OPTIMIZE

Vietnam

Summary of Optimize Activities Conducted with Vietnam's National Expanded Programme on Immunization

October 2012

OPTIMIZE Immunization systems and technologies for tomorrow

NATIONAL INSTITUTE OF HYGIENE AND EPIDEMIOLOGY
PATH
World Health Organization

This report was developed by Optimize: Immunization Systems and Technologies for Tomorrow, a collaboration of the World Health Organization and PATH. The report was authored by team members from PATH and the National Institute of Hygiene and Epidemiology in Vietnam.

The authors and Optimize representatives hope this report will contribute to ongoing discussions about immunization logistics. We welcome comments from interested parties.

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Cover photo: PATH/Nguyen Phu Cuong

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TABLE OF CONTENTS

ACRONYMS

BCG	Bacillus Calmette-Guérin
CHC	Commune health center
DTP	Diphtheria-tetanus-pertussis
EPI	Expanded Programme on Immunization
EVM	Effective vaccine management
HCMC	Ho Chi Minh City
HepB	Hepatitis B
IHE	Institute of Health and Epidemiology
IR	Digital immunization registry system
IT	Information technology
MOH	Ministry of Health
NEPI	National Expanded Programme on Immunization (Vietnam)
NIHE	National Institute of Hygiene and Epidemiology (Vietnam)
PMC	Preventive medicine center
SMS	Short message service
SOP	Standard operating procedure
VVM	Vaccine vial monitor
WHO	World Health Organization

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EXECUTIVE SUMMARY

Between 2010 and 2012, Optimize collaborated with Vietnam's National Institute of Hygiene and Epidemiology–National Expanded Programme on Immunization to demonstrate innovations in the supply chain that can help to meet the demands expected as Vietnam's immunization program continues to grow into the future.

Optimize and Vietnam's National Institute of Hygiene and Epidemiology conducted four major activities under the project:

1. Developing a computerized system for tracking vaccine stock and reporting aggregated monthly immunizations data. (VaxTrak).
2. Testing the use of computer- and mobile phone-based technologies to track children due for immunization and to record the immunizations given to them on an individual basis. (Digital Immunization Registry System—IR).
3. Using a newly developed passive cooling device to store vaccines in commune health centers. (NanoQ cold box).
4. Installing newly developed direct-drive solar refrigerators to store vaccines in district health centers. (Sure Chill).

Other project activities included conducting the WHO effective vaccine management assessment, strengthening standard operating procedures, and working with a local manufacturer on initial steps toward vaccine vial monitor adoption.

The software interventions, VaxTrak and IR, were successful at reducing the time burden of reporting, and there are some indications that VaxTrak helped improve the accuracy of vaccine stock records. Most users of both software systems reported that they were acceptable and feasible for scale-up, although there was some concern at the national level that IR would be too costly to scale up. Users liked having access to the data online and found the interfaces user friendly.

The cold chain interventions were also found to be acceptable to users. Users liked having vaccine cooling systems that were independent of the electric grid. Users of the NanoQ found it easy to use and recommended it for remote communes that have no specialized vaccine refrigerator. Users cited stable running temperature and electricity cost savings as two reasons the Sure Chill solar refrigerator was acceptable.

There were a number of challenges with the technologies. Due to a number of reasons, the schedule for all interventions was delayed, limiting the amount of information we were able to gather. With the VaxTrak intervention, users at the national and regional levels were sometimes reluctant to use the system, which made it more difficult at the province level. With IR, many users preferred to run the program on the computer rather than on mobile phones. NanoQ had difficulty maintaining temperatures above 2°C when ambient temperatures dropped below 20°C in the north and central regions. Users of the Sure Chill struggled with the accumulation of condensation resulting from high humidity in Vietnam, and the refrigerators suffered some breakdowns due to faulty electronic components. All of these difficulties enriched the learning of the project, and the information can help in the development of better technologies for the future.

1. INTRODUCTION

1.1. Overview

Project Optimize is a collaboration between the World Health Organization (WHO) and PATH to identify ways in which supply chains can be optimized to meet the demands of an increasingly large and costly portfolio of vaccines. Our 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 vaccines to people around the world.

Between 2010 and 2012, Optimize collaborated with Vietnam's National Institute of Hygiene and Epidemiology (NIHE) to demonstrate innovations in the supply chain that can help to meet the demands expected as Vietnam's immunization program continues to grow into the future.

This report describes the demonstrations undertaken in Vietnam as part of the collaboration.

2. CONTEXT

2.1. The need for global action

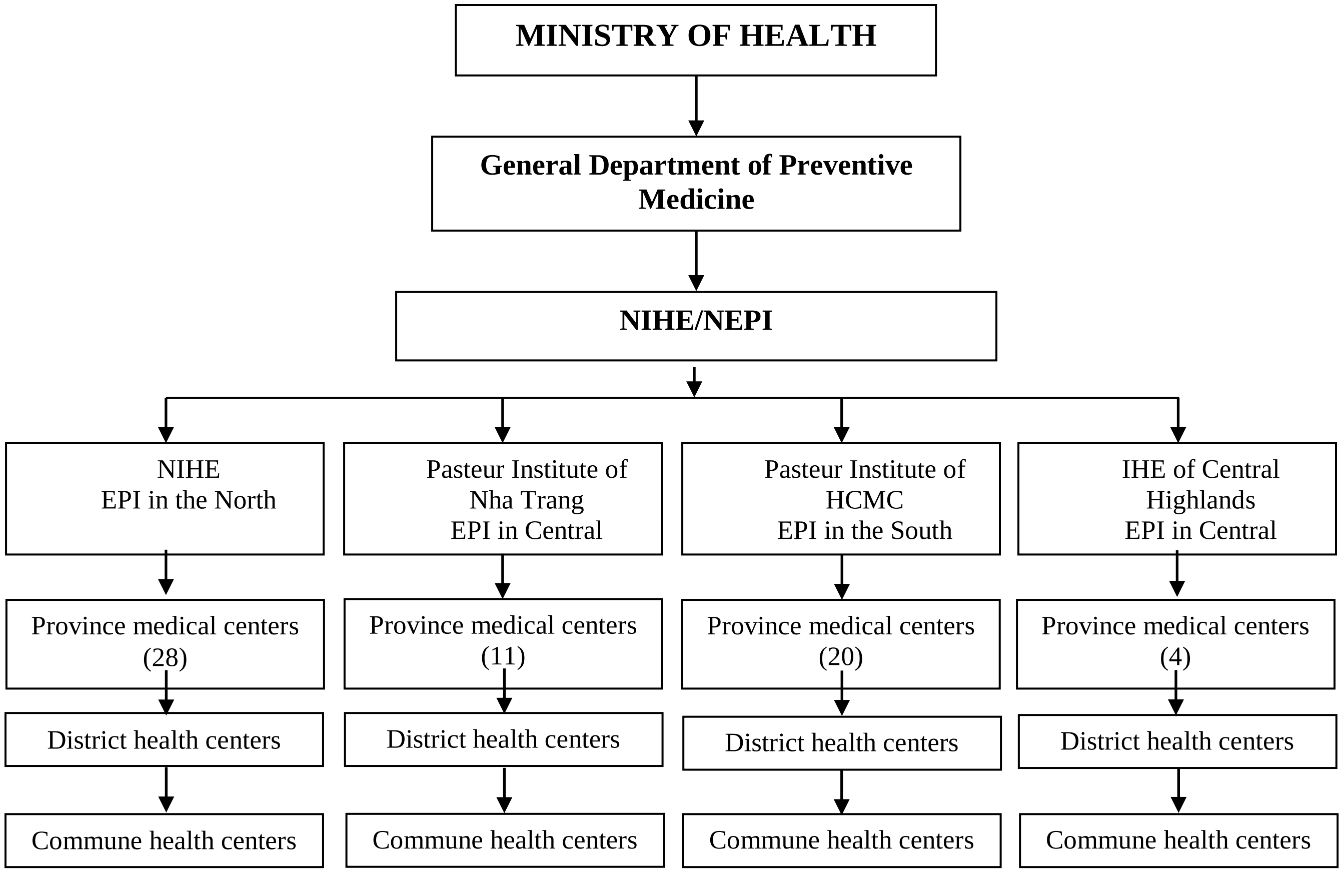
The vaccine cold chain and logistics systems used in most countries were developed 30 years ago, prior to the availability of computers and sophisticated tracking equipment in developing countries, and before vaccines cost more than US$0.10 per dose. Until today, many persistent logistics and cold chain problems could be overcome by maintaining high stock levels and tolerating high wastage rates. However, with the rising cost of vaccines and the enormous storage capacity now required at each level of the cold chain, managers must be able to maintain lower stock levels, reduce wastage, accurately forecast vaccine demand, and prevent equipment breakdowns or malfunctions.

2.2. The supply chain in Vietnam

2.2.1. Current supply chain

Vietnam has a well-established vaccine supply chain. Local manufacturers produce vaccines for diphtheria-tetanus-pertussis (DTP), bacillus Calmette-Guérin (BCG), polio, Japanese encephalitis, cholera, typhoid, measles, and hepatitis B (HepB), and deliver them either to the national cold store or directly to the four regional cold stores. Imported vaccines such as pentavalent are received at the national cold store before being transported to regional stores. Vaccines are moved from the regional level to provincial, to district, and finally to communes. Generally, vaccines are only supplied to the commune level for one to three days per month for immunization activities. During the rest of the month, vaccines are not stored at the commune level except in some remote communes where vaccine refrigerators have been provided. Figure 1 shows the administrative structure of the national immunization program in Vietnam.

Figure 1. Administrative structure of the national immunization program in Vietnam



Acronyms: EPI = Expanded Programme on Immunization; IHE =Institute of Health and Epidemiology; HCMC = Ho Chi Minh City; NIHE = National Institute of Hygiene and Epidemiology (Vietnam); NEPI = National Expanded Program on Immunization (Vietnam).

There are presently a total of 696 districts and 11,132 communes in Vietnam.

2.2.2. Opportunities

The Vietnamese vaccine cold chain is based on structure, practices, and procedures developed 30 years ago. Many advances in supply chain technology, developed largely by commercial players in recent years, could be used to create a system in Vietnam that will help the government meet the challenges of the future. Due to the rising cost of vaccines and the increased storage capacity that will be required at each level of the cold chain to accommodate new vaccines, managers will need to maintain lower stock levels, reduce wastage, accurately forecast vaccine requirements, and aggressively prevent equipment breakdowns to protect vaccine stock.

Based on assessments conducted in 2009, Optimize identified opportunities to demonstrate innovation in the Vietnamese vaccine supply chain (see Table 1).

Table 1. Opportunities for innovation in the Vietnamese vaccine supply chain

Challenges	Opportunities
Health care workers face a significant burden of work related to the paper-based reporting system; this burden will increase with the introduction of new vaccines.	The reporting burden can be reduced, enabling health care workers to spend more time providing direct patient care.
Immunization data recorded in the current system are often delayed or incomplete at the higher levels.	The completeness and timeliness of report data can be improved at all levels.
Immunization data recorded in the current system are often incorrect due to estimation and arithmetic errors.	The quality and accuracy of information available can be improved at all levels.
Managers at the national or regional level find it difficult to locate specific vaccines in the supply chain.	Real-time information about vaccines in stock can be increased at all levels.
Delivery of the HepB vaccine within 24 hours of birth is relatively low, resulting in a missed opportunity for the best protection of infants against this pathogen.	On-time delivery of the HepB birth dose can be increased by providing small-volume cool storage containers at CHCs.
Commune health centers often have intermittent grid electricity; they also have trouble securing funds to cover electricity bills.	The use of passive cooling technologies that require intermittent or no electricity can be explored for CHCs.
The Vietnamese immunization system relies on various administration, storage, and reporting procedures. However, there is a lack of documented SOPs to ensure that these processes are conducted correctly and consistently.	Efficiency and consistency of performance across the NEPI system can be improved through the development of high-quality SOPs.

Acronyms: HepB = hepatitis B; CHCs = commune health centers; NEPI = National Expanded Program on Immunization (Vietnam); SOPs = standard operating procedures.

Following the assessment, and corresponding to the opportunities identified, Optimize and NIHE decided on four major demonstration activities to be conducted under the project:

1. Developing a computerized system for tracking vaccine stock and reporting aggregated monthly immunizations data.
2. Testing the use of computer and mobile phone technologies to track children due for immunization and to record the immunizations given to them on an individual basis.
3. Using passive cooling technology to store vaccines in commune health centers.
4. Installing direct-drive solar refrigerators to store vaccines in district health centers.

