.7%	Optimize
Vehicles		**$301,678**	**46.8%**	
	Electric vehicles	$258,085	40.0%	Optimize
	Maintenance	$14,235	2.2%	Optimize
	Storage during revolution	$9,287	1.4%	Optimize
	Customs clearance	$2,774	0.4%	Optimize
	Decoration	$1,742	0.3%	Optimize
	Transport to Kasserine	$1,397	0.2%	Optimize
	Insurance, registration, and circulation taxes	$10,242	1.6%	Optimize
	GeoTab	$2,265	0.4%	Optimize
	Spare parts	$1,651	0.3%	Optimize
Building		**$296,621**	**46.0%**	
	Integration of vaccines and drugs stores	$12,025	1.9%	DSSB
	Garage for electric vehicles	$8,775	1.4%	DSSB
	Solar panel (including installation)	$228,090	35.4%	Optimize

Cost category	Component	Cost ($)	Cost (%)	Funding
	Solar panel subsidy (ANME)	$45,618	7.1%	ANME
	Efficient lighting	$2,113	0.3%	Optimize
Activities		**$17,748**	**2.8%**	
	Development of SOPs (including consultants and review meetings)	$0	0.0%	Optimize
	Training activities	$10,459	1.6%	Optimize
	CRT	$7,289	1.1%	Optimize
	CETIME	$9,357	1.4%	Optimize
Total		**$646,530**	**100%**	

Abbreviations: ANME = National Agency for Energy Conservation; CRT = controlled room temperature storage; CETIME = Ministry of Industry and Technology; DSSB = Department of Basic Health Care; PCM = phase-change material; SOP = standard operating procedure.

*Indirect costs incurred by the DSSB for staff time and salaries are not included.

Approximately $646,500 was spent to implement the net-zero energy supply chain system. The bulk of these direct expenditures (46.8 percent) were related to the electric vehicles and their overheads. Procurement and installation of the solar panels in the four sites accounted for 35 percent of costs (excluding the subsidy received from the ANME). The remaining funds were spent on cold chain equipment and temperature monitoring systems (4.4 percent of the costs) and activities related to controlled room temperature storage options development and the laboratory testing of domestic refrigerators (CETIME), as well as on development of standard operating procedures for the demonstration and corresponding training activities. Although Optimize provided the main source of funding, the DSSB covered 3.2 percent of overall expenditures, and ANME covered 7.1 percent.

4.10. Challenges

4.10.1. Delays in implementation

The installation of solar panels took longer than scheduled, and the monitoring system had numerous issues. Although the system was operational by the end of 2011 (almost a year later than planned), systems in some districts that were incompatible with the national electrical grid caused various malfunctions throughout 2012.

Contextual issues also caused delays. The start of the Arab Spring at the end of 2010 meant shipment of the electric vehicles was delayed by a few months. Because Tunisia had never

imported electric vehicles before, the team had to negotiate an entirely new administrative procedure with customs. The vehicles finally were transported to Kasserine in September 2011.

4.10.2. Limited autonomy of electric vehicles

A demonstration of a delivery circuit using the electric vehicle in Kasserine highlighted the vehicles' limited autonomy. Adjustments to the planned delivery circuits were made to account for actual vehicle autonomy and driver behaviors.

4.10.3. Lack of adherence to new supply system

In the first half of 2012, vaccine procurement issues caused intermittent shortages of vaccine in Kasserine and other regions. Consequently, during this period scheduled deliveries of certain vaccines could not be made according to the schedule of the Optimize vaccine delivery system.

4.10.4. Faulty or incorrectly installed equipment

Faulty or incorrectly installed electrical connections caused system overload and power outages. In one district, only two-thirds of solar panels were connected correctly. The other solar panels were not producing electricity, a problem that wasn't discovered for six months (but was corrected by the time the installations were inspected by ANME).

The Sunny Boy web-based monitoring system set up by Solar Electric Supply to display real-time site performance data was misleading. It took six months to resolve metric challenges in analyzing the net-zero energy data from the monitoring system.

Two electric vehicles also required repairs, causing project suspensions at both sites.

4.11. Lessons learned

The main lessons learned from this intervention relate to results rather than process implementation. Most delays were due to exogenous factors (the Arab Spring and related challenges in the country), and there is little we would change about the process.

4.11.1. Net-zero energy

- 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. 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, as well as a reduction in the carbon footprint of the system.

- If amortization of the equipment at today's prices is included over ten years, the value proposition loses its appeal. The amortization of the solar panels offsets any of the 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.

