KINGDOM OF CAMBODIA
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National Center for HIV/AIDS, Dermatology and STD

FOCUSING AND SUSTAINING THE HIV RESPONSE IN CAMBODIA:

Findings from an Optima HIV modelling analysis 2023

TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

FIGURES

TABLES

ACKNOWLEDGEMENTS

The Optima HIV Modelling Analysis was conducted under the leadership of Dr Ouk Vichea, Director of National Center for HIV/AIDS, Dermatology and STD (NCHADS) of the Ministry of Health, Cambodia, and NCHADS management team and Technical Units (Dr. Samreth Sovannarith, Dr. Ngauv Bora, Deputy Director, Dr. Kim Bunna, Head of Technical Bureau, International TAs: Dr. Gary Daigle and Mr. Fabrice Petit). The Burnet Institute team (Rowan Martin-Hughes, Thomas Walsh, Kelvin Burke, Anna Bowring, Debra ten Brink, Nisaa Wulan, Anna Roberts, and Nick Scott) provided technical support in using the Optima HIV tool (available from http://optimamodel.com/hiv) to develop HIV investment scenario tailored to the Cambodia context and drafted this report. The UNAIDS team (Ms Patricia Ongpin, Dr Khin Cho Win Htin, and Mr Polin Ung) guided the overall coordination and technical discussion of the study, including collection of data, analysis and development of the report, and finally with the inputs of key stakeholders listed below, especially HE Dr. Tia Phalla, Vice-chair of NAA, Dr. Deng Serongkea, WHO's representative.

This study was conducted from January to March 2023 with funding support through the Technical Support Mechanism of UNAIDS and was made possible through consultation and collaboration with national and international partners, as well as communities of key populations and people living with HIV.

Key stakeholders

- National Center for HIV/AIDS Dermatology and STD (NCHADS)
- National AIDS Authority (NAA)
- Ministry of Health (MOH)
- Ministry of Economy and Finance (MEF)
- National Maternal and Child Health Center (NMCHC)
- Joint United Nations Programme on HIV/AIDS (UNAIDS)
- United Nations Population Fund (UNFPA)
- World Health Organization (WHO)
- Khmer HIV/AIDS NGO Alliance (KHANA)
- Reproductive Health Association of Cambodia (RHAC)
- Catholic Relief Services (CRS)
- Chhouk Sar Clinic
- Friends International
- Community partners/implementing NGOs, including ARV Users Association (AUA), Cambodian Women for Peace and Development (CWPD), National Female Entertainment Workers Network (EWNET), Bandanh Chaktomuk (BC), Cambodian Network of People Who Use Drugs (CNPUD)
- FHI 360 – EpiC
- United States Agency for International Development (USAID)
- United States Centers for Disease Control (US CDC)
- Clinton Health Access Initiative (CHAI)
- Local health system sustainability project (LHSS)

Suggested citation: NCHADS/MOH-Cambodia. Focusing and sustaining the HIV response in Cambodia: Findings from An Optima HIV Modelling Analysis. 2023.

ABBREVIATIONS

AEM	AIDS Epidemic Model
AIDS	Acquired immune deficiency syndrome
ART	Antiretroviral therapy
ARV	Antiretroviral (drugs)
B-IACM	Boosted integrated active case management
CHAI	Clinton Health Access Initiative
Clients	Clients (of entertainment workers)
CRS	Catholic Relief Services
CSE	Comprehensive sexuality education
EpiC	Meeting Targets and Maintaining Epidemic Control
FEW	Female entertainment workers
FI	Friends International (International Organization)
FHI360	Family Health International 360
Global Fund	Global Fund to Fight AIDS, Tuberculosis and Malaria
HACC	Health Action Coordinating Committee
HCV	Hepatitis C virus
HIV	Human immunodeficiency virus
HSSP	Health Sector Strategic Plan
HTS	HIV testing services
IBBS	Integrated Biological and Behavioural Surveillance
KHANA	Khmer HIV/AIDS NGO Alliance
KP	Key population (at risk of HIV transmission)
MOH	Ministry of Health
MSM	Men who have sex with men
MSMUD	Men who have sex with men engaged in sexualized drug use
NAA	National AIDS Authority
NASA	National AIDS Spending Assessment
NCHADS	National Center for HIV/AIDS, Dermatology and STD
NGO	Non-governmental organization
OAMT	Opioid agonist maintenance treatment
PDI+	Peer-driven intervention plus
PEPFAR	President's Emergency Plan For AIDS Relief
PITC	Provider-initiated HIV testing and counselling
PLHIV	People living with HIV
PMTCT	Prevention of mother-to-child transmission (of HIV)
PrEP	Pre-exposure prophylaxis
PWID	People who inject drugs
PWUD	People who use drugs (non-injecting)
RGC	Royal Government of Cambodia
RHAC	Reproductive Health Association of Cambodia
SBCC	Social and behavioural change communication
STI	Sexually transmitted infection
TG	Transgender women
TGUD	Transgender women engaged in sexualized drug use
TWG	Technical working group
UNAIDS	Joint United Nations Programme on HIV/AIDS
US CDC	United States Centers for Disease Control
WHO	World Health Organization

EXECUTIVE SUMMARY

Current situation

Cambodia has achieved remarkable success in reducing annual new HIV infections, from an estimated 15,000 in 1996 to 1,400 in 2022 [1, 2]. However, rising HIV incidence among young people aged 15-24, particularly among young men who have sex with men (MSM), transgender women (TG), and people engaged in sexualized drug use (chemsex) is counteracting reductions in new infections [1], with the overall number projected to remain stable at approximately 1,400 new HIV infections per year if baseline 2022 spending continues. The target of 95% of people living with HIV being diagnosed and aware of their status is not on track to be achieved by 2025 with an estimated 86% diagnosed in 2022. The proportion of diagnosed people living with HIV on treatment and those on treatment with viral suppression are already exceeding the 95% targets, and there is a strong government, civil society, and development partner commitment to sustaining these achievements.

The main purpose of this analysis is to develop an investment scenario that maximises the impact of resource allocations in HIV prevention, tailored to the needs of key populations, differentiated to subpopulations by risk and age, and aligned with the Global AIDS Strategy. Investment scenarios will also inform policy decisions in the remaining National Strategic Plan (2023 to 2025).

Optimized response

Maintaining funding for HIV prevention programmes remains critical to prevent a rise in new HIV infections in Cambodia, but there are opportunities to enhance the current HIV response through **prioritizing investment into differentiated service delivery** including Peer-Driven Interventions Plus (PDI+), virtual outreach, HIV self-testing, night-time and mobile outreach, and pre-exposure prophylaxis (PrEP). Although the 95% diagnosis target is not on track by 2025, this enhanced response may make the 95% diagnosis target achievable by 2030.

To achieve and sustain the target reduction in new HIV infections to less than 250 per year (Figure 1), we estimate that 2022 HIV prevention spending of US$3.3M would need to be increased by additional annual US$2M plus PrEP demand creation costs from 2024-2026 to scale-up PrEP, and US$4M per year thereafter (Figure 2). An additional US$2M per year would equate to a 60% increase in spending on HIV prevention programmes, but less than 10% increase in total HIV spending. Refocused outreach

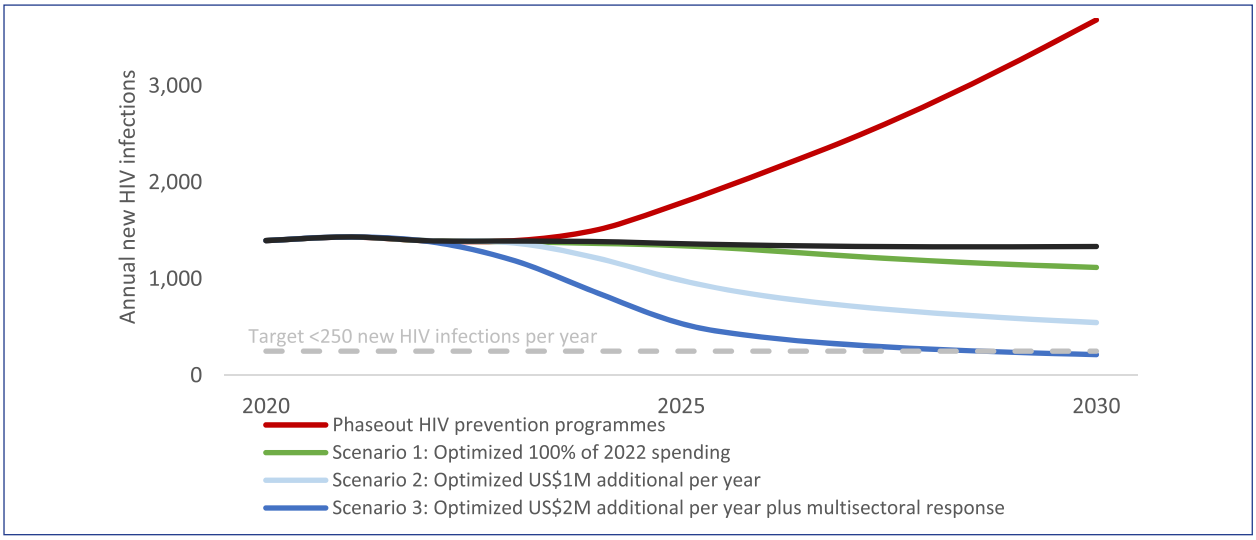


Figure 1: Projected reduction in new HIV infections with additional HIV prevention spending

modalities and rapid scale-up of PrEP would need to be combined with **implementation efficiencies** and a **multisectoral response** defined below that leverages resources from outside of the HIV sector to reduce risk among populations not routinely reached through HIV services, including adolescents.

Optimized HIV investment priorities 2024-2026 and potential impacts from 2024-2030

SCENARIO 1:

Within the 2022 HIV prevention budget envelope (US$3.3M per year), expand high-yield interventions of PDI+, self-testing availability, virtual outreach for MSM and TG (+$250k/year overall), and prioritize PrEP demand creation among MSM and TG aged 20-24 (+$50k/year). Expansion of these interventions is possible through cost-efficiencies of 10% in other HIV prevention modalities, including physical outreach, and may avert 8% of cumulative new HIV infections projected from 2024 to 2030.

SCENARIO 2:

With an additional annual US$1M on average per year from 2024-2026 to reach scale and annual US$2M to sustain HIV services from 2027-2030, implement additional modalities as Scenario 1; further expand night-time, mobile, virtual, and other physical outreach for MSM and TG (+$250k/year overall); and implement wider PrEP demand creation among MSM and TG, prioritized to reach those engaged in sexualized drug use (+$750k/year). This additional investment may avert 41% of cumulative new HIV infections projected from 2024 to 2030.

SCENARIO 3:

With both implementation efficiencies and a multisectoral response defined below combined with an additional annual US$2M plus PrEP demand creation costs from 2024-2026 to reach scale, and annual US$4M per year to sustain HIV services from 2027-2030, implement modalities as Scenario 2; more rapid scale-up of PrEP including long-acting PrEP subject to procurement availability and demand (+$750k/year); expand outreach to female entertainment workers (FEW), with a primary focus on night-time and mobile outreach that reaches street-based FEW (+$100k/year); further expand outreach to MSM and TG (+$100k/year); and expand ART adherence support for key populations (+$50k/year). This additional investment in HIV services may avert 70% of cumulative new HIV infections projected from 2024 to 2030, but assumes that **sufficient demand creation** will make it possible to **reach national PrEP coverage targets for key populations by 2026** (which would be strengthened through the availability of long-acting PrEP).

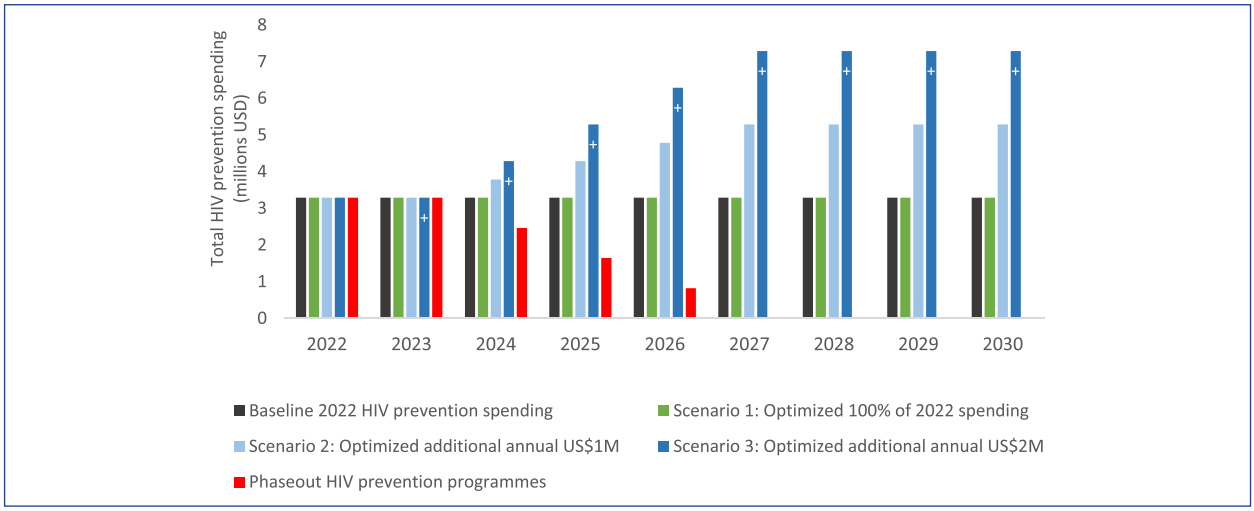


Figure 2. Annual HIV prevention programme spending in each key scenario. Scenario 3 modelled impact includes additional implementation efficiencies and multisectoral response that was not costed as part of this analysis.

Implementation efficiencies modelled within Scenario 3 included:

1. Improved **partner notification** tracing and testing (PNTT) to address gaps in the diagnosis care cascade.
2. Improved **logistics of condom distribution and addressing legal barriers** to condom availability.
3. Budgeted **higher renumeration for outreach workers** was factored into HIV service delivery unit costs beyond 2023 in all scenarios. Incentives and skill differentiation between service modalities for outreach workers may both reduce turnover and lead to improved service provision.

Multisectoral response modelled within Scenario 3 included:

1. Improved **STI diagnosis and treatment** to reverse the rapid increase in syphilis and other STI prevalence since 2020, especially among young people 15-24.
2. **Comprehensive sexuality education** (CSE) and other education to reach 10 to 14-year-old adolescents before they experience HIV transmission risk and before they are able to routinely access HIV prevention and testing services, as part of **long-term maintenance of HIV awareness and sustainability of reductions in HIV transmission beyond 2030.**
3. Expanded HIV service availability including **self-test and self-referral through private or social enterprise.**

The following ministries are key to work with the Ministry of Health to support, improve and ensure enabling environment, equity in access to services, and mobilize domestic resources:

- Ministry of Tourism
- Ministry of Social Affairs, Veteran and Youth Rehabilitation
- Ministry of Information
- Ministry of Interior
- Ministry of Planning
- Ministry of Education, Youth and Sports
- Ministry of Labour and Vocational Training
- Ministry of Economy and Finance
- Ministry of Posts and Telecommunication
- Ministry of Women's Affairs

Flexibility to efficiently re-program allocated funds within the Global Fund grant cycle from 2024–2026 would allow the HIV programme to re-reallocate funds that cannot be spent due to slower than expected scale-up or factors that make it difficult to deliver some planned services (such as COVID-19 from 2020 to 2023), as well as to respond to emerging epidemiological evidence more rapidly.

Expanded and prioritized resources for HIV services that reach key populations who have not previously had access to HIV services may allow Cambodia to continue a remarkably successful HIV response and exceed all national HIV targets by 2030. Development and operationalization of **social contracting mechanisms may offer sustainability of those HIV services beyond 2030.**

1 INTRODUCTION

1.1 Country context

The journey of the AIDS response in Cambodia is remarkable. In 1990s, Cambodia experienced one of the fastest growing HIV epidemics in Asia, but successfully turned the epidemic around through phases of "Cambodia 1.0, 2.0 and 3.0" responses coupled with strong commitments towards ending AIDS epidemic as a public health threat. These commendable responses and commitments led the country to become one of the first seven countries globally to achieve 90-90-90 treatment targets in 2017.

On the HIV prevention front, the country has achieved a 33% decline in new infections between 2010 and 2022. New HIV infections peaked in 1996 at 15,000 with a notable decreasing trend in infections thereafter. However, the overall number projected to remain stable at approximately 1,400 new HIV infections per year if baseline 2022 spending continues, with projections that new infections could be higher by 2030 [1]. Notably, new HIV infections among men who have sex with men (MSM) and transgender women (TG) as a share of total new HIV infections is growing. In 2022, 40% of new HIV infections were estimated to be among MSM, a five-fold increase from 8% in 2010 [1].

Programme data, studies, surveys and case reporting indicated that risk patterns, networks, vulnerabilities and access to HIV-related services are very much diverse - not only between different key populations of female entertainment workers (FEW), MSM, TG, and people who inject drugs (PWID) – but also within sub-sets of key populations. There is overlapping risk behaviour with particular emphasis on sexualized drug use among younger populations aged 15-24 and youth who are also key populations not reachable through traditional prevention interventions.

Data from innovative interventions such as virtual outreach and HIV self-testing demonstrate that it is possible to reduce gaps in diagnosis among priority populations. Around half of MSM and TG that were virtually reached in the first half of 2021 were first ever HIV testers with a yield of 33% and 44% respectively, indicating that interventions are "reaching the unreached with high risks" [2]. Programme data from January to June 2022 indicated that HIV yield from virtual interventions were between 5% (among FEW) to 14% (among MSM and TG) [2]. HIV self-testing also achieved high positive yields, between 5% among FEW and 17% among TG for those that reported results [2]. Peer-Driven Interventions Plus (PDI+) is an incentive-based approach where individuals with high-risk behaviours and large social networks recruit peers and has reported yields of 9% among MSM and TG [2]. Pre-Exposure Prophylaxis (PrEP) services were available in 23 sites across ten provinces with 7211 people ever on PrEP as by end of 2022 with the number of sites planned to continue increasing in 2023 [3, 4]. These evolving risks, behaviour dynamics, and novel interventions called for understanding of the impact and efficiency of differentiated and innovative services tailored to the needs of key populations and sub-population groups.

In terms of HIV financing, according to the National AIDS Spending Assessment (NASA) 2016-2017, estimated US$34.5 million was spent in 2017, of which 76% came from international funding [5]. There is an increasing government commitment, with contributions through the Global Fund

co-financing mechanism, whilst the government has committed to contribute US$19.6 million to HIV for the 2021-2023 grant financing period [6]. Although domestic commitments and contributions are gradually stepping up, these contributions are mainly for antiretroviral drugs (ARV) and contract staff salaries [6]. Continuity of funding from Global Fund and other donors is uncertain, therefore it is essential that national key stakeholders prepare a sustainable HIV response, particularly around sustainability of prevention services for key populations.

The 2020 Optima HIV investment case for Cambodia [7] informed the previous Global Fund funding application (2021-2023). This investment scenario analysis builds upon the prior analysis and incorporates new programmatic data and updates from the mid-term review of Health Sector National Strategic Plan (2021-2025) [3] in order inform the Global Fund funding request application in May 2023 for the implementation period of 2024-2026.

The main purpose of this analysis is to develop an investment scenario that maximises the impact of resource allocations, tailored to the unique and specific investment needs in Cambodia and aligned with the Global AIDS Strategy. Investment scenarios will also inform policy decisions in the remaining National Strategic Plan (2023 to 2025) and allocate resources to ensure:

1. Sustained and improved early treatment initiation, treatment coverage and retention across all populations
2. Intensified HIV prevention efforts through differentiated combination prevention packages that are community-led and adequately diversified to serve prevention needs among key populations including the sub-population groups, aligned with the Global Coalition on HIV prevention
3. Bringing new approaches to scale (PrEP, self-testing, index testing) for the right populations and assessing their impact on the HIV response
4. Maximised impact through understanding cost of inaction vis-à-vis returns on investment of high impact interventions including efficiency gains, trade-offs, and alternative options.

2 METHODOLOGY

Mathematical modelling is the primary tool used for key outcomes of the study, informed through stakeholder consultations. This will be achieved by using models to explore the causative relationship between HIV programmes and their impacts on Cambodian HIV epidemic. Thus, the choice of modelling methods and model structures will have considerable importance to ensure the key outcomes can be obtained and analysed rigorously.

This section describes (1) a summary of previously-used HIV transmission models in Cambodia and the modelling methodology we have chosen, (2) stakeholder consultations informing the allocative efficiency analysis including potential implementation efficiencies, (3) the population groups and programmes included in the modelling, (4) the scenarios and optimizations conducted as part of this analysis, including constraints and objective functions.

2.1 Model choice

A number of alternative software packages for modelling HIV epidemics and HIV program impacts and costs already exist, including the AIDS Epidemic Model (AEM) [1], Spectrum, and Optima HIV. Each of these models have a similar structure, and are dynamic compartmental models that track the HIV epidemic over time, relate behavioural parameters to coverage, prevalence and incidence, and produce long-term forecasts. Thus, each of these models requires detailed demographic, epidemiological, behavioural, and clinical data, and all have been used as part of HIV strategic planning. Each model also allows for counterfactual analyses to be run, in terms of both epidemic and programmatic parameters.

Several key differences between models also exist. In both AEM and Spectrum, both the population groups (including people who inject drugs, MSM, and low-, medium-, and high-risk individuals) and the types of HIV programmes that can be modelled (including condom promotion programmes, workplace programmes, male circumcision, ART, HIV testing and counselling, and PMTCT) are fixed. In contrast, Optima HIV allows HIV programmes to be defined to target specific subpopulations within specific geographic areas, with different service delivery models, and with user-specified efficacies. Another difference between AEM and Spectrum compared with Optima HIV is that the former two models do not include undiagnosed PLHIV, so HIV testing is instead assigned an HIV prevention benefit (i.e., HIV testing directly reduces HIV incidence because of behavioural changes by those who either test positive or negative). Finally, although Spectrum and AEM both produce outputs that allow for costs to be calculated externally, they do not include full costing modules, and thus do not currently support mathematical optimization analysis. For optimization, Optima HIV allows users to incorporate real-world constraints associated with all programmes in the optimization analyses (e.g., no one who starts ART is to stop ART; programmes cannot be immediately defunded but may only have reduced funding up to a certain percentage each year to enable a realistic transition).

All models produce similar results regarding epidemic trends. However, due to the importance of conducting a costed optimization analysis, and since this feature is currently only available in Optima HIV, this model has been chosen for the purposes of this study. Appendix A describes key model details.

2.2 Stakeholder consultation

To meet stakeholder needs, the flexibility of Optima HIV to model context-specific subpopulations and programmes was leveraged to answer policy questions through scenario and optimization analyses. This study was conducted in consultation with stakeholder groups through a preliminary workshop and individual discussions that were held in January 2023 listed in Table 1.

Follow-up consultations were held to validate key assumptions for programme costing and programme impacts following cross-referencing of available programmatic data and operational research. Modelling results, recommendations, and policy brief were reviewed and validated by all stakeholder groups during a national workshop held in March 2023. The draft technical report was independently reviewed and shared with all national stakeholder groups for additional feedback and inputs on the context and interpretation of technical results in June 2023.

