Achieving Effective Sharps Waste Management In GAVI Host Countries

A Proposed Approach with Estimates of Costs

Prepared for the Bill & Melinda Gates Foundation
By Program for Appropriate Technology in Health (PATH)

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Selected Acronyms and Definitions

AD: Autodisable
CDC: United States Centers for Disease Control and Prevention
DALY: Disability-Adjusted Life Year
HBV: Hepatitis B Virus
HCV: Hepatitis C Virus
HCW: Health Care Worker
HSS: Health System Strengthening
GAVI Global Alliance for Vaccines and Immunization
LMP: Lead Managing Partner
MOH: Ministry of Health
NGO: Nongovernmental Organization
PEPFAR: President's Emergency Plan for AIDS Relief
SIGN: Safe Injection Global Network
SOP: Standard Operating Procedures
TB: Tuberculosis
UNEP: United Nations Environment Programme
UNICEF: United Nations Children's Fund
USAID: United States Agency for International Development
WHO: World Health Organization.

Regions include:

- **AFR**: Africa
- **AMR**: Americas
- **EMR:** Eastern Mediterranean
- **EUR:** Europe
- **SEAR:** South East Asia
- **WPR:** Western Pacific

Sub-regions (A,B,C,D,E) are in parentheses.

Executive Summary

Each year, approximately 1 billion injections are given for immunizations in developing countries, from a total of 16 billion injections across both the curative and immunization sectors. Because needles and syringes are often exposed to bloodborne pathogens, they carry the risk of transmitting infection if they are reused or discarded in an unsafe manner that can cause injury. This risk creates a significant public health burden: an estimated 21 million hepatitis B infections, 2 million hepatitis C infections, and 260,000 HIV infections are inadvertently caused by infectious sharps waste each year.[1] Global attention to this issue can reduce these infections by improving sharps waste management systems.

A proposed approach to achieving effective sharps waste management

This exercise examines the impact that GAVI's facilitation and support of sharps waste management practices would have in member GAVI countries. The analysis is based on activities involving the best and most practical options for meeting acceptable standards and practices of sharps waste management using available or emerging technologies and a standardized classification of various infrastructure settings. The activities would seek to reduce disease burden from contaminated sharps waste by moving toward safer practices that effectively contain sharps and destroy waste.

This coordinated set of activities would include:

- Providing generic guidelines for management of sharps waste that are applicable and adaptable to different conditions.
- Developing a toolkit that would enable countries to assess their own waste-management situations and plan waste-management systems.
- Conducting regional- and country-level advocacy and planning for GAVI's support of sharps waste management.
- Providing countries with technical assistance in assessment, proposal development, and project implementation, where needed.
- Setting up systems for monitoring and evaluation of country-, regional-, and global-level waste management systems.

This set of activities would be expected to lead to the implementation of comprehensive waste management systems, including deployment of selected technologies, coupled with logistics, training, and maintenance programs.

Performing the analysis

The analysis determines the cost-effectiveness of implementing waste management systems in four infrastructure settings: urban with infrastructure, urban with low infrastructure, rural with infrastructure, and rural with low infrastructure. A decision tree framework was employed to map disposal pathways. Risk factors were assigned to each disposal pathway, depending on the risk that the pathway imposes on patients, health care workers, and communities. Because sharps waste management solutions involve system changes and technology deployment that impact all sharps waste within a health facility, costs were calculated for both immunization and curative injections. The premise for GAVI's role would be to catalyze and facilitate a wider investment in sharps waste management from other donors and developing-country governments.

The analysis takes a total cost approach that estimates the total current spending on waste management in 2006 (baseline costs) as well as the total cost of introducing the proposed new interventions from 2007 to 2015 (total costs) to arrive at incremental costs. Costs include both capital and recurrent expenditures calculated at assumed utilization levels for the equipment. The costs for each developing country were calculated and then averaged for each World Health Organization region (excluding the high-income countries) to match impact data, which was estimated only at the regional level.

The potential impact of sharps management interventions

The results show that the adoption of sharps waste management interventions that contain and destroy sharps waste could be considered a cost-effective intervention. The baseline costs for current sharps waste disposal interventions in 2006 are estimated to be approximately US$0.01 per injection. With reasonable levels of adoption of the proposed interventions, about US$0.04 per injection would be required by 2015. Assuming eight immunization injections per infant in the first year of life, US$0.31 per infant would be required in 2015 for appropriate management of sharps waste. In exchange for this investment, the global health community would achieve significant health impact: up to 25 million DALYs avoided through improved injection safety. These findings—and those generated by refining and adapting the model for select countries or regions—could be used to heighten global commitment to sharps waste management and help establish sustainable financing commitments from partner agencies that focus on other aspects of global health, such as HIV/AIDS, tuberculosis, malaria, or essential drugs.

Achieving GAVI's objectives

Interventions like autodisable syringes, which are intended to achieve the objective of a sterile syringe for every injection, are bringing about a significant improvement in safety. However, they are also causing a large increase in potentially infectious sharps waste due to their single-use nature and the need to dispose of every one. An investment in sharps waste management is a critical component of injection safety and GAVI's priorities for injection safety.

Management plan

A lead managing partner would organize and implement the proposed activities in close collaboration with the GAVI Vaccine Fund, bilateral and multilateral agencies, government ministries, nongovernmental organizations, and equipment manufacturers. The sustainability of safe waste handling and disposal systems would be addressed in both managerial and financial terms, and the project would include a robust monitoring and evaluation plan for country implementation activities.

Given the magnitude of the problem of sharps waste management, for the purpose of this analysis, the model intervention is based on implementation in all GAVI countries. It is assumed that GAVI would develop criteria for scaling their investment, according to available funds and various criteria.

The anticipated duration for this investment is nine years (2007–2015). The budget for global-level management and technical assistance is approximately US$10,000,000 for the first five years. Separately, the estimated budget for full implementation of safe sharps management systems in all 72 GAVI countries (in both immunization and curative sectors) is estimated to be US$1,840,600,000. It is anticipated that most of these funds will be derived from a mixture of nationally allocated funds, other global initiatives involving use of sharps, investment in specific countries by GAVI partners, and other projects funded by other donors. GAVI's role is viewed as catalytic and facilitative, stemming from the key activities described in this program and from active solicitation of support from other global initiatives.

GAVI's role

Sharps waste management should be an integral component of GAVI's effort to make immunizations safer. By focusing on safe disposal of immunization-related sharps waste, GAVI would be in a unique position to stimulate and build consensus on global- and country-level waste management policies, strategies, and priorities, and to catalyze other parts of the public health system. GAVI could instigate a major and rapid improvement in the management of sharps waste, thus improving safety for patients, health care workers, and communities.

Part I. A Proposed Approach to Achieving Effective Sharps Waste Management

Section 1. Objective

The World Health Organization's (WHO) Safe Injection Global Network (SIGN) has delineated three primary components to achieving injection safety: (1) behavior change, (2) provision of safe injection supplies, and (3) implementation of sharps waste management systems. While GAVI's past activities have greatly augmented the first two components of this strategy, the waste management component is only now being addressed. Because system changes to improve sharps management affects all injections administered within a facility, this exercise examines the costs and impact of adopting safe sharps waste management systems for both immunization and curative sharps waste within all GAVI countries. Since the costs of establishing safe sharps waste management must be borne by all programs involving injections, and ultimately by the countries themselves, the minimum contribution from GAVI is estimated for catalyzing and facilitating safe sharps waste management in GAVI member countries. The analysis of costs and benefits shows that GAVI's investment in the management of sharps waste—primarily used needles and syringes—would increase the safety of patients, health care workers, and communities at a cost of less than US$.04 per injection by 2015.

The analysis is based on activities involving the best or most practical options for meeting acceptable standards and practices for sharps waste management, using available or emerging technologies. The analysis focuses on immediate implementation of solutions that are currently available. It also assumes that new technologies for sharps waste management will be available in the next one to five years and incorporates these into longer-term planning. The program used as the basis for this analysis is described in Section 3.

The problem of sharps waste extends far beyond immunization services. GAVI has a vital role to play—first, to address the immediate problem in countries requesting assistance and, second, to catalyze and motivate the participation of other parts of the public health system. This will ensure that the entire primary health system benefits and also shares in the cost.

Section 2. Description of the Problem

2.a. The Hazard of Sharps Waste

Each year, more than one billion injections are given for immunizations in developing countries, accounting for an estimated 5 to 10 percent of the 16 billion injections given per year.

The syringes and needles that are used to give these injections are frequently exposed to blood-borne pathogens. Contaminated syringes remain infectious after use and easily transmit infection through intentional reuse or accidental needlestick injury. Prompt and safe disposal, particularly of the needle, is a critical safety procedure for any injection.

Inadequate disposal has three negative consequences:

- Infection: The safety of many individuals—health care workers, clients, and members of the community—is compromised by the increased risk of transmission of pathogens such as hepatitis B virus (HBV), hepatitis C virus (HCV), and HIV, which can result from the reuse of disposable (single use) syringes and improperly sterilized multiuse injection equipment. Infections can also be caused by needlestick injury during waste handling or when the community comes in contact with medical waste.
- Coverage: If clients perceive that visits to a health facility may expose them to the risk of infection, immunization coverage may be reduced.
- Environment: The harmful emissions that are released when certain plastics are burned in open fires or poorly controlled incinerators, or spread through groundwater contamination when waste is buried incorrectly, pollute the environment and lead to long-term health risks.

WHO estimates that in 2000, contaminated syringes and needles caused 21 million HBV infections (32 percent of all new infections), 2 million HCV infections (40 percent of all new infections), and 260,000 HIV infections (5 percent of all new infections).[2] These infections cause significant morbidity and mortality and result in substantial costs for families, communities, and nations. GAVI's attention to the issue of sharps waste can reduce these risks and improve the conditions surrounding the management of sharps waste.

In rural areas, lower population density means there is more land available for shallow burial of waste; open burning is also widely practiced. Public transportation is often used for health service trips, but personnel are reluctant to carry bulky and hazardous sharps waste for disposal, even in safety boxes. Since health vehicles are scarce the transport of waste tends to be of lower priority. Road conditions may be so poor that waste cannot be transported safely, so the waste ends up being treated and disposed of in the immediate area.

2.b. The Challenge

The risks associated with sharps waste are particularly high in developing countries because few systems for managing the waste have been established. Few waste-processing technologies are available for remote locations or other settings with little or no infrastructure. Furthermore, health workers have not been universally trained to follow standard policies and practices.

Because needs vary by country, solutions must be tailored to urban and rural health facilities and various clinic sizes and levels of care, and they must take into account the availability and quality of other services.

In urban areas, high population density and high volumes of waste generated by busy clinics makes safe disposal of sharps waste an immediate need. Sharps waste collection services are rare in most settings, and municipal garbage services pick up only noninfectious, non-sharps waste. Urban hospitals that are equipped with incinerators may not share their disposal facilities with neighboring primary health facilities. As a result, infectious sharps waste is frequently dumped at the nearest public waste site and is accessible by the community. Rag pickers search the waste daily, collecting syringes and needles for perfunctory washing and resale to the public. Syringes are frequently sold or given to rag pickers coming to the doors of health facilities. On-site burial is often impractical due to the limited availability of land in urban settings. Open burning, though obnoxious and often toxic, is widely practiced. In urban areas with weaker infrastructure, intermittent electricity, lack of municipal garbage service, and limited road access serve as additional challenges to clinics' waste disposal, with dumping often being the only option.

When waste is burned or buried near health facilities, scavengers may sift through the debris, uncovering partly burned syringes and sharps in the shallow pits and scattering them over a large area. It is common to find used syringes and needles on the ground around health facilities—right in the path of the community members who come for services. Children can be seen playing with discarded medical waste; needles are sometimes collected and fashioned into jewelry.

Although public health interventions, including immunization, require that a safe and efficient system of sharps waste disposal be in place, this has not been achieved in many developing countries.

Section 3. Description of Activities Required to Solve the Problem

To effectively address the problems of sharps waste within the scope of immunization programs in GAVI countries, several activities will need to be coordinated at the global level.
First, for the purpose of assigning appropriate systems of health care waste management, countries may be subdivided into areas classified according to four different levels of population density and infrastructure that require different strategies for management of sharps waste:[3]

- **Urban with infrastructure.** These settings have an existing municipal waste system, electricity, all-season road surfaces, possible access to a centralized waste treatment facility, high population density, and a high volume of waste.
- **Urban with low infrastructure.** These settings have no municipal waste system, intermittent electricity, limited road access, high population density, and a high volume of waste.
- **Rural with infrastructure.** These settings have no municipal waste system, probable electricity, all-season road surfaces, low population density, and a low volume of waste.
- **Rural with low infrastructure.** These settings have no municipal waste system, unreliable electricity, remote areas with limited road access, low population density, and a low volume of waste.

The following tasks would be undertaken at the global, regional, and local levels:

- Development of generic guidelines on management of sharps waste that are applicable and adaptable to different conditions.
- Development of a toolkit that countries can use to assess and plan solutions customized to their own waste management situations.
- Conduct of regional- and country-level advocacy and planning for GAVI's support of sharps waste management.
- Provision of technical assistance to countries in assessment and proposal development, where needed.
- Set up of systems for monitoring and evaluation of country-, regional-, and global-level waste management systems.

Once the first three components are in place, countries will be able to analyze their own situations and develop implementation plans for sharps waste management systems to qualify for GAVI assistance. GAVI assistance would lead to the establishment of more effective systems. Ultimately, the challenges of prompt and adequate disposal of immunization sharps will be fully solved only if the other 90 percent of sharps used for curative care in health facilities are also managed safely and effectively. By undertaking the activities described above, GAVI will directly address the problem of sharps waste for immunization programs and help catalyze the larger health sector outside of immunization to take action against the problem.

3.a. Overview of Activities

Global and Country Activities

Activities 1, 2, and 3 below would be conducted at both global and country levels. A lead managing partner (see Overview Management below) should be identified to organize and coordinate the activities at the global level. This would be done in close collaboration with other identified partners and medical waste specialists who could be assigned to work under contract on specific components or activities, depending on their expertise and locations throughout the world.

Activity 1—Develop generic guidelines on management of sharps waste that are applicable and adaptable to different conditions.

Clear global guidance is needed on acceptable and effective technologies and priorities, as existing policies are sometimes contradictory. Without clear guidance, decisions on sharps waste disposal are made on a facility-by-facility basis without building more efficient and wider-reaching systems. Best practical options to solve the problems of sharps waste management at primary health facilities depend greatly on the level of the infrastructure available and the population density.

To meet the immediate challenge of sharps waste management for primary health facilities, standard solution systems need to be defined for each category of infrastructure and population density. Three general predisposal strategies would be applied to primary health care settings to make sharps waste safer and reduce the volume of waste in all countries. These include waste segregation and containment (into sharps, infectious, and noninfectious streams), reduction in hazardous sharps volume (by using needle removal/containment, and other means of volume reduction), and the use of safety boxes and safe storage. The following approaches to disposal of waste would be considered:

Table 1. Proposed Solutions for Sharps Waste Management

Immediate Interventions to Strengthen Current Systems*	Improved Disposal Solutions*
Urban with infrastructure	
• Make noninfectious syringes safe for municipal waste pick up using needle removal, needle containment, and syringe disinfection. • Improve existing fuel-fed incinerators at hospitals or install improved incinerators at community sites. • Develop collection/transport systems for neighboring health care centers to take advantage of existing or improved hospital incinerators.	• Establish large-scale, centralized collection/transport system to an environmentally optimal, legally approved treatment and disposal facility out of town (high temperature incineration, autoclave/shredder, or microwaves). Include industrial recycling of plastics and reusable collection containers. • Introduce melting or compacting of syringes where centralized system not available.
Urban with low infrastructure	
• Needle removal and needle containment in protected pit or barrel on site. • Develop collection/transport systems to optimize utilization of existing hospital incinerators. • Improve existing fuel-fed incinerators at hospitals or install improved incinerators at community sites.	• Establish large-scale, centralized collection/transport system to an environmentally optimal, legally approved treatment and disposal facility out of town (high temperature incineration, autoclave/shredder, or microwaves). Include industrial recycling of plastics and reusable collection containers. • Introduce melting or compacting of syringes using electric, solid-fuel, or solar technology.
Rural with infrastructure	
• Needle removal and needle containment in protected pit on site. • Syringe burial in protected pit on site or disinfection and transport to local dump. • Establish collection/transport system to a small-scale fuel- or waste-fed incinerator, on site or at nearby health center.	• Broader use of needle removal and needle containment in protected pit on site. • Establish collection/transport system to medium-scale (e.g., district level) high-temperature incinerator (possibly using existing transport used for delivery of supplies). • Introduce melting or compacting of syringes using electric or solar technology.
Rural with low infrastructure	
• Needle removal and needle containment in protected pit on site. • Syringe burial in protected pit on site or disinfection and storage for intermittent transport to local dump. • Establish collection/transport system to a small-scale fuel- or waste-fed incinerator, on site or at nearby health center.	• Broader use of needle removal and needle containment in protected pit on site. • Establish local collection/transport system to a small-scale fuel- or waste-fed incinerator, on site or at a nearby health center. • Introduce melting or compacting of syringes using solid fuel or solar technology.

*Immediate solutions available in 1 to 6 years; improved solutions available in 3 to 10 years.

The interventions could be refined and adapted for select countries or regions as appropriate. To ensure the ongoing relevance of policies and guidelines, a series of policy workshops would be held and would be instrumental in reaching consensus on the best practices and technologies for sharps waste management. Participants in this process would be technical agencies, global policy groups, country representatives, and public health and medical waste experts who would be encouraged to reach a practical consensus. Periodic review would ensure that the latest technologies and lessons learned are incorporated into guidance updates. The most recent guidance and information on technical options would be updated periodically through publication and dissemination of an update bulletin.

Activity 2—Develop a toolkit that countries can use to assess and plan solutions customized to their own waste management situations.

A package of tools must be developed to direct countries through the process of establishing a sharps waste management system for their primary health care facilities. The tools would be universal enough to be easily adapted to country-specific needs and opportunities. The package would include:

- An assessment tool, based on the existing WHO/ United Nations Environment Programme (UNEP) rapid assessment tool for health care waste management[i] and adapted to incorporate tracking for monitoring and evaluation. Such a tool would help countries identify needs and opportunities; segment the country into different sharps waste infrastructure scenarios; and develop input, process, and output indicators to track performance against goals and objectives. (Section 10.b. provides a list of potential indicators.)
- Templates for national health care sharps waste plans and legislation.
- Underlying support for the development of waste management systems and guidelines on logistics, management, training, supervision, and standard operating procedures for best practices—including recommended milestones and process conditions.
- Training materials for all levels (supervisors to waste collectors).
- Information on equipment specifications and commercial suppliers.
- Case studies of existing locations where sharps waste management systems are in place and can serve as models.
- Evaluation procedures and metrics.
- Behavior change communication materials and approaches for all levels.

Activity 3—Conduct regional- and country-level advocacy and planning for GAVI's support of sharps waste management.

To make countries aware of GAVI support of sharps waste activities, the lead managing partner or a designated partner or partners would be charged with undertaking a series of regional presentations. The presentations would include the rationale for sharps waste management, the generic guidelines and solutions, and the costs and benefits associated with potential solutions in terms of safety (e.g., reduced inadvertent infections). The toolkit and the process for applying for GAVI support would also be discussed. The presentations could take place at WHO/UNICEF

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[i] http://www.who.int/water_sanitation_health/medicalwaste/ratupd05.xls

regional workshops.