4.11.2. Preventing freezing during transport

- The demonstration highlighted the benefits of having an appropriate cold box for vaccine transport. In the past, cold boxes used to transport vaccines have often been associated with accidental freezing of vaccines, partly due to the low level of compliance with the WHO-recommended procedure of conditioning deep-frozen icepacks and inadequate guidance on the use of chilled water-filled packs to replace icepacks.
- The testing of the passive RCW 27 cold box with PCM packs showed that it is essential to have the appropriate cold chain equipment during transport. Results showed that:
    - The risk of freezing vaccine can be significantly reduced. The design of the RCW 27 with the aluminum separator plate and the PCM icepacks drastically minimized the risks of freezing vaccine compared to the conventional cold box lined with deep-frozen icepacks. The RCW 27 also reduced the exposure of vaccines to heat when compared with domestic picnic boxes.
    - The process of loading the cold boxes with vaccines and temperature-sensitive products is more streamlined with the PCM pack. Health workers can immediately pack the cold box and avoid the WHO-recommended process of conditioning frozen icepacks.
- Despite the potential benefits of PCM packs, there are several caveats and downsides:
    - Although using PCM packs has been shown to reduce the risk of freezing vaccines, they are expensive. The project's delivery system minimized the number of packs required to make distribution trips, reducing this expense.
    - Project staff initially thought that PCMs could be stored in the same refrigerator as vaccines. Unfortunately, it turned out that PCM packs require their own refrigerator to solidify overnight, and placing them in the same refrigerator as vaccines is not recommended. Additionally, if PCM packs are incorrectly placed in a deep freezer, they present the same risk of freezing as ordinary icepacks. Future use of PCMs may thus require a new piece of cold chain equipment.
- Although continuous temperature monitoring for storage proved to be a very powerful managerial tool, both for the health worker and the supervisor, it was problematic to collect and analyze transport data for the following reasons:
    - The logger must be loaded correctly among the vaccines (those with integral sensors should be packed in the center of the vaccine load, surrounded by vaccine if possible and never in contact with the cooling packs), checked at each stage of distribution, started and stopped at the correct time, and downloaded at the end of the trip to ensure that the temperature report is correct.
    - Unless alarms are set on the logger to alert the driver or health workers, the temperature record is not rigorously monitored, and temperature deviations are not seen until after the journey is complete.

- Short journeys (less than 30 minutes) do not allow enough time for the cold box to stabilize following loading, so continuous recording is not worth reporting.

- The lesson learned regarding continuous temperature monitoring during transport is that continuous monitoring with real-time data transfer is clearly justified for central and local monitoring of trips if distances are far enough and the volume of vaccines is great (such as at higher, primary levels of the supply chain). But at lower, service-delivery levels of the system, when distances and amounts of vaccines transported begin to shrink, it is best to use a temperature logger as an appropriately configured alarm device during transport and not to attempt temperature data collection and reporting.

4.11.3. Temperature monitoring

- The project confirmed that use of domestic refrigerators poses a risk to vaccines. The team documented numerous incidents of accidental freezing due to faulty and inadequate domestic refrigerators. These incidents should have been followed by a "shake-test" (according to the SOP), which often results in the disposal of closed vials. Perhaps because of concerns about being reprimanded for a high rate of freezing, health workers often did not report these incidents.

  If there is no option to procure and use refrigeration equipment that has been prequalified by WHO for the storage of vaccines, other options include:

  - Laboratory tests of cold chain equipment used in the field to identify the best-performing domestic refrigerators.[19]
  - Insertion of water-filled packs surrounding the vaccine load inside the refrigerator to provide mass that slows down the rise of internal temperatures during a power cut.
  - Use of models from manufacturers who are prepared to modify equipment for vaccine storage if testing and field experience reveal failures.
  - Continuous temperature monitoring in the field with the appropriate devices, preferably with automated data transmission to facilitate supervision.

- Continuous temperature monitoring with 30-day data loggers proved to be a very powerful managerial tool for domestic refrigerators. It helped staff identify malfunctioning equipment and take corrective measures (either verifying the thermostat setting or replacing the equipment). In Kasserine, the DSSB replaced equipment at its own expense after reviewing the temperature monitoring reports. Specific lessons learned include:

  - The manual collection, transmission, and analysis of temperature data are a complex and cumbersome process to adopt as a routine reporting mechanism.
  - To be feasible, a system for routinely monitoring vaccine storage temperatures needs to automate data transmission, analysis, and reporting.

- Laboratory results showed that there are clear temperature stability benefits from surrounding the vaccine load with water-filled packs. This is consistent with tests

[19] PATH, WHO. *Domestic Refrigerators for Vaccine Storage in Tunisia; Conclusion and Recommendations.* Seattle: PATH, WHO; 2012.

conducted elsewhere and is an accepted practice. Tests also suggested, however, that there is no marginal benefit of using packs filled with PCMs rather than water-filled packs. Further testing of this option may be needed to confirm this finding.

4.12. Scaling up

4.12.1. Net-zero energy

Table 23 shows the project's capital costs and two commercial cost estimates, one for 2012 and one for 2020.[20] Capital costs for the regional store and three districts were for:

- Electric vehicles: Fiat Micro-vett Fiorino (3), including annualized maintenance contract.
- Lighting: 10-watt LED tubes (to replace standard fluorescent tubes of 18 to 20 watts) and 20-watt LED tubes (to replace standard fluorescent tubes of 34 to 40 watts).
- Laptop computers (4).
- Solar photovoltaic arrays and control equipment: 15.84 kilowatt peak (kWp) for Kasserine, 7.26 kWp for districts.