Table 1: Individual stakeholder consultations

Stakeholder	Key topics	Study inputs reviewed
National Center for HIV/AIDS, Dermatology and STD (NCHADS)	Outline of consultancy, overview discussions	All major model inputs ◆ Population stratification ◆ Program modalities
National AIDS Authority (NAA)	Policy and multisectoral response	◆ Ensuring scenarios and optimizations capture the range of future policy decisions
Ministry of Health (MOH)	Multisectoral response, health system integration of HIV	◆ Ensuring scenarios and optimizations capture the range of future policy decisions
MOH Lead Implementation Team (MOH-LIT)	Global Fund primary recipient perspective	◆ Ensuring scenarios and optimizations capture the range of future policy decisions
Ministry of Economy and Finance (MEF)	Sustainable government financing of HIV	◆ Long-term sustainability ◆ Mechanisms for multisectoral financing
UNAIDS	Overview of HIV response	◆ Overview of all scenarios, optimizations, and model implementation
UNFPA and NMCHC	Efficiency gains through PMTCT programme/ services	◆ Linkage between PMTCT, infant, child, and adolescent programs for HIV
WHO and CRS	Good practices in treatment programme,	◆ Program effects, HIV treatment and adherence, prisoner programs ◆ Potential cost and implementation efficiencies

Stakeholder	Key topics	Study inputs reviewed
KHANA and RHAC	Efficiency gains through community-led response	◆ Detailed key population outreach modality costing, implementation details, and targeting ◆ Opportunities for implementation efficiencies
Chhouk Sar Clinic	Novel program implementation	◆ Scalability of innovative program modalities ◆ Program efficacy values, focusing on loss to follow up
Community partners/implementing NGOs ◆ ARV Users Association (AUA) ◆ Cambodian Women for Peace and Development (CWPD) ◆ National Female Entertainment Workers Network (EWNET) ◆ Bandanh Chaktomuk (BC) ◆ Cambodian Network of People Who Use Drugs (CNPUD	Efficiency gains through community-led response	◆ Risks present in scenarios around future funding: what behavioural impacts would there be if coverage was reduced? ◆ Saturation levels of programmes: could coverage be increased? ◆ Opportunities for efficiencies? ◆ Understanding of key population perspectives on HIV services available
FHI 360-EpiC	Innovations and programmatic components	◆ Program costings and effects
PEPFAR (USAID and US CDC)	PEPFAR support, sustainability, programme components	◆ Risks present in scenarios around future funding ◆ Priorities and realistic constraints on programmes
Clinton Health Access Initiative (CHAI)	Supply chain, ARV (incl paediatric), VL, PrEP, self-test kits	◆ Unit costs for ART modalities and other commodity procurement costs ◆ Opportunities for stratification of ART modalities ◆ Future costing scenarios to be explored PMTCT
LHSS	Costing and policy analysis	◆ Subnational prioritization, deconcentration and decentralization

2.3 Population and programmes

This analysis stratified populations by risk and age group, and included programmes as outlined in Table 2. Each population is disaggregated by age (for key populations 15-19, 20-24, 25-49, for non-key populations 0-14, 15-19, 20-24, 25-49, and 50+). Detailed population definitions are available in Appendix B and programme definitions are available in Appendix C.

Table 2: Population groups and HIV programmes included in this analysis

Population groups	HIV prevention programmes
Males who inject drugs (PWID)	◆ HIV prevention and testing for PWID through physical outreach ◆ HIV self-testing for PWID reached by other modalities ◆ Needle-syringe programmes ◆ Opioid agonist maintenance therapy ◆ PrEP with demand creation for PWID
Female entertainment workers 1 (FEW 1) Female entertainment workers 2 (FEW 2)	◆ HIV prevention and testing for FEW through night-time or mobile van outreach ◆ HIV prevention and testing for FEW through physical outreach ◆ HIV prevention and testing for FEW through virtual outreach ◆ HIV self-testing for FEW reached by other modalities ◆ PrEP with demand creation for FEW
Men who have sex with men 1 (known risk and/or reachable) (MSM 1) Men who have sex with men 2 (unknown risk) (MSM 2) Men who have sex with men who use drugs (engaged in sexualized drug use) (MSMUD)	◆ HIV prevention and testing for MSM through virtual outreach ◆ HIV self-testing for MSM reached by other modalities
	Programmes that reach mixed networks of MSM and TG populations ◆ Enhanced key population tracing and outreach (PDI+, index testing) ◆ HIV prevention and testing for MSM and TG through physical outreach ◆ HIV prevention and testing for MSM and TG through night-time or mobile van outreach ◆ Pre-exposure prophylaxis (PrEP) ◆ PrEP with wider demand creation for MSM and TG ◆ PrEP with demand creation for MSM and TG 20-24 ◆ PrEP with demand creation for MSM and TG engaged in chemsex
Transgender women (TG) Transgender women who use drugs (engaged in sexualized drug use) (TGUD)	◆ HIV prevention and testing for TG through virtual outreach ◆ HIV self-testing for TG reached by other modalities
Clients of female entertainment workers (Clients) Non-key population males Non-key population females	*Programmes that reach a mix of key and non-key populations* ◆ ART adherence support for key populations ◆ HIV testing for prisoners ◆ Prevention of mother-to-child transmission (testing) *HIV treatment programmes assumed to continue at reported 2022 coverage levels of 99% of people diagnosed and retained in care: Antiretroviral therapy (ART) including multi-month dispensing and community aided delivery (CAD), viral load testing, and prevention of mother-to-child transmission (PMCT)*

2.4 Model calibration

Inputs for the model were updated based on sources shared by stakeholders including programmatic data, with historical trends calibrated closely to final 2022 modelled values from AEM and Spectrum (modelling conducted for national HIV estimates). This was done to identify the potential for Cambodia to reach virtual elimination of HIV by 2030 given a rapid and sustained scale-up of funding by the Royal Government of Cambodia. See Appendix B.

2.5 Scenario and optimization analyses

The optimized spending scenarios apply a mathematical optimization algorithm (Appendix A) to determine the most cost-effective distribution of spending across HIV prevention and adherence programmes projected to maximise the reduction of new HIV infections and AIDS-related deaths by 2030. Scenarios and budget optimization were conducted relative to a baseline scenario. This baseline scenario consisted of assumed continuation of 2022 HIV prevention spending. The annual HIV prevention spending for 2022 was estimated at US$3.3 million based on the costs of HIV service delivery and number of people in key populations reached in 2022, using programmatic and costing data supplied and validated by civil society organisations (CSOs) and other organizations implementing current modalities. HIV prevention spending in 2023 was assumed to remain unchanged from 2022, with any changes in spending by scenario taking place from 2024 to 2026. Figure 3 shows the HIV prevention spending in the context of the estimated total 2023 HIV budget of US$21 million, which includes one third of US$42 million in Global Fund financing over three years (US$14 million per year), and annual US$6.9 million in government co-financing committed for 2023. Not included in these estimates is direct technical assistance through Meeting Targets and Maintaining Epidemic Control (EpiC) and multisectoral and enabling environment expenses through the National AIDS Authority (NAA). Appendix D details the estimated baseline allocation of HIV prevention spending to programmes.

Stakeholders identified key scenarios in Table 3, covering the risk of reduced resource availability for HIV prevention programmes in the future, the opportunity for increased funding through the Global Fund over the next funding cycle, and what optimized response would be necessary to reach the national 2025 and ending AIDS targets. The targets include 95% diagnosis, 95% treatment coverage, and 95% viral suppression combined with less than 250 new HIV infections per year.

2.5.1 Optimization constraints

In all scenarios, ART and prevention of mother-to-child transmission (PMTCT) were assumed to remain available to all diagnosed people living with HIV, with additional funding for these treatment programmes to remain available. An additional constraint was applied that spending on Opioid agonist maintenance therapy (OAMT) could not be decreased due to ethical considerations of ongoing treatment.

In optimizations with decreased available resources, a constraint was applied that it was not possible to increase spending on any existing programme by more than 10% (to represent that for example it would not be possible to significantly increase PrEP coverage if outreach was reduced at the same time).

In optimizations with increased available resources, a constraint was applied that it was not possible to decrease spending on any existing programme by more than 10% (due to considerations of equity and the risk of impacting on non-HIV-related benefits of existing programmes to key populations).

2.5.2 Optimization objectives

Optimized budget allocations were run with an objective function to minimize the total number of projected HIV infections and HIV-related deaths from 2023 to 2030, using a 1 to 5 weighting ratio for infections to deaths, assuming an immediate change in allocation (Appendix A.3 gives full details).

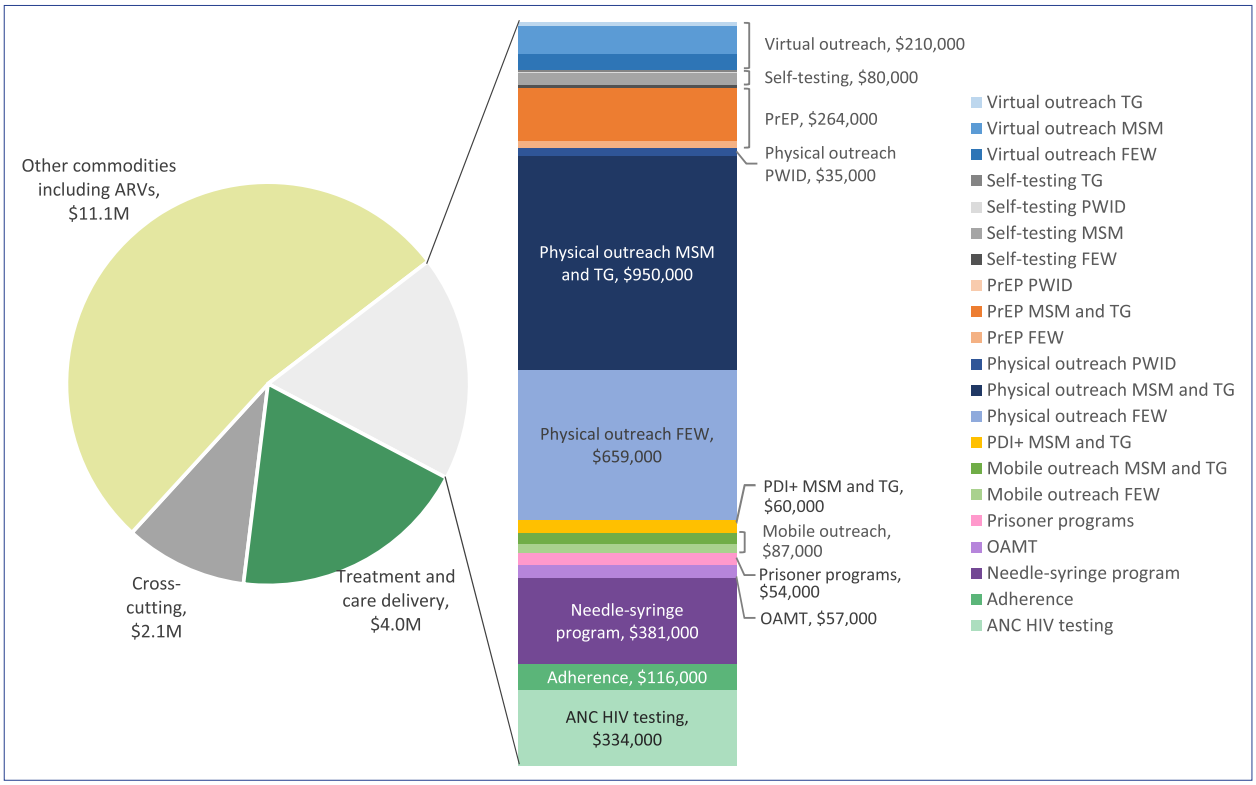


Figure 3. a) Total HIV budget for 2023 and b) breakdown of key population outreach and HIV prevention including commodities and adherence budget in 2022 (excluding prospective modalities not yet implemented).

Table 3: Optimization analyses

Scenario	Description
Phaseout of key population outreach and HIV prevention programmes	This counterfactual scenario represents a 'worst case' if all international support for HIV programmes in Cambodia ceased and was not replaced by additional government spending. In this scenario, all key population outreach and HIV prevention spending would be defunded by 2025.
Baseline spending on key population outreach and HIV prevention programmes	This scenario represents consistent ongoing annual spending and allocation for key population outreach and HIV prevention programmes from 2024 to 2030, fixed at the estimated 2022 HIV budget of US$3.3 million per year.

Scenario	Description
Optimized spending on key population outreach and HIV prevention programmes at different budget levels, with an assumption that there has been no change in allocation in 2023, and changes in allocation would take place over 3 years 2024 to 2026 and then be held constant from 2027 to 2030. Total future budget envelopes considered for optimization included: ◆ US$1 million less per year available (US$2.3 million per year) ◆ Continued 2022 baseline resource envelope (US$3.3 million per year) ◆ US$1 million additional per year from 2024 to 2026 to reach scale (US$5.3 million per year from 2027 to 2030) ◆ US$2 million additional per year from 2024 to 2026 to reach scale (US$7.3 million per year from 2027 to 2030	These optimizations represent the potential for reduced HIV infections and HIV-related deaths if spending was optimally allocated, both within the 2022 budget envelope, as well as if either fewer or additional resources were available. 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 2030 given the local epidemic parameters and data, cost of delivering services, subject to the above constraints.
Necessary interventions to meet 95-95-95 targets and less than 250 new HIV infections by 2030	This analysis explores the identification of a combination of the most cost-effective interventions and implementation efficiencies that will bring the national HIV targets for Cambodia within reach by 2030.
Historical impact of investments in HIV prevention programmes for key populations	This analysis aims to estimate HIV infections averted through historic investment (2001 to 2022) in targeted HIV prevention and testing programmes for key populations.

3 RESULTS

3.1 Optimized budget scenarios

The optimized allocation of spending across 24 modelled HIV prevention and adherence interventions to minimize new HIV infections and HIV-related deaths prioritizes additional spending on tailored services for MSM and TG (Figure 4) with a focus on virtual outreach, PrEP demand creation and PDI+ (Figure 5). With 2022 budget maintained, additional spending comes from up to 10% cost-efficiency savings on other programmes. With up to $2M additional budget available, PrEP is most highly prioritized for expansion. Recommendations based on the prioritized allocation of HIV resources are summarized in Table 4.

With 100% of 2022 spending optimized, it may be possible to reduce cumulative new HIV infections over 2024 to 2030 by 8% compared to if current spending and allocations were maintained. This could increase to 46% of new infections averted with the optimized investment of an additional annual US$1M. With the optimized investment of an additional annual US$2M plus multisectoral response initiatives, up to 70% of new HIV infections could be averted (Figure 6).

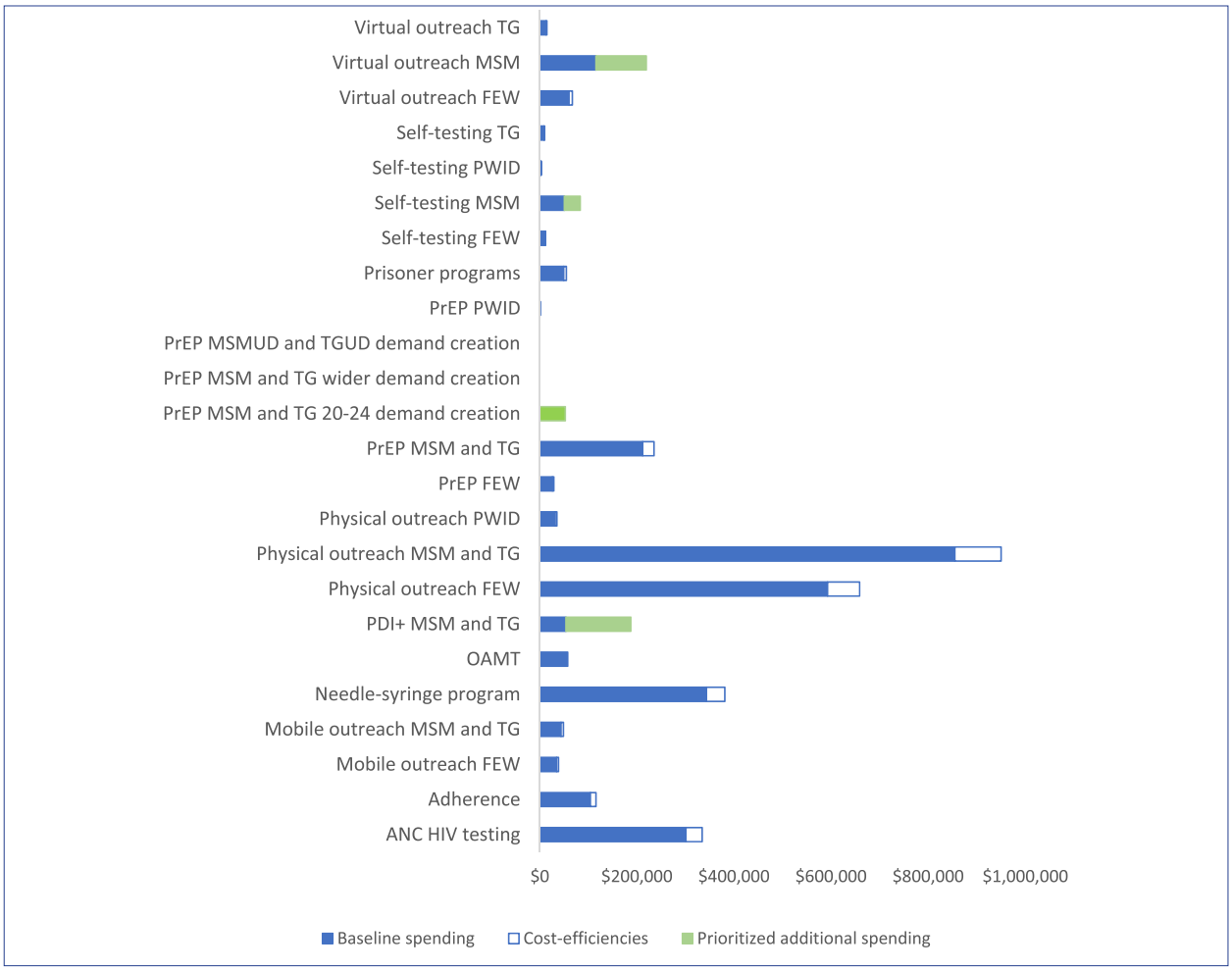
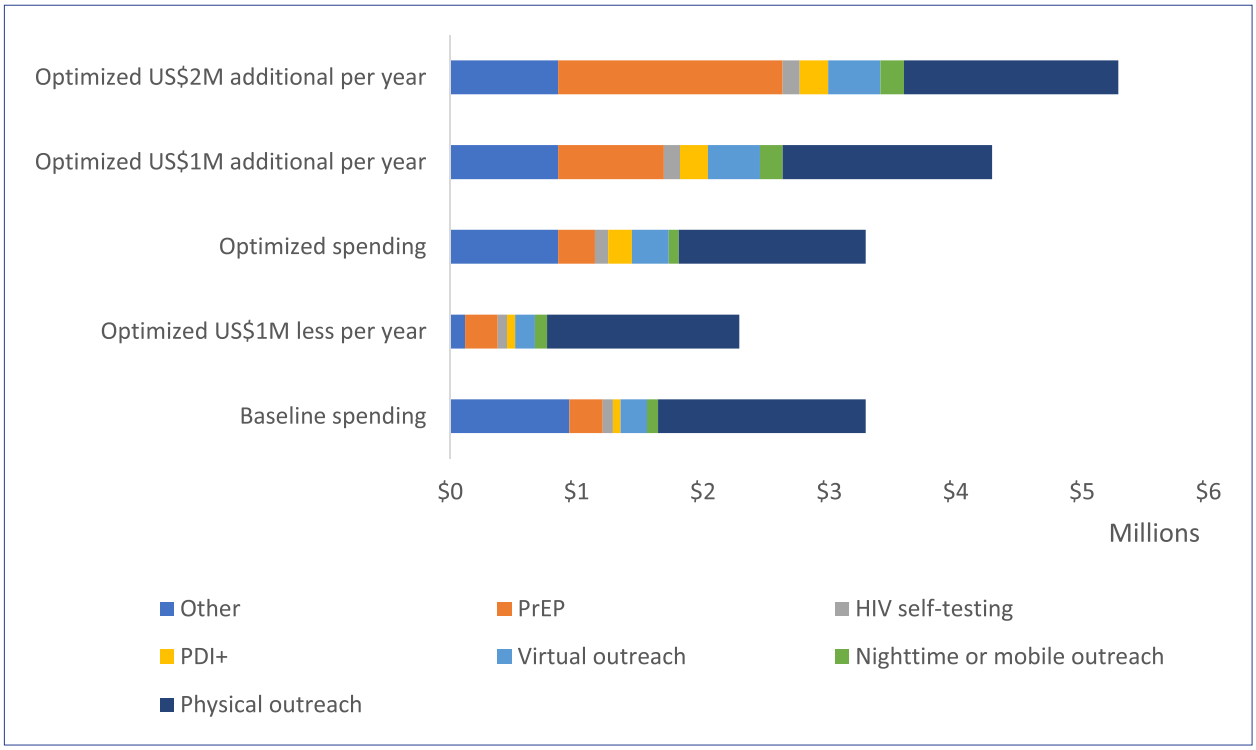
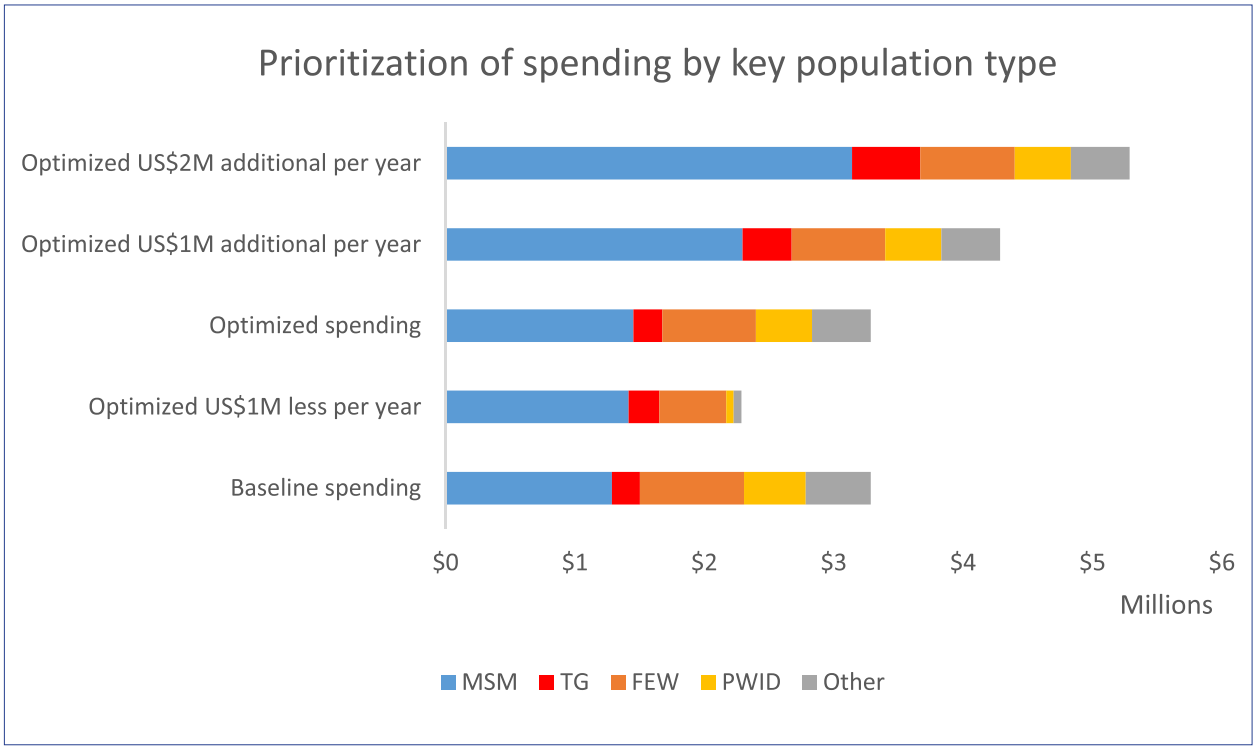


Figure 4: Reallocation of funds by program within the optimized spending of the estimated 2022 HIV prevention budget, showing reduced spending as cost-efficiencies.