In addition to the four demonstrations, Optimize also conducted other activities in Vietnam. These included:

- Providing technical support in the preparation of an effective vaccine management (EVM) assessment in 2012.
- Strengthening standard operating procedures (SOPs) to standardize best-practice procedures, and designing a training system to support them.

Supporting early steps toward the adoption of vaccine vial monitors (VVMs) by local manufacturers and the Vietnam Ministry of Health (MOH).The remainder of this report details the findings of these demonstrations and activities.

3. COMPUTERIZED VACCINE TRACKING AND IMMUNIZATION REPORTING

3.1. Goal and rationale

Photo: PATH/Nguyen Phu Cuong

Optimize collaborated with NEPI to pilot a computerized logistics management information system (VaxTrak) that helps immunization health workers track vaccine stock as it is received and dispatched throughout the system and that facilitates monthly reporting on immunizations given. The goal was to increase the accuracy and timeliness of vaccine inventory and immunization records, to reduce the amount of time health care workers spend on reporting duties, and to increase the availability of the data, especially for upper levels at different locations.

A major challenge in managing a supply chain is the lack of centralized, timely, and accurate data for effective vaccine stock control and management. Without these data (for example, 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 understocking (which can lead to stockouts and missed opportunities to vaccinate children) or overstocking (which can lead to wasting vaccines from expiry).

3.2. Implementation

In discussing the requirements for this software, the users wanted a web-based tool to track vaccine stock movements and to record immunizations administered. They wanted data that were aggregated in a central database accessible at the national level as well as other levels, with appropriate permission. ANZ Solution was chosen from among several Hanoi-based software development firms who responded to the request for proposal, and the software was developed over several months.

The VaxTrak tool was introduced in three provinces—Phu Tho (north), Quang Tri (central), and Ben Tre (south)—as well as at regional and national levels. Once installation and training were completed in October 2011, immunization workers at the participating locations began using VaxTrak for registering vaccine receipts and dispatches, and reporting immunizations administered.

After the first three months of implementation, based on feedback from users, NEPI leadership decided to enter into a second phase of the intervention, expanding the number of participating provinces to 13 in total, and adding all 13 districts in Phu Tho province to pilot the software at the district level. Due to human resource limitations, Optimize could not monitor all locations, but of those added in the second phase, the project monitoring was expanded to an additional three provinces and two districts.

3.3. Results

3.3.1. Accuracy of vaccine stock data

Prior to designing and implementing the VaxTrak software, we developed a monitoring and evaluation framework to identify the indicators we wanted to measure. One thing we wanted to evaluate was accuracy of vaccine and immunization data before and after intervention. However, in many cases, the electronic data that we wanted to analyze were not available, making it difficult to evaluate the VaxTrak system's accuracy. There are several reasons for this:

- This software has not been in place long enough for all users to become accustomed to the vaccine management and immunization reporting functions.
- Although the users expressed a high level of appreciation for the software, they did not prioritize it, as it was considered just a pilot and not compulsory. Data were not often updated and users tended to revert to the more familiar paper-based system.
- During the implementation period, provincial health workers were asked to use two different immunization programs, which created a heavy work burden. Only one of these systems was related to Optimize activities.
- At some locations users reported that the VaxTrak reporting forms met EPI's requirements but not their financial reporting requirements, so it was not helpful to use VaxTrak.

However, in spite of these challenges, in the three original provinces that had the longest experience with VaxTrak, it was possible to collect data from the system database on the quantities of vaccine by lot number and compare them with the actual stock on hand. To be considered a match, the vaccine had to share the same vaccine name, manufacturer, lot number, expiry date, and dose quantity. In the baseline survey before implementing VaxTrak, the number of lots in the vaccine ledger matching the actual stock on hand was only 30 of 39 (77 percent accurate) in the three provincial stores. After one year of the VaxTrak intervention, the accuracy of vaccine data improved, with 40 of 40 (100 percent accurate) lots in the software matching the stock on hand.

3.3.2. Reporting process before and after VaxTrak

At the time of the baseline survey, health workers used either a calculator or computer to aggregate data from commune reports. For those using a computer, predesigned Microsoft Excel files allowed health workers to enter data from commune immunization reports, automatically generating results for the entire district. The process of compiling the report on vaccine use was more complicated. Health workers were seen poring over the vaccine register, previous month's reports, and distribution vouchers, trying to reconcile data in order to provide an accurate report.

To create immunization reports with VaxTrack, the reporting district workers input and save data to the “Immunization Report” application of the system. The province can then quickly generate reports that compile all the reporting districts’ data. The software includes various report formats according to NEPI requirements.

To generate vaccine use reports, the reporting district workers input and save data on the quantities of stock remaining and discarded at the commune level to the “Vaccine Used Report” application of the system. In provinces where the software has not been implemented down to the district level, the province-level reporting officer must confirm data with each commune EPI officer before entering the data. The system then uses the commune-level data on stock remaining and discarded, and combines it with the stock data generated when shipments are dispatched and received in order to automatically generate vaccine use reports.

3.3.3. Time burden of compiling reports

We observed the average amount of time that health workers spent making three kinds of reports every month including: vaccine use report, child immunization report, and woman immunization report. We conducted observations before and after the VaxTrak intervention at five facilities—three provincial and two district.

Due to time limitations, we could not conduct observations for all three types of reports in all five facilities. In the end, we observed the child immunization and vaccine reports at all three provincial facilities, and the child immunization and woman immunization reports at district level, all before and after intervention.[i] From these data, we found that at the provincial level the average time health workers spent on the child immunization report changed from 22 minutes before VaxTrak implementation to 16 minutes using VaxTrak. For the vaccine use report, the average time spent changed from 88 minutes to 43 minutes. At the district level, the average time spent on the child immunization reports changed from 39 minutes before implementation to 23 minutes after VaxTrak implementation, and for woman immunization reports the change was from 10 minutes to 8 minutes.

Phu Tho was the only province where VaxTrak was implemented down to the district level. Once the districts came online, the immunization data were then entered into the VaxTrak system at district level rather than province level, so the immunization reporting time at the provincial level decreased dramatically since the report was automatically aggregated without any data entry steps. The final observed child immunization report in Phu Tho took only 5 minutes to complete compared to 22 minutes before VaxTrak implementation. This shows that the power of the software to save time in the immunization program increases as its use is expanded down to lower levels.

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[i] The vaccine report includes information about vaccine quantities received, used, discarded, and returned. The child immunization report includes information about number of children vaccinated by type of vaccine and location. The woman immunization report includes information about the number of women vaccinated with tetanus vaccine by location (targeted toward women aged 15 to 35 and pregnant women).

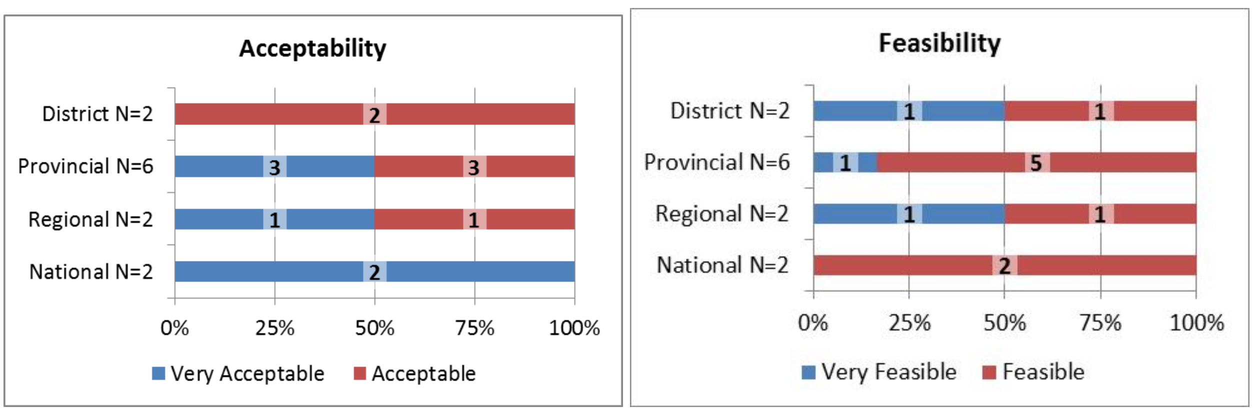
3.3.4. User acceptability of VaxTrak

Twelve participants from different levels were included in qualitative research to try to understand user response to the VaxTrak software intervention. All respondents were asked to rate both the acceptability and the feasibility of the VaxTrak using a five point scale as shown in Figure 2. [ii] Their responses are presented in Figure 3.

Figure 2. Evaluation scale for acceptability and feasibility questions

Very Unacceptable	Unacceptable	Do Not Know	Acceptable	Very Acceptable
1	2	3	4	5
Very Unfeasible	Unfeasible	Do Not Know	Feasible	Very Feasible

Figure 3. Individual interview responses on acceptability and feasibility of VaxTrak software



Some reasons that health workers gave for responding that the VaxTrak is “acceptable” or “very acceptable” include: the Vietnamese interface is easy-to-use; because it is online, it is convenient to access the data anywhere and anytime users have Internet access. In addition, some respondents mentioned they felt it helps them manage vaccines more accurately and effectively. Users at regional and national levels liked being able to see the real-time balance of vaccines at all locations under their responsibility, with lot number and expiration date information included.

Respondents mentioned an increase in timeliness of reporting, and since the software automatically aggregates reports from input data, the time they need to complete reports is reduced. Some also like the graphical presentation of data provided by VaxTrak.

[ii] We explored acceptability and feasibility separately, because although similar, there is an important distinction—an intervention may be acceptable to an individual user in her daily work while at the same time she considers it unfeasible for long-term use or scale-up for a number of reasons.

The respondents were asked to consider pros and cons of the software system with regard to scale-up. Factors favoring scale-up that respondents listed include high user acceptability and the availability of computer and Internet connections at most health facilities. Some of the challenges listed include the work required to keep staff trained (in places with high turnover rates), the lack of budget for monitoring and supporting the system in the early stages of implementation, and unstable or unavailable Internet connections in some remote areas.

User responses pertaining to acceptability and feasibility of the VaxTrak system did not reflect the challenges we observed during monitoring, such as those described in the next section. It could be that the interventions were acceptable and feasible to users in spite of those problems, or users may have been reluctant to report dissatisfaction in the research interviews.

3.4. Challenges and informal lessons learned

3.4.1. Schedule challenges

Development and introduction of the VaxTrak software took significantly more time than was originally planned in the project proposal. There were a number of reasons why delays occurred: it took longer than planned to bring together users to provide input to the system requirements, review of intermediate deliverables from the software developer tended to take longer than planned, and there was more iteration to the program during development than planned. Many small delays contributed to a launch date that was significantly later than originally planned. In the end, this resulted in having less time than expected for the intervention to run in the field sites, which meant that users had less time to get over the learning curve before the end of the project. How this affected our findings is not certain, but for future information system interventions, we recommend that project managers build more time into the schedule to allow for unexpected delays.

3.4.2. Motivation for users at higher levels

The vaccine tracking function of the VaxTrak software relies on users at the origin of a vaccine shipment to input data about that shipment into the system. Then when the shipment arrives at its destination, a user can search the VaxTrak system, find that shipment’s data, and electronically confirm receipt. Because shipments originate at a high level, users at the national and/or regional level must initiate shipments in the VaxTrak system. However, because early interventions took place in only a few provinces, a very small portion of shipments that were being sent by the upper levels needed to be put into VaxTrak, and the storekeepers did not have much motivation to enter the data at all. As a result, when shipments arrived at the provinces, often there was no data in the system corresponding to the shipment—thus provincial workers could not use the system, and reverted to using only the paper-based system. This problem has not been resolved and still hinders the use of the vaccine tracking function at provincial level.

3.4.3. Managing multiple software interventions

Within Optimize, there were several different applications being tested: the VaxTrak and immunization registry described in this report, as well as a system for tracking vaccines given outside of the free national immunization program. NEPI also was in the midst of several other software projects outside of the Optimize interventions. They were working with WHO on vaccine stock management software and with a local vendor on an immunization reporting tool. Though NEPI welcomed the opportunity to evaluate the advantages and disadvantages of several different tools, the variety did create a challenge for users, especially at higher levels where multiple interventions were taking place. NEPI recommends that countries use caution when evaluating different software applications—clear instructions and communication with users are important for success.

3.5. Next steps

Based on the strong performance, useful functionality, and good acceptability of the VaxTrak system, NEPI is interested in exploring avenues for scaling up the system to additional provinces following the close of project Optimize. If funding can be identified, additional steps going forward would include:

- Reinstating monitoring and evaluation, especially at district level, to identify all issues that need to be resolved in the next stage.
- Working with software developers on improvements to the system and ensuring that software design allows for the proposed number of users in the system.
- Designing stages for roll-out to new sites and ensuring that adequate training and technical support are available for all users.