Table 23. Cost of solar intervention at regional and district stores

Cost	Optimize cost 2010	Commercial estimate 2010[a]	Commercial estimate 2020[b]
Solar modules, including installation	$228,090	$87,210	$23,750

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) Reference 14.

As Table 23 shows, intervention costs are expected to fall significantly over the next eight years, although the Optimize cost is particularly high because monitoring instrumentation and maintenance services were included. The solar panel systems cost the project $6.91 per peak watt in 2010; in the same year, the benchmark commercial price was $4.59/WPdc (Watt-Peak Direct Current, a unit of solar electricity production). By the end of 2012, the lowest price was $1.06/WPdc,[21] and it is expected to fall further by 2020. (This reduction is expected to be driven by the rapid expansion of demand coupled with a commensurate increase in production and competition from new Chinese manufacturers.) Small proportional reductions in the cost of lighting and computers are unlikely to change the picture, but due to the prospect of lower cost

[20] Goodrich A, James E, Woodhouse M. *Residential, Commercial, and Utility-Scale Photovoltaic (PV) System Prices in the United States: Current Drivers and Cost-Reduction Opportunities*. US Department of Energy, Office of Energy Efficiency & Renewable Energy, Technical Report, NREL/TP-6A20-53347; February 2012.
[21] Module pricing page. Solarbuzz (solar market research and analysis) website. Available at: www.solarbuzz.com/facts-and-figures/retail-price-environment/module-prices.

batteries and reductions in electric vehicle costs due to market expansion, the transport component could fall by two thirds.

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

Most components of net-zero energy would be practical and economical to fully implement in the future, perhaps after 2020. However, full implementation may take place progressively, in three steps (Table 24).

Table 24. Scaling up net-zero energy

Time frame	Step	Task
Present to 2015	Perform energy audits of stores keeping vaccines and medicines	Implement improvements to building insulation, lighting, refrigeration, and informatics equipment to minimize energy consumption.
		Critically assess the choice of district vehicles and refrigeration equipment to minimize energy consumption.
		Reclassify the procurement class of vaccine refrigerators as medical equipment, subject to prequalification and investigate if the ANCSEP can be made responsible for selection of appropriate models.
		Seek opportunities to integrate the delivery of vaccines and medicines and to establish a standard delivery circuit system to all health centers.
2015 to 2020	Link solar photovoltaic energy production to the grid	Conduct study of requirements and create phased plan.
		Begin with large, primary, high-value vaccine stores at central and regional levels.
		Progressively extend to districts.

Time frame	Step	Task
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 prioritization of requirements.
		Make plan for phased introduction, beginning with small-scale pilot introduction.

Abbreviations: ANCSEP = National Agency for the Sanitary and Environmental Control of Products.

4.12.2. Preventing freezing during transport

Improving the transport of vaccines system-wide would require:

- Ensuring that each vaccine delivery store can dedicate a vehicle to planned delivery trips for vaccines and medicines with supervision.
- Equipping all districts and regional stores with vaccine transport cold boxes, temperature loggers/alarms, a PCM-pack refrigerator, and PCM-filled packs for distribution of vaccine.
- Providing related training and SOPs.

PCM packs pose two challenges that should be addressed if they are to be used more widely. First, although the Dometic model "freezes" at 5°C (other models freeze at other temperatures), freezing the packs overnight required setting the temperature in the refrigerator at 2°C. This required that an additional refrigerator be provided in each store, dedicated to freezing PCM packs. Vaccines could not be stored with PCM packs because they risk exposure to temperatures below 2°C, and because the temperature of vaccine storage (5°C) may be too warm to allow the PCM to "freeze" overnight. The second issue is the high cost of PCM packs ($47 per unit), although the cost is expected to decrease in the future. Early in 2013, WHO will release PQS specifications to guide the prequalification of PCMs.

4.12.3. Temperature monitoring

It is important for the integrity of the Tunisian vaccine cold chain—and the protection of children—for the government to move toward procurement of refrigerators for vaccine storage that perform adequately for the whole health system. This would require the government to:

- Reclassify refrigerators intended for vaccine storage as medical equipment that should meet international or national norms for performance.
- Require that models be prequalified in an independent laboratory, according to international or national norms, before Tunisia procures them.
- Require that health workers follow SOPs for refrigerators, using 30-day temperature recorders that meet WHO norms (E006/TR06.3) to monitor temperatures in all refrigerators used to store vaccines, and provide sufficient training for this purpose.