(a) Prioritization of spending by outreach type. "Other" includes antenatal HIV testing, needle-syringe programmes, OAMT, adherence programmes, and prisoner programmes.



(b) Prioritization of spending by reach of key population. "Other" includes antenatal HIV testing, adherence programmes, and prisoner programmes, that each reach a mix of key and non-key populations.

Figure 5: Average allocation of annual HIV resources in each scenario from 2024 to 2026 by a) outreach modality, b) target population.

Table 4: Prioritized allocation of HIV resources under optimization allocation, 2020 – 2030

Resource availability	Recommendation	Pathway
2022 HIV prevention budget envelope	Investigate implementation efficiencies, plus: ◆ Expand the high-yield interventions of PDI+, self-testing availability, and virtual outreach for MSM and TG (+$250k/year) ◆ Prioritize PrEP demand creation among MSM and TG aged 20-24 (+$50k/year)	Cost savings of 10% on other HIV prevention including physical outreach
Optimized US$1M additional per year from 2024-2026 to reach scale and US$2M per year to sustain HIV services	With recommendations (including 10% cost savings) within the 2022 HIV prevention budget envelope plus: ◆ Expand the high-yield interventions of PDI+, self-testing availability, and virtual outreach for MSM and TG (+$250k/year) ◆ Further expand night-time, mobile, virtual, and other physical outreach for MSM and TG (+$250k/year) ◆ Wider PrEP demand creation among MSM and TG (+$800k/year), prioritized to reach MSM and TG aged 20-24 as well as MSM and TG engaged in sexualized drug use. Sustain higher levels of 2026 coverage from 2027-2030 with additional annual US$2M per year (total estimated annual US$5.3M for HIV prevention programmes)	
Optimized US$2m additional per year plus PrEP demand creation costs from 2024-2026 to reach scale, and US$4M per year and a multisectoral response to sustain HIV services	With recommendations (including 10% cost savings) within the 2022 HIV prevention budget envelope plus: ◆ Expand the high-yield interventions of PDI+, self-testing availability, and virtual outreach for MSM and TG (+$250k/year) ◆ Further expand night-time, mobile, virtual, and other physical outreach for MSM and TG (+$350k/year) ◆ More rapid scale-up of PrEP including long-acting PrEP, subject to procurement availability and demand (+$1,550k/year), prioritized to reach MSM and TG aged 20-24 as well as MSM and TG engaged in sexualized drug use. ◆ Expand outreach to female entertainment workers (FEW), with a primary focus on night-time and mobile outreach that reaches street based FEW (+$100k/year) ◆ Expand ART adherence programmes for key populations (+$50k/year) Sustain higher levels of 2026 coverage from 2027-2030 with additional annual US$4M per year (total estimated annual US$7.3M for HIV prevention programmes, excluding costs for multisectoral response that leverages resources from outside of the HIV sector)	◆ GF PAAR request ◆ Potential cost savings ◆ Domestic mobilization ◆ Private sector engagement

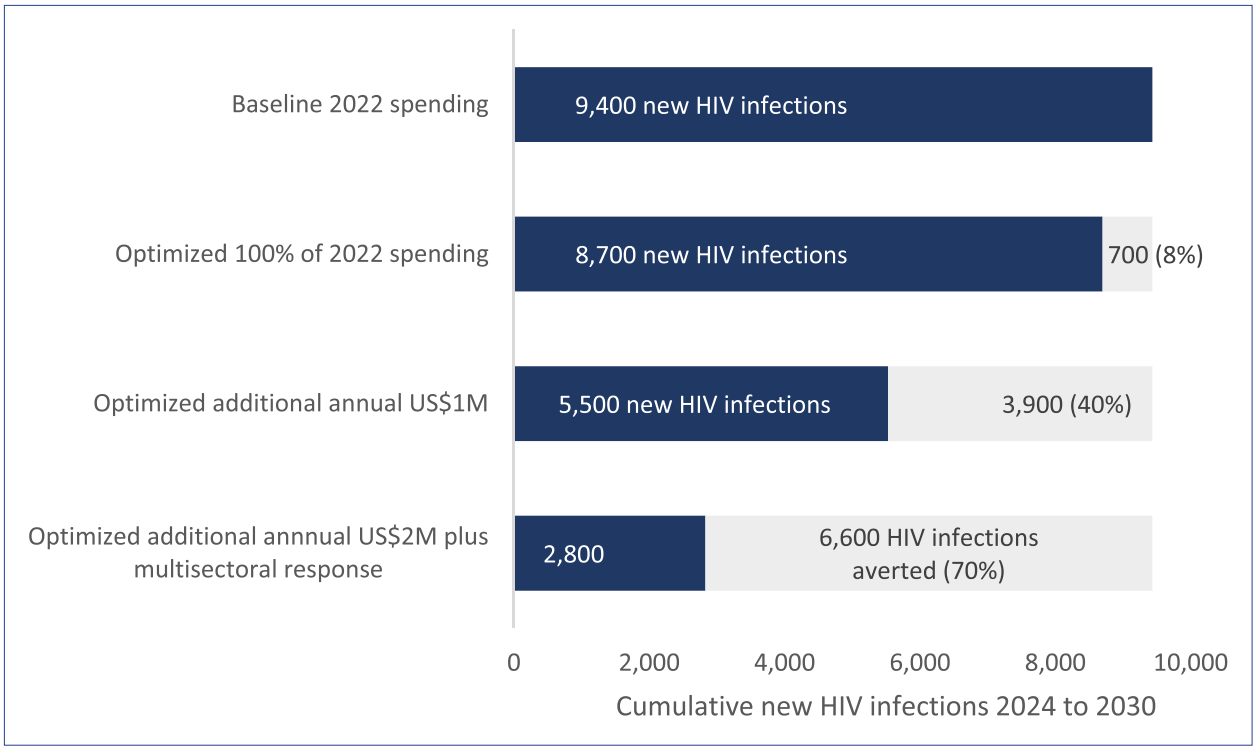


Figure 6: Projected cumulative new HIV infections 2024 to 2030 with optimized and additional resources.

3.2 Progress toward 2025 targets

If HIV programme spending as given in the 2022 HSSP budget were to be maintained from 2023 to 2030 in the baseline scenario, it is projected that 95-95-95 targets are within reach or will be exceeded by 2030, but that the target reduction in new infections will not be possible within the current budget envelope as summarized in Table 5.

Table 5: Projected achievement status of HIV targets by 2025

HIV targets by 2025	Projected baseline status by 2030
95% HIV diagnosis	Not on target: 86% in 2022; but achievable by 2030 with optimized allocation of resources.
95% treatment among those diagnosed	Exceeded: 99% achieved
95% viral suppression among those on treatment	Exceeded: 98% achieved
<250 new HIV infections	Not on target: 1,400 in 2022; but may be **within reach by 2030** with increased HIV prevention resources combined with a multisectoral response.

3.2.1 Within reach: 95% HIV diagnosis

Meeting the target of diagnosing 95% of people living with HIV will be challenging, but it is within reach for Cambodia. If the most recently reported spending is maintained, it is projected that diagnosis will be 92% by 2030. However, reaching the remaining population will be increasingly

difficult and expensive, as many of those undiagnosed are from key and vulnerable populations with 'unknown risk', as well as their partners who are not being reached at the current scale and modality of prevention interventions.

Additional diagnoses are projected to be possible through a combination of innovative outreach modalities including self-testing (both assisted and unassisted), physical and virtual outreach, social media and night-time outreach, peer-driven intervention plus (PDI+). Figure 7 shows that US$2M in additional budget, under an optimized allocation is projected to approach this target, but additional implementation efficiencies may be necessary to reduce undiagnosed infections further.

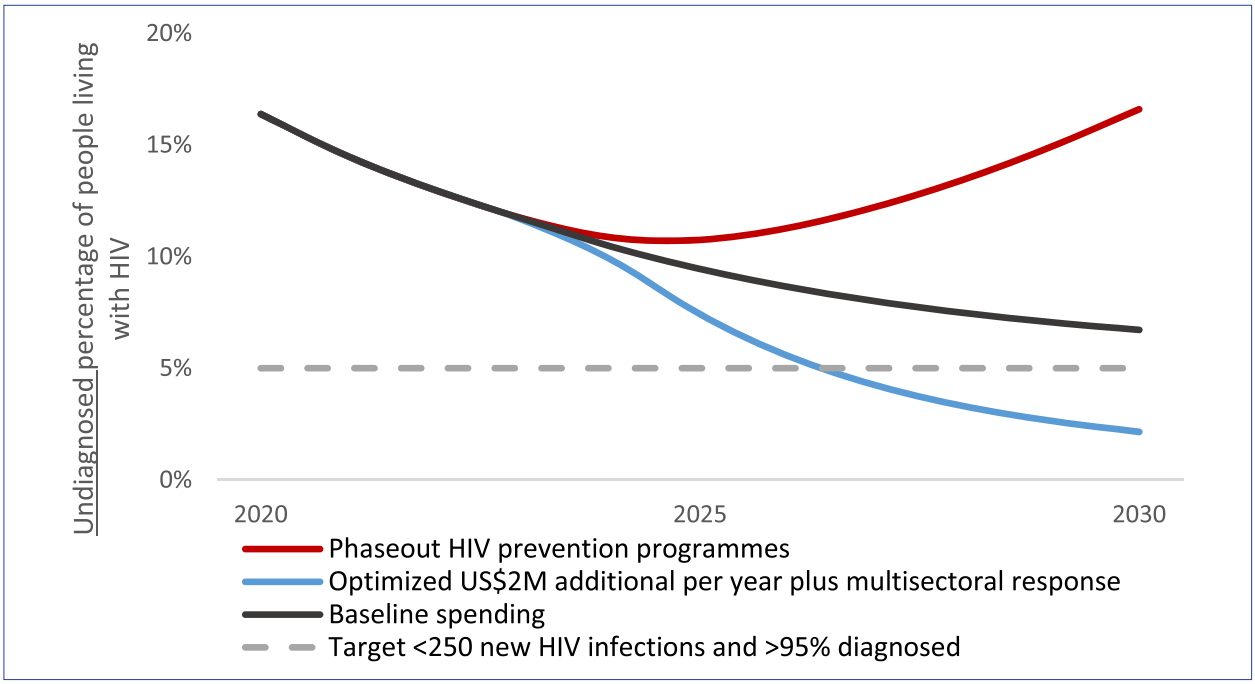


Figure 7: Projected progress toward 95% HIV diagnosis

3.2.2 Exceeded: 95% treatment among those diagnosed

Based on programmatic data, Cambodia is already exceeding the 95% target for people living with HIV who are diagnosed and receiving treatment. Further gains in ensuring continuity of care may be possible by reducing rates of loss to follow-up through improved delivery of adherence programmes such as effective enhanced adherence counselling.

3.2.3 Exceeded: 95% viral suppression among those on treatment

Based on programmatic data, Cambodia is already exceeding the 95% target for viral suppression among diagnosed people living with HIV and receiving treatment. Further gains may be made by reducing rates of loss to follow up through adherence programmes for key populations on treatment. Additional recommendations as part of the National Strategic Plan include strengthening understanding of viral suppression among people living with HIV and continuing to move to newer ARV regimens which are well tolerated and highly efficacious such as Tenofovir, Lamivudine, and Dolutegravir (TLD) [3].

3.2.4 Not on target: Less than 250 new HIV infections per year

Cambodia has had great success in reducing the number of new HIV infections, from an estimated 15,000 per year in 1996 to approximately 1,400 in 2022. However, the remaining reduction in incidence

needed to reach less than 250 new infections per year is also the most difficult, and projections are that under the current interventions, new HIV infections are likely to stabilize at around 1,300 per year.

With an additional US$2M per year and optimized allocation of resources including a multisectoral response detailed in Section 3.3, the target of less than 250 new infections per year may be achievable by 2030.

Although it is recommended to invest additional resources in new interventions, continued investment in current prevention programmes remains important to prevent a rebound in new HIV infections. In the absence of prevention programmes for key populations, there is the risk that HIV progress could be reversed, with new infection projected to nearly triple from 2022 values by 2030 with those new infections primarily in MSM, MSMUD, TG and TGUD (Figure 8).

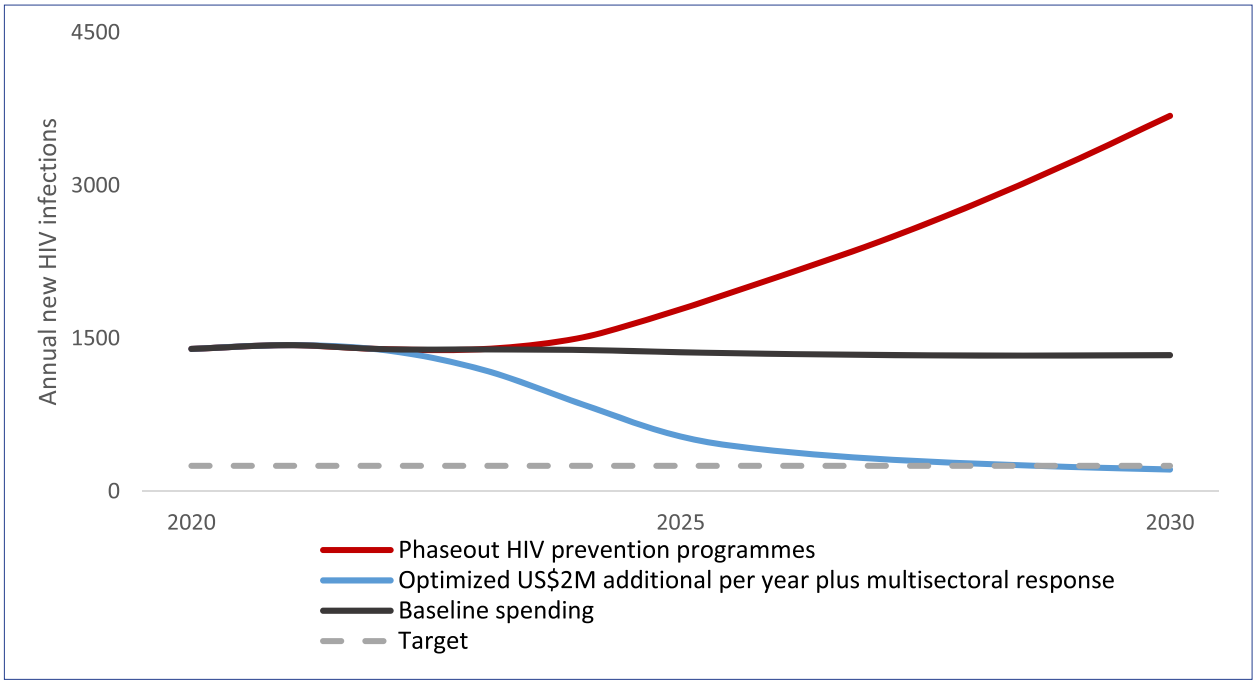


Figure 8: Projected progress toward less than 250 new HIV infections per year

3.3 Implementation efficiencies and multisectoral response

There are very cost-effective opportunities to reduce new infections through existing programmes with additional investment, and a focus on novel HIV prevention and testing modalities may make 95% diagnosis achievable by 2030. However, even with additional spending of up to US$2 million per year it is projected that the target of less than 250 new infections will not be met by 2030. Additional optimizations were conducted at higher budget levels to determine the minimum spending necessary to reach these targets. Achieving the target using only defined programme modalities was projected to require prohibitively increased spending to reach people living with HIV outside of the accessible 'known risk' key populations.

Implementation efficiencies

Stakeholders identified the following opportunities as potentially improving either cost-efficiency or impact of existing HIV programmes, and that could be modelled as having a quantifiable impact. Appendix F details the modelled assumptions for each of these potential efficiencies.

3.3.1 Improved partner notification tracing and testing (PNTT)

There is a large loss in the diagnosis cascade between people that agree to PNTT and partners that are tested. Improved PNTT as an implementation efficiency is likely to increase diagnosis rates especially for clients and regular partners of clients who are currently under-diagnosed.

3.3.2 Condom availability

10% of MSM identified a lack of availability as being the main reason they did not use a condom the last time they had condomless sex (IBBS 2019). Logistics to get already procured condoms where and when they are needed combined with legal concerns about storing condoms on premises where sex may occur means that there is scope to increase condom use without extra HIV spending by both improving logistics and reducing legal barriers.

3.3.3 Proposed higher renumeration for outreach workers

Outreach work continues to be the cornerstone of HIV prevention and testing in Cambodia. For example, in-person outreach has the greatest reach and contribution to case finding. However, outreach is an extremely demanding job with overwhelming caseloads, extended hours and security concerns, which lead to stress-related burnout and high turnover. In addition, the compensation package for outreach workers of US$200 per month is only US$6 more than the national minimum wage as of 01 January 2022. Due to agreement from stakeholders, increased renumeration for outreach workers was factored into an estimated 15% increase in the CSO component of unit costs for delivery of HIV services from 2024. While no direct impact on the quality of service delivery was modelled, stakeholders viewed this change as enabling more specialised responses to meet the needs of key populations including delivering high-yield interventions tailored to reach young people aged 15-24.

Multisectoral response

The below changes in service delivery requiring a multisectoral response and funding from outside of the HIV sector were identified by stakeholders as potentially improving HIV prevention or diagnosis, and that could be modelled as having a quantifiable impact. Appendix F details the modelled assumptions for each of these multisectoral responses.

Delivery of these and other multisectoral responses recommended by stakeholders in Section 4 will require ministries including the following identified key ministries to work with the Ministry of Health to support, improve and ensure enabling environment, equity in access to services, and mobilize domestic resources: Ministry of Tourism, Ministry of Social Affairs, Ministry of Information, Ministry of Interior, Ministry of Planning, Ministry of Education, Youth and Sports, Ministry of Labour and Vocational Training, Ministry of Economy and Finance, Ministry of Posts and Telecommunication, and Ministry of Women's Affairs.

3.3.4 Improved STI diagnosis and treatment

Syphilis prevalence has risen rapidly from 2020 to 2023 [3]. This could indicate an increase in sexual risk-behaviour and increases susceptibility to HIV transmission by nearly three-fold. Improved STI testing and treatment and reduced syphilis prevalence may have benefits in earlier diagnosis of HIV and reduced HIV transmission in addition to other health benefits, especially for entertainment workers.

3.3.5 Comprehensive sexuality education (CSE)

There is decreasing awareness among youth (especially key populations) aged 15-24 about HIV and other STIs, and lower condom use as a result. Additionally, there are legal barriers and other challenges to accessing HIV services before age 18 years, which leaves a critical gap in services for key populations aged 15-17 who are no longer in school, infrequently access regular health services, and are not readily able to access HIV services, at the same time as experiencing heightened HIV transmission risks. School-based CSE presents an opportunity to reach young persons aged 10-14 with appropriate information before they become sexually active. This may be able to increase HIV awareness and intention to use condoms for a longer-term HIV epidemic impact as well as providing other health and social benefits for youth.

3.3.6 Private self-test availability and self-referral

Increased availability of HIV self-testing and awareness of HIV test availability may enable increased diagnosis among additional people who have experienced HIV transmission risk but are not comfortable accessing HIV services.

3.4 Historical impact of HIV prevention programmes for key populations

The modelled implementation of programmes is focused on their cost and impact relative to the most recently reported epidemic situation. However, there is also interest in understanding the cumulative historical impact of HIV prevention programmes for key populations, which requires counterfactual assumptions about what would have happened in the absence of these scenarios.

The cumulative impact of targeted spending on HIV prevention for key population programmes for MSM, TG, FEW, and PWID can be estimated through comparing the baseline scenario with counterfactual scenarios where this spending ended after 2001, 2010, or 2020 (Figure 9). All other programmes including generalized education campaigns, condom distribution, antenatal testing, provider-initiated testing (including testing for people with AIDS), HIV treatment and viral load testing including for key populations, were assumed to remain available in all scenarios.

An estimated 67,000 HIV infections occurred from 2001 to 2023 in Cambodia, which may have reached 126,000 in the absence of these programmes. In total, 59,000 cumulative new HIV infections over 23 years from 2001 to 2023 may have been averted by HIV prevention programmes for key populations, which is nearly half of the potential new HIV infections. These results suggest that key population programmes have become increasingly important since 2015 due to both lower spending on generalized programmes and novel risk among key populations (e.g. sexualized drug use). If HIV prevention programmes for key populations were defunded in 2020, new HIV infections may have been nearly double in 2023 (2,600 compared with 1,400).

In these scenarios, the reduction in new HIV infections occurring in all scenarios from 2001 to 2012 can primarily be attributed to the rapid scale-up of ART. In line with historical epidemic trends, FEW and Clients would have experienced most additional new HIV infections from 2001 to 2010 without key population programmes. MSM would have been most disproportionately impacted overall by defunding HIV prevention programmes since 2001, with up to five times as many cumulative new HIV infections. Due to experiencing both higher risk of transmission and lower probability of testing in the absence of programmes, MSM remain most vulnerable to reduced prevention spending in 2023.