4. DIGITAL IMMUNIZATION REGISTRY

4.1. Goal and rationale


Photo: PATH/Nguyen Phu Cuong

Optimize collaborated with NEPI to demonstrate the benefits of using computer and mobile phone technology to record immunization registry data, tracking individual children due for immunization and recording the vaccinations they have received. The goal was to evaluate how a digital registry might improve the ability to track children due for vaccination and how it might shorten the time required for recording and reporting immunizations compared to a paper-based registry.

Currently, a detailed paper-based system is used in every commune health center in Vietnam to track children due for immunization and record the vaccinations they have received. This system involves making a list of children due and vaccines needed every month before immunization day and adding up the number of vaccines of each type administered for monthly reporting to the district. Searching through the registry for this information on a monthly basis takes significant time and requires copying information and making calculations by hand, which is subject to error.

Meanwhile, Vietnam has developed a strong mobile phone and data network, reaching almost every location in the country, and mobile-phone penetration is very high within the population. In addition, more and more commune health centers are going online, and have personal computers and Internet connections that allow them to use web-based applications. This strong technology infrastructure provided a ripe environment to explore the potential benefits of a digital immunization registry.

4.2. Implementation

The digital immunization registry pilot study took place in one district and its communes. Mo Cay Nam district in the southern project province of Ben Tre was selected by NEPI. There are 17 communes in Mo Cay Nam district, located in the Mekong Delta area south of Ho Chi Minh City. The software requirements included the ability to enter individual children's names and information by personal computer or mobile phone, to search for children across different commune centers within the district, to generate lists of children due for immunization in a given month, to generate monthly immunization reports in the exact format currently specified by NEPI, and to send reminders to parents by short message service (SMS) a few days before immunization day.

Custom development of the immunization reporting software was chosen as the best approach to achieve the desired performance requirements and to ensure the best local fit for language and mobile network interface. iBase company, a local developer specializing in web and mobile applications, was selected through a formal bidding process.

In January 2012, Nokia C3 mobile phones were distributed to the commune health workers, and training was conducted to demonstrate how to use the phone- and web-based software. The software was used for immunization tracking and reporting from February through May, and monitoring and support visits were conducted regularly during that period.

4.3. Results

4.3.1. Time-burden of immunization tracking and reporting

One of the expected benefits of the digital immunization registry system (IR) was a reduction in time needed by health workers to prepare immunization reports. We found that the time spent to enter data after every immunization session during the intervention was similar to the amount of time needed to enter data into the paper-based registry (one to four hours, depending on the size of the commune). However, the time for generating the monthly immunization report was greatly reduced by use of IR. Health workers reported spending about 30 minutes to prepare the immunization report without the software system, but using IR, it took only one to two minutes.

4.3.2. Advantages of electronic data

In addition to time savings during report generation, there are several advantages of having immunization registry data in an electronic format:

- Lists of children due for immunization in a given month can be quickly generated without needing to page through the immunization registry to manually count.
- Automatically generated SMS reminders to parents can replace the tedious job of creating handwritten appointment forms for each child as practiced in some communes.
- Districts can access the data electronically at any time they have Internet access, so they do not need to wait for the communes to report.
- If a child from another commune in the pilot district appears on immunization day, health workers can look up the child's immunization history and see what vaccines she needs.

4.3.3. On-time delivery of vaccines

To help ensure on-time vaccination, the IR automatically generates an SMS reminder prior to immunization day to parents of all children who are due for vaccination. To evaluate the effect of the SMS reminder on the timely delivery of vaccines, we compared the rate of on-time delivery of BCG and pentavalent (DTP-HepB-*Haemophilus influenzae* type b) vaccine before and after the IR intervention. Table 2 shows the results of this comparison. The on-time vaccination rates for all the doses show an increase. These data indicate that the SMS component of the IR may be helping more children receive their vaccines on time. One anticipated challenge in ongoing use of the IR would include the work required to keep parents' phone numbers updated in the system.

Table 2. On-time delivery of BCG and pentavalent vaccine

Vaccine dose (Due date for vaccination)	Rate of on-time delivery			
	Before intervention (1 June 2009–30 May 2010)		After intervention (1 Jan. 2012–31 Aug. 2012)	
	N	%	N	%
BCG (within 30 days of birth)	1,048	44%	806	49%
Pentavalent dose #1 (between 60 to 89 days of birth)	1,252	54%	880	75%
Pentavalent dose #2 (29 to 30 days after previous dose)	1,316	61%	719	86%
Pentavalent dose #3 (29 to 30 days after previous dose)	1,178	58%	458	87%

Acronyms: BCG = bacillus Calmette-Guérin.

4.3.4. User acceptability of immunization registry system

Respondents from the national level down to the commune level shared their perceptions regarding the acceptability and feasibility of the immunization registry software. (Please see introduction to and evaluation scale for acceptability and feasibility research in Section 3.3.4.) Views and opinions varied. Some respondents found the system very acceptable and feasible, some found it unfeasible, and one respondent was uncertain about the acceptability. Figure 4 below shows interviewee responses, and Table 3 lists the factors that contributed to users' perception of acceptability and feasibility of the IR.

Figure 4. Individual interview responses regarding immunization registry system acceptability and feasibility

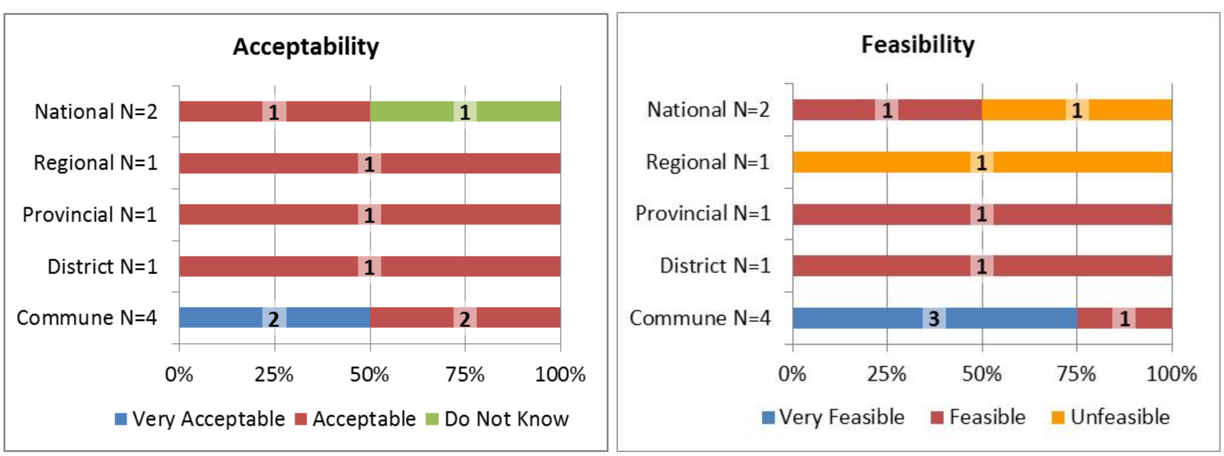


Table 3. Immunization registry system acceptability and feasibility factors

<table>
<tr><th colspan="2">Factors cited by users</th></tr>
<tr><td>Acceptability factors
Easy to use, user-friendly interface.
Convenience and flexibility of web-based application—health workers can access the data anytime and anywhere they have Internet access.
Helps health workers track and manage every child's immunization events.
SMS reminders to parents increase the rate of on-time immunization.
Data are more accurate than in the paper-based system.
Increase timeliness of report and reduces time spent generating the report.</td><td>Unacceptability factors
Small font and keyboard size in mobile interface make it challenging for older health workers.
Internet is unstable in some communes.</td></tr>
<tr><td>Feasibility factors
Software is compatible with most commune health workers' IT skills.
Availability of computer and Internet connection at commune centers.
Mobile phone fee is reasonably priced.
More than 90 percent of the population has mobile phones, so SMS reminders to parents are effective in most cases.</td><td>Unfeasibility factors
CHCs have no income and national immunization budget is limited, so the cost of scaling up the equipment would require donor support.
Health workers at CHCs do not have sufficient experience with using computers.</td></tr>
</table>

Acronyms: CHC = commune health center; IT = information technology; SMS = short message service.

4.4. Challenges and informal lessons learned

4.4.1. Schedule challenges

Similar to the VaxTrak software (see Section 3.4.1), the IR development took longer than originally planned, resulting in less time for monitoring and for users to learn the system.

4.4.2. Range of experience with computer and mobile-phone use

Unlike the VaxTrak system described in Section 3, the IR was implemented at commune health centers, where users had different levels of experience using mobile phones—some had never used the SMS function of their phones, while others were very adept at mobile-based applications. There was a similar range of computer experience. Users for whom the digital equipment was novel had a very steep learning curve and some did not have time within the monitoring period to become comfortable with the technology. Others quickly adapted to the technology, were able to problem-solve within the system, and expressed a strong appreciation for working electronically. Projects working at small health centers with new mobile- or personal computer-based applications should ensure that there is adequate technical support to help users, especially technologically naïve users, overcome their difficulties without becoming frustrated.

4.4.3. Inconsistent requirements across locations

During the IR implementation, Optimize was surprised to find that even within a single district there was some variation in the way communes reported indicators. Small differences in reporting practice can present challenges to software applications. One example was the way that HepB and BCG birth doses were recorded. Some communes reported the birth doses of all the children in the commune regardless of where the immunization was administered, and others reported only those birth doses that were administered within the CHC. Resolving these types of reporting differences requires that: (1) someone discovers the differences, (2) program leaders communicate a clear direction, and (3) users comply with directions.

4.4.4. Long-term technical support needed

Implementation of software technologies such as the IR requires long-term technical support in order to be sustainable. Since the commune level has not yet used many information technologies, the NEPI structure does not currently provide information technology support at commune level. Providing more technical support to commune health workers would require significant commitment from the MOH to provide the budget and management guidance needed.

4.5. Next steps

The IR has had some level of success in the Mo Cay Nam district demonstration, especially among users with a medium to high level of comfort with computer and mobile phone technology. This system is quite forward looking, and Vietnam MOH has only just begun to build a strategy around electronic health information management. Individual registry software similar to what Optimize has demonstrated has applications beyond immunization—it can track women in antenatal care, children in the nutrition program, and patients on long-term care regimens such as tuberculosis and HIV treatment. The base application that was developed and the lessons learned could have a direct impact on Vietnam’s broader health system in the near future.

5. PASSIVE COOLING AT COMMUNE HEALTH CENTERS

5.1. Goal and rationale

Photo: PATH/Nguyen Phu Cuong

Optimize collaborated with NEPI to evaluate a new passive cooling technology that can function without electricity. The goal of doing so was to enable vaccines storage at CHCs all month along, instead of only during one to three days per month as is the current practice at most CHCs. More access to vaccines at the CHC might increase immunization rates, particularly the rate of on-time delivery of vaccines scheduled for the first day following birth.

Given the large number of CHCs in Vietnam (nearly 11,000) and the small population served at each center, it is neither practical nor cost effective to equip every CHC with its own vaccine refrigerator. In addition, sporadic power availability at many health centers would make electric refrigeration difficult in these locations. Using a monthly immunization day system, commune health workers have been able to deliver vaccines to an impressively high percentage of the population while bringing in vaccine stock for only one to three days per month. However, the immunization program is still striving to increase the on-time delivery rate of the first dose of HepB, which must be administered within 24 hours of birth to be most effective in preventing mother-to-child disease transmission. Optimize hoped that a passive-cooling technology for CHC vaccine storage that required no electricity and no maintenance could enable an increase in coverage of the critical HepB birth dose.

5.2. Implementation

NanoQ is a new device from US-based Savsu Technologies that uses state-of-the-art insulation materials and a unique configuration designed to maintain appropriate temperatures for vaccine storage without electricity. Optimize chose NanoQ because it can provide up to seven days of cooling between recharges at an ambient temperature of 32°C and recharging can be accomplished with normal ice available for purchase close to the CHCs.

The NanoQ was piloted in 12 communes within three provinces: Phu Tho (north), Quang Tri (central), and Ben Tre (south). The criteria used to select the communes included the number of births at the CHC, coverage of HepB birth doses given within 24 hours, and reliability of electricity.

The demonstration began in September 2011, and after a trial period to test stability of temperature performance, commune workers began to store vaccines in the container. Temperatures in the vaccine compartment and in the room where the NanoQ cold box was kept were monitored by electronic temperature recorders.

