# IMPROVING EFFICIENCY OF THE HIV RESPONSE IN MALAWI

Findings from an Optima HIV modelling analysis

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Burnet Institute
Medical Research. Practical Action.

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optima DECISION SCIENCE

# Acknowledgements

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# I Abbreviations

| | |
|---|---|
| AGYW | Adolescent girls and young women |
| AIDS | Acquired immune deficiency syndrome |
| ART | Antiretroviral therapy |
| Clients | Clients of sex workers |
| FSW | Female sex workers |
| Global Fund | The Global Fund to Fight AIDS, Tuberculosis and Malaria |
| HIV | Human immunodeficiency virus |
| HTS | HIV testing services |
| MSM | Men who have sex with men |
| NSP | National Strategic Plan |
| PIT | Provider-initiated HIV testing |
| PLHIV | People living with HIV |
| PMTCT | Prevention of mother-to-child transmission |
| PrEP | Pre-exposure prophylaxis |
| SBCC | Social and behavioral change communication |
| VMMC | Voluntary medical male circumcision |

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# V Executive summary

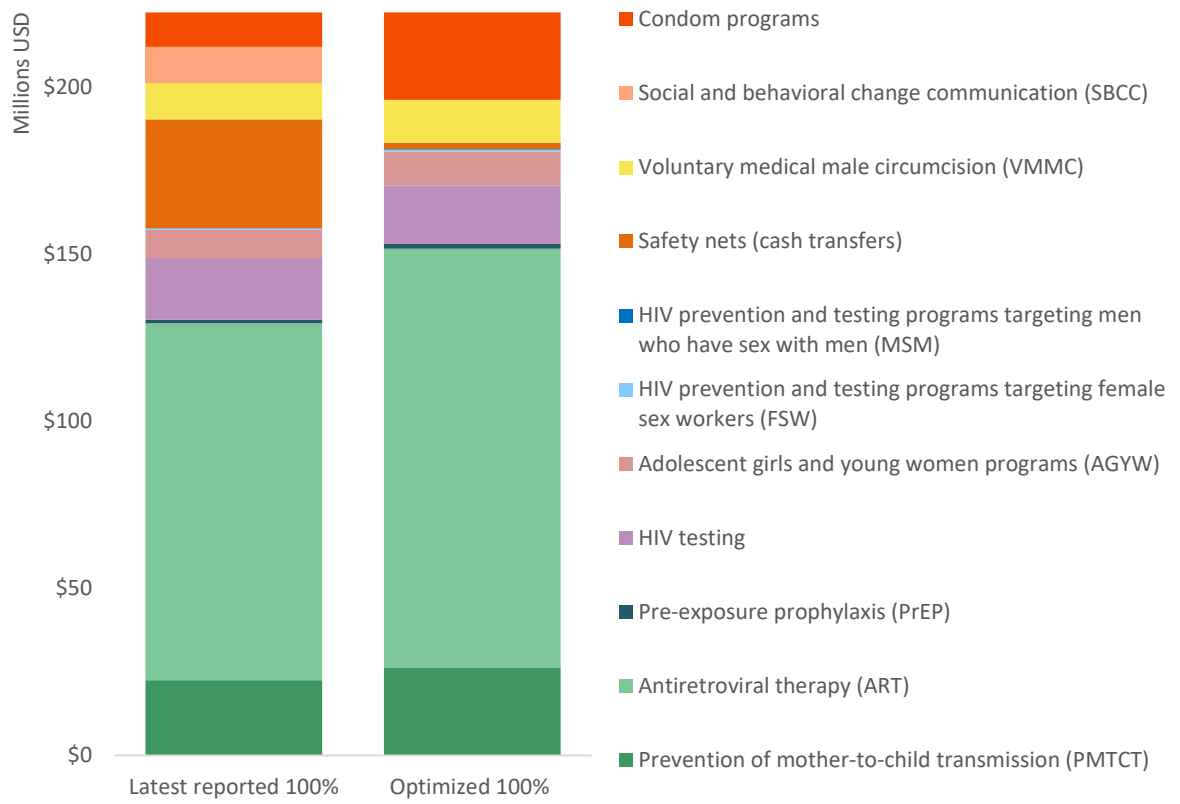
Malawi is a low-income country making significant strides in preventing new HIV infections and HIV-related deaths. Despite these efforts, it is estimated that there were 1 million people living with HIV in Malawi in 2019, with HIV remaining the leading cause of death in the country. However, sustainability of funding for the HIV response is under threat, with donor contributions declining worldwide. Since more than 97% of the HIV program in Malawi is funded through donor financing, it is essential that funds be allocated most efficiently, where they can make the greatest impact.

This report outlines findings from an HIV modeling analysis conducted for Malawi by the country team, the Global Fund to Fight AIDS, Tuberculosis and Malaria, the Clinton Health Access Initiative (CHAI), and the Optima Consortium for Decision Science. For this analysis, the Optima HIV model was applied to estimate the optimized resource allocation to improve the response to the HIV epidemic in Malawi. The aim of this analysis is to inform the 2020-2025 National Strategic Program (NSP) and the 2020 Global Fund funding request. The primary focus of Malawi's 2020-2025 NSP is to end the HIV epidemic in the country by 2030. Recommendations from a previous Optima HIV modeling analysis conducted for Malawi in 2017 included scale-up of treatment and HIV testing for the general population, including a district-level analysis recommending allocation of funding to 'hotspots' to increase impact.

# VI Key recommendations

To minimize new HIV infections and HIV-related deaths over the 2020-2025 NSP period, recommendations from this analysis suggest prioritizing scale-up of:

1. antiretroviral therapy (ART),
2. condom programs,
3. prevention of mother-to-child prevention (PMTCT),
4. voluntary medical male circumcision (VMMC),
5. HIV prevention programs targeting adolescent girls and young women (AGYW),
6. pre-exposure prophylaxis (PrEP),
7. HIV prevention and testing programs targeting female sex workers (FSW), and
8. HIV prevention and testing programs targeting men who have sex with men (MSM).




If HIV resources are optimized at the **national level** from 2020 to 2025, then approximately 37,000 more new HIV infections could be averted (over 20% more) and 2,000 more HIV-related deaths could be averted (approximately 5% more) by 2025. Should additional HIV budget become available, it is recommended to proportionally scale-up in priority order antiretroviral therapy (ART), condom programs, prevention of mother-to-child prevention (PMTCT), voluntary medical male circumcision (VMMC), HIV prevention programs targeting adolescent girls and young women (AGYW), pre-exposure prophylaxis (PrEP), HIV prevention and testing programs targeting female sex workers (FSW), HIV prevention and testing programs targeting men who have sex with men (MSM).

At budget levels above 150%, it is recommended to scale-up condom programs ahead of HTS. With a doubling of budget under optimized allocation it is not projected that there will be a doubling in reduction of infections and deaths. A diminishing return on investment at very high budget increase is not surprising, as it will cost more to deliver services to harder to reach populations.

To optimize HIV resources **across districts,** including 28 districts and 4 cities, it is suggested to invest 40% of the national budget to five districts with the highest HIV burden Blantyre City, Lilongwe City, Mulanje, Mangochi, and Zomba. For these districts it is recommended to scale-up investment by ordered priority for ART, VMMC, PMTCT, condoms, HTS, FSW programs, and PrEP. In districts with higher prevalence of HIV, reallocating funds towards VMMC and condom programs is recommended. It was modeled that considering geographical profile for prioritization of funding could result in even more new HIV infections and HIV-related deaths being averted by 2025, 45,000 (over 25% more or 8,000 more than national-level optimization) and 3,300 (almost 10% more or over 1,000 more than national-level optimization) more, respectively.

# 1. Economic development and health financing in Malawi

Malawi is a land-locked country in Southern Africa, bordered by Mozambique, Tanzania, and Zambia. As a low-income country, Malawi relies heavily on its agricultural sector, leaving it vulnerable to weather circumstances. As such, high rates of poverty persist. In 2016, 52% of the population lived below the poverty line, although extreme poverty declined from 25% in 2010 to 20% in 2016 [1]. Investment in health has increased over the last decade, with the Government of Malawi financing over 50% of the health budget in most recent years [2]. However, almost the entire HIV program in 2017, 97%, was financed through donor funding [2]. Since it is expected that donors will reduce their contributions in the coming years [3], it is essential that available HIV funds be allocated in the most impactful way.

## 1.1 HIV epidemic in Malawi – past, present, and future

Malawi has a generalized HIV epidemic, accompanied by high HIV prevalence among key populations including female sex workers (FSW) and their clients, and among men who have sex with men (MSM). Tremendous progress has been made in reducing new HIV infections and HIV-related deaths from levels in the mid-2000's onwards; however, in 2019 it was estimated that one million people were living with HIV, with an estimated 30,000 new HIV infections having occurred in the same year. In 2017, HIV remained the leading cause of death in Malawi [4]. New HIV infections and HIV-related deaths have steadily declined since 2004 (figure 1), corresponding to a dramatic scale-up of HIV treatment since then (appendix 1).

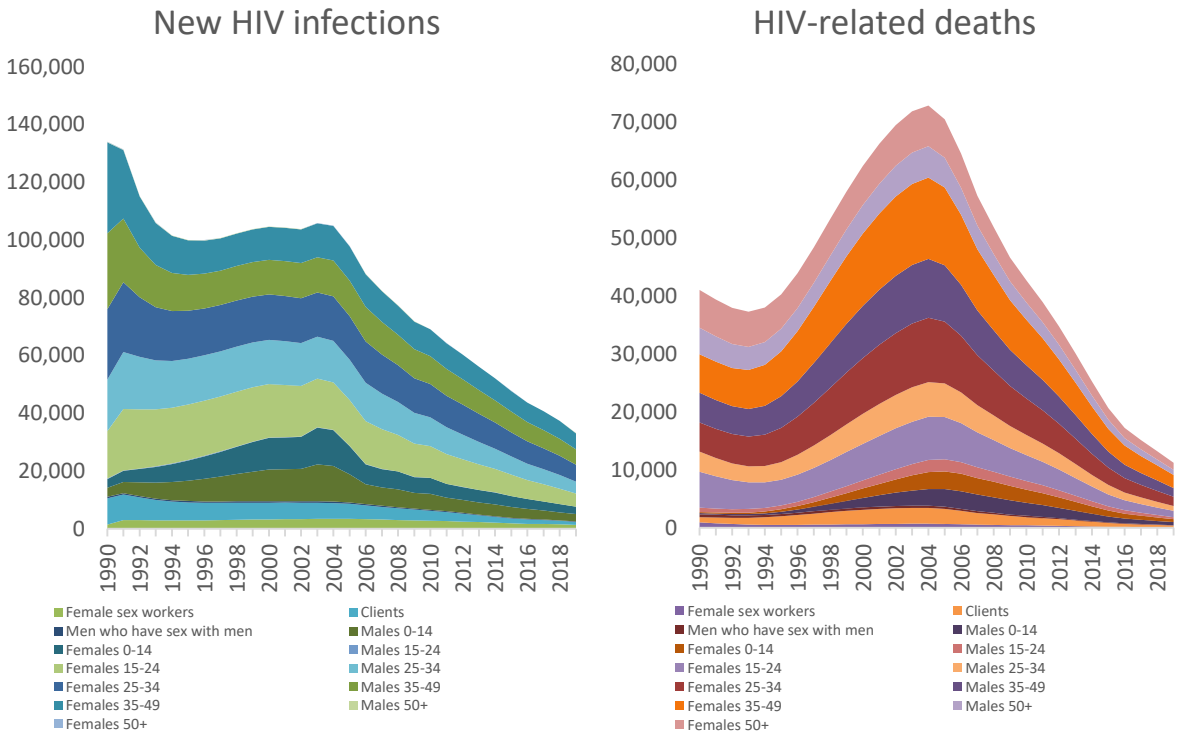



Figure 1: Estimated new HIV infections and HIV-related deaths, 1990 to 2019 Source: Optima HIV model, 2020

It was estimated that almost 60% of new HIV infections and HIV-related deaths occurred in females in 2019 (figure 2).