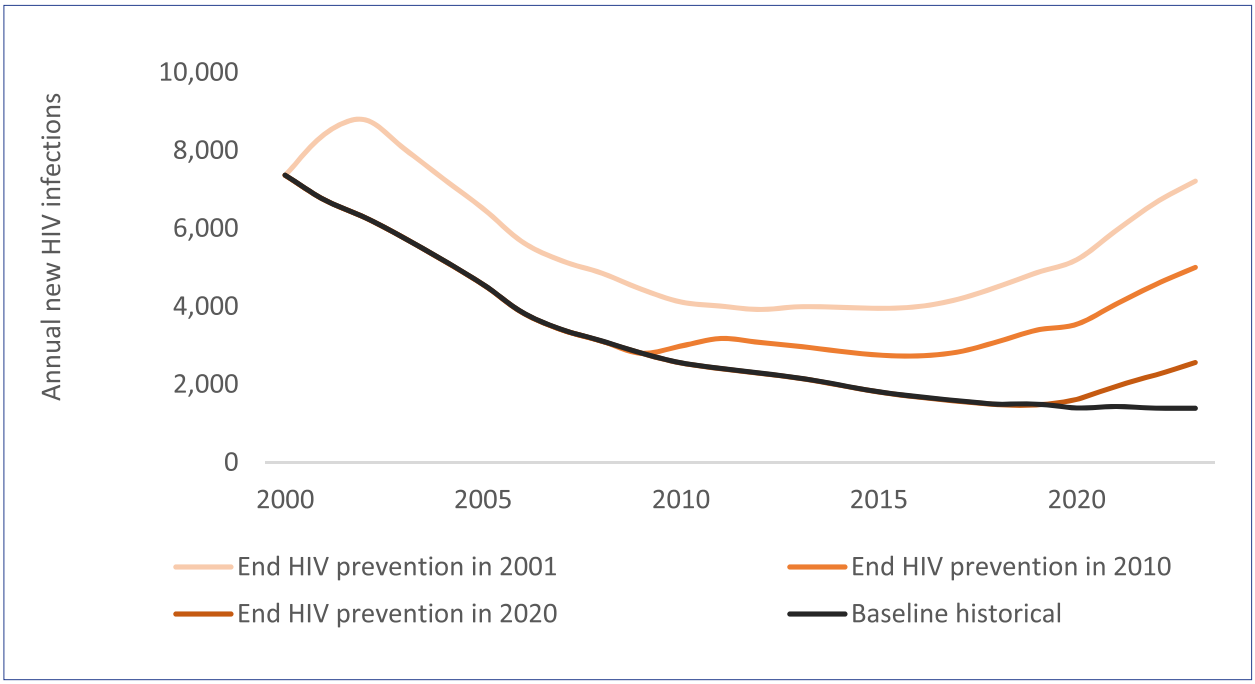


Figure 9: Estimated new HIV infections 2000 to 2023 under baseline and counterfactual scenarios

Cumulative HIV infections in non-key populations may have been 30% higher in the absence of HIV prevention programmes for key populations due to secondary partnerships.

4 DISCUSSION

A comprehensive package of HIV services is needed

Included in this analysis are a number of modalities for delivering prevention and testing interventions. These modalities are physical outreach, night-time or mobile van outreach, virtual outreach, peer driven interventions plus (PDI+) and HIV self-testing. Each modality has strengths and weaknesses, but when implemented together they combine to have maximum impact and reach that caters to the varying needs and preferences of key population groups and their sub-populations.

Physical outreach programmes are the most effective modality for reaching hotspot-based key populations (including some FEW 1, MSM 1, and some FEW 2, MSMUD, TG, TGUD). They provide primary prevention and through regular engagement, and are effective in increasing condom used with casual and commercial partners. Physical outreach programmes typically have a low positivity yield in HIV testing, which may be a sign of successful prevention and repeat engagement. However, they tend to have a lower impact among youth, especially for condom use-based prevention, and have limited reach for those populations engaged in chemsex and injecting drug use.

Night-time or mobile van outreach programmes are effective at expanding the primary prevention in physical outreach to harder-to-reach populations for hotspot-based key populations. They have a moderate effect on condom use with casual or commercial partners given less regular contact with clients. However, similarly to physical outreach programmes, night-time or mobile van outreach programmes tend to have a lower impact among youth and only have partial reach among populations engaged in chemsex and injecting drug use.

Virtual outreach programmes are the most effective modality for reaching key populations aged 15-24. They are also effective at reaching those key populations engaged in chemsex. They have an extremely high yield for HIV testing, especially for MSM, although this is limited by a low conversion from reach to testing. However, they are less effective at reaching people aged over 30, and only have a partial reach for hotspot-based key populations. They also have a limited impact on condom use with casual and commercial partners, as many of the contacts do not result in either testing or condom distribution.

PDI+ programmes are effective at reaching "hidden" populations at all age ranges and those outside hotspot-based populations, especially those engaged in chemsex, whom other modalities may find difficult to reach. They have an extremely high conversion rate from reach to testing, combined with high positivity yields, especially for TG populations.

HIV self-testing programmes are effective at improving the acceptability and accessibility of HIV testing in all age ranges and risk categories, as self-testing may help overcome stigma associated with traditional HIV testing. They have an extremely high positivity yield in Cambodia, especially among MSM, which indicates success in providing acceptable care to people who are reached by outreach modalities and HIV services, but who have not previously been tested.

Hence, to reach all age ranges, risk categories and impacts via condom use and HIV testing rates it is necessary to implement all these modalities. Reducing funding for any of these may limit the ability for HIV programmes to have maximum impact on both case prevention and detection.

Engaging young MSM and TG with HIV services

Delivery of HIV prevention and testing services through comprehensive service modalities can help to overcome the limits of any single modality and achieve greater reach and impact among young MSM and TG. While 86% of all people living with HIV are estimated to be diagnosed in 2022, we estimate that 66% of all young people living with HIV aged 15–24 years are diagnosed, and just 40% of young MSM and TG living with HIV are diagnosed. Among 15–19-year-old MSM and TG engaged in chemsex and living with HIV (less than 200 people), only 20% are estimated to be diagnosed. More focus on differentiated outreach to reach these populations at a younger age with HIV awareness, prevention, and testing is critical to meeting HIV targets.

There are significant opportunities to expand the reach of HIV services and engage more MSM and TG aged 15-24 through the expansion of virtual outreach, self-testing, PDI+, and night-time and mobile outreach as shown in Figure 10.

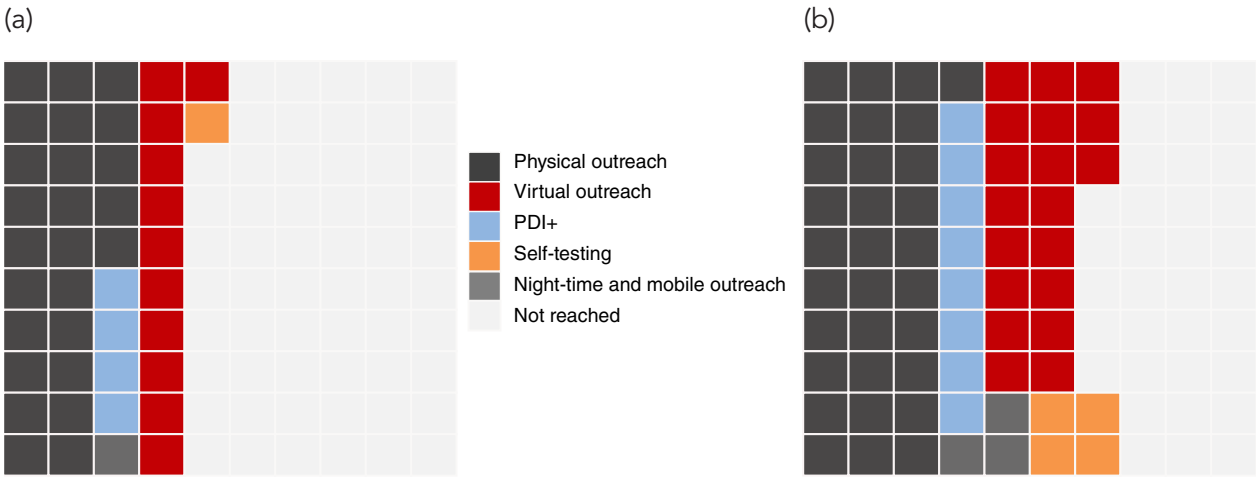


Figure 10: Estimated coverage of MSM aged 15-24 in a) 2023 (42%) and b) with optimized US$2M additional (65%). Each square represents 1% of the MSM aged 15-24 population.

Additional stakeholder recommendations

There were a number of recommendations made by stakeholders that could not be quantified in the Optima HIV model as part of this analysis, either due to a lack of evidence on impact, a lack of cost estimates, or outside of the scope of allocative efficiency.

- Additional modalities of PrEP
  - Stakeholders reported that one of the key barriers to PrEP uptake is the acceptability of taking daily oral pill. Long-acting PrEP, such as the injectable CAB-LA, if available to Cambodia at a procurement cost in line with oral PrEP, has been suggested as a key potential pathway to rapid expansion of PrEP coverage among key populations at highest risk of HIV both through increasing uptake and reduced turnover. At the time of this analysis cost comparisons were not possible, and survey data to compare acceptability of PrEP modalities was not available. However, awareness of long-acting PrEP is high among stakeholders, and this can be seen as a priority for further exploration.

- Similarly, the dapivirine ring may be an effective and acceptable method of HIV prevention for FEW at highest risk (e.g. street-based FEW). At the time of this analysis neither the cost or acceptability of the dapavirine ring could be evaluated, but a feasibility and acceptability study to be conducted in the second half of 2023 may generate evidence necessary to evaluate this as an alternative intervention.

- In addition to these modalities of drug delivery that may increase the acceptability of PrEP, modalities of PrEP that improve accessibility are under consideration in Cambodia. TelePrEP would allow clients to self-test or go to a commercial lab and have PrEP sent by courier. Mobile PrEP would be offered to clients screening negative in the field during hotspot testing. Both have the potential to increase the participation of key populations at high risk of HIV transmission, as part of achieving PrEP scale-up targets.

- Health service access for people living with HIV

  - The inclusion of people living with HIV under the IDPoor scheme and thus able to access free health services was seen as very positive both for individuals and for structural change, but there may be opportunities to improve the implementation in terms of clinic incentives for multi-month dispensing and privacy of individual people living with HIV.

- Geographical prioritization

  - While outside of the scope of this analysis, stakeholders have reported increasing evidence of subnational heterogeneity in HIV incidence patterns. There may be opportunities to prioritize expansion of programmatic coverage and address barriers to accessing existing HIV services in locations with higher incidence.

- Reallocation within grant cycles

  - Flexibility to efficiently re-program within the grant cycle from 2024–2026 would allow the HIV programme to respond to emerging evidence more rapidly.

- Community-based services or social contracting

  - Expanded and prioritized resources for HIV services that reach key populations who have not previously had access to HIV services may allow Cambodia to continue a remarkably successful HIV response and exceed all national HIV targets by 2030. Development and operationalization of social contracting mechanisms may offer sustainability of those HIV services beyond 2030.

- Sexualized drug use among other populations

  - Stakeholders reported anecdotal evidence that while chemsex is highest-risk and most commonly between a proportion of MSM and TG, it is also occurring in heterosexual partnerships especially between clients and FEW, which may also increase HIV transmission risks for those populations.

An updated national IBBS survey among MSM and TG populations in 7 provinces was planned to start in April 2023 and data was not available at the time of this analysis or consultations but may provide additional data to focus programming where there is uncertainty in current recommendations.

5 STUDY LIMITATIONS

As with any modelling study, there are limitations that should be considered when interpreting results and recommendations from this analysis.

- **Population sizes:** For consistency in interpretation at a national level, all population size estimates are aligned with official population sizes and previous AEM modelling. However, there is always uncertainty in population size estimates, and for key populations stigma may lead to underestimation of population size. There is especially uncertainty around the number of people engaged in chemsex across different populations as this proportion is based on operational research and no official national estimates exist. This may influence estimates of people living with HIV and subsequently, service and funding needs for each key population.
- **Epidemiological indicators** come from population surveys or programmatic data that have varying degrees and types of biases. Uncertainty in these indicators combined with uncertainty in population sizes can lead to uncertainty in model calibration and projected baseline outcomes and subsequently, service and funding needs for each key population.
- **Effect (i.e. impact) sizes for interventions** are taken from global literature (e.g. the effectiveness of condom use for preventing infections). Actual program impacts may vary depending on context or quality of implementation.
- **Geographical heterogeneity is not modelled,** and outcomes represent national averages. As recommended by stakeholders, there may be opportunities for additional efficiency gains through appropriate geographical targeting.
- **Cost functions for each program** are a key driver of model optimizations. Cost functions determine how program coverage will change if funding is reallocated, as well as maximum achievable program coverage. There is uncertainty in the shapes of these cost functions, values which could influence how easily or how high programs could be scaled up.
- **Equity** in program coverage or HIV outcomes was not captured in the model except where a quantified link between policy change and HIV transmission could be estimated, but equity should be a key consideration in program implementation. Policy makers and funders are encouraged to consider resources required to improve equity, such as through investment in social enablers to remove rights-based barriers to health, and technical or implementation efficiency gains. In addition, prevention programs may have benefits outside of HIV, such as for sexually transmitted infections, hepatitis C, and community empowerment. These were not considered in the optimization but should be factored into programmatic and budgeting decisions.
- **Migration of people**, especially people living with HIV was not considered. Migrants with HIV can sometimes explain changes in the numbers of people living with HIV or can affect the number of new HIV infections.

6 CONCLUSIONS

Key recommendations to improve the HIV response in Cambodia include:

- Maintain and increase coverage of key population programmes for MSM and TG.
- At the same time, refocus limited resources for key population outreach modalities to prioritize PDI+, self-testing availability, and virtual outreach for MSM with more targeted physical outreach.
- Prioritize PrEP demand creation among MSM and TG aged 20-24, and those engaged in chemsex.
- A combination of HIV prevention outreach modalities is needed to be most effective and impactful at engaging all key populations and their sub-populations.
- Additional resources for HIV prevention and testing will be necessary to reach the first 95 by 2030.
- Reaching less than 250 new HIV infections will require a multisectoral approach to address a lack of awareness among youth prior to when they become 'key populations' and they can be reached by HIV services.

Reaching the 95-95-95 targets with available HIV service modalities is projected to be within reach but will require reallocation of current resources to proven high yield interventions such as PDI+, virtual outreach, and HIV self-testing while pursuing implementation efficiencies. Reaching less than 250 annual new infections by the target year will require both additional spending as well as identifying implementation efficiencies including a multisectoral response.

Lastly, it is important to maintain the success of the HIV treatment programme in Cambodia, and continue to scale up the quality of treatment services including adherence and regimen optimization in Cambodia.

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APPENDIX A TECHNICAL SUMMARY OF THE OPTIMA HIV MODEL

The Optima HIV model is similar to AEM in terms of overall design principles. Optima HIV can be described in very broad terms as a compartmental HIV epidemic model. A compartmental epidemic model divides the entire population into compartments that (a) characterize their risk of transmitting a pathogen associated with disease, and/or (b) characterize their chance of experiencing morbidity or mortality. Movement between compartments is determined by the rates of transition.

The risks of transmitting, acquiring, and dying from HIV depend on a host of different factors that can vary across the population, across partnerships, and over time. In the Optima HIV epidemic model, the population is stratified in three different ways in order to reflect this variation: by demographic and/or risk group, by health/disease state (stratified by CD4 count category), and by stage of care. Optima HIV defines the different demographic/risk groups as populations, the different disease progression stages as health states, and the different care and treatment stages as care states. For example, a given person might be a female entertainment worker (their population) and be living with HIV with a CD4 count of 350–500 (their health state), and currently be linked to care but not on treatment (their care state).

HIV programmes can be flexibly defined in the Optima HIV model. Programmes are based on the key National AIDS Spending Assessment (NASA) [6] categories and in keeping with the guidelines from the Global Fund Modular Framework Handbook [7]. Only programmes that have a directly quantifiable impact on the epidemic or health outcomes can be included in typical Optima HIV analyses. Additional cross-cutting programmes including management, programmes for orphans and vulnerable children, human resources and training, enabling environment, social protection, and Boosted-Integrated Active HIV Case Management (B-IACM) are included as part of the funding landscape in the analysis, but were not included in the optimization or scenario analysis, as the direct impact of these programmes on HIV transmission and treatment is not readily measured, and as such cannot be reliably modelled at this time. HIV programmes that have a directly quantifiable impact on the epidemic or health outcomes may also be excluded from optimization and assumed to continue at current coverage levels as a proportion of the target population if there are no policy considerations being given to changes in allocation.

Optima HIV version 2.12.0 updated March 2023, available at http://optimamodel.com/hiv was used for this analysis.

A.1 Parameterization

Three different types of HIV transmission are modelled: transmission between sexual partners, transmission via sharing injecting equipment, and mother-to-child transmission. The input data associated with populations, sexual partnerships, injecting partnerships, and births are outlined in Table A1.

Table A1: Input variables used to characterize population groups in the Optima HIV model

Sexual risk factors
Prevalence of circumcision in population P_i at time t (defined for male populations only)
Prevalence of ulcerative sexually transmitted infections in population P_i at time t
Proportion of population P_i using pre-exposure prophylaxis at time t
Proportion of population P_i covered by PMTCT at time t (defined for female populations only)
The sex of population Pi (can be male, female, transgender, or unspecified)
Factors influencing mortality
Probability of dying of non-HIV-related causes in population P_i between time t and $t+dt$
Prevalence of tuberculosis in population P_i at time t
Factors influencing testing and treatment uptake
Probability of taking and receiving the results of an HIV test between time t and $t+dt$ for population P_i
Average time taken for population P_i to be linked into care at time t
Proportion of people from population P_i who are lost from care between time t and $t+dt$
Factors specifying sexual partnerships
Probability at time t that condoms are used in partnerships of type f and act a between populations P_i and P_j (where *f is regular, casual, or transactional* and *a is insertive penile-anal, receptive penile-anal, insertive penile-vaginal, or receptive penile-vaginal)*
Number of interactions that occur between time t and $t+dt$ of type f and act a between populations Pi and Pj
Factors specifying injecting partnerships
Number of shared injections that occur between time t and $t+dt$ between populations P_i and P_j
Factors specifying births
Number of births between time t and $t+dt$ where population P_i gives birth into population P_j
Proportion of population P_i that breastfeeds population P_j at time t

For female populations, Optima HIV models seven states related to the care and treatment cascade (susceptible, undiagnosed, diagnosed and never linked to care, in care and not receiving ART, receiving ART and not virally suppressed, receiving ART and virally suppressed, and, finally, lost-to-follow-up), and eight for male populations (as above, but with the susceptible compartment divided into those who have been circumcised versus those who have not been circumcised). All infected stages are further disaggregated into six CD4-related health states (acute HIV infection, >500 cells/μL [μL = microliter], 350–500 cells/μL, 200–350 cells/μL, 50–200 cells/μL, <50 cells/μL). Taken together, this gives 38 health and care states (Figure A1), one of which is not included for female populations (circumcised compartments are not shown).

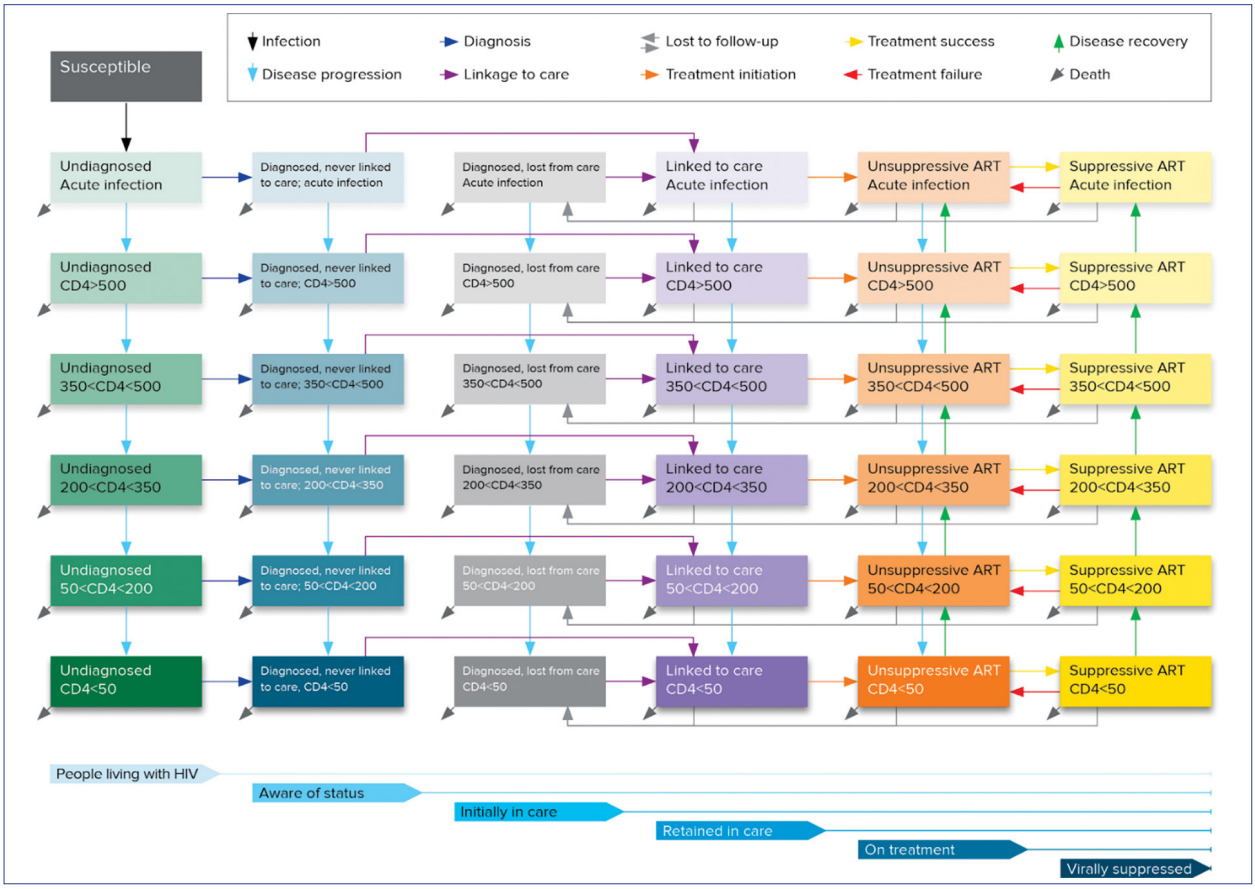


Figure A1: Optima HIV model structure

A.2 Methodology for model calibration

The aim of calibration is to match model outputs to available epidemiological data as best as possible given the underlying model structure and assumptions. This is done by running simulations of the model using samples from the joint prior of all the input parameters to produce a posterior distribution for each parameter. These posteriors show how likely different parameter values are given how well the model simulations they produce compare to specific epidemiological data. Using standard Bayesian terminology, this can be reformulated in the following way. Let ϑ denote the model inputs (i.e., parameters), ρ denote the model outputs (i.e. prevalence), and W denote the empirical prevalence data. The model M maps the input parameters to the output, i.e. $\rho=M(\vartheta)$. Using empirical measurements of (or expert knowledge on) the parameters θ, it is possible to calculate the prior probability $p(\vartheta)$, for any choice of θ. Thus, the prior probability $p(\rho)=p(M(\theta))$ can also be estimated. Combining this estimate with the prevalence data yields $p(W|\rho)$, which is the likelihood of the empirical prevalence W given the model output prevalence ρ. The posterior distribution of the output (i.e., the most likely values of the prevalence) is given by $p(\rho|W)=p(\rho)p(W|\rho)$, while the posterior distribution of the inputs (i.e., the most likely values of the model parameters) is given by $p(\vartheta|W)=p(\vartheta)p(W|\rho)$. The likelihood function is based on how closely the outputs of the model given θ matches the observed data W, as well as how much uncertainty there is in W; it can also incorporate any prior knowledge or expert opinion. The basic idea is that when the simulation output resembles the data well, the likelihood is large, and when it does not resemble the data, the likelihood is small.

