An Investment Case for Eliminating Malaria in Indonesia

A report by the UCSF Global Health Group, Center for Health Research at the University of Indonesia, and Indonesia Sub-directorate for Malaria

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UCSF Global Health Sciences Global Health Group

REPORT

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Cover photo: A father and daughter outside of emergency malaria treatment tents in Sukabumi, West Java, Indonesia, where coastal residents experienced a malaria plague.© 2004 Arie Basuki, Courtesy of Photoshare

The **Malaria Elimination Initiative (MEI)** at the University of California San Francisco (UCSF) Global Health Group believes a malaria-free world is possible within a generation. As a forward-thinking partner to malaria-eliminating countries and regions, the MEI generates evidence, develops new tools and approaches, documents and disseminates elimination experiences, and builds consensus to shrink the malaria map. With support from the MEI's highly-skilled team, countries around the world are actively working to eliminate malaria – a goal that nearly 30 countries will achieve by 2020.

shrinkingthemalariamap.org

Contents

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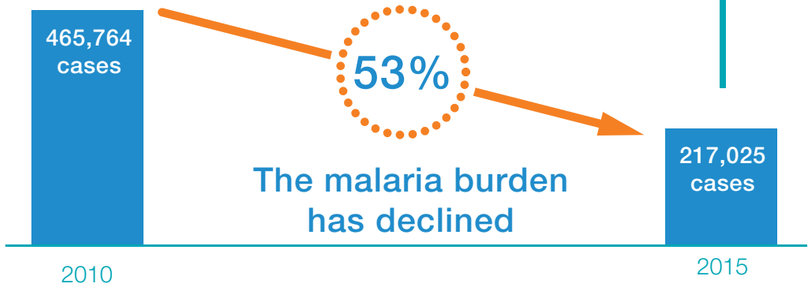
The authors are responsible for any errors or omissions.

Key Terms and Acronyms

API	Annual parasite incidence
BPJS	Badan Penyelenggara Jaminan Sosial
CSR	Corporate social responsibility
D	Diagnosis
DHO	District Health Office
GDP	Gross domestic product
Global Fund	Global Fund to Fight AIDS, Tuberculosis and Malaria
IDR	Indonesian Rupiah
IEC	Information, education, and communication
IP	Inpatient
IQR	Interquartile range
IRS	Indoor residual spraying
LLIN	Long-lasting insecticidal net
ME	Monitoring and evaluation
MOH	Ministry of Health
NMCP	National Malaria Control Program
NMSP	National malaria strategic plan
OOP	Out-of-pocket
OP	Outpatient
PAR	Population at risk
PARR	Population at risk of reintroduction (used in malaria free areas only)
PERDHAKI	Persatuan Karya Dharma Kesehatan Indonesia
PHO	Provincial Health Office
PM	Program management
PVC	Prevention and vector control
ROI	Return on investment
SEM	Surveillance and epidemic management
TP	Treatment and prophylaxis
UCSF	University of California, San Francisco
UI	University of Indonesia
ULY	Useful life year
USD	United States Dollar
VLY	Value of life year
WHO	World Health Organization

REPORT

ECONOMIC BURDEN



The malaria burden has declined

However, gains are fragile and threatened by declining domestic and donor support

THE TOTAL ECONOMIC BURDEN OF MALARIA IN 2015

USD 205 million

Direct economic cost

USD 147 million

USD 0.79 per capita

Indirect costs such as productivity losses

USD 58 million

THE COST OF MALARIA PROGRAM'S RECURRENT BUDGET LINE ITEMS IN 2015

USD 60.9 million

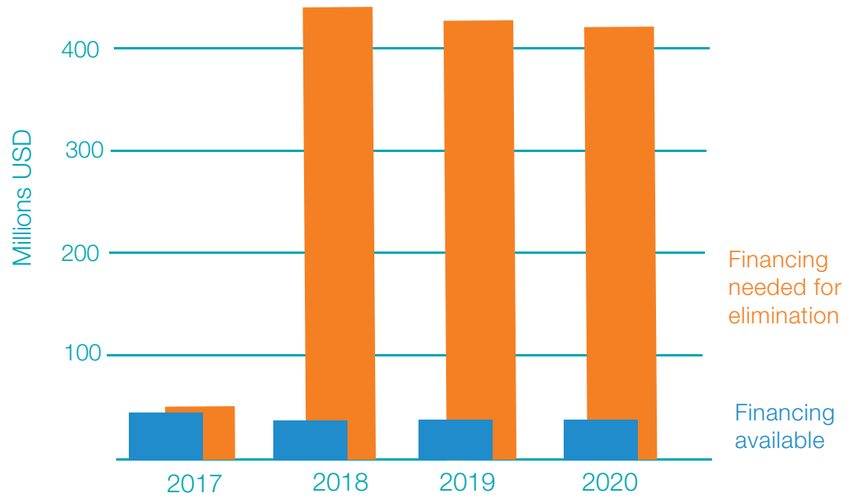
USD 0.85
per person at risk

COST OF ELIMINATION

USD 2 billion (2016-2030)

Range USD 1.7 - 2.6 billion

FUNDING GAP FOR THE NEXT 4 YEARS



SECURING ADEQUATE RESOURCES

- National health budget: increase allocation to Malaria
- Subnational advocacy
- Private sector investment
- Sin taxes
- Innovative financing mechanisms

BENEFITS & RETURN ON INVESTMENT (ROI)

2030

Indonesia has committed to eliminating malaria within its borders by 2030

Malaria cases averted: 25 million

Malaria deaths averted: 41,000

Saving in healthcare costs, lost wages and productivity due to illness	Incremental cost
USD 18 billion	**USD 1.75 billion**

ROI

10 : 1

Malaria elimination is a "best buy" comparable to other high value investments such as immunization.

Executive Summary

Indonesia has made significant progress towards the regional goal of malaria elimination by 2030, reducing confirmed malaria by 53% between 2010 and 2015. However, gains are fragile and threatened by declining domestic and donor support. Without adequate resources, malaria interventions would be scaled down, creating an opportunity for malaria to resurge. To turn this tide, the Center for Health Research at the University of Indonesia and the UCSF Global Health Group's Malaria Elimination Initiative, in collaboration with the Sub-directorate of Malaria, developed an investment case to generate economic evidence that highlights the benefits of malaria elimination that can be used to advocate for sustained financial resources.

The study found that the median economic cost of the malaria program in 2015 was estimated at USD 147 million (USD 0.79 per capita). The financial cost, defined as the cost of the program's recurrent budget line items (i.e., excluding non-recurrent expenses such as capital or non-malaria personnel), for 2015 was estimated at USD 60.9 million (USD 0.85 per person at risk). The major cost driver at the central and provincial levels were services (mainly trainings) and at the district level, the main driver was consumables, largely for vector control interventions.

Eliminating malaria in Indonesia is expected to cost a median of USD 2 billion (interquartile range USD 1.7– 2.6 billion) over 15 years. During this period, each additional dollar invested in malaria elimination in Indonesia will generate a return of 10 to 1. By eliminating malaria by 2030, over 25 million clinical cases (range 5.8-42.5 million) would be averted, over 41,000 deaths prevented (range 8,848-68,638), and over USD 18 billion (range USD 3.4-30.2 billion) in economic benefits will be accrued, in addition to substantial returns with harder to quantify benefits not included in this study.

By preventing resurgence, malaria elimination results in major cost savings to the health system and generates broader economic benefits through increased productivity. With enough political and financial commitment, Indonesia can look forward to a prosperous and malaria-free future.

Introduction

Indonesia has committed to eliminating malaria within its borders by 2030. To date, great progress has been made to reduce malaria burden around the country. Confirmed malaria cases have gone down by 53% from 465,764 to 217,025 between 2010 and 2015.[1] By 2015, 232 out of 514 total districts achieved malaria-free certification from the Ministry of Health (MOH), while the remaining districts continue efforts to control and eliminate the disease.[1]

The burden of malaria is variable among Indonesia's districts; therefore the Sub-directorate of Malaria, referred to as the National Malaria Control Program (NMCP) throughout this report, proposes a phased elimination strategy, which is outlined in the National Malaria Strategic Plan (NMSP) for 2015-2019. The strategy involves three distinct phases, each targeted for different levels of endemicity, namely: elimination, intensification, and acceleration (described in detail, below).[1]

The progress in malaria control in Indonesia has been possible through sustained political and financial commitment from the government as well as the financial contribution from donors, particularly the Global Fund to Fight AIDS, Tuberculosis and Malaria (Global Fund). As Indonesia tries to maintain its gains and accelerate toward national elimination by 2030,[2, 3] having adequate financial resources to achieve these goals is crucial. While overall funding from both domestic sources and the Global Fund has increased in the last five years, the NMCP predicts a significant funding gap in the coming years. This financial gap may hinder Indonesia's progress to becoming malaria-free, as a gap or reduction in funding has historically been associated with outbreaks and resurgences in other countries.[4]

Background and context

Because of the country's size and geographic spread, Indonesia faces several challenges in its malaria elimination efforts. Indonesia is the third most populous country in the region (following China and India),[5] and roughly 26% of its 255 million people live in areas of malaria transmission.[6] It is the world's largest archipelagic nation and is composed of over 17,500 islands, of which about one third are inhabited.[7] Ten of 24 *Anopheles* mosquito species found in the country are the leading transmitters of *Plasmodium* parasites, and exhibit diverse biting and breeding behaviors.[7-10] Figure 1 shows the geographical spread of the malaria burden in Indonesia, with higher endemic areas mainly in the easternmost part of the country.

Figure 1. Map of confirmed malaria cases per 1,000 population, 2015 for A) *Plasmodium vivax* and B) *Plasmodium falciparum*[6]

A)

B)

All four *Plasmodium* species that cause malaria in humans have been reported in Indonesia,[7-9] although the majority of infections are due to *Plasmodium falciparum* (*P. falciparum)* and *Plasmodium vivax (P. vivax)*. Of the 217,025 confirmed malaria cases in 2015, roughly 55% were *P. falciparum* infections, 44% were *P. vivax*, and the remaining cases were caused by other *Plasmodium* species.[6] *Plasmodium knowlesi*, which causes malaria in monkeys, has also been found in human populations in Indonesia.[11, 12]

Malaria transmission occurs year-round in Indonesia, and risk of infection is determined largely by socioeconomics, human behavior, ecology and geography. The tropical climate, extensive human migration, inadequate infrastructure, and inequitable healthcare delivery, particularly in the rural areas, all contribute to challenges in controlling and eliminating malaria.[8] The five easternmost provinces of Indonesia (Maluku, Maluku Utara, Nusa Tenggara Timur, Papua, and Papua Barat) are composed of 8% of the country's population but contribute to 70% of all malaria cases.[1] These less developed islands are rich in natural resources yet have poor infrastructure and more aggressively human biting *Anopheles* mosquitoes compared to other islands in Indonesia. The mix of poor access to healthcare and malaria vectors result in an environment highly conducive for malaria transmission. The formal health sector is considered weakest in eastern Indonesia with a dearth of human resources, compounding the issue further.

Malaria control program in Indonesia

Malaria elimination has been a priority in several administrations in Indonesia. During the global malaria eradication era (1955-1969), Indonesia had a vertical malaria program called Komando Pembasmian Malaria (KOPEM).[1, 13] KOPEM was dissolved in 1968 and its activities were integrated with the Directorate General for Disease Control, the MOH arm that houses the current NMCP. In 2009, the Indonesian Minister of Health released a decree calling for the elimination of malaria in the country by 2030,[14] which was supported by a 2010 circular from the Minister of Internal Affairs urging local governments to aspire for malaria elimination.[1] In 2014, Indonesian President Joko "Jokowi" Widodo endorsed the Asia Pacific Leaders Malaria Alliance (APLMA) goal of a malaria-free Asia Pacific by 2030 and included malaria elimination in the 2015-2019 midterm national development plan.[13]

To achieve this goal, a subnational spatially progressive approach to elimination, based on district endemicity, was implemented. This three-pronged approach includes:

- Intensification: In high burden districts, malaria control strategies, such as improved diagnostics and case management, indoor residual spraying (IRS), and mass long-lasting insecticidal net (LLIN) campaigns are scaled-up.
- Acceleration: In medium burden districts, strategies are intensified in areas with focal transmission, such as in mining, forested, or agricultural areas.

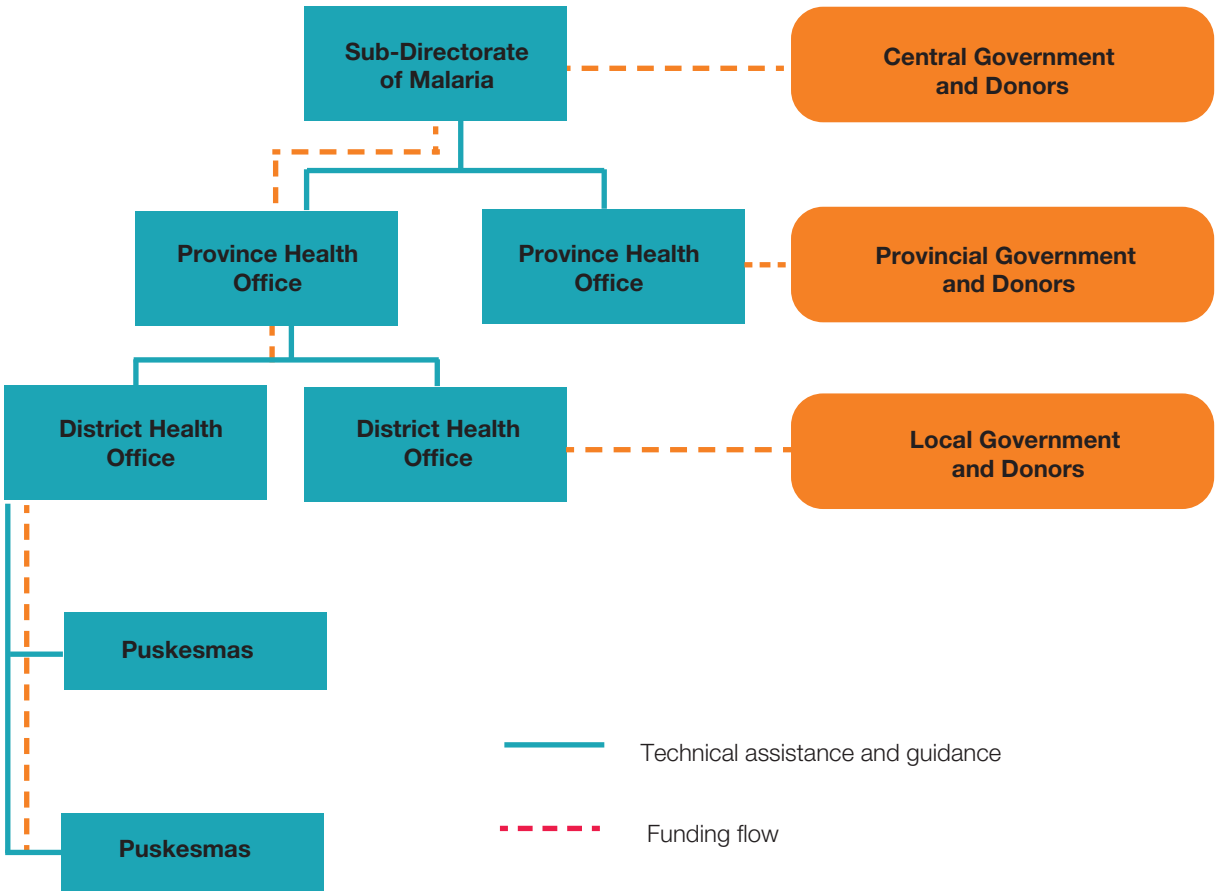
- Elimination: In low burden districts, malaria strategies shift to an elimination focus, which include active case detection, migration surveillance, and monitoring receptive areas.

Governance for health programs in Indonesia

Indonesia has a decentralized governance system, which can lead to fractures in health care delivery. Although the central government plays an oversight role, both the funding as well as the operations are mainly controlled and managed by the local governments at the provincial and district levels.