Activity 4—Provide countries with technical assistance in assessment and proposal development, where needed.

This information would enable countries to then apply to GAVI for planning funds. With a planning grant, countries would conduct the following two activities, with assistance from the lead managing partner or from local or regional experts:

- **Situation assessment.** Using the standardized assessment tool provided in the toolkit, each country would first assess its needs for sharps waste disposal and opportunities within the different scenarios. They would then determine what assistance should be requested from GAVI. This diagnostic would be used to analyze the volume of waste generated and the current collection and treatment methods. Technical assistance would be available as needed.
- **Proposal development.** Based on the assessment findings, each country would then determine which solution set it should implement and in which locations. Due to the complex demographic and infrastructure settings that coexist in most countries, each country would most likely require a mix of solutions. Countries could then apply for funding, for example, using a cost per infant as the basis for their proposal budgets. Assuming eight immunization injections per infant in the first year of life, the average total cost (across the four levels of infrastructure) would be approximately $0.14 per infant in 2007 and up to $0.31 per infant in 2015, assuming reasonable levels of adoption of the key interventions proposed. The calculation of these premiums is discussed in detail in Section 9.

Activity 5—Set up systems for monitoring and evaluation of country-, regional-, and global-level waste management systems.

See Section 10 for more detailed information on this activity.

Country-Level Implementation

Once funding is available, countries would apply the tools from the toolkit in planning sharps waste management systems and infrastructure. Systems building would include establishing a national committee for health care waste management, conducting an assessment of waste-generating activities at health care centers (both immunization and curative related) and waste treatment facilities, as well as developing a multiyear national strategic plan. Subsequently, deployment of selected technologies; implementation of associated supply, training, and maintenance programs; and infrastructure development requirements would be phased in and refined. Regional examples and lessons learned would be shared to build support between neighboring countries. Technical assistance, supportive supervision, and development of a national policy umbrella would be required. The lead managing partner or local or regional experts would assist as needed. As noted above, countries will likely have a mix of requirements based on their infrastructure levels and the location of facilities in urban and rural locations. Cost of any waste handling system will vary according to the infrastructure scenario.

3.c. Overview of Management

A lead managing partner (LMP) should be identified to organize and coordinate the activities in close collaboration with other identified partners and medical waste specialists hired to help with implementation. The LMP would be responsible for either carrying out or for arranging the following activities:

- Adapt for specific countries the sharps waste management analysis developed in this exercise in order to mobilize the global community and countries.
- Coordinate and synthesize generic guidelines that are applicable and adaptable to different conditions.
- Develop a toolkit that countries can use to assess their own sharps waste management situations.
- Work with national health care waste management committees and facilitate country-level planning for GAVI sharps waste support.
- Provide technical assistance to countries in assessment, proposal development, and project implementation, including the deployment of technology solutions, where needed.
- Set up and implement monitoring and evaluation systems at the global, national, and local levels, as needed.

These LMP activities would require GAVI Vaccine Fund support. Initial specific country activities, including planning grants, would be funded through GAVI. However, with proactive leadership from GAVI, Vaccine Fund resources could be leveraged through funds from other sectors (i.e., curative) accountable for generating potentially infectious sharps waste.

3.d. Partners and Responsibilities

The following table delineates the roles and responsibilities envisioned for the various parties that would collaborate on this global program.

Table 2. Partners and Responsibilities

Partner	Role
Global Partners	
LMP, WHO, UNICEF, NGOs	Policy guidance, standards, purchasing
GAVI/Vaccine Fund, World Bank, USAID, other donors	Funding, planning
Regional Partners	
LMP, medical waste experts, NGOs, WHO, UNICEF	Assistance, policy workshops
Equipment manufacturers, LMP, medical waste experts, NGOs	Product specifications, training support
Country Partners	
Ministry of health, Ministry of environment, LMP, local experts and consultants, NGOs	Funding, country guidance, policy, implementation
NGOs, medical groups, environmental groups	Planning, training
Manufacturers, LMP, local experts and consultants, NGOs	Product sourcing, specifications, training support

3.e. Implementation Work Plan and Timeline

The following table describes the proposed timeline for the various activities.

Table 3. Implementation Work Plan and Timeline (Based on Funding Approval in June 2006)

Activity	Deliverables	Activity Location	Time Period
Global and Country Activities			
Generic guidelines applicable and adaptable to different conditions	Agreed-upon guidance for inclusion in toolkit at the end of Year 1. Semi-annual publication of waste management policy guidance and updates. Policy updates publication.	Meetings in all six regions (combined with WHO regional meetings). Policy updates publication: lead partner.	Meetings: To be completed in the first year of the project. Publications: Semiannual from December 2006 onward.
Toolkit that countries can use to assess their own sharps waste management situations and plan solutions for implementation	CD and bound toolkit containing: assessment tool; national plan and legislation templates; guidelines on logistics, management, training, and supervision; standard operating procedures for best practices (including recommended milestones and process conditions); training materials for all levels; equipment specifications and list of commercial suppliers; case studies and models; evaluation procedures and metrics; behavior change communication materials and approaches for all levels.	Field research in Asian and African countries, policy coordination in Geneva, liaison and coordination with global manufacturers; guideline publication.	Toolkit development: June 2006–January 2008. Publication: January 2008
Regional- and country-level advocacy and planning	Rationale for sharps waste management practices, including costs and benefits of potential solutions. Clarification of GAVI process.	WHO/UNICEF regional meetings.	July 2007–July 2008
Situation analysis/ assessments	Country assessments. Technical assistance available if needed.	GAVI countries in Africa, Asia, Latin America, Central Europe.	July 2007 onward
Proposal development	Analysis of country assessments and development of country proposals. Technical assistance available if needed.	GAVI countries in Africa, Asia, Latin America, Central Europe	July 2007 onward
Country Implementation			
Country implementation	Implementation at the country level of sharps waste management systems and technologies. Regional examples shared. Technical assistance required.	GAVI countries in Africa, Asia, Latin America, Central Europe.	January 2008 onward

Section 4: Proposal Cost and Funding Need

4.a. Projected Costs

The premise of this exercise is that sharps waste interventions, to have the maximum benefit, would need to be integrated and implemented across both the immunization and the curative sectors of public health in a whole systems approach. The analysis that shows that these interventions are cost-effective is based on the benefit achieved by having sharps waste handled properly for both sectors (as explained in Section 7). The estimated costs of the entire investment, therefore, must also account for the costs of implementing sharps waste management interventions for curative injections as well as immunization injections.

While the total cost of applying these solutions to all injections (immunization and curative) in all GAVI countries is estimated at US$1,840,600,000—plus the cost of global management and technical assistance (US$10,000,000)—over nine years, it is anticipated that most of these funds will be derived from a mixture of nationally allocated funds, other global initiatives involving use of sharps, investment in specific countries by GAVI partners, and other projects funded by other donors. GAVI's role is viewed as catalytic and facilitative, stemming from the key activities described in this program and from active solicitation of support from other global initiatives. Costs proportioned to cover only immunization-generated sharps in all GAVI countries would be one tenth of that total. While it is not possible to confine sharps management interventions exclusively to immunization injections, this proportioned cost of US$184,000,000 might be viewed as the limit of the contribution from the immunization sector. This analysis is based upon the premise that an early investment of only US$10,000,000 in coordinated global and country activities will catalyze system improvement that will ultimately be supported by country health and environmental budgets and a wide constituency of programs and donors. Further investments by GAVI are anticipated based on grants to countries to improve their systems. However, those activities involved with assisting at the country level are scaleable based on available funding and on criteria to be developed to determine countries with the greatest need for interventions.

The specific amount required for global-level management and technical assistance is estimated to be US$10,168,854 in the first five years. This is detailed in the table below.

Table 4. Global Management and Technical Assistance Costs: Five-Year Budget (2006- 2010)

Components	Cost	Total Costs
Generic Guidelines		
Development of Generic Guidelines	$122,546	
Policy Workshops	$351,385	
Publication of Update Bulletin	$209,223	
Subtotal		$683,154
Toolkit Development		
Adapted Medical Waste Assessment Tool		
Templates for Planning and Legislation		
Guidelines on Logistics, Management, Training, Supervision, Standard Operating Procedures (SOPs)		
Training Materials and Manuals		
Equipment Specifications		
Case Studies		
Evaluation Procedures and Metrics		
Behavior Change Communication Materials		
Subtotal		$477,261
Regional- and Country-Level Planning Technical Assistance		
Regional Presentations	$254,789	
Situation Assessment Technical Assistance $74,144 per large country x 9 large countries $55,608 per medium country x 24 medium-size countries $37,072 per small country x 36 small countries	 $667,296 $1,334,592 $1,334,592	
Proposal Development Technical Assistance $67,510 per large country x 9 large countries $50,632 per medium country x 24 medium-size countries $33,755 per small country x 36 small countries	 $607,590 $1,215,168 $1,215,180	
Subtotal		$6,629,207
Lead Managing Partner Costs		
Coordination and Management at Global Level	$1,638,099	
Monitoring and Evaluation of Implementation	$741,133	
Subtotal		$2,379,232
Total		**$10,168,854**

The following detailed cost tables are attached in Annex E:

- Total Costs by Core Expenditure Category and Components During Investment Period
- Total Costs by Expenditure Category and Investment Year
- Total Costs by Component and Investment Year

Assumptions for Global and Country Activity Costs

The main assumptions for each activity component listed above are as follows:

Generic Guidelines

This is the estimated cost of the review of existing guidelines and practices, and development of a set of unified, generic guidelines that will be acceptable among all stakeholders. LMP staff would communicate with experts and decision-makers in the field to arrive at a set of acceptable guidelines. The guidelines would then be presented at regional policy workshops in each of the six WHO regions in year I. Semiannual update bulletins would be published and distributed via email throughout the life of the project. Costs would include personnel, travel workshop costs, publication costs, and associated office costs. This work could be coordinated by the LPM or subcontracted out to other medical waste specialists or consultants as appropriate.

Toolkit Development

In years I and II, the eight components of the sharps waste management toolkit would be developed or adapted by agency staff, based on the generic guidelines. Whenever possible, the toolkit developers will utilize background research and existing materials developed by WHO, the private sector, NGOs, and by the US President's Emergency Plan for AIDS Relief (PEPFAR) safe injection projects. Information on available and upcoming medical waste technologies in the development pipeline would be rigorously assessed and constantly monitored as new and improved technologies arrive on the market. All materials would be published in CD format and as hard copy bound documents, and updated regularly. Estimates include the costs of personnel to do research, writing, and testing of materials, travel to the field and Geneva, publication costs, and associated office costs. The LMP would coordinate the effort, and many of the individual components could be done by the LMP or carried out under contract by experts in the field or at other agencies.

Regional- and Country-Level Planning Technical Assistance

In year III, the guidelines and toolkit will be presented at six WHO/UNICEF regional workshops in order to prepare stakeholders for the implementation phase. The cost of "situation assessment" is a per-country cost for technical assistance to be provided by either the lead partner or global or local experts to ministries of health (MOH) as they assess the specific needs in their countries. The cost was determined by estimating the level of effort and travel expenses required to provide assistance to a small, medium, and large country multiplied by the number of countries in each category. The "proposal development" cost is a per-country cost for technical assistance to MOHs and local staff as they evaluate and use the assessment findings to apply for GAVI funding for implementation. The cost estimate was based on a similar approach as above. The situation assessments and proposal development activities would take place in years III-IV. Costs include estimates for personnel, travel to each WHO/UNICEF regional workshop, travel to and within countries where the technical assistance is occurring, and associated office costs.

Lead Managing Partner

A lead partner agency will be responsible for global organization, coordination, and overall management for all project activities during the first five years of the project. This would include identification and arrangements for appropriate global- and country-level experts to be tasked with individual components and with country-specific technical assistance. All monitoring and evaluation activities of country implementation (as discussed in Part III, Section 10) would be performed by the lead managing partner as well. Costs include personnel, international travel including travel to each GAVI region, and associated office costs.

Assumptions for Country Implementation Costs

The estimated cost of country implementation is based on the calculated cost per injection of the proposed waste management interventions described in Section 9a and shown in Table 11. This cost would be US$1,840,600,000 if the interventions were totally implemented in all 72 GAVI countries. To obtain the cost of the proposed waste management interventions related to immunization only (excluding curative injections) in GAVI countries, the sharps waste management cost per injection was multiplied by eight (to account for eight vaccine injections per infant) to arrive at a cost per infant. This cost per infant for each year was then multiplied by the number of live births for that year to arrive at an estimate of sharps waste management costs attributable to immunization in each country. To put these immunization costs in context for what is needed to implement the proposed interventions across both immunization and curative sectors, the total per capita cost of waste management in each year (Table 11, Section 9a) was multiplied by the total population in that year. For example, for India the total cost of the proposed waste management interventions for immunization alone was calculated to be US$70,700,000, but across both sectors, US$718,000,000 would be needed to develop the full system.

Note that the per-injection cost of implementing waste management solutions increases over the modeled horizon (2007–2015) due to adoption of the more capital-intensive interventions. These in turn provide permanent and highly effective sharps/infectious waste management systems with long-term positive impacts on patient and health care worker safety.

It should be emphasized that although immunization only contributes to one tenth of sharps waste, solutions can only be effective if they deal uniformly with all injection waste within a facility. A system improvement that will improve all sharps waste management is required. Consequently, the costs must ultimately be borne by all sectors of the health care system as well as national environmental authorities.

4.b. Financial Support for the Proposed Program

It is anticipated that most of the funds required to initiate these safe practices in all GAVI countries could be derived from a mixture of nationally allocated funds, other global initiatives involving use of sharps, investment in specific countries by GAVI partners, and other projects funded by other donors. GAVI's role is viewed as catalytic and facilitative, stemming from the key activities described in this program and from active solicitation of support from other global initiatives. Those activities involved with assisting at the country level are scaleable based on available budgets and criteria to determine countries with the greatest need for sharps waste management interventions.

Based on the number of injections that are given annually, nonimmunization programs have a much larger stake in mitigating the harm that is being done due to infectious sharps and should offer additional resources and opportunities for implementation. Many countries are now writing capital investments for health care waste management into World Bank loan proposals. Also, sharps waste management policy, infrastructure, and systems are already being developed in parts of sub-Saharan Africa through the Making Medical Injections Safer project (which is supported by USAID and US CDC under PEPFAR funding). This program is working at all levels in 14 priority countries to build commitment, identify funding, assess and prioritize needs, and identify the best possible options for sharps waste management considering cost and environmental impact. Other programs and donors currently contribute to sharps waste disposal solutions as well. Examples include Family Health International's reproductive health programs, the CDC's blood safety program, and the Global Environment Facility project. Future opportunities are also likely to exist through HIV/AIDS, tuberculosis (TB) and malaria programs. GAVI has lead the movement toward use of injection equipment with reuse-prevention features and is well positioned to rally other global health programs around the need for system improvements in sharps management.

GAVI's leadership might be used in the short term to bring together other global health initiatives with similar safe injection concerns and to build a pan-program global approach to funding sharps waste management interventions. In this way the resources needed to finance a comprehensive program would be shared by multiple parties including GAVI, other global health initiatives such as HIV/AIDS, TB, malaria, essential drugs, and family planning as well as private foundations and countries directly participating in the activities.

The total of GAVI's initial investment for these activities is estimated at US$10,000,000. Additional investments beyond this amount to support implementation by individual countries can be estimated from the cost data presented in this analysis and can be scaled to fit available budgets. Member GAVI countries will submit proposals for GAVI funding for a portion of the cost of in-country implementation. Selection criteria are not addressed in detail in this exercise but could be based on evident need or other prioritization criteria.

Section 5. Financial Sustainability

Clearly, the estimated cost of applying these solutions to all injections (immunization and curative) in all GAVI countries is beyond the budgets of any single global health intervention program. However, it should be emphasized that sources of funding external to the country budgets themselves should only be needed to initiate the changes necessary to achieve safe levels of sharps waste management.

While countries must ultimately absorb the cost of these systems, given the large capital investments needed to establish medical waste systems, donor input, both for capital costs and a portion of initial recurrent costs, will likely be required in some countries. One approach to donor funding of the recurrent costs, is the "polluter pays" approach, where programs would be required to contribute a per-syringe fee to the country's medical waste management system.

Sustainability of safe systems of waste handling and disposal can be seen in both managerial and financial terms:

A **managerially sustainable** system should include all types of waste-generating health facilities, including both primary and referral health facilities, and it should cover all public- and private-sector health care waste-processing facilities. This integration of policies, regulation, and practices between the health and environment ministries is essential for long-term managerial sustainability.

A **financially sustainable** system may be "front-loaded" by an externally supported project, but it should steadily integrate into the government budget of the health and environment ministries, including both recurrent costs and amortization to ensure capital equipment replacement. Local recurrent costs of health care waste management, both in hospitals and district primary health facilities, are best covered by local recurrent budgets, not external aid. Therefore, hospitals should budget for their own recurrent health care waste management costs. Districts in countries that use sector-wide approaches should use "basket funds". Districts in other countries should use annual district micro-planned budgets. Transport costs should be, to the greatest extent possible, integrated into the supply and supervision system, so that the same transport system collects waste as distributes supplies and provides supervision. This minimizes cost and maximizes utilization of transport.

Part II. Rationale for Investing

Section 6. Relevance to GAVI Objectives

The 2006 GAVI work plan introduces new areas of focus for GAVI II, including waste management (Area 1.4). GAVI's leadership in introducing injection equipment with reuse prevention features—for example, autodisable (AD) syringes with fixed needles—has had a major impact in reducing needle and syringe reuse and the associated disease transmission. However, the solution to the reuse problem has exacerbated another problem—increased volume of hazardous sharps waste resulting from more children being immunized with nonreusable syringes. Furthermore, only one half of immunizations are currently given with AD syringes. This places a particular responsibility on GAVI to ensure that better practices are put into place. During the recent country consultations evaluating GAVI I, waste management was identified as a central concern for many countries.

6.a. Alignment with GAVI Priorities

The approach proposed in this model is aligned with GAVI's priorities of making immunizations safer and of accelerating development of and access to affordable immunization-related technologies. By pursuing the problem of sharps waste management, which affects other public health services in addition to immunization, the activities described in this model will help reduce health systems barriers to greater access to high-quality immunization services. GAVI II is planning to establish a new window of support for health systems strengthening (HSS), which will be aimed at reducing health systems barriers to immunization service development and could include sharps waste management. A priority of GAVI II is to build the capacity to deliver immunization services synergistically with other public health interventions so as to maximize the impact of these interventions on achievement of the Millennium Development Goals.

6.b. Contribution to GAVI Milestones

GAVI's milestones are all measures of access to immunization services and to new and under-used vaccines. Implicit in all the milestones is the assumption that the quality of the delivery systems is adequate. A critical measure of quality is the safety of administration of vaccines and the safe disposal of infectious sharps waste. The activities described in this model aim to address safety of the service in *all* situations found in developing countries. Therefore, they may also contribute to the GAVI goal to achieve 90 percent routine immunization coverage of all GAVI countries by 2010, with at least 80 percent in every district.

6.c. Consistency with GAVI's Concept of Value Added

GAVI has already provided leadership through the introduction of AD syringes with reuse prevention features into immunization programs. As a result, these devices are becoming more widely available for curative injections as well. Similarly, by focusing on safe disposal of immunization-related sharps waste, GAVI will be in a unique position to help stimulate and build consensus around global- and country-level waste management policies, strategies, and priorities. By investing in the activities outlined in this model, GAVI would instigate a major and rapid improvement in the management of sharps waste, thus increasing safety for patients, health care workers, and communities.