From the posterior distribution of the parameters obtained using the algorithm above, posterior predictive distributions of the model can be generated. Furthermore, the empirical posterior distribution can be bootstrapped (i.e., Monte Carlo sampling with replacement) to generate parameter sets for use in further analyses (e.g., scenarios and optimizations).

The main calibration parameters used for Optima HIV are 'initial prevalence' (the percentage of each population with HIV in the first time step of the model, January 1, 2000), and 'force of infection' which represents all factors which are not modelled explicitly but which impact on the likelihood of each population becoming infected relative to other populations.

As priority where available, individual population prevalence estimates are calibrated to prevalence survey data relating to each population, and secondarily to match existing country estimates including new HIV infections and HIV-related deaths to provide consistency with an agreed baseline.

A.3 Optimization analysis

A novel component of Optima HIV is its ability to calculate allocations of resources that optimally address one or more HIV-related objectives (e.g., impact-level targets in a country's HIV National Strategic Plan). Because Optima also calculates the coverage levels required to achieve these targets, it can be used to inform HIV strategic planning and the determination of programme coverage levels. The key assumptions of resource optimization are the relationships between (1) the cost of HIV programmes for specific target populations, (2) the resulting coverage levels of targeted populations with these HIV programmes, and (3) how these coverage levels of HIV programmes for targeted populations influence behavioural and clinical outcomes. Such relationships are required to understand how incremental changes in spending (marginal costs) affect HIV epidemics. Optima uses a logistic function fitted to available input data to model cost–coverage curves. Logistic functions can incorporate initial start-up costs and allow changes in behaviour to saturate at high spending levels, thus better reflecting programme reality. For best fits, saturation values of the coverage to match behavioural data in countries with heavily funded HIV responses are typically chosen. Programme coverage for zero spending is assumed to be zero; behavioural outcomes for zero coverage are inferred using data from early in the epidemic or just before significant investment in HIV programmes. Practically, the zero and high spending cases are also discussed with local experts who can advise on private sector HIV service delivery outside the governments' expenditure tracking systems.

For each HIV program, it is necessary to derive one set of logistic curves that relate funding to programme coverage levels and another set of curves (generally linear relationships) between coverage levels and clinical or behavioural outcomes (i.e., the impacts that HIV strategies aim to achieve). Outcomes expected from changes in programme funding are assumed by interpolating and extrapolating available data using a fitted logistic curve. A limitation of this approach is that all changes in behaviour are assumed to be because of changes in programme funding.

Optima HIV can be used to minimize either (1) a given outcome (e.g., number of infections, number of disability-adjusted life years [DALYs], number of HIV-related deaths, or future HIV-related costs) given a fixed total budget over a determined programme period, or (2) the amount of funding required to meet a particular epidemiological goal (e.g., reducing HIV incidence by 50%). Optima HIV can also determine the amount of money required to simultaneously meet multiple goals (e.g., all impact-level targets in an HIV national strategic framework) or the optimal allocation of a fixed amount of resources that will simultaneously get as close as possible to achieving one or multiple target objectives. Constraints may be placed on the optimization; for example, the number of people on ART may not be allowed to decrease, or programmes cannot increase or decrease from a baseline level by more than a defined percentage each year to account for political or other constraints.

To perform the optimization, Optima HIV uses a global parameter search algorithm called adaptive stochastic descent (ASD) [8]. ASD is similar to simulated annealing in that it makes stochastic downhill steps in parameter space from an initial starting point. However, unlike simulated annealing, ASD chooses future step sizes and directions based on the outcome of previous steps. For certain classes of optimization problems, ASD has been shown to determine optimal solutions with fewer function evaluations than traditional optimization methods, including gradient descent and simulated annealing.

APPENDIX B POPULATION DEFINITIONS AND CALIBRATION

Population definitions are consistent with operational definitions used in AIDS Epidemic Model and Global AIDS Monitoring Reporting [1], as discussed withing the HIV Estimates Technical Working Group (TWG) 2022 However the Optima HIV model includes additional key populations of MSMUD and TGUD, due to stakeholder concerns on the significance of those populations to the HIV epidemic, as well as additional age stratification in both the key and non-key population males and females. A total of 37 sub-populations were modelled (Table B1), with each population below further disaggregated by age as follows: 0-14 for non-key populations, 15-19 and 20-24 for all populations; 25+ for key populations; and 25-49 and 50+ for non-key populations.

Key assumptions:

- Data for MSMUD and TGUD are emerging but limited. Where no data were available, behavioural data were assumed to align with MSM 1 and TG populations, respectively, which in prior studies have implicitly included a proportion of MSMUD and TGUD. Differences in sexual risk behaviour were informed by survey data and stakeholder consultations, and calibrated to align with observed diagnosis rates.
- Data to disaggregate behavioural differences for populations aged 15-19 and 20-24 from ages 25+ were limited. Where no data were available, age-based differences in risk behaviour were informed by stakeholder consultations and calibrated to align with observed diagnosis rates relative to age, taking into account lower rates of testing.

Table B1: Population groups modelled in this analysis

Abbreviation	Population groups	2022 baseline epidemic status
Clients	Clients of female entertainment workers	Representing 43% of new infections in 2000 but dropping to 9% by 2022 (AEM 2022 results) due to increases in condom use during commercial sex as well as falling prevalence in FEW over that time period. Modelled as including males who use non-injecting drugs as part of sexualized drug use, but who do not have sex with men.
TG	Transgender women	Defined in the HIV Estimates TWG 2022 as 'Biological male at birth, 15-49 years old, self-identified as female or third gender.' Modelled as excluding transgender women who use drugs as part of sexualized drug use. Representing a small but increasing proportion of total new infections, through risk behaviours including commercial/transactional sex.

Abbreviation	Population groups	2022 baseline epidemic status
TGUD (Unofficial acronym for easy reference)	Transgender women who use drugs (engaged in sexualized drug use)	A key risk demographic is men who have sex with men and transgender women engaged in sexualized drug use (or "chemsex"), with high numbers of partnerships combined with low condom use reported, as well as challenges in reaching this demographic due to primarily online planning for partnerships. Modelled to reflect latest behavioural survey data and self-reporting on risks through Chouuk Sor clinic[9].
PWID	Males who inject drugs	Defined in the HIV Estimates TWG 2022 as 'Biological male at birth, 15-49 years old, who injected drug one or more time in the last month.' Modelled as including clients of female entertainment workers who also inject drugs, but excluding men who have sex with men and transgender women who use drugs including injecting drugs as part of sexualized drug use. The estimated number of people who inject drugs in Cambodia is small, but HIV prevalence was estimated to be disproportionately high. Outreach programmes including education, condom distribution, testing, needle syringe programmes, and opioid agonist maintenance therapy have reduced the number of new infections in PWID dramatically since an estimated peak in 2013.
FEW 1	Female entertainment workers 1	Defined in the HIV Estimates TWG 2022 as 'Non-freelance entertainment workers who works permanently in massage parlour, beer garden, pub, clubs and other places for recent year with change in sex work dynamics due to COVID-19 and increased use of social media to find partners. For historical trend any entertainment workers who have 7 clients and more per week'. Modelled as including females who inject drugs and females who use drugs as part of sexualized drug use, who are also entertainment workers. The overall reduction in FEW (both direct and indirect) prevalence has been driven by high level of condom use with clients, more rapid diagnosis and treatment through extensive outreach programmes. FEW represent 28% of new HIV infections in 2000 and 7% in 2022 (AEM 2022 results)
FEW 2	Female entertainment workers 2	Defined in the HIV Estimates TWG 2022 as 'The freelance entertainment workers who impermanently in massage pallor, beer garden, pub, clubs and other places in post-COVID-19 context and historically it used to be any entertainment workers who have less than 7 clients per week'. Modelled as including females who use drugs as part of sexualized drug use, who are also entertainment workers.

Abbreviation	Population groups	2022 baseline epidemic status
MSM 1	Men who have sex with men 1 (known risk and/or reachable)	Defined in the HIV Estimates TWG 2022 as 'Go, work or visit: Hotspot, Sauna, spa, Beer garden, online and offline. "Known risk".' Modelled as including Male Sex Workers (MSW): Defined as 'Selling sex at Hotspot, sauna, spa, online & offline, "Known risk"', but excluding MSM who are engaged in sexualized drug use (chemsex) who are categorized as MSMUD. New infections in MSM have increased to represent up to 40% of new infections in 2022 (AEM 2022 results) making these populations a high priority for detailed modelling of programme impact.
MSM 2	Men who have sex with men 2 (unknown risk)	Defined by HIV estimates TWG 2022 as 'men who have sex with men with "unknown risk"'. Modelled as excluding MSM who are engaged in sexualized drug use (chemsex) who are categorized as MSMUD. New infections in MSM have increased to represent up to 40% of new infections in 2022 AEM results making these populations a high priority for detailed modelling of programme impact.
MSMUD (Unofficial acronym for easy reference)	Men who have sex with men who use drugs (engaged in sexualized drug use).	A key risk demographic is men who have sex with men and transgender women engaged in sexualized drug use (or "chemsex"), with high numbers of partnerships combined with low condom use reported, as well as challenges in reaching this demographic due to primarily online planning for partnerships. Modelled to reflect latest behavioural survey data and self-reporting on risks through Chouuk Sor clinic[10]. MSMUD are drawn half from MSM 1 and half from MSM 2 based on the proportion who report being reached by outreach HIV services.
	Non-key population males	Age stratified populations analogous to non-key population males and females in AEM.
	Non-key population females	Infections in children 0-14 caused through mother-to-child transmission, with PMTCT programme coverage estimated to be 92% with MTCT rate of 9.3% in 2022 (AEM 2022 results).

Based on a national Optima HIV model of Cambodia developed by the Optima Consortium for Decision Science as part of a global model of HIV [11], the project was updated with data sources for each parameter, supplemented by expert advice from stakeholder consultations.

Table B2: Model parameter data sources

Data input	Sources
Population size	Age and gender stratified population sizes will be aligned with AEM 2022 and including: ◆ National Institute of Statistics. General Population Census of the Kingdom of Cambodia 2019 [12]. Supplemented if necessary, with: ◆ United Nations World Population Prospects 2022: online edition [13] Consistent with AEM, key population sizes for higher risk populations are estimated from sources including: ◆ Program reports [14-18] ◆ Published articles [19, 20] ◆ Integrated Biological and Behavioral Surveys (IBBS) in 2017 (PWID and PWUD) [21], 2019 (MSM and TG)[22] and 2022 (FEW) [23] ◆ Clinic data from Chouuk Sor clinic[9].
HIV prevalence by population groups	HIV prevalence data values are used as the primary point of reference during calibration. Values are taken from a combination of primary research including survey data where available and expert opinion/assumptions where no data exists. Sources include: ◆ National reports [3, 14, 15, 24, 25] ◆ IBBS reports from 2016 (TG) [26], 2017 (PWID and PWUD) [21], 2019 (MSM and TG) [27] and 2022 (FEW) [23] ◆ UNAIDS reports and fact sheets, including Key Population Atlas [28-31] ◆ Published articles and conference abstracts[32-42] ◆ United Nations General Assembly Special Session on HIV/AIDS 2006 [43]
Other epidemiology ◆ Percentage of people who die from non-HIV-related causes per year ◆ Prevalence of any ulcerative STIs ◆ Tuberculosis prevalence	Key population non-HIV-related mortality estimates consistent with AEM. Overall background mortality is taken from: ◆ United Nations, World Population Prospects 2022 [13] ◆ Quarterly report on HIV/AIDS and HCV-HIV co-infection. NCHADS, 2022 [44]

Data input	Sources
Testing & treatment ◆ Percentage of population tested for HIV in the last 12 months ◆ Probability of a person with CD4<200 being tested per year ◆ Number of people on treatment ◆ Percentage of people covered by ARV-based prophylaxis ◆ Number of women on PMTCT (Option B/B+) ◆ Birth rate (births per woman per year) ◆ Percentage of HIV-positive women who breastfeed	The percentage of the population tested per year represents the likelihood that someone with an undiagnosed HIV infection will be diagnosed over the course of a year. As such inputs may be adjusted as part of calibration to match the proportion of HIV infections estimated to be diagnosed in each year, while maintaining trends in reported testing percentages. Sources for original data include: ◆ National reports [16, 45-47] ◆ Cambodia Demographic and Health Surveys [48, 49] ◆ UNAIDS reports and databases, including Key Population Atlas [28, 50] ◆ Program data ◆ Published articles [51-54].
Optional indicators ◆ Number of HIV tests per year ◆ Number of HIV diagnoses per year ◆ Modelled estimate of new HIV infections per year ◆ Modelled estimate of HIV prevalence ◆ Modelled estimate of number of PLHIV ◆ Number of HIV-related deaths ◆ Number of people initiating ART each year ◆ PLHIV aware of their status (%) ◆ Diagnosed PLHIV in care (%) ◆ PLHIV in care on treatment (%) ◆ Pregnant women on PMTCT (%) ◆ People on ART with viral suppression (%)	Data entered in this section of the Optima HIV databook are not used by the model directly to generate output, but rather allows comparison points to be entered from other reliable sources or models in order to ensure consistency. In this case AEM and Spectrum have been used to fill the optional indicators and matched closely based on already being accepted nationally through a consultative process and the NCHADS National ART database[55].
Cascade ◆ Average time taken to be linked to care (years) (by population groups) ◆ Average time taken to be linked to care for people with CD4<200 (years) ◆ Percentage of people in care who are lost to follow-up per year (%/year) ◆ Percentage of people with CD4<200 lost to follow up (%/year) ◆ Viral load monitoring (number/year) ◆ Proportion of those with VL failure who are provided with effective adherence support or a successful new regimen (%/year) ◆ Treatment failure rate	◆ Joint Program Review 2019 ◆ NGO and NCHADS programmatic data 2022 ◆ Mid-Term Review of Cambodia's Strategic Plan for HIV and STI Prevention and Care in the Health Sector 2021 – 2025. NCHADS, 2022[3] ◆ NCHADS National ART database[55].

Data input	Sources
Sexual behavior ◆ Average number of acts with regular partners per person per year ◆ Average number of acts with casual partners per person per year ◆ Average number of acts with commercial partners per person per year ◆ %age of people who used a condom at last act with regular partners ◆ Percentage of people who used a condom at last act with casual partners ◆ Percentage of people who used a condom at last act with commercial partners ◆ Percentage of males who have been circumcised	◆ IBBS reports from 2017 (PWID and PWUD) [21], 2019 (MSM and TG) [27] and 2022 (FEW) [23] ◆ National reports [16] ◆ UNAIDS reports and fact sheets [29, 30] ◆ Published articles [35, 56, 57].
Injecting behaviors ◆ Average number of injections per person per year ◆ Percentage of people who receptively shared a needle/syringe at last injection ◆ Number of people who inject drugs who are on opiate substitution therapy	◆ 2017 IBBS (PWID and PWUD) [21] ◆ UNAIDS reports, fact sheets and databases, including Key Population Atlas [28, 48] ◆ Technical note on national and sub-national HIV estimates and Projections, September 2019 [16] ◆ AEM-Spectrum. 2022. [1]
Partnerships & transitions ◆ Interactions between regular partners ◆ Interactions between casual partners ◆ Interactions between commercial partners ◆ Interactions between people who inject drugs ◆ Birth ◆ Aging ◆ Risk-related population transitions (average number of years before movement)	◆ Technical note on national and sub-national HIV estimates and Projections, September 2019[16] ◆ AEM-Spectrum. 2022 [1].

Data input	Sources
Constant ◆ Interaction-related transmissibility (% per act) ◆ Relative disease-related transmissibility ◆ Disease progression (average years to move) ◆ Treatment recovery due to suppressive ART (average years to move) ◆ CD4 change due to non-suppressive ART (%/year) ◆ Death rate (% mortality per year) ◆ Changes in transmissibility (%) ◆ Disutility weights	Source for constant values used for Optima HIV are given in the Optima HIV user guide available through the online tool at http://optimamodel.com/hiv, or directly from: https://docs.google.com/document/d/1VIxB08G-jnLhUjRwLAKuBJ-To2WXud7krK9CNNu6NwIg/

Calibration plots

While the epidemic in Cambodia has remained concentrated in key populations, there has been a shift in incidence from primarily occurring through transactional sex (both clients and female entertainment workers) at the peak of the epidemic in 1998, to rising infection rates among people who inject drugs, and stakeholders expressed concern at rapidly rising risk behaviour and incidence among men who have sex with men and transgender populations, as seen in individual calibration plots for each population below (Figure B2). The model was closely calibrated to the epidemic trends in the most recent AEM estimates [1]. Figure B1 demonstrates the overall HIV care cascade with an increasing proportion of people living with HIV being diagnosed and on treatment.

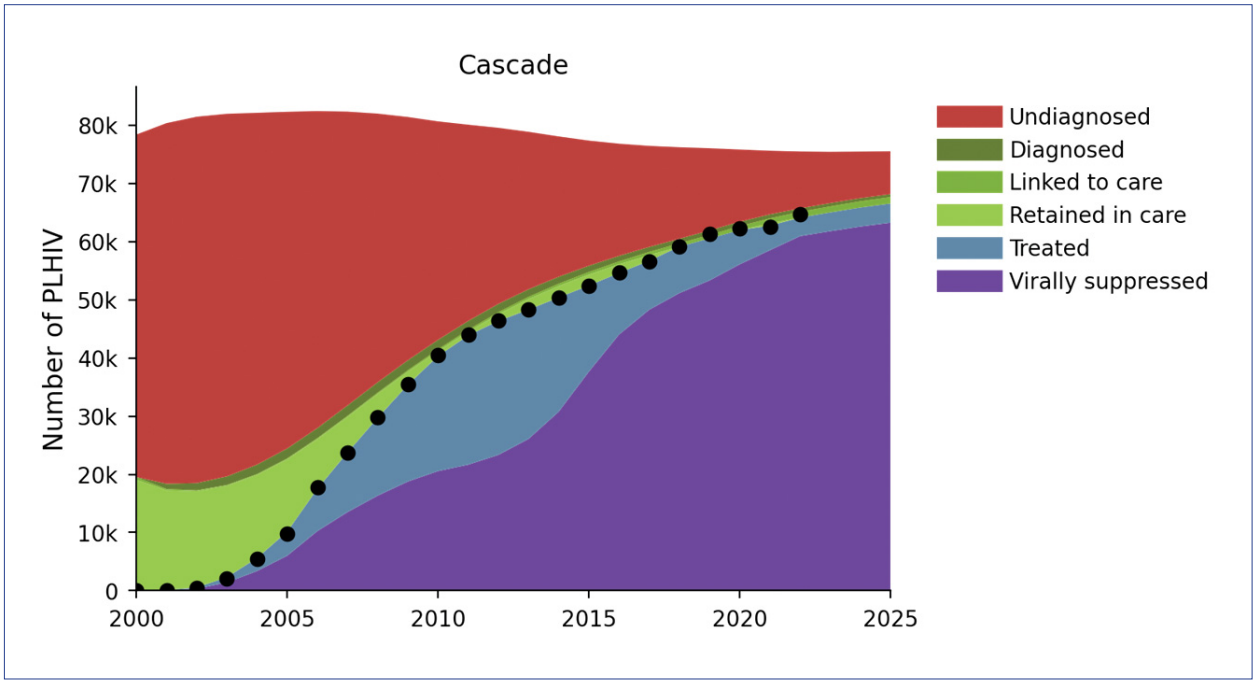
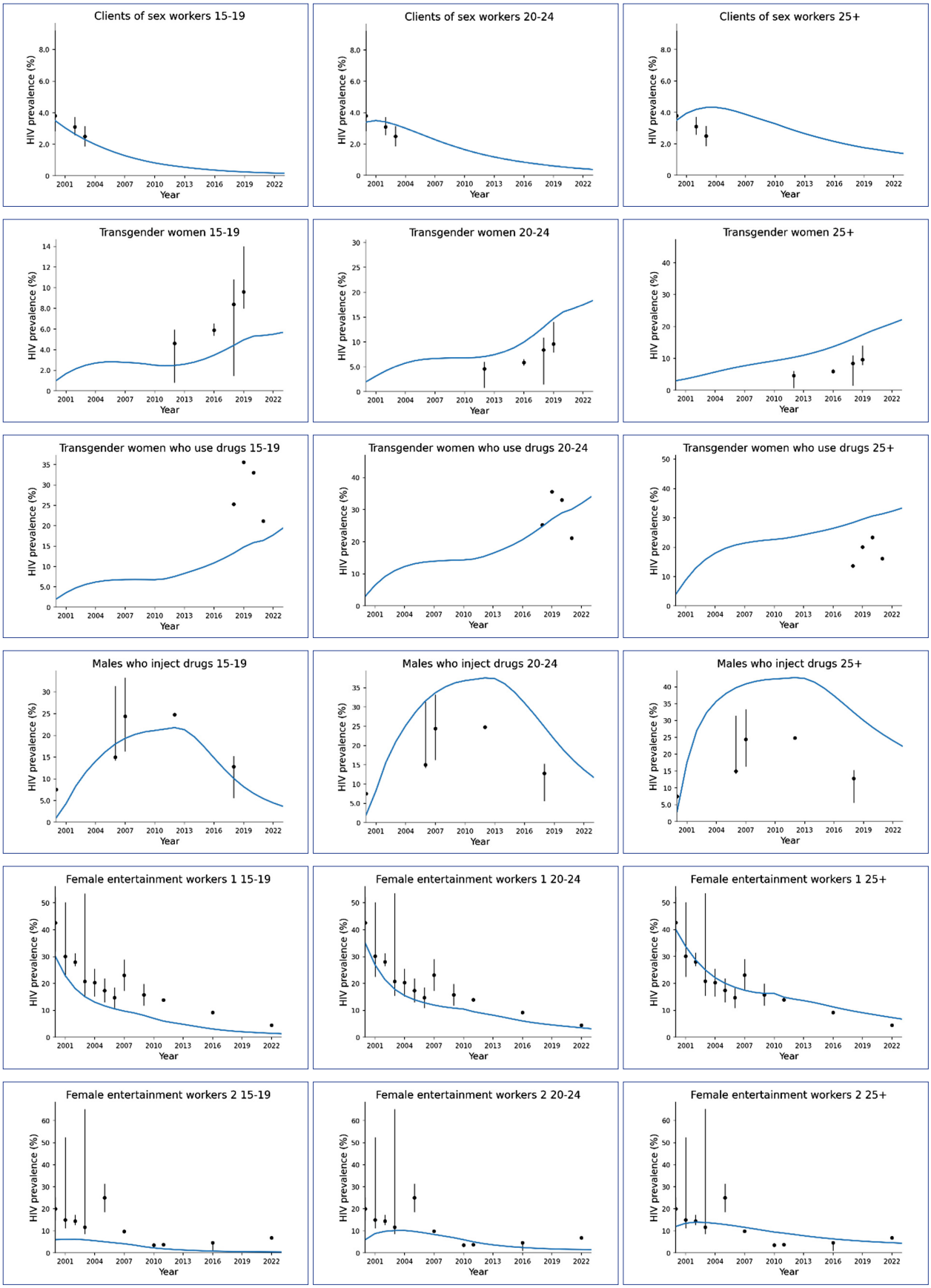
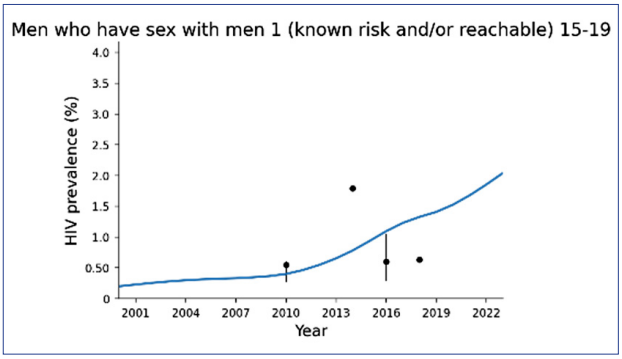
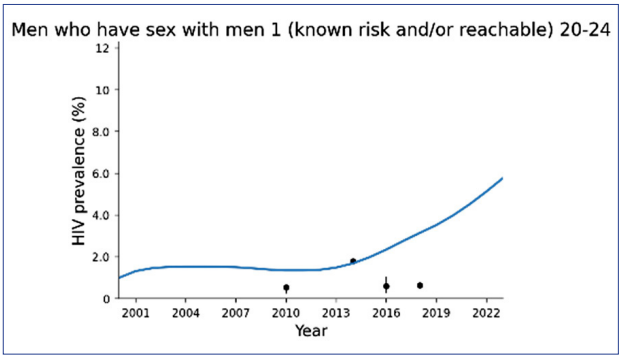


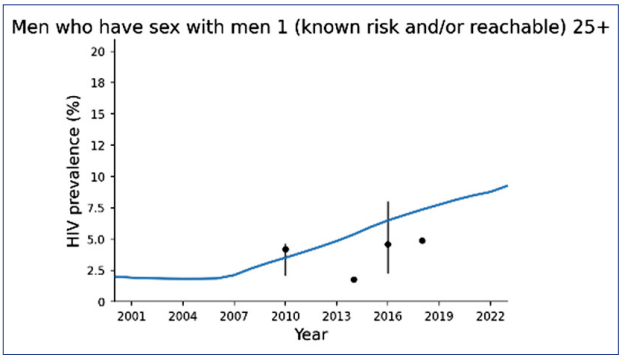
Figure B1: HIV care cascade estimated from 2000 to 2025.