The malaria control program at the national level is managed by the Sub-directorate of Malaria under the Directorate General of Disease Prevention and Control. The Sub-directorate of Malaria serves as the NMCP and has the primary role in policy formulation, developing guidelines/ standards, partnerships with donors, overarching systems for monitoring, evaluation, and surveillance, as well as conducting operational research. Provinces and districts have their own governance system and can independently organize their health programs based on their needs and resources with technical and limited financial guidance from the central government. In addition to the central level funding, the provincial government also provides funding for health programs at the provincial health offices (PHO), as well as the district health offices (DHO) within each province. The PHO is responsible for provision of health services at provincial level health centers and hospitals and may also provide some guidance and monitoring to the district level activities. The DHOs are ultimately responsible for delivering care for malaria at the district level and several village health facilities (also referred to as "puskesmas") located within the district. A brief overview of the structure of the malaria program can be found in Figure 2.

Figure 2. Structure of the malaria program in Indonesia



Financing for malaria in Indonesia

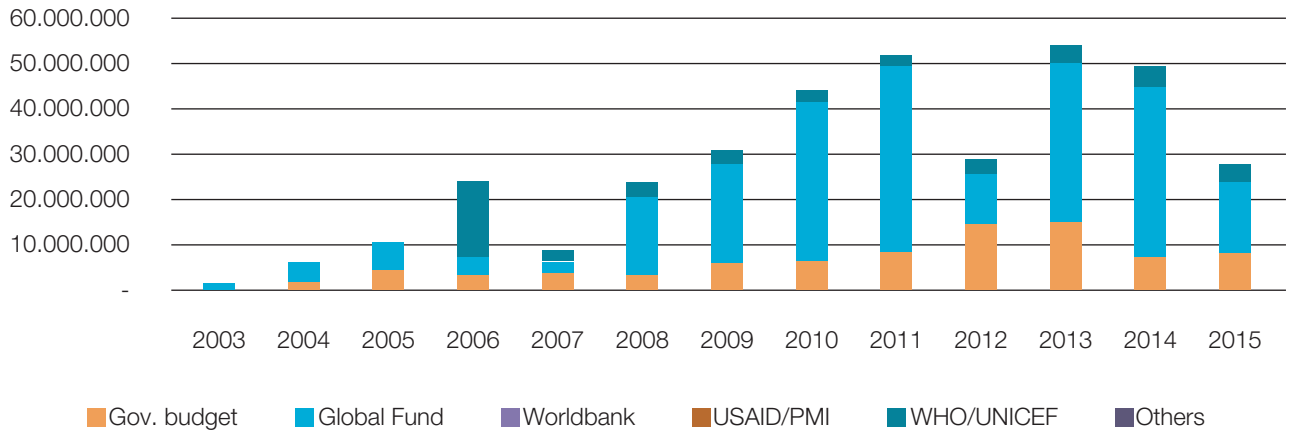
Domestic financing streams for malaria come from many sources and fund various levels of government. National government funding for malaria mainly covers the national level program and extends limited support to the provincial level health facilities and districts. Malaria programs at the provincial level rely on revenue generated from their jurisdictions and extend some support to districts within their territories. At the district level, programs have their own revenue base from the district government and provide support to puskesmas. Puskesmas also receive Global Fund funding channeled through the central level and the Global Fund principal recipient. Given that the majority of the source of funding for programs at the local level comes from local revenue bases, stark differences in funding for programs across provinces and districts exist depending on the resources available for generating the revenue at the local level.

In addition to the central and local government funding for malaria, the Global Fund, World Health Organization (WHO), and UNICEF provide funding for the malaria program in Indonesia (Figure 3). Among the external donors, the Global Fund is the largest external funding source in Indonesia, providing total funding of about USD 189 million between 2003 and 2014. The country first received a grant of USD 19.7 million from the Global Fund in the Round 1 funding cycle to support the intensified malaria control in four highly endemic eastern provinces from 2003 to 2008. During the Global Fund's Round 6 funding cycle, the country received USD 51.5 million to implement the intensified and integrated malaria control activities together with maternal health and immunization activities, as well as USD 65.6 million to intensify malaria control in Kalimantan and Sulawesi Islands. In the Round 8 funding cycle, USD 12.5 million was granted by the Global Fund for continued support to the malaria program in Kalimantan and Sulawesi Islands. Within the new funding model, the Global Fund provided an additional USD 153.5 million of financing under two grants (one to Persatuan Karya Dharma Kesehatan Indonesia [PERDHAKI] and one to the MOH for 2013 to 2017) to accelerate progress in Kalimantan, Sulawesi, Sumatra and six provinces in eastern Indonesia.

Challenges to attaining malaria elimination

Maintaining necessary resources: The fractured financing and health systems in Indonesia require strong leadership by both provincial and DHOs in managing and financing malaria programs, and ensuring equitable financing. Between 2010 and 2014 (with the exception of 2012), donor funding was relatively consistent. The proportion of funding from domestic sources (both central and local) increased during the same period. However, the NMCP predicts that donor funding will likely decrease and domestic financing will likely plateau, which will result in a significant gap in funding which may jeopardize future progress. Past studies have suggested that major financial constraints and lack of political can derail the successes and lead to a resurgence of malaria.[15] The local governments with a relatively low resource base for revenue generation and a high burden of disease are particularly at high risk of losing momentum.

Figure 3. Malaria financing in Indonesia, 2003-2015 (in USD)[6]



Battling importation: As of 2015, 232 districts have been declared malaria-free by the MOH. Many of these malaria-free districts and provinces share borders with highly endemic districts and provinces, exposing them to the constant threat of outbreaks and resurgence of cases. Sustaining the gains made by these champion districts and provinces is crucial for progressive elimination. Progress made in low transmission provinces is easily reversible due to migrant workers from high transmission parts of the country bringing malaria to these areas. This is especially the case for migrant palm oil workers returning home from high endemic areas such as Kalimantan during the holiday season (for example, Ramadan).

Significance of the study

This study was conducted to develop an investment case for malaria by assessing the economic impact of the malaria burden in Indonesia. Based on the actual costs of delivering a malaria program countrywide, this study projects the need of continuing current efforts in the country until 2020. In addition, modeled costs for elimination are projected through 2030. By estimating the benefits of investing in malaria, this study generates the estimates of return on investments (ROI) in malaria. The study also identifies the gaps in malaria funding and explores the potential opportunities for generating financial resources for achieving elimination goals. The country-specific evidence generated by this investment case can provide the NMCP with an estimate of the resources required to eliminate malaria to aid program budgeting and planning, as well as evidence to advocate for sustained financial resources from both domestic and external sources.

Specific objectives of the study

The general objective of this study was to estimate the costs of elimination and to develop an investment case for eliminating malaria in Indonesia. Specifically, this study aims to:

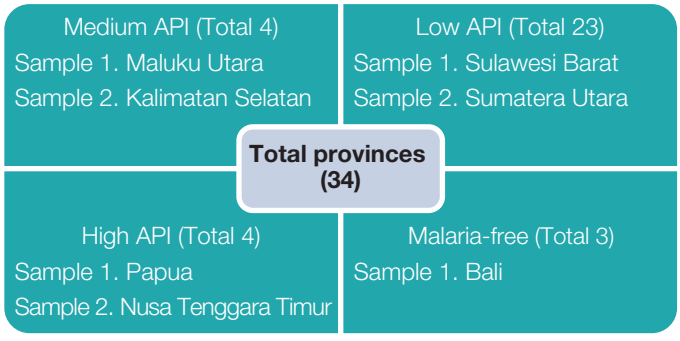
- Estimate the total economic cost and financial cost of malaria program activities in Indonesia for the year 2015;
- Based on the financial cost of the malaria program in 2015, project the cost of malaria elimination efforts for years 2016-2020; and based on a dynamic transmission model's outputs, model the cost of achieving elimination by 2030;
- Generate the economic costs of malaria by levels of disease endemicity across the country and compare those costs;
- Estimate gaps in funding for malaria financial cost and modeled elimination for 2016 through 2020;
- Determine the benefits and the ROI on malaria elimination through elimination by 2030; and
- Explore opportunities for financing and resource mobilization for malaria elimination.

Methodology

In estimating the total economic cost of malaria and the total financial cost (only the cost of the program's recurrent budget) of the malaria program in Indonesia, we divided the estimation methods into two components: (1) public health program perspective, and (2) broader economic perspective.

To capture the economic and financial cost of malaria from a public health program perspective, we used a micro-costing approach to measure the cost of the malaria program in Indonesia for the year 2015. The estimates of cost from the micro-costing were aggregated to compute the total cost of the malaria activities for the entire country. The total financial cost for malaria specific funding was approximated by removing all pre-existing capital costs, non-essential personnel (defined as personnel, not identified as the "malaria program manager" or equivalent, or with a time allocation for malaria work as less than 100%), and any costs that were not from domestic or donor sources (i.e., in-kind donations). To measure the broader economic costs of malaria, we estimated the indirect costs incurred by the individual patients and caretakers, as well as the cost to the society due to malaria. All costs of malaria were analyzed across various levels of endemicity to infer thecost savings from malaria elimination. Lastly, a modeled elimination scenario was used to calculate the benefits and ROI for elimination. Lastly, the costs and benefits of elimination were generated using outputs from the Malaria Elimination Transmission and Costing in the Asia Pacific (METCAP) model to calculate the benefits and ROI for elimination.

Figure 4. Sample districts in seven provinces selected for cost data collection



API: Annual parasite incidence

Study setting

Seven PHOs were selected based on varying levels of endemicity for detailed micro-costing data collection, namely, Bali, Kalimantan Selatan, Maluku Utara, Nusa Tenggara Timur, Papua, Sulawesi Barat, and Sumatera Utara (Figure 4). Two DHOs in each of the provinces were further selected, and two puskesmas from each of the selected districts were visited for data collection. In addition, one malaria center in Sumatera Utara province was also included in data collection. In total, 28 health facilities (puskesmas), one malaria center,14 DHOs, 7 PHOs and the central level NMCP office were included in the study. Based on input from the NMCP and other in-country experts, these sampled districts were considered to be representative of the remaining districts with respect to programmatic costs and levels of suitability of the local environment for malaria transmission (receptivity) and the risk of importation of malaria (vulnerability) to malaria transmission.

Data collection

Data collection for this study took place between May and June 2016. Eight qualified survey enumerators from the University of Indonesia (UI) were trained for four days on the data collection protocol and tool used in this study. Each data collection team included two enumerators, one senior researcher from UI, and at least one supervisor (either from UCSF, UI, or the NMCP). Data were organized and entered in a costing tool developed in Microsoft® Excel® 2011 by the enumerators and were quality checked sequentially by senior researchers and the supervisors. Data were stored on encrypted, password-protected computers. All monetary figures are expressed in 2015 United States Dollar (USD), using a mid-year exchange rate of 13.389 Indonesian Rupiah (IDR) per USD.[16]

We obtained data on the costs associated with malaria activities from a combination of interviews and direct observation of key stakeholders at various levels of government, as well as review of financial and expenditure records. Extensive review of literature, both published and grey literature, was conducted to supplement the data collection. Relevant data were also extracted from the national information systems and malaria program records.

Estimating costs of malaria from public health program perspective

We conducted a micro-costing exercise using an ingredients-based approach to capture costs of malaria elimination in Indonesia from the perspective of the public health sector. Cost inputs included fixed and recurrent costs incurred by the health system, as well as donations and

in-kind contributions. Cost inputs were identified and valued to produce cost estimates. When the most current cost was unavailable, program expenditures from previous years were used as estimates to fill gaps in information. A detailed list of assumptions and methodology that were made for the malaria program costing can be found in **Annex 1**.

Direct costs to the public health system were collected from the NMCP and each sample province, district, and health facility for the year 2015, and were organized and aggregated according to three predetermined categories: (1) funding source, (2) input, and (3) activity (Table 1). All fixed and recurrent cost data were analyzed based on these categories in order to identify the cost drivers of malaria elimination.

Table 1. Categories for direct health systems cost

Cost by source	Cost by input	Cost by activity
Domestic: • National • Provincial • District • Others External • Global Fund • Others	Capital Personnel Consumables Services	Prevention and vector control (PVC) Diagnosis (D) Treatment and prophylaxis (TP) Surveillance and epidemic management (SEM) Monitoring and evaluation (ME) Information, education, and communication (IEC) Program management (PM)

Generating national level estimates of economic cost and financial cost of malaria

To obtain national level estimates of the economic cost and financial cost of malaria elimination, we aggregated the cost estimates at each level, based on the data collected from sample provinces, districts, and health facilities, as well as from the central level program.

For the total economic cost, we first calculated the cost per capita separately for each sample level (central, province, district and puskesmas). Given that the sample districts and provinces were selected to represent the various levels of endemicity, we generated the average costs per capita for each endemicity level. For high, medium, and low endemicities, the total population was assumed to be at risk for infection and is represented as cost per capita. For malaria-free settings, we used the population at risk of reintroduction of malaria (PARR)[a] data if available, or if PARR data were unavailable, PARR was approximated by using 60% of total population (assumed from the average ratio of PARR to total population of the malaria-free districts were PARR data was available).

The average sample cost per capita at district and puskesmas level for each endemicity band was then multiplied by the respective populations at the national level for each endemicity band. Similarly, at the provincial level, the average provincial cost per capita was multiplied by the respective populations within each provincial endemicity band. Central costs were apportioned to each endemicity band based on the proportion of district and provincial costs. The total district, provincial, and central level costs for each endemicity band were then added together to calculate the national cost estimate.

The financial cost was also estimated (without capital costs, non-essential personnel, and "other" funding such as in-kind donations) in order to better approximate the cost the NMCP incurs. For the total financial cost, the same methodology was employed; however, costs at each level were calculated by the population at risk (PAR) rather than the total population.

Estimating costs of malaria from the broader economic perspective

Based on the total economic cost, we also calculated the overall economic burden of malaria, by estimating the cost incurred in treating malaria as well as the indirect costs associated with malaria borne by the society. Detailed inputs can be found in **Table A1.3** of **Annex 1**. These include:

- **Direct cost of treating malaria patients (to the broader health system):** Costs of treating malaria patients are derived from Indonesia's national health insurance program, under the Social Security Management Agency for the Health Sector, locally known as Badan Penyelenggara Jaminan Sosial (BPJS). The BPJS database covers more than 80% of the population in Indonesia. Costs of treating malaria in year 2015 were derived from the BPJS claims data for all patients with reference to malaria.
- **Indirect medical cost of treating malaria:** The indirect medical cost treating malaria includes expenses incurred by the patient or family members including any out-of-pocket (OOP) expenses incurred while seeking treatment. Estimates of indirect medical cost of treatment are based on supporting evidence from similar studies on dengue in Indonesia from published literature.[17]

[a] The population at risk of reintroduction (PARR) is used in this report to clarify specific definitions of population at risk, however the data from the NMCP refers to this as simply PAR.

- **Productivity losses due to malaria morbidity for patients and their caretakers:** Productivity losses due to malaria morbidity for patients were estimated for all malaria cases (217,025 cases in 2015 as reported by the NMCP) by multiplying the gross domestic product (GDP) per capita per day and the average length of illness derived from a study from Sri Lanka.[18] Data on Indonesia's GDP per capita for 2015 was obtained from the World Bank.[19] For the distribution of malaria cases into in-patient (IP) and outpatient (OP) cases, we used the case distribution observed from a dynamic epidemiological transmission model, described later in the methodology. To estimate the productivity losses among the caregivers, the number of caretakers for each OP was considered one, whereas the numbers of caretakers for each IP were considered two, based on expert opinion. Productivity losses for caretakers were then estimated by multiplying the number of patients with the GDP per capita per day and the respective length of illness.
- **Productivity losses due to malaria mortality**: The full income approach was used to estimate the social value of life lost due to malaria as proposed by the *Lancet Commission on Investing in Health*.[20] The full income approach combines growth in national income with the value individuals place on increased life expectancy, or the value of their additional life years (VLYs). This approach accounts for people's willingness to trade off income, pleasure, or convenience for an increase in life expectancy. One VLY is the value in a particular country or region of a one year increase in life expectancy.