- Continue and expand the use of 30-day temperature recorders and the completion of low and high temperature alarm reporting. Although it may not be possible yet to transmit temperature data, monthly paper reporting of the number of alarm interventions at each store would be very worthwhile, providing supervisors with a monthly overview of vaccine handling in an area.
- Until higher performance refrigerators can be used in health centers, the Optimize laboratory findings support the use of water-filled packs placed around the vaccine load inside the domestic refrigerators to protect against the failures in electricity supply and extreme variations in outside temperature. This policy requires few additional supplies and can be applied quickly and at scale.

4.13. Conclusion

The capacity of Tunisia's vaccine distribution system and the value of vaccines handled are set to increase up to five-fold by 2020. This, in itself, justifies planning for a high-performance logistics system that is effective, reliable, and highly efficient. In addition, expectations for the timely supply and proper handling of vaccines and medicines are increasing. Finally, integration of supply systems will be needed to minimize the investment in change and future recurrent costs.

The net-zero energy demonstration showed that the quality of vaccine handling in storage and transport can be raised by monitoring temperatures, procuring appropriate cold chain equipment, and establishing a regulated delivery system using electric vehicles. The project has also shown that the energy cost of storage and transport of vaccines and medicines can be entirely offset by generating and crediting electricity to the Tunisian Company of Electricity and Gas by solar electricity production. With these interventions, the supply system can be developed to be more efficient, reliable, and environmentally acceptable, as well as less expensive, in the next five to ten years.

5. COMPUTERIZED LOGISTICS MANAGEMENT INFORMATION SYSTEM

5.1. Goal

The goal of the computerized logistics management information system (LMIS) project was to introduce a system to track and trace vaccines in real time throughout the supply chain. This would help to improve the efficiency of vaccine and stock management and help to mitigate the risk of overstocking, expiry, and vaccine wastage. This work was intended to demonstrate the benefits of transitioning from a paper-based system to a computerized system that links national, regional, and district levels. Such a networked, information-driven supply chain would enable the exchange of real-time data on vaccine forecasting, stock management, and order status, thus helping to ensure the timely delivery of vaccines.

5.2. Rationale

A major challenge in managing a vaccine supply chain is a lack of centralized, timely, and accurate data. Without this information (such as data on doses procured, doses distributed, doses administered, remaining stock, and wastage rates), it is difficult to determine the necessary quantities of vaccines to order or how to manage their distribution. In the absence of reliable information, the supply chain operates on best-guess estimates. The ability to track and trace vaccines throughout an information-driven supply chain mitigates the risks of under-stocking (leading to stockouts and missed opportunities to vaccinate children) or overstocking (leading to wasting vaccines from expiry).

5.3. System overview

Following a review of available information systems solutions and consultations with local stakeholders, the web-based Vaccination Supplies Stock Management (wVSSM) system was selected.

VSSM is an open-source software application developed by the World Health Organization (WHO) to enable immunization program managers and vaccine store staff to manage vaccines and related supplies. It is based on existing WHO and United Nations Children's Fund (UNICEF) policies on vaccine management, with consideration for common field practices in developing countries. Although the focus is on vaccines, the application can be used to manage health supplies, particularly those provided through primary health care services. First deployed in 2006, VSSM is now available in ten languages and used by immunization programs in more than twenty countries.

The web-based version of VSSM, named wVSSM, has all the features of the standalone version. Being web-based, wVSSM is simple to use and easy to access. Inventory data are stored on a central server that can be viewed by anyone with a wVSSM account, a computer, and a working

Internet connection. Once connected, staff can view the total current stock of any item up to the country level.

Although wVSSM is a comprehensive stock-management solution, some modifications were needed to accommodate the local context in Tunisia. In particular, some Arabic and French text was modified to make it more easily understood by Tunisians. Relevant forms for ordering vaccines also needed to be added. After these adaptations were made, the application was installed at the Computer Center of the Ministry of Public Health (CIMSP). With all regions and districts already connected to a national health information system, any health center with an Internet connection could access the application.

5.4. Implementation

Table 25 summarizes the project timeline and major milestones.

Table 25. Computerized LMIS implementation timeline

Year	Month	Milestone
2010	December	User requirements defined by conducting a landscape analysis of the advantages and disadvantages of existing information systems and by conducting workshops with key stakeholders.
		wVSSM chosen as software solution.
		Information technology platform and server identified (CIMSP).
2011	March	MOU signed by CIMSP, DSSB, and WHO Tunisia.
	June	Adaptations of wVSSM for deployment in Tunisia completed.
	September	System testing completed.
	October	Training workshops conducted.
	November	wVSSM implemented at the national level (vaccine primary store) and in the five regions that implemented the demonstration project on streamlining and integrating the supply chain (Sousse, Monastir, Mahdia, Kairouan, and Kasserine).
	November	Project extended to the three districts implementing the net-zero energy demonstration project (Foussana, Hassi El Frid, and Feriana).

Abbreviations: CIMSP = Computer Center of the Ministry of Public Health; DSSB = Department of Basic Health Care; LMIS = logistics management information system; MOU = memorandum of understanding; wVSSM = web-based Vaccination Supplies Stock Management; WHO = World Health Organization.