6.d. Target Countries

Given the magnitude of the problem of sharps waste management, this analysis targets all GAVI countries. GAVI funds would most likely be made available based upon some criteria of need or other prioritization means.

Section 7. Expected Incremental Impact of the Investment

7.a. Description of Benefits and Beneficiaries

The primary beneficiaries of injection safety activities are patients, health care workers, the community, and health care services, including immunization programs.

Patients will benefit from the drastic reduction in needle reuse, estimated at 39 percent of all injections globally[4] and resulting in over 21 million HBV infections, 2 million HCV infections, and 260,000 HIV infections per year. Infants suffer a disproportionate amount of the disease burden caused by contaminated sharps due to the age at which they become infected. Patients will also benefit from improved confidence in the immunization system.[5,6] While the adoption of AD syringes has made substantial progress in protecting patients, approximately 50 percent of immunization injections in the developing world are still given with disposable needles and syringes.[7] Furthermore, virtually all injections in the curative sector are currently given with disposable needles.

Health care workers will experience fewer infections resulting from needlestick injury, particularly those 40 percent of needlesticks that occur after the injection.[8] In addition to improved disposal methods, the waste management interventions described in this paper facilitate removal and containment of sharps immediately after use, thereby helping to protect health care workers from accidental needlestick after injection. Although not quantified in this model, health care workers and patients may also benefit from an increased awareness of the ”do no harm” imperative for quality health care.[9]

Members of the community like waste workers, rag pickers, and others will also benefit from a reduction in needlestick injury, which may occur at a rate of five to six times per day for those who make a living from reselling sharps waste.[10]

Country and global immunization programs as well as other health care services will benefit from reducing the negative effects caused by their programs (e.g., the infections resulting from needle reuse and needlestick injuries).

7.b. Baseline Burden of Disease

Calculation of Baseline Infections in the Absence of a Waste Management Intervention

Baseline HIV, HBV, and HCV infections caused by needle reuse on patients and needlestick injury to health care workers, occurring across both the curative and immunization sectors in the year 2000, has been estimated.[4,11] Since data were not available at the country level, regional projections were made (excluding AMR A, EUR A, and WPR A) of the number of future infections over the ten-year modeling horizon from 2006 to 2015 (Figures 1 and 2).[ii] Although the risk of sharps to the community is fairly well known, no solid data are available regarding the number of infections occurring among rag pickers or others in the community.[10,12,13,14,15,16] Primary research in this area was considered outside the scope of the exercise and therefore baselines were established only for patients and health care workers.

The estimated infections averted from use of AD syringes were subtracted from the overall baseline of patient infections caused by needle reuse that are still to be averted because these infections can no longer be impacted by a waste management intervention. In addition to AD adoption, it was recognized that other more recent safe injection interventions would further reduce the baseline of infections that a waste management intervention could impact.[iii] These include: increasing the availability of disposable syringes, which in turn reduces incentives for reuse; broad awareness-raising among health care workers and the community; and disease-specific interventions such as those associated with the prevention of HIV. Since the collective impact of these interventions is unknown, the baseline of patient infections was reduced by 20 percent in the base case (below) and later by 50 percent in the sensitivity analysis conducted in Section 9b to understand its impact on cost-effectiveness ratios. As shown in Figure 1, the combined effect of AD syringes and other safe injection interventions reduces the baseline only slightly, due to the large number of injections that will continue to be made with disposable syringes in the curative sector. For health care workers, since the vast majority of needlestick injuries occur during or after injection, it was assumed that AD syringes would not mitigate health care worker infections and therefore the baseline of HIV/HBV/HCV infections would rise over the modeling horizon (Figure 2). Annex A provides detailed information on the methodology and assumptions relating to the calculations surrounding the baseline burden of disease.

For patients as well as the community, the proposed sharps waste management interventions theoretically have the potential to eliminate the baseline burden of disease caused by needle reuse, assuming that the main effects of all other safe injection interventions are removed from the baseline. In other words, if sharps waste is completely destroyed or contained after use, patients and the community would have little, if any, risk of coming into contact with a contaminated needle. However, the same is not true for health care workers. While improved sharps waste management practices can reduce the needlestick injuries that occur among health care workers after injection, the risk of infection occurring during injection use remains unmitigated through the proposed set of interventions. To accommodate for this fact, the baseline of infections for health care workers was reduced (assuming equal probability of infection occurring before and after injection), using data that suggest approximately 40 percent of needlestick incidents occur after injection. The health care worker infection data shown in Figure 2 reflect this reduction.

[ii] A ten rather than fifteen year modeling horizon was used to accommodate for the potential adoption of needle-free and other technology that may change the nature of the waste management systems needed after ten years time.

[iii] Post-2000, since the baseline patient infections were projected from infection data calculated in the year 2000.

Figure 1. Baseline Infections Among Patients, Net of Infections Averted from AD Use, 2006–2015.

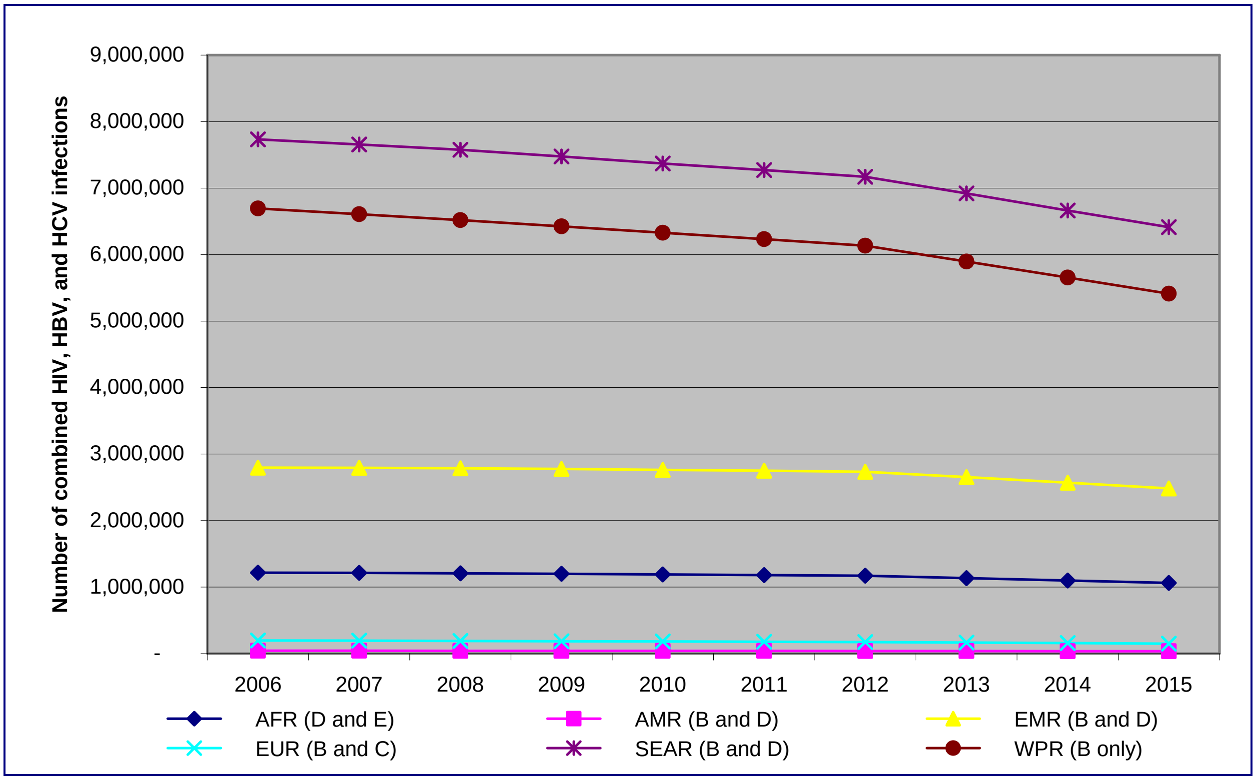
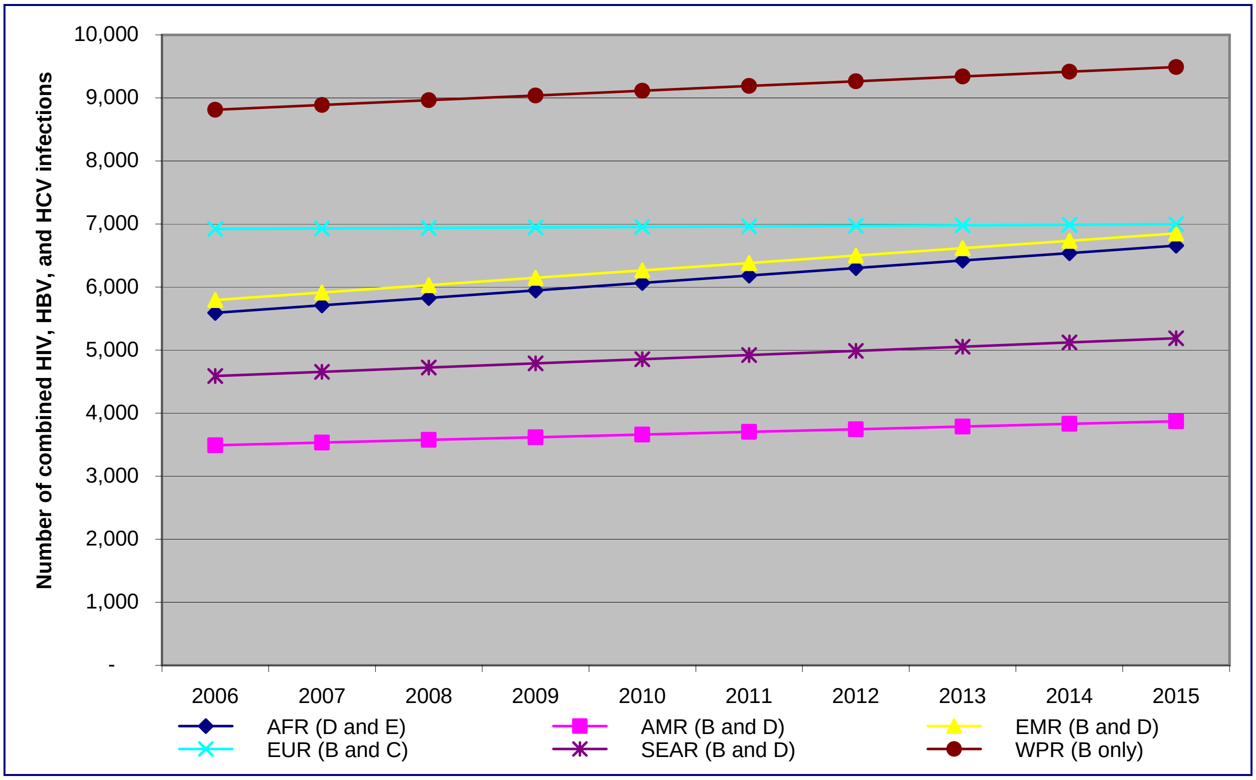


Figure 2: Baseline Infections Among Health Care Workers, Net of Infections Occurring During Injection Use, 2006–2015.



As these figures show, there is wide regional variation in the number of infections. SEAR has the largest number of patient infections, followed by WPR and EMR. These variations are driven largely by population but also by injection practices; the strength of the informal economy supporting the recycling of sharps waste may also have an affect. With respect to health care workers, the WPR region has the largest number of infections, followed by EUR and EMR. In addition to the numbers of health care workers in these regions, variations in the type of injection equipment, containment procedures, and disposal practices employed may help explain the variation.

DALYs Associated With Baseline Infections

The numbers of disability-adjusted life years (DALYs) associated with these infections in the years 2006 and 2015 are shown in Table 5. The burden is many times higher among patients compared to health care workers, accounting for their younger age at which infection occurs, the higher efficiency of disease transmission from injection compared to that of needlestick injury (approximately 15 times greater),[17] and the larger number of patients relative to health care workers. However, the disease burden among health care workers is likely underestimated using DALYs as an indicator, as they do not incorporate the value that these workers bring to a society due to their critical role in serving public health.

Table 5. DALYs Associated With Infections in 2006 and 2015.

	2006		2015	
	Infections	DALYs	Infections	DALYs
Health Care Workers				
AFR (D and E)	5,592	7,001	6,657	8,334
AMR (B and D)	3,490	1,252	3,871	1,407
EMR (B and D)	5,795	713	6,851	843
EUR (B and C)	6,920	1,096	6,997	1,108
SEAR (B and D)	4,590	1,321	5,187	1,476
WPR (B only)	8,813	1,269	9,490	1,367
Health Care Workers Total	**35,201**	**12,652**	**39,053**	**14,535**
Patients				
AFR (D and E)	1,208,057	1,812,471	1,063,333	1,713,504
AMR (B and D)	41,693	28,850	35,152	24,871
EMR (B and D)	2,787,019	496,574	2,483,167	486,289
EUR (B and C)	189,738	53,366	150,071	43,412
SEAR (B and D)	7,576,162	3,857,859	6,413,656	3,293,933
WPR (B only)	6,519,321	983,993	5,413,003	788,055
Patients Total	**18,321,990**	**7,233,113**	**15,558,382**	**6,350,063**

Burden of Disease Across the Four Scenarios of Health Care Infrastructure

To estimate the distribution of disease burden resulting from needle reuse and needlestick injury across the four scenarios of health care infrastructure (urban with infrastructure, urban with low infrastructure, rural with infrastructure, and rural with low infrastructure), it was assumed that disease burden would follow the distribution of injections across these different scenarios. While differences in current waste management practices across the scenarios would theoretically factor into the distribution of disease burden (and hence not strictly follow injection distribution), the safety risks quantified for each of the four scenarios were fairly similar in the base year (2006) (Figure 3). Therefore, for simplicity, the affect of differing current waste management practices was not used in calculating the distribution of disease burden. Table 6 shows that for the “rural with infrastructure” settings, clinics in AFR, SEAR, and WPR generate the greatest number of injections and associated disease burden. For the “urban with infrastructure” settings, the greatest number of injections and the associated disease burden are generated in clinics in AMR, EMR, and EUR.

Table 6. Distribution of Injections/Disease Burden

	Urban With Infrastructure	Urban With Low Infrastructure	Rural With Infrastructure	Rural With Low Infrastructure
AFR (D and E)	25%	16%	35%	24%
AMR (B and D)	71%	8%	17%	4%
EMR (B and D)	45%	5%	45%	5%
EUR (B and C)	65%	0%	34%	2%
SEAR (B and D)	27%	7%	50%	17%
WPR (B only)	39%	7%	46%	8%
Average	**45%**	**7%**	**38%**	**10%**

7.c. Impact of the Investment on Burden of Disease

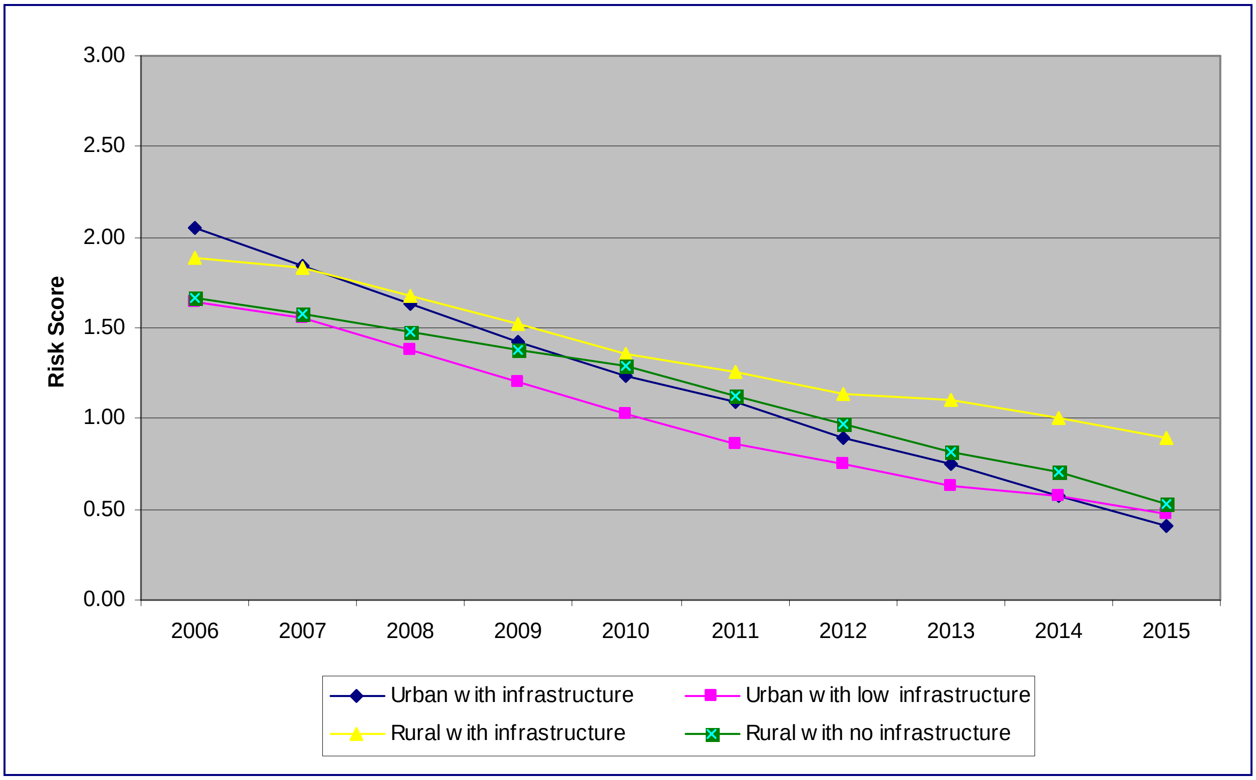
This analysis models the costs and benefits associated with the proposed solutions only in terms of safety, represented by reduced inadvertent infections caused by needle reuse and needlestick injury. The model does not attempt to represent the affect of unsafe medical waste practices on either immunization coverage or the environment, because credible data on those outcomes have not been found.

Calculation of Risk Reduction From Proposed Interventions

The sharps waste management activities described in this paper seek to reduce infections and DALYs associated with needle reuse and needlestick injuries by moving toward safer practices that contain sharps immediately and destroy waste completely. A decision-tree model was employed to map the various combinations of key procedures that contribute to the risk that sharps impose: which injection equipment is utilized; whether segregation of needle and syringe is employed; and the disposal options chosen for syringes alone, needles alone, or a needle/syringe combination. The decision-tree model (shown in Annex B, Figure 1) contains both pathways of current practice as well as the sharps waste management interventions that are proposed in this model.

Six risk factors were considered for each node/disposal pathway, depending on the risk that the pathway imposes on patients, health care workers, and the community. For each constituency group, one risk score was established for containment of waste in a safety box, and another for containment in a plastic bag. These risk scores range from zero (implying no risk) to three (implying highest risk). Changes in risk over the modeling horizon are driven by changes in adoption rates of the proposed interventions. Annex B describes the methods relating to the calculation of both risk and adoption rates, and provides a table of scores for each disposal pathway within each group. Figure 3 (next page) illustrates the estimated reduction in risk of reuse of contaminated needles on patients from the effect of the proposed sharps waste management interventions alone. The effect of increasing AD use in immunization and to a limited extent in the curative sector was subtracted from the overall effect and therefore not contained in the final risk reduction (impact) calculation.

Figure 3. Estimated reduction in risk of infection due to needle reuse on patients (injection safety interventions, including sharps waste management).