  To estimate the cost of life lost due to malaria mortality using the full income method, we multiplied the potential number of adult deaths due to malaria by the remaining life years at death and the VLYs. The *Lancet Commission on Investing in Health* estimates the VLY average across low- and middle-income countries to be 2.2 times the income per capita.[20]

Malaria Elimination Transmission and Costing in the Asia Pacific (METCAP)

A dynamic epidemiological transmission model, METCAP, was developed by MORU in collaboration with MEI, to assess the costs and epidemiological trends from 2016-2030 for Indonesia in 80 varying scenarios. Empirical cost data were incorporated into the epidemiological model to estimate the cost of elimination and the economic impact of interventions against transmission of *P. falciparum* and *P. vivax*; this permitted the examination of numerous control and elimination scenarios to determine cost and economic and epidemiological efficiencies.

- **Business as usual**: This scenario projects the malaria burden in 2016-2030 based on continuing the mix and coverage of malaria interventions implemented in 2014.
- **Reverse scenario**: This scenario projects the malaria burden in 2016-2030 assuming that IRS activities and LLIN distribution ceases and treatment rates fall by 50%.
- **Indonesia targets scenario**: In consultation with the NMCP, this scenario was developed to include Indonesia specific targets that reflect the current NMSP stratified strategy. This includes the "business as usual" baseline interventions, 13% of PAR coverage of LLINs, 2% of PAR coverage of IRS, 80% coverage test and treat, using injectable artesunate for management of severe disease, increasing effectiveness of LLINs, and increasing surveillance.
- **Elimination scenario**: This scenario includes the same mix and scale of the Indonesia targets scenario and adds mass drug administration (MDA) to enable elimination. MDA is applied at five annual rounds at 50% coverage from 2018, starting 4 months before the peak of the season.

For each scenario above, we assumed as a baseline a 5% probability of treatment failure due to artemisinin resistance. In a separate set of simulations, we increased the treatment failure rate to 30% from 2018 to 2025 to account for the possibility of artemisinin resistance spreading in Indonesia; this is referred to as "with resistance". Although the results of both simulations are presented in this report, primary results are based on the scenarios with drug resistance.

In addition, we simulated the effect of improved targeting of malaria interventions on costs. We did this by reducing intervention coverage by 30% among the PAR for the business as usual and elimination scenarios with the resistance.

Cost projections

Economic cost and financial cost projections of current activities through 2020

Between 2015 and 2020, the NCMP projects that about 100 more districts will achieve malaria-free status and numerous districts will shift from high to medium burden and from medium to low burden. As districts move from high to medium, medium to low, or low to free, different intervention strategies are employed that affect the cost of the malaria program. Using the endemicity specific average cost per capita (for economic cost) or cost per PAR (for financial cost), projections were calculated for the years 2016-2020 based on the total population (for economic cost) and PAR (for financial cost) that the NMCP projects to be in each endemicity level. This method of projection takes in to account the projected changes in interventions implemented by districts at each endemicity level over the specified timeframe; however it does not include any additional innovative interventions.

Epidemiological transmission model cost projections

In addition to current interventions, Indonesia will likely need to implement additional interventions or increase coverage or effectiveness of current interventions in order to eliminate by 2030. Using outputs from the dynamic epidemiological transmission model, unit costs from our costing exercise, and published literature (Table A1.4 in Annex 1), we estimated the costs of eliminating with the suite of interventions that will allow Indonesia to become malaria-free by 2030. These estimates are separate from the NMCP projections of district elimination. To account for potential underestimation of reported cases, clinical cases were used to calculate modeled costs and benefits. A reported malaria case refers to a malaria case reported by medical units and medical practitioners to either the health department or the malaria control program, as prescribed by national laws or regulations. A clinical malaria case is an individual who tests positive for malaria while displaying malaria-related symptoms such as fever, headache, and vomiting.

To calculate the incremental costs of elimination (which is used to calculate the ROI), we subtracted the estimated costs of the business as usual from the elimination scenario.

Cost comparison by endemicity level

Distribution of malaria burden in Indonesia is heterogeneous. The same national program strategically delivers services to both malaria-free and high endemic geographies. This heterogeneity in itself provides a natural counterfactual context to compare and infer the potential, unrealized cost savings of making the country malaria-free.[21,22] Theoretically, the high cost per capita of the malaria program currently used in high endemic areas would have been averted or been very low compared to areas that have been successful in already attaining and maintaining malaria-free status. High costs in high endemic areas can thus be interpreted as the potential averted costs that the country failed to avert.

We compared the costs between malaria programs at each endemicity level to provide the potential cost savings that could occur if programs in high endemicities were to achieve low or free endemicity status. Using the data from the micro-costing, the economic cost and financial cost were calculated per capita and per PAR respectively, across each endemicity level. Cost savings due to investments in malaria are inferred from the public health program perspective and the broader economic perspective, as described previously.

Both the direct economic costs and broader economic costs were compared among the following settings:

- High burden and malaria-free
- High burden and low burden
- High plus medium burden and free plus low burden
- High plus medium plus low and malaria-free

Benefits of elimination through 2030

To estimate the benefits of elimination, the differences in modeled outputs from the scenario comparisons listed below were used to calculate averted costs, cases, deaths, and ROI. We also estimated the direct and indirect costs averted in 2016 through 2030.

To calculate the ROI, we divided the difference between total benefits of elimination and incremental costs for elimination as compared to business as usual, by the incremental cost of elimination. The ROI is interpreted as the incremental returns of additional investment in the malaria burden over 15 years with eventual interruption of local transmission by 2030.

The following scenarios were compared:

1. Business as usual compared to the elimination scenario
2. Business as usual compared to the elimination scenario, assuming resistance
3. Business as usual compared to the reverse scenario to simulate a “worst case” scenario.

Scenario comparison 2, business as usual compared to elimination scenario with resistance, is assumed to be the most realistic, thus main findings will be assessed through this scenario.

Gap analysis and opportunities for resource mobilization

We collected data on available malaria funding in Indonesia from the NMSP. From this data we were able to calculate the financial gap between 2016 and 2020 by subtracting the projected estimated financial cost based on current malaria activities from the projected funding available for malaria. This financial gap represents what will be needed to continue current interventions. A financial gap was also calculated for the costs of the modeled elimination scenario for 2016 and 2020, which represents what will be needed in the near term in order to achieve elimination by 2030. Lastly, we assessed potential opportunities for resource mobilization to fill potential financial gaps by mapping the main private sector investors and analyzing the domestic funding landscape.

Limitations

It should be noted that this transmission model was not designed for accurately modeling individual countries as it uses only 1 patch for each country. Thus it is unable to take account of subnational heterogeneities in transmission and delivery of interventions. Treating the whole country as a single unit in this way is likely to lead to over-estimates in costs of elimination. The project team are planning to develop the METCAP model to incorporate multiple patches for each country to model scenarios for individual countries in detail

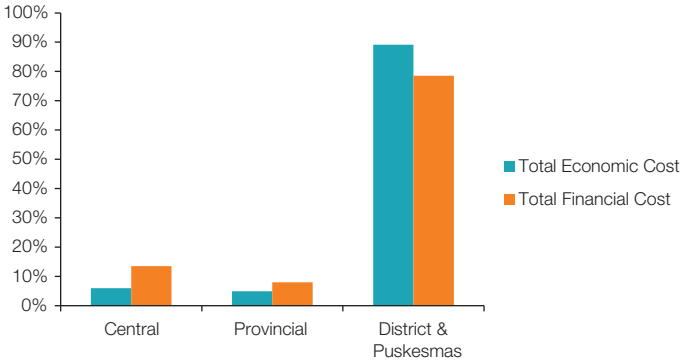
Results

Cost of malaria from public health program perspective

The total economic cost of the malaria program in 2015 was estimated to be USD 147 million, which translates to about USD 0.79 per capita at the national level. Based on the aggregated sample health facility data, almost 89% of the total cost was attributed to either districts or puskesmas levels; central level and provincial level program seach accounted for about 6% of the total expenditures (Figure 5). The total financial cost (i.e., cost of the program's recurrent budget line items) is USD 60.9 million, or USD 0.85 per PAR. The total financial cost share is lower at the district and puskesmas levels, but slightly higher at the central and provincial levels.

Total economic cost per district, including puskesmas and DHO costs, varied significantly depending on endemicity. Malaria-free districts Badung and Klungkung in Bali had the lowest costs at USD 25,926 (USD 0.07 per PARR) and USD 17,972 (USD 0.41 per PARR) in 2015, while high endemic district Sumba Barat Daya in Nusa Tenggara Timur had one of the highest total costs at USD 542,941 (USD 1.70 per capita). While high burden district Keroom in Papua had relatively lower total costs at USD 192,225, it had one of the highest costs per capita at USD 3.58. Jayapura, a high burden district in Papua, was an outlier, having spent upwards of USD 1 million (USD 3.80 per capita) on malaria control.

Figure 5. Economic cost and financial cost share by level of health facility



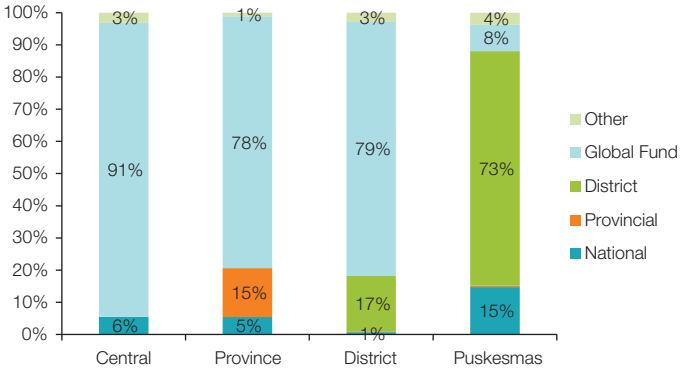
Puskesmas:village health facility

Economic cost by source

In Indonesia, various sources of funding provide support to different levels of the malaria program. The breakdown of funding sources across each level is shown in Figure 6.

At the central level, the majority of funding (91%) is from the Global Fund, while 6% is from national sources. The Global Fund contributes 78% of provincial, 79% of district, and 8% of puskesmas level funding. At the lower levels of PHOs, DHOs, and puskesmas, a higher percentage of funding comes from domestic sources, including provincial and district revenue streams. The national level

Figure 6. Distribution of total economic cost by source



Puskesmas: village health facility

provides funding for malaria activities at the province (5%) and health facility level (15%), while provincial funding supports activities at the provincial level. Funding from district revenue streams mainly support 17% of activities on the district level, and 73% at the health facility level.

Economic cost by inputs

The distribution of economic cost across inputs varies by levels of health facilities. At the central and province level, as shown in Figure 7, costs are highest on services, particularly at the central level (over 90%). The majority

Figure 7. Distribution of economic input cost across central and provincial levels

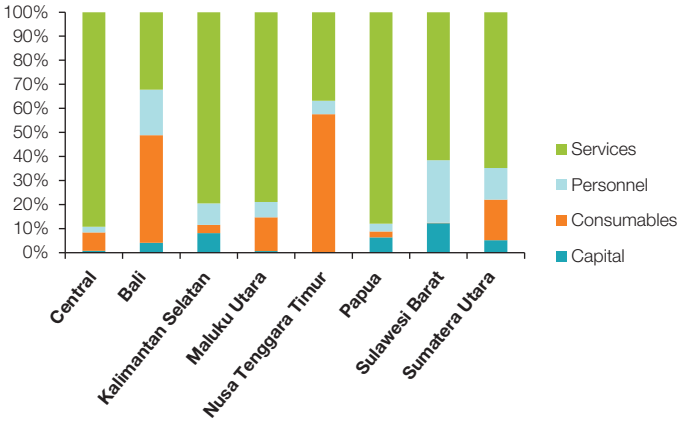


Figure 8. Distribution of economic input cost across sample districts

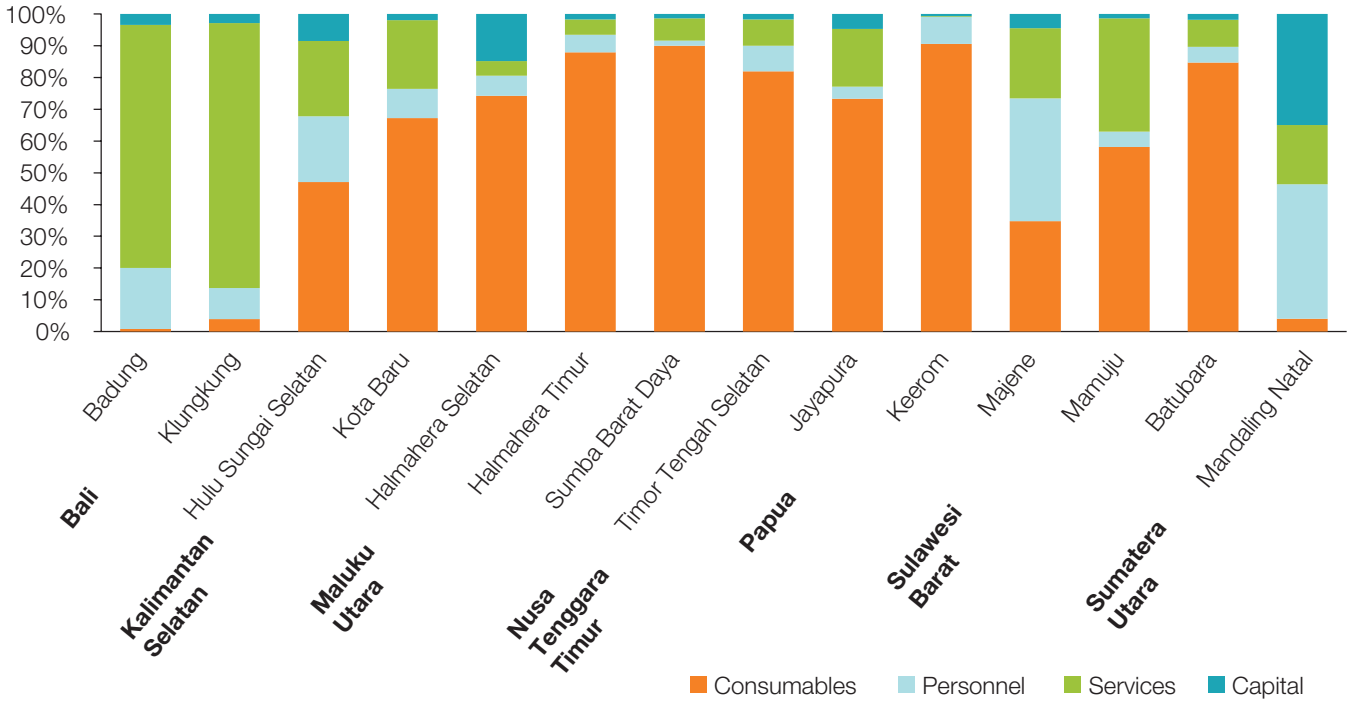


Table 2. Distribution of economic input cost across sample district health offices in 2015

District	Malaria endemicity phase	Capital		Personnel		Consumables		Services		Total cost (USD)	Total cost per capita (USD)
		Cost (USD)	%	Cost (USD)	%	Cost (USD)	%	Cost (USD)	%		
Badung	Free	254	3%	1,410	19%	58	1%	5,608	77%	7,329	0.02
Batubara	Medium	3,805	2%	10,292	5%	173,358	85%	17,343	8%	204,798	0.51
Halmahera Selatan	Medium	63,445	15%	27,021	6%	317,483	74%	19,516	5%	427,466	1.94
Halmahera Timur	Medium	2,110	2%	6,785	6%	107,177	88%	5,891	5%	121,963	1.43
Hulu Sungai Selatan	Low	1,994	8%	4,856	21%	11,067	47%	5,572	24%	23,488	0.10
Jayapura	High	15,425	5%	12,687	4%	240,683	73%	59,654	18%	328,449	1.16
Keerom	High	638	1%	7,792	8%	83,216	91%	199	0%	91,846	1.71
Klungkung	Free	313	3%	1,092	10%	432	4%	9,255	83%	11,092	0.25
Kota Baru	Low	992	2%	4,732	9%	34,394	67%	11,063	22%	51,182	0.16
Majene	Low	595	5%	5,088	39%	4,571	35%	2,891	22%	13,146	0.08
Mamuju	Low	863	1%	3,040	5%	37,025	58%	22,742	36%	63,670	0.24
Mandailing Natal	High	5,868	35%	7,097	42%	686	4%	3,106	19%	16,756	0.04
Sumba Barat Daya	High	6,381	1%	7,578	2%	434,076	90%	34,282	7%	482,317	1.51
Timor Tengah Selatan	Medium	1,869	2%	8,767	8%	88,701	82%	8,917	8%	108,255	0.24

of the service costs at the provincial and central level consist of trainings for the malaria program. At the DHO level (Figure 8 and Table 2), consumables constituted the largest share of costs at 57% across sample districts (ranging 1% in malaria-free areas to 90% of the total cost in high burden districts), with most of the cost in the medium to high endemic districts. Services and personnel accounted for the next largest share at about 24% (range 0%-83%) and 13% (range 2%-42%) respectively. Capital costs constituted about 6% (range 1%-35%) of total expenditures on malaria.