5.5. Results

The impact of the demonstration project was measured by comparing the scores of the baseline (2010) and endline (2012) EVM assessments.

5.5.1. Records management

Data from the 2010 and 2012 EVM assessments were used to measure two indicators relating to records management:

- The extent of wastage reporting.
- The extent of evidence-based vaccine forecasting. (This indicator implies that the forecasting depends on information on wastage data in the LMIS. The assumption is that this information improves the forecasting process.)

For the two indicators, the EVM assessment calculates a score between 0 and 5. In Table 26, the score is converted into a percentage.

Table 26. Evaluation of records management in 2010 and 2012, expressed as percentage of completion

Level	Sublevel	Wastage reporting (%)		Forecast improvements (%)	
		2010	2012	2010	2012
National	**Total**	**0**	**0**	**35**	**100**
Regional[a]	Sousse	100	100	100	100
	Kairouan	100	75	100	100
	Kasserine	0	50	0	50
	Total	**67**	**75**	**67**	**83**
District	Hassi El Frid	0	75	0	50
	Foussana	0	0	100	50
	Feriana	0	100	0	75
	Total	**0**	**58**	**33**	**58**

a. The EVM in 2010 did not assess the regions of Monastir and Mahdia.

The findings suggest that improvements occurred in the pilot areas between 2010 (paper-based system) and 2012 (wVSSM). The only exception was a drop in the score related to wastage reporting in Kairouan between 2010 and 2012 and the fact that wastage was not recorded at a national level either before or after the introduction of the wVSSM system.

5.5.2. Data accuracy

Data from the 2010 and 2012 EVM assessments were used to measure the accuracy of inventory data in the wVSSM system. By calculating the ratio of the physical stock count to the actual stock records, we were able to see to what extent the physical count of vaccines matched the stock records from the ledger. This is expressed as a percentage in Table 27.

Table 27. Accuracy of stock inventory in 2010 and in 2012, expressed as the ratio of the physical stock count to the actual stock records

Level	Sublevel	Stock ledger (2010)	wVSSM (2012)
National	**Total**	**100%**	**100%**
Regional[a]	Sousse	44%	101%
	Kairouan	100%	100%
	Kasserine	163%	100%
	Total	**101%**	**100%**
District	Foussana	27%	100%
	Hassi El Frid	81%	100%
	Feriana	250%	102%
	Total	**80%**	**101%**

Abbreviation: wVSSM = web-based Vaccination Supply Stock Management.

a. The EVM in 2010 did not assess the regions of Monastir and Mahdia.

At the national level, the accuracy of data in the wVSSM system was 100 percent in both 2010 and 2012, reflecting a close match between stock records and the actual stock count. At the regional level, significant improvements in data accuracy were found in Sousse and Kasserine. Major improvements were also documented in the three pilot districts.

The overall findings suggest improvements in data accuracy between 2010 and 2012. Areas with 100 percent data accuracy in 2010 retained this level of accuracy in 2012.

5.6. Acceptability and feasibility

5.6.1. Factors of acceptability

Six interviews were completed regarding the acceptability and feasibility of this demonstration project—five with implementers and one with a responsible manager. All respondents replied that the intervention was appropriate and either acceptable (2/6) or very acceptable (4/6).

The main reason cited for acceptability was the improved ability to control data quality and stock management. A regional-level warehouse manager described how influential the system has been: "The VSSM system has helped to improve working organization—stock control, vaccine expiry dates. Orders are now more precise and based on real requirements."

One key respondent said:

> *To begin with, I was not happy with the new system. We were used to the paper system…. After use, we realized that the system can replace paperwork. What's more, the system is a good means of ensuring traceability, checking the orders submitted, and determining the needs of the regions.*

Respondents also noted improved organization and communication as a factor of acceptability. Respondents said the system was more efficient than the previous system, especially in the areas of stock management and inventory. One respondent stated:

> *Exhaustive information is available in the system. It's all well-organized and simplifies the working organization…. Back-up stock is known, and no vaccines are lost. I think that this is extraordinary.*

5.6.2. Factors of unacceptability

Although respondents overwhelmingly said the demonstration was acceptable, they described some factors of unacceptability, including unstable Internet connections and the need for more training to use the system, especially for more specialized functions. As one respondent explained:

> *Extensive training was required to learn to use the application—almost three months. However, no continuous training was available. Sometimes, it was the doctor for the center, and sometimes, it was the Optimize team who assisted us. I sometimes work from home due to the workload and because my home Internet access is faster than the connection at work. What's more, we do not have enough personnel to allow me to concentrate exclusively on the VSSM application.*

In addition, some respondents reported being dissatisfied with the stock reporting functions of the wVSSM. A regional-level nurse complained, "We can use the wVSSM application to obtain details of batches but not remaining stock. I would like stock to be specified." They hoped for improvements to the functions that display batches and not total stock and the ability to correct errors in the system with stock as needed.