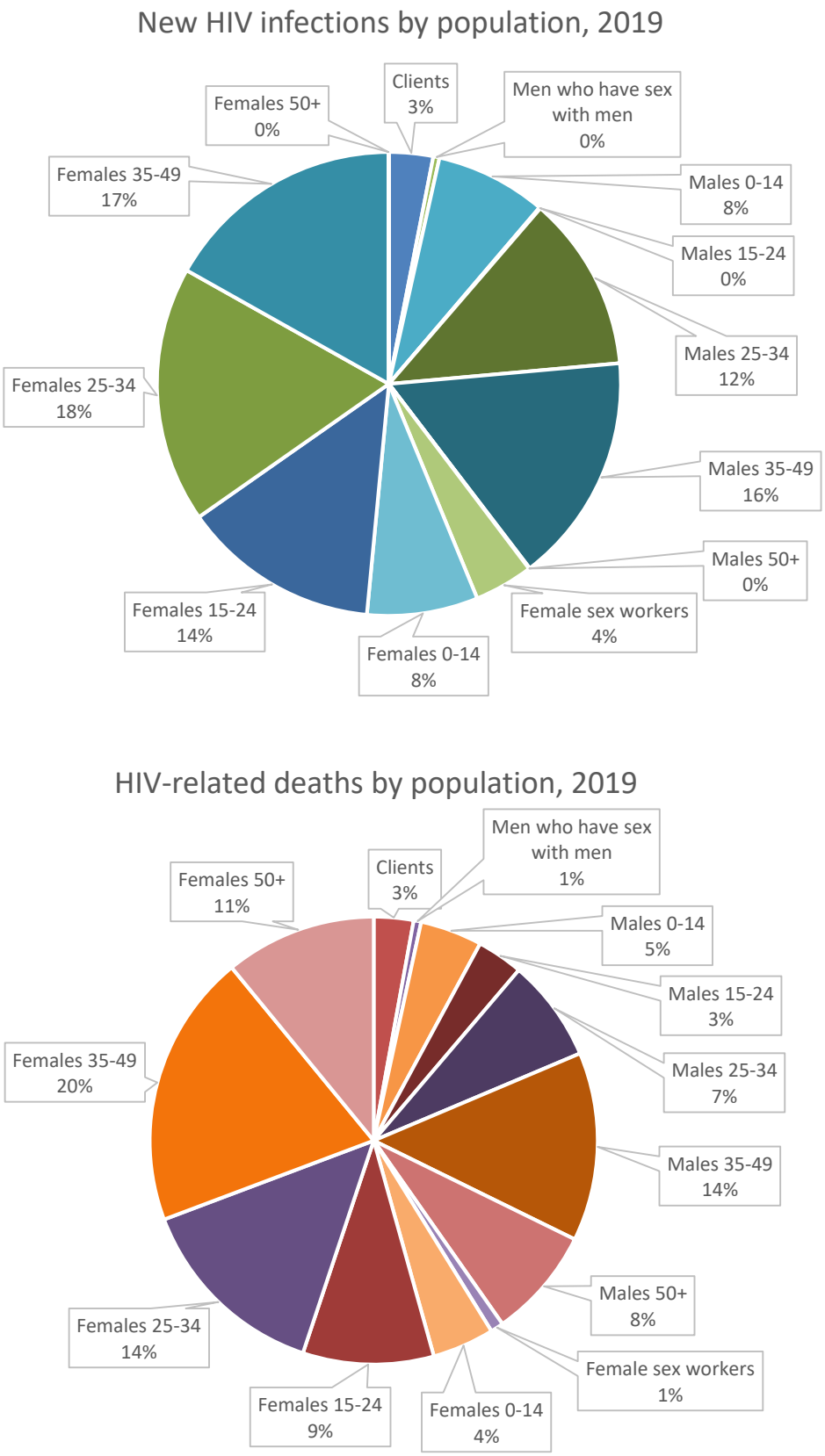



Figure 2: Estimated new HIV infections and HIV-related deaths by population group, 2019
Source: Optima HIV model, 2020

# 2. Methodology

This analysis was conducted using Optima HIV, an epidemiological model of HIV transmission overlayed with economic and programmatic data that applies a resource optimization algorithm. Optima HIV uses HIV epidemic modelling structure and incorporates parameter values for biological transmission probabilities, CD4 progression, as well as HIV prevalence estimates, sexual behavioral values, and sexual mixing patterns. HIV program cost and coverage data and efficacy estimates are used to develop cost functions, which represent the relationship between cost and coverage and coverage and outcome for each program. Within the model, an optimization algorithm is applied to estimate the optimized distribution of investment across a combination of HIV programs. Constraints were applied within the optimizations to ensure those on treatment remained on treatment unless lost by natural attrition. As such, in the optimized allocation, budgets for antiretroviral therapy (ART) and prevention of mother-to-child transmission (PMTCT) could not be reduced to ensure at least the same number of people were maintained on treatment. Last, for the objective function, the model algorithm aimed to estimate a theoretical optimal distribution of resources and emphasis of different HIV programmatic responses which minimizes both new HIV infections and HIV-related deaths by the target time horizon (2025 or 2035) given the local epidemic parameters and data, cost of delivering services, subject to the constraints as defined. Appendices 1 through 3 show model calibration and cost coverage curves, key model parameters, and unit costs used in this study.

## 2.1 Objectives

This analysis is an update to an Optima HIV analysis completed in 2017 for Malawi. Similar objectives to the original analysis were modeled here with findings to be used to inform the 2020-2025 National Strategic Plan.

Objective 1. To estimate the optimized annual HIV resource allocation to minimize new HIV infections and HIV-related deaths from 2020 to 2025.

Objective 2. To estimate the optimized annual HIV resource allocation to minimize new HIV infections and HIV-related deaths from 2020 to 2025 and from 2020 to 2035 under varying budget levels. Using the HIV testing budget from the original optimization for 2020 to 2025, determine how funding should be optimized across HIV testing modalities over this period.

Objective 3. To estimate the budget necessary to achieve 2020-2025 NSP targets

Objective 4. To estimate the optimized annual HIV resource allocation across the 32 districts

## 2.2 Populations modeled

The following key populations were included in this analysis, with general populations including: females aged 0-14 years, males 0-14 years, females 15-24 years, males 15-24 years, females 25-34, males 25-34 years, females 35-49, males 35-49, females 50 years and older (females 50+), and males 50 years and older (males 50+) years, and key populations including female sex workers (FSW), clients of female sex workers, and men who have sex with men (MSM).

## 2.3 HIV programs modeled

HIV programs included in this modeling analysis are as follows: antiretroviral therapy (ART), condom programs, HIV prevention and testing programs targeting adolescent girls and young women (AGYW), HIV prevention and testing program targeting female sex workers (FSW), HIV prevention and testing programs targeting men who have sex with men (MSM), HIV testing for the general population, pre-exposure prophylaxis (PrEP) for MSM and FSW, prevention of mother-to-child transmission (PMTCT), safety nets (cash transfers), social and behavior change communication (SBCC), and voluntary medical male circumcision (VMMC). Programs not included in this analysis due to uncertainly or missingness in data and/or program efficacy values were as follows: active defaulter tracing, CD4 count tests, routine adherence support, serum Cryptococcal antigen test, urine lipoarabinomannan (LAM) screening for HIV-TB detection, and viral load monitoring (including genotyping).

Six HIV testing service delivery modalities were modeled including: client-initiated testing, index testing, mobile testing, provider-initiated testing (PIT), recency testing, and self-testing. Outcome functions for each modality were scored according to unit cost and yield. Since mobile and self-testing are conducted outside of fixed health facilities, they were scored lower due to an expected reduced rate for linkage to care, compared with other modalities. The score for mobile testing was reduced by 70% to reflect a 30% linkage to care rate, and by 40% to reflect a 60% linkage to care rate for self-testing.

# 3. Results

**Objective 1:** To estimate the optimized annual HIV resource allocation to minimize new HIV infections and HIV-related deaths from 2020 to 2025.

The US$222M national HIV budget for Malawi was optimized over the 2020 to 2025 National Strategic Plan period to minimize new HIV infections and HIV-related deaths by 2025. Findings from this analysis suggest prioritizing scale up of ART, condom programs, prevention of mother-to-child prevention (PMTCT), voluntary medical male circumcision (VMMC), HIV prevention targeting adolescent girls and young women (AGYW), pre-exposure prophylaxis (PrEP), and HIV prevention and testing programs targeting female sex workers (FSW) (figure 3, table 1). Since there is often a paucity of and/or uncertainly in behavioural data, the full impact of social and behavior change communication programs may not be captured in this analysis. As well, the multi-sector benefit of safety nets (cash transfers) was outside the scope of this analysis, which can at least partly explain why these programs were not identified for prioritization over this period.

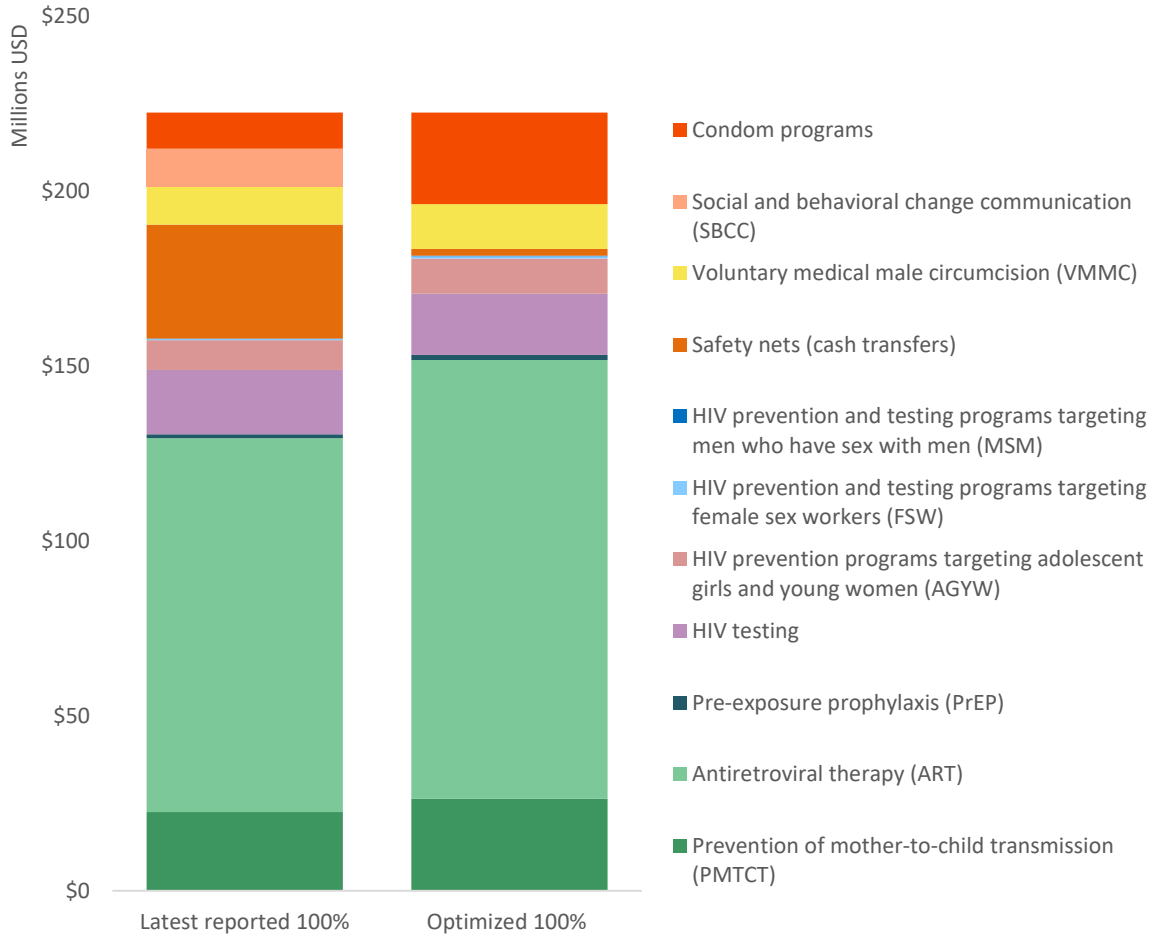



Figure 3: Annual optimized HIV resource allocation for 2020 to 2025

With the same amount of budget, optimized reallocation could result in an additional 37,000 new HIV infections being averted (over 20% more) and 2,000 HIV-related deaths (approximate 5% more) by 2025 (figure 3). Estimates of HIV program spending and coverage under optimized budget are shown alongside those from the latest reported allocation in table 1.

Table 1: Optimized annual HIV budget for 2020 to 2025

| HIV program | 100% latest reported budget (USD) | 100% optimized budget (USD) | 100% latest reported coverage | 100% optimized coverage |
|---|---|---|---|---|
| Condom programs | $10,300,000 | $26,000,000 | 8,400,000 | 11,900,000 |
| Social and behavior change communication (SBCC) | $10,800,000 | Not prioritized | 7,700,000 | Not prioritized |
| Voluntary medical male circumcision (VMMC) | $10,800,000 | $12,800,000 | 90,000 | 110,000 |
| Safety nets (cash transfers) | $32,600,000 | $2,000,000 | 290,000 | 17,500 |
| Men who have sex with men (MSM) programs | $140,000 | $150,000 | 1,600 | 1,700 |
| Female sex worker (FSW) programs | $290,000 | $650,000 | 3,300 | 7,200 |
| Adolescent girls and young women programs (AGYW) | $8,500,000 | $10,000,000 | 90,000 | 110,000 |
| HIV testing | $18,400,000 | $17,500,000 | 2,900,000 | 3,700,000 |
| Pre-exposure prophylaxis (PrEP) for FSW and MSM | $1,000,000 | $1,500,000 | 8,200 | 11,000 |
| Antiretroviral therapy (ART) | $107,000,000 | $125,000,000 | 860,000 | 1,000,000 |
| Prevention of mother-to-child transmission (PMTCT) | $22,500,000 | $26,300,000 | 116,000 | 136,000 |
| **Total** | **$222,300,000** | **$222,300,000** | Not applicable | Not applicable |

**Objective 2:** To estimate the optimized annual HIV resource allocation to minimize new HIV infections and HIV-related deaths from 2020 to 2025 and from 2020 to 2035 under varying budget levels. Using the HIV testing budget from the original optimization for 2020 to 2025, determine how funding should be optimized across HIV testing modalities over this period.