This is not unusual for malaria programs responding to varying endemicity levels, which require differing interventions. Higher burden districts such as those in Maluku Utara, Nusa Tenggara Timur, and Papua have wider vector control activities to control transmission and require more consumables. Districts in malaria-free areas such as Bali do not need as much for vector control, yet spend more on personnel and services for surveillance to prevent reintroduction.

An additional figure for district financial cost by input can be found in **Annex 3**.

Economic cost by activity

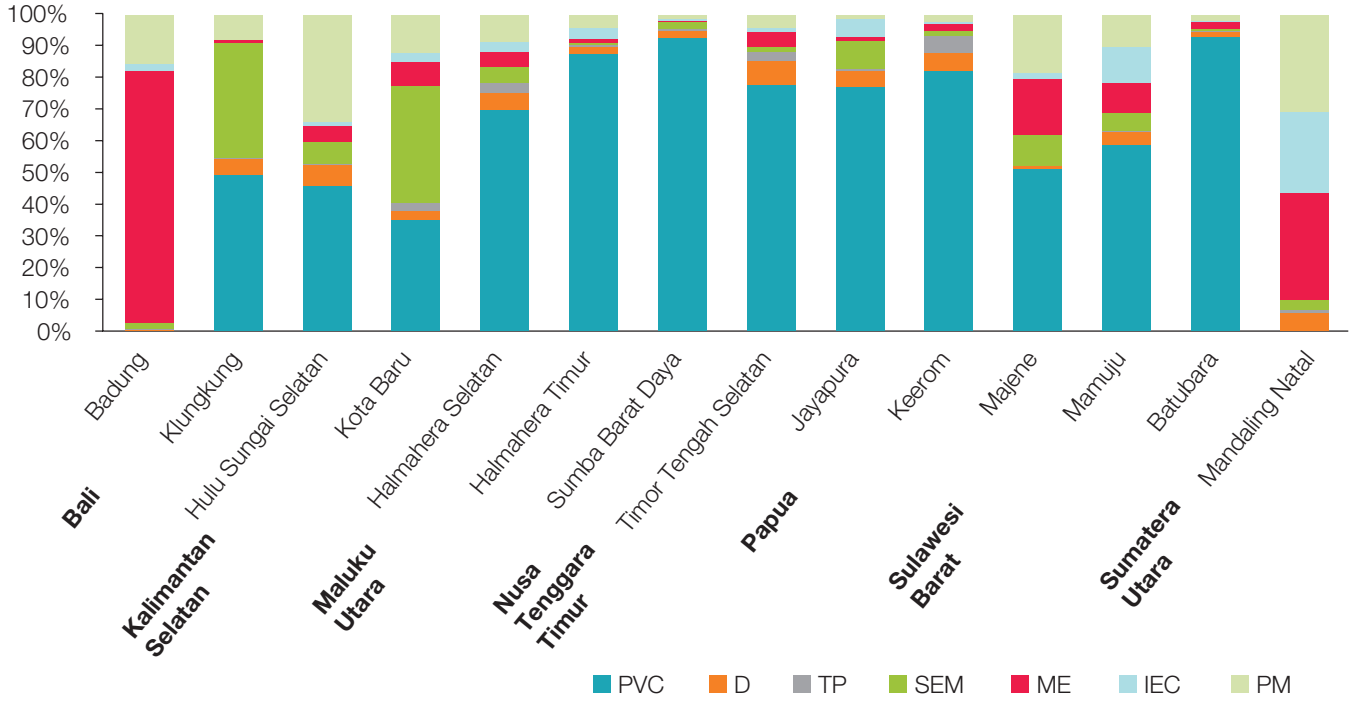
We classified costs across seven activity groups for malaria: prevention and vector control (PVC); diagnosis (D); treatment and prophylaxis (TP); surveillance and epidemic management (SEM); monitoring and evaluation (ME); information, education, and communication (IEC); and program management (PM). Figure 9 illustrates the sample distribution of DHO costs across activities. The major cost driver in 12 of the 14 sample districts was PVC ranging from 35% to 95%, followed by SEM ranging from 5% to 20% of the share of total costs. In the other two districts, Badung and Mandailing Natal, ME was the largest cost driver ranging from 40% to 80% of the share of total costs.

An additional figure for district financial cost by activity can be found in **Annex 3**.

Distribution of economic cost by activity as a proportion across endemicities

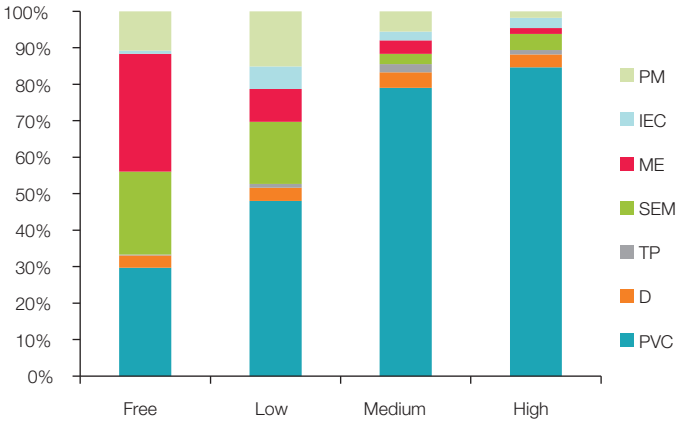
Cost proportions of activities also vary greatly across DHO endemicities and are shown in Figure 10. As one would expect, the majority of PVC activities are conducted in medium to high burden areas where transmission is more frequent and LLINs are distributed more often, however even in malaria-free areas, PVC still comprises 30% of total costs. PVC activities are still conducted in malaria-free areas such as Bali, mainly in the form of larviciding in order to prevent outbreaks from occurring. Malaria-free and low endemic areas also tend to spend more as a share of total cost on ME (32% and 9%, respectively) and

Figure 9. Proportion of economic cost by activity across districts



PM: program management; SEM: surveillance and epidemic management; PVC: prevention and vector control; D: diagnosis; ME: monitoring and evaluation; TP: treatment and prophylaxis; IEC: information, education, and communication.

Figure 10. Distribution of activity economic cost as a proportion across endemicities



PM: program management; SEM: surveillance and epidemic management; PVC: prevention and vector control; D: diagnosis; ME: monitoring and evaluation; TP: treatment and prophylaxis; IEC: information, education, and communication.

SEM (20% and 15%, respectively).

Costs of malaria from the broader economic perspective

In addition to the estimated economic cost, the broader economic burden of malaria for year 2015 was estimated to be USD 58 million (Table 3). This included the cost of treatment paid by the BPJS, which amounted to USD 8.7 million; the indirect cost of treating malaria incurred by the patients, which included OOP, which were estimated at USD 3 million. The losses in productivity due to malaria faced both by the malaria patients and their care-takers were estimated at USD 40 million, and the losses in productivity due to malaria mortality were estimated to be USD 6 million.

When taken together, the aggregate economic cost and broader economic cost of malaria control and elimination in Indonesia in 2015 totals USD 205.7 million.

Economic and financial cost projections

Economic and financial cost projections of current activities through 2020

Based on current intervention costs, total economic costs are projected to decrease by 25% from USD 147 million in 2015 to USD 110 million by 2020 as more and more districts move along the elimination continuum and become malaria-free (Figure 11).This equates to USD 0.79 per capita in 2015, which subsequently falls to USD 0.59 per capita by 2020. Projected financial cost (i.e., cost of the program's recurrent budget line items) declines by 19% between 2015 and 2020, from USD 60.9 million (USD 0.85 per PAR) to USD 49.5 million (USD 0.74 per PAR). During this period, the NMCP projects 103 additional districts will achieve malaria elimination.

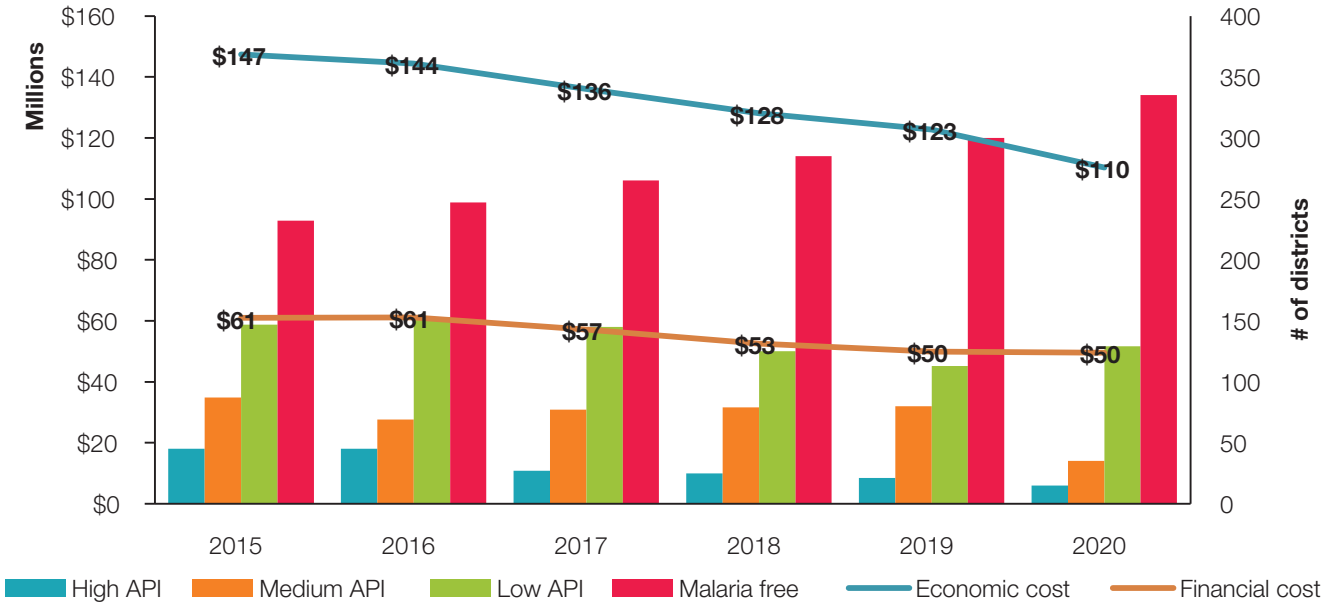
Modeled elimination scenarios

Based on the epidemiological outputs of the transmission model, the scenarios illustrated in Figure 12 model

Table 3: Economic costs of malaria by levels of endemicity, 2015 (USD)

	Level of endemicity				
1. Program cost (malaria program)	**Free**	**Low**	**Medium**	**High**	**TOTAL**
Total cost @ district and puskesmas levels	24,740,415	72,607,422	13,977,837	19,960,352	131,286,025
Total cost @ province level	1,427,048	3,088,712	2,253,295	490,883	7,259,937
Total cost @ central level	1,908,263	3,279,220	2,227,482	1,358,682	8,773,648
Total cost (1) of malaria program	**28,075,726**	**78,975,354**	**18,458,614**	**21,809,917**	**147,319,611**
2. Other economic costs of malaria					
2.1 Direct cost of treatment (BPJS payments)					
	363,624	**347,599**	**2,316,799**	**5,666,443**	**8,694,466**
2.2 Indirect medical cost of treating malaria (including OOP)					
	52,487.37	**40,968.14**	**468,327.30**	**2,475,836.22**	**3,037,619**
2.3 Productivity loss due to malaria morbidity					
	697,058	**544,077**	**6,219,613**	**32,880,301**	**40,341,048**
2.4 Productivity loss due to malaria mortality					
	974,916	**1,706,103**	**243,729**	**3,412,205**	**6,336,952**
Total other economic cost (2) of malaria	**2,088,085**	**2,638,747**	**9,248,468**	**44,434,785**	**58,410,085**
Total (1+2) economic cost of malaria	**30,163,811**	**81,614,101**	**27,707,082**	**66,244,702**	**205,729,697**

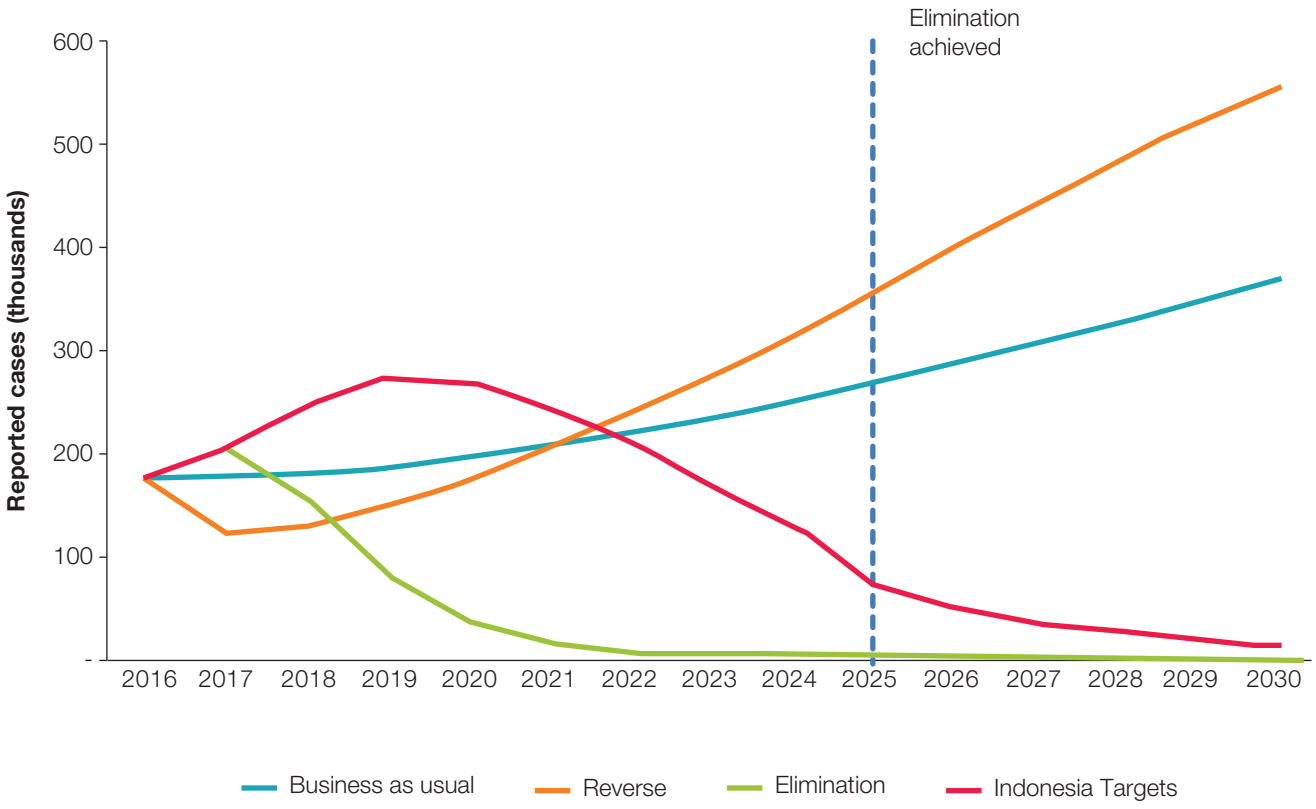
Figure 11. Economic cost and financial cost projections for 2015-2020 of future malaria activities based on NMSP