5.6.3. Factors of feasibility

All respondents indicated that the intervention was either feasible (2/6) or very feasible (4/6). Respondents cited changes in workload, better organization, and ease of tasks. They described the feasibility of the intervention with examples demonstrating how the intervention was improving their work quality. One respondent stated, "The system is really convenient and precise and optimizes the organization of management processes."

For the demonstration to be viewed as feasible, the Internet connection, computer equipment, and training must be in place. As one respondent said, “Training is very important for the future of this operation. Computers must be purchased for all members of personnel managing the wVSSM application, and the Internet connection is critical.”

5.6.4. Factors of unfeasibility

Factors of unfeasibility included the need for adequate training as well as the need for a stable Internet connection. Several respondents explained the challenges of overcoming a steep learning curve to acquire the level of proficiency needed to perform on the wVSSM. Staff members who were not accustomed to using a computer regularly for their work found this particularly challenging. All eventually reported successfully overcoming this challenge. A regional warehouse manager said, “To begin with, it was fairly difficult, but after having used the system, I now find that it is quite easy.”

The wVSSM was found to be highly acceptable and feasible. In fact, it was such a popular intervention that it was often cited in interviews about demonstration projects.

5.7. Cost

Approximately $97,000 was spent to implement wVSSM at the national level, in five regions, and in three districts. Software development accounted for 53 percent of all expenditures. Funds were invested at the international level to finalize development of a web-based version of the stand-alone VSSM tool and to create a module that would allow using the wVSSM offline during temporary interruptions in Internet access. Important software development occurred in Tunisia to ensure that the wVSSM was tailored to the local context.

The second largest cost drivers were training activities, workshops to define user requirements, and the cost of hosting the server at the CIMSP. Combined, these expenses represented 26 percent of overall costs. The remaining spending was on information technology (IT) equipment, which represented 21 percent of overall expenditures. Table 28 details costs of the demonstration project.

Table 28. Costs of the LMIS demonstration project by component and funding source[a]

Cost category	Component	Expenditure	
		$	%
IT equipment	Server (for the CIMSP)	2,433	3
	Computers and printers	11,573	13
	Internet connection	6,425	7
	Total	**20,431**	**21**

Cost category	Component	Expenditure	
		$	%
Software development	Web function of the VSSM	16,500	17
	Local adaptations of the wVSSM	20,800	21
	Offline module of the wVSSM	14,500	15
	Total	**51,800**	**53**
Other	User requirements workshop	2,514	3
	Training activities	14,666	15
	CIMSP contract	7,800	8
	Total	**24,980**	**26**
Total		**97,211**	**100**

Abbreviations: CIMSP = Computer Center of the Ministry of Public Health; IT = information technology; LMIS = logistics management information systems; wVSSM = web-based Vaccination Supplies Stock Management.

a. Indirect costs are not included.

All funding was through project Optimize if one considers only the demonstration sites. The DSSB invested its own funds to train staff in wVSSM and to scale up the system to other regions.

5.8. Challenges

5.8.1. Funding for hosting wVSSM

One of the main obstacles to getting started on this demonstration was the intense negotiations with the CIMSP to host the wVSSM on its IT platform. The main sticking point occurred when the CIMSP requested a signed MOU with the DSSB stipulating payment for the services it would be rendering. This was a surprise given that the CIMSP is a unit of the Ministry of Health that oversees all the IT systems for the Ministry, and our intervention was supporting the DSSB. Consequently, the DSSB initially objected to signing an MOU. In the end, a joint MOU between the CIMSP, the DSSB, and WHO was developed, and WHO Tunisia (through Optimize) agreed to fund the cost of using the CIMSP system. It took most of 2010 and early 2011 to get the MOU signed.

5.8.2. Establishing Internet connectivity

A second challenge was establishing Internet connectivity in the demonstration regions and districts—particularly in Kasserine, a region that is among the poorest in Tunisia. Although the

CIMSP has connected all regions and districts to its system, the installations were still lacking within the buildings themselves. That meant that the vaccine storage points in Kasserine and in the three districts did not have a direct Internet connection. For instance, the CIMSP Internet connect for Kasserine was in the main regional office building of the DSSB and not in an annex building where the vaccine store was located. A customized solution was required for each of the demonstration sites (e.g., wireless router, Ethernet cabling, 3G dongle).

5.8.3. Unreliable connectivity

Even after Internet connectivity was established, the reliability of the Internet connection was a major issue, particularly in Kasserine and the districts of Foussana, Feriana, and Hassi El Frid. When the Internet connection was down, users could not use the wVSSM. Thus, many sites continued to use the paper-based LMIS instead of the wVSSM until Internet reliability could be improved. Although connectivity remained an issue throughout the demonstration period, an offline module of the wVSSM was developed by consultants so information could be entered in the wVSSM offline and then synchronized once the connection was reestablished. However, this was never implemented in Tunisia.