At reduced budget levels, condom programs, ART, and PMTCT should be retained as priority programs (figure 4). Should additional funds become available above the latest reported budget level, it is recommended to scale-up ART, PMTCT, condom programs, HIV testing services (prioritize ahead of condom programs above 150% optimized budget), VMMC, AGYW programs, PrEP, and FSW programs.

The impact of varying budget allocations is illustrated in figure 5. At 100% budget, new HIV infections and HIV-related deaths could be markedly reduced by cost-effectively reinvesting resources; however, as budget levels continue to increase over 200%, the potential reduction of new HIV infections and HIV-related deaths decreases, with smaller gains anticipated.

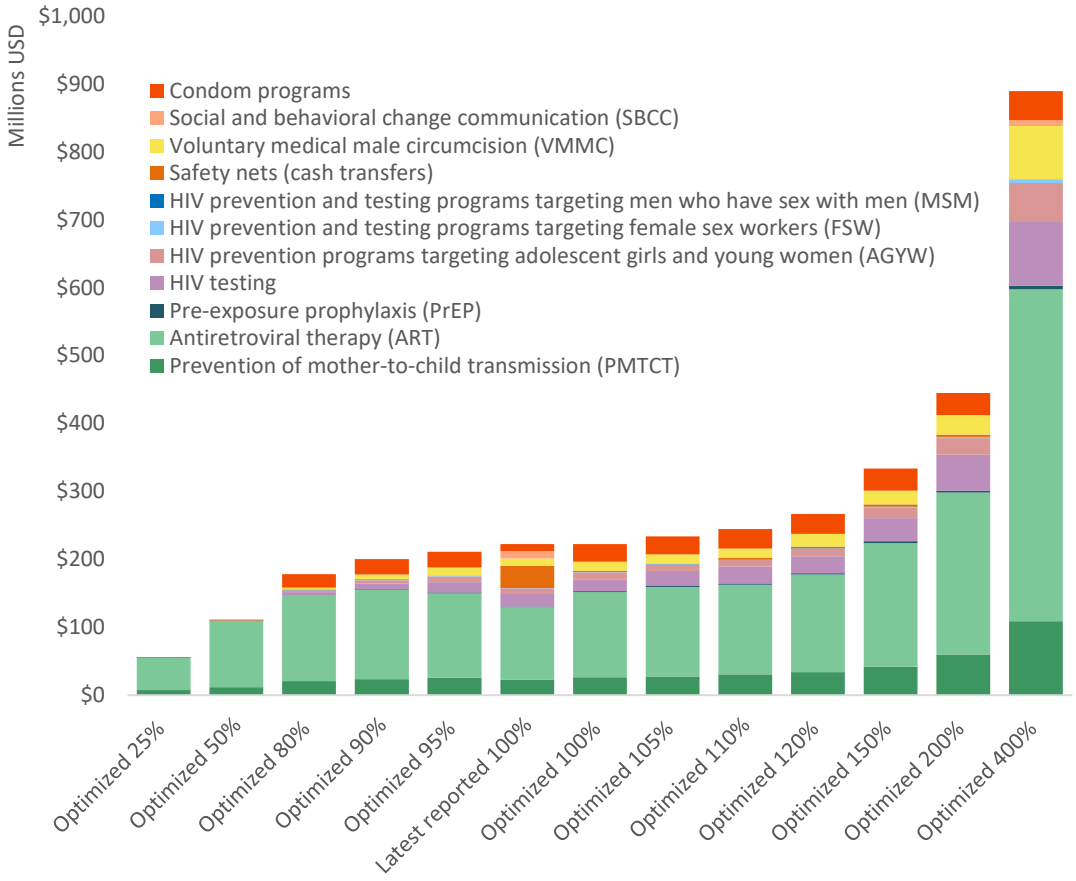
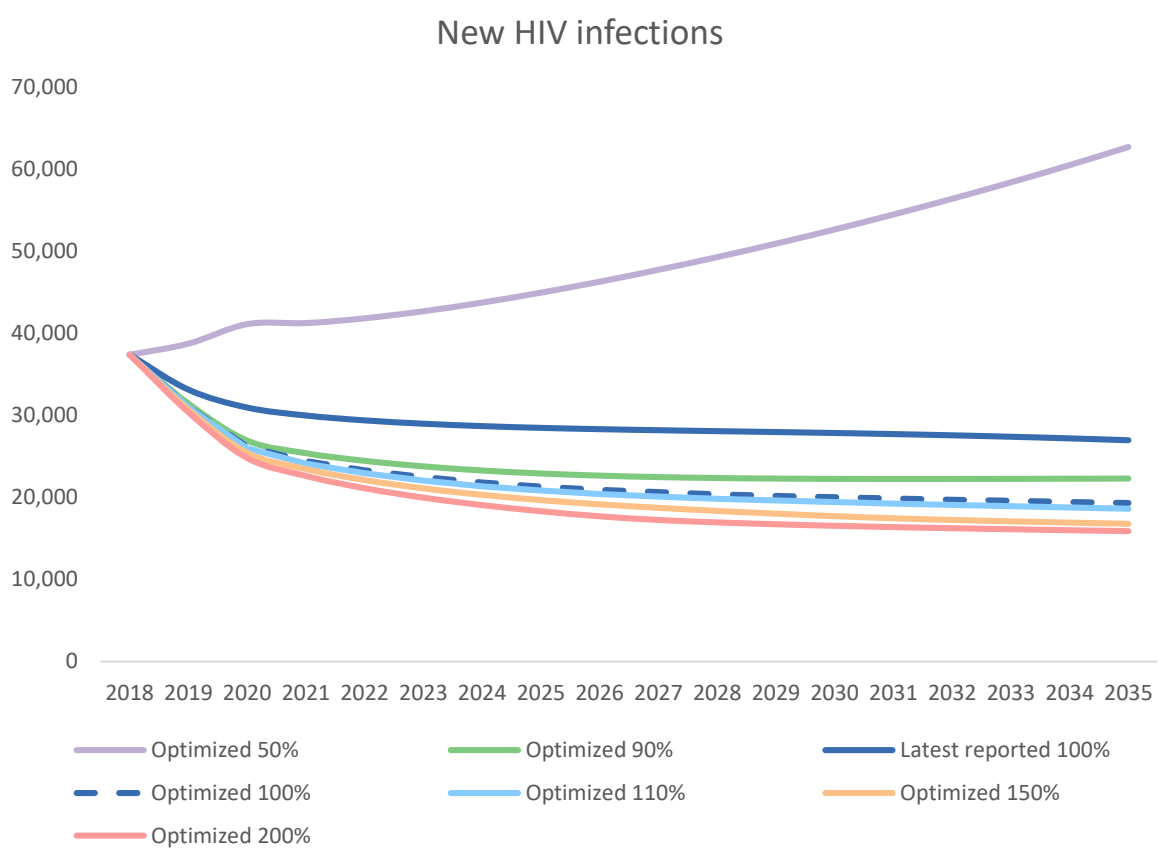



Figure 4: Annual HIV budget optimization for varying budget levels, 2020 to 2025



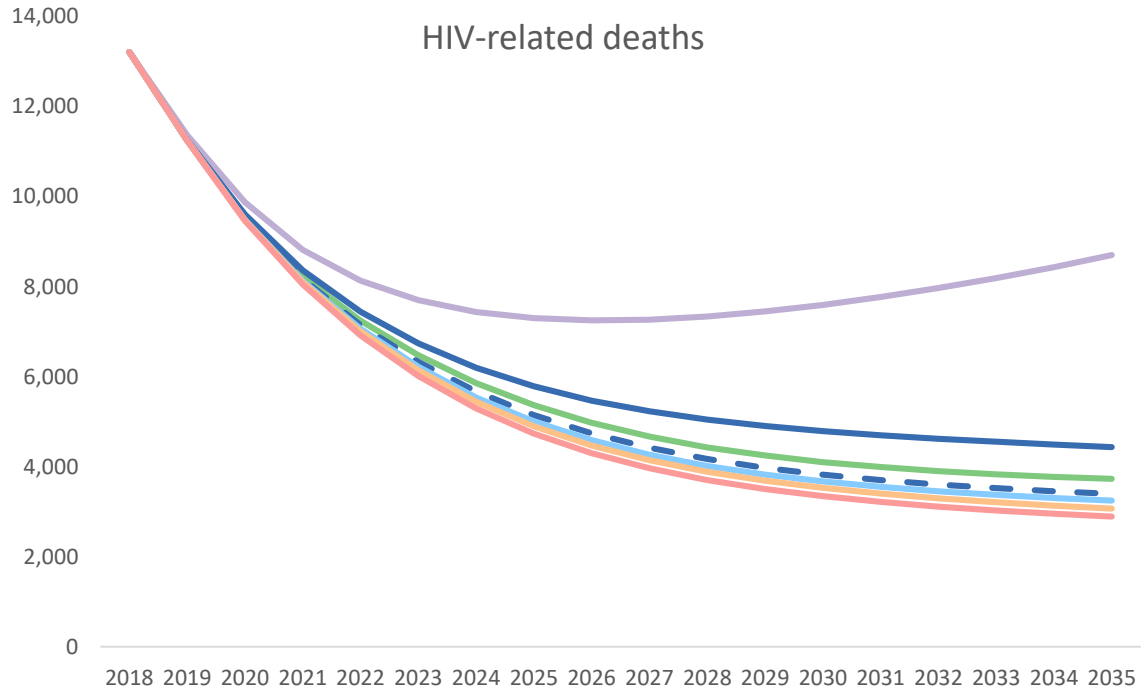




Figure 5: Impact of optimization for varying HIV budget levels from 2020 to 2025 on new HIV infections and HIV-related deaths projected to 2035

Figure 6 and table 2 illustrate allocation of the HIV testing budget from the original optimization across six HIV testing service delivery modalities. The total invested in the six HIV testing modalities was

US$18.4M within the latest reported budget. With optimization of this total HIV program budget for Malawi, the HIV testing program was allocated slightly less, at US$17.5M, to allow for treatment and other prevention programs to be prioritized at this budget level. Recommendations to optimize allocation of this $17.5M across the six HIV testing modalities, include prioritizing index testing, provider-initiated testing, and client-initiated testing (figure 6 and table 2). This is based on unit cost, yield (excluding for recency testing), and assumed linkage to care by testing modality (Appendix 3). If the national budget were to be increased and the resulting optimized allocation for overall HIV testing to be cost-effectively distributed across testing modalities, index testing would still be prioritized, but depending on the budget level, self-testing, client-initiated testing, and provider-initiated testing are recommended to be scaled-up in different priority order.

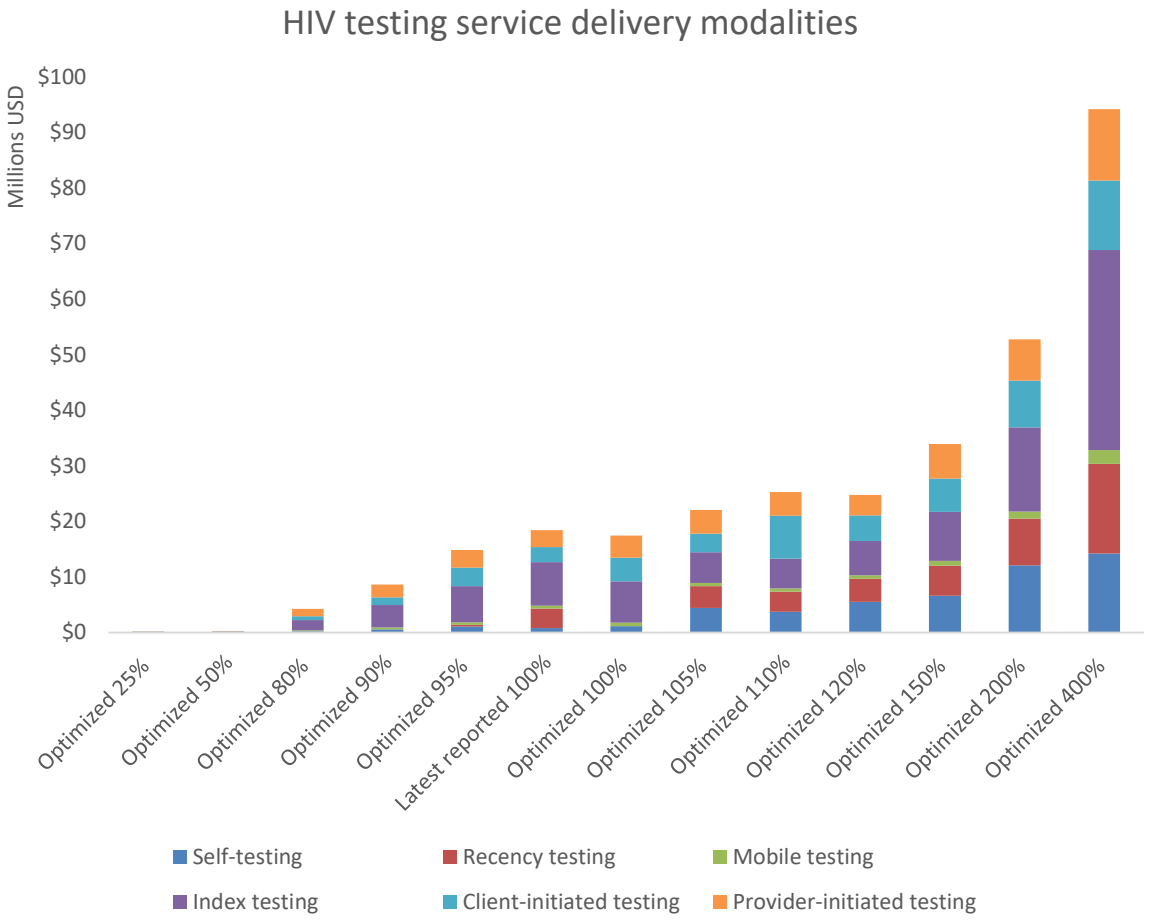



Figure 6: Optimization of HIV testing budget from optimized overall budget at varying budget levels across the HIV testing modalities from 2020 to 2025