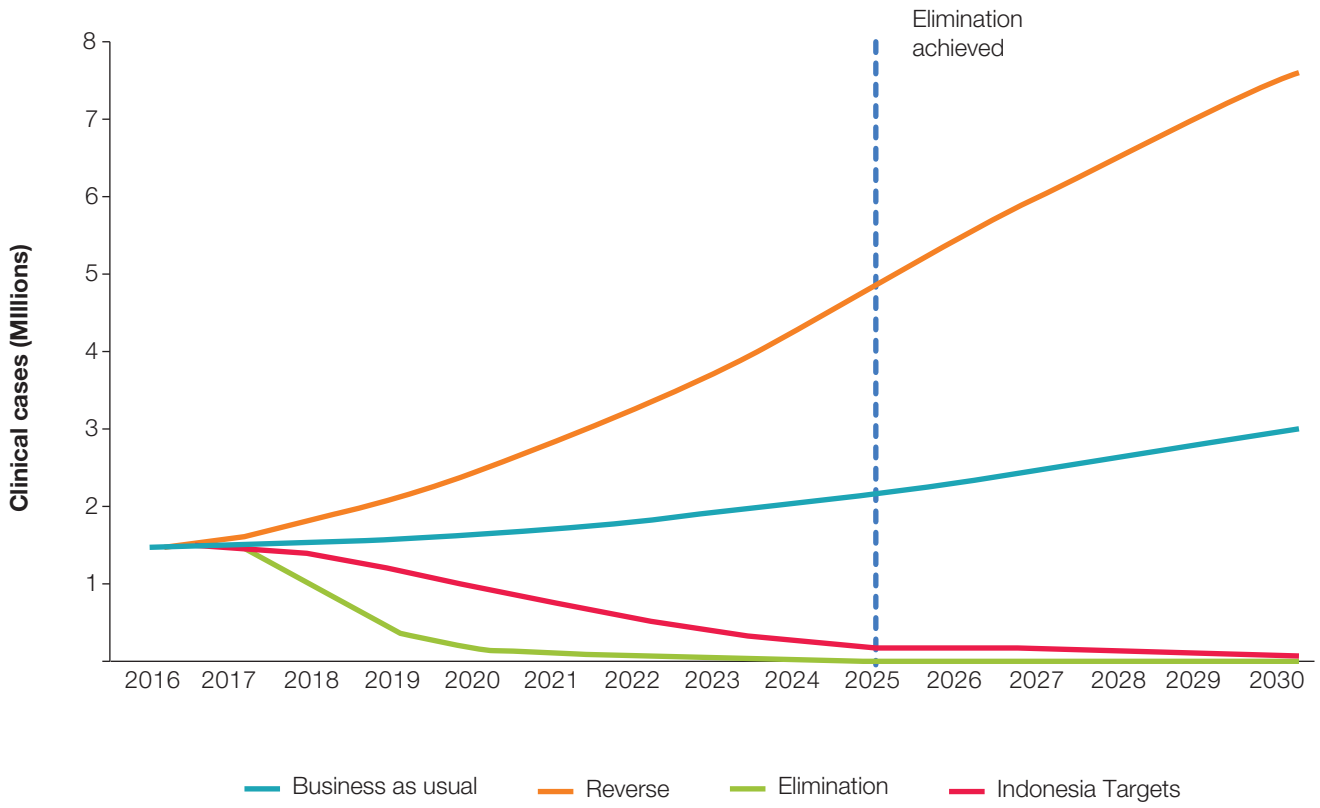
Economic cost: total direct financial burden of malaria. Financial cost: cost of the program's recurrent budget line items (excluding non-recurrent costs such as capital, non-essential personnel, or "other" sources of funding). API: annual parasite incidence

Figure 12. Epidemiological projections from transmission model scenarios 2016-2030 for A) reported cases of malaria and B) clinical cases of malaria

A)



B)



Reported case: a malaria case reported by medical units and medical practitioners to either the health department or the malaria control program, as prescribed by national laws or regulations. *Clinical case*: an individual who tests positive for malaria while displaying malaria-related symptoms such as fever, headache and vomiting. *Business as usual*: projects the malaria burden in 2016-2030 based on continuing the mix and coverage of malaria interventions implemented in 2014. *Reverse scenario*: projects the malaria burden in 2016-2030 assuming that IRS activities and LLIN distribution ceases and treatment rates fall by 50%. *Indonesia targets*: scenario developed to include Indonesia specific targets that reflect the current NMSP stratified strategy including the "business as usual" baseline interventions, 13% of PAR coverage of LLINs, 2% of PAR coverage of IRS, 80% coverage test and treat, using injectable artesunate for management of severe disease, increasing effectiveness of LLINs and increasing surveillance (this scenario does not achieve elimination by 2030). *Elimination*: scenario includes the same mix and scale of the Indonesia targets scenario and adds MDA applied at five annual rounds at 50% coverage from 2018, starting 4 months before the peak of the season.

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the mean number of reported and clinical cases between 2016 and 2030.

If current interventions are maintained and there is a probability of drug resistance in the future, reported cases rise from just under 200,000 in 2016 to over 350,000 in 2030. If interventions are halted or reduced, Indonesia can expect reported cases to dramatically increase to 540,000 by 2030.

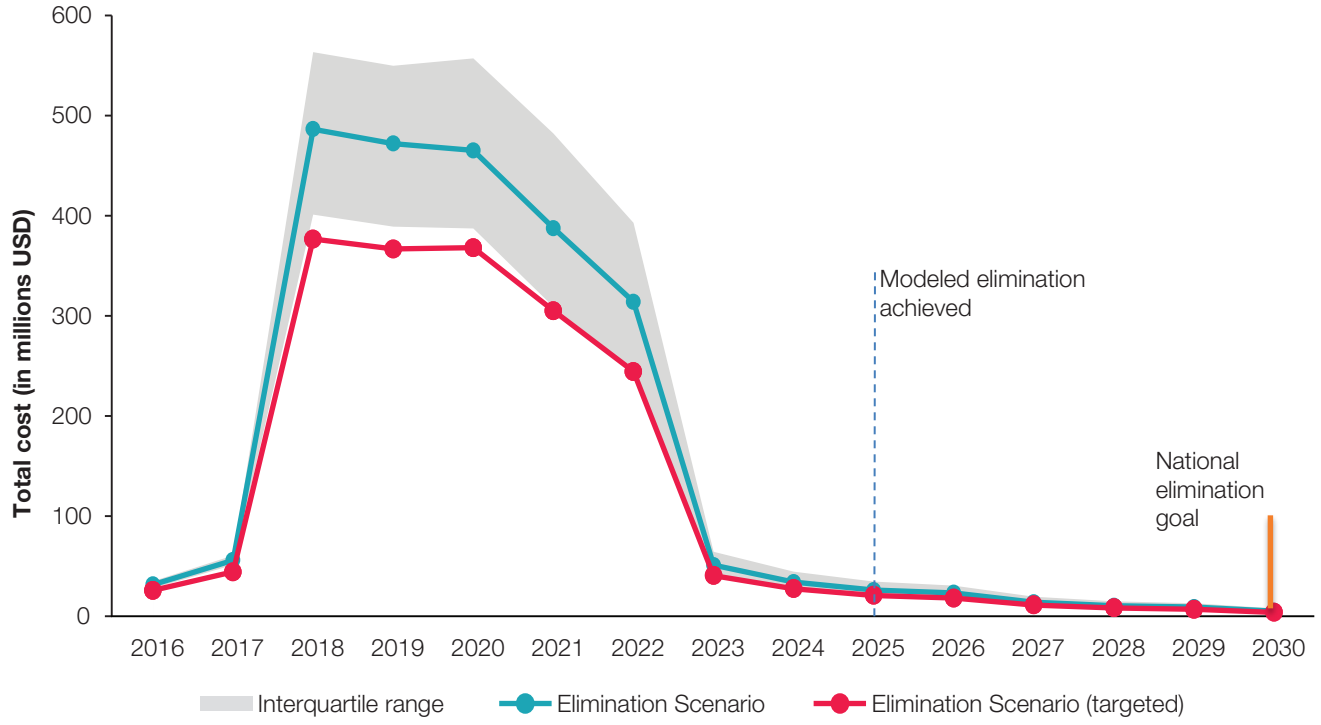
If Indonesia's current targets are implemented, reported cases will decrease but elimination will not be achieved by 2030 unless MDA is added as an additional intervention. If MDA is implemented, Indonesia could achieve elimination by 2025 despite the threat of drug resistance.

The costs and benefits of the elimination scenario as described in the methods will be assessed as the main scenario of interest in the following sections.

Elimination scenario projected costs through 2030

Given that drug resistance is a growing issue in the Asia Pacific region, elimination scenario costs were modeled based on the elimination scenario with a probability of drug resistance as defined in the methods. The median cost in 2016 for the elimination scenario is USD 30 million (interquartile range [IQR] of USD 27 million to USD 33 million) (Figure 13). Total median costs peak in 2018 at USD 442 million (IQR of USD 365 million to USD 512 million), then decrease to USD 25 million in 2025 when elimination is expected to be achieved (IQR of USD 19 million to USD 32.9 million). In total, elimination is estimated to cost USD 2 billion (IQR of USD 1.7 billion to USD 2.6 billion) through 2030. Costs incurred after 2025 are expected as interventions change to prevent the reintroduction of malaria. The transmission model does not account for the cost of the additional prevention of reintroduction (POR) activities beyond 2030, but global eradication will likely not occur

Figure 13. Modeled costs of the elimination scenario with 100% PAR and reduced PAR, 2016-2030



until years after. Until global eradication is achieved, lower level of POR costs will remain.

With improved targeting of interventions (approximated by a reduction of the percent of PAR covered by interventions), median costs between 2016 and 2030 would be reduced by an average of 21% over the 15 year period.

The difference between the current economic and financial costs of the malaria program and the modeled cost of elimination is due to differences in methodology – the model assumes 100% efficiency of interventions and does not include broader program costs (i.e., program costs including capital, non-essential malaria personnel). Hence, modeled elimination costs before MDA is implemented (2016-2017) are much lower than the estimated economic and financial costs estimated for 2015.

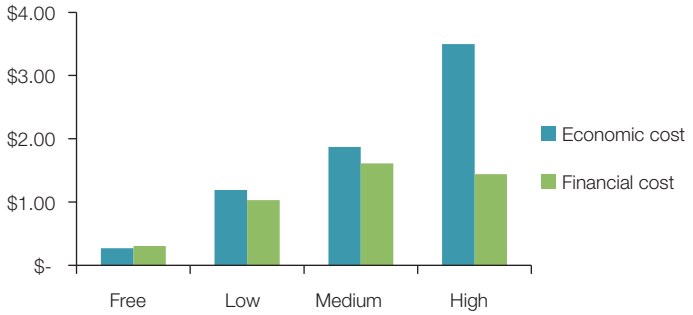
Economic cost and financial cost comparison by endemicity level

The economic cost per capita for malaria activities is highest in high burden areas at an average of USD 3.49 (Figure 14). In medium and lower burden areas, the average malaria cost per capita is lower, at USD 1.87 and USD 1.19 respectively. The cost per PARR in malaria-free areas is USD 0.27.

The financial cost per PAR ranges from USD 1.44 in areas of high endemicity to USD 0.30 in malaria-free areas. Low endemicities have an average financial cost of USD 1.03 per PAR and medium endemicities have an average financial cost of USD 1.61 per PAR.

Comparing only the economic costs, the cost per capita in high burden areas is more than 13 times higher than the cost per capita in malaria-free areas. This suggests a more than 13 fold cost savings that can be accrued by moving from high burden to malaria-free. The higher costs associated with high endemic areas can be avoided by accelerating efforts to achieve malaria-free status.

Figure 14. Economic cost per capita and financial cost per PAR by level of endemicity, 2015 (USD)



When comparing broader economic costs including direct and indirect costs of treating malaria patients, and productivity losses due to morbidity and mortality, the high endemic areas are 21 times higher than the total cost of malaria-free areas, and when high endemic areas are compared to low endemic areas, it is 17 times more costly.

When the economic costs and the broader economic costs are taken together for a total cost comparison, the endemic areas combined are six times more costly than those that are malaria-free.

Benefits of elimination through 2030

If implemented, the elimination scenario assuming drug resistance will avert an estimated 25 million clinical cases and 41,031 deaths between 2016 and 2030 (Table 4). The ROI for each additional dollar invested in malaria elimination in this scenario was calculated to be 10 to 1 over this time period. If interventions are better targeted (as in the reduced PAR scenario), the ROI increases to 14:1. If drug failure rates in Indonesia remain at a minimal 5%, Indonesia can still expect an ROI for elimination of 8:1.

In a "worst case" scenario, where malaria elimination interventions are halted and reduced as compared to business as usual, there would be over 35 million new clinical cases and 74,000 additional deaths (data not shown).

Gaps in financing malaria

Financial gaps

By comparing the total financial cost projected in this report through 2020 to the domestic and donor funding expected to be available, our estimates suggest that Indonesia faces a significant funding gap to maintain their current interventions, averaging USD 13.4 million per year over the next five years. The financial gap ranges from about USD 23 million in 2016, to a low of USD 9.5 million in 2020 (Table 5). However, this suite of interventions is not projected to rid Indonesia of malaria by 2030.

The financial gap between the estimated elimination scenario costs and available funding averages USD 234.7 million per year, ranging from a USD 7 million surplus in 2016 to a USD 403 million shortfall in 2018. The apparent surplus in 2016 is due a combination of the modeled elimination intervention costs at 100% efficiency and an underestimation of domestic resources available from the subnational levels. While MDA is being implemented between 2018 and 2020 there is a

Table 4. Median costs and benefits of malaria elimination compared to counterfactuals, 2016-2030

Scenario comparisons	Clinical cases averted	Deaths averted	Economic benefits (USD)	Incremental cost (USD)	ROI
1. Business as usual vs elimination (minimal drug resistance)	20,205,831	30,685	13,522,911,914	1,757,089,253	8:1
2. Business as usual vs elimination (drug resistance)	25,303,015	41,037	18,034,800,484	1,754,829,814	10:1
30% reduction in PAR					
1. Business as usual vs elimination (drug resistance)	25,303,015	41,037	18,428,392,196	1,361,238,103	14:1

Table 5: Estimated financial gaps for the financial cost of Indonesia's malaria program and modeled elimination scenario, 2016-2020 (USD)

	2016	2017	2018	2019	2020	Average
Domestic financing	20,475,442	16,244,511	21,089,201	21,578,081	22,143,297	**20,306,106**
Global Fund (anticipated)	17,399,166	30,336,061	17,881,635	17,881,635	17,881,635	**20,276,027**
Projected financial cost from investment case	61,134,894	57,084,725	52,517,182	49,861,312	49,564,216	**54,032,466**
Financial gap (financial cost vs available resources)	23,260,285	10,504,153	13,546,346	10,401,595	9,539,285	**13,450,333**
Modeled elimination scenario costs	30,274,598	52,234,058	442,215,172	429,167,743	422,960,425	**275,370,399**
Financial gap (elimination scenario vs available resources)	-7,600,010	5,653,486	403,244,335	389,708,026	382,935,493	**234,788,266**

significant increase in associated cost; however, elimination costs are expected to decrease beginning in 2021 with a precipitous drop off in 2023 to under USD 48 million (as shown in Figure 13).

Opportunities for resource mobilization

Successfully achieving elimination in Indonesia will require intensive financial resources; however the returns are favorable at ten times the initial investment. The Global Fund currently plays a large role by funding 39% of Indonesia's malaria program in 2015 and is projected to increase to 65% by 2017 if full grant amounts are disbursed. However, given declining trends in epidemiology and Indonesia's lower-middle-income status, this level of support will not be sustained in the following years. The new allocation for 2018-2020 from the Global Fund is USD 54 million. Given current available resources and the estimated elimination costs, this will result in an average annual financial gap of USD 234 million between 2016 and 2020. In light of declining donor funding, increased focus should be placed on mobilizing domestic sources of financing.