NEPI and PATH staff visited the communes approximately every three months to download data from the temperature recorders. In addition, after the stabilization period and at the end of the project, the research team collected information about acceptability of the device from the commune health workers.

5.3. Results

5.3.1. Temperature performance of NanoQ

The temperature performance of the NanoQ was good, generally maintaining temperatures between 2°C and 8°C. This was due not only to the performance of the NanoQ but also to the user compliance. Users were required to monitor the temperature daily and change the ice in the device when the thermometer indicated rising temperature in the vaccine compartment.

Table 4 below displays an analysis of the temperatures outside of the 2°C and 8°C range that the data loggers recorded. The amount of out-of-range time is shown in hours and as a percentage of total logged time. There are several points to note from this analysis. First is the near-absence of freezing temperatures. The one instance of freezing in Van Lung commune may have been due to a worker accidentally leaving the temperature probe outside the vaccine compartment after changing the ice. The second point to note is the considerably greater number of instances of temperatures below 2°C in Phu Tho and Quang Tri provinces compared to Ben Tre province. This is due to the lower ambient temperatures in the central and northern regions of Vietnam during winter months and is discussed later in this section. However, even though it was quite common in Phu Tho and Quang Tri for the vaccine compartment temperature to drop below 2°C, it generally did not drop far below this mark as indicated by the small number of hours with a recorded temperature below 1°C.

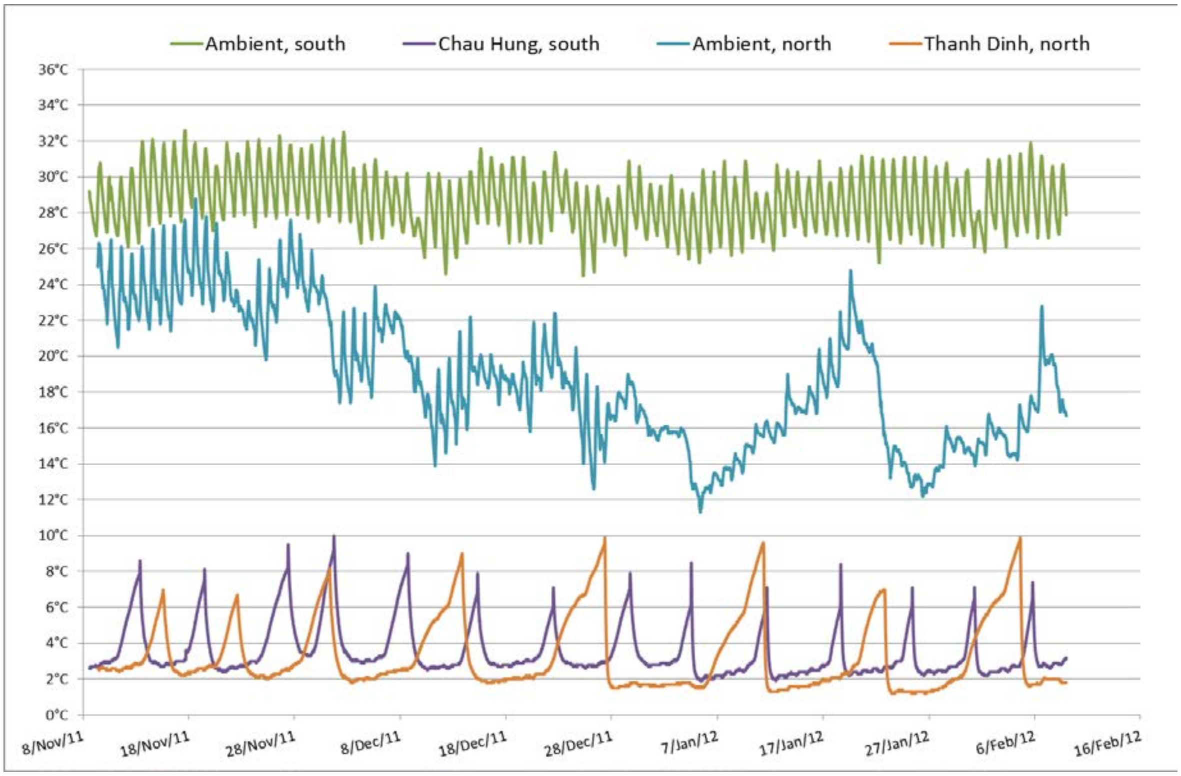
Looking at the number of hours with recorded temperatures above 8°C, the table shows that most communes had only a day or two of cumulative time in this range out of a total of eight months of monitoring in Ben Tre, and five months of monitoring in each of the other provinces. Several exceptions merit discussion. In Kim Duc commune, Phu Tho province, the logger recorded 455 hours above 8°C. About 340 hours of this took place over a two-week period during which no ice was maintained in the device. This was shortly before the discontinuation of the study in Phu Tho and Quang Tri—health staff may have been confused about the study instructions. In Vinh Kim commune in Quang Tri province, many of the 270 hours recorded above 8°C took place during two periods when the ice was apparently not replaced—an 11 day stretch in January 2012, which may have been deliberate; and a three-day period at the end of March, which may have been a compliance issue. Appendix A shows temperature traces for all communes over the full monitoring period.

Table 4. NanoQ vaccine compartment temperatures out of the 2°C to 8°C range

		Time above 8°C		Time below 2°C		Time below 1°C		Time below 0°C	
	Commune	**# of hours**	**% of total**	**# of hours**	**% of total**	**# of hours**	**% of total**	**# of hours**	**% of total**
Phu Tho	Van Lung	50.0	1.5%	955.3	28.8%	31.7	1.0%	11.3	0.3%
	Ha Loc	12.3	0.4%	772.7	23.0%	0	0%	0	0%
	Thanh Dinh	82.0	2.4%	677.3	20.2%	0	0%	0	0%
	Kim Duc	455.0	13.7%	81.0	2.4%	0	0%	0	0%
Ben Tre	Loc Thuan	22.7	0.41%	0	0%	0	0%	0	0%
	Chau Hung	30.0	0.54%	5.3	0.10%	0	0%	0	0%
	Thanh Phong	118.7	2.15%	27.0	0.49%	3.0	0.05%	0	0%
	Tan Phong	52.7	1.05%	0	0%	0	0%	0	0%
Quang Tri	Trieu Lang	0.3	0.0%	286.2	9.4%	5.0	0.2%	0	0%
	Trieu Son	2.3	0.1%	275.0	9.1%	0	0%	0	0%
	Vinh Kim	270.3	9.1%	252.0	8.4%	0	0%	0	0%
	Ben Quan	7.0	0.2%	384.7	12.8%	0	0%	0	0%

Starting in late November, demonstration CHCs in Phu Tho province in the north and Quang Tri province in the central region noted that vaccine compartment temperatures were dropping below 2°C. This was due to the low ambient temperatures that occur in the wintertime in these regions. Figure 5 below shows a comparison between a NanoQ in Ben Tre province in the south, where average ambient temperatures stay near 30°C all year, and a NanoQ in Phu Tho province. It is clear from this chart that as the ambient temperature drops below 20°C in Phu Tho, the NanoQ vaccine compartment begins to exhibit temperatures below 2°C. However, the temperature does not approach freezing, remaining well above 1°C. The periodic rise and fall of temperature in the vaccine container is due to the cycle of ice replacement and gradual melting over six to eight days. This figure indicates that the period between ice replacements is longer in colder ambient temperature than in warmer temperatures, as expected.

Figure 5. Comparison of the behavior of the NanoQ in cool and warm ambient conditions



5.3.2. On-time delivery of hepatitis B birth dose

Data collected during the longer demonstration period in Ben Tre province does not sufficiently support the project hypothesis that the use of NanoQ increases on-time delivery of the HepB birth dose. Several factors may have contributed to this finding:

- The number of births occurring at most of the CHCs was small and decreased as more mothers chose to deliver at district hospitals.
- Some CHCs were already making an effort to collect HepB vaccine for birth doses from the district before the intervention. Consequently, though NanoQ may have made it easier for health workers, it would not result in an increase in the on-time rate.
- All CHCs have small domestic refrigerators that are sometimes used for storing HepB vaccine for birth doses. In this case, again the presence of the NanoQ would not increase the HepB birth-dose rate, but the quality of storage would improve, as domestic refrigerators often operate with frequent periods of temperatures below freezing.

5.3.3. User acceptability of NanoQ

In May 2012, the Optimize team conducted acceptability and feasibility research. (Please see introduction to and evaluation scale for acceptability and feasibility research in Section 3.3.4.) Formal analysis of these data are underway and will be reported in the full-length Vietnam country report to be published by early 2013. Preliminary results for the NanoQ are reported here.

The eight respondents at commune, district, and province level interviewed about the NanoQ cold box reported that they found it either “acceptable” (6) or “very acceptable” (2) and “feasible” (6) or “very feasible” (2). Health workers listed several positive aspects of the technology, including the ability of the NanoQ to maintain safe temperatures and prevent freezing and the ease of managing and monitoring. Users also appreciated the fact that it does not require electricity. Several health workers expressed satisfaction with having a safe place to keep vaccines at the CHC between immunization sessions, and at least one worker mentioned that the NanoQ creates extra capacity in the cold chain. Some mentioned that it is a good size for CHCs, while others expressed concern that it is not big enough for larger communes or campaigns. In centers that provide frequent labor and delivery services, workers highly valued the ability to keep HepB vaccine on hand in the CHC. Most interviewees agreed that the NanoQ is a good fit for communes that have no specialized vaccine refrigerator and where electricity is poor, distances are far, and travel is difficult.

When interviewees were asked what aspects of the NanoQ were unacceptable, they mentioned the extra work required to change the ice, and one user mentioned the expense of extra petrol that is used to fetch ice. In Phu Tho province, it was noted that the ice supply is limited in winter when there is lower demand. In summer it is easily available, but higher demand makes it more expensive.

5.4. Challenges and informal learning

The biggest challenge for the NanoQ passive vaccine storage boxes were the low ambient temperatures in Phu Tho and Quang Tri provinces and the corresponding drop in vaccine storage temperature below 2°C. After careful analysis of the data, it is noted that the temperature did not drop very far below 2°C and the NanoQ provided good protection against freezing even in low ambient temperatures. After observing the low temperatures starting in November, PATH arranged for a laboratory test of the NanoQ at Seattle headquarters to see how it would perform when ambient temperature was held at 10°C for an extended period of time. The NanoQ was acclimatized in the environmental chamber set to 10°C, then loaded with ice and the temperature in the vaccine compartment was monitored over 25 days as the ice slowly melted. Results showed that the vaccine compartment temperature never fell below 1°C, so even in this cold condition, the NanoQ protected the contents well against freezing. Given these findings and the minor scale of the excursions below 2°C in the field, NEPI may want to consider the NanoQ as potentially acceptable even in cooler settings. Advice from WHO may be helpful in this matter.

5.5. Next steps

The NanoQ boxes situated in Ben Tre province in the south of Vietnam will continue to be used. NEPI will decide what to do with the boxes in the central and north regions, which were discontinued during the demonstration when temperatures dropped below 2°C in the vaccine compartment. There are at least three options for NEPI at this time:

- Reconsider the use of the boxes for year-round storage in north and central regions.
- Keep the boxes in north and central regions for use during warm months only.

- Move the boxes from north and central regions to the southern region and recommission them in appropriate commune locations there.

Large-scale purchase and distribution of additional NanoQ devices in Vietnam's immunization program in the short term is considered unlikely due to the high capital investment needed.

Optimize would like to encourage Savsu to consider submitting the NanoQ to WHO for prequalification as soon as the appropriate standards are published, expected later this year. The device has performed well in Vietnam and offers a number of benefits for specific settings in the immunization cold chain.

6. DIRECT-DRIVE SOLAR REFRIGERATORS

6.1. Goal and rationale

Photo: PATH/Nguyen Phu Cuong

Optimize collaborated with NEPI to determine whether direct-drive solar technology is a viable option for storing vaccines in different regions of Vietnam, in terms of equipment performance, cost, and available solar energy.

For years, solar refrigeration has helped developing countries to increase their cold-chain capacity while decreasing energy costs and consumption. However, the large batteries used to store energy for the night and cloudy days presented maintenance and cost problems that have inhibited faster growth of this technology in vaccine cold chains. To address these problems, manufacturers have created a new type of refrigerator that eliminates the need for a battery—the direct-drive solar refrigerator. Direct-drive solar refrigerators store energy in the form of ice in the cooling system, which provides the temperature control needed at night and other times of insufficient solar radiation.