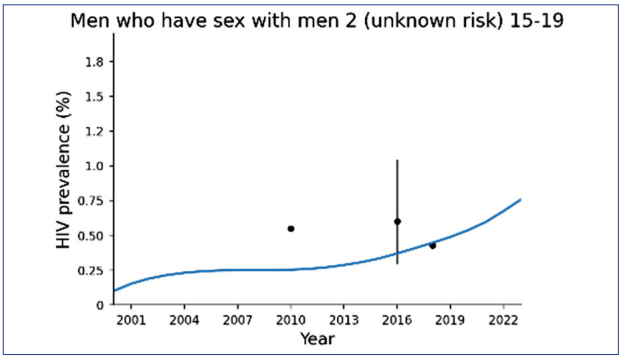
Figure B2: Calibration plots (following pages). Data points are not disaggregated by age for most populations, so the calibration reflects lower rates of prevalence among younger populations who have been exposed to lower cumulative risk of HIV transmission.

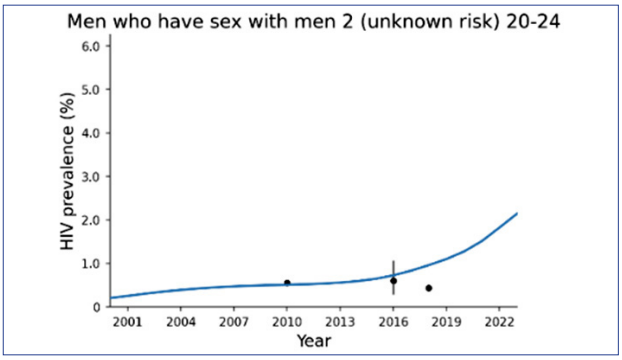


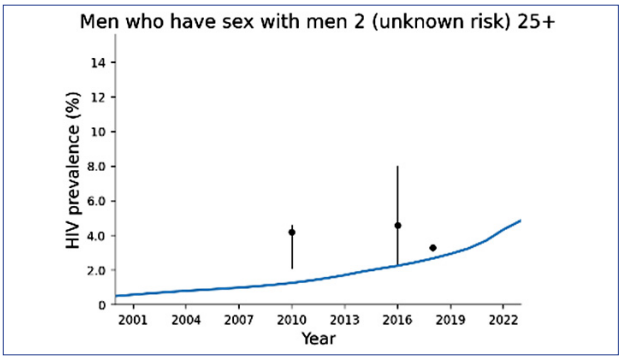

Men who have sex with men 1 (known risk and/or reachable) 15-19
HIV prevalence (%)
Year

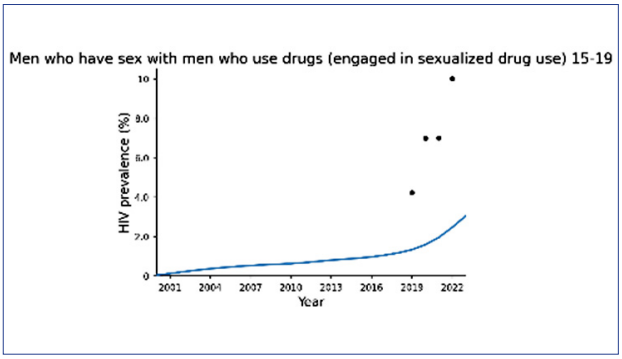

Men who have sex with men 1 (known risk and/or reachable) 20-24
HIV prevalence (%)
Year

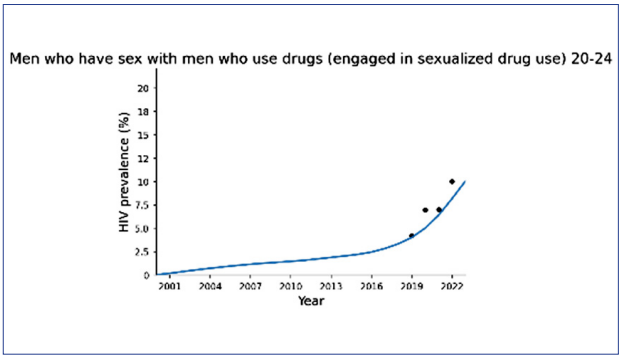

Men who have sex with men 1 (known risk and/or reachable) 25+
HIV prevalence (%)
Year

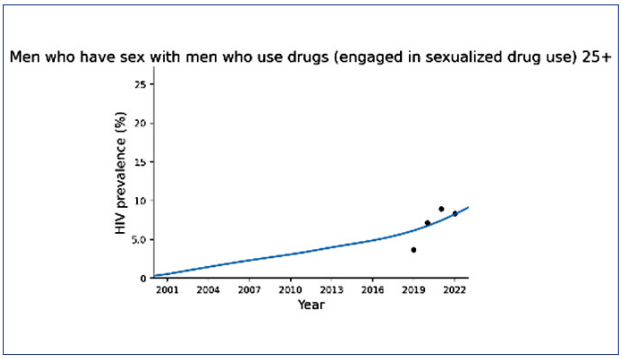

Men who have sex with men 2 (unknown risk) 15-19
HIV prevalence (%)
Year

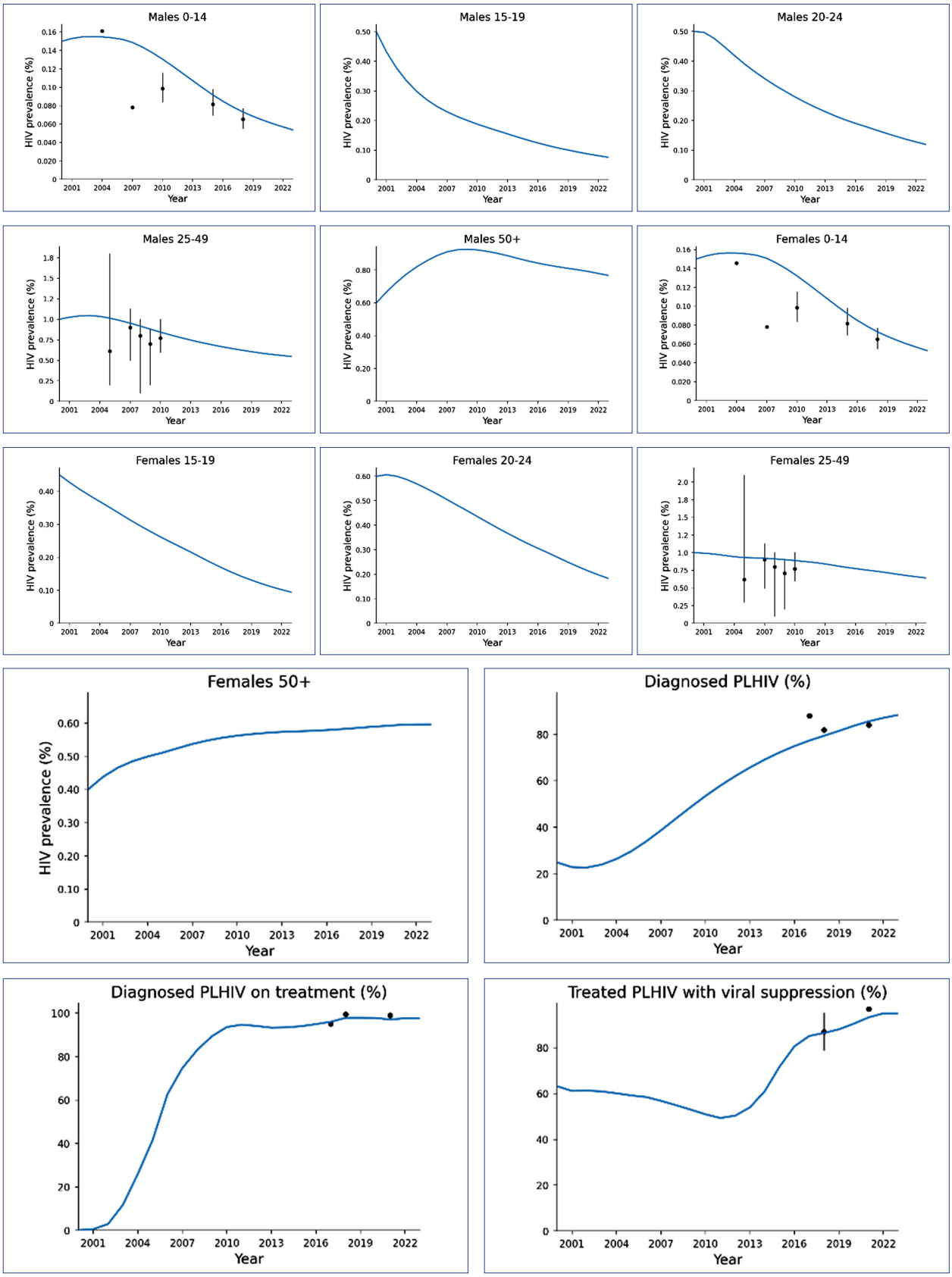

Men who have sex with men 2 (unknown risk) 20-24
HIV prevalence (%)
Year


Men who have sex with men 2 (unknown risk) 25+
HIV prevalence (%)
Year


Men who have sex with men who use drugs (engaged in sexualized drug use) 15-19
HIV prevalence (%)
Year


Men who have sex with men who use drugs (engaged in sexualized drug use) 20-24
HIV prevalence (%)
Year


Men who have sex with men who use drugs (engaged in sexualized drug use) 25+
HIV prevalence (%)
Year


Males 0-14
Males 15-19
Males 20-24
Males 25-49
Males 50+
Females 0-14
Females 15-19
Females 20-24
Females 25-49
Females 50+
Diagnosed PLHIV (%)
Diagnosed PLHIV on treatment (%)
Treated PLHIV with viral suppression (%)
HIV prevalence (%)
Year

APPENDIX C

PROGRAMME DEFINITIONS

Individual programme budgets were estimated based on unit costs determined below, and are consistent with total HIV prevention spending reported through top-down estimates of HIV spending.

Table C1: HIV programmes included in the model; budget and unit costs US dollars; unit costs rounded to nearest 10 cents.

HIV programme	2022 unit cost (USD)	2024 unit cost (USD)	2022 total spending (estimated)	2022 coverage reported number reached [7]	2022 coverage proportion	Saturation (low) [1]	Saturation (high) [1]	Unit cost components (2022) Components of CSO service delivery costs in 2024 estimated to increase by 15%.
ART adherence support for key populations	$56.50	$65.00	$115,563	2,045	25%	33%	50%	CSO service delivery cost [2]
Enhanced key population tracing and outreach (PDI+, index testing)	$20.50	$23.10	$59,672	2,904	3%	5%	10%	CSO service delivery cost [2] Condom package per person reached [3] HIV test per 99% of persons reached [4]
HIV prevention and testing for FEW through night-time or mobile van outreach	$18.90	$21.30	$38,384	2,029	7%	5%	10%	CSO service delivery cost [2] Condom package per person reached [3] HIV test per 83% of persons reached [4]
HIV prevention and testing for FEW through physical outreach	$18.30	$20.60	$658,677	35,974	69%	65%	85%	CSO service delivery cost [2] Condom package per person reached [3] HIV test per 88% of persons reached [4]
HIV prevention and testing for FEW through virtual outreach	$21.00	$23.90	$66,972	3,191	9%	10%	25%	CSO service delivery cost [2] Condom package per 50% of persons reached [3] HIV test per 14% of persons reached [4]
HIV prevention and testing for MSM and TG through night-time or mobile van outreach	$19.10	$21.30	$48,511	2,545	4%	3%	10%	CSO service delivery cost [2] Condom package per person reached [3] HIV test per 84% of persons reached [4]
HIV prevention and testing for MSM and TG through physical outreach	$21.00	$23.60	$950,023	45,323	74%	65%	85%	CSO service delivery cost [2] Condom package per person reached [3] HIV test per 88% of persons reached [4]

HIV programme	2022 unit cost (USD)	2024 unit cost (USD)	2022 total spending (estimated)	2022 coverage reported number reached [7]	2022 coverage proportion	Saturation (low) [1]	Saturation (high) [1]	Unit cost components (2022) Components of CSO service delivery costs in 2024 estimated to increase by 15%.
HIV prevention and testing for MSM through virtual outreach	$21.60	$24.40	$128,240	5,944	10%	10%	25%	CSO service delivery cost [2] Condom package per 50% of persons reached [3] HIV test per 37% of persons reached [4]
HIV prevention and testing for PWID through physical outreach	$43.60	$43.60	$35,103	806	23%	20%	50%	Estimated physical outreach cost 2020 [5], assumed to include condom package per person reached [3] and HIV test per 56% of persons reached [4]
HIV prevention and testing for TG through virtual outreach	$20.10	$22.90	$14,389	715	7%	5%	25%	CSO service delivery cost [2] Condom package per 50% of persons reached [3] HIV test per 43% of persons reached [4]
HIV self-testing for FEW reached by other modalities	$19.60	$22.20	$11,922	609	1%	1%	5%	CSO service delivery cost [2] HIV test per 100% of persons reached [4]
HIV self-testing for MSM reached by other modalities	$20.00	$22.70	$55,915	2,793	3%	2%	5%	CSO service delivery cost [2] HIV test per 100% of persons reached [4]
HIV self-testing for PWID reached by other modalities	$19.90	$22.50	$2,466	124	4%	4%	10%	CSO service delivery cost [2] HIV test per 100% of persons reached [4]
HIV self-testing for TG reached by other modalities	$20.10	$22.70	$9,697	483	3%	3%	5%	CSO service delivery cost [2] HIV test per 100% of persons reached [4]
HIV testing for prisoners	$15.30	$17.60	$54,370	3,550	10%	10%	30%	Estimated programme spending (CRS) divided by HIV tests provided to prisoners in 2022. HIV test per 100% of persons reached [4]
Needle-syringe programmes	$114.20	$114.20	$381,125	3,339 [8]	17%	40%	70%	Estimated unit cost 2020 [5]
Opioid agonist maintenance therapy	$440.10	$440.10	$57,208	130	0%	5%	10%	Estimated unit cost 2020 [5]
Pre-exposure prophylaxis (PrEP)	$94.00	$96.50	$235,304	2,503	5%	5%	18%	CSO cost including demand creation activities [2] Pre-exposure prophylaxis cost per person reached [6]
PrEP with demand creation for FEW	$93.70	$96.10	$28,674	306	1%	1%	20%	CSO cost including demand creation activities [2] Pre-exposure prophylaxis cost per person reached [6]

HIV programme	2022 unit cost (USD)	2024 unit cost (USD)	2022 total spending (estimated)	2022 coverage reported number reached [7]	2022 coverage proportion	Saturation (low) [1]	Saturation (high) [1]	Unit cost components (2022) Components of CSO service delivery costs in 2024 estimated to increase by 15%.
PrEP with demand creation for PWID	$94.00	$96.50	$94	1	0%	0%	20%	CSO cost including demand creation activities [2] Pre-exposure prophylaxis cost per person reached [6]
PrEP with demand creation for MSM and TG engaged in chemsex	$94.00	$96.50	$0	-	0%	0%	9%	CSO cost including demand creation activities [2] Pre-exposure prophylaxis cost per person reached [6]
PrEP with demand creation for MSM and TG 20-24	$94.00	$96.50	$0	-	0%	0%	6%	CSO cost including demand creation activities [2] Pre-exposure prophylaxis cost per person reached [6]
PrEP with wider demand creation for MSM and TG	$94.00	$96.50	$0	-	0%	0%	28%	CSO cost including demand creation activities [2] Pre-exposure prophylaxis cost per person reached [6]
Prevention of mother-to-child transmission (testing)	$1.10	$1.10	$334,284	303,895	95%	95%	100%	Commodity cost for dual-test HIV + syphilis.

1. Saturation: maximum possible coverage of the defined modality. Coverage increases linearly (e.g. for each increase in spending of one unit cost, one additional person is reached) up to the "saturation (low)" value, and then non-linearly approaching the "saturation (high)" value as spending increases, to reflect increased but uncertain delivery costs to expand coverage beyond a known point.
2. CSO service delivery costs taken as a weighted average of costs from KHANA and RHAC for that program, estimated by CSOs based on a breakdown of all CSO spending apportioned to activities aligned with each mode of service delivery and each key population. HIV prevention and testing costs range from $14.95 to $19.33 by population and modality – with the similarity of implementation costs for all modalities reflecting primarily that the same outreach workers are responsible for implementing all modalities. PrEP counselling and demand creation activity costs range from $16.24 to $16.55. Adherence support for key populations estimated at $56.51.
3. A standard condom package per year includes 27 condoms + lubricant, commodities cost estimated based on NCHADS procurement costs February 2022: $1.42. Virtual programmes are estimated to provide condom packages to half of the people reached relative to other modalities of service delivery.
4. HIV test commodity cost estimated based on a weighted average of HIV self-testing rapid diagnostic tests (80% oral quick, 20% finger prick): US$2.20, the proportion of people receiving an HIV test varies by modality based on reported CSO test numbers divided by people reached by each modality.
5. Programmes for people who inject drugs used unit costs estimated in 2020, Ending the AIDS epidemic in Cambodia: Findings from an Optima HIV modelling analysis, 2020. NCHADS.
6. Pre-exposure prophylaxis annual commodity cost per person of $77.46 includes laboratory test costs for HIV, hepatitis B, and hepatitis C $14.50, PrEP drug costs $40.60, creatinine for 40% of people ($3.5), and incentives ($5 at initiation and $4 for each follow-up visit).
7. Coverage numbers as reported in national statistics through the HIV prevention database 2022.
8. Estimated coverage for needle-syringe programmes includes people who inject drugs in other populations (including a proportion of FEW 1, MSMUD, and TGUD), with a total effective indirect coverage of 3,339 people. Estimated total spending includes portions of other services reaching those populations that reduce needle sharing. Annual direct spending for needle-syringe programmes of US$155,197 in 2020 reached 1,359 PWID, and both coverage and direct spending for this intervention are estimated to be lower in 2023.