Indonesia had a healthy annual GDP growth rate of 4.8% in 2015[23] and in 2014, it was estimated that Indonesia allocated just 0.06% of its total domestic health spending on malaria (USD 16,108,194).[6] A recent analysis by Jha and colleagues[24] suggests that if Asian countries were to allocate 2% of their health budgets to malaria, the funding gap would be reduced significantly.

Another option would be to find financing and programmatic efficiencies in the current domestic funding landscape. For example, the Sub-directorate for Malaria can work with other ministries or other sub-directorates like agriculture or vector-borne diseases to pool resources for mutually beneficial programs (i.e., streamlining IRS or environmental management efforts across departments). Additional program efficiencies could be identified through a more in-depth assessment by the Malaria Program Efficiency Analysis Tool[25], a new assessment tool developed by the UCSF Global Health Group that evaluates program performance drivers in a number of areas.

A potential untapped resource is the private sector. Indonesia's has a number of major industries and about 40% of labor force works in agriculture. The palm oil and rubber industries in particular are major employers in the endemic areas of Kalimantan and Sumatra. The mining industry also plays a large role, with one of the world's largest gold mines located in high-endemic Papua. Tourism is expected to be one of the top three industries in Indonesia, with new government initiatives recently put in place to attract tourists to destinations beyond malaria-free Bali. Engaging these sectors and making a business case for why becoming malaria-free will be beneficial to their industry (increasing worker productivity or increasing tourism), could lead to further investments and diversify Indonesia's domestic funding portfolio.

Indonesia's private sector is thriving – it accounts for 60% of GDP and employs almost 70% of the workforce.[26] Many of Indonesia's large multinational companies have corporate social responsibility (CSR) programs that fund projects covering a wide range of issues such as environmental protection, health, and climate change.[27] One such company, PT Freeport Indonesia, an affiliate of the Freeport-McMoRan Copper & Gold Inc., has been investing in the health of the communities they work in, particularly in Mimika, Papua. Through their CSR program, PT Freeport Indonesia has worked with the local malaria control program, supporting trainings, distributing bed nets, spraying homes with insecticide, and funding malaria studies. Aligning interests with CSRs, especially those with community health programs in malaria endemic areas, could provide another source of services or funding for malaria. This type of collaboration with the private sector could also serve as a way to monitor workers and reduce case importation when migrant workers return home to lower burden areas. A more robust assessment of private sector contributions to malaria elimination are published in *Business case studies in Bangladesh, Indonesia, and Papua New Guinea*, a companion report by the UCSF Global Health Group.[28]

Sin taxes, or taxes on harmful products such as alcohol and tobacco, are another way to potentially increase supplementary revenue for health and has been successfully implemented in other Asian countries. The Philippines instituted a sin tax that generated an additional USD 2.3 billion in revenue during the first two years of implementation.[29] As a result, funding for health in the Philippines increased by 57.3% in 2014 and 63.2% in 2015 compared to 2013. In Indonesia, taxes on cigarettes amount to 46% of the price (in 2015), yet the maximum excise rate under Indonesian law is 57%. As taxes gradually rise to 57%, the government is expected to see an increase in revenue by 20-34%.[30] In 2015, tax revenue as a percent of GDP in Indonesia was 10.7%.[31] The Addis Ababa Accord for the Sustainable Development Goals recommends that countries with government revenue below 20% of GDP from taxes should progressively increase tax revenues to meet the 20% target by 2025.[32] Allocating a portion of tax revenue to malaria could provide a sustainable source of funding to help Indonesia fight malaria and achieve elimination.

Other means of increasing domestic financing include the use of innovative financing mechanisms such as health bonds, diaspora bonds, "Debt 2 Health," airline taxes, and financial transaction taxes to provide additional revenue and have been described in detail elsewhere.[33] Social impact bonds or 'pay-for-performance' bonds and blended mechanisms are other promising innovations instruments that have been used to raise financing for health and other sectors such as education and environment.[33] However, analysis of their applicability or feasibility for implementation in Indonesia is beyond the scope of this study.

Discussion

The total economic cost of Indonesia's malaria program in 2015 was estimated to be USD 147 million, which translates to about USD 0.79 per capita at the national level and is comparable to costs per capita reported from other control settings.[34] Given that most capital costs are not recurrent and many personnel do not work on malaria full-time and are funded by other programs, the total financial cost of the program (i.e., cost of the program's recurrent budget line items) is much lower at USD 60.9 million, or USD 0.85 per PAR. To achieve elimination, it is estimated that USD 2 billion will be needed over the next 15 years, or an average annual USD 145 million investment.

With the cost per capita of the program in high endemic areas more than 13 times higher than the cost per capita in malaria-free areas, the savings of becoming malaria-free by 2030 surpass the costs to sustain control efforts. The ROI for malaria elimination was estimated to be 10 to 1, far exceeding the range of returns for high-impact health investments.[b, 35] This ROI will be even higher if there is better targeting of interventions and if the indirect effects of malaria on society were included such as the effects on education, child development, and tourism, which some studies have reported to be areas that malaria can significantly impact. Furthermore, elimination will avert over 25 million clinical cases and 41,000 deaths over the next 15 years – the social impact of which is difficult to measure.

The overwhelming majority of the costs of the malaria program is shouldered by the districts or village health facility levels, and is supported largely by district revenue streams and the Global Fund. However, districts with higher burdens tend to also be districts with lower fiscal capacity and therefore fewer resources to commit to intensifying malaria control efforts. Additionally, even though the Global Fund is the major source of funding, the level of support is slowly declining. Under the Global Fund's new funding model, average annual disbursements between 2015 and 2017 have been 12% lower than between 2009 and 2014 (under the old funding model).[36] For the next funding period, Indonesia's allocation for malaria is USD 53.6 million for three years, which if fully granted, will be a further 39% less than the average annual funding received between 2015 and 2017.[37] One potential barrier to receiving maximum Global Fund grant allocations is past performance of grant absorption. The decentralization of the government has caused challenges for grant implementation and fiscal policies have contributed to low utilization of funds. Other factors for poor grant absorption rates were highlighted in the December 2015 audit conducted by the Global Fund's Office of the Inspector General[38] and included significant weaknesses in medicine quantification, distribution planning and inventory controls, and a wide variation in program management across PHOs and DHOs. If Global Fund funding were to decrease further, it could pose a threat to the malaria elimination strategy.

Increasing program efficiencies can help target limited resources and increase absorption. While there currently is no global recommendation for an optimal mix of interventions to achieve malaria elimination, this costing exercise captures potential inefficiencies in the current malaria program that if improved, may significantly decrease the projected cost of elimination. Greater efficiency can be achieved by implementing an optimal mix of malaria interventions that will create the most impact, or by maximizing the impact of current inputs to the malaria program. To this end, 80 scenarios were run by the transmission model to identify a minimum set of interventions that could enable Indonesia to achieve elimination by 2030. The output from the model suggested the set of minimum interventions to achieve elimination would include increasing coverage of test and treat to 80% of PAR, covering 13% of PAR with LLINs, targeting IRS to 2% of PAR, switching from quinine to injectable artesunate for management of severe disease, increasing effectiveness of LLINs, and increasing surveillance. This would require Indonesia to not only add new interventions to their mix, but also implement a large scale, effective MDA campaign.

Our findings suggest that if Indonesia can accelerate progress by adopting a more aggressive elimination strategy, there are substantial benefits to be had. The malaria transmission model we used predicted that with effective usage of interventions plus MDA can collectively interrupt local malaria transmission in Indonesia by 2025—five years before the 2030 national and regional goal. Though malaria elimination is technically feasible based on our model, operational and monetary constraints may hamper the rollout and implementation of certain interventions.

An inadequately funded malaria program will severely impact the national program and its activities including management and leadership, an important requirement to achieve malaria elimination,[39] especially in such a large, decentralized, and geographically diverse country. Over the last few years, the Indonesian government has increased domestic spending on malaria, however this is projected to plateau through 2020, a critical period in

b Mills and Shilcutt (2004) estimate a benefit-cost ratio of investment in malaria control to be between 1.9 to 4.7.

the trajectory towards elimination. External financing is projected to decline after 2017, resulting in a widening financial gap after 2018. Our estimates show an average annual gap of USD 13 million between available funding and the total financial cost for the malaria program to maintain current interventions. If the NCMP strives to achieve elimination by implementing the interventions and coverage levels from the modeled elimination scenario, the average annual gap is estimated to be over USD 234 million between 2016 and 2020. Either gap, if left unfilled, could jeopardize the malaria program's success, hamper progress toward elimination, and limit potential benefits from achieving country-wide elimination. Strong financial and political commitment will be needed to achieve their elimination goal.

Various methods to increase domestic funding through innovative financing mechanisms have been proposed in this report. These must be coupled with expanded advocacy to increase the national budget for elimination.

Beyond the benefits of achieving malaria-freedom reported in this analysis, other potential benefits of malaria elimination are harder to quantify. As a byproduct of national elimination, other positive externalities such as increased tourism, a strengthened health system, and improved regional health security could result.[40, 41] Waning donor commitment and stagnating government funds are imminent threats to the accelerated progress that Indonesia needs, which must be addressed through high-level advocacy to policy makers and donors. This investment case provides evidence for the benefits of continued prioritization of funding for malaria, and can be used to develop an advocacy strategy for increased domestic and external funding for Indonesia to reach is goal to be malaria-free by 2030.

This study has several limitations which include but are not limited to potential sample selection bias, collecting accurate and complete expenditure data, and quantifying additional benefits due to malaria elimination. **Annex 1** provides more insight into the limitations to both the methods and data used in this study. Despite these limitations, the findings presented in this investment case provide a valuable tool for stakeholders and the NMCP to better budget and plan for future elimination activities.

Limitations

It should be noted that this transmission model was not designed for accurately modeling individual countries as it uses only 1 patch for each country. Thus it is unable to take account of subnational heterogeneities in transmission and delivery of interventions. Treating the whole country as a single unit in this way is likely to lead to over-estimates in costs of elimination. The project team are planning to develop the METCAP model to incorporate multiple patches for each country to model scenarios for individual countries in detail.

There is much uncertainty in the estimated malaria burden in each country with a resulting impact on the predicted costs of elimination. Population movement was not included in the model and this is is likely to have reduced the predicted costs.

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Annex 1. Costing assumptions and methodology

Personnel time

Personnel times were all self-reported. We interviewed one person or staff member from each position to determine his or her time allocations by malaria activity. We then applied the time allocation of the staff member we interviewed to all staff members with the same designation. For certain positions where multiple people shared the same designation but conducted very different work activities (e.g., NMCP medical officers), each person's time allocation was determined separately and used in the costing.

Cars and other motor vehicles

We used the unit costs and year of purchase found in NMCP or Global Fund records for the costing of cars and other motor vehicles. When a match between the NMCP records and Global Fund records was not found, the next closest match was used. For time allocations of cars and other motor vehicles, we used the time allocations reported by the personnel who use them or are in charge of the vehicles' maintenance and care.

Computers, printers, photocopiers, and other equipment

We used the equipment inventory provided by the NCMP as a basis for costing the functioning computers, printers, fax machines, and photocopiers at the NCMP. If a particular computer or computer equipment had a designated owner, we applied that personnel's time allocation to the equipment. For computers and computer equipment that are used by multiple staff, we used the average of their time allotments.

When no time allotments were provided, we used the average of the self-reported time allotments of all the staff that use the computers or computer equipment. We used the unit costs and year of purchase found in NMCP or Global Fund records for the costing of computers and computer equipment.

Depreciation

To calculate the depreciated value of capital resources, we divided the original total cost of the good by an annuity factor (Table A1.1) based on a 3% discount rate and the good's useful life years (ULYs) (Table A1.2) and multiplied that value by the remaining ULYs.

*Depreciated value = (Original Total Cost/Annuity Factor) * Remaining ULYs*

Remaining ULYs = ULYs – (2014 – Year of Purchase)

Table A1.1 Annuity factors at 3% discount rate*

Useful Life Years	Annuity Factor
1	0.971
2	1.913
3	2.829
4	3.717
5	4.58
6	5.417
7	6.23
8	7.02
9	7.786
10	8.53

* Taken from Drummond, Michael F., et al. *Methods for the Economic Evaluation of Health Care Programmes*. 3rd ed. Oxford, UK: Oxford University Press, 2005.

Table A1.2. Useful life years for capital goods and equipment

Capital Goods	Useful Life Years
Motorcycles	5
Vehicles	10
Computers	5
Microscopes	10
Buildings	20

† The ULYs used are based on the recommendations in the Bill & Melinda Gates Foundation's "Guidance for Estimating Cost for Malaria Elimination Projects."

Services

To estimate time allocation for buildings and office spaces, we used the average of the time allocations of all the personnel who occupy the building or space.

Data collection methodology

Using an interview guide, staff at the NMCP, PHOs, DHOs, village health facilities (also referred to as puskesmas), and malaria centers (where applicable) were interviewed in a semi-structured format and observed to determine how much time they spent on various malaria elimination activities. At the central level, officers at the NMCP including the director; director of finance and accounting; diagnostic, surveillance, and monitoring and

evaluation unit staff; and the Global Fund project finance manager were interviewed. At the provincial, district, and village levels, malaria officers and their staff were interviewed and observed.

We developed a checklist to facilitate data collection on all potential costs incurred outside the program perspective, including societal costs. Most of the data for the cost savings was collected from existing literature. We also conducted key informant interviews with Sub-directorate staff to gather additional data on societal costs of malaria and to build consensus on the assumptions used.

Cost by source

The main sources of funding for malaria in Indonesia are (1) domestic funding, in the form of direct government allocations from the national health budget as well as provincial and district revenue streams, and (2) external funding, primarily from the Global Fund directly provided to the MOH and grant principal recipient PERDHAKI. Government resources are disbursed to provinces and districts for all health activities including malaria prevention and control. To the extent possible, we identified the specific source of funding for each input.

Cost by input

Direct costs to the health systems were also classified based on four inputs of production: capital, personnel, consumables, and services. Capital costs included vehicles, buildings and office space, furniture, computers, and other durable supplies. Personnel costs included salaries, allowances, and any other compensation to staff involved in malaria. Consumable costs included office and laboratory supplies, medicines, insecticides, and other expendable products. Service costs included utilities, transport (domestic and international), trainings, maintenance, and security.

Costs were also categorized as fixed (i.e., capital) and recurrent (i.e., personnel, consumables, and services). Capital goods were annualized and discounted using common ULYs and standard annuity factors based on a 3% discount rate (see Table A1.1-1.2 for ULYs and annuity factors used). Maintenance costs for equipment, vehicles, and buildings were calculated using actual information on the expenditure of maintaining these resources. No replacement costs were used for the value of capital resources when the current value of such resources was already depreciated to zero, assuming that the replacement would not occur in the near future.

For inputs shared across multiple health or disease programs, only the cost attributed to malaria was included based on the proportion of time spent on malaria-specific activities. Shared resources such as staff time spent on each activity were self-reported and determined through interviews and likely subject to reporting bias. Due to time and resource constraints, a time in motion study was not conducted.

Cost by activity

We classified costs across seven activity groups for malaria: prevention and vector control (PVC); diagnosis (D); treatment and prophylaxis (TP); surveillance and epidemic management (SEM); monitoring and evaluation (ME); information, education, and communication (IEC); and program management (PM). While the conduct of most of these activities is integrated, we created activity groups for this study to facilitate analysis. A detailed list of activities included under each category is provided in Table A1.3. Resources were apportioned across activities based on self-reported time spent by interviewees.