For patients, the baseline levels of risk (in 2006) were fairly similar, with slightly higher risk to patients coming from urban health care centers with infrastructure, where the comingling of contaminated sharps waste into the existing municipal waste stream is more likely to occur. This stream of municipal waste provides significant opportunity for rag pickers to recirculate contaminated sharps back into urban health centers. To understand the maximum impact of the proposed interventions, the model assumes 100 percent compliance at the established adoption rates. The reduction in patients' risk of infection due to needle reuse was estimated to be 50 to 80 percent less by 2015 than in 2006 across the four scenarios. Similar reductions in risk (of needlestick injury) were calculated for both health care workers and the community. Annex B provides more details pertaining to these groups. In general, the levels of risk reduction were slightly lower in the rural areas than in urban areas, because the established adoption rates for the proposed interventions are predicted to be lower in rural areas. This is due to the higher cost relative to the interventions proposed for urban locations, where higher utilization from larger volumes of sharps waste is likely, resulting in a lower cost per injection. Table 4 in Annex C provides a comparison of the costs per injection for each proposed intervention.

Infections and DALYs Avoided

With the assumption that a reduction in risk (i.e., exposure) produces a proportional reduction in disease,[18] the infections and DALYs avoided from safe waste management procedures were calculated for each scenario and region. The DALYs avoided are shown in Table 7. When the results for all four scenarios are viewed collectively, the impact of improved sharps waste management is more than 22 million DALYs avoided in the nine-year time frame. The majority of disease burden avoided can be seen in the urban and rural clinics with infrastructure, largely because the majority of injections and sharps waste originates from these clinics. While the level of risk reduction also factors into this calculation, Figure 3 (above) illustrates the reduction of risk is fairly similar across the different scenarios.

Table 7. Total DALYS Avoided

	Urban With Infrastructure	Urban With Low Infrastructure	Rural With Infrastructure	Rural With Low Infrastructure	Total
AFR (D and E)	1,836,809	1,122,021	1,745,537	1,280,254	5,984,620
AMR (B and D)	83,378	8,476	12,804	3,496	108,154
EMR (B and D)	943,017	96,054	625,683	76,507	1,741,261
EUR (B and C)	131,324	-	44,868	2,581	178,773
SEAR (B and D)	3,971,441	909,280	4,881,480	1,785,309	11,547,510
WPR (B only)	1,415,462	228,692	1,109,342	214,142	2,967,639
Total	**8,381,430**	**2,364,525**	**8,419,714**	**3,362,289**	**22,527,957**

Section 8. Constraints and Probability of Success

8.a. Social and Cultural Constraints

Chief among the constraints to establishing good sharps waste management practices are social norms and behavior associated with limited resources. For example, in many low-resource countries, waste scavengers and rag pickers sort through waste to resell certain items, and sharps-waste containers and devices are often reused (e.g., safety boxes are used as file drawers, waste bins are used for water collection). For cultural and economic reasons, it is difficult to convince health care workers to discard single-use devices. Public advocacy and community involvement are needed to increase awareness about the risk of infection from sharps waste.

A second constraint is the low social status of waste handlers within the health care system. They are often day laborers and, unlike health workers, usually are not immunized against hepatitis B. One mitigation strategy could be to elevate the role of the waste handler in the facility by offering them special recognition, providing protective clothing and immunizations, and including them in general staff training programs.

Because management of sharps waste has been largely neglected, most communities have only experienced haphazard efforts to improve sharps waste management that have left them with incomplete systems and nonfunctioning equipment, including poorly built, sited, and maintained incinerators. To gain acceptance for and increase awareness of the sharps waste disposal systems being established, communities must be involved in the process.

8.b. Epidemiological and Environmental Constraints

In many low-resource settings, sharps waste management has not been a high priority, particularly where the public health benefits of other interventions can be more easily proven. Data on rates of needlestick injury due to sharps waste and the proportion of needlestick injury to the community and health care workers are relatively scarce. Contributing to this lack of data is the general lack of institutionalized reporting systems, such as EPINet,[iv] to track needlestick injuries and raise awareness of the problem.

With respect to environmental issues, some segments of the global public health community are opposed to incineration, although they do not have sufficient data to support the risk/benefit. Risk/benefit studies on the impact of eliminating incineration as an option in the absence of other viable alternatives may help to demonstrate its value as an interim solution.

[iv] The Exposure Prevention Information Network (EPINet™) provides standardized methods for recording and tracking percutaneous injuries and blood and body fluid contacts. The EPINet system consists of a Needlestick and Sharp Object Injury Report and a Blood and Body Fluid Exposure Report, and software programmed in Access® for entering and analyzing the data from the forms. Since its introduction in 1992, more than 1,500 hospitals in the US have acquired EPINet for use. It has also been adopted in other countries, including Canada, Italy, Spain, Japan and the UK. See http://www.healthsystem.virginia.edu/internet/epinet/about_epinet.cfm for more information.

Global environmental treaties like the Stockholm protocols that require nations to reduce output of persistent organic pollutants. Incinerators are the biggest contributor to this. In the longer term, development of practical and affordable alternatives to incineration will be necessary. For large facilities and high-infrastructure urban environments, alternatives to incineration already exist, but these would benefit from adaptation, cost reduction, and the propagation of installation, repair, and maintenance networks.

Further refinement of the evidence base for sharps waste management, generic guidelines, and related resources (such as the toolkit) as proposed in this model will facilitate understanding of the tradeoffs between various disposal approaches, including incineration, so that countries can make the most informed decisions. If incinerators are used, appropriate guidelines should be provided to ensure that they are installed away from people, animals, crops, and water sources, and are used correctly.

The limited availability of land for waste burial is another constraint. Even where land is available, there is resistance to burying infectious waste. Above-ground solutions, such as needle barrels, and volume-reduction technologies can help overcome this obstacle.

8.c. Technical Constraints

A major technical constraint is the shortage of appropriate, affordable, and environmentally friendly waste management technologies adapted for developing countries. As a result, incineration is a prominent interim solution, despite its drawbacks. Further refinement of the evidence base and generic guidelines are expected to facilitate acceptance of existing technologies and approaches. Funding for product adaptation and validation—for example for small-scale shredders, simplified autoclaves, syringe melters and compactors, small-scale protected landfill systems, syringe and needle recycling systems, and pollution-free incinerators—is still needed. Developing equipment specifications and commercial sourcing will help make products more accessible. Local capacity to conduct country assessments, write proposals, and implement country-specific plans may be limited. To strengthen local capacity, national health care waste management committees should be formed or strengthened and should include representatives of public health, environmental, and other related professions. These committees can oversee the use of the toolkit on sharps waste management and receive assistance from the LMP. Regional workshops will facilitate the sharing of experiences, information, and lessons learned.

8.d. Institutional Constraints

Implementation of sharps waste disposal systems represents an additional burden of up-front costs. Yet the sharps waste management problem is more than just a financial question, as it affects people's health and safety, immunization coverage, the environment, and communities' perceptions. Managing infectious sharps waste effectively should be a priority for every health care system.

Agreement and consensus on clear global and national policies and responsibilities for sharps waste management may be challenging and may require extensive coordination, meetings, and methodical review of field experiences. Yet as the GAVI country consultation process showed, countries have a strong interest in improving management of infectious sharps waste. Even though high-level policymakers may consider sharps waste management a key priority, the challenge lies in translating this commitment to lower levels in the health care system where budgets are allocated and to the peripheral primary health care center level, where solutions are actually implemented. Training and advocacy activities will be crucial in demonstrating the value of implementing waste management systems to the health and safety of health workers, patients, and communities.

At the health-facility level, institutional constraints include staff turnover and incentives to decrease staff levels and salaries. Waste-disposal personnel usually are day laborers, rather than staff. System strengthening is needed to provide standard operating procedures, training, supervision, and monitoring.

To create far-reaching, sustainable systems, management of sharps waste must be acknowledged as a public health problem—not just an immunization problem—at both global and country levels. A successful sharps waste management initiative will require collaboration among multiple sectors, including international donor agencies, ministries of health and the environment, nongovernmental organizations, and the private sector. Any GAVI initiative should include coinvestment with other partners that can support the nonimmunization share of sharps waste, including country ministries of health and the environment, as well as other donors.

8.e. Point-Counterpoint Process

Anticipated partner concerns include (1) the challenges inherent in obtaining consensus on acceptable technology solutions for sharps waste management and (2) the financial sustainability of maintaining sharps waste management systems. These concerns are addressed in Section 3.a. and Section 5, respectively.

8.f. Critical Risks

One of the greatest risks to a global initiative on sharps waste management is the requirement for a sustained, well-coordinated investment by multiple partners. The process of strengthening sharps waste management will require commitment to and the development and maintenance of infrastructure at all levels.

In addition, political and economic instability and the rising price of fuel are risks to waste transport and destruction systems. The limited range of appropriate, affordable, environmentally friendly solutions for sharps waste management and opposition to the interim measure of incineration serve as additional barriers (page 5, Table 1).

Table 8. Addressing Critical Risks to a Sharps Waste Management Initiative

Risk	Risk Rating*	Risk-Minimization Measure
Financial sustainability	4	Communication about the negative impacts of poor sharps waste management practices and the financial responsibility of other sectors and organizations, both at the global and country levels.
Political and economic instability	3	No measure feasible within project, but visibility and awareness of sharps waste management problem justifies proceeding.
Rising price of fuel for waste pick-up transport systems, which are key proposed solutions	3	No measure feasible within project, but visibility and awareness of sharps waste management justifies proceeding.
Lack of affordable, environmentally friendly solutions for sharps waste management	3	Developing equipment specifications and listing commercial suppliers will help in making products more accessible.
Opposition to incineration	3	Further refinement of the evidence base and generic guidelines are expected to facilitate acceptance of the technologies and approaches that do exist. A longer-term commitment by the international public health community to advance alternative disposal solutions is also needed.

*Risk ratings refer to the potential impact on the project: 1 = very low; 2 = low; 3 = moderate; 4 = high; 5 = very high.

Section 9. Economic Analysis

9.a. Cost-Effectiveness Analysis

Because sharps waste management solutions make the most practical sense if introduced for all sharps waste coming from a health center, regardless of whether the waste results from an immunization or curative injection, the costs in this analysis have been calculated accordingly. This increased the utilization of waste equipment and systems proposed and hence kept the cost premium per injection to reasonable levels. Prior analyses have shown the financial and logistical difficulty of introducing waste systems for immunization sharps waste alone.[19,20] This economic analysis took a total cost approach to modeling the cost-effectiveness of the proposed interventions. The total current spending on waste management in 2006 (baseline costs) was estimated as well as the total cost of introducing the proposed new interventions (total costs) to arrive at incremental costs. The costs include both capital (e.g., purchase of an incinerator) as well as recurrent expenditures (e.g., fuel and electricity costs to transport sharps and run an incinerator) calculated at assumed utilization levels. Costs were calculated for each developing country and then averaged for each WHO region (excluding high income/low mortality subregions—AMR A, EUR A, and WPR A) to match the impact data, which were estimated by WHO region only. Additionally, the cost of treating infections resulting from needle reuse or needlestick injury was modeled to arrive at net incremental costs by region.

Over the course of the modeling horizon, it is expected that open burning of medical waste will decrease due to the availability of alternative disposal options. Theoretically, this development would reduce overall societal costs associated with the health and environmental consequences of open burning. However, accurate data on the impact of open burning of medical waste could not be found, so the overall resource savings from the proposed interventions is limited to treatment costs avoided, and therefore is likely conservatively estimated.

Cost-Effectiveness of Intervention

Table 9 depicts the different costs described above, DALYs averted, and the cost-effectiveness of the intervention by WHO region. The package of interventions appears cost-effective, resulting in an average incremental cost per DALY averted of approximately US$88. Using net incremental costs, which incorporate a reduction in costs associated with treating the HBV and HIV infections resulting from needle reuse, the package of interventions is reduced to approximately US$36 per DALY averted. In the SEAR region alone, the cost is less than US$5 per DALY averted, due to the high number of baseline HIV and HBV cases due to needle reuse and needlestick injury in that region.

Variations in the cost-effectiveness ratios exist due to vast differences in baseline DALYs across the WHO regions. It follows that the DALYs avoided from prevention of needle reuse and needlestick injury vary regionally as well.

Table 9. Total Costs and Effects Across All Four Infrastructure Scenarios, 2007–2015

	Baseline Costs*	Total Cost	Incremental Cost**	Net Incremental Costs***	DALYs Averted	Incremental Cost/DALY Averted	Net Incremental Cost/DALY Averted
AFR	$140,026,296	$418,786,461	$278,760,165	$96,280,369	5,984,620	$46.58	$16.09
AMR	$109,696,697	$258,604,130	$148,907,433	$130,498,396	108,154	$1,376.81	$1,206.60
EMR	$125,072,708	$344,333,415	$219,260,706	$181,584,224	1,741,261	$125.92	$104.28
EUR	$131,764,693	$307,697,818	$175,933,125	$166,778,661	178,773	$984.11	$932.91
SEAR	$377,687,340	$1,079,729,784	$702,042,444	$65,171,111	11,547,510	$60.80	$5.64
WPR	$286,063,055	$741,792,383	$455,729,329	$183,832,958	2,967,639	$153.57	$61.95
Total	**$1,170,310,790**	**$3,150,943,991**	**$1,980,633,201**	**$824,145,718**	**22,527,957**	**$87.92**	**$36.58**

*Baseline costs = estimated 2006 costs x 9 years (2007-2015).
**Incremental cost = total cost minus baseline costs spent on waste management in each year (assume 2006 level).
***Net incremental costs = incremental costs minus cost of treating HIV and HBV infections resulting from needle reuse and needlestick injury.

Variation by Level of Infrastructure

Variations in cost-effectiveness ratios can also be explained by differences in the package of sharps waste management interventions proposed for each scenario. This analysis assumes higher adoption of the more decentralized (on-site) systems for the rural facilities. Conversely, higher adoption of the more centralized systems for the urban facilities is expected, due to the cost economies of centralized processing and the shorter distances needed to transport sharps waste. Despite the large capital investment needed for centralized processing, some of the more decentralized options tend to be higher in cost on a per injection basis due to their lower utilization. Therefore, costs in the rural areas tend to be higher (Figures 4 and 5). Annex C provides methodologies and assumptions employed for calculating these costs as well as the average cost for each proposed waste management intervention, on a per injection basis (Annex C, Table 4).

Figure 4. Incremental Costs Per Injection, 2007–2015

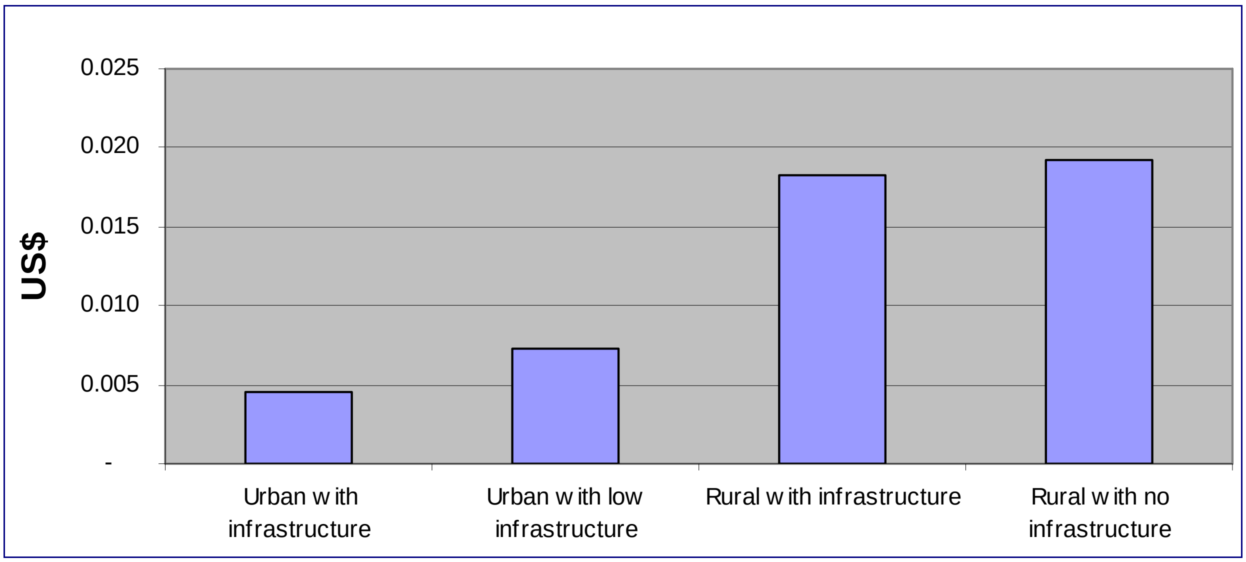


Figure 5. Incremental Costs of Waste Management Interventions 2007–2015

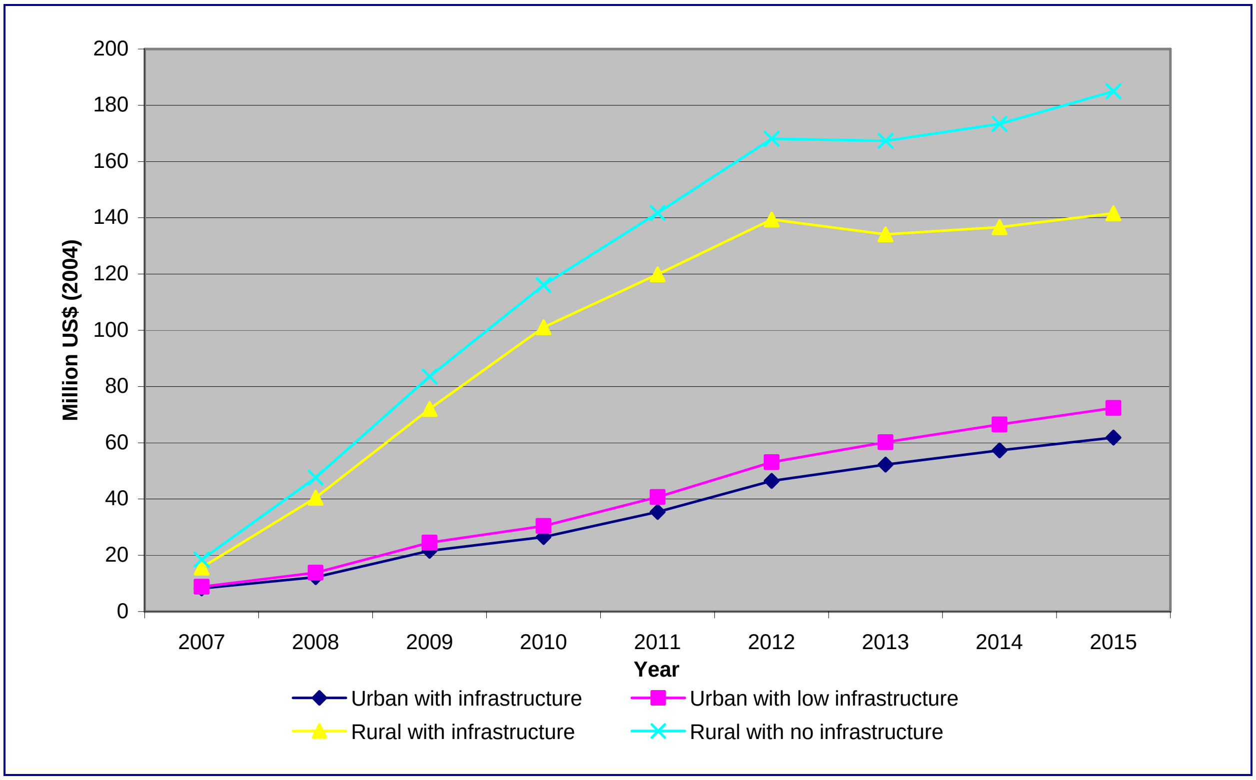


Table 10 shows differences in the cost per DALY averted across the four scenarios. This variation largely reflects differences in the package of interventions proposed for each scenario. The urban with low infrastructure scenario is shown to be the most cost-effective of the four scenarios due to less use of the higher-cost solutions compared to other scenarios. For instance, such a setting makes less use of centralized incineration compared to urban areas with infrastructure and less use of the yet higher cost on-site incineration recommended for rural areas. The urban with low infrastructure scenario makes most use of community incineration, a lower-cost alternative to the transportation of sharps waste to a large, centralized facility.