Table 2: Testing modality percentage of total HIV testing budget

| HIV testing modality | Optimized 50% | Optimized 80% | Optimized 90% | Optimized 95% | Latest reported 100% | Optimized 100% | Optimized 105% | Optimized 110% | Optimized 120% | Optimized 150% | Optimized 200% | Optimized 400% |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Self-testing | 2% | 5% | 6% | 7% | 4% | 6% | 20% | 15% | 22% | 20% | 23% | 15% |
| Recency testing | 16% | 0% | 0% | 2% | 19% | 0% | 18% | 15% | 17% | 16% | 16% | 17% |
| Mobile testing | 4% | 3% | 4% | 3% | 3% | 4% | 3% | 2% | 3% | 2% | 2% | 3% |
| Index testing | 45% | 44% | 47% | 44% | 42% | 43% | 25% | 21% | 25% | 26% | 29% | 38% |
| Client-initiated testing | 12% | 17% | 16% | 23% | 15% | 24% | 15% | 31% | 19% | 18% | 16% | 13% |
| Provider-initiated testing | 20% | 31% | 27% | 21% | 17% | 23% | 19% | 17% | 15% | 18% | 14% | 14% |
| **Total HIV testing budget** | **$243,719** | **$4,215,627** | **$8,607,238** | **$14,834,914** | **$18,441,136** | **$17,464,499** | **$22,024,987** | **$25,259,381** | **$24,766,261** | **$33,924,570** | **$52,745,488** | **$94,224,538** |

**Objective 3:** To estimate the budget necessary to achieve 2020-2025 NSP targets

For the 2020-2025 National Strategic Plan (NSP) period, annual coverage targets for 2021 to 2025 for condom programs, VMMC, FSW programs, MSM programs, HIV testing, HIV prevention programs for AGYW, PrEP for FSW and MSM, and ART were used (table 3) to estimate the additional budget and allocation to achieve these targets. For 2020, coverage levels from the latest reported budget were used. The NSP target for PrEP included coverage of AGYW; however, PrEP was not specified as targeting AGYW in the model, therefore only budget requirements to reach FSW and MSM PrEP coverage targets were included. NSP targets for AGYW included covering a certain number of high-risk adolescent girls and young women aged 15-24 years (defined as the portion of AGYW with HIV prevalence greater than or equal to 3%), as well as a certain number of AGWY at low-risk (those having a prevalence of HIV below 3%). Since the AGYW population was not originally specified in the Optima model by risk or HIV prevalence level, the total targeted coverage for this group was used. Since no targets are set in the 2020-2025 NSP for social behaviour change communication (SBCC), safety nets (cash transfers), and prevention of mother-to-child transmission (PMTCT), optimized coverage levels and allocation generated from objective 1 of this study were applied for these three programs from 2021 to 2025.

Table 3: 2020-2025 NSP coverage targets for 2021 to 2025

| | Latest reported coverage | NSP coverage targets | | | | |
|---|---|---|---|---|---|---|
| HIV program | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 |
| Condom programs (people covered) | 10,066,140 | 10,183,153 | 10,483,160 | 10,792,264 | 10,798,539 | 11,117,670 |
| VMMC | 90,141 | 150,000 | 200,000 | 190,000 | 180,000 | 180,000 |
| HIV prevention and testing for FSW | 3,272 | 23,467 | 27,268 | 31,686 | 36,819 | 42,783 |
| HIV prevention and testing for MSM | 1,566 | 5,248 | 5,835 | 6,489 | 7,216 | 8,024 |
| HIV prevention for AGYW* | 89,855 | 122,400 | 153,700 | 170,040 | 189,280 | 208,800 |
| HIV testing (people tested) | 2,964,986 | 5,518,749 | 5,995,362 | 6,462,406 | 6,919,100 | 7,364,618 |
| PrEP for FSW and MSM | 8,267 | 2,000 | 2,600 | 3,914 | 3,914 | 3,914 |
| ART | 862,582 | 941,578 | 967,770 | 987,979 | 1,003,174 | 1,015,291 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **No targets are set in the NSP for the following programs, optimized coverage levels were applied from 2021 to 2025** | | | | | | |
| SBCC | 8,707,527 | 0 | 0 | 0 | 0 | 0 |
| Safety nets (cash transfers) | 289,749 | 17,000 | 17,000 | 17,000 | 17,000 | 17,000 |
| PMTCT | 116,209 | 136,000 | 136,000 | 136,000 | 136,000 | 136,000 |

*Sum of coverage targets for high-risk adolescent and young women (AGYW) (HIV prevalence ≥3%) and lower-risk AGYW (HIV prevalence <3%)

Figure 7 illustrates the estimated annual budget requirements for 2021 to 2025. In 2021 the budget is increased by approximately $2M and increased each year until 2025 to achieve increasing coverage targets. Increasing or decreasing coverage levels, and thus budgets, for SBCC, safety nets, and PMTCT, for which no targets were set so optimized budgets were applied, would have an impact on the infections and deaths that could be averted.

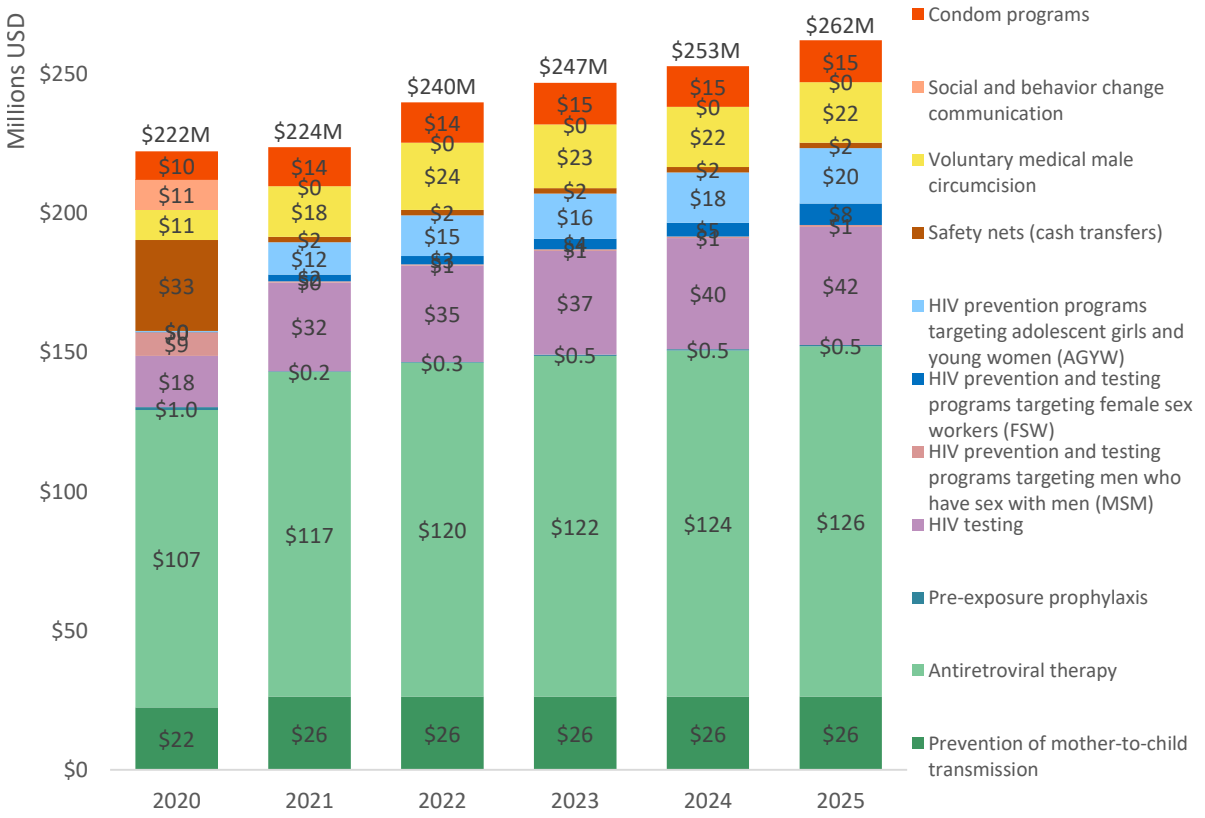



Figure 7: Annual budget levels and allocations to achieve 2020-2025 NSP coverage targets for 2021 to 2025, with the latest reported budget allocation applied for 2020, and the optimized budget for SBCC, safety nets, and PMTCT applied for 2021 to 2025 as no targets are set for these three programs

The potential impact of these reallocations with increased annual budgets to achieve 2020-2025 NSP coverage targets for 2021 to 2025 is illustrated in figure 8. With an additional US$114M over the latest reported budget to achieve 2021-2025 NSP coverage targets, over 21,000 more new HIV infections (approximately 15% more) and approximately 1,600 HIV-related deaths (approximately 5% more) could be averted by 2025.

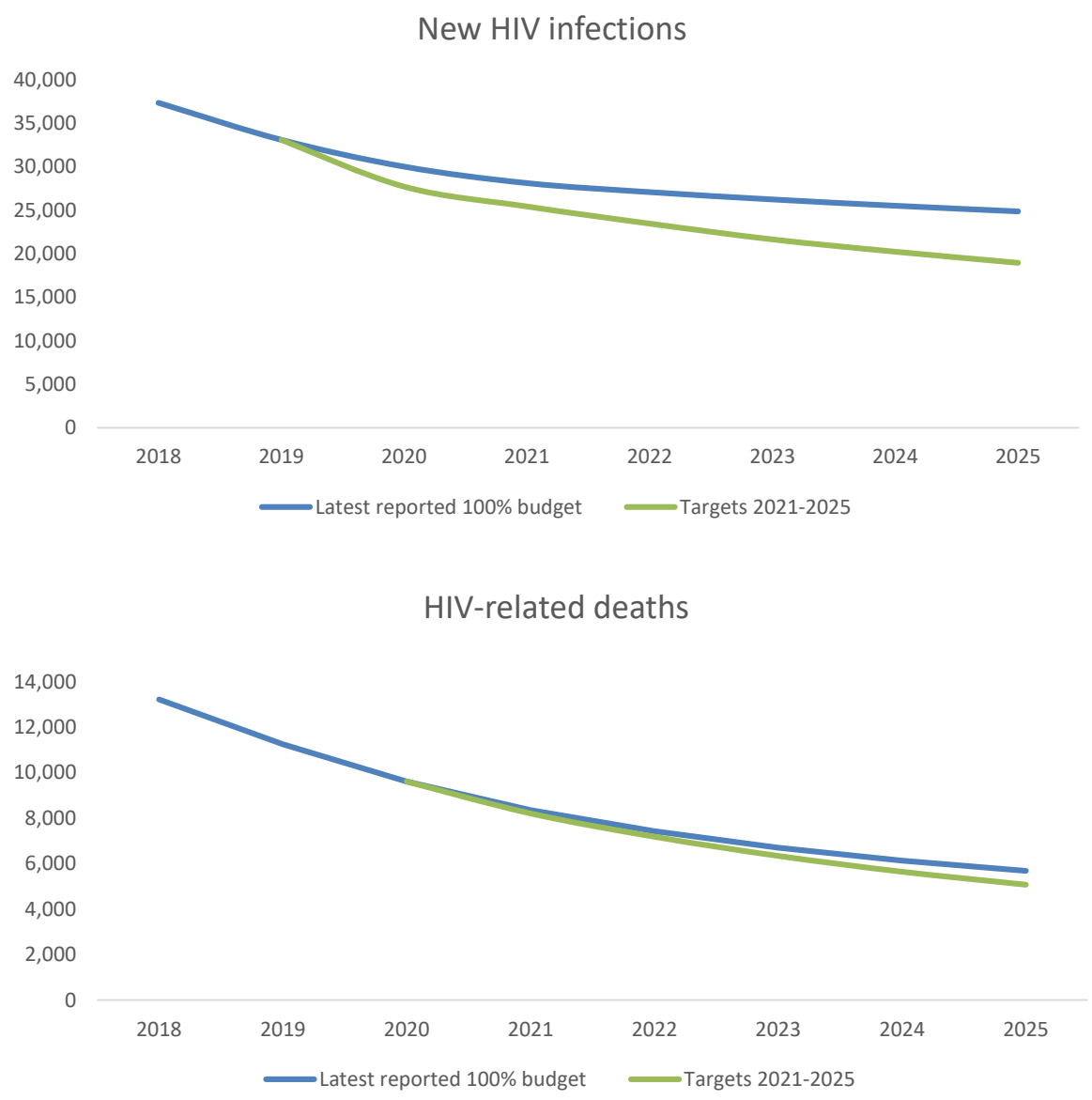



Figure 8: Estimated impact of achieving 2021-2025 NSP coverage targets through to 2025

**Objective 4:** To estimate the optimized annual HIV resource allocation across the 32 districts

For this objective, the HIV budget was optimally redistributed across the 32 districts (28 districts and 4 cities) to minimized new HIV infections and HIV-related deaths by 2025.