Given the difficulty of reliable temperature control with liquefied petroleum gas and kerosene absorption refrigerators (the traditional technology of choice where grid energy is not available) and the continued cost reduction of solar panels, direct-drive solar refrigeration is poised to become increasingly important in developing country vaccine cold chains.

6.2. Implementation

The BLF 100 DC Sure Chill® vaccine refrigerator manufactured by True Energy was selected for use in the demonstration. Laboratory testing showed that it can successfully maintain a cabinet temperature in the range of 4°C to 7°C, and once its ice bank is fully charged, it can maintain that temperature for more than 10 days. At the beginning of the project, of the devices available, the Sure Chill had the largest vaccine capacity, was close to approval by WHO, and had the longest autonomy of any of the solar direct-drive refrigerators. (“Autonomy” describes the length of time that the refrigerator can maintain vaccine-safe temperatures with no or low solar input.) Long autonomy was important for the northern site in the Optimize in Vietnam demonstration. The Sure Chill was prequalified by WHO in September 2011.

Optimize installed and evaluated the Sure Chill refrigerator in two district preventive medicine centers (PMCs)—one in Phu Tho province (north) and the other in Ben Tre province (south). Each of the two power systems installed included two 235-watt power solar arrays, tilted at 21 degrees to the south in Phu Tho province, and 15 degrees to the south in Ben Tre province. At both sites the solar modules were installed on the roof, where there was no shading to interfere with solar collection.

Using digital loggers, the team monitored ambient and refrigerator temperatures, refrigerator energy consumption, solar radiation, and energy generated by the solar panels. The team visited the project sites approximately every three months, and used questionnaires to gather data related to the acceptability and cost of the technology.

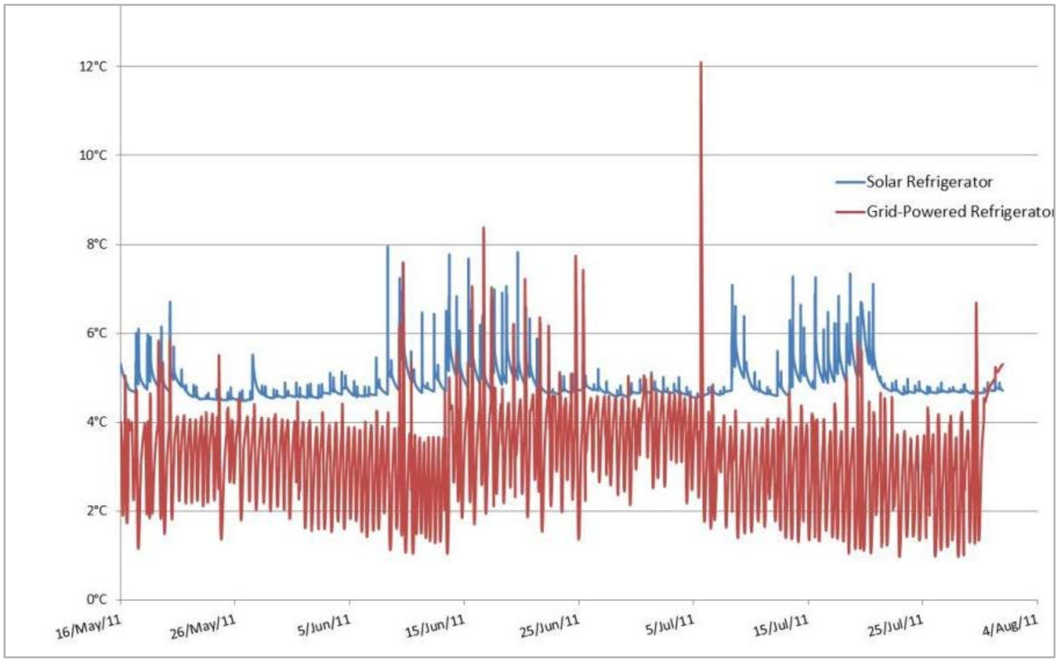
6.3. Results

6.3.1. Temperature performance of Sure Chill

The Sure Chill solar refrigerator maintains extremely stable temperatures. For the refrigerators in both the northern and southern provinces, the temperature recorded in the refrigerator center fluctuated only between 4°C and 5°C for most of the operating period of one year. When the door is opened, the temperatures increase more at the top front of the refrigerator cabinet than in the center or the bottom. Generally, when the refrigerator was closed, there was less than 0.5°C difference between the average temperature at the top of the cabinet and the average temperature at the bottom. For graphs showing the temperature recordings in both refrigerators during the project period, please see Appendix B.

The periodic temperature fluctuation in the Sure Chill is much less than that in typical grid-electric compressor refrigerators used for vaccine storage. Figure 6 compares the temperature performance of a solar refrigerator and a grid-electric vaccine refrigerator in Phu Tho. The Sure Chill was successful at maintaining the temperature between 2°C and 8°C over a long period.

Figure 6. Comparison of solar refrigerator and grid-electric refrigerator temperatures in Phu Tho



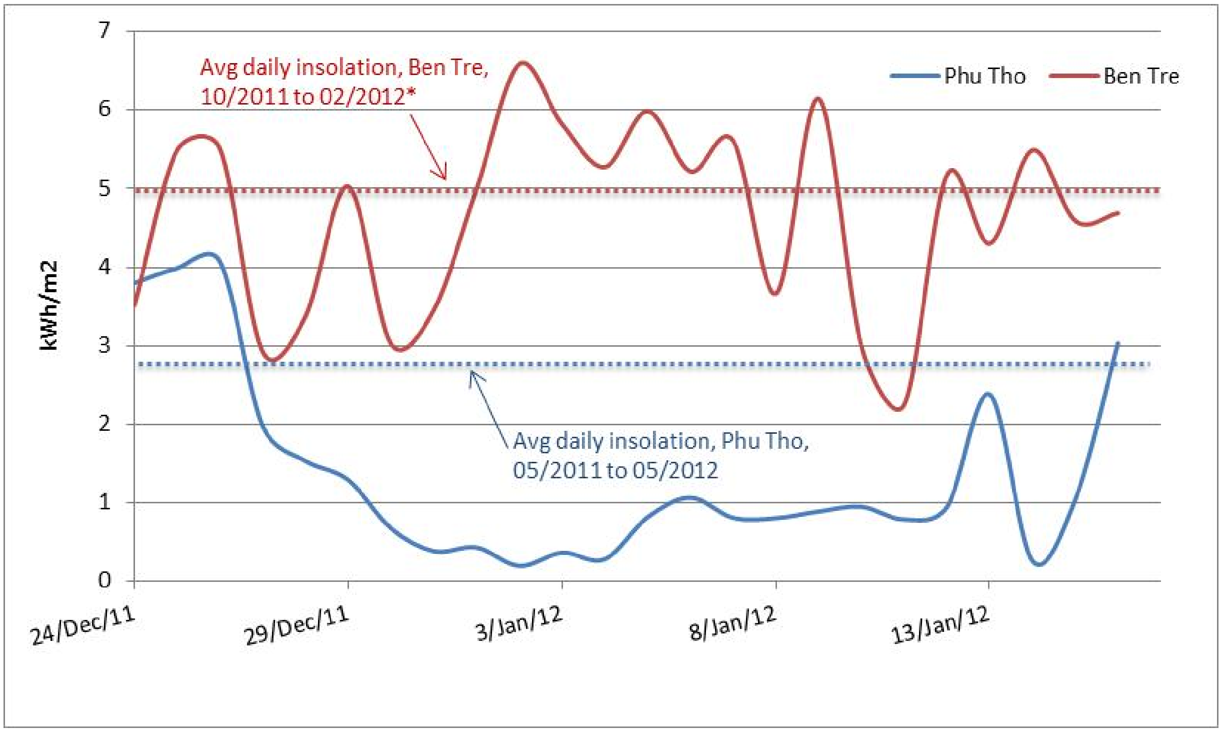
6.3.2. Performance in low-light conditions

"Insolation" is the technical term for incident solar radiation, or the amount of sunlight falling on a particular place at a particular time. At a cloudy location, insolation measured over time would be lower than that at a sunny location. For a direct-drive solar refrigerator, a certain minimum amount of insolation is needed in order for it to maintain proper temperatures in the vaccine compartment. This amount varies depending on factors such as the temperature in the room where the refrigerator is located and the amount of vaccine that needs to be cooled.

Periods of low insolation are commonly encountered from December through March in northern Vietnam. The average daily insolation measured over a one-year period in northern Phu Tho province was 2.8 kWh/m^2day. However, the winter average, measured from 1 December 2011 through 31 March 2012, was only 1.5 kWh/m^2day. Meanwhile, four months of winter insolation data in southern Ben Tre province averaged 5.0 kWh/m^2day (a clear sunny day will result in an insolation value around 6.0 kWh/m^2).

Prior to the demonstration, we did not know if there would be enough insolation in Phu Tho for the Sure Chill, but even through a two-week period of low-light conditions, the Sure Chill performed well, keeping temperatures in the safe range for vaccine storage. This is a very useful finding for other countries considering direct-drive solar refrigerators in cloudy locations, though it is noted that the cloudy period also coincides with significantly lower ambient temperatures, which lessons the cooling work the refrigerator has to do. Figure 7 shows the solar insolation measured in the north and the south over a three-week period that was particularly cloudy in Phu Tho. The dotted lines show the average insolation over a longer period for the two sites. For ambient temperatures, see the temperature charts in Appendix B.

Figure 7. Insolation measured at solar panels during three weeks in winter



6.3.3. System failures

Both solar refrigerators experienced major system failures in November/December 2011 and then again after the monitoring period, in summer and fall 2012. In most cases it was the compressor controller that failed, though in one case there was a failure of the compressor itself. True Energy is investigating the failures, and Optimize hopes that a solution will be identified soon. In the meantime, the demonstration in Vietnam has highlighted the importance of monitoring compressor performance and having spare controllers to replace the damaged ones.

6.3.4. User acceptability of Sure Chill

The Optimize team is analyzing the acceptability and feasibility data collected in May 2012 and will report the results in the full-length Vietnam country report to be completed by early 2013. (Please see introduction to and evaluation scale for acceptability and feasibility research in Section 3.3.4.) Preliminary results for the Sure Chill are reported here.

The four district- and province-level staff who were interviewed about the solar refrigerator categorized it as “highly acceptable” and “highly feasible.” At the national level, the one respondent interviewed about this intervention was more reserved, answering that the solar refrigerator is acceptable but at a low level. All respondents were asked what factors contribute to and what factors diminish the acceptability and feasibility of the solar refrigerator. Table 5 below lists the factors given by respondents.

Table 5. Solar refrigerator technology—acceptability and feasibility responses

Factors contributing to acceptability/feasibility	Factors opposing acceptability/feasibility
• Very stable temperature, which makes it secure for vaccines. • No freezing temperatures. • No need to worry about vaccines during power cuts. • Saves electricity cost. • Functions even in winter when the weather is cloudy (north).	• Too much condensation in the refrigerator, making everything in it very wet. • Difficult and scary to climb to the roof to clean the solar panels. • No one available with the right knowledge and experience to fix the refrigerator if it breaks. • Need more capacity at districts for campaign vaccines. • Price makes large-scale uptake of this technology unfeasible in Vietnam. • It is loud.

6.4. Challenges and informal learning

6.4.1. Fungus growth on vaccine boxes

In spite of the high acceptability reported by users in May, a problem arose in June, after the acceptability and feasibility data had been collected, that resulted in the removal of all vaccines from the solar refrigerators: fungus began to appear on vaccine boxes stored in both refrigerators. Since the heat and humidity in Vietnam is very high, condensation was constantly forming on all the cold surfaces in the refrigerator, including the vaccine boxes. The inside of the refrigerator was exposed to moist air from the room whenever the refrigerator was opened—at least twice daily for temperature monitoring and more frequently during vaccine distribution days.

Unacceptably wet conditions were observed in both refrigerators as soon as storekeepers began to store vaccines there in fall 2011. Water was pooling on the shelves and dripping down from above, completely soaking the vaccine boxes. So users removed the vaccines and stopped using the refrigerator while the manufacturer responded with a change of shelf design and the addition of a plastic piece that fits below the ceiling inside the refrigerator and directs water to the back and bottom of the refrigerator. These changes improved the management of the water, but less than two months later fungus appeared on the vaccine boxes (see Figure 8). NEPI requested that vaccines be moved out of the refrigerators again and Optimize is continuing to work with NEPI and the manufacturer to find a solution.