Table 10. Cost Effectiveness by Scenario (all WHO Regions)—Total Costs and Effects, 2007–2015

	Baseline Costs (2006) Costs	Total Cost	Incremental Cost*	DALYs Averted	Incremental Cost/ DALY Averted
Urban with infrastructure	$300,174,991	$755,499,195	$455,324,203	5,872,375.14	$77.54
Urban with low infrastructure	$24,484,135	$102,503,626	$78,019,491	1,702,423.03	$45.83
Rural with infrastructure	$733,497,667	$1,865,168,010	$1,131,670,342	5,982,155.01	$189.17
Rural with low infrastructure	$112,153,995	$427,773,158	$315,619,163	2,441,750.46	$129.26

* Incremental cost = total cost minus baseline (current) costs spent on waste management in each year (assumes 2006 level).

Analysis of Costs per Injection

To facilitate decision-making on how to allocate immunization resources to contribute to the combined (curative and immunization) system for sharps waste, it is useful to examine the cost per injection for the set of waste management interventions. As shown in Table 11, the baseline costs for current sharps waste disposal interventions in 2006 are estimated to be approximately US$0.01 per injection. With reasonable levels of adoption of the proposed interventions, almost US$0.04 per injection would be required by 2015. Per-injection costs increase over time due to adoption of the more expensive interventions, which in turn improve patient and health care worker safety. Examples of the more expensive options include the centralized treatment of sharps waste at large incinerators or other treatment plants, or rural incineration that may be utilized at lower capacity than in urban areas and therefore cost more per injection.

Assuming eight immunization injections per infant in the first year of life, GAVI could expect to pay up to US$0.31 per infant for sharps waste management in 2015, assuming reasonable levels of adoption of the interventions proposed. As a reference, the per capita (whole population) costs are also included in Table 11. The per-capita costs are lower because the average person receives fewer injections than an infant.

Table 11. Total Cost of Waste Management Interventions, Averaged Across All Regions and Scenarios, 2006–2015

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Total cost per injection	$0.012	$0.017	$0.022	$0.026	$0.029	$0.032	$0.034	$0.035	$0.036	$0.038
Total cost per infant (assume 8 injections/ infant)	$0.099	$0.138	$0.175	$0.207	$0.233	$0.253	$0.275	$0.281	$0.291	$0.307
Total cost per capita (approx. 2 injections/ person)	$0.025	$0.034	$0.044	$0.052	$0.058	$0.064	$0.069	$0.071	$0.074	$0.079

9.b. Sensitivity Analysis

Analysis of Cost Drivers

The incremental costs of the proposed set of interventions depend most importantly on (1) the mix of interventions modeled and (2) the estimated utilization of equipment and systems that comprise each intervention. Both were varied independently to understand the impact of each on incremental costs.

Mix of Interventions

Since the mix of interventions varies by scenario, the difference between urban clinics with and without infrastructure, and then the difference between rural clinics with and without infrastructure, was each changed and analyzed separately. In both cases, it was assumed that 25 percent fewer injections are occurring in clinics with infrastructure. As a result, more weight is put on the sets of interventions proposed for the clinics with less or no infrastructure. As seen in Table 12, this actually reduces incremental costs in the early years when assumed uptake of the interventions in clinics with less infrastructure is low. In later years, however, costs increase over the base case due to increasing adoption of the options that require either building infrastructure (i.e., transporting sharps to a community incinerator) or purchasing on-site equipment (i.e., De Montfort-like incinerators, melters, etc.) These interventions tend to have lower utilization due to the fewer number of injections that are processed, especially for rural clinics with low infrastructure. On a per-injection basis, this increases the cost per injection in the last three years of the intervention only, by an average marginal cost of $.0006.

Utilization of Equipment and Systems

To calculate the base case utilization of each proposed piece of equipment, the annual number of injections occurring in the average facility in each of the four scenarios was first estimated (assumptions can be found in Annex C). These calculations implied a certain number of health care facilities in a given country and were factored into the average utilization rates. The more distributed the injections (more facilities, fewer injections occurring in each), the lower the utilization of equipment in each facility. To assess a worse situation than that presented in the base case, it was assumed that 25 percent fewer injections would occur in both urban and rural facilities. As seen in Table 12, this increases incremental costs from the year the proposed interventions commence in 2007. On a per-injection basis, this increases the overall costs by US$.003 on average over the modeling horizon.

The total cost premium per injection shown in Table 11 is obviously more sensitive to assumptions regarding the utilization of equipment than to the changing mix of interventions. Designing the package of waste management interventions such that they maximize utilization will clearly be an important step in keeping the cost premium low.

Table 12. Incremental Costs of Waste Management Interventions

	2007	2008	2009	2010
Base case	$54,690,382	$107,881,812	$157,097,238	$199,562,778
With less infrastructure (electricity, roads, etc.) in both urban and rural facilities*	$48,568,133	$98,631,675	$147,396,893	$187,789,648
With more distributed facilities/ injections**	$66,901,789	$132,602,906	$190,922,582	$241,571,941

	2011	2012	2013	2014	2015
Base case	$235,251,069	$272,869,655	$289,707,153	$314,771,354	$348,801,761
With less infrastructure (electricity, roads, etc.) in both urban and rural facilities*	$227,938,456	$270,387,370	$295,487,614	$324,711,204	$364,782,257
With more distributed facilities/ injections**	$281,405,493	$323,724,367	$339,328,140	$365,353,391	$404,038,831

*Twenty-five percent fewer facilities with infrastructure and correspondingly twenty-five percent more facilities with less infrastructure

**More distributed facilities creates the need for more equipment purchases, as well as less utilization of the equipment at each health care facility. Twenty-five percent fewer injections in each urban and rural facility was assumed.

Analysis of Key Impact Driver

As discussed in Section 7b, the baseline burden of disease that can be averted with sharps waste management interventions was reduced by an estimate of the averted cases attributable to increasing use of AD syringes over the modeling horizon. The baseline was also reduced by a percentage to account for the impacts of other safe injection interventions expected to occur simultaneously (i.e., health care worker education and training, increasing supply of disposable syringes to prevent incentive for needle reuse, etc.). The collective impact of these latter interventions was estimated to reduce the baseline burden of disease by an additional 20 percent in the analysis above. Due to the uncertainty around the selection of the percentage for that parameter, in the sensitivity analysis the baseline was reduced to 50 percent to understand its impact. As shown in Table 13, this change increases the incremental cost per DALY averted to US$124 from the base case of US$87.

Table 13. Total DALYs Averted and Cost/DALY Averted, Base Case vs. 50 Percent Reduction in Baseline Burden of Disease, 2007-2015, Across All Four Infrastructure Scenarios

	Base Case		50% Reduction in Baseline Burden of Disease	
	DALYs Averted	Incremental Cost/DALY Averted	DALYs Averted	Incremental Cost/DALY Averted
AFR	5,984,620	$47	3,749,386	$74
AMR	108,154	$1,377	69,428	$2,145
EMR	1,741,261	$126	1,089,258	$201
EUR	178,773	$984	113,154	$1,555
SEAR	11,547,510	$61	7,218,788	$97
WPR	2,967,639	$154	1,856,351	$245
Total	22,527,957	$88	14,096,365	$141

9.c. Market Analysis

As noted earlier, international consensus on acceptable technologies and approaches must still be obtained. A market analysis would therefore be premature at this time. While some proposed interventions are largely available today, increased demand resulting from countries adopting waste management systems should help to decrease prices. Although this model program does not estimate costs of any activities such as design refinement/product adaptation or field evaluation of new technologies, these activities are predicted to continue or accelerate in the commercial sector under the stimulus of GAVI support for activities outlined in this analysis. Annex D lists many of the current major suppliers of the proposed sharps waste management interventions, excluding transport systems.

9.d. Equity Impact

The proposed set of sharps waste management interventions could arguably be one of the most equitable interventions in global health. The containment and destruction of sharps waste broadly and favorably impacts patients, health care workers, and the community. Furthermore, the intervention affects all levels of health care infrastructure, further underscoring its equitable impact. To ensure that this equity is achieved, implementers should consider adopting the proposed solutions in each infrastructure scenario, despite differences in the cost per injection of developing proper waste systems that are appropriate for each scenario.

Part III. Monitoring and Evaluation Implementation

Section 10. Monitoring and Evaluation

10.a. Success and Milestones

Success and milestones for sharps waste management will be measured at the global and country levels. Key measures of success would include:

1. Availability of generic guidelines on appropriate sharps waste management solutions that are adaptable to different conditions.
2. Availability of a toolkit that countries can use to assess their own waste management situations.
3. Completion of regional- and country-level advocacy and planning for GAVI sharps waste management support.
4. Availability and active use of waste management technologies and practices in countries.

Improved safety and coverage would be monitored at the country level using the indicators from the initial assessment tool that would be developed. These input, process, and output indicators would be used for both initial assessment and as a means for tracking performance against goals and objectives.

10.b. Data and Information Required

Specific indicators would be selected by country partners to reflect national policies, strategies, and priorities. At the country level, indicators may include the existence of a regulatory framework, policy documents, action plans, a waste management authority, inclusion of waste management in medical and nursing school training curricula, and budgets for health care waste. At the country level, indicators would include evidence that:

1. Primary health care facilities fulfill approximately ten criteria for waste management within the facility such as the presence of safety boxes or the establishment of color-coded segregation systems, needlestick reporting systems, and secure storage locations for safety boxes.
2. Each transport system has storage areas to separate new supplies from waste, picks up waste according to an established schedule, and delivers the waste to approved treatment sites.
3. Each treatment site meets approximately ten treatment criteria such as the existence and use of personal protective clothing, the number of trained incinerator operators, secure storage areas, the number of incinerators with service contracts, and the number of working incinerators.
4. The cost (per kilogram of waste treated) is known and budgeted.
5. The quantity of waste processed is known.

10.c. Responsibilities for Monitoring and Evaluation

The LMP would be responsible for tracking and gathering monitoring and evaluation results for the global level. These would be presented in the form of routine reports. At the country level, data could be routinely gathered by designated staff in the relevant ministries—most likely ministries of health and the environment. Priority for sharps waste management and, therefore, data collection would need to be clearly stated and supported at the highest government levels. This would add an additional data collection burden, so indicators would need to be carefully targeted to maximize use of data collection for ongoing decision making. Periodic spot visits would be made by appropriate authorities to observe practices and conduct audits of sharps waste management systems.

10.d. Monitoring and Evaluation Timetable

The proposed implementation work plan (Section 3.e.) identifies management activities with deliverables and a timeline. Individual countries report data annually on national and district levels through the WHO databases. Countries would be offered technical assistance in defining a minimum set of core indicators that would be useful at the local level to improve sharps waste management, are feasible to collect, and do not overburden the district or health facility. These data would be incorporated into routine reporting schedules. Country and regional data collection must be seen as an ongoing process with periodic monitoring and assessment by the responsible national authority.

Annex A

Methodologies and Assumptions: Baseline Burden of Disease

Methodology for Modeling Baseline Infections

The modeling of baseline infections among patients and health care workers resulting from needle reuse and needlestick injury involved three steps:

1. Project infection estimates found in the literature for the base year of 2000.
Estimates were found in the literature for infections resulting from needle reuse and needlestick injury across both the curative and immunization sectors.[1, 5] The probability of infection was assumed to be constant at 2000 levels over the modeling horizon. With the probability of infection constant, the number of HIV, HBV, and HCV infections was increased proportionally with regional growth in the number of injections. The average number of injections per person for each WHO region was found in the literature and kept constant,[1] thus increasing the number of infections with the population growth for that region. This assumes, most importantly, a constant proportion of both patients and health care workers to the general population over the modeling time horizon. The resulting estimates are likely conservative due to the increasing incidence of HIV/HBV/HCV infections for many countries in the subset over the modeling horizon. All infection estimates were made using region-specific data.

2. Reduce baseline infections by increasing use of AD syringes over the modeling horizon.
To account for the reduction in exposure to unsafe injection due to AD use in the immunization sector, and to a lesser extent in the curative sector, the levels of future patient infections were reduced accordingly. AD use was projected over the modeling horizon (Table 1). Baseline health care worker infections were left unchanged due to increasing AD use, as needlestick injury remains unchanged with the adoption of ADs. The estimated infections eliminated due to projected AD use in both the immunization and curative sector can be found in Table 2.

3. Reduce baseline infections further to account for other safe injection activities occurring over the modeling horizon.
Due to the uncertainty around the impact of other activities that may reduce unsafe injections, the baseline was further reduced by 20 percent in the base case. The baseline was reduced by 50 percent in the sensitivity analysis in Section 9b to examine impact on cost-effectiveness ratios.

Methodology for Calculating Baseline DALYs

1. Patients

Patient DALY data from needle reuse was found in the literature for the year 2000. Future estimates of DALYs from needle reuse were assumed to follow calculated infection growth. This assumes a constant age distribution of patients infected over the modeling time horizon. The baseline of DALYs was reduced by the number of DALYs averted from AD use in the immunization sector and, to a lesser extent, in the curative sector.

DALYs averted from AD use were calculated from regional infections averted from AD use as noted in Table 2. The following assumptions were made:

- Average age of infection in the immunization sector was assumed to be six months.
- Average age of infection in the curative sector was assumed to be the mid-point of the life expectancy for each WHO region. Life expectancy for each WHO region was taken from WHO country data. Life expectancy for the largest country (in each region) was used to represent the region.
- Nelson Gay's model that calculates probabilities for chronic infection and deaths for each five year age group for each infection (HBV, HCV, HIV, and AIDS) was used.
- Separate disability weights and duration of illness episode data for HIV and AIDS was used.
- A discount factor of three percent was applied to all future disability.

DALYs eliminated due to projected AD use in both the immunization and curative sector can be found in Table 3.

2. Health Care Workers

Health care worker DALY data could not be obtained in the literature, so DALY calculations were made by taking the infection estimates among health care workers over the modeling time horizon. The same assumptions were used as above, except the average age of infection. For simplicity, this age was assumed to be 35. Since the DALYs from needlestick injury are only a fraction of those resulting from needle reuse on patients, the accuracy with which this estimate is made would not significantly affect the overall baseline of projected DALYs.

Key Assumptions/Calculations

Table 1. Adoption of AD Syringes in Curative and Immunization Sectors

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Immunization										
ADs	50%	53%	56%	60%	64%	67%	70%	72%	74%	75%
Disposable Needle/Syringe	50%	47%	44%	40%	36%	33%	30%	28%	26%	25%
Curative										
ADs	1%	3%	5%	7%	9%	11%	13%	17%	21%	25%
Disposable Needle/Syringe	99%	97%	95%	93%	91%	89%	87%	83%	79%	75%

The 2004 *Global Status of Immunization Report* suggests that 60 percent of nonindustrialized countries use ADs but that only 38 percent use them exclusively.[19] For 2006, it was assumed that 50 percent of countries would have exclusive use. For simplicity, it was assumed that these countries would account for 50 percent of injections. Another approach led to a similar percent: worldwide syringe use is 15 billion; immunization use of syringes is 10 percent, or 1.5 billion. As 700 million ADs were sold in 2005, this represents about 50 percent of the 1.5 billion immunization syringes used.

For the curative sector, virtually all injections are currently given with disposable needle and syringe. The increase of AD use to 25 percent was estimated.

Table 2. Estimated Patient Infections Eliminated Though Use of AD Syringes

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Immunization										
AFR (D and E)	139,574	151,078	162,936	178,118	193,771	206,810	220,204	230,747	241,526	249,219
AMR (B and D)	2,830	3,036	3,246	3,519	3,798	4,022	4,250	4,421	4,594	4,708
EMR (B and D)	90,542	97,917	105,512	115,247	125,276	133,603	142,151	148,851	155,697	160,550
EUR (B and C)	6,398	6,790	7,183	7,706	8,229	8,626	9,023	9,292	9,562	9,703
SEAR (B and D)	886,699	953,496	1,021,833	1,110,212	1,200,644	1,274,111	1,349,118	1,406,133	1,464,175	1,503,201
WPR (B only)	216,666	231,627	246,810	266,660	286,806	302,730	318,875	330,650	342,574	349,979
Total infections	**1,342,709**	**1,443,945**	**1,547,521**	**1,681,462**	**1,818,524**	**1,929,902**	**2,043,620**	**2,130,094**	**2,218,129**	**2,277,358**
Curative										
AFR (D and E)	13,957	42,758	72,739	103,902	136,245	169,770	204,475	272,410	342,706	415,365
AMR (B and D)	509	1,547	2,609	3,695	4,807	5,943	7,104	9,394	11,734	14,124
EMR (B and D)	34,406	105,307	178,993	255,464	334,721	416,762	501,589	667,760	839,502	1,016,814
EUR (B and C)	2,431	7,302	12,186	17,081	21,988	26,907	31,838	41,685	51,556	61,451
SEAR (B and D)	88,670	269,857	456,175	647,624	844,203	1,045,912	1,252,752	1,660,019	2,077,546	2,505,334
WPR (B only)	82,333	249,108	418,696	591,097	766,310	944,335	1,125,174	1,483,334	1,847,120	2,216,531
Total infections	**222,307**	**675,880**	**1,141,399**	**1,618,863**	**2,108,274**	**2,609,630**	**3,122,931**	**4,134,603**	**5,170,165**	**6,229,619**

Table 3. Estimated Patient DALYs Eliminated Though Use of AD Syringes

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Immunization										
AFR (D and E)	265,805	287,713	310,296	339,208	369,018	393,850	419,357	439,435	459,963	474,612
AMR (B and D)	2,881	3,090	3,305	3,582	3,866	4,094	4,326	4,500	4,676	4,793
EMR (B and D)	12,216	13,211	14,235	15,549	16,901	18,025	19,162	20,083	21,005	21,661
EUR (B and C)	1,437	1,526	1,615	1,731	1,849	1,939	2,028	2,088	2,148	2,181
SEAR (B and D)	612,303	658,430	705,619	766,650	829,096	879,828	931,624	970,994	1,011,100	1,038,024
WPR (B only)	116,221	124,938	133,853	145,388	157,187	166,759	176,529	183,943	191,487	196,543
Total DALYs	**1,010,862**	**1,088,907**	**1,168,923**	**1,272,108**	**1,377,917**	**1,464,494**	**1,553,026**	**1,621,042**	**1,690,380**	**1,737,812**
Curative										
AFR (D and E)	16,687	51,118	86,962	124,219	162,887	202,965	206,294	250,973	332,417	416,686
AMR (B and D)	322	978	1,648	2,335	3,036	3,754	3,877	4,731	6,183	7,666
EMR (B and D)	4,281	13,101	22,269	31,783	41,643	51,849	61,089	80,502	101,783	123,749
EUR (B and C)	563	1,692	2,823	3,957	5,094	6,233	6,770	8,448	10,732	13,023
SEAR (B and D)	42,206	128,447	217,131	308,257	401,826	497,836	519,845	639,624	834,568	1,034,396
WPR (B only)	10,565	31,964	53,725	75,847	98,329	117,088	141,891	185,412	232,013	279,451
Total DALYs	**74,624**	**227,301**	**384,557**	**546,396**	**712,815**	**879,725**	**939,766**	**1,169,690**	**1,517,697**	**1,874,971**

Annex B

Methodologies and Assumptions: Impact

Methodology for Assigning Risk

Four classifications of risk were used: 0 = no risk of infection, 1 = low risk of infection, 2 = moderate risk of infection, 3 = high risk of infection. The relationship between risk was assumed to be linear (i.e., a 2 implies twice as much risk as 1, a 3 implies three times as much risk as 1). With that assumption, waste management experts developed risk scores for each node as shown in Table 1.