### HIV prevalence by district

Across the 28 districts and 4 cities in Malawi, 2019 HIV prevalence estimates for all age groups varied from 1.7% in Ntchisi to 12% in Blantyre City. It was estimated that there were less than 1,000 people living with HIV (PLHIV) in Likoma district in 2019, while for Blantyre City it was almost 100,000. Estimates of HIV prevalence and PLHIV by district and city for 2019 are listed in appendix 4.

Figure 9 shows the ranked order of districts for redistributed HIV funds and the annual optimization of those funds from 2020 to 2025. The top five districts by amount of funding to be redistributed, are Mangochi, Lilongwe City, Blantyre City, Zomba, and Mulanje. For these districts it is recommended to scale-up investment by ordered priority in treatment, VMMC, condom programs, and HIV testing,

prevention programs targeting female sex workers, and PrEP. In districts with higher prevalence of HIV, reallocating funds towards VMMC and condom programs is recommended. Geographical optimal allocation of funds could result in an additional 45,000 new HIV infections and 3,300 HIV-related deaths averted, therefore increasing the potential impact compared to the national optimization. Appendix 5 lists estimated spending and coverage by district.

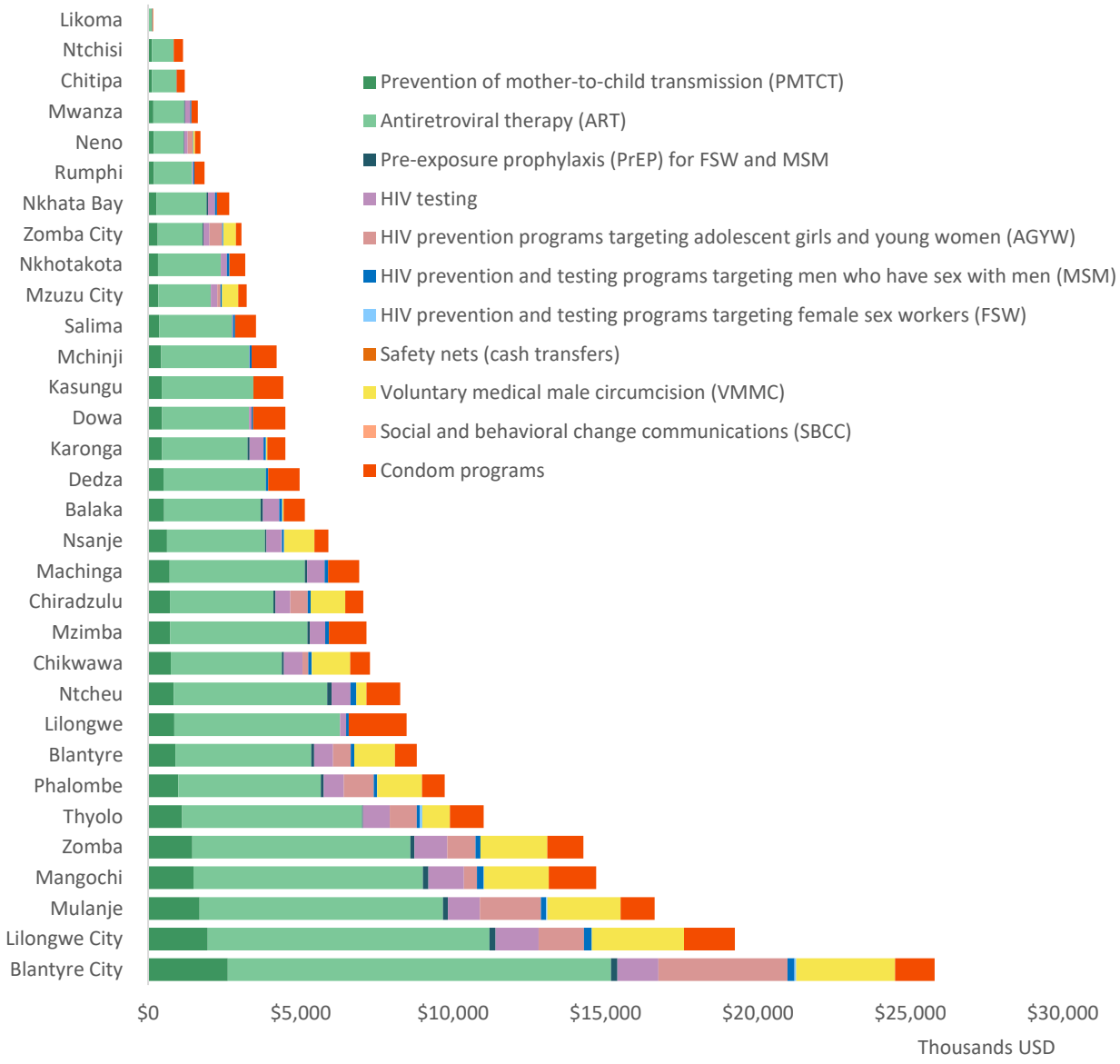



Figure 9: Optimized re-distribution of annual HIV resources across 32 districts, 2020 to 2025

# 4. Study limitations

As with any modelling study, there are limitations in this analysis. The following key limitations should be considered when interpreting results and recommendations. First, limitations in data availability and reliability can lead to uncertainty around projected results. Although the model optimization algorithm accounts for inherent uncertainty, it might not be possible to account for all aspects of uncertainty because of poor quality or insufficient data, particularly for key cost values that inform cost functions. Coupled with epidemic burden, cost functions are a primary factor in modeling optimized resource allocations. For the district-level analysis, since HIV prevalence estimates are not available for each key population for every district, this analysis was informed using overall HIV prevalence and numbers of people living with HIV (PLHIV) per district for the latest reported years. HIV prevalence values by population were then derived using overall district prevalence and PLHIV. HIV Program cost and coverage values were also not available by district, so baseline spending by program we derived based on national level and derived population prevalence values. Second, we used context-specific values and expert opinion where available, otherwise evidence from systematic reviews of clinical and research studies were used to inform model assumptions. Third, the HIV testing modality analysis was informed by unit cost, yield (not applicable for recency testing), and assumed linkage to care by modality. Finally, these findings are only modeled projections and have not been confirmed in a practical setting in Malawi. The country model used in this study has been calibrated to reflect country- and UNAIDS-endorsed epidemiological estimates, but validation of results suggesting optimized reallocations will lead to minimization of infections and deaths in real-world practice has not been done. Shifting resources following evidence from this study will not always be feasible and may not necessarily be politically favourable but should be considered if there is the will to make a greater impact.

# 5. Conclusions

If the latest reported HIV budget is optimized from 2020 to 2025 by scaling-up investment in priority order of antiretroviral therapy (ART), condom programs, prevention of mother-to-child prevention, voluntary medical male circumcision (VMMC), HIV prevention targeting adolescent girls and young women (AGYW), pre-exposure prophylaxis, and HIV prevention and testing programs targeting female sex workers (FSW), more new HIV infections and HIV-related deaths can be averted. Within the HIV testing optimized budget, it is recommended to prioritize index, provider-initiated, and client-initiated testing. With increasing budget, investment in these seven programs should be proportionately increased. If the budget is optimized over a longer time period from 2020 to 2035, it is recommended to scale-up ART, condoms, PMTCT, VMMC, and HIV prevention and testing programs for FSW. It is also estimated that an additional $114M will be required to achieve the 2020-2025 NSP coverage targets over the NSP period. However, it was modeling that more infections and deaths could be averted if the latest reported budget were optimized, rather than increasing the budget to meet set NSP coverage targets.

Optimization of HIV resources across the 28 districts and four cities in Malawi, considering burden by district, suggests shifting funds towards five districts with the highest HIV burden (Blantyre City, Lilongwe City, Mulanje, Mangochi, and Zomba) and prioritizing towards the highest-impact interventions, including those listed for national optimization, but including HIV prevention and testing for men who have sex with men rather than for FSWs. If geographical epidemic profiles are considered for prioritizing resources, then even more infections and deaths could be averted by 2025.

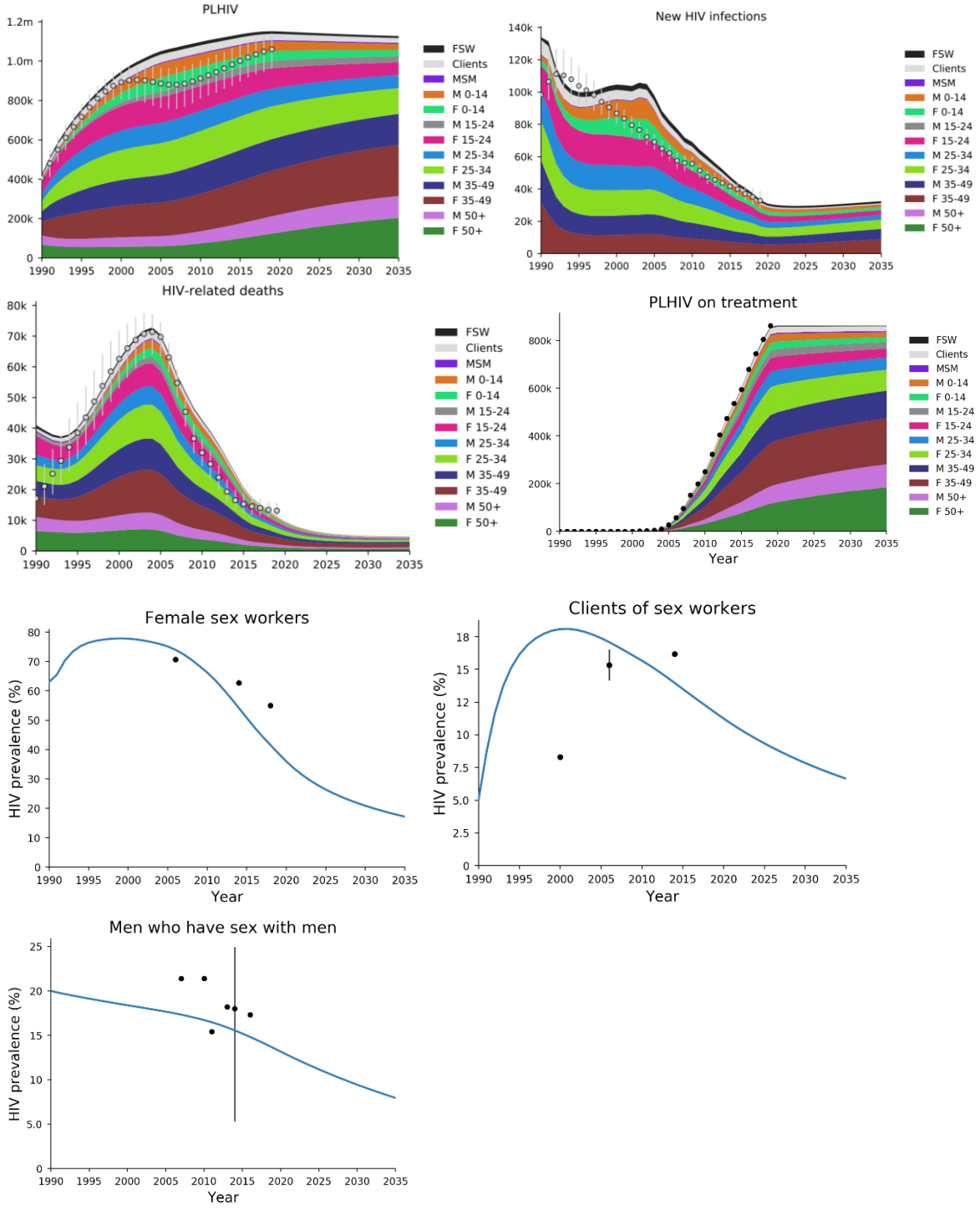
# References

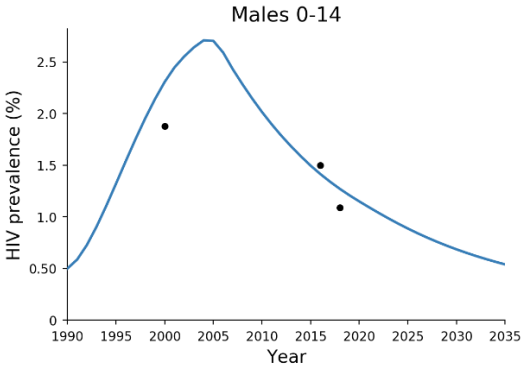

1. The World Bank Group. Malawi - Overview 2019 [Available from: https://www.worldbank.org/en/country/malawi/overview].
2. UNAIDS. Financial Dashboard - Malawi Geneva2018 [Available from: http://hivfinancial.unaids.org/hivfinancialdashboards.html#].
3. Kates J, Wexler A, Foundation KF, Lief E, UNAIDS. Donor government funding for HIV in low- and middle-income countries in 2017. Menlo Park: Kaiser Family Foundation; 2018.
4. Wang H, Abajobir AA, Abate KH, Abbafati C, Abbas KM, Abd-Allah F, et al. Global, regional, and national under-5 mortality, adult mortality, age-specific mortality, and life expectancy, a systematic analysis for the Global Burden of Disease Study 2016. The Lancet. 2017;390(10100):1084-150.