Table A1.3. Ingredients based costing categories and activities

Cost categories	Activities
Prevention and vector control	Environmental management
	Targeted biological control
	Personal and community protection (LLINs and IRS)
	Chemical larviciding
Diagnosis	Rapid diagnostic test
	Molecular diagnosis and confirmation
	Quality assurance
	Case management
Treatment and prophylaxis	Chemoprophylaxis
	Passive case detection
	Provider training
Surveillance and epidemic management	Active case detection
	Activated passive case detection
	Entomological surveillance
	Case investigation and response
	Epidemic response
	Surveillance training
	Private sector surveillance
Monitoring and evaluation	Internal monitoring and evaluation
	External monitoring and evaluation
	Health information system
	Periodic surveys

Information, education, and communication	Private sector engagement
	Partnership development
	Behavior change communication programs
	Policy advocacy
	School-based education
	Operational research
Program management	Administrative training
	Capacity building
	Staff placement and recruitment
	Meetings
	Supervision and monitoring
	General administration

Population numbers for costing samples

We used 2015 mid-year population estimates by district published by the NMCP to calculate costs in sample puskesmas and districts. For total economic costs, total population numbers were used for high, medium, and low burden areas, while 60% of the total population in malaria-free areas was assumed to be at risk of reintroduction of malaria. For the estimated financial cost, PAR estimates from the NMCP for each endemicity level were used. These estimates will be published by the NMCP in the upcoming NMSP update for 2017.

Generating national level estimates of cost and of malaria

To estimate the total economic cost, the average cost per capita at the puskesmas level were weighted by the population for the sample district, then added to the DHO cost to generate total cost of malaria at the district level. Each district cost per capita was then averaged within each endemicity band and the average district cost per capita was then applied to the total national population residing within the respective endemicity. For example, the average cost per capita of two sampled high burden districts as multiplied by the total population residing within high burden areas in Indonesia was used to generate high burden district level cost estimates for the entire country. This was conducted for each endemicity level.

Similarly, at the province level, the average provincial cost per capita for each of the sampled provinces in each endemicity band were multiplied by the respective population within each band. Costs across all districts and provinces were then added to the central level costs (allocated based on proportion of district and province costs) to generate the estimates of total cost of malaria elimination for the entire country for 2015.

The total financial cost was calculated in a similar methodology, but used PAR estimates in place of total population. The financial cost also excludes capital costs, costs funded by "other" sources, and all non-essential personnel (personnel working <100% of the time on malaria or not holding title of "malaria program manager" or equivalent).

Other assumptions

Table A1.4 below describes other assumptions used in the data analysis.

Limitations

Collecting accurate and robust data from a complex health system such as in Indonesia is challenging. A portion of the expenditure data we received was in aggregate. Where possible, costs were apportioned by activity using cross referencing with other data or information from key personnel interviews, potentially introducing reporting bias.

The sample provinces were not chosen randomly, which may be a source of bias. Though the sample provinces were selected based on their representativeness on predetermined criteria (a combination of (1) endemicity; (2) population; (3) elimination status; (4) location and geographic spread; and (5) accessibility), spending across the sample may not fully capture the diversity of malaria spending at the subnational level.

As mentioned previously, many benefits of malaria elimination cannot be valued accurately and were excluded from the calculations; thus, our benefits estimations are likely to be underestimates.

The malaria transmission model used has inherent limitations, which may introduce uncertainty to the benefits estimations. The sensitivity analysis conducted aims to address such issues.

Table A1.4. Inputs and assumptions used in various analyses

Name	Value	Source
Cost		
Cost of OP malaria treatment (USD)	13.43	BPJS
Cost of IP malaria treatment per day (USD)	159.60	BPJS
Cost of rapid diagnostic test per case (USD)	0.40	NMCP
Cost of slide per case (USD)	0.86	NMCP
Cost of antimalarials per OP case (USD)	2.2	NMCP
Cost of antimalarials per IP case (USD)	25.89	NMCP
Cost per LLIN (USD)	2.00	NMCP
Cost per LLIN distributed (USD)	7.28	NMCP
Cost per person protected by IRS (USD)	3.88	NMCP
Annual cost of training per capita (USD)	0.03	[a] Investment Case data
Annual cost of surveillance per capita (USD)	0.23	[a] Calculated by NMCP. Average unit cost of active case detection, passive case detection, and reactive case detection weighted by the number of PAR in each endemicity band
Annual cost of IEC per capita (USD)	0.04	[a] Investment Case data
OOP per OP malaria case (USD)	36.35	[17] Proxy
OOP per IP malaria case (USD)	9	[17] Proxy
Coverage		
PAR covered by LLINs (%)	.13	NMCP. Calculated to approximate the NMSP strategy of 100% high burden PAR covered and 20% of medium burden PAR covered.
PAR covered by IRS (%)	.02	NMCP. Calculated to approximate the NMSP strategy of 20% high burden PAR covered.
Economics		
GDP per capita (USD)	3,347	[19]
Coefficient for VLY calculation	2.2	[20]
Mortality		
Life expectancy at 40 (years)	33.55	UN World Population Prospect: https://esa.un.org/unpd/wpp/dataquery/
Epidemiology and length of disease		
Proportion of malaria cases that are treated OP	0.82	[a] Transmission model output
Proportion of malaria cases that are treated IP	0.18	[a] Transmission model output
Average duration of illness for OP case (days)	9.3	[18]
Average duration of illness for IP case (days)	9.3	[18]
Length of IP malaria hospitalization	3.65	BPJS

[a] Calculated by authors using data from the references cited.
IEC: Information, education, and communication

Annex 2. Transmission model methodology

The investment case for malaria elimination was generated using the output of a mathematical model to project rates of decline to elimination by at least 2030 and determine the associated costs. The dynamic epidemiological models estimated the impact of a variety of interventions against the transmission of *P. falciparum* and *P. vivax* using four infection classes: severe, clinical, asymptomatic and detectable by microscopy, asymptomatic and undetectable by microscopy. *P. vivax* infections were characterized by relapses of malaria arising from persistent liver stages of the parasite (hypnozoites). The relationship between Glucose 6-phosphate dehydrogenase deficiency (G6PDd) and *P. vivax* malaria was captured using existing estimated G6PDd proportions in the population (those with G6PDd have a reduced probability of clinical infection compared to the non-G6PD proportion of the population)[c]. The model was designed to be spatially explicit with interconnected patches representing whole countries. A diagram of the model structure is shown in Figure A2.1.

c Unpublished estimates from the Malaria Atlas Project (MAP)

Data on historical malaria incidence (2000-2014) and intervention coverage used to calibrate and validate the models were sourced from:

1. World Malaria Reports (WMR) 2008-2015
2. Mahidol Oxford Tropical Medicine Research Unit
3. Peer reviewed literature
4. Country level data from NMCP

The models were validated against the estimated burden of disease separately for *P. falciparum* and *P. vivax* malaria and accumulated case fatalities. While reported coverage of interventions (particularly LLINs and IRS distribution), were included in the models to inform changes in incidence, there was little available data on health system advances between 2000 and 2015, such as the introduction of community health workers, and these were imputed based on observed changes in reported incidence. The fatalities predicted by the models were validated against reported case fatalities. As mentioned above, the METCAP transmission model was only able to provide rough estimates of predicfed costings. It was not designed to study individual countries in detail as it uses only on patch per country. Future work will adapt METCAP to incorporate multiple subnational units to model individual countries in detail. A full description of the mathematical models and the parameters driving the models is available elsewhere.[42, 43]

Figure A2.1. Transmission model structure

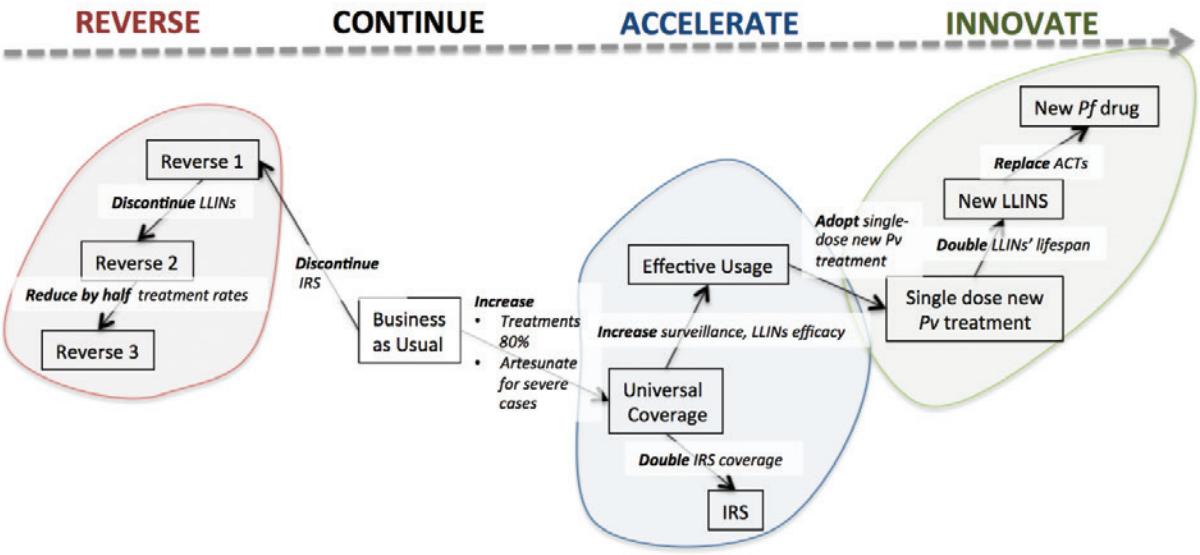


Table A2.1. Intervention coverage scenarios

REVERSE	CONTINUE	ACCELERATE	INNOVATE
Reverse scenario 3 • Discontinue IRS activities in 2017 • Discontinue LLN activities in 2017 • Reduce health system treatment rates by 50% until 2030 **Reverse scenario 2** • Discontinue IRS activities in 2017 • Discontinue LLIN activities in 2017 **Reverse scenario 1** • Discontinue IRS activities in 2017	**Business as Usual** • Continue existing vector control interventions (IRS and LLIN distribution at 2014 coverage rates and maintain health system treatment rates until 2030	**Universal Coverage:** • 2% coverage of PAR for IRS • 13% coverage of PAR for LLINs • Increase in health system treatment rates to 80% by 2025 • Switching from quinine to injectable artesunate for treatment of severe malaria in 2017 **IRS:** • Universal Coverage • Double IRS coverage from 2017 in a linear fashion over 8 years **Effective Usage:** • Universal Coverage • Increase effectiveness of LLINs from 15% to 30% • Increase surveillance	**Single dose radical:** • Effective Usage • Replace Primaquine with a single dose drug such as Tafenoquine **New LLINs:** • Single dose radical cure • New LLINs with double life of existing nets **New Pf drug:** • New LLINs • Replace ACT with new candidate for *P. falciparum*. treatment

The models predicted reductions of malaria incidence required to reach malaria elimination on or before 2030 (based on a set of intervention coverage scenarios described in Table A2.1). Elimination was defined as the first year in which less than one reported clinical case is achieved. Note that the models do not distinguish between indigenous and imported cases. Hence, the definition of elimination is strict compared to zero indigenous cases. The scenario that allowed attainment of the elimination threshold using a minimum package of interventions was considered as the "elimination" scenario. The outputs of averted mortality and morbidity under the elimination scenarios were used to estimate the cost, benefits, and ROI.

The PAR values used to estimate costs in the model were adjusted to incorporate the decrease in incidence predicted due to elimination-focused interventions. Historical incidence and PAR data were analyzed statistically to infer a predicted change in PAR for a given change in incidence. This relationship was applied to the 2015 PAR data and updated every year until 2030 as interventions were applied in the modelled scenarios. This method has limitations including a non-standardized definition of PAR.

The 10 scenarios shown in Table A2.2 were modeled separately using three baselines:

- **Baseline 1**: a constant 5% probability of treatment failure to ACTs across all countries and separately for a baseline in which the probability of treatment failure to ACTs increased to 30% by 2025 across all countries.
- **Baseline 2**: no MDA and separately using five annual rounds of MDA at 50% coverage of PAR, from 2018, starting four months before the peak of the season.
- **Baseline 3**: maintaining LLIN coverage at 2015 levels and separately scaling up LLINs to 80% effective coverage deployed in a 3-year cycle (50%, 25% and 25%).

These additional baseline scenarios produced a total of 80 scenarios (with and without resistance; with and without MDA; and with and without LLIN scale up).

Table A2.2. Modeled scenarios

	Scenario	Description
1	Business as usual	Continue all interventions at 2014 levels until 2030
2	Reverse scenario 1	Business as usual Stop Indoor residual spraying activities
3	Reverse scenario 2	Reverse scenario 1 Stop the distribution of new LLINs
4	Reverse scenario 3	Reverse Scenario 2 Reduce treatment rates by 50%

	Scenario	Description
5	Universal coverage	Business as Usual (scenario 1) PLUS Switch from quinine to injectable artesunate for management of severe disease in 2017 Increase in health system treatment rates to 80% by 2025 IRS coverage of 2% of PAR LLIN coverage of 13% of PAR
6	Add IRS	Universal coverage (scenario 6) PLUS Double IRS coverage from 2017 in a linear fashion over 8 years
7	Effective usage	Universal coverage Increase % of effectiveness of LLINs from 15% to 30% (due to the implementation of hang-up campaigns and other interventions) Increase surveillance activities
8	New *P. vivax* treatment	Effective usage (scenario 7) PLUS Replace primaquine with a single dose treatment for *P. vivax* such as tafenoquine
9	New LLINs	New *P. vivax* treatment (scenario 8) PLUS Double the life of nets (new, longer lasting nets)
10	New *P. falciparum* treatment	New LLINs (scenario 9) PLUS Replace ACT with new candidate for treatment of *P. falciparum*

Cost estimation

We built a companion cost estimation model aligned with the outputs of the transmission model to estimate the costs associated with implementing each of the scenarios above. Program costs were modeled to include costs of testing and treatment of uncomplicated and severe malaria, LLINs, IRS, supply chains, service delivery (OP and IP), surveillance, community health workers, IEC, training, MDA, new treatments and a new radical cure for *P. vivax* (tafenoquine), and new LLINs. Costs for each of these inputs were obtained using a combination of empirical data collected in the country by the UCSF Global Health Group, literature reviews and proxies when neither of the previous options was available. The cost inputs for the model are provided in Table A1.4 in Annex 1. The minimum total cost of the elimination packages were costed under two scenarios:

- Interventions are applied to the entire PAR (low and high risk)
- Interventions are applied focally to a subset of the PAR

The total cost of the elimination scenario(s) of interest was used to construct the investment case.

Economic benefits estimation

We used outputs from the transmission models that estimated the mortality and morbidity averted and compared the elimination scenario(s) to the counterfactual baseline scenarios: a business as usual scenario in which interventions continued at the same coverage levels in 2015 and a reverse scenario in which LLINs, IRS were stopped and treatment coverage rates were reduced to 50%. The economic benefits estimation was developed using the full-income approach as recommended by the *Lancet Commission on Investing in Health*.[20]

The economic burden averted in the elimination scenario was categorized based on three broad dimensions: 1) cost to the health system, 2) cost to the individual households, and 3) cost to the society and estimated using the averted deaths and cases through elimination.

1. Cost averted to the health system: These were the costs averted for diagnosis and treatment costs as inpatients and outpatients,
2. Cost averted to the individual households: OOP expenditures for seeking care,
3. Cost averted to the society: Patients' lost productivity due to premature death and morbidity and reduced caretakers reduced economic output as a result of taking care of patients.

The same inputs used in the cost estimates were used for the economic benefits estimation. Unit costs of case management include outpatient visits, diagnostic tests and drug treatments for uncomplicated malaria cases; hospital hotel costs and drug treatments for severe malaria cases. OOP expenditures were estimated by applying the country-specific OOP expenditure per capita for each outpatient and inpatient. We calculated productivity loss among patients and caretakers by multiplying an estimate of daily productivity by the number of days lost due to illness or care seeking. The total income approach was used to determine the economic impact of lost productivity due to illness and death. This approach quantifies the value that people place on living longer and healthier lives. The value-of-statistical-life method was used to evaluate population-level reductions in mortality risk. Specifically, we assumed that the global value of a one-year increase in life expectancy was 2.2 times the GDP per capita for Indonesia, as recommended by the *Lancet Commission on Investing in Health*. This was applied to the numbers of life-years saved though elimination.