Methodology for Calculating Adoption Along the Nodes of the Decision Tree

Adoption rates were established for each intervention. Year 2006 was considered the base year for preexisting waste management interventions, and 2007 was considered the commencement year for the proposed set of interventions. Adoption rates were established for both disposal options as well as container options, based on what is being thrown away (needle alone, syringe alone, needle/syringe combination—either AD or disposable). These rates assumed full support from a combination of GAVI and MOH funding. See Tables 3–6 for the adoption rates established for each intervention.

Since each node was composed of several interventions, the final adoption rate assigned to each node was a product of several adoption rates. Every node also included the type of injection device used. Since AD use differs so significantly between the immunization and curative sectors, adoption rates were calculated first by sector and then a weighted average was taken assuming that 90 percent are curative injections and 10 percent are immunization injections, to arrive at one set of adoption rates (e.g., percent of injections flowing through each node) per year for each scenario. See Tables 7–10 for the percent of injections flowing through each node for each scenario.

Methodology for Determining Risk Reduction and Infections Avoided

To determine overall risk for each year in each scenario, the risk scores established for each node (explained above) were weighted by the percent of injections along each node (also explained above). The risk reduction for each year was calculated by determining the change in absolute risk relative to the base year (2006). Changes in risk were calculated for each key constituency group (Table 2). It was assumed that a reduction in risk would create a proportional (1:1) reduction in infections and DALYs.

Figure 1. Decision-Tree Model of Disposal Pathways

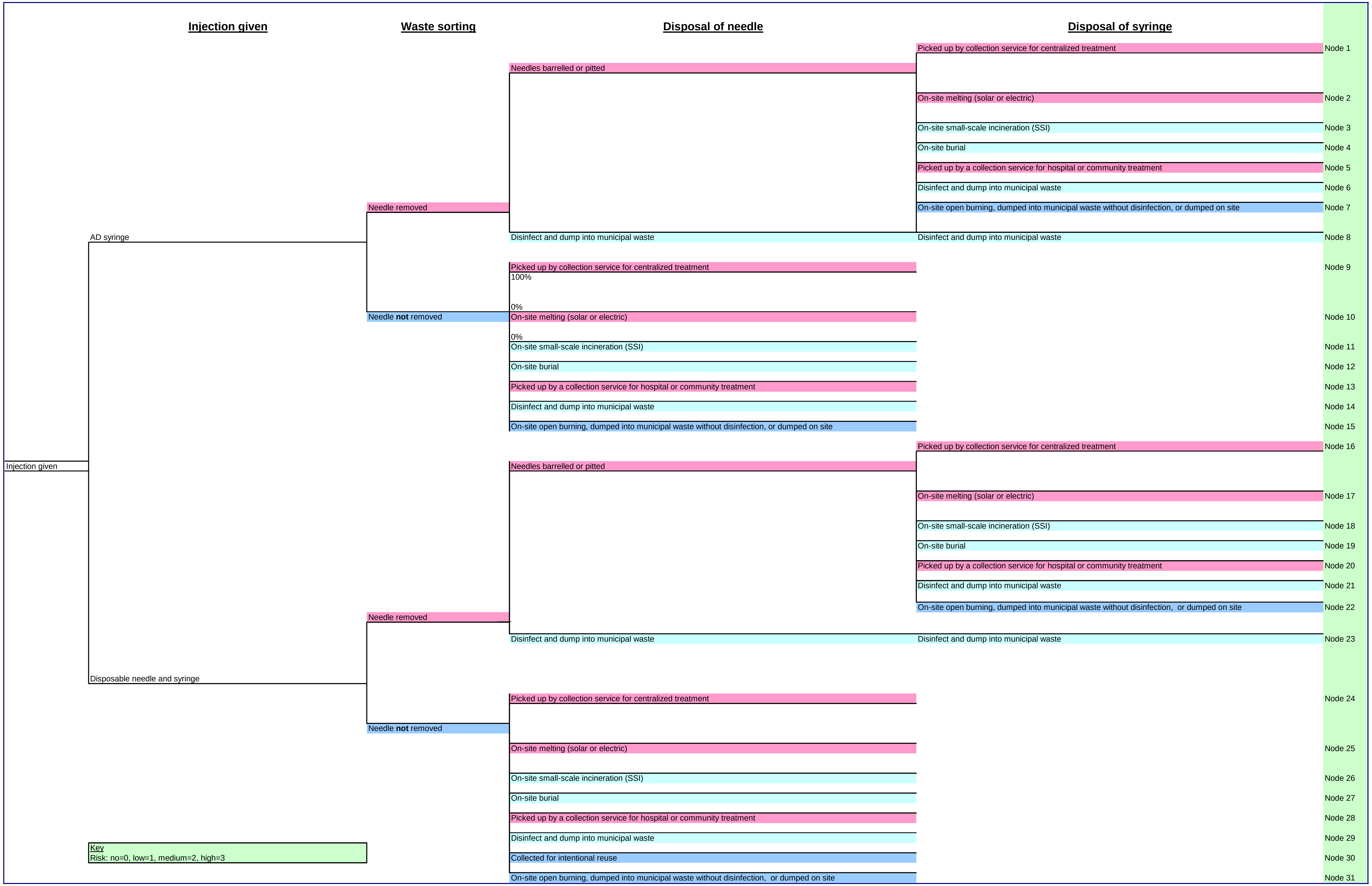


Table 1. Risk by Node for Each Constituency Group and Type of Container

Disposal Pathway	Health-Worker Infection Risk From Needlestick		Patient Infection Risk From Needle Reuse		Community Infection Risk From Needlestick	
	Medical Waste in Plastic Bags	Medical Waste in Safety Box	Medical Waste in Plastic Bags	Medical Waste in Safety Box	Medical Waste in Plastic Bags	Medical Waste in Safety Box
Node 1	0	0	0	0	0	0
Node 2	0	0	0	0	0	0
Node 3	1	0	0	0	0	0
Node 4	1	0	0	0	1	1
Node 5	1	0	0	0	1	1
Node 6	1	0	0	0	1	1
Node 7	1	0	0	0	1	1
Node 8	0	0	0	0	3	2
Node 9	2	0	0	0	0	0
Node 10	1	0	0	0	0	0
Node 11	2	0	0	0	2	1
Node 12	2	0	0	0	2	1
Node 13	2	0	0	0	2	1
Node 14	2	0	0	0	2	1
Node 15	2	0	0	0	2	1
Node 16	0	0	0	0	0	0
Node 17	0	0	0	0	0	0
Node 18	1	0	0	0	1	1
Node 19	1	0	0	0	1	1
Node 20	1	0	0	0	1	1
Node 21	1	0	1	1	1	1
Node 22	1	0	1	1	1	1
Node 23	1	0	1	1	3	2
Node 24	0	0	0	0	0	0
Node 25	0	0	0	0	0	0
Node 26	2	1	0	0	2	1
Node 27	2	1	0	0	2	1
Node 28	2	1	2	1	2	1
Node 29	2	1	3	3	2	1
Node 30	2	1	3	3	2	1
Node 31	2	1	2	2	2	1

Table 2. Risk Reduction by Constituency Group and Scenario

	2007	2008	2009	2010	2011	2012	2013	2014	2015
Urban With Infrastructure									
HCW*	7%	15%	24%	34%	43%	54%	62%	72%	80%
Patients	10%	21%	31%	40%	47%	57%	64%	72%	80%
Community	6%	13%	22%	30%	38%	48%	56%	65%	72%
Urban With Low Infrastructure									
	2007	2008	2009	2010	2011	2012	2013	2014	2015
HCW	4%	12%	20%	30%	39%	48%	57%	66%	74%
Patients	5%	16%	27%	37%	48%	55%	61%	65%	71%
Community	3%	10%	18%	26%	35%	43%	50%	58%	65%
Rural With Infrastructure									
	2007	2008	2009	2010	2011	2012	2013	2014	2015
HCW	4%	9%	15%	21%	27%	32%	40%	50%	58%
Patients	3%	11%	20%	29%	34%	40%	42%	47%	53%
Community	3%	7%	13%	17%	21%	26%	32%	38%	44%
Rural With Low Infrastructure									
	2007	2008	2009	2010	2011	2012	2013	2014	2015
HCW	4%	9%	14%	20%	26%	32%	40%	49%	57%
Patients	5%	11%	17%	22%	32%	42%	51%	58%	68%
Community	3%	8%	12%	16%	21%	25%	31%	37%	43%

*HCW=health care worker

Table 3. Adoption Rates for Each Intervention: Urban With Infrastructure

	Urban with infrastructure									
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
DISPOSAL OPTIONS - IMMUNIZATION AND CURATIVE										
% of injections using NEEDLE REMOVER	0%	2%	5%	8%	12%	17%	22%	26%	30%	33%
… of which….										
% of needles barreled or pitted	80%	80%	83%	85%	87%	89%	92%	93%	94%	95%
% needles disinfected and dumped into municipal waste	20%	20%	17%	15%	13%	11%	8%	7%	6%	5%
check	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Syringe-only disposal options										
% syringes picked up by collection service for centralized treatment	5%	7%	10%	15%	20%	25%	33%	38%	44%	50%
% syringes melted (solar or electric)	0%	1%	2%	3%	4%	5%	6%	7%	8%	10%
% syringes incinerated with SSI	5%	8%	10%	10%	9%	8%	7%	6%	5%	4%
% syringe buried	5%	5%	5%	4%	4%	3%	3%	2%	2%	1%
% syringes picked up by a collection service for hospital/community treatment	10%	15%	20%	25%	25%	25%	25%	25%	25%	25%
% syringes disinfected and dumped into municipal waste	10%	15%	15%	15%	15%	15%	15%	14%	12%	10%
% syringes open burned, dumped into municipal waste without disinfection, or dumped on site	65%	49%	38%	28%	23%	19%	11%	8%	4%	0%
check	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
% of injections NOT using NEEDLE REMOVER	100%	98%	95%	92%	88%	83%	78%	74%	70%	67%
… of which….	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Needle/syringe disposal options (disposable syringes only)										
% needle/syringe picked up by collection service for centralized treatment	5%	7%	10%	15%	20%	25%	33%	38%	44%	50%
% needle/syringe melted (solar or electric)	0%	1%	2%	3%	4%	5%	6%	7%	8%	10%
% needle/syringe incinerated with SSI	5%	8%	10%	10%	9%	8%	7%	6%	5%	4%
% needle/syringe buried	5%	5%	5%	4%	4%	3%	3%	2%	2%	1%
% needle/syringe picked up by a collection service for hospital/community treatment	10%	15%	20%	25%	25%	25%	25%	25%	25%	25%
% needle/syringe disinfected and dumped into municipal waste	10%	10%	10%	10%	10%	10%	10%	8%	5%	2%
% needle/syringe collected for intentional reuse	39%	33%	27%	20%	15%	12%	10%	8%	6%	5%
% needle/syringe open burned, dumped into municipal waste without disinfection, or dumped on site	26%	21%	16%	13%	13%	12%	6%	6%	5%	3%
check	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Needle/syringe disposal options (A/Ds)										
% needle/syringe picked up by collection service for centralized treatment	5%	7%	10%	15%	20%	25%	33%	38%	44%	50%
% needle/syringe melted (solar or electric)	0%	1%	2%	3%	4%	5%	6%	7%	8%	10%
% needle/syringe incinerated with SSI	5%	8%	10%	10%	9%	8%	7%	6%	5%	4%
% needle/syringe buried	5%	5%	5%	4%	4%	3%	3%	2%	2%	1%
% needle/syringe picked up by a collection service for hospital/community treatment	10%	15%	20%	25%	25%	25%	25%	25%	25%	25%
% needle/syringe disinfected and dumped into municipal waste	10%	15%	15%	15%	15%	15%	15%	14%	12%	10%
% needle/syringe open burned, dumped into municipal waste without disinfection, or dumped on site	65%	49%	38%	28%	23%	19%	11%	8%	4%	0%
check	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
CONTAINER OPTIONS - IMMUNIZATION AND CURATIVE										
TO DETERMINE WEIGHTED AVERAGE RISKS AND WEIGHTED AVERAGE COSTS TO APPLY TO NODES										
Disposal of needle/syringe combo										
Picked up by collection service for centralized treatment										
Plastic bags/Cardboard box	10%	8%	6%	5%	4%	3%	2%	1%	0%	0%
Non-reusable safety boxes	90%	90%	90%	89%	88%	87%	86%	84%	82%	80%
Reusable safety boxes	0%	2%	4%	6%	8%	10%	12%	15%	18%	20%
On-site melting (solar or electric)										
On site small scale incineration (SSI)										
On-site burial										
Picked up by a collection service for hospital/community treatment										
Disinfected and dumped into municipal waste										
Collected for intentional reuse										
Open burned, dumped into municipal waste without disinfection, or dumped on site										
Plastic bags/Cardboard box	90%	85%	80%	75%	70%	65%	60%	50%	37%	25%
Non-reusable safety boxes	10%	15%	20%	25%	30%	35%	40%	50%	63%	75%
Disposal of syringe alone										
Picked up by collection service for centralized treatment										
Plastic bags/Cardboard box	10%	8%	6%	5%	4%	3%	2%	1%	0%	0%
Non-reusable safety boxes	90%	90%	90%	89%	88%	87%	86%	84%	82%	80%
Reusable safety boxes	0%	2%	4%	6%	8%	10%	12%	15%	18%	20%
On-site melting (solar or electric)										
On site small scale incineration (SSI)										
On-site burial										
Picked up by a collection service for hospital/community treatment										
Disinfected and dumped into municipal waste										
Open burned, dumped into municipal waste without disinfection, or dumped on site										
Plastic bags/Cardboard box	90%	85%	80%	75%	70%	65%	60%	50%	37%	25%
Non-reusable safety boxes	10%	15%	20%	25%	30%	35%	40%	50%	63%	75%

Table 4. Adoption Rates for Each Intervention: Urban With Low Infrastructure

	Urban with low infrastructure									
	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
DISPOSAL OPTIONS - IMMUNIZATION AND CURATIVE										
% of injections using NEEDLE REMOVER	0%	2%	5%	8%	12%	17%	22%	26%	30%	33%
… of which….										
% of needles barreled or pitted	80%	80%	83%	85%	87%	89%	92%	93%	94%	95%
% needles disinfected and dumped into municipal waste	20%	20%	17%	15%	13%	11%	8%	7%	6%	5%
check	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Syringe-only disposal options										
% syringes picked up by collection service for centralized treatment	2%	2%	5%	8%	12%	15%	20%	25%	30%	35%
% syringes melted (solar or electric)	0%	0%	1%	3%	5%	8%	10%	12%	14%	15%
% syringes incinerated with SSI	25%	25%	25%	25%	25%	25%	22%	20%	15%	10%
% syringe buried	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
% syringes picked up by a collection service for hospital/community treatment	10%	20%	25%	30%	30%	30%	30%	30%	30%	30%
% syringes disinfected and dumped into municipal waste	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
% syringes open burned, dumped into municipal waste without disinfection, or dumped on site	58%	48%	39%	29%	23%	17%	13%	8%	6%	5%
check	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
% of injections NOT using NEEDLE REMOVER	100%	98%	95%	92%	88%	83%	78%	74%	70%	67%
… of which….	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Needle/syringe disposal options (disposable syringes only)										
% needle/syringe picked up by collection service for centralized treatment	2%	2%	5%	8%	12%	15%	19%	22%	25%	30%
% needle/syringe melted (solar or electric)	0%	0%	1%	3%	5%	8%	10%	12%	14%	15%
% needle/syringe incinerated with SSI	25%	25%	25%	25%	25%	25%	22%	20%	15%	12%
% needle/syringe buried	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
% needle/syringe picked up by a collection service for hospital/community treatment	5%	10%	15%	20%	20%	20%	20%	20%	20%	20%
% needle/syringe disinfected and dumped into municipal waste	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
% needle/syringe collected for intentional reuse	39%	33%	27%	22%	20%	18%	16%	14%	12%	10%
% needle/syringe open burned, dumped into municipal waste without disinfection, or dumped on site	24%	25%	22%	17%	13%	9%	8%	7%	9%	8%
check	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Needle/syringe disposal options (A/Ds)										
% needle/syringe picked up by collection service for centralized treatment	2%	2%	5%	8%	12%	15%	20%	25%	30%	35%
% needle/syringe melted (solar or electric)	0%	0%	1%	3%	5%	8%	10%	12%	14%	15%
% needle/syringe incinerated with SSI	25%	25%	25%	25%	25%	25%	22%	20%	15%	10%
% needle/syringe buried	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
% needle/syringe picked up by a collection service for hospital/community treatment	10%	20%	25%	30%	30%	30%	30%	30%	30%	30%
% needle/syringe disinfected and dumped into municipal waste	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
% needle/syringe open burned, dumped into municipal waste without disinfection, or dumped on site	58%	48%	39%	29%	23%	17%	13%	8%	6%	5%
check	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
CONTAINER OPTIONS - IMMUNIZATION AND CURATIVE										
TO DETERMINE WEIGHTED AVERAGE RISKS AND WEIGHTED AVERAGE COSTS TO APPLY TO NODES										
Disposal of needle/syringe combo										
Picked up by collection service for centralized treatment										
Plastic bags/Cardboard box	10%	8%	6%	5%	4%	3%	2%	1%	0%	0%
Non-reusable safety boxes	90%	90%	90%	89%	88%	87%	86%	84%	82%	80%
Reusable safety boxes	0%	2%	4%	6%	8%	10%	12%	15%	18%	20%
On-site melting (solar or electric)										
On site small scale incineration (SSI)										
On-site burial										
Picked up by a collection service for hospital/community treatment										
Disinfected and dumped into municipal waste										
Collected for intentional reuse										
Open burned, dumped into municipal waste without disinfection, or dumped on site										
Plastic bags/Cardboard box	90%	85%	80%	75%	70%	65%	60%	50%	37%	25%
Non-reusable safety boxes	10%	15%	20%	25%	30%	35%	40%	50%	63%	75%
Disposal of syringe alone										
Picked up by collection service for centralized treatment										
Plastic bags/Cardboard box	10%	8%	6%	5%	4%	3%	2%	1%	0%	0%
Non-reusable safety boxes	90%	90%	90%	89%	88%	87%	86%	84%	82%	80%
Reusable safety boxes	0%	2%	4%	6%	8%	10%	12%	15%	18%	20%
On-site melting (solar or electric)										
On site small scale incineration (SSI)										
On-site burial										
Picked up by a collection service for hospital/community treatment										
Disinfected and dumped into municipal waste										
Open burned, dumped into municipal waste without disinfection, or dumped on site										
Plastic bags/Cardboard box	90%	85%	80%	75%	70%	65%	60%	50%	37%	25%
Non-reusable safety boxes	10%	15%	20%	25%	30%	35%	40%	50%	63%	75%