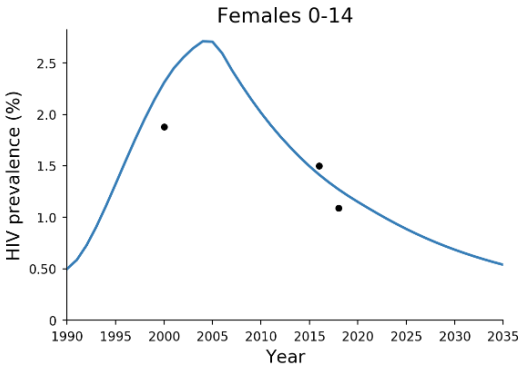
# Appendices

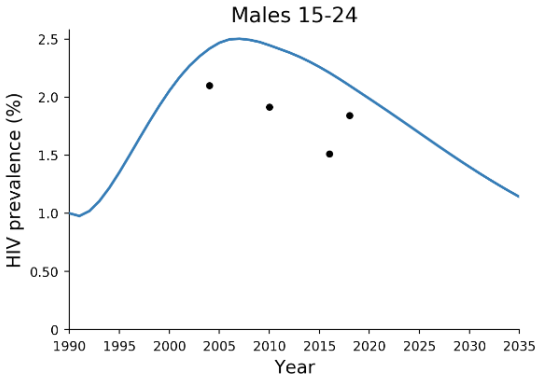
## Appendix 1: Model calibration and cost coverage curves

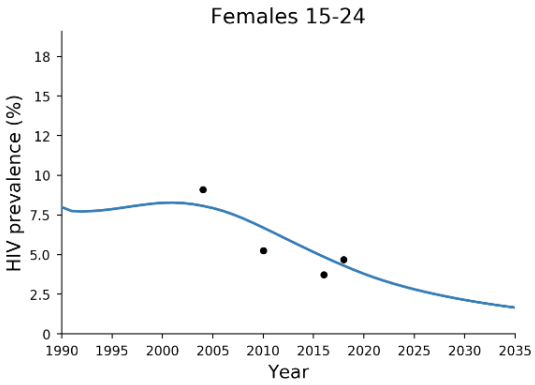
### Model calibration

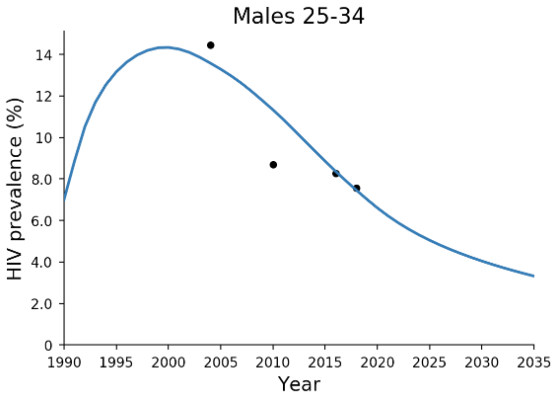


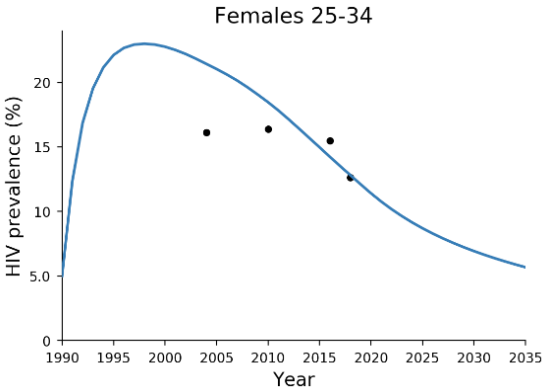

Males 0-14
HIV prevalence (%)
Year

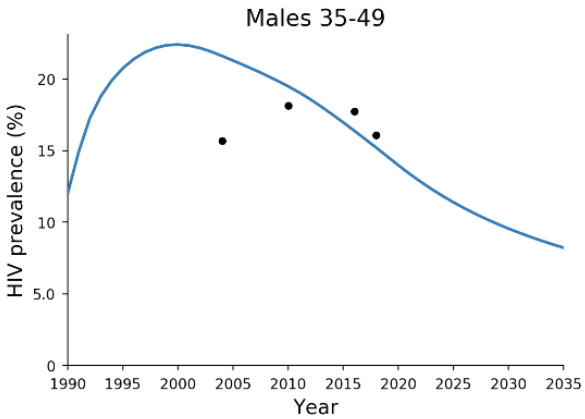

Females 0-14
HIV prevalence (%)
Year

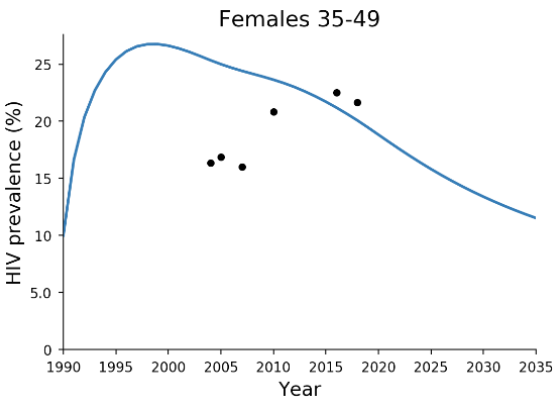

Males 15-24
HIV prevalence (%)
Year

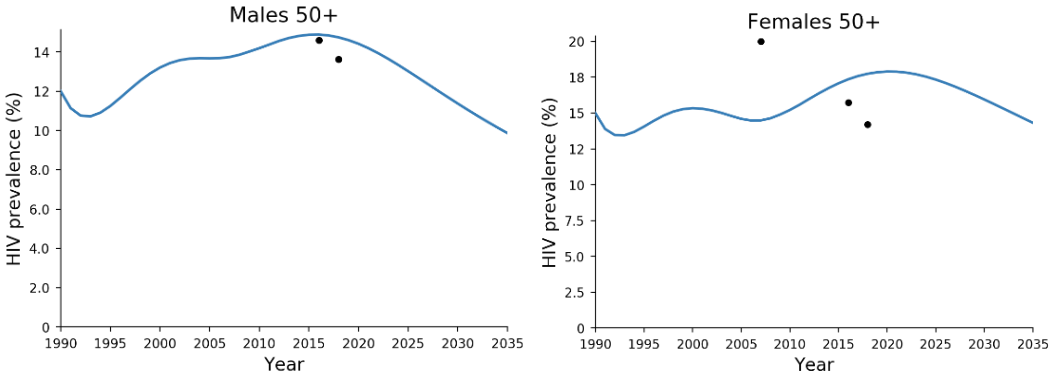

Females 15-24
HIV prevalence (%)
Year


Males 25-34
HIV prevalence (%)
Year

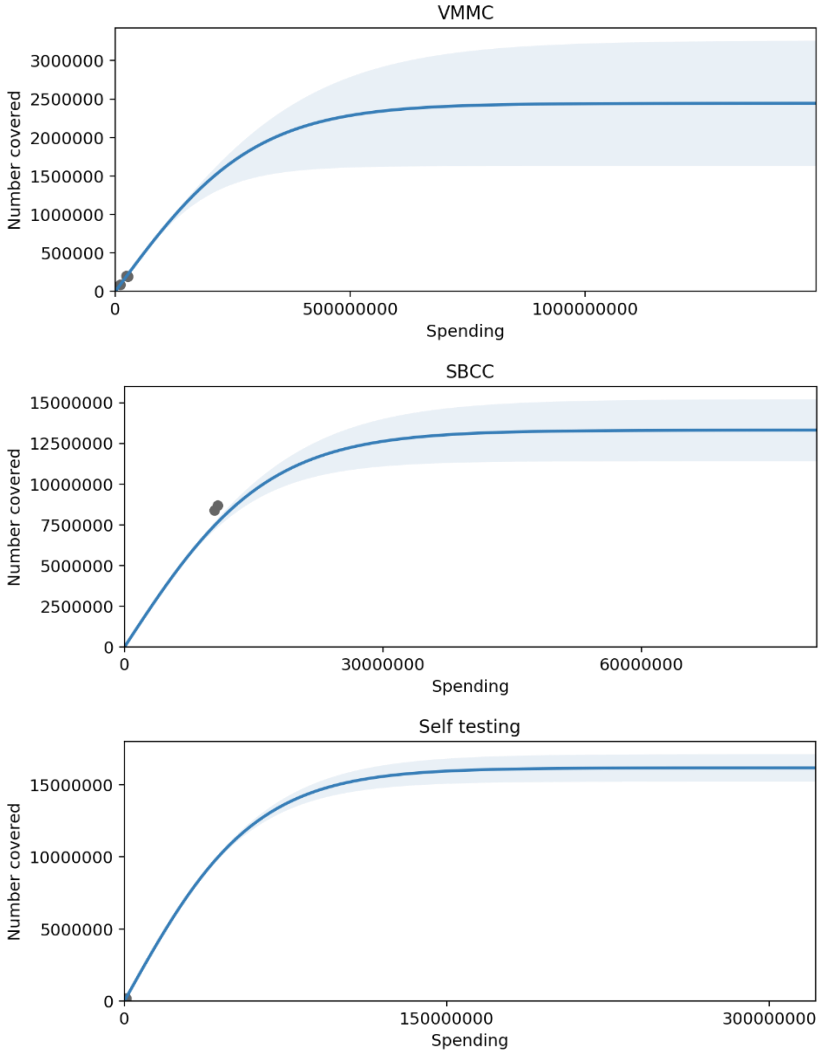

Females 25-34
HIV prevalence (%)
Year

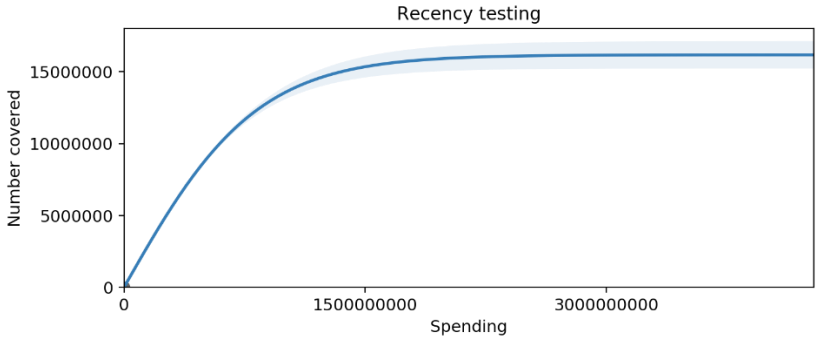

Males 35-49
HIV prevalence (%)
Year


Females 35-49
HIV prevalence (%)
Year




## Cost coverage curves




Recency testing
Number covered
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5000000
0
0
1500000000
3000000000
Spending


Client testing
Number covered
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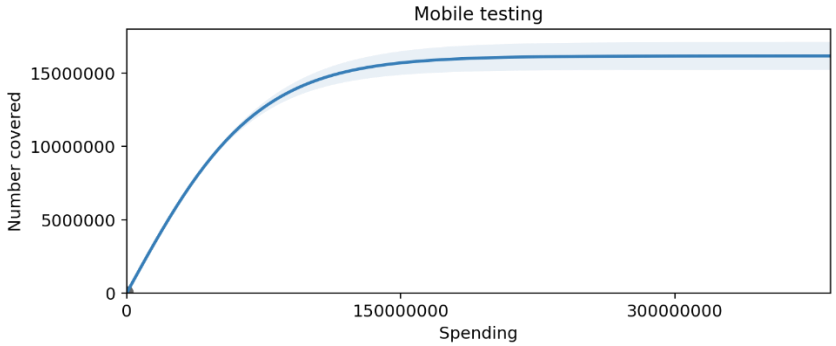
10000000
5000000
0
0
80000000
160000000
Spending