Figure 8. Fungus growth on vaccine boxes in solar refrigerators

Photo: NEPI/Nguyen Van Cuong

6.4.2. Technician support for refrigerator maintenance and repair

As reported in Section 6.3.4, one of the factors users listed that diminishes acceptability and feasibility of the refrigerators was the lack of knowledge and experience of local technicians with the equipment. The project team faced this challenge as well, which made it difficult to quickly repair refrigerators when they broke down. We relied heavily on the manufacturer to help in these situations. While they were very responsive, for larger projects in the future we recommend that local technicians be identified and trained so they can assist with technical issues.

6.4.3. Limited vaccine storage time

Another challenge of this demonstration was the relatively short period of vaccine storage in the refrigerators. Because it was important to first understand the temperature performance of each refrigerator before storing vaccines, we had a trial period at the beginning of the project during which we monitored refrigerator temperatures without the vaccines. Then, shortly after vaccine storage began, the fungus growth described in Section 6.4.1 emerged, resulting in the need to remove the vaccine and the need to again monitor temperature performance before returning the vaccines to the refrigerators. As a result, vaccines had only been stored in the refrigerators for a cumulative period of about three or four months when we collected our final data, and the fungus issue did not emerge until after the final monitoring visits. We recommend that future projects plan at least 18 months for refrigerator monitoring to allow for unexpected interruptions and to ensure that users can gain ample experience with the equipment during the project.

6.5. Next steps

The two refrigerators placed in Ben Tre and Phu Tho provinces by project Optimize will remain in the districts for use as NEPI leaders designate. The manufacturer will address the current issues with compressor controllers, condensation, and fungus. NEPI will not be expanding the use of this technology in the near future, primarily because recent investments have allowed them to purchase new refrigerators in most districts over the last five years, and there is currently no funding available for purchasing solar equipment. However, the experience with these direct-drive refrigerators has been valuable not only for NEPI but for potential users around the world, and NEPI will keep in mind the advantages of this equipment for future cold chain planning.

7. OTHER PROJECT ACTIVITIES

7.1. Effective vaccine management assessment

The Effective Vaccine Management (EVM) Tool was developed by WHO to provide countries a means for systematic assessment of vaccine management processes and to help them identify and focus on areas for improvement in their vaccine management performance. An EVM assessment uses a structured questionnaire to evaluate countries' supply chains at different levels using specific criteria based on good storage and distribution practices. The tool also can be used as a supervisory aid to monitor and support individual facilities on a regular basis.

Optimize conducted an EVM assessment in 2009 as part of the first phase of the project in Vietnam. In 2012, NEPI carried out a follow-up EVM assessment to evaluate the effect of the system-strengthening activities like those described in Section 7.1. The results reveal that key improvements have been made since the 2009 assessment. For example, at the national level NEPI made significant improvements in procedures for vaccine arrival, stock management, and distribution. The national store now meets the WHO-recommended target of 80 percent in all criteria compared to only two of nine criteria that met 80 percent in 2009. At the provincial level, results are strengthened for most criteria, most notably in vaccine management and storage capacity. Like the 2009 assessment, the recent EVM assessment has been a useful mechanism to help identify opportunities for improvement so that NEPI can prioritize and direct resources and training to strengthen the vaccine management system.

Key recommendations of the 2012 assessment include the following:

- Integrate the EVM Tool into regular EPI supervision at all levels, urging managers to reinforce and regularly check on areas identified as needing strengthening.
- Improve temperature monitoring by upgrading the monitoring equipment for vaccine refrigerators, cold rooms, and refrigerated trucks at national, regional, and provincial level with devices capable of continuous temperature monitoring.
- Raise awareness of the importance of freeze prevention for vaccines, retrain staff in the "shake test" for detecting freeze damage to vaccines, and provide freeze indicators for district-level refrigerators and for transport between province and district.
- At district level, improve the timeliness of repairing broken cold chain equipment.
- Disseminate all SOPs to all levels so that staff are provided with specific and clear guidelines on vaccine management practices.

Trainings conducted by the Optimize consultant on developing and disseminating SOPs have provided NEPI staff with the skills and knowledge they need to confidently administer improvement activities in the EPI system. In 2012, NEPI staff managed the EVM assessment and conducted assessment visits. Their ownership of the EVM assessment process as well as the results leave NEPI in a good position to make the best use of the tool.

Summary reports of the 2012 EVM assessment in both Vietnamese and English are available from NEPI by request.

7.2. Strengthening the development and dissemination of standard operating procedures

One of the key findings of the first EVM assessment performed in 2009 in Vietnam was that NEPI should develop a well-documented system of high-quality SOPs for vaccine management at every level. Based on the EVM results, NEPI prioritized eight procedures for developing written SOPs. International cold chain management consultant Andrew Garnett conducted a two-day training with a group of national- and regional-level staff on best practices in the development and dissemination of SOPs. NEPI then worked to develop the content of the SOPs, and used a workshop setting to invite detailed input and feedback on each SOP from regional and selected provincial EPI staff. The SOPs were then published in a booklet and distributed to all EPI centers from regional to district level. NEPI will conduct training of trainers sessions over the following months to disseminate the revised SOPs.

The following is a list of the SOPs completed under this program:

- Vaccine arrival at national level.
- Vaccine arrival and distribution at regional level.
- Vaccine arrival and distribution at provincial and district level.
- Vaccine storage in cold room.
- Vaccine storage in refrigerator.
- Loading vaccine into vaccine carrier.
- Vaccine storage during immunization session.
- Maintenance for vaccine refrigerator and freezer.

7.3. Encouraging vaccine vial monitor adoption

VVMs were developed in the early 1990s by PATH in collaboration with a temperature-indicator company, Lifelines Technology (now Temptime). VVM is a small label used on a vaccine vial that indicates how much heat exposure the vial has sustained over time. Instructions for using the VVM are shown in Figure 9 below. VVMs are extremely useful in circumstances when the cold chain has been compromised during transit or due to a power outage—it takes the guesswork out of assessing how much heat exposure is too much and it can prevent unnecessary wastage as well as ensure that vaccines are effective when administered.

Figure 9. Example vaccine vial monitor (VVM) instruction for use

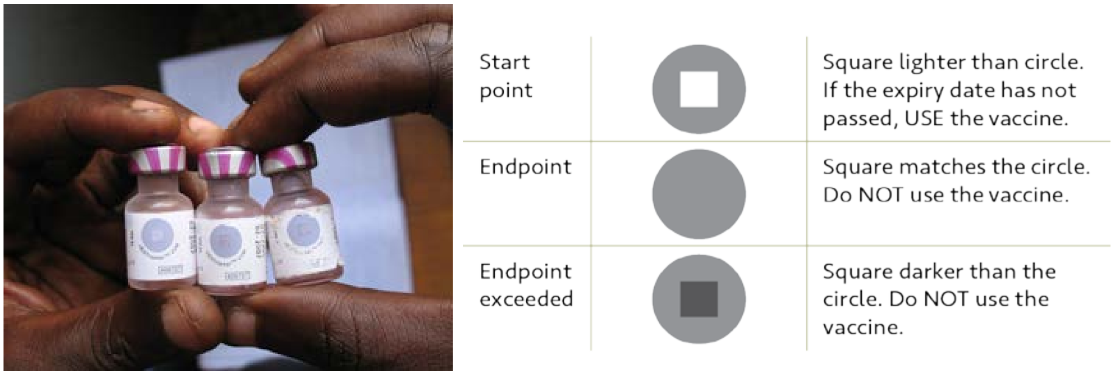


Photo: PATH

VVMs were first used in 1997, and their adoption has been increasing ever since. However, up until now, domestic manufacturers in Vietnam have not used VVMs. Since most vaccines used in the Vietnam's immunization program are domestically produced, this prevents Vietnam EPI health workers from benefitting from VVMs. Also, since VVMs are required by the United Nations Children's Fund for international vaccine procurement, the absence of VVMs prevents Vietnamese manufacturers from exporting product to other countries.

Because of the advantages to the supply chain management of vaccines, Optimize was eager to help support adoption of VVMs by a Vietnamese vaccine manufacturer. Activities supported by the project included organizing a national workshop and contracting for technical support to the manufacturer, Polyvac. Polyvac also obtained a donation of the VVM labeling equipment from the Japan International Cooperation Agency. Optimize cost analysis shows that VVM use can result in modest savings for higher-cost, relatively heat-stable vaccines such as pentavalent. However, in modeling scenarios that would result in the large-scale wastage of vaccine without VVMs, the model indicates significant savings when VVMs are added because the model assumes that not all the vaccine would reach their heat exposure limit under those circumstances. Examples of this scenario include national disasters that result in widespread and long-lasting power outages.

In addition to cost savings, VVMs can enable improvements in vaccine coverage by allowing workers to remove vaccines from the cold chain for certain types of immunization outreach. For instance, by using VVMs, health care workers can keep HepB birth doses at CHCs for several days without cooling, which allows vaccine access immediately after the birth of babies delivered at CHCs or in homes. In 2005, PATH and NEPI piloted this model for HepB vaccine delivery in Thanh Hoa province and showed an increased rate of HepB birth dose immunization and positive safety and immunogenicity outcomes.[iii] However, this model for vaccine delivery cannot be safely implemented without the use of VVMs on vials.

[iii] PATH. Out-of-cold chain delivery model for hepatitis B vaccine birth dose in four districts in Vietnam. Manuscript in draft.

Though Polyvac has put in place VVM application equipment and received technical support, during early trials they still had several technical challenges with applying VVM stickers. In addition, the MOH has not prioritized VVMs as important in their procurement of vaccines. If Vietnam EPI is to benefit from VVMs, then more support is needed to move this initiative forward.

8. DISCUSSION

8.1. What were the most important lessons learned?

8.1.1. Plan more time for in-country technology demonstrations

All our demonstrations could have benefitted from more time to allow users to move beyond the learning curve and benefit from the lessons that come later in the life of technology use. We intended to have all our interventions in place by mid-2010, but various delays in the startup phase, the slow process of collaborative development, and the heavy load of demonstrating four different technologies all resulted in delays so that the earliest intervention was not launched until May 2011, and the latest were not in place until early 2012. All final data collection took place from May to September 2012, so in some cases, we had only a few months of use on which to base the results of these technology demonstrations—certainly not enough time to take in all the lessons that could be gleaned from real-use demonstrations.

8.1.2. Though Optimize is focused on the future, NEPI has to focus on today

Though project Optimize had the luxury of looking into the future for inspiration, the solutions that we brought to NEPI had to have some relevance in today's world. Interacting with a real-life immunization program, in a country as big as Vietnam, we learned that there was little opportunity to try to operate outside the regulations and norms of the current system. This was seen, for example, when the temperature of the NanoQ cold box began to drop below 2°C. NEPI is in no position to take on what they perceive as risks to the Vietnamese immunization program in order to indulge the project. Luckily, however, we were also able to offer a number of technologies that NEPI could use for dealing with today's challenges. For this reason, it was good that project Optimize selected countries like Vietnam, with strong and growing immunization programs (e.g., NEPI introduced pentavalent vaccine during the project term and is preparing a GAVI Alliance application for measles-rubella support as we close).

8.1.3. Country leadership needs to be prepared for challenges as well as successes

Testing new technologies is exciting, but it can also be frustrating if you forget that this type of work often results in failures along the road to success. Designers and engineers who do product development are used to this process of iteration and learning from the errors they make along the way. But in any country, MOH immunization programs expect their systems to work and can be discouraged and embarrassed when problems crop up. For this reason, it is important to make sure that the national partner's leadership is prepared for some unexpected challenges along the way and that regular communication continues about this aspect of technology demonstration.

8.1.4. Software systems required more training and support than originally planned

The original plans to conduct user training and then launch into a monitoring phase did not provide enough support to the users since they had to learn new software programs that required significant changes to their work. Luckily, Optimize was flexible enough to be able to respond to the apparent need, and we conducted additional training sessions, convened user meetings, and provided extra user support so that immunization workers could, in most cases, become proficient in the software. Of course, there was wide variation in computer skills and experience across the user community, and not surprisingly, some individuals were better able to master the process than others. The implementation might have been smoother if we had included an IT professional on the project team to help better evaluate deliverables from the software developers and participate in design and troubleshooting. Also, it would have been better for users if the project had provided strategically located IT staff at field sites to support users on an ongoing basis.

8.1.5. Leveraging local service providers can pay off

Project Optimize was able to identify strong providers of software development and solar installation services that were based in Vietnam. These were identified through careful procurement processes, with clearly identified needs and scopes of work, and a bidding process that sought proposals from multiple providers. There are several benefits of using local providers, where available:

- Language and cultural barriers are lowered—these providers can easily communicate directly with users, NEPI staff, and interfacing organizations. This greatly reduces the chances of miscommunication, which can hinder international projects.
- In the case of the software providers, they could be directly involved in user interaction including training and project monitoring, which can increase the quality of the training, and also provide feedback to the developer, which helps with bug resolution and functional software adjustments.
- NEPI can maintain access to these providers after the project finishes. Since the providers remain in Vietnam, and a relationship has been established between them and NEPI, it is easier for NEPI to access them later for project upgrades or additional services, helping to build sustainability into the project.