5.8.4. wVSSM training

Although users were generally excited and eager to move from a paper to a paperless system using the wVSSM, many did not know how to use a computer. Several rounds of training were required because workshops needed to include basic computer instruction.

5.8.5. Delays

Because of the intricate link between the streamlining and integrating demonstration project and the wVSSM project, delays in the former hindered the implementation of the latter. For example, because the January 2012 order of vaccines for Kasserine did not arrive until February, when these vaccines did arrive, Kasserine was rushed to deliver the vaccine down to the districts, and the districts were rushed to deliver the vaccines to health centers. Because of the rush, stock-management information was entered retrospectively into the wVSSM, which is not good practice.

5.8.6. Ensuring that users actively used wVSSM

Because using any new software can initially create more work (new system to learn) before eventually reducing the LMIS data management burden, the temptation to continue operating the paper system in parallel was high. This problem was worsened by unreliable Internet connectivity (see section 5.8.3), as it was impossible to use wVSSM when an Internet connection could not be made.

5.9. Lessons learned

Overall, this demonstration was perhaps the most appreciated of the three projects in Tunisia. Although there were numerous implementation challenges, the benefits of transitioning from a paper-based system to a networked and computerized LMIS were largely proven.

In drawing lessons learned, it is worth reflecting on actions that made headway possible and created opportunities for breakthroughs. A key to getting this intervention off on the right track was developing a full landscape analysis of the advantages and disadvantages of the information systems in place and conducting workshops to define user requirements. Without a thorough understanding of users' needs and expectations for an improved LMIS, we could well have provided a solution that would not have met those needs. Another key activity was to fully landscape existing software that could respond to the needs and avoid having to recreate something from scratch. We were lucky to identify a tool that required only modest development investment to bring it to a web-based version.

Overall, a general lesson learned was that any intervention to set up an LMIS will likely take more time than expected. From a technical perspective, the following key lessons are also worth highlighting.

5.9.1. The importance of expert knowledge at the national level

It is essential for one or more people at the national level to develop expert knowledge and skills related to the software. A challenge with any information system using a software application developed at the international level is to ensure that at least one person at the national level is proficient in the system and able to: (a) conduct training activities, (b) support installation of the software and respond to troubleshooting issues, and (c) access the source codes to be able to program local adaptations to the software. Having one or more national-level experts is critical to ensuring sustainability of the system.

5.9.2. Don't overlook the need for basic IT training

Users need basic training on use of IT as well as on use of the software—a major difficulty in implementing the wVSSM software was that many users did not have basic computer skills. Multiple training sessions were required to get users (especially at regional and district levels) to be proficient in using a computer and the software.

5.9.3. Unreliable Internet connectivity can cause major problems

The wVSSM intervention was plagued by unreliable and slow Internet connectivity. The initial version of the software could not be used if the Internet connection was down, whether due to a power outage or problems with the service provider. For the first six months of the demonstration, the temptation to continue to use the paper LMIS was high and use of the wVSSM was not optimal. To resolve the problem, an offline module for the wVSSM was developed. That way, stock movements and vaccine transactions could be entered offline, and these would be

synchronized with the server database once the Internet connection was back up. Unfortunately, the demonstration time was too short to test the offline module. In the end, the paper-based LMIS was kept alongside the wVSSM, and information was retroactively entered into the wVSSM.

5.9.4. Consider technical limitations

The new system is not a last-mile LMIS solution—a web-based LMIS is a worthwhile system at higher levels of the supply chain where Internet connectivity is more reliable and investing in a PC is a justifiable expense (compared to putting a computer in every health center, for instance). For national and regional levels, the wVSSM was a very good LMIS solution. At lower levels of the system, a web-based LMIS was rather impractical—too cumbersome in terms of IT equipment and slow/unreliable Internet service. Options that rely more on mobile technology might be a better alternative.

5.9.5. The complexity of the system needs to be adjustable

The level of complexity of the LMIS needs to diminish as one moves down the supply chain system. The wVSSM is a very powerful software tool, but many of its options are not needed at lower levels. The LMIS should have the potential to hide options so that users at lower levels (at a district store, for instance) do not feel overwhelmed by the dashboard.

5.9.6. Upgrading to newer version is not straightforward

A newer version of the LMIS (version 2.0) became available during the demonstration, and the DSSB faced a difficult decision about whether to upgrade its software. Given all the recent investments in training on version 1.0, the DSSB was not ready to invest in refresher training on a newer version. Also, not enough time had lapsed between getting users comfortable with version 1.0 and the availability of version 2.0. Moreover, it was felt that the improvements in version 2.0 were relatively minor. In addition, and possibly more importantly, Tunisia had made local adaptations to wVSSM version 1.0, and these adaptations were not available in version 2.0. To upgrade its software, the DSSB would need to recruit a local software developer to ensure that local adaptations in version 1.0 were available in version 2.0. In the end, Tunisia felt that it could wait for a subsequent version to upgrade.