Table C2: HIV programme impacts by parameter as absolute change relative to baseline [1]

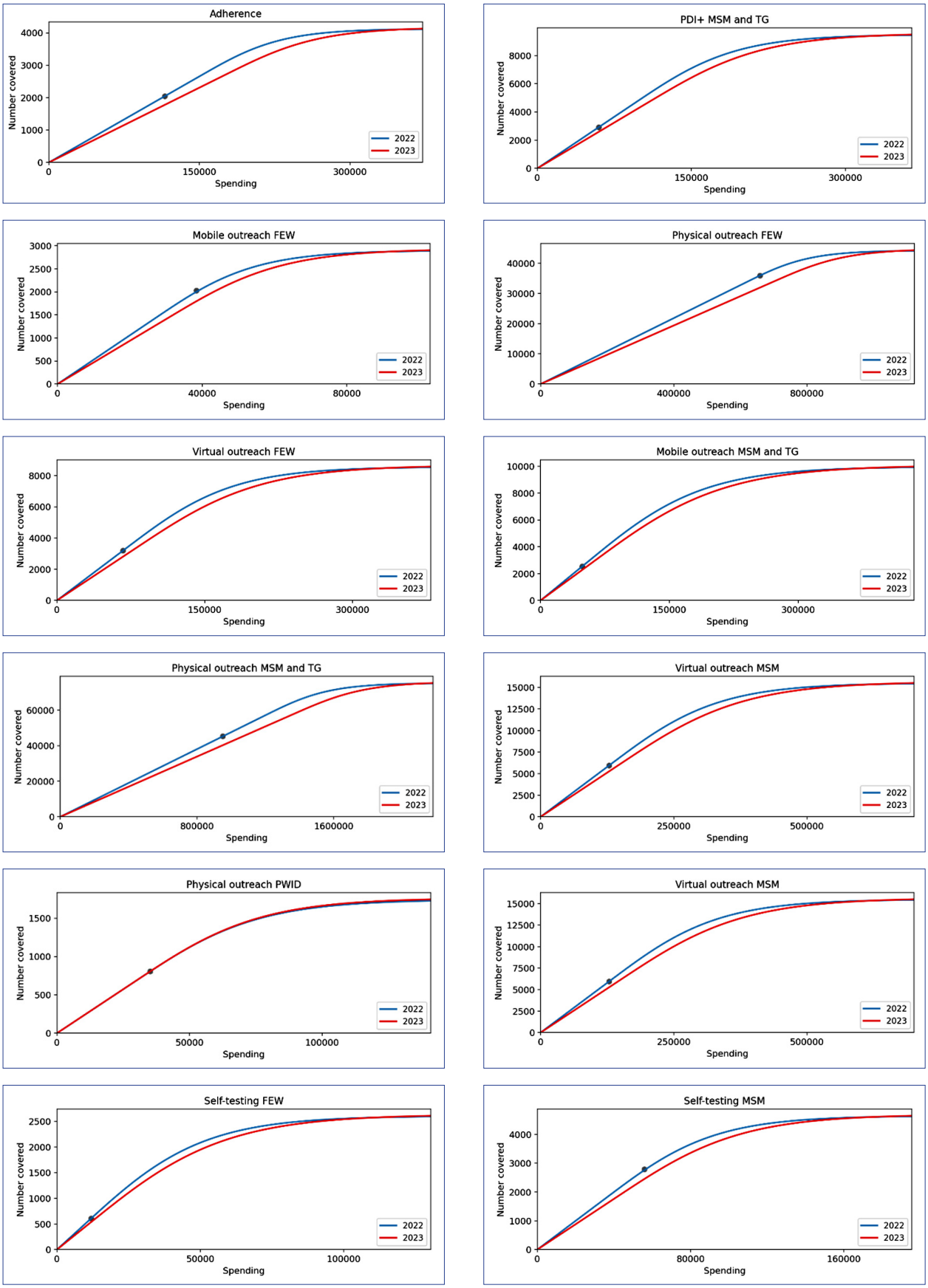
HIV programme	Reported HIV test rate [2]	Adjusted test rate PLHIV [2]	Condom use (by partnership type)	Other impacts	Differentiated reach and impact by population [3]
ART adherence support for key populations				7% reduction in loss to follow-up	Targets all TG, PWID, FEW, and MSM populations of all ages and risk groups, who are diagnosed and on ART Limited impact for MSMUD populations of all ages
Enhanced key population tracing and outreach (PDI+, index testing)	99%	126%	30% casual		Targets TG, TGUD, MSM 1, MSM 2, MSMUD of all ages
HIV prevention and testing for FEW through night-time or mobile van outreach	83%	114%	30% casual 40% commercial		Targets FEW 1 and FEW 2 of all ages Limited reach for FEW 2
HIV prevention and testing for FEW through physical outreach	88%	120%	40% casual 40% commercial		Targets FEW 1 and FEW 2 of all ages Limited impact for FEW aged 15-24
HIV prevention and testing for FEW through virtual outreach	14%	72%	20% casual 10% commercial		Targets FEW 1 and FEW 2 of all ages Limited reach for FEW 1 and FEW 2 aged 25+
HIV prevention and testing for MSM and TG through night-time or mobile van outreach	84%	78%	30% casual		Targets TG, TGUD, MSM 1, MSM 2, MSMUD of all ages Limited reach for TGUD and MSMUD of all ages
HIV prevention and testing for MSM and TG through physical outreach	88%	54%	40% casual		Targets TG, TGUD, MSM 1, MSM 2, MSMUD of all ages Limited reach for TG, TGUD, MSMUD of all ages Limited reach for all populations aged 15-24
HIV prevention and testing for MSM through virtual outreach	37%	102%	20% casual		Targets MSM 1, MSM 2, MSMUD of all ages Limited reach for all populations aged 25+
HIV prevention and testing for PWID through physical outreach	56%	1% [4]	40% casual	4% reduction in receptive needle sharing	Targets PWID of all ages
HIV prevention and testing for TG through virtual outreach	43%	84%	20% casual		Targets TG, TGUD of all ages Limited reach for all populations aged 25+
HIV self-testing for FEW reached by other modalities	100% [5]	282%			Targets FEW 1 and FEW 2 of all ages

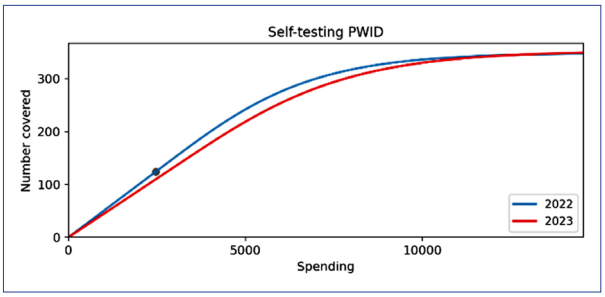
HIV programme	Reported HIV test rate [2]	Adjusted test rate PLHIV [2]	Condom use (by partnership type)	Other impacts	Differentiated reach and impact by population [3]
HIV self-testing for MSM reached by other modalities	100% [5]	156%			Targets MSM 1, MSM 2, MSMUD of all ages
HIV self-testing for PWID reached by other modalities	100% [5]	6% [4]			Targets PWID of all ages
HIV self-testing for TG reached by other modalities	100% [5]	156%			Targets TG, TGUD of all ages
HIV testing for prisoners	60%	60%			Targets a proportion of all populations aged 15-49 based on total prisoner numbers in Cambodia and estimated proportion of prisoners who are also key populations
Needle-syringe programmes				8% reduction in receptive needle sharing	Targets PWID of all ages (including PWID, and a proportion of TGUD, MSMUD, FEW 1)
Opioid agonist maintenance therapy				Increase in the number of people who inject drugs receiving OAMT	Targets PWID of all ages (including PWID, and a proportion of TGUD, MSMUD, FEW 1)
Pre-exposure prophylaxis (PrEP)	100%	11%		Increase in PrEP coverage with a population factor of 0.6. At 18% saturation coverage, 30% of risk events would be covered. [6]	Targets TG, TGUD, MSM 1, MSM 2, MSMUD of all ages
PrEP with demand creation for FEW	100%	11%		Increase in PrEP coverage with a population factor of 0.43. At 20% saturation coverage, 46% of risk events would be covered. [6]	Targets FEW 1, FEW 2 of all ages (with demand creation focused on reaching street-based entertainment workers)
PrEP with demand creation for PWID	100%	11%		Increase in PrEP coverage with a population factor of 0.81. At 20% saturation coverage, 25% of risk events would be covered. [6]	Targets PWID of all ages
PrEP with demand creation for MSM and TG engaged in chemsex	100%	11%		Increase in PrEP coverage with a population factor of 0.89. At 9% saturation coverage, 10% of risk events would be covered. [6]	Targets TGUD, MSMUD of all ages

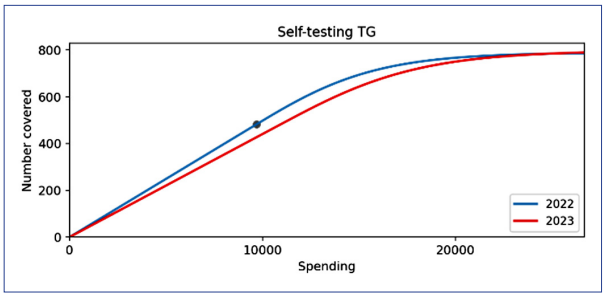
HIV programme	Reported HIV test rate [2]	Adjusted test rate PLHIV [2]	Condom use (by partnership type)	Other impacts	Differentiated reach and impact by population [3]
PrEP with demand creation for MSM and TG 20-24	100%	11%		Increase in PrEP coverage with a population factor of 0.59. At 6% saturation coverage, 10% of risk events would be covered. [6]	Targets TG, TGUD, MSM 1, MSM 2, MSMUD aged 20-24
PrEP with wider demand creation for MSM and TG	100%	11%		Increase in PrEP coverage with a population factor of 0.56. At 28% saturation coverage, 50% of risk events would be covered. [6]	Targets TG, TGUD, MSM 1, MSM 2, MSMUD of all ages Limited reach for TGUD, MSMUD of all ages
Prevention of mother-to-child transmission (testing)	100%			Increase in the proportion of pregnant women living with HIV who are diagnosed prior to child-birth (and eligible for PMTCT)	Targets all female populations who give birth annually

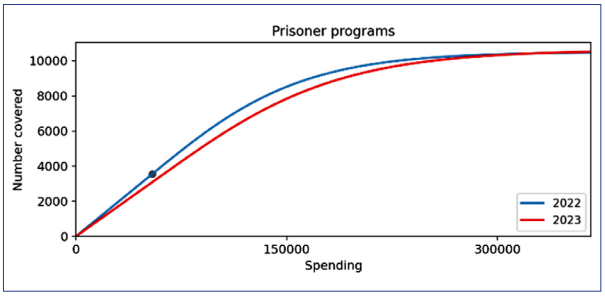
1. "Baseline" values were determined through an automated fitting process for each population and each parameter that used the reported impact of programmes, the programme coverage in 2022, and the calibrated parameter value for 2022 to determine a baseline value for each population and parameter if no modelled HIV programmes were available, based on the formula baseline + proportion covered * programme impact = parameter value, followed by adjustments to respect minimum and maximum parameter bounds.
2. "Reported HIV test rate" is the proportion of people reached by the programme who are provided with an HIV test based on programme data. "Adjusted test rate PLHIV" is the estimated annual probability that an undiagnosed person living with HIV will be diagnosed during the year, which is the raw test rate per person adjusted by the yield of testing through that modality relative to the estimated prevalence of undiagnosed people living with HIV among the target population(s). Because programmes can be effectively targeted to the people at highest risk within a population relative to random testing, the impact "per person reached" can be greater than 100% (which is limited in overall impact by low saturation levels).
3. Reach of programmes is based on the saturation levels defined in Table C1 for the population(s) targeted. Qualitative assumptions informed and validated through stakeholder consultations may apply that limit either the reach or the impact for specific key populations, ages, or risk groups for a given modality. "Limited reach" reflects that while the programme may have full impact for each individual person reached, only 50% of the population(s) specified may be accessible through that modality relative to the saturation value defined overall. "Limited impact" reflects that while the full cost applies to reach the population, only 50% of the defined impact applies for that population primarily due to external factors that make programme impact more challenging for a given population.
4. HIV testing impacts for PWID reflect extremely low yield from HIV testing – this reflects the programme reach in providing effective HIV prevention for a consistent group of PWID but not reaching new individuals.
5. HIV self-testing has a test rate of 100% due to only including data on those who have returned test results.
6. See Appendix A for description of the assumptions and calculations to differentiate PrEP coverage and impact by modality.

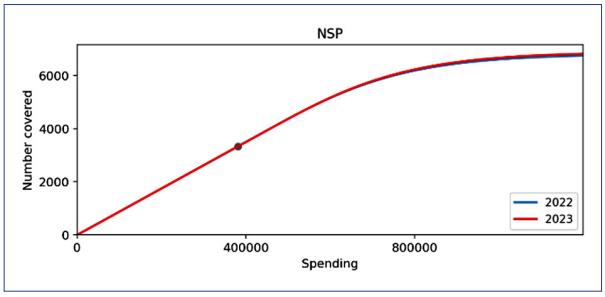
Figure C1. Cost-coverage curves showing the relationship between increased programmatic spending and increased programme coverage (number of people reached).

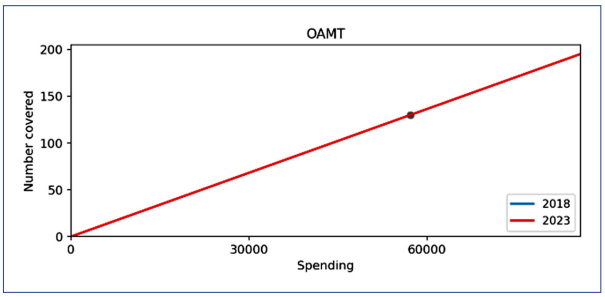


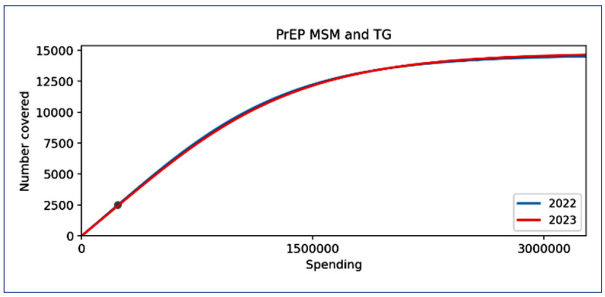

Self-testing PWID
Number covered
Spending
2022
2023

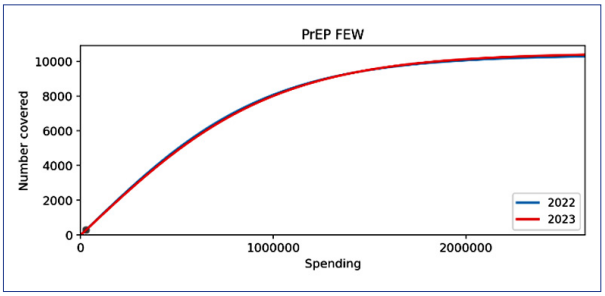

Self-testing TG
Number covered
Spending
2022
2023

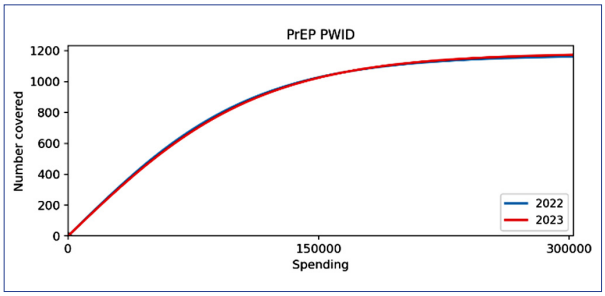

Prisoner programs
Number covered
Spending
2022
2023

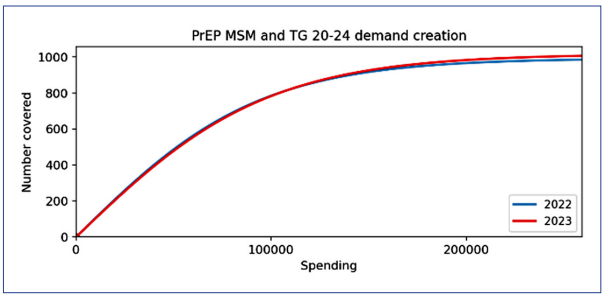

NSP
Number covered
Spending
2022
2023

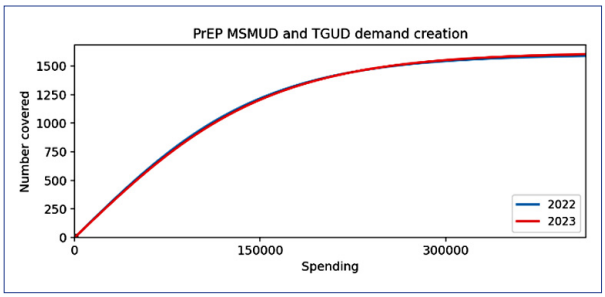

OAMT
Number covered
Spending
2018
2023

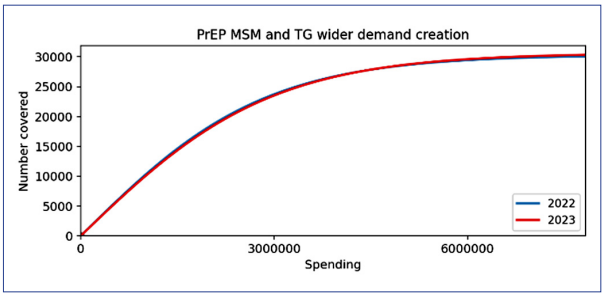

PrEP MSM and TG
Number covered
Spending
2022
2023

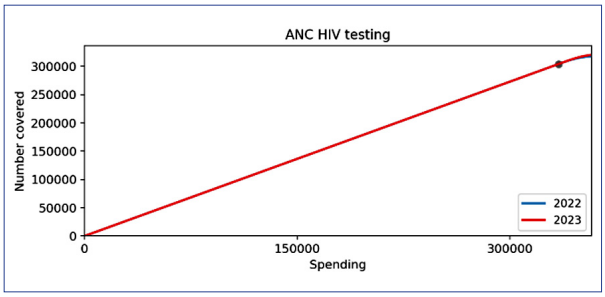

PrEP FEW
Number covered
Spending
2022
2023


PrEP PWID
Number covered
Spending
2022
2023


PrEP MSM and TG 20-24 demand creation
Number covered
Spending
2022
2023


PrEP MSMUD and TGUD demand creation
Number covered
Spending
2022
2023


PrEP MSM and TG wider demand creation
Number covered
Spending
2022
2023


ANC HIV testing
Number covered
Spending
2022
2023

APPENDIX D

OPTIMIZATION RESULTS

The below tables show the detailed budget scenarios based on the baseline spending scenario matching the estimated HIV prevention spending in 2022. Budget allocations were optimized from 2023 to 2030 and are fully applied from 2027 to 2030. It was assumed following stakeholder consultations that 2022 spending would be representative of 2023 spending and that changes in budget allocation would scale from 2024 to 2026 to reach these optimized allocations.

Table D1: Optimized spending allocation with varying resource availability, average US dollar budget 2027 to 2030 following time to reach scale on programmes from 2024 to 2026.

Modelled program	*Baseline spending (2022 resource envelope)*	*US$1M less per year*	*Optimized spending*	*US$1M additional per year 2027 – 2030*	*US$2M additional per year 2027 – 2030*	*US$3M additional per year 2027 – 2030*	*US$4M additional per year 2027 – 2030*	*US$5M additional per year 2027 – 2030*	*US$6M additional per year 2027 – 2030*
ART adherence support for key populations	**$115,563**	$0	**$104,007**	$104,007	**$104,007**	$104,007	**$104,007**	$104,007	**$202,383**
Enhanced key population tracing and outreach (PDI+, index testing)	**$59,672**	$65,639	**$187,477**	$221,562	**$225,748**	$231,032	**$235,596**	$246,406	**$259,006**
HIV prevention and testing for FEW through night-time or mobile van outreach	**$38,384**	$42,222	**$34,546**	$34,546	**$40,995**	$52,160	**$55,981**	$63,239	**$69,012**
HIV prevention and testing for FEW through physical outreach	**$658,677**	$475,429	**$592,809**	$592,809	**$592,809**	$627,560	**$787,464**	$868,826	**$908,486**
HIV prevention and testing for FEW through virtual outreach	**$66,972**	$0	**$60,275**	$60,275	**$60,275**	$60,275	**$60,275**	$60,275	**$60,275**
HIV prevention and testing for MSM and TG through night-time or mobile van outreach	**$48,511**	$53,362	**$43,660**	$142,946	**$147,618**	$153,676	**$159,818**	$160,472	**$184,210**
HIV prevention and testing for MSM and TG through physical outreach	**$950,023**	$1,045,025	**$855,021**	$1,033,336	**$1,071,528**	$1,117,232	**$1,274,090**	$1,257,053	**$1,228,347**

Modelled program	*Baseline spending (2022 resource envelope)*	*US$1M less per year*	*Optimized spending*	*US$1M additional per year 2027 – 2030*	*US$2M additional per year 2027 – 2030*	*US$3M additional per year 2027 – 2030*	*US$4M additional per year 2027 – 2030*	*US$5M additional per year 2027 – 2030*	*US$6M additional per year 2027 – 2030*
HIV prevention and testing for MSM through virtual outreach	**$128,240**	$141,064	**$219,235**	$311,942	**$313,390**	$315,723	**$317,984**	$331,514	**$343,463**
HIV prevention and testing for PWID through physical outreach	**$35,103**	$0	**$31,593**	$31,593	**$31,593**	$31,593	**$39,908**	$60,527	**$72,377**
HIV prevention and testing for TG through virtual outreach	**$14,389**	$15,828	**$12,950**	$39,554	**$38,256**	$30,628	**$36,470**	$46,783	**$54,795**
HIV self-testing for FEW reached by other modalities	**$11,922**	$0	**$10,730**	$10,730	**$10,730**	$10,730	**$10,730**	$10,730	**$10,730**
HIV self-testing for MSM reached by other modalities	**$55,915**	$61,507	**$83,255**	$103,944	**$107,738**	$111,849	**$114,928**	$121,939	**$129,171**
HIV self-testing for PWID reached by other modalities	**$2,466**	$0	**$2,219**	$2,219	**$2,219**	$2,219	**$2,219**	$2,219	**$2,219**
HIV self-testing for TG reached by other modalities	**$9,697**	$10,667	**$8,727**	$11,986	**$13,857**	$15,611	**$16,541**	$18,027	**$19,053**
HIV testing for prisoners	**$54,370**	$59,807	**$48,933**	$48,933	**$48,933**	$48,933	**$48,933**	$48,933	**$48,933**
Needle-syringe programmes	**$381,125**	$0	**$343,013**	$343,013	**$343,013**	$343,013	**$343,013**	$343,013	**$343,013**
Opioid agonist maintenance therapy	**$57,208**	$57,208	**$57,208**	$57,208	**$57,208**	$57,208	**$57,208**	$57,208	**$57,208**
Pre-exposure prophylaxis (PrEP)	**$235,304**	$258,834	**$211,774**	$614,254	**$818,312**	$1,001,724	**$1,142,225**	$1,360,714	**$1,594,543**
PrEP with demand creation for FEW	**$28,674**	$0	**$25,807**	$25,807	**$25,807**	$25,807	**$25,807**	$25,807	**$25,807**
PrEP with demand creation for PWID	**$94**	$0	**$85**	$85	**$85**	$85	**$85**	$85	**$85**
PrEP with demand creation for MSM and TG engaged in chemsex	**$0**	$0	**$0**	$100,590	**$115,842**	$131,258	**$145,552**	$174,751	**$196,372**
PrEP with demand creation for MSM and TG 20-24	**$0**	$0	**$52,415**	$94,400	**$100,500**	$108,368	**$117,892**	$130,536	**$144,539**
PrEP with wider demand creation for MSM and TG	**$0**	$0	**$0**	$0	**$715,277**	$1,405,047	**$1,889,013**	$2,492,675	**$3,031,709**
Prevention of mother-to-child transmission (testing)	**$334,284**	$0	**$300,856**	$300,856	**$300,856**	$300,856	**$300,856**	$300,856	**$300,856**
Total HIV prevention spending	**$3,286,593**	$2,286,593	**$3,286,593**	$4,286,593	**$5,286,593**	$6,286,593	**$7,286,593**	$8,286,593	**$9,286,593**

Selection of key budget scenarios

Figure D1 captures the rationale for the selected key budget scenarios that form the recommendations. Cambodia has a projected trajectory of a relatively constant number of annual new HIV infections with baseline spending continued. While optimization of the baseline 2022 budget envelope has some impact, the first additional investment of US$0.5M to $1M per year from 2024-2026 then US$1M to $2M per year to maintain coverage has disproportionately large impact on the new HIV infections target per dollar spent. US$2M per year from 2024-2026 then US$4M per year to maintain coverage is enough to bring the targets within reach, if combined with additional implementation efficiencies and a multisectoral response. Higher levels of investment may bring the target even closer but investment at this point has diminishing returns, with additional risk given higher uncertainty over feasibility of uptake.