On the other hand, the team did struggle at times in the selection and management of the software providers. Because we lacked experience and technical knowledge related to software development, we were sometimes unsure what to expect of the contractors and how to evaluate the quality of their deliverables. As mentioned above, the inclusion of an IT professional on our team could have improved this aspect of the project.

8.1.6. Benefits of pilot projects are sometimes hard to measure

With the software implementations, Optimize had hoped to demonstrate improved report accuracy, increased timeliness of reporting, and decreased work burden on users, but these aspects of the technology are hard to measure in an objective, quantitative manner. It was not possible in our study to draw many conclusions from the data we collected in these categories. For future projects, more consideration should be given to showing these aspects of software technology impact.

8.2. Effects of project Optimize on Vietnam's immunization program

As a result of working with project Optimize, NEPI has experienced several benefits:

- NEPI has been able to appreciate the positive impact that a well-built software program could have on the information system management within their program. NEPI relies on reporting of a great deal of information from all over the country, and there are some distinct advantages of digitizing this information. However, to make sure it was done correctly, the effort needed investment and oversight. Optimize was able to contribute a critical mass of capital and international expertise while leveraging highly skilled software development resources within Vietnam to bring success to this effort. The VaxTrak system in particular is well poised for successful expansion if additional investment can be identified.
- NEPI has gained experience with a few different types of cooling technologies, and due to temperature monitoring results, has a clearer vision of temperature conditions in the cold chain. It has learned the value of continuous temperature monitoring and the importance of freeze-prevention. Because the immunization program is administered all the way out at the commune level, NEPI was already aware that different locations face different challenges, and when it comes to cooling equipment, one size does not fit all. NEPI now has first-hand experience with solar direct-drive as well as passive-cooling equipment, and has some ideas of the pros and cons of each, as well as those of traditional electric vaccine refrigerators. This can help NEPI as it evaluates different possible technologies for future investments in the cold chain.
- NEPI has taken advantage of the opportunities that Optimize has presented by using the EVM Tool to conduct two EVM assessments—the second was self-driven. This strengthened staff knowledge and practices system-wide through the development of new SOPs for key vaccine management processes. Also, it boosted freeze-prevention awareness and led to an upgraded temperature monitoring system at the national, regional, and provincial cold stores.

9. CONCLUSION

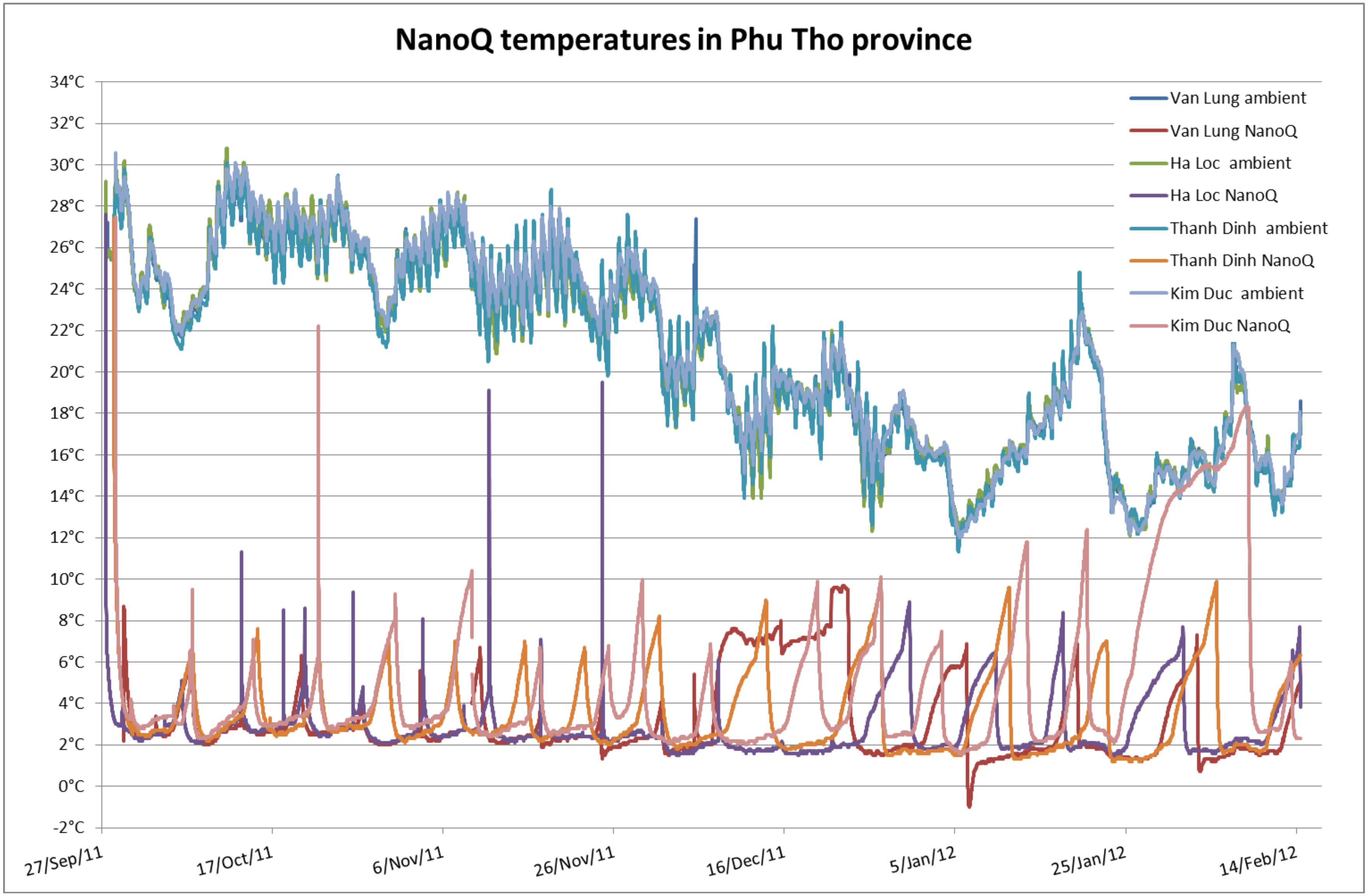
NEPI in Vietnam has been an extremely strong partner in project Optimize's global quest to explore the immunization systems and technologies for tomorrow. The work we have done has yielded valuable lessons about several different classes of new technologies. Thanks to NEPI's commitment and diligent work over the last three years, we have together accomplished the following:

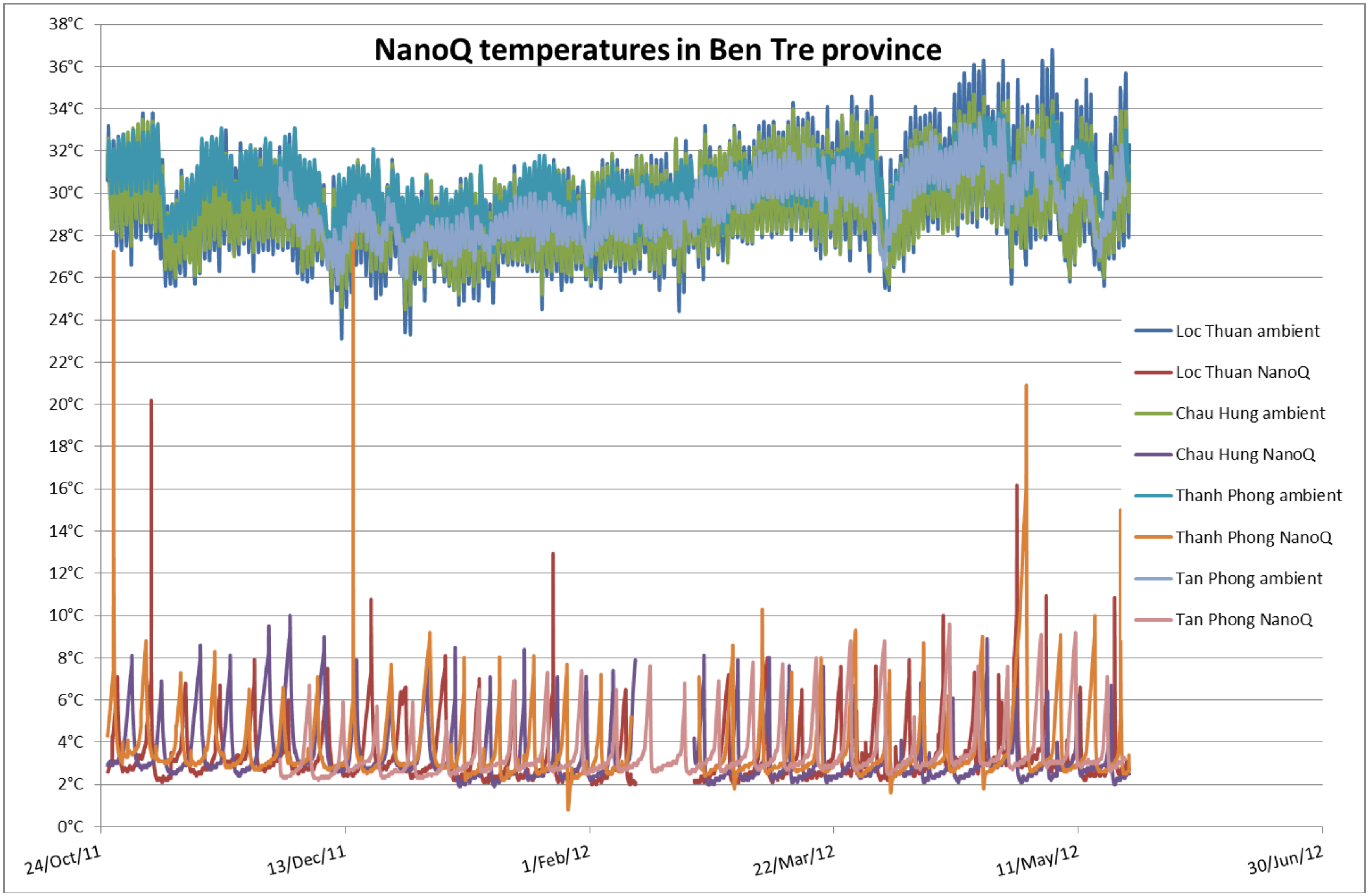
- We have opened the door to the future of electronic data management for NEPI's stock management and monthly reporting systems, as well as immunization registry data. The software solutions we have demonstrated have strong potential for scale-up.
- We have shown that one direct-drive solar refrigerator has extraordinary capability to perform under poor solar conditions, as well as uncovering a serious defect in the electronics of the refrigerator, the resolution of which will improve the device for future users in other countries.
- We have built capacity among the national and regional program staff for cold chain system assessment as well as individual intervention monitoring and evaluation. These skills will serve the program well in the future.