Table 5. Adoption Rates for Each Intervention: Rural With Infrastructure

	Rural with infrastructure									
	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
DISPOSAL OPTIONS - IMMUNIZATION AND CURATIVE										
% of injections using NEEDLE REMOVER	0%	2%	5%	8%	12%	17%	22%	26%	30%	33%
… of which….										
% of needles barreled or pitted	80%	80%	83%	85%	87%	89%	92%	93%	94%	95%
% needles disinfected and dumped into municipal waste	20%	20%	17%	15%	13%	11%	8%	7%	6%	5%
check	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Syringe-only disposal options										
% syringes picked up by collection service for centralized treatment	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
% syringes melted (solar or electric)	1%	1%	2%	4%	5%	6%	7%	8%	10%	12%
% syringes incinerated with SSI	10%	10%	13%	16%	20%	20%	20%	15%	12%	10%
% syringe buried	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
% syringes picked up by a collection service for hospital/community treatment	10%	20%	30%	33%	35%	36%	37%	38%	39%	40%
% syringes disinfected and dumped into municipal waste	10%	15%	20%	25%	25%	25%	25%	25%	25%	25%
% syringes open burned, dumped into municipal waste without disinfection, or dumped on site	59%	44%	25%	12%	5%	3%	1%	4%	4%	3%
check	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
% of injections NOT using NEEDLE REMOVER	100%	98%	95%	92%	88%	83%	78%	74%	70%	67%
… of which….	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Needle/syringe disposal options (disposable syringes only)										
% needle/syringe picked up by collection service for centralized treatment	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
% needle/syringe melted (solar or electric)	1%	1%	2%	4%	5%	6%	7%	8%	10%	12%
% needle/syringe incinerated with SSI	10%	10%	13%	16%	20%	20%	20%	15%	12%	10%
% needle/syringe buried	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
% needle/syringe picked up by a collection service for hospital/community treatment	10%	20%	25%	26%	27%	28%	29%	32%	35%	40%
% needle/syringe disinfected and dumped into municipal waste	5%	6%	7%	8%	9%	10%	10%	10%	10%	10%
% needle/syringe collected for intentional reuse	39%	36%	33%	30%	27%	25%	22%	18%	14%	10%
% needle/syringe open burned, dumped into municipal waste without disinfection, or dumped on site	25%	17%	10%	6%	2%	1%	2%	7%	9%	8%
check	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Needle/syringe disposal options (A/Ds)										
% needle/syringe picked up by collection service for centralized treatment	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
% needle/syringe melted (solar or electric)	1%	1%	2%	4%	5%	6%	7%	8%	10%	12%
% needle/syringe incinerated with SSI	10%	10%	13%	16%	20%	20%	20%	15%	12%	10%
% needle/syringe buried	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
% needle/syringe picked up by a collection service for hospital/community treatment	10%	20%	30%	33%	35%	36%	37%	38%	39%	40%
% needle/syringe disinfected and dumped into municipal waste	10%	15%	20%	25%	25%	25%	25%	25%	25%	25%
% needle/syringe open burned, dumped into municipal waste without disinfection, or dumped on site	59%	44%	25%	12%	5%	3%	1%	4%	4%	3%
check	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
CONTAINER OPTIONS - IMMUNIZATION AND CURATIVE										
TO DETERMINE WEIGHTED AVERAGE RISKS AND WEIGHTED AVERAGE COSTS TO APPLY TO NODES										
Disposal of needle/syringe combo										
Picked up by collection service for centralized treatment										
Plastic bags/Cardboard box	10%	8%	6%	5%	4%	3%	2%	1%	0%	0%
Non-reusable safety boxes	90%	92%	94%	95%	96%	97%	98%	99%	100%	100%
Reusable safety boxes	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
On-site melting (solar or electric)										
On site small scale incineration (SSI)										
On-site burial										
Picked up by a collection service for hospital/community treatment										
Disinfected and dumped into municipal waste										
Collected for intentional reuse										
Open burned, dumped into municipal waste without disinfection, or dumped on site										
Plastic bags/Cardboard box	90%	85%	80%	75%	70%	65%	60%	50%	37%	25%
Non-reusable safety boxes	10%	15%	20%	25%	30%	35%	40%	50%	63%	75%
Disposal of syringe alone										
Picked up by collection service for centralized treatment										
Plastic bags/Cardboard box	10%	8%	6%	5%	4%	3%	2%	1%	0%	0%
Non-reusable safety boxes	90%	92%	94%	95%	96%	97%	98%	99%	100%	100%
Reusable safety boxes	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
On-site melting (solar or electric)										
On site small scale incineration (SSI)										
On-site burial										
Picked up by a collection service for hospital/community treatment										
Disinfected and dumped into municipal waste										
Open burned, dumped into municipal waste without disinfection, or dumped on site										
Plastic bags/Cardboard box	90%	85%	80%	75%	70%	65%	60%	50%	37%	25%
Non-reusable safety boxes	10%	15%	20%	25%	30%	35%	40%	50%	63%	75%

Table 6. Adoption Rates for Each Intervention: Rural With Low Infrastructure

	Rural wth low infrastructure									
	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
DISPOSAL OPTIONS - IMMUNIZATION AND CURATIVE										
% of injections using NEEDLE REMOVER	0%	2%	5%	8%	12%	17%	22%	26%	30%	33%
… of which….										
% of needles barreled or pitted	80%	80%	83%	85%	87%	89%	92%	93%	94%	95%
% needles disinfected and dumped into municipal waste	20%	20%	17%	15%	13%	11%	8%	7%	6%	5%
check	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Syringe-only disposal options										
% syringes picked up by collection service for centralized treatment	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
% syringes melted (solar or electric)	1%	1%	2%	3%	4%	5%	6%	7%	8%	10%
% syringes incinerated with SSI	10%	12%	15%	18%	20%	25%	30%	33%	35%	40%
% syringe buried	20%	20%	18%	16%	14%	12%	10%	10%	10%	10%
% syringes picked up by a collection service for hospital/community treatment	1%	3%	5%	8%	10%	12%	15%	18%	20%	22%
% syringes disinfected and dumped into municipal waste	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
% syringes open burned, dumped into municipal waste without disinfection, or dumped on site	68%	64%	60%	55%	52%	46%	39%	32%	27%	18%
check	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
% of injections NOT using NEEDLE REMOVER	100%	98%	95%	92%	88%	83%	78%	74%	70%	67%
… of which….	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Needle/syringe disposal options (disposable syringes only)										
% needle/syringe picked up by collection service for centralized treatment	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
% needle/syringe melted (solar or electric)	1%	1%	2%	3%	4%	5%	6%	7%	8%	10%
% needle/syringe incinerated with SSI	10%	12%	15%	18%	20%	25%	30%	33%	35%	40%
% needle/syringe buried	20%	20%	18%	16%	14%	12%	10%	10%	10%	10%
% needle/syringe picked up by a collection service for hospital/community treatment	1%	3%	5%	8%	10%	12%	15%	18%	20%	22%
% needle/syringe disinfected and dumped into municipal waste	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
% needle/syringe collected for intentional reuse	39%	36%	33%	30%	27%	22%	18%	14%	12%	10%
% needle/syringe open burned, dumped into municipal waste without disinfection, or dumped on site	29%	28%	27%	25%	25%	24%	21%	18%	15%	8%
check	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Needle/syringe disposal options (A/Ds)										
% needle/syringe picked up by collection service for centralized treatment	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
% needle/syringe melted (solar or electric)	1%	1%	2%	3%	4%	5%	6%	7%	8%	10%
% needle/syringe incinerated with SSI	10%	12%	15%	18%	20%	25%	30%	33%	35%	40%
% needle/syringe buried	20%	20%	18%	16%	14%	12%	10%	10%	10%	10%
% needle/syringe picked up by a collection service for hospital/community treatment	1%	3%	5%	8%	10%	12%	15%	18%	20%	22%
% needle/syringe disinfected and dumped into municipal waste	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
% needle/syringe open burned, dumped into municipal waste without disinfection, or dumped on site	68%	64%	60%	55%	52%	46%	39%	32%	27%	18%
check	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
CONTAINER OPTIONS - IMMUNIZATION AND CURATIVE										
TO DETERMINE WEIGHTED AVERAGE RISKS AND WEIGHTED AVERAGE COSTS TO APPLY TO NODES										
Disposal of needle/syringe combo										
Picked up by collection service for centralized treatment										
Plastic bags/Cardboard box	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Non-reusable safety boxes	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Reusable safety boxes	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
On-site melting (solar or electric)										
On site small scale incineration (SSI)										
On-site burial										
Picked up by a collection service for hospital/community treatment										
Disinfected and dumped into municipal waste										
Collected for intentional reuse										
Open burned, dumped into municipal waste without disinfection, or dumped on site										
Plastic bags/Cardboard box	90%	85%	80%	75%	70%	65%	60%	50%	37%	25%
Non-reusable safety boxes	10%	15%	20%	25%	30%	35%	40%	50%	63%	75%
Disposal of syringe alone										
Picked up by collection service for centralized treatment										
Plastic bags/Cardboard box	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Non-reusable safety boxes	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Reusable safety boxes	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
On-site melting (solar or electric)										
On site small scale incineration (SSI)										
On-site burial										
Picked up by a collection service for hospital/community treatment										
Disinfected and dumped into municipal waste										
Open burned, dumped into municipal waste without disinfection, or dumped on site										
Plastic bags/Cardboard box	90%	85%	80%	75%	70%	65%	60%	50%	37%	25%
Non-reusable safety boxes	10%	15%	20%	25%	30%	35%	40%	50%	63%	75%

Table 7. Percent of Injections Along Each Node: Urban With Infrastructure

	Urban with infrastructure									
	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Node 1	0.0%	0.0%	0.0%	0.1%	0.1%	0.2%	0.4%	0.5%	0.7%	0.9%
Node 2	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%	0.2%
Node 3	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
Node 4	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Node 5	0.0%	0.0%	0.0%	0.1%	0.2%	0.2%	0.3%	0.4%	0.4%	0.5%
Node 6	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%	0.2%	0.2%	0.2%	0.2%
Node 7	0.0%	0.0%	0.1%	0.1%	0.1%	0.2%	0.1%	0.1%	0.1%	0.0%
Node 8	0.0%	0.0%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
Node 9	0.3%	0.4%	0.6%	0.8%	1.0%	1.2%	1.5%	1.7%	1.8%	2.0%
Node 10	0.0%	0.1%	0.1%	0.2%	0.2%	0.2%	0.3%	0.3%	0.3%	0.4%
Node 11	0.3%	0.5%	0.6%	0.5%	0.5%	0.4%	0.3%	0.3%	0.2%	0.2%
Node 12	0.3%	0.3%	0.3%	0.2%	0.2%	0.1%	0.1%	0.1%	0.1%	0.0%
Node 13	0.6%	0.9%	1.1%	1.4%	1.3%	1.2%	1.2%	1.1%	1.0%	1.0%
Node 14	0.6%	0.9%	0.8%	0.8%	0.8%	0.7%	0.7%	0.6%	0.5%	0.4%
Node 15	3.8%	2.8%	2.1%	1.5%	1.2%	0.9%	0.5%	0.3%	0.2%	0.0%
Node 16	0.0%	0.1%	0.4%	1.0%	2.0%	3.6%	6.3%	8.6%	11.7%	14.8%
Node 17	0.0%	0.0%	0.1%	0.2%	0.4%	0.7%	1.1%	1.6%	2.1%	3.0%
Node 18	0.0%	0.1%	0.4%	0.6%	0.9%	1.1%	1.3%	1.4%	1.3%	1.2%
Node 19	0.0%	0.1%	0.2%	0.3%	0.4%	0.4%	0.6%	0.5%	0.5%	0.3%
Node 20	0.0%	0.2%	0.8%	1.6%	2.5%	3.6%	4.8%	5.7%	6.6%	7.4%
Node 21	0.0%	0.2%	0.6%	1.0%	1.5%	2.1%	2.9%	3.2%	3.2%	3.0%
Node 22	0.0%	0.7%	1.5%	1.8%	2.3%	2.7%	2.1%	1.8%	1.1%	0.0%
Node 23	0.0%	0.4%	0.8%	1.1%	1.5%	1.8%	1.7%	1.7%	1.7%	1.6%
Node 24	4.7%	6.5%	8.9%	13.0%	16.6%	19.5%	24.2%	26.5%	29.0%	31.5%
Node 25	0.0%	0.9%	1.8%	2.6%	3.3%	3.9%	4.4%	4.9%	5.3%	6.3%
Node 26	4.7%	7.4%	8.9%	8.7%	7.5%	6.2%	5.1%	4.2%	3.3%	2.5%
Node 27	4.7%	4.6%	4.5%	3.5%	3.3%	2.3%	2.2%	1.4%	1.3%	0.6%
Node 28	9.4%	13.8%	17.9%	21.6%	20.7%	19.5%	18.3%	17.4%	16.5%	15.8%
Node 29	9.4%	9.2%	8.9%	8.7%	8.3%	7.8%	7.3%	5.6%	3.3%	1.3%
Node 30	36.7%	30.4%	24.1%	17.3%	12.4%	9.4%	7.3%	5.6%	4.0%	3.2%
Node 31	24.5%	19.4%	14.3%	11.3%	10.8%	9.4%	4.4%	4.2%	3.3%	1.9%

Table 8. Percent of Injections Along Each Node: Urban With Low Infrastructure

	Urban with low infrastructure									
	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Node 1	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.2%	0.4%	0.5%	0.6%
Node 2	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.2%	0.2%	0.3%
Node 3	0.0%	0.0%	0.1%	0.1%	0.2%	0.2%	0.3%	0.3%	0.2%	0.2%
Node 4	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%	0.1%
Node 5	0.0%	0.0%	0.1%	0.1%	0.2%	0.3%	0.4%	0.4%	0.5%	0.6%
Node 6	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Node 7	0.0%	0.0%	0.1%	0.1%	0.1%	0.2%	0.2%	0.1%	0.1%	0.1%
Node 8	0.0%	0.0%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
Node 9	0.1%	0.1%	0.3%	0.4%	0.6%	0.7%	0.9%	1.1%	1.2%	1.4%
Node 10	0.0%	0.0%	0.1%	0.2%	0.3%	0.4%	0.5%	0.5%	0.6%	0.6%
Node 11	1.5%	1.4%	1.4%	1.4%	1.3%	1.2%	1.0%	0.9%	0.6%	0.4%
Node 12	0.3%	0.3%	0.3%	0.3%	0.3%	0.2%	0.2%	0.2%	0.2%	0.2%
Node 13	0.6%	1.2%	1.4%	1.6%	1.6%	1.5%	1.4%	1.3%	1.2%	1.2%
Node 14	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Node 15	3.4%	2.8%	2.2%	1.6%	1.2%	0.8%	0.6%	0.3%	0.2%	0.2%
Node 16	0.0%	0.0%	0.2%	0.5%	1.2%	2.1%	3.8%	5.7%	8.0%	10.3%
Node 17	0.0%	0.0%	0.0%	0.2%	0.5%	1.1%	1.9%	2.7%	3.7%	4.4%
Node 18	0.0%	0.4%	1.0%	1.6%	2.5%	3.6%	4.2%	4.6%	4.0%	3.0%
Node 19	0.0%	0.1%	0.2%	0.3%	0.5%	0.7%	1.0%	1.1%	1.3%	1.5%
Node 20	0.0%	0.3%	1.0%	1.9%	2.9%	4.3%	5.7%	6.8%	8.0%	8.9%
Node 21	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Node 22	0.0%	0.7%	1.5%	1.9%	2.3%	2.4%	2.5%	1.8%	1.6%	1.5%
Node 23	0.0%	0.4%	0.8%	1.1%	1.5%	1.8%	1.7%	1.7%	1.7%	1.6%
Node 24	1.9%	1.8%	4.5%	6.9%	9.9%	11.7%	13.9%	15.3%	16.5%	18.9%
Node 25	0.0%	0.0%	0.9%	2.6%	4.1%	6.2%	7.3%	8.4%	9.2%	9.5%
Node 26	23.5%	23.1%	22.3%	21.6%	20.7%	19.5%	16.1%	13.9%	9.9%	7.6%
Node 27	4.7%	4.6%	4.5%	4.3%	4.1%	3.9%	3.7%	3.5%	3.3%	3.2%
Node 28	4.7%	9.2%	13.4%	17.3%	16.6%	15.6%	14.7%	13.9%	13.2%	12.6%
Node 29	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Node 30	36.7%	30.4%	24.1%	19.0%	16.6%	14.1%	11.7%	9.7%	7.9%	6.3%
Node 31	22.6%	23.1%	19.7%	14.7%	10.8%	7.0%	5.9%	4.9%	5.9%	5.0%

Table 9. Percent of Injections Along Each Node: Rural With Infrastructure

	Rural with infrastructure									
	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Node 1	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Node 2	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%	0.2%	0.2%
Node 3	0.0%	0.0%	0.0%	0.1%	0.1%	0.2%	0.2%	0.2%	0.2%	0.2%
Node 4	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%	0.1%	0.2%	0.2%
Node 5	0.0%	0.0%	0.1%	0.1%	0.2%	0.3%	0.4%	0.5%	0.6%	0.7%
Node 6	0.0%	0.0%	0.0%	0.1%	0.2%	0.2%	0.3%	0.4%	0.4%	0.5%
Node 7	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%
Node 8	0.0%	0.0%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
Node 9	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Node 10	0.1%	0.1%	0.1%	0.2%	0.3%	0.3%	0.3%	0.3%	0.4%	0.5%
Node 11	0.6%	0.6%	0.7%	0.9%	1.0%	1.0%	0.9%	0.7%	0.5%	0.4%
Node 12	0.6%	0.6%	0.6%	0.5%	0.5%	0.5%	0.5%	0.4%	0.4%	0.4%
Node 13	0.6%	1.2%	1.7%	1.8%	1.8%	1.8%	1.7%	1.7%	1.6%	1.6%
Node 14	0.6%	0.9%	1.1%	1.4%	1.3%	1.2%	1.2%	1.1%	1.0%	1.0%
Node 15	3.5%	2.5%	1.4%	0.7%	0.3%	0.1%	0.0%	0.2%	0.2%	0.1%
Node 16	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Node 17	0.0%	0.0%	0.1%	0.3%	0.5%	0.9%	1.3%	1.8%	2.7%	3.5%
Node 18	0.0%	0.2%	0.5%	1.0%	2.0%	2.8%	3.8%	3.4%	3.2%	3.0%
Node 19	0.0%	0.2%	0.4%	0.6%	1.0%	1.4%	1.9%	2.3%	2.7%	3.0%
Node 20	0.0%	0.3%	1.2%	2.1%	3.4%	5.1%	7.0%	8.6%	10.3%	11.8%
Node 21	0.0%	0.2%	0.8%	1.6%	2.5%	3.6%	4.8%	5.7%	6.6%	7.4%
Node 22	0.0%	0.7%	1.0%	0.8%	0.5%	0.4%	0.2%	0.9%	1.1%	0.9%
Node 23	0.0%	0.4%	0.8%	1.1%	1.5%	1.8%	1.7%	1.7%	1.7%	1.6%
Node 24	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Node 25	0.9%	0.9%	1.8%	3.5%	4.1%	4.7%	5.1%	5.6%	6.6%	7.6%
Node 26	9.4%	9.2%	11.6%	13.9%	16.6%	15.6%	14.7%	10.4%	7.9%	6.3%
Node 27	9.4%	9.2%	8.9%	8.7%	8.3%	7.8%	7.3%	7.0%	6.6%	6.3%
Node 28	9.4%	18.4%	22.3%	22.5%	22.4%	21.9%	21.3%	22.3%	23.1%	25.2%
Node 29	4.7%	5.5%	6.3%	6.9%	7.5%	7.8%	7.3%	7.0%	6.6%	6.3%
Node 30	36.7%	33.2%	29.5%	26.0%	22.4%	19.5%	16.1%	12.5%	9.2%	6.3%
Node 31	23.5%	15.7%	8.9%	5.2%	1.7%	0.8%	1.5%	4.9%	5.9%	5.0%