Economic benefits were calculated by adding together the cost averted to the health system to the cost averted to the individual households and cost averted to society.

Return on investment calculation

The ROI was calculated by obtaining the net economic benefit first by subtracting the incremental cost of elimination from the economic benefits obtained above. The net benefit was then divided by the incremental cost of elimination. We performed the ROI analysis for 2016-2030 for the elimination scenario with drug resistance compared with the counterfactual business as usual scenario.

All costs and economic benefits are presented in 2015 USD and future costs are discounted at 3% to the present.

Uncertainty analysis

A range of estimated incidence levels generated by MORU were used as inputs into the model. We performed a stochastic sensitivity analysis on the epidemiological and cost outputs of the transmission model. For the costs, we assigned an uncertainty interval of +/-25% on the value of the input costs used. Three hundred random samples were drawn, which generated a range of costs. From the range of costs generated, we determined the minimum, maximum, median, mean, and other measures (e.g., percentiles) and are shown in Figure A2.2.

For the ROI, the minimum, median, and maximum malaria cases and deaths predicted by the model for each scenario were used to calculate the minimum, median, and maximum economic benefits (Figure A2.3).

Figure A2.2 Uncertainty analysis on modeled elimination scenario costs

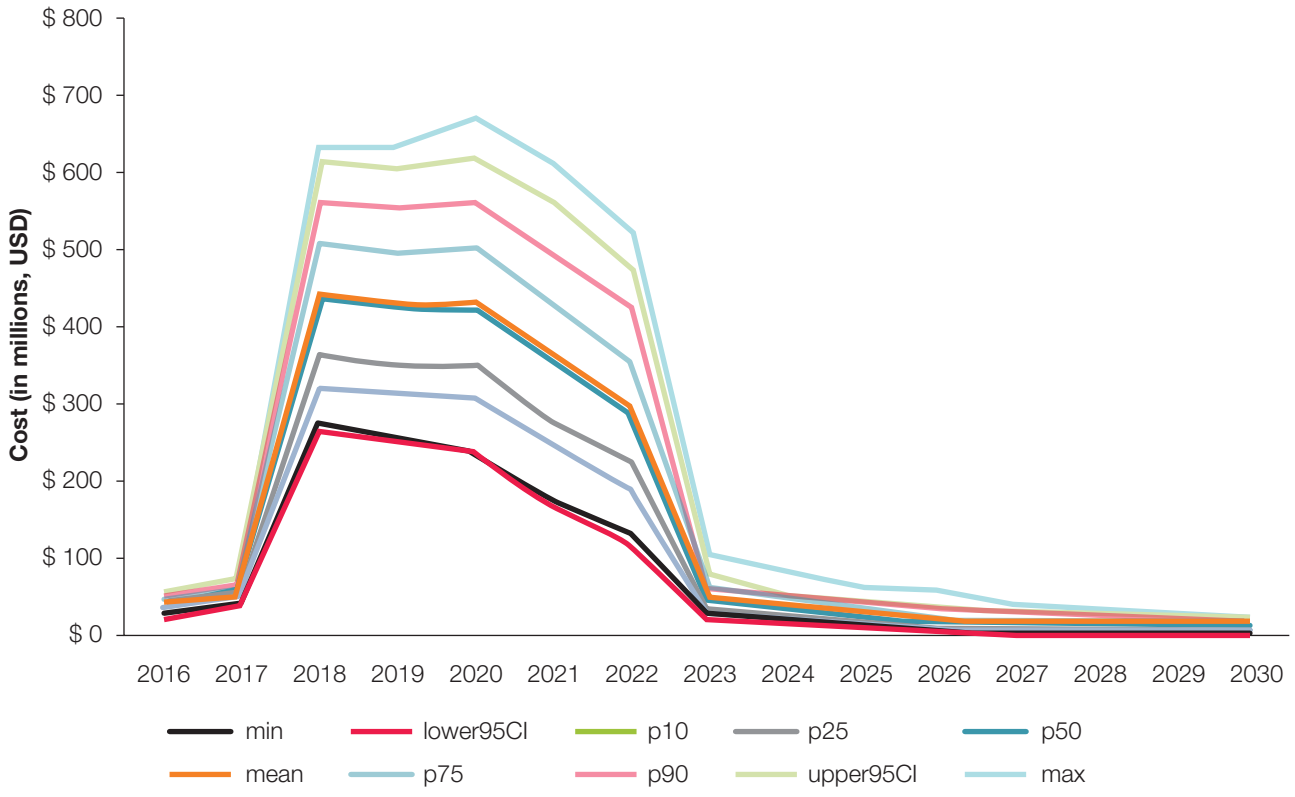
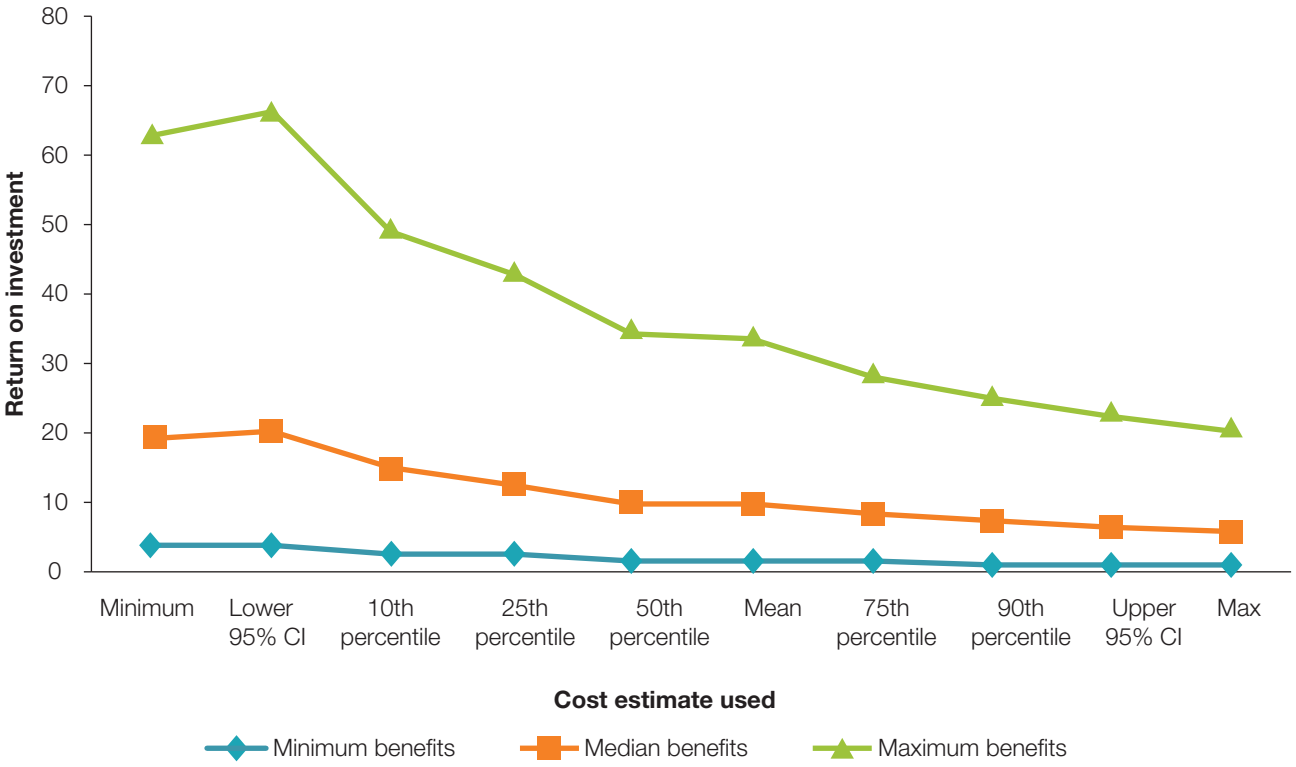


Figure A2.3 Uncertainty analysis on modeled ROI



Limitations

There is considerable uncertainty associated with the estimates. A range of possible incidence estimates was used as input to the model. The model itself was not designed to model individual countries in detail. We were unable to predict the impact that economic development and housing improvements may have on malaria transmission or how the costs of commodities or interventions may change at the global or national levels. Furthermore, the cost of new interventions such as new LLINs, treatments and tafenoquine are based on historical estimates of the cost of new tools when they were first adopted.

Annex 3. Additional findings for total financial cost

Figure A3.1 Distribution of total financial cost by input across sample districts

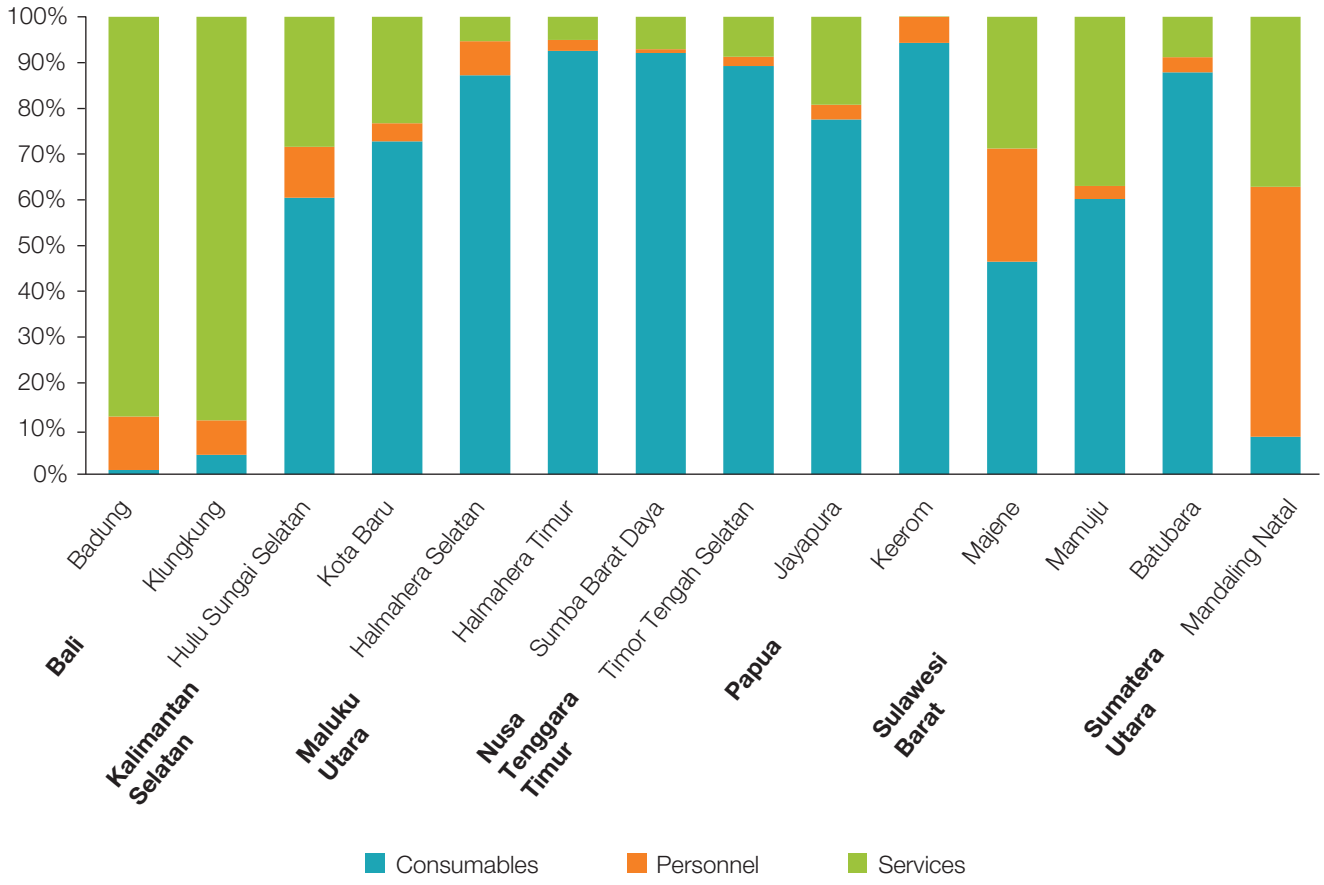
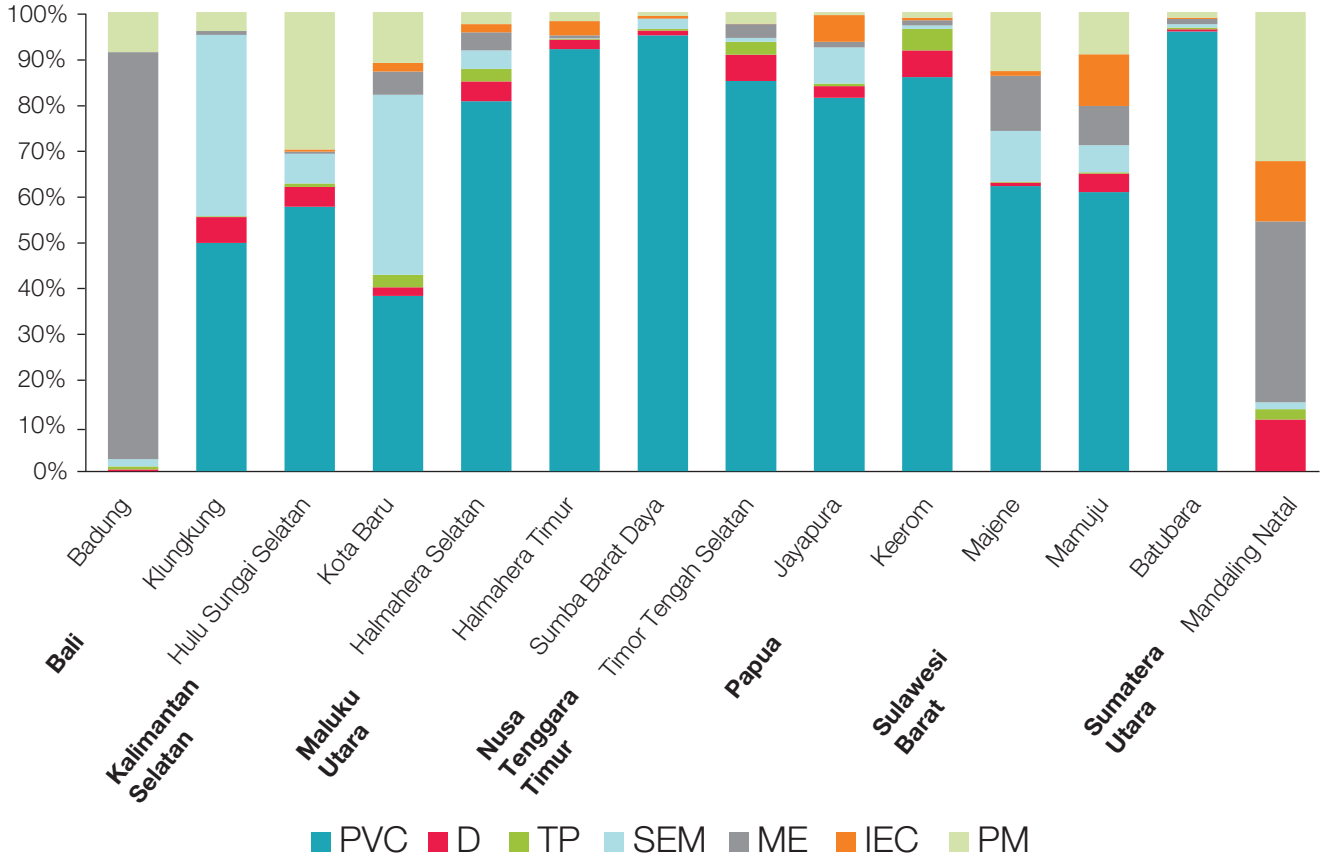


Figure A3.2 Distribution of total financial cost by activity across sample districts



PM: program management; SEM: surveillance and epidemic management; PVC: prevention and vector control; D: diagnosis; ME: monitoring and evaluation; TP: treatment and prophylaxis; IEC: information, education, and communication.

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