Mobile testing
Number covered
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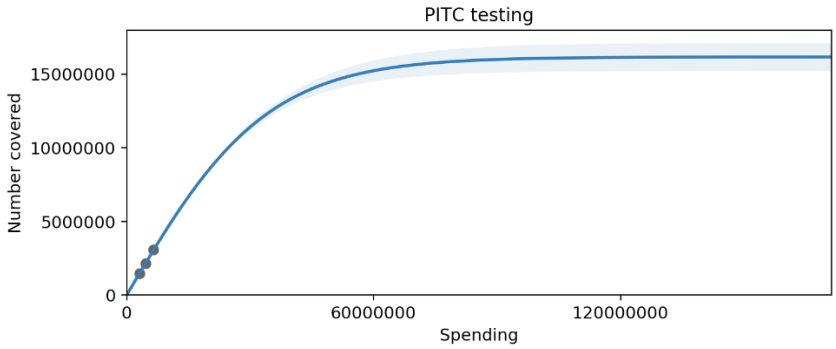
10000000
5000000
0
0
150000000
300000000
Spending


PITC testing
Number covered
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5000000
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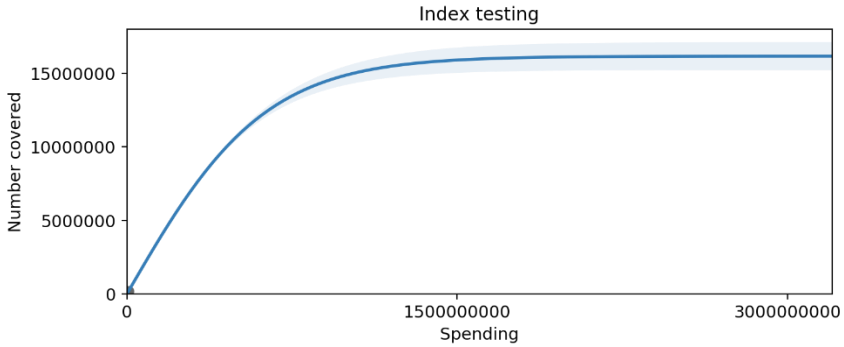
0
60000000
120000000
Spending


Index testing
Number covered
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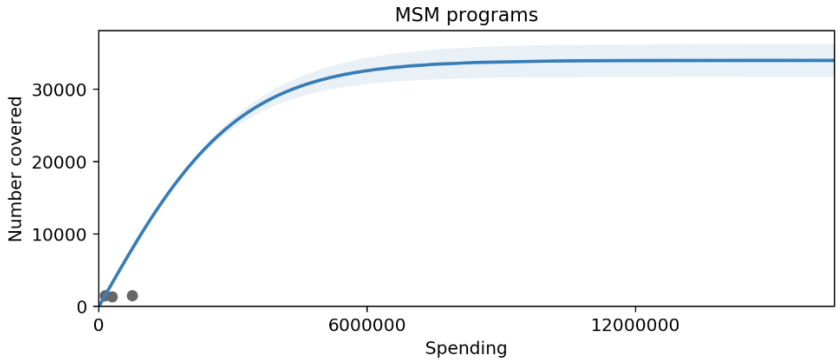
5000000
0
0
1500000000
3000000000
Spending


MSM programs
Number covered
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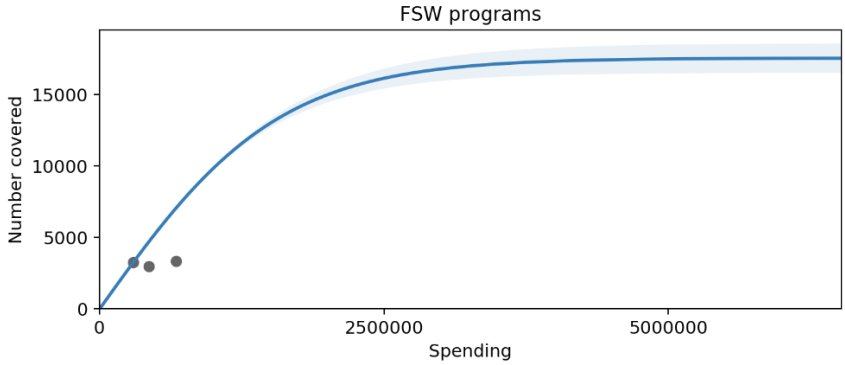
20000
10000
0
0
6000000
12000000
Spending


FSW programs
Number covered
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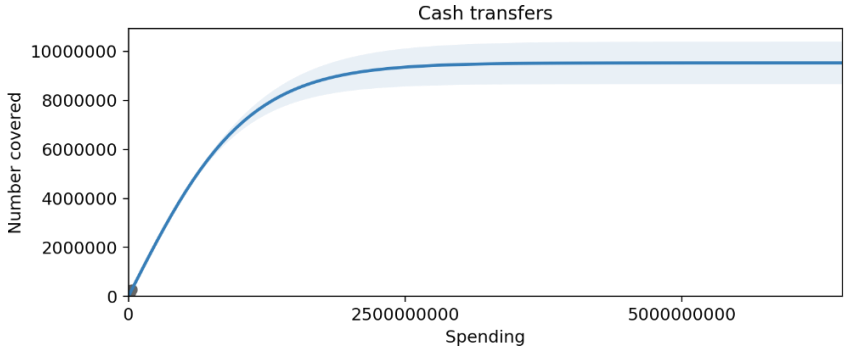
10000
5000
0
0
2500000
5000000
Spending


Cash transfers
Number covered
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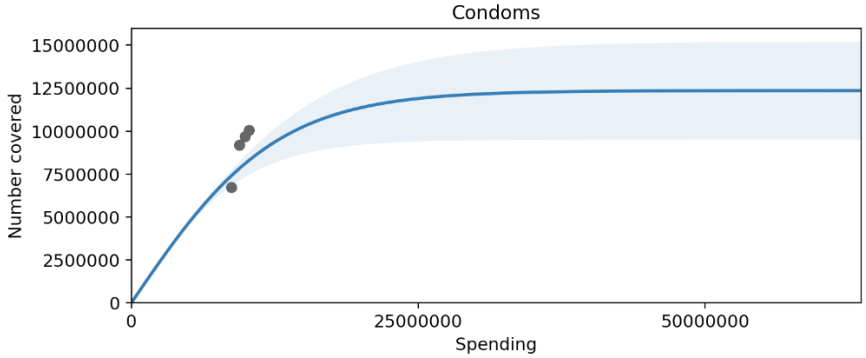
4000000
2000000
0
0
2500000000
5000000000
Spending


Condoms
Number covered
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5000000
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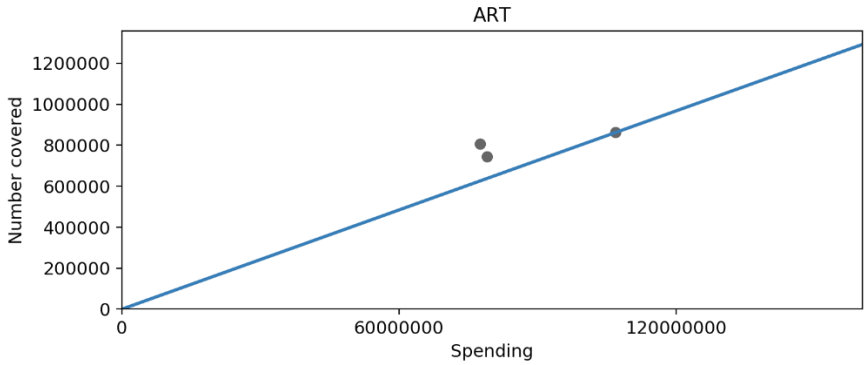
0
25000000
50000000
Spending


ART
Number covered
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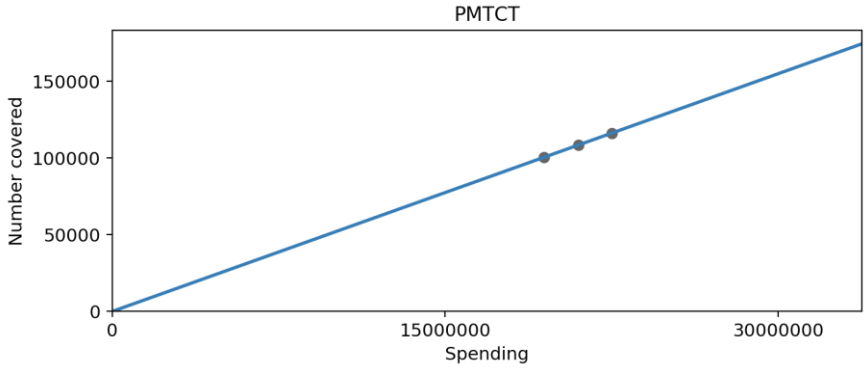
400000
200000
0
0
60000000
120000000
Spending


PMTCT
Number covered
150000
100000
50000
0
0
15000000
30000000
Spending

# Appendix 2: Key model parameters

| | |
|---|---|
| Interaction-related transmissibility (% per act) | |
| Insertive penile-vaginal intercourse | 0.04% |
| Receptive penile-vaginal intercourse | 0.08% |
| Insertive penile-anal intercourse | 0.09% |
| Receptive penile-anal intercourse | 1.38% |
| Intravenous injection | 0.80% |
| Mother-to-child (breastfeeding) | 36.70% |
| Mother-to-child (non-breastfeeding) | 20.50% |
| Relative disease-related transmissibility | |
| Acute infection | 5.60 |
| CD4(>500) | 1.00 |
| CD4(500) to CD4(350-500) | 1.00 |
| CD4(200-350) | 1.00 |
| CD4(50-200) | 3.49 |
| CD4(<50) | 7.17 |
| Disease progression (average years to move) | |
| Acute to CD4(>500) | 0.24 |
| CD4(500) to CD4(350-500) | 0.96 |
| CD4(350-500) to CD4(200-350) | 3.00 |
| CD4(200-350) to CD4(50-200) | 3.74 |
| CD4(50-200) to CD4(<50) | 1.50 |
| Changes in transmissibility (%) | |
| Condom use | 95% |
| Circumcision | 58% |
| Diagnosis behavior change | 0% |
| STI cofactor increase | 265% |
| Opiate substitution therapy | 54% |
| PMTCT | 90% |
| Pre-exposure prophylaxis | 73% |
| Unsuppressive ART | 30% |
| Suppressive ART | 92% |
| Disutility weights | |
| Untreated HIV, acute | 0.15 |
| Untreated HIV, CD4(>500) | 0.01 |
| Untreated HIV, CD4(350-500) | 0.02 |
| Untreated HIV, CD4(200-350) | 0.07 |
| Untreated HIV, CD4(50-200) | 0.27 |
| Untreated HIV, CD4(<50) | 0.55 |
| Treated HIV | 0.05 |
| Treatment recovery due to suppressive ART (average years to move) | |
| CD4(350-500) to CD4(>500) | 2.20 |
| CD4(200-350) to CD4(350-500) | 1.42 |
| CD4(50-200) to CD4(200-350) | 2.14 |
| CD4(<50) to CD4(50-200) | 0.66 |
| Time after initiating ART to achieve viral suppression (years) | 0.20 |
| Number of VL tests recommended per person per year | 1.00 |

| | |
|---|---|
| CD4 change due to non-suppressive ART (%/year) | |
| CD4(500) to CD4(350-500) | 2.60% |
| CD4(350-500) to CD4(>500) | 15.00% |
| CD4(350-500) to CD4(200-350) | 10.00% |
| CD4(200-350) to CD4(350-500) | 5.30% |
| CD4(200-350) to CD4(50-200) | 16.20% |
| CD4(50-200) to CD4(200-350) | 11.70% |
| CD4(50-200) to CD4(<50) | 9.00% |
| CD4(<50) to CD4(50-200) | 11.10% |
| Death rate (% mortality per year) | |
| Acute infection | 0.36% |
| CD4(>500) | 0.36% |
| CD4(350-500) | 0.58% |
| CD4(200-350) | 0.88% |
| CD4(50-200) | 5.90% |
| CD4(<50) | 43.20% |
| Relative death rate on suppressive ART | 30.00% |
| Relative death rate on non-suppressive ART | 84.17% |
| Tuberculosis cofactor | 217.00% |