Table 10. Percent of Injections Along Each Node: Rural With Low Infrastructure

	Rural wth low infrastructure									
	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Node 1	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Node 2	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%	0.2%
Node 3	0.0%	0.0%	0.0%	0.1%	0.1%	0.2%	0.4%	0.5%	0.6%	0.7%
Node 4	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%	0.1%	0.1%	0.2%	0.2%
Node 5	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.2%	0.3%	0.3%	0.4%
Node 6	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Node 7	0.0%	0.1%	0.1%	0.2%	0.3%	0.4%	0.5%	0.5%	0.4%	0.3%
Node 8	0.0%	0.0%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
Node 9	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Node 10	0.1%	0.1%	0.1%	0.2%	0.2%	0.2%	0.3%	0.3%	0.3%	0.4%
Node 11	0.6%	0.7%	0.8%	1.0%	1.0%	1.2%	1.4%	1.4%	1.4%	1.6%
Node 12	1.2%	1.2%	1.0%	0.9%	0.7%	0.6%	0.5%	0.4%	0.4%	0.4%
Node 13	0.1%	0.2%	0.3%	0.4%	0.5%	0.6%	0.7%	0.8%	0.8%	0.9%
Node 14	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Node 15	4.0%	3.7%	3.4%	3.0%	2.7%	2.3%	1.8%	1.4%	1.1%	0.7%
Node 16	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Node 17	0.0%	0.0%	0.1%	0.2%	0.4%	0.7%	1.1%	1.6%	2.1%	3.0%
Node 18	0.0%	0.2%	0.6%	1.2%	2.0%	3.6%	5.7%	7.5%	9.3%	11.8%
Node 19	0.0%	0.3%	0.7%	1.0%	1.4%	1.7%	1.9%	2.3%	2.7%	3.0%
Node 20	0.0%	0.0%	0.2%	0.5%	1.0%	1.7%	2.9%	4.1%	5.3%	6.5%
Node 21	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Node 22	0.0%	1.0%	2.3%	3.5%	5.1%	6.5%	7.4%	7.3%	7.2%	5.3%
Node 23	0.0%	0.4%	0.8%	1.1%	1.5%	1.8%	1.7%	1.7%	1.7%	1.6%
Node 24	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Node 25	0.9%	0.9%	1.8%	2.6%	3.3%	3.9%	4.4%	4.9%	5.3%	6.3%
Node 26	9.4%	11.1%	13.4%	15.6%	16.6%	19.5%	22.0%	23.0%	23.1%	25.2%
Node 27	18.8%	18.4%	16.1%	13.9%	11.6%	9.4%	7.3%	7.0%	6.6%	6.3%
Node 28	0.9%	2.8%	4.5%	6.9%	8.3%	9.4%	11.0%	12.5%	13.2%	13.9%
Node 29	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Node 30	36.7%	33.2%	29.5%	26.0%	22.4%	17.2%	13.2%	9.7%	7.9%	6.3%
Node 31	27.3%	25.8%	24.1%	21.6%	20.7%	18.7%	15.4%	12.5%	9.9%	5.0%

Annex C

Methodologies and Assumptions: Costs

Methodology for Estimating the Cost Premium per Injection

One main outcome of the modeling exercise was to calculate the cost premium per injection for implementing the proposed set of waste management interventions for each of the four scenarios. The total costs (cost premium per injection multiplied by total injections) were then divided by the total DALYs averted to determine cost-effectiveness ratios.

Key elements in determining the cost premium per injection for each scenario in each country included:

- Determining the cost per injection for each intervention, based on capital and recurrent costs as well as assumed utilization of each piece of equipment.
- Determining the cost for each node on the decision tree (Annex B, Figure 1) by summing the cost of each intervention (on a per injection basis) along the node. Each node contained several interventions.
- Taking a weighted average (using the percent of injections along each node) of the cost associated with each node based on established adoption rates (Annex B, Tables 7–10) to determine the cost premium per injection.

Elements of each intervention were classified as either capital or recurrent. Further classifications were made about whether the resource items were traded or nontraded. Cost estimates for the various interventions were often found for only one or two countries so purchasing power parities were used to determine equivalent costs of nontraded items in other countries.

Key Assumptions

Table 1. Key Parameters Affecting Utilization of Interventions

Key Parameters	Number	Source
Number of syringes that can fit into a safety box (reusable and nonreusable	150	PATH
Number of syringes that can fit into a plastic bag	200	PATH
Annual number of syringes per year in average health facility-Urban	64,000	Guateng study*
Annual number of syringes per year in average health facility-Rural	12,000	PATH
Sharps as percent of all medical waste treated in centralized facilities	8%	Guateng study
Barrel capacity (no. of needles)	175,000	PATH
Urban 1 m3 pit capacity (no. of needles)	1,000,000	PATH
Rural 120,000 cm3 pit capacity (no. of needles)	120,000	PATH
Maximum capacity use of needle cutter per year (no. of syringes)	4,000	Calculated
Urban capacity utilization of needle cutter	90%	PATH
Rural capacity utilization of needle cutter	60%	PATH
Number of burns with De Montfort incinerator per week	2	PATH

*Status Quo Report: Feasibility Study on the Possible Regionalization of Health Care Risk Waste Treatment/Disposal Facilities in Gauteng.

Table 2. Capital Costs of Proposed Interventions

Capital Costs	Purchasing Price (2005 US$)	Notes	Source
Waste Segregation			
Needle remover	$38		PATH*
Centralized Disposal Options			
Autoclave	$1,403,308	Includes land and building costs. Equipment alone is $900,000. 500 kg/hr capacity.	Guateng study**
Large-scale incinerator	$1,012,368	Includes land and building costs. Equipment alone is $621,000. 350 kg/hr capacity.	Guateng study
Microwave	$1,470,787	Includes land and building costs. Equipment alone is $1.1M. 440 kg/hr capacity	Guateng study
Community incinerator	$12,500	Weighted average of fixing up old incinerators ($5,000 each) vs. buying new ones ($20,000 each).	PATH
Decentralized Disposal Options			
Electric melting machine	$1,000		TechNet estimates
Solar melter	$500		IT Power India, evaluation in Senegal
On-site incineration (De Montfort)	$2,000		Kenya 2003 study***
Rural needle pit	$100		Estimates made by PATH Senegal
Urban needle barrel	$60		Estimates made by PATH Senegal
Rural needle/syringe burial	$20		PATH
Urban (low infrastructure) needle/syringe burial	$20		PATH

*Based on procurement experience.
** Status Quo Report: Feasibility Study on the Possible Regionalization of Health Care Risk Waste Treatment/Disposal Facilities in Gauteng.[21]
*** Immunization Technologies Evaluation in Senegal during 2004.[22]

Table 3. Key Parameters Affecting Volume of Injections

WHO Region	Injections per Person per Year*
AFR	2.1
AMR	1.8
EMR	4.3
EUR	3
SEAR	3.05
WPR	2.4

*Unsafe injections in the developing world and transmission of bloodborne pathogens: a review.[1]

Resource-Savings Calculations

The costs of treating HIV and HBV in developing-country settings were found in the literature; however, equivalent costs could not be found for HCV so these infections were eliminated from the resource-savings calculations. Assumptions included:

- Only direct costs of medicine and hospitalization were included.
- Lifetime discounted direct costs associated with HIV, $4,139, HBV, $68.[23] Upper estimates were used to account for the shorter discount period associated with the assumed higher average age of infection from reused sharps or needlestick injury compared to that used in the paper as base case (infancy).
- Percent of HIV and HBV cases treated: 11% (AFR), 62% (AMR), 5% (EMR), 13% (EUR), 14% (SEAR), 14% (WPR).[24]

Costs per Injection for Each Intervention

Table 4. Costs per Injection and Split between Capital and Recurrent Costs, Calculated At 2012 Assumed Levels of Utilization

Intervention	Total Costs* per Injection	Capital Costs* per Injection	Recurrent Costs* per Injection	Percent Capital Costs*
Rural on-site incineration	$0.163	$0.059	$0.104	36%
Urban on-site incineration	$0.115	$0.011	$0.104	10%
Collection for off-site centralized treatment	$0.061	$0.008	$0.053	12%
Collection for off-site hospital or community treatment	$0.047	$0.042	$0.004	91%
Disinfect and dump into municipal waste	$0.040		$0.040	0%
Rural electric melter	$0.020	$0.020		100%
Rural solar melter	$0.010	$0.010		100%
Rural needle removal	$0.009	$0.003	$0.006	36%
Urban needle removal	$0.008	$0.002	$0.006	27%
Nonreusable safety box	$0.005		$0.005	0%
Urban electric melter	$0.004	$0.004	$0.000	100%
Reusable safety box	$0.003	$0.000	$0.003	0%
Urban solar melter	$0.002	$0.002	$0.000	100%
Open burning, dumping into municipal waste without disinfecting, dumped on site	$0.002		$0.002	0%
Needle pitting	$0.001	$0.001		100%
Needle barreling	$0.0004	$0.0004		100%
Rural burial	$0.0002		$0.0002	0%
Urban burial	$0.0002		$0.0002	0%
Plastic bag	$0.00001			0%
Collected for intentional reuse	$0			

*Costs are calculated at 2012 utilization levels.

Annex D

Sharps Waste Management Interventions

Table 1. Proposed Sharps Waste Management Interventions, Excluding Transport Systems

Technology Intervention	Capacity	Capital Cost (US$)
Needle Removers		
Balcan needle remover	Each device can cut 200,000 needles. Each container holds 250 needles	42
NoMoreSharps needle remover	Each container holds 250 needles	22
Becton Dickinson Hub Cutter	Each device cuts and holds 450-600 needles	approx. 2.50
Autoclaves		
Mark Costello Company (includes sterilizer, electric steam boiler and grinder)	Model AS23: 23 kg/cycle	98,500
Mark Costello Company (includes sterilizer, electric steam boiler and grinder)	Model AS36: 100 kg/cycle	115,125
Ecodas Models T300, T1000, T2000 (shredding before disinfection)	25-180 kg/hr	145,000 and greater
Sanipak multiple models (does not include shredder)	50-700 kg/hr	26,000–600,000
Medivac MetaMizer Series I (shredding during disinfection)	30-50 kg/hr	190,000
Tempico Rotoclave® 1500 D1 (includes shredder)	135-350 kg/hr	392,000–1,700,000
STI Series 2000™ chemical autoclave (includes shredder)	275 kg/hr model	367,000
STI Series 2000™ chemical autoclave (includes shredder)	450 kg/hr model	427,000
Tuttnauer T-Max sterilizer models	up to 680 kg/hr	100,000–200,000
Hydroclave multiple models	25-910 kg/hr	46,000–375,000
Red Bag Solutions model SSM-150 autoclave plus shredder	70 kg/hr	200,000
BondTech (includes sterilizer, bins and shredder)	115 kg/hr	180,000
Environmental Tectonics Corp. (does not include shredder)	1800-6000 kg/day	150,000–275,000
Ecolotec advanced autoclave (includes shredder)	135 kg/hr	325,000

Technology Intervention	Capacity	Capital Cost (US$)
Microwaves		
Sanitec HG-A 100, HG-A 250 (includes shredder)	100-250 kg/hr	500,000–600,000
SINTION disinfector microwave (no shredding, steam generator is internal)	35 kg/hr	45,000
Meteka Medister 10 and Medister 140	60 L	84,000
Incinerators		
De Montfort (small)	7 kg/hr	2,500
MediBurn (small)	20 kg/hr	17,000
Firestream Clinical (medium)	250 kg/hr	300,000
Gencor (large)	750 kg/hr	1,600,000
Shredders		
Sanipak Sharps Machine	90+ kg/hr	110,000-125,000

Annex E

Detailed Cost Tables

Table 1. Total Costs by Core Expenditure Category and Components During Investment Period

Expenditure Category	Unified Guidelines	Toolkit Development	Regional- and Country-Level Planning	Lead Managing Partner Costs	Total
I. Nonrecurrent Costs					
	$0	$0	$0	$0	$0
II. Recurrent Costs					
Personnel Costs	$378,534	$346,611	$4,002,400	$1,636,715	$6,364,260
Workshops and Presentations	$78,000	$0	$0	$0	$78,000
Travel	$129,987	$18,047	$1,776,878	$394,954	$2,319,866
Publication Costs	$16,250	$39,000	$0	$0	$55,250
Other Recurrent Costs (Copying, Telephone, Postage, Facilities)	$80,383	$73,603	$849,927	$347,563	$1,351,476
Total	**$683,154**	**$477,261**	**$6,629,205**	**$2,379,232**	**$10,168,852**

Table 2. Total Costs by Expenditure Category and Investment Year

Expenditure Category	Year 1	Year 2	Year 3	Year 4	Year 5	Total
I. Nonrecurrent Costs						
	$0	$0	$0	$0	$0	$0
II. Recurrent Costs						
Personnel Costs	$826,112	$1,570,990	$1,353,684	$1,298,348	$1,315,109	$6,364,243
Workshops and Presentations	$78,000	$0	$0	$0	$0	$78,000
Travel	$189,014	$575,900	$563,789	$525,600	$465,562	$2,319,865
Publication Costs	$16,250	$29,250	$3,250	$3,250	$3,250	$55,250
Other Recurrent Costs (Copying, Telephone, Postage, Facilities)	$175,431	$333,609	$287,464	$275,716	$279,274	$1,351,494
Total	**$1,284,807**	**$2,509,749**	**$2,208,187**	**$2,102,914**	**$2,063,195**	**$10,168,852**

Table 3. Total Costs by Component and Investment Year

Component	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Unified Guidelines	$522,476	$37,500	$39,220	$41,028	$42,930	$683,154
Toolkit Development	$228,288	$248,973	$0	$0	$0	$477,261
Regional- and Country-Level Planning	$0	$1,718,914	$1,723,083	$1,593,604	$1,593,604	$6,629,205
Lead Managing Partner Costs	$534,043	$504,362	$445,884	$468,282	$426,661	$2,379,232
Total Costs	**$1,284,807**	**$2,509,749**	**$2,208,187**	**$2,102,914**	**$2,063,195**	**$10,168,852**

References

[1] Simonsen L, Kane A, Lloyd J, Zaffran M, Kane M. Unsafe injections in the developing world and transmission of bloodborne pathogens: a review. *Bulletin of the World Health Organization.* 1999;77(10):789–800.

[2] World Health Organization (WHO). *Safe Healthcare Waste Managemen: Policy Paper*. Geneva: WHO; 2004. Available at: http://www.healthcarewaste.org/en/160_hcw_policy.html. Accessed November 11, 2005.

[3] WHO. *Management of Solid Health-Care Waste at Primary Health Care Centers: A Decision-Making Guide*. IVB/PHE/WSH. Geneva: WHO; 2005.

[4] Hauri AM, Armstrong GL, Hutin YJ. The global burden of disease attributable to contaminated injections given in health care settings. *International Journal of STD & AIDS.* 2004;15(1):7–16.

[5] Lakshmi R. India's vaccines come with risk: dirty needles used for immunization can spread other diseases. *The Washington Post*. February 9, 2005:A18.

[6] Muller N, United States Agency for International Development (USAID). *Evaluation of a Disposable Needle-Removal Device in Uganda*. A HealthTech Report. Seattle: PATH; 2005.

[7] Global status of immunization safety: a report based on the WHO/UNICEF Joint Reporting Form, 2004 update. *Weekly Epidemiological Record.* 2005;80(42):361–368.

[8] University of Virginia Health System: the International Health Care Worker Safety Center website. Available at: http://www.healthsystem.virginia.edu/internet/epinet/#1. Accessed October 2, 2005.

[9] WHO, Safe Injection Global Network. *Injection Safety: First Do No Harm*. WHO/BCT/DCT/01.3. Geneva: WHO; 2001.

[10] Nazareth S, Rathi MK. Poking danger: sharps handling and disposal [fact sheet]. New Delhi: Srishti; 1998.

[11] Prüss-Üstün A, Rapiti E, Hutin Y. *Global Burden of Disease from Sharps Injuries to Health-care Workers*. Geneva: WHO; 2003. WHO Environmental Burden of Disease Series, No.3.

[12] Medical wastes recycled at deadly risk page. SOS-Arsenic.net website. Available at: http://www.sos-arsenic.net/english/environment/syringe.html. Accessed October 18, 2005.

[13] Medical waste on the UK coastline page. Bandolier website. Available at: http://www.jr2.ox.ac.uk/bandolier/booth/needlestick/medwaste.html. Accessed October 15, 2005.

[14] Community Adoption and Monitoring Program for Schools (CAMPS). *Waste Management*. New Delhi: TERI. The Green Crusader, No.4.

[15] Toxics Link website. Available at: www.toxicslink.org/index.php. Accessed October 23, 2005.

[16] Malik S. Used syringes dumped in open bins, recycled. *The Tribune* (Chandigarh, India) [online edition]. July 24, 2005. Available at: http://www.tribuneindia.com/2005/20050724/main7.htm. Accessed October 13, 2005.

[17] Gisselquist D. HIV through unsafe health care: what contribution does it make to Africa's HIV epidemics and what can be done about it? Presented at: Infection Safety Solutions for Africa, September 15, 2003; Mombassa, Africa.

[18] Kane A, Lloyd J, Zaffran M, Simonsen L, Kane M. Transmission of hepatitis B, hepatitis C and human immunodeficiency viruses through unsafe injections in the developing world: model-based regional estimates. *Bulletin of the World Health Organization.* 1999;77(10):801–807.

[19] Lydon P. *Costing of Waste Management in Cambodia, West Pacific Region: Case Study: Sicim Incinerator in Kompong Chnang Province*. Geneva: WHO; 2002.

[20] Hart T. *Rapid Assessment of Small Scale Incinerators.* Report submitted to the Department of Immunization, Vaccines, and Biologicals, World Health Organization. Pondicherry: IT Power India; 2003.

[21] Kobus Otto and Associates Waste Management Consultants. *Status Quo Report: Feasibility Study on the Possible Regionalisation of Health Care Risk Waste Treatment/Disposal Facilities in Gauteng*. Johannesburg, South Africa: Gauteng Provincial Government; 2000.

[22] IT Power India (ITPI). *Immunization Technologies Evaluation in Senegal During 2004*. Pondicherry, India: ITPI; 2005.

[23] Ekwueme DU, Weniger BG, Chen RT. Model-based estimates of risks of disease transmission and economic costs of seven injection devices in sub-Saharan Africa. *Bulletin of the World Health Organization.* 2002;80(11):859–870.

[24] Joint United Nations Programme on HIV/AIDS (UNAIDS), WHO. *Progress on Global Access to HIV Antiretroviral Therapy: an Update on 3 by 5*. Geneva: WHO; 2005. Available at: http:www.who.int/3by5/fullreportJune2005.pdf Accessed November 11, 2005.