5.10. Scaling up

The benefits of the computerized and networked LMIS for vaccines demonstrated in the pilot areas became so rapidly visible to the DSSB that it spontaneously decided to scale up the system to all regions. This scale-up occurred even though the demonstration had not yet been fully implemented and before any quantitative and qualitative results could be shown.

A major advantage of the LMIS that was developed and installed in Tunisia is that it could be scaled up at any point. Because the wVSSM was installed on a server located at the CIMSP, any health facility with an Internet connection and a PC could install the system and use it. Given that

most regions in Tunisia had a computer and Internet connections, by the end of project Optimize, more than 20 regions were using the wVSSM. Those that were not connected to the Internet were using the desktop version (VSSM).

The spontaneous scaling up of the wVSSM is a testimony to national ownership in the LMIS solution and a hallmark of a sustainable system. All the elements required for the system to have a life beyond Optimize are in place. For the DSSB, this was a clearly a high-impact, low-cost solution. It is noteworthy that the wVSSM system has been incorporated into a much broader collaborative platform for immunization information systems, including immunization coverage.

5.11. Conclusion

The web-based version of the Vaccination Supply Stock Management (wVSSM) software was successfully deployed and field-tested in Tunisia though project Optimize. The main objective of this work was to demonstrate the benefits of transitioning from a paper-based system to a computerized, networked information system that links national, regional, and district levels. The web-based system enabled the exchange of real-time data on vaccine forecasting, stock management, and order status information by anyone with a wVSSM account, a computer, and a working Internet connection.

Moving from a paper-based system to a computerized one has worked well, and health workers are pleased with the change. Currently, the national, regional, and district levels of the system have all been linked, and complete stock-management information for vaccines can be seen in real time at each level.

Although wVSSM is a comprehensive stock-management solution, some modifications were needed to accommodate the local context in Tunisia. Moreover, implementation has not been free of challenges. Without a reliable Internet connection, wVSSM cannot function. In the more remote areas of Tunisia, where connectivity cannot be guaranteed, this has made it difficult for health workers to use the new system. It has also taken time for health workers to adapt to the new tool.

APPENDIX

A. Acceptability and feasibility assessment

Project Optimize included an external assessment of factors related to the feasibility and acceptability of the interventions in Tunisia. The overall purpose of this assessment[22] was to identify key advantages and challenges associated with the interventions within the global project Optimize monitoring and evaluation framework. To accomplish this, the assessment explored the perceptions of stakeholders engaged in the development and implementation of the demonstrations in Tunisia.[23]

The terms "acceptability" and "feasibility" can often overlap. For the purpose of this assessment, the two terms were defined as follows:

- "Acceptability" refers to what the stakeholder likes and dislikes about an intervention. An acceptable intervention is desirable and satisfactory.

  Examples: An intervention might be considered acceptable because of benefits to mothers and infants who have better access to immunization or because of benefits to Ministry of Health (MOH) immunization staff through reduced workload. An intervention might be considered unacceptable if it has little benefit for mothers and infants or MOH staff.

- "Feasibility" refers to the difficulty or ease with which the stakeholder can implement required activities. If an intervention is feasible, it is practical and easy to carry out and achieve.

  Examples: A feasible intervention is practical to achieve with available time, staff, and resources. A feasible scenario would be the introduction of a new vaccine that comes in vials similar to existing vaccines and that is handled in the same cold chain conditions as existing vaccines. An unfeasible intervention is not practical to achieve with available time, staff, and resources. An unfeasible scenario would be the introduction of a new vaccine with packaging so large that you cannot fit enough doses in the district refrigerator or that requires dry ice to be transported, or a new vaccine with a shelf life that is only a few weeks long.

The assessment used qualitative methods to provide descriptive findings. A Tunisian team of consultants used a variety of locally adapted methods to collect and analyze qualitative data from intervention stakeholders. The methods included semistructured interviews, focus group discussions, site visits, and stakeholder meetings. Data collection occurred in October and November 2012.

The team conducted interviews with implementers and decision-makers/stakeholders from key intervention partners, including pertinent national government ministries, and other implementing partners, such as health workers. Each respondent gave verbal consent and was asked for

[22] This assessment was deemed "non-research" in accordance with PATH's Research Determination Committee's policies.
[23] As required by PATH's Research Ethics Committee for the protection of human research subjects, PATH employees were not included as stakeholders in this research.

approval to be recorded. Recordings were transcribed and translated, and responses were analyzed using ATLAS.ti qualitative software. Results were triangulated with monitoring data.

The assessment team held two focus group discussions with implementers and managers to explore acceptability and feasibility issues from a different perspective in greater detail. Each focus group had three to ten participants and lasted approximately two hours. The final analysis triangulated the interview and focus group data. The findings from the acceptability and feasibility assessment contributed to the global project Optimize monitoring and evaluation framework.