# Appendix 3: HIV program unit costs

| HIV program | 100% latest reported budget USD, 2019 | 100% latest reported coverage | Unit cost USD, 2019 |
|---|---|---|---|
| Adolescent girls and young women (AGYW) programs | $8,517,740 | 89,855 | $94.79 |
| Antiretroviral therapy (ART) | $106,859,061 | 862,582 | $123.88 |
| Condom programs | $9,558,251 | 10,066,140 | $1.02 |
| HIV prevention and testing programs targeting female sex workers (FSW) | $239,940 | 3,272 | $89.84 |
| HIV prevention and testing programs targeting men who have sex with men (MSM) | $143,675 | 1,566 | $91.74 |
| Pre-exposure prophylaxis (PrEP) | $1,016,400 | 8,400 | $121.00* |
| Prevention of mother-to-child transmission (PMTCT) | $22,498,118 | 116,209 | $193.60 |
| Safety nets (cash transfers) | $32,601,709 | 289,749 | $112.30 |
| Social and behavioral change communication (SBCC) | $10,809,565 | 8,707,527 | $1.24 |
| Voluntary medical male circumcision (VMMC) | $32,601,709 | 289,749 | $112.30 |

| HIV testing modality | 100% latest reported budget (USD) | 100% latest reported coverage | Unit cost (USD) | Yield | Assumed linkage to care |
|---|---|---|---|---|---|
| Self-testing | $783,675 | 209,539 | $3.74 | 5.30% | 60% |
| Recency testing | $691,187 | 13,490 | $51.24 | NA | 100% |
| Mobile testing | $516,213 | 117,055 | $4.41 | 3.70% | 30% |
| Index testing | $7,413,154 | 191,406 | $38.73 | 6.50% | 100% |
| Client-initiated testing | $2,574,826 | 960,756 | $2.68 | 2.70% | 100% |
| Provider initiated testing | $3,100,506 | 1,472,740 | $2.11 | 1.80% | 100% |
| *Total HIV testing* | *$15,079,561* | *NA* | *NA* | *NA* | *NA* |

*For 2020

# Appendix 4: Optimized spending and coverage per district

Estimates for HIV prevalence and people living with HIV (PLHIV) for all ages by district or city, 2019

| District | HIV prevalence | PLHIV |
|---|---|---|
| Balaka | 6.0% | 27,703 |
| Blantyre | 7.9% | 38,010 |
| Blantyre City | 11.0% | 96,327 |
| Chikwawa | 6.5% | 38,819 |
| Chiradzulu | 8.4% | 31,826 |
| Chitipa | 2.6% | 6,173 |
| Dedza | 3.1% | 26,040 |
| Dowa | 2.4% | 18,908 |
| Karonga | 5.1% | 19,419 |
| Kasungu | 2.7% | 22,712 |
| Likoma | 5.5% | 847 |
| Lilongwe | 2.6% | 43,050 |
| Lilongwe City | 8.2% | 87,694 |
| Machinga | 4.6% | 35,853 |
| Mangochi | 6.3% | 76,720 |
| Mchinji | 3.6% | 21,931 |
| Mulanje | 10.1% | 75,819 |
| Mwanza | 5.1% | 7,019 |
| Mzimba | 3.9% | 35,802 |
| Mzuzu City | 7.1% | 17,273 |
| Neno | 6.4% | 9,271 |
| Nkhata Bay | 4.7% | 13,831 |
| Nkhotakota | 4.1% | 16,474 |
| Nsanje | 8.1% | 25,860 |
| Ntcheu | 5.2% | 35,907 |
| Ntchisi | 1.8% | 5,627 |
| Phalombe | 9.3% | 43,636 |
| Rumphi | 4.1% | 9,584 |
| Salima | 3.8% | 18,471 |
| Thyolo | 7.7% | 59,115 |
| Zomba | 7.7% | 60,768 |
| Zomba City | 11.9% | 13,768 |
| **Total** | **5.6%** | **1,040,257** |

Source: Naomi model, 2020

Annual optimized HIV program budget allocations across districts for 2020 to 2025

| District | AGYW | ART | Condoms | FSW programs | HIV testing | MSM programs | PMTCT | PrEP | VMMC |
|---|---|---|---|---|---|---|---|---|---|
| Balaka | $0 | $3,165,923 | $698,889 | $95,367 | $530,518 | $11,627 | $520,114 | $80,644 | $36,319 |
| Blantyre | $4,229,350 | $12,567,349 | $1,299,528 | $228,333 | $1,347,611 | $64,570 | $2,610,608 | $213,375 | $3,235,491 |
| Blantyre City | $582,924 | $4,451,114 | $724,022 | $109,523 | $619,446 | $0 | $892,512 | $99,349 | $1,334,357 |
| Chikwawa | $189,806 | $3,648,426 | $642,319 | $107,789 | $610,106 | $11,524 | $735,693 | $64,263 | $1,259,678 |
| Chiradzulu | $577,922 | $3,392,181 | $597,120 | $86,327 | $481,412 | $0 | $714,190 | $70,932 | $1,137,046 |
| Chitipa | $0 | $799,903 | $270,882 | $8,284 | $0 | $0 | $121,499 | $0 | $0 |
| Dedza | $0 | $3,353,269 | $1,033,361 | $74,835 | $0 | $0 | $502,344 | $0 | $0 |
| Dowa | $0 | $2,846,193 | $1,052,075 | $53,310 | $87,686 | $0 | $454,805 | $0 | $0 |
| Karonga | $0 | $2,806,855 | $586,258 | $80,360 | $451,451 | $9,355 | $454,805 | $65,913 | $39,073 |
| Kasungu | $0 | $3,004,240 | $975,188 | $0 | $0 | $0 | $448,068 | $0 | $0 |
| Likoma | $0 | $99,835 | $22,939 | $2,570 | $14,861 | $0 | $16,393 | $566 | $4,822 |
| Lilongwe | $1,484,198 | $9,249,267 | $1,668,471 | $255,517 | $1,414,220 | $4,501 | $1,947,342 | $198,995 | $3,019,765 |
| Lilongwe City | $0 | $5,432,445 | $1,893,953 | $83,852 | $204,576 | $0 | $857,400 | $0 | $0 |
| Machinga | $0 | $4,434,433 | $1,016,779 | $114,106 | $575,904 | $789 | $700,201 | $76,688 | $0 |
| Mangochi | $431,816 | $7,525,265 | $1,555,842 | $221,396 | $1,164,503 | $4,348 | $1,487,454 | $177,345 | $2,130,019 |
| Mchinji | $0 | $2,885,863 | $818,958 | $73,623 | $7,776 | $0 | $426,314 | $0 | $0 |
| Mulanje | $2,010,401 | $7,985,974 | $1,121,044 | $173,298 | $1,041,604 | $32,661 | $1,681,368 | $165,462 | $2,402,295 |
| Mwanza | $8,000 | $1,012,604 | $212,737 | $29,188 | $170,429 | $4,115 | $164,876 | $27,238 | $0 |
| Mzimba | $0 | $4,501,442 | $1,232,674 | $126,185 | $505,658 | $0 | $724,863 | $71,768 | $0 |
| Mzuzu City | $98,691 | $1,723,413 | $279,751 | $48,971 | $215,383 | $2,456 | $327,270 | $2,070 | $535,853 |
| Neno | $152,979 | $985,598 | $184,596 | $21,193 | $120,440 | $326 | $173,456 | $17,921 | $57,460 |
| Nkhata Bay | $0 | $1,648,283 | $406,087 | $65,170 | $226,752 | $660 | $269,224 | $43,645 | $460 |
| Nkhotakota | $0 | $2,060,347 | $521,912 | $83,775 | $196,587 | $699 | $322,399 | $0 | $0 |
| Nsanje | $24,794 | $3,210,985 | $457,868 | $62,182 | $485,302 | $8,265 | $614,583 | $51,411 | $989,781 |
| Ntcheu | $0 | $5,037,739 | $1,103,177 | $190,782 | $624,650 | $158 | $836,503 | $139,293 | $333,443 |
| Ntchisi | $0 | $718,312 | $306,309 | $0 | $0 | $0 | $115,368 | $0 | $0 |
| Phalombe | $983,207 | $4,675,187 | $747,791 | $110,675 | $660,506 | $8,983 | $984,314 | $92,881 | $1,462,765 |
| Rumphi | $0 | $1,253,573 | $333,241 | $31,494 | $36,950 | $0 | $186,376 | $0 | $0 |
| Salima | $0 | $2,395,300 | $691,942 | $68,649 | $20,517 | $0 | $358,059 | $3,618 | $0 |
| Thyolo | $888,310 | $5,904,949 | $1,106,375 | $95,199 | $881,392 | $86,606 | $1,113,224 | $25,325 | $898,726 |
| Zomba | $417,897 | $1,471,236 | $188,535 | $29,855 | $200,369 | $14,428 | $309,754 | $26,683 | $402,019 |
| Zomba City | $929,196 | $7,150,331 | $1,180,032 | $162,813 | $1,073,031 | $0 | $1,444,313 | $139,828 | $2,192,153 |
| **Total** | **$13,009,491** | **$121,397,834** | **$24,930,655** | **$2,894,621** | **$13,969,640** | **$266,071** | **$22,515,692** | **$1,855,213** | **$21,471,525** |

Annual HIV program coverage from optimization across districts for 2020 to 2025

| District | AGYW | ART | Condoms | FSW programs | HIV testing | MSM programs | PMTCT | PrEP | VMMC* |
|---|---|---|---|---|---|---|---|---|---|
| Balaka | 0 | 25,529 | 307,107 | 698 | 151,173 | 126 | 2,687 | 531 | 301 |
| Blantyre | 6,057 | 35,858 | 314,524 | 743 | 167,267 | 0 | 4,610 | 603 | 10,966 |
| Blantyre City | 36,645 | 100,914 | 551,090 | 1,358 | 326,101 | 660 | 13,483 | 1,154 | 26,354 |
| Chikwawa | 1,996 | 29,426 | 368,496 | 847 | 173,144 | 125 | 3,800 | 482 | 10,395 |
| Chiradzulu | 5,959 | 27,330 | 247,156 | 582 | 130,054 | 0 | 3,689 | 449 | 9,328 |
| Chitipa | 0 | 6,456 | 154,454 | 91 | 0 | 0 | 628 | 0 | 0 |
| Dedza | 0 | 27,060 | 555,552 | 758 | 0 | 0 | 2,595 | 0 | 0 |
| Dowa | 0 | 22,969 | 528,686 | 561 | 32,025 | 0 | 2,349 | 0 | 0 |
| Karonga | 0 | 22,630 | 255,220 | 583 | 127,694 | 101 | 2,349 | 437 | 324 |
| Kasungu | 0 | 24,245 | 555,278 | 0 | 0 | 0 | 2,314 | 0 | 0 |
| Likoma | 0 | 805 | 10,256 | 21 | 4,243 | 0 | 85 | 5 | 40 |
| Lilongwe | 0 | 43,842 | 1,076,735 | 904 | 76,618 | 0 | 4,429 | 0 | 0 |
| Lilongwe City | 15,359 | 74,530 | 698,328 | 1,669 | 364,495 | 49 | 10,058 | 1,264 | 24,806 |
| Machinga | 0 | 35,770 | 509,720 | 998 | 186,945 | 9 | 3,617 | 585 | 0 |
| Mangochi | 4,541 | 60,693 | 789,068 | 1,744 | 337,531 | 47 | 7,683 | 1,242 | 17,610 |
| Mchinji | 0 | 23,284 | 410,167 | 695 | 2,079 | 0 | 2,202 | 0 | 0 |
| Mulanje | 19,835 | 64,282 | 476,396 | 1,138 | 267,711 | 348 | 8,684 | 954 | 19,663 |
| Mwanza | 84 | 8,164 | 91,998 | 211 | 47,242 | 44 | 852 | 170 | 0 |
| Mzimba | 0 | 36,320 | 634,147 | 1,156 | 159,748 | 0 | 3,744 | 567 | 0 |
| Mzuzu City | 1,037 | 13,895 | 151,802 | 359 | 64,572 | 27 | 1,690 | 17 | 4,419 |
| Neno | 1,595 | 7,948 | 93,188 | 184 | 38,479 | 4 | 896 | 131 | 477 |
| Nkhata Bay | 0 | 13,296 | 195,455 | 460 | 72,912 | 7 | 1,391 | 305 | 4 |
| Nkhotakota | 0 | 16,622 | 265,691 | 617 | 70,415 | 8 | 1,665 | 0 | 0 |
| Nsanje | 261 | 25,857 | 206,121 | 464 | 118,611 | 89 | 3,174 | 346 | 8,113 |
| Ntcheu | 0 | 40,618 | 465,215 | 1,144 | 190,957 | 2 | 4,321 | 866 | 2,766 |
| Ntchisi | 0 | 5,798 | 198,068 | 0 | 0 | 0 | 596 | 0 | 0 |
| Phalombe | 9,950 | 37,648 | 303,093 | 722 | 169,834 | 98 | 5,084 | 570 | 11,985 |
| Rumphi | 0 | 10,113 | 157,769 | 287 | 13,206 | 0 | 963 | 0 | 0 |
| Salima | 0 | 19,326 | 331,055 | 617 | 5,477 | 0 | 1,849 | 30 | 0 |
| Thyolo | 9,240 | 47,599 | 497,314 | 876 | 251,958 | 827 | 5,750 | 207 | 7,445 |
| Zomba | 9,663 | 57,609 | 517,081 | 1,181 | 281,173 | 0 | 7,460 | 910 | 18,016 |
| Zomba City | 3,909 | 11,826 | 72,586 | 177 | 45,493 | 132 | 1,600 | 148 | 3,280 |
| **National total** | **126,131** | **978,262** | **11,988,816** | **21,845** | **3,877,157** | **2,703** | **116,297** | **11,973** | **176,292** |

*No district had circumcision coverage >85% by 2025 (excluding traditional circumcisions from 2017 to 2025) other than Machinga district which had 91% circumcision coverage reported for 2016 (source: Malawi Demographic and Health Survey, 2015-16)