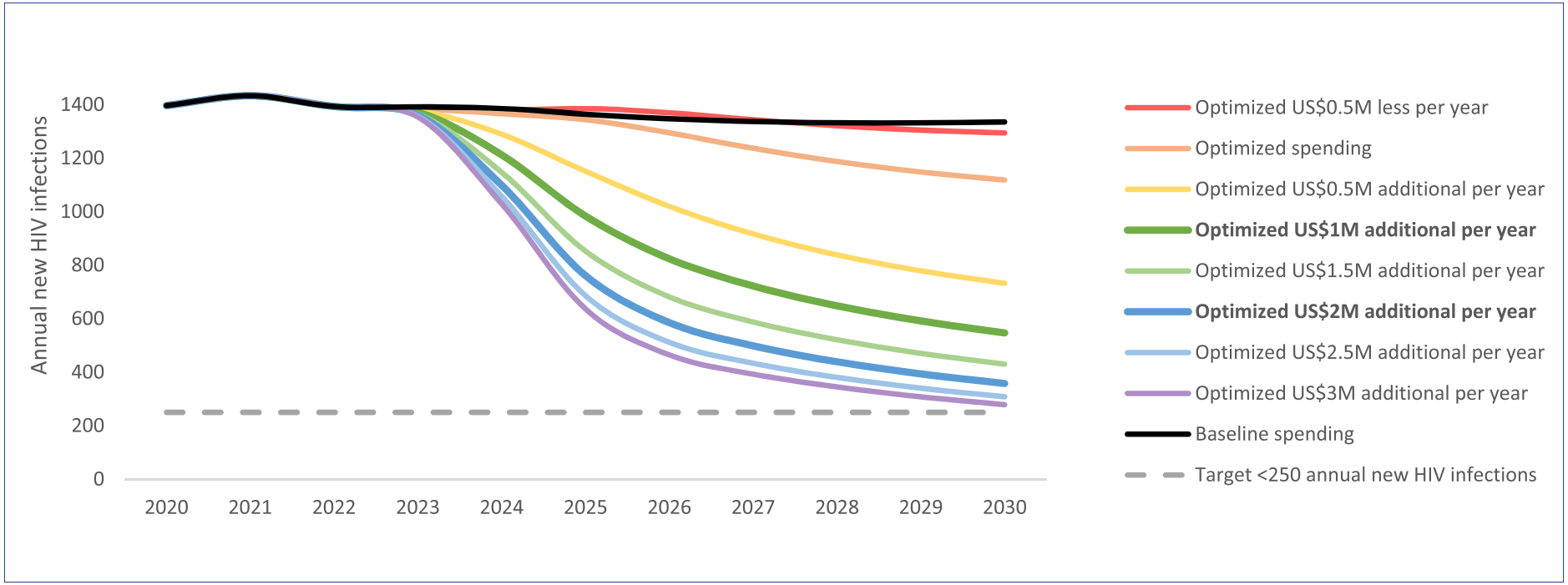


Figure D1: Annual new HIV infections with varying resource availability, with additional spending per year from 2024 to 2026 given planned time to reach scale on programmes

Table D2: Annual new HIV infections projected under each scenario

Scenario	2022	2023	2024	2025	2026	2027	2028	2029	2030
Prevention programmes scaled back by 2025	1,393	1,396	1,510	1,787	2,104	2,438	2,814	3,233	3,682
Baseline	1,393	1,391	1,386	1,364	1,347	1,337	1,332	1,332	1,335
Optimized baseline budget (scale up by 2026)	1,393	1,385	1,366	1,344	1,295	1,237	1,187	1,149	1,118
Optimized US$1M additional (scale up by 2026)	1,393	1,371	1,212	983	824	722	648	591	547
Optimized US$2M additional	1,393	1,361	1,098	761	585	499	439	394	358
Optimized US$2M additional with multisectoral efficiencies	1,393	1,186	851	537	394	320	272	239	214

Table D3: Annual HIV-related deaths projected under each scenario

Scenario	2022	2023	2024	2025	2026	2027	2028	2029	2030
Prevention programmes scaled back by 2026	684	612	568	539	522	518	527	549	583
Baseline	684	612	557	509	467	431	400	373	351
Optimized baseline budget (scale up by 2026)	684	611	556	509	466	426	390	360	333
Optimized US$1M additional (scale up by 2026)	684	611	555	506	457	412	373	339	311
Optimized US$2M additional	684	611	555	505	454	408	368	334	305
Optimized US$2M additional with multisectoral efficiencies	684	610	552	489	424	366	317	278	246

Table D4: Optimized spending allocation with varying resource availability, average US dollar budget 2024 to 2026 given planned time to reach scale on programmes

Modelled program	*Baseline spending*	*Phaseout HIV prevention by 2026*	*Optimized spending*	*Optimized US$1M additional*	*Optimized US$2M additional*
ART adherence support for key populations	**$115,563**	$57,782	**$109,785**	$109,785	**$109,785** [2]
Enhanced key population tracing and outreach (PDI+, index testing)	**$59,672**	$29,836	**$123,575**	$140,617	**$142,710**
HIV prevention and testing for FEW through night-time or mobile van outreach	**$38,384**	$19,192	**$36,465**	$36,465	**$39,689**
HIV prevention and testing for FEW through physical outreach	**$658,677**	$329,339	**$625,743**	$625,743	**$625,743**
HIV prevention and testing for FEW through virtual outreach	**$66,972**	$33,486	**$63,623**	$63,623	**$63,623**
HIV prevention and testing for MSM and TG through night-time or mobile van outreach	**$48,511**	$24,256	**$46,085**	$95,728	**$98,064**
HIV prevention and testing for MSM and TG through physical outreach	**$950,023**	$475,012	**$902,522**	$991,680	**$1,010,775**
HIV prevention and testing for MSM through virtual outreach	**$128,240**	$64,120	**$173,737**	$220,091	**$220,815**
HIV prevention and testing for PWID through physical outreach	**$35,103**	$17,552	**$33,348**	$33,348	**$33,348**
HIV prevention and testing for TG through virtual outreach	**$14,389**	$7,195	**$13,670**	$26,971	**$26,323**
HIV self-testing for FEW reached by other modalities	**$11,922**	$5,961	**$11,326**	$11,326	**$11,326**
HIV self-testing for MSM reached by other modalities	**$55,915**	$27,958	**$69,585**	$79,930	**$81,827**

Modelled program	*Baseline spending*	*Phaseout HIV prevention by 2026*	*Optimized spending*	*Optimized US$1M additional*	*Optimized US$2M additional*
HIV self-testing for PWID reached by other modalities	**$2,466**	$1,233	**$2,343**	$2,343	**$2,343**
HIV self-testing for TG reached by other modalities	**$9,697**	$4,849	**$9,212**	$10,841	**$11,777**
HIV testing for prisoners	**$54,370**	$27,185	**$51,652**	$51,652	**$51,652**
Needle-syringe programmes	**$381,125**	$190,563	**$362,069**	$362,069	**$362,069**
Opioid agonist maintenance therapy	**$57,208**	$28,604	**$57,208**	$57,208	**$57,208**
Pre-exposure prophylaxis (PrEP)	**$235,304**	$117,652	**$223,539**	$424,779	**$526,808**
PrEP with demand creation for FEW	**$28,674**	$14,337	**$27,240**	$27,240	**$27,240**
PrEP with demand creation for PWID	**$94**	$47	**$89**	$89	**$89**
PrEP with demand creation for MSM and TG engaged in chemsex	**$0**	$0	**$0**	$50,295	**$57,921**
PrEP with demand creation for MSM and TG 20-24	**$0**	$0	**$26,208**	$47,200	**$50,250**
PrEP with wider demand creation for MSM and TG	**$0**	$0	**$0**	$0	**$357,638**
Prevention of mother-to-child transmission (testing) 1	**$334,284**	$167,142	**$317,570**	$317,570	**$317,570**
Total HIV prevention spending	**$3,286,593**	$1,643,297	**$3,286,593**	$3,786,593	**$4,286,593**

1. Although optimization outputs did not include additional resources for ANC HIV testing, needle-syringe programmes, OAMT, and prisoner programmes in order to focus on defined modalities of HIV prevention for key populations, each of these programmes has additional health and societal benefits not included in modelled direct HIV impact and may be prioritized based on considerations of those benefits.
2. Although the primary optimization outputs did not include additional resources for adherence programmes until higher resource availability levels, these are recommended at the level of US$2M additional per year from 2024 to 2026 and US$4M per year from 2027 to 2030 to maintain coverage, due to uncertainty over the PrEP scale-up timeframe and prioritization of this programme at higher resource availability.

APPENDIX E PRE-EXPOSURE PROPHYLAXIS ASSUMPTIONS

With a focus on bringing pre-exposure prophylaxis (PrEP) to scale in Cambodia in future years, assumptions around this programme are given in more detail below.

Table E1: Pre-exposure prophylaxis assumptions

<table>
<tr><th>Indicator</th><th>Optima HIV input/output value (2022)</th><th>Reference/assumption</th></tr>
<tr><td>HIV transmission</td><td>71% of new HIV infections in adults are estimated to be in MSM/TG including male sex workers.

Estimated proportion of new HIV infections of those occurring among key populations (1,034):

<table>
<tr><th></th><th>15-19</th><th>20-24</th><th>25+</th></tr>
<tr><td>TG</td><td>3%</td><td>6%</td><td>5%</td></tr>
<tr><td>TGUD</td><td>4%</td><td>3%</td><td>4%</td></tr>
<tr><td>PWID</td><td><1%</td><td><1%</td><td>1%</td></tr>
<tr><td>FEW 1</td><td><1%</td><td><1%</td><td>2%</td></tr>
<tr><td>FEW 2</td><td>1%</td><td>2%</td><td>1%</td></tr>
<tr><td>MSM 1</td><td>6%</td><td>12%</td><td>26%</td></tr>
<tr><td>MSM 2</td><td><1%</td><td>1%</td><td>4%</td></tr>
<tr><td>MSMUD</td><td>3%</td><td>8%</td><td>8%</td></tr>
</table></td><td>71% of new HIV infections in adults are estimated to be in MSM/TG including male sex workers in AEM 2022.

Historical assumptions around the number acts per week are in the region of 1.28 – 1.5 acts per week, half of which are with regular partners and half with casual partners [1].

Most recent behavioural data (IBBS 2019) and [27] suggest the number of acts may have climbed to over 4 per week average especially among MSM aged 15-24, and over 2 in MSM aged 25-49, with 30% reporting recent casual partners. Among MSM and TG populations engaged in chemsex, by definition 100% are at high risk.</td></tr>
</table>

<table>
<tr><th>Indicator</th><th>Optima HIV input/output value (2022)</th><th>Reference/assumption</th></tr>
<tr><td>Reachable and eligible populations</td><td>Estimated PrEP reachability by key population, risk group and age, given as number of people (proportion of population)
<table><tr><th></th><th>15-19</th><th>20-24</th><th>25+</th></tr><tr><td>TG</td><td>1,056 (46%)</td><td>1,027 (52%)</td><td>3,983 (46%)</td></tr><tr><td>TGUD</td><td>206 (41%)</td><td>204 (47%)</td><td>779 (41%)</td></tr><tr><td>PWID</td><td>124 (20%)</td><td>107 (20%)</td><td>467 (20%)</td></tr><tr><td>FEW 1</td><td>131 (20%)</td><td>120 (20%)</td><td>926 (20%)</td></tr><tr><td>FEW 2</td><td>1,571 (20%)</td><td>1,433 (20%)</td><td>6,240 (20%)</td></tr><tr><td>MSM 1</td><td>4,081 (46%)</td><td>3,970 (52%)</td><td>15,395 (46%)</td></tr><tr><td>MSM 2</td><td>1,379 (28%)</td><td>1,441 (34%)</td><td>5,200 (28%)</td></tr><tr><td>MSMUD</td><td>1,098 (41%)</td><td>1,083 (47%)</td><td>4,141 (41%)</td></tr></table></td><td>These are ‘known risk’ population that can be reached with programmes.

While PrEP availability is not restricted based on these criteria, individuals are considered “eligible” for PrEP based on having multiple partners within 12 months, being reachable through an HIV prevention programme modality, and not already HIV infected.

IBBS 2019 survey data indicates that 67% of TG have had multiple partners in the last 6 months (implying up to 89% over 12 months as different people may have different seasons of risk). Similarly, we can estimate 90% of FEW 1, 20% of FEW 2, and 51% of MSM 1 and MSM 2 have multiple partners over 12 months (based on stricter eligibility for FEW to include only those with 7 or more partners per week or who are street-based).</td></tr>
<tr><td>New HIV infections estimated to be among eligible populations as proportion of new infections</td><td>Estimated proportion of new HIV infections among eligible key populations by risk group and age, given as a proportion of all new HIV infections in that key population.
<table><tr><th></th><th>15-19</th><th>20-24</th><th>25+</th></tr><tr><td>TG</td><td>80%</td><td>90%</td><td>80%</td></tr><tr><td>TGUD</td><td>65%</td><td>75%</td><td>65%</td></tr><tr><td>PWID</td><td>25%</td><td>25%</td><td>25%</td></tr><tr><td>FEW 1</td><td>46%</td><td>46%</td><td>46%</td></tr><tr><td>FEW 2</td><td>46%</td><td>46%</td><td>46%</td></tr><tr><td>MSM 1</td><td>80%</td><td>90%</td><td>80%</td></tr><tr><td>MSM 2</td><td>50%</td><td>60%</td><td>50%</td></tr><tr><td>MSMUD</td><td>65%</td><td>75%</td><td>65%</td></tr></table></td><td>The effectiveness of targeted PrEP depends on the risk profile of who uses PrEP.

Based on IBBS 2019 data, MSM who reported 2 or more partners over the past six months had HIV prevalence of 7.7% compared to 2.5% for MSM with 0 or 1 partner. TG who reported 2 or more partners had HIV prevalence of 11.1% compared to 6.4% for MSM with 0 or 1 partner. Among FEW, prevalence among street-based FEW has been estimated to be as much as 20 times higher than HIV prevalence for venue-based FEW, and PrEP demand creation for FEW is focused on street-based FEW.

After accounting for people living with HIV and people with lower risk of HIV transmission who would be unlikely to use PrEP, and multiple modes of PrEP delivery for MSM and TG populations, an overall proportion of HIV transmission that could be affected by PrEP can be estimated.</td></tr>
</table>

Indicator	Optima HIV input/output value (2022)	Reference/assumption
'Saturation' coverage	Saturation coverages (with all modalities of PrEP fully funded) were estimated based on stakeholder consultations and aligned with the proportion of eligible and reachable key populations relative to the proportion of people at risk: MSM: 37,786 TG: 7,254 FEW: 10,422 PWID: 697 Total: 56,159	Cambodia PrEP forecasting targets (March 2023 stakeholder consultations), projected actively using PrEP at the end of 2026 based on initiations from 2024 to 2026 and a 65% retention rate: MSM: 25,398 to 44,068 TG: 6,194 to 9,444 FEW: 5,339 to 8,892 PWID: up to 262 Total: 36,931 to 62,666 An independent national planning process leading to these targets suggests that the saturation levels implemented in the model are largely feasible if prioritized.
PrEP efficacy	95% [92% - 97%] efficacy in preventing new infections	See Optima HIV user guide at http://hiv.optimamodel.com for detailed sources, these values reflect high levels of adherence for people using PrEP.

APPENDIX F SCENARIO ASSUMPTIONS

Historical impact scenario

Methods

Overall, annual HIV spending has decreased from a peak of US$58 million in 2010 to US$47 million in 2015, US$34 million in 2017 (National AIDS Spending Assessments 2006 to 2017, including all indirect costs). Estimated annual HIV spending in 2019 and 2022 used in Optima analyses is not directly comparable, but has been estimated at US$21 million.

Targeted HIV outreach, prevention, and testing programmes for key populations include all programmes specifically reaching men who have sex with men (MSM), transgender women (TG), female entertainment workers (FEW), and people who inject drugs (PWID). Approximately 10% of total HIV spending since 2006 has been attributed to targeted HIV prevention programmes.

To evaluate the impact of spending on HIV prevention for key population programmes, the baseline (historical estimate of HIV trends) is compared with counterfactual scenarios where this spending ended after 2001, 2010, or 2020.

All other programmes including generalized education campaigns, condom distribution, antenatal testing, provider-initiated testing (including testing for people with AIDS), HIV treatment and viral load testing including for key populations, were assumed to remain available in all scenarios.

Scenario limitations

Changes in population definitions and the delivery and unit costs of programmes over time make it impossible to directly evaluate annual spending on specific historical HIV programmes using the most recently available calibrated model.

In the baseline scenario, model parameters for HIV testing for people with CD4>200, condom use in casual and commercial partnerships, and needle sharing follow historical trends. In counterfactual scenarios, these parameters were assumed to follow historical trends to capture the impact of generalized HIV prevention programmes, with an upper bound of the modelled behavioural estimates for people not reached by any prevention programmes in 2023.

However, the 2023 modelled behavioural estimates for people not reached by any programmes implicitly includes social norms developed through the cumulative effects of education and awareness through all HIV prevention programmes (both generalized and targeted) in all prior years. This method likely attributes some impact of historical investments in targeted HIV prevention programmes for key populations prior to 2019 to generalized HIV prevention.

Therefore, results are cautious estimates of the impact of HIV prevention programmes for key populations, the real impact may be significantly higher and has substantial uncertainty prior to 2019.

Crossing the last mile with implementation efficiencies and a multisectoral response

There may still be opportunities to reach the target of <250 infections per year. Combining Rapid PrEP scale-up by 2026 with allocative efficiencies in HIV spending will have the most significant direct impact on HIV transmission and may be projected to reach 350 new HIV infections by 2030. Individual implementation efficiencies and components of a multisectoral response and technical efficiencies can each contribute a part of the remaining last mile to the HIV elimination target, but none are sufficient by themselves (Figure F1).

These multisectoral response and technical efficiencies are described in Table F1. Improved condom accessibility and STI treatment have the potential to be quickly addressed with a large impact, especially for STIs which directly increase HIV transmission. CSE and self-referrals will take much longer to have an impact but may be important parts of sustaining the HIV response beyond 2030.

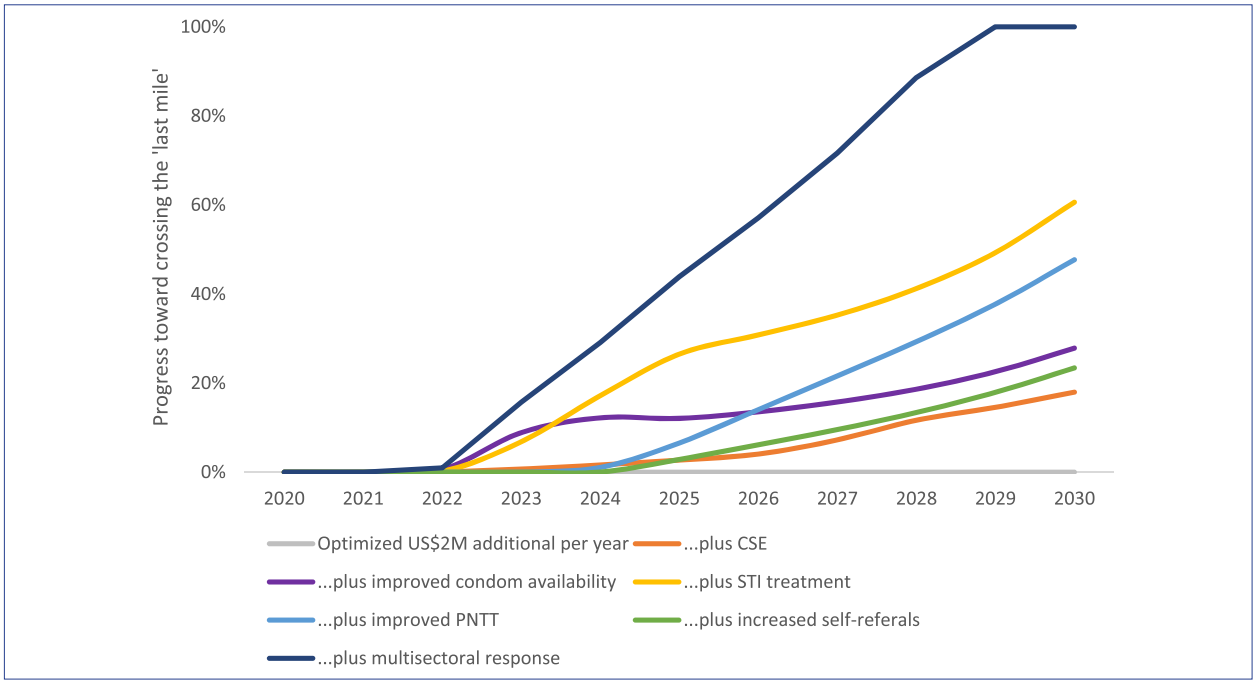


Figure F1: Proportion of the 'last mile' that is crossed with the addition of specific implementation efficiencies or multisectoral responses.

The 'last mile' considers the difference between the projected 360 new HIV infections in 2030 with the optimized allocation of US$2M additional per year from 2024 to 2026 and US$4M per year to sustain HIV services and the national HIV target of less than 250 new HIV infections.

Table F1: Multisectoral response and technical efficiencies

Response	Description	Model implementation
1. Improved STI diagnosis and treatment	Syphilis prevalence has risen rapidly from 2020 to 2023, and both indicates extra sexual risk and increases susceptibility to HIV transmission by nearly three-fold. Although STI screening for syphilis is standard at antenatal clinics through the use of dual test kits, there are often limitations in procurement and supply of treatment for STIs other than HIV. Where STIs are identified in pregnant women, male partners are rarely tested. Improved STI testing and treatment and reduced syphilis prevalence may have benefits in earlier diagnosis of HIV as well as reduced HIV transmission, in addition to other health benefits especially for entertainment workers.	Reduced STI prevalence by 80% between 2023 and 2025 (returning to historic levels prior to 2019).
2. Improved partner notification and testing (PNTT)	There is a large loss in the diagnosis cascade between people that agree to PNTT and partners that are tested. Improved PNTT as an implementation efficiency is likely to increase diagnosis rates especially for clients and regular partners of clients who are currently under-diagnosed.	Based on PNTT referral numbers by population, the number of HIV cases identified through PNTT, and the estimated number of undiagnosed PLHIV in populations, and assumptions about primary partner populations, an increase in the annual probability that an undiagnosed person living with HIV is diagnosed and linked to care for populations: Non-key males: 1.6%, Non-key females: 6.5%, MSM and TG: 4.6%, Clients: 1.8%
3. Condom accessibility	10% of MSM identified a lack of availability as being the main reason they did not use a condom the last time they had condomless sex (IBBS 2019), and logistics to get already procured condoms where and when they are needed combined with legal concerns about storing condoms on premises means that there is scope to increase condom use without extra HIV spending.	Immediate in 2023 increase condom use by 10% among those who would otherwise have not used a condom, e.g. with reported 60% condom use an increase to 64% condom use

Response	Description	Model implementation
4. Private self-test availability and self-referral	Increased availability of HIV self-testing and awareness of their availability may enable increased diagnosis among additional people who have experienced HIV transmission risk but are not comfortable accessing HIV services.	10% increase in the annual probability that an undiagnosed person living with HIV is diagnosed and linked to care.
5. Comprehensive sexuality education (CSE) and other education	There is decreasing awareness among youth (especially key populations) aged 15-24 about HIV and other STIs, and lower condom use as a result. In particular there is a need to reach youth before the age of 18 and before they become "key populations" with education as there are legal and other challenges in providing HIV services to children. CSE may be able to reverse this trend through earlier education among young persons aged 10-14 and have a longer-term HIV epidemic impact as well as other health and social benefits for youth.	From 2023 to 2028 increase condom use in 15-19 year olds to align with condom use in 25+ who had exposure to more HIV awareness as youth. From 2028 to 2030 increase condom use in 20-24 year older to also align with condom use in 25+.
6. Outreach worker incentives	Turnover among outreach workers (OW) is high and this impacts on HIV service quality. Increased renumeration is considered by stakeholders to be vital to improve OW retention. Furthermore, currently all OW do a "little bit" of all outreach modalities, but implementation efficiencies may be possible through skill differentiation so that