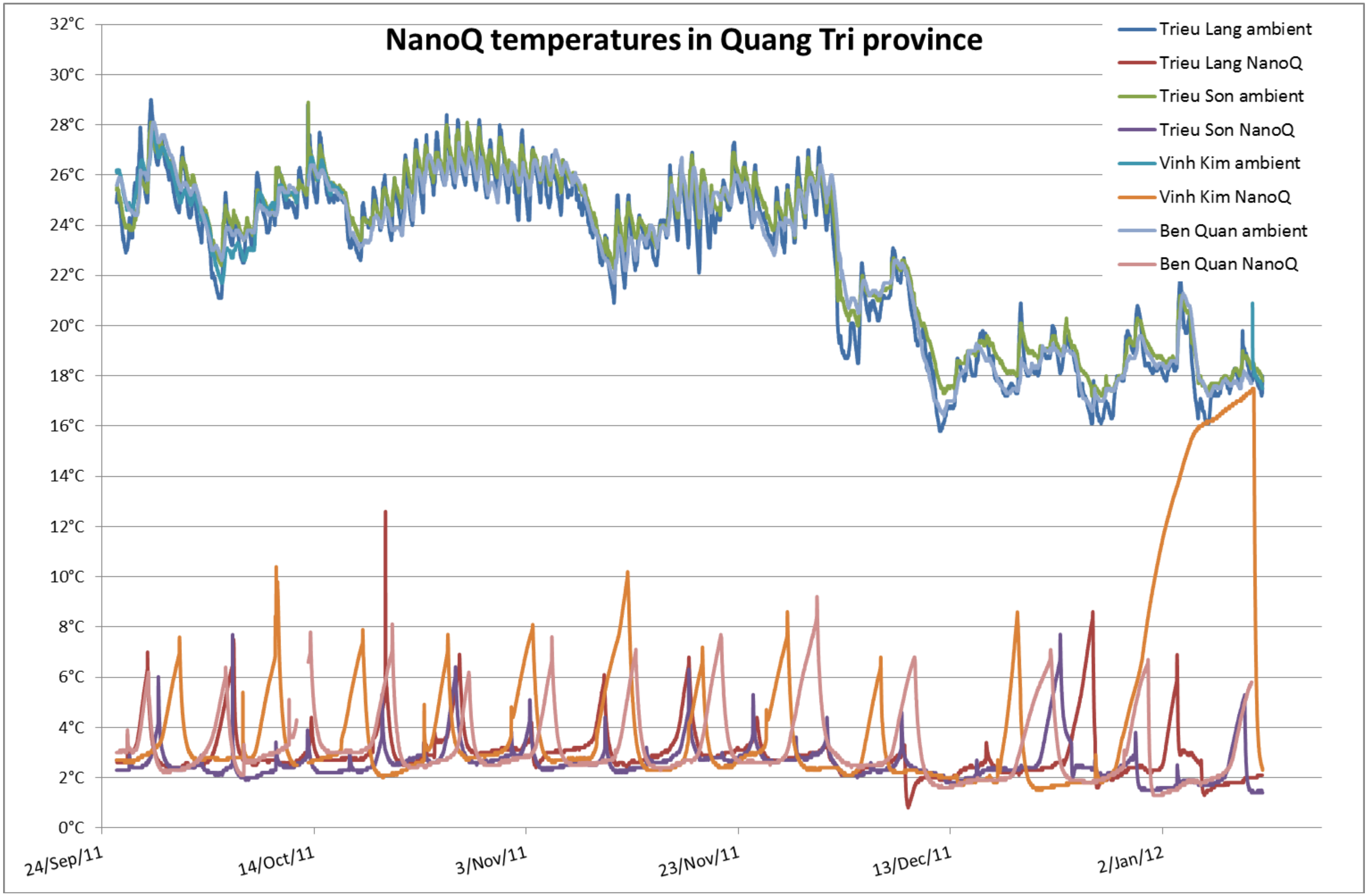
In most cases, the users interacting with the Optimize technologies at all levels were very open to participating in the demonstrations and could recognize the benefits that we were trying to evaluate. They demonstrated dedication to the project protocols, collected valuable data, and provided thoughtful feedback. The project team is extremely grateful for the commitment and time devoted by these individuals.

As NEPI continues their journey into the future, which surely holds a fair mix of promise and challenge, we hope that the experience and skills they have gained will serve them well and that the lessons learned here will propagate, benefitting not only the immunization system of Vietnam, but of many countries around the world.

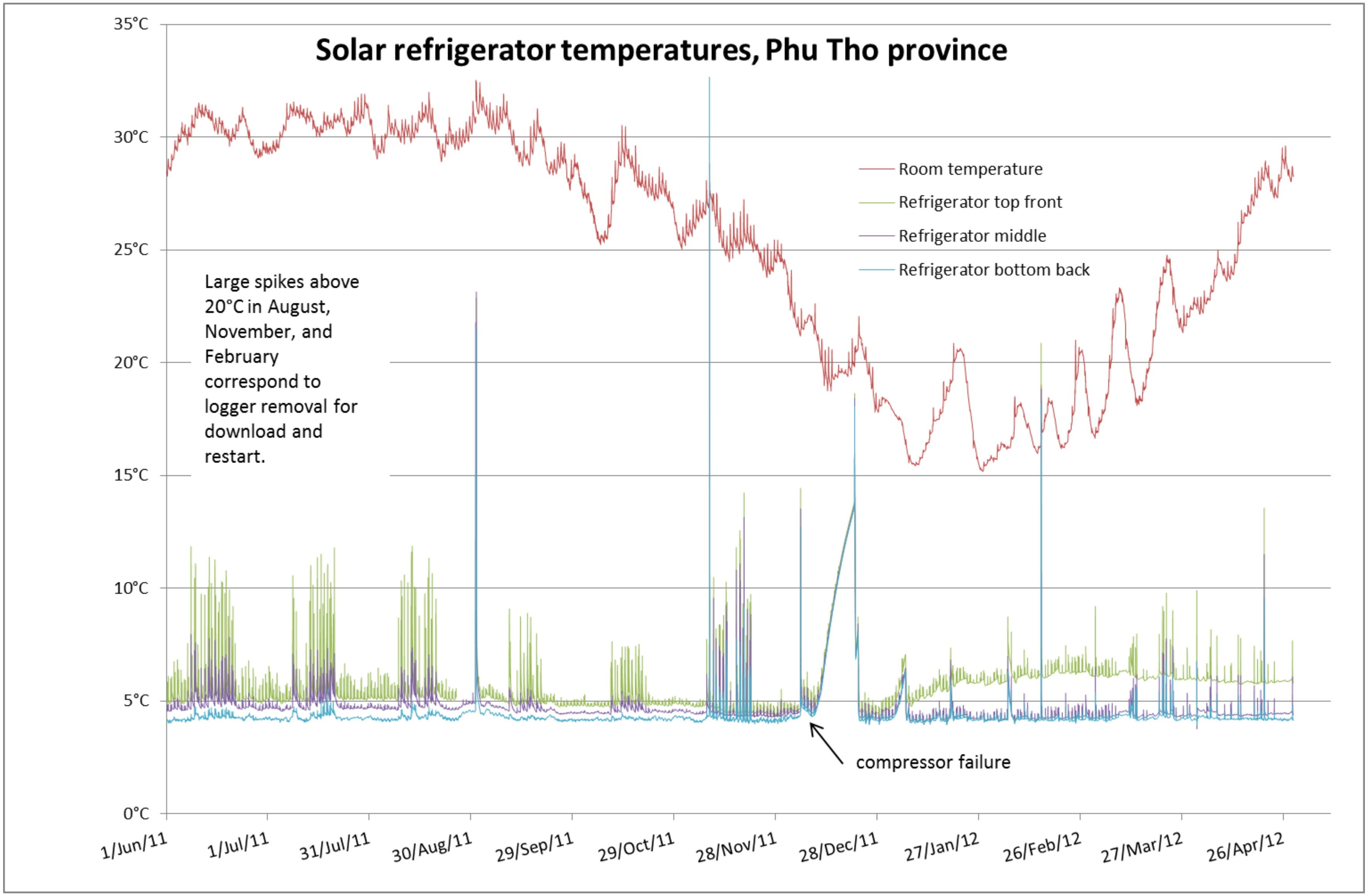
APPENDIX A. TEMPERATURE RECORDINGS FROM SAVSU NANOQ PASSIVE VACCINE COOLERS

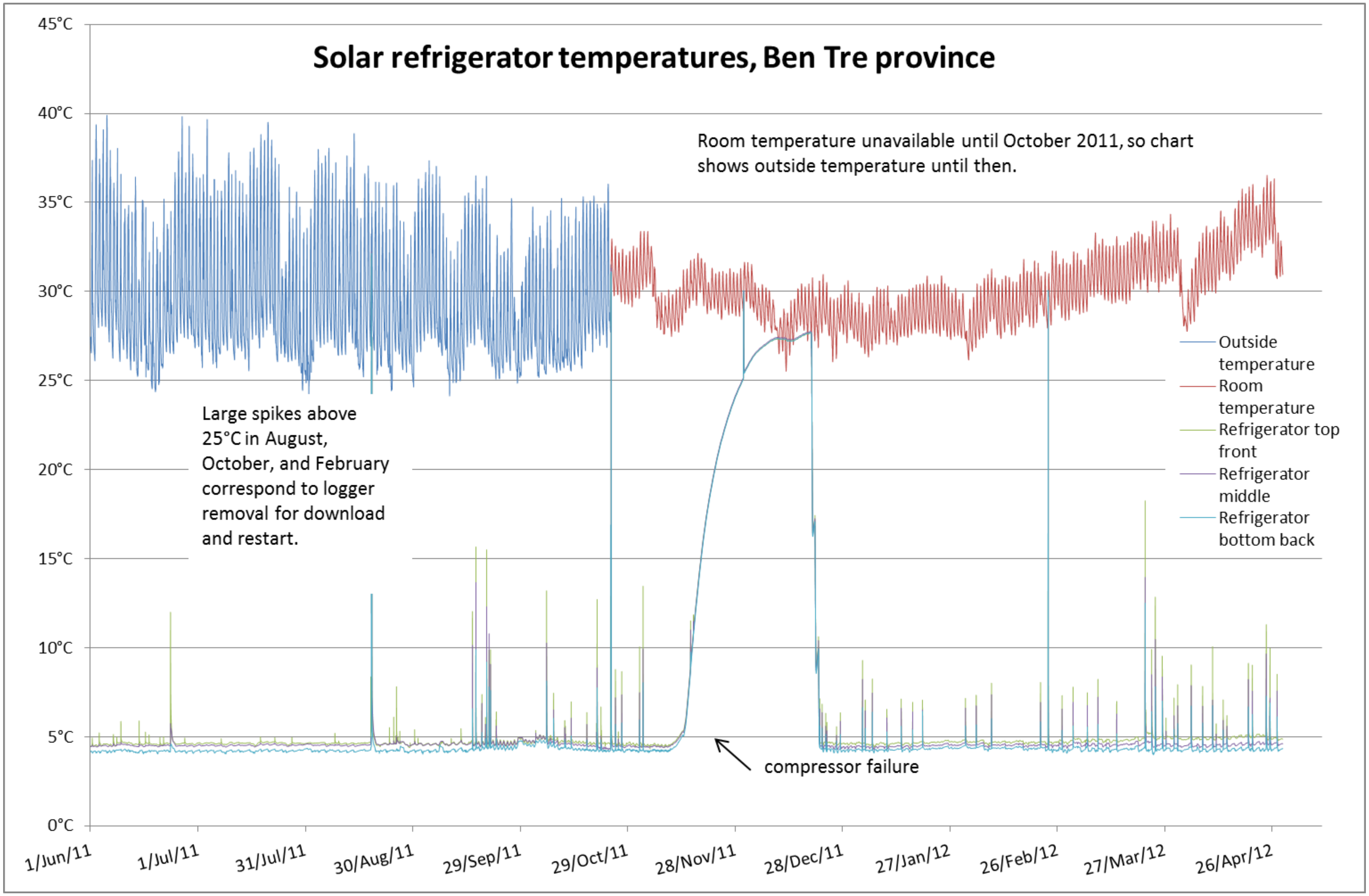



NanoQ temperatures in Ben Tre province
38°C
36°C
34°C
32°C
30°C
28°C
26°C
24°C
22°C
20°C
18°C
16°C
14°C
12°C
10°C
8°C
6°C
4°C
2°C
0°C
24/Oct/11
13/Dec/11
1/Feb/12
22/Mar/12
11/May/12
30/Jun/12
Loc Thuan ambient
Loc Thuan NanoQ
Chau Hung ambient
Chau Hung NanoQ
Thanh Phong ambient
Thanh Phong NanoQ
Tan Phong ambient
Tan Phong NanoQ


NanoQ temperatures in Quang Tri province
32°C
30°C
28°C
26°C
24°C
22°C
20°C
18°C
16°C
14°C
12°C
10°C
8°C
6°C
4°C
2°C
0°C
24/Sep/11
14/Oct/11
3/Nov/11
23/Nov/11
13/Dec/11
2/Jan/12
Trieu Lang ambient
Trieu Lang NanoQ
Trieu Son ambient
Trieu Son NanoQ
Vinh Kim ambient
Vinh Kim NanoQ
Ben Quan ambient
Ben Quan NanoQ

APPENDIX B. TEMPERATURE RECORDINGS FROM SOLAR REFRIGERATORS




Solar refrigerator temperatures, Ben Tre province
45°C
40°C
35°C
30°C
25°C
20°C
15°C
10°C
5°C
0°C
Room temperature unavailable until October 2011, so chart shows outside temperature until then.
Large spikes above 25°C in August, October, and February correspond to logger removal for download and restart.
compressor failure
Outside temperature
Room temperature
Refrigerator top front
Refrigerator middle
Refrigerator bottom back
1/Jun/11
1/Jul/11
31/Jul/11
30/Aug/11
29/Sep/11
29/Oct/11
28/Nov/11
28/Dec/11
27/Jan/12
26/Feb/12
27/Mar/12
26/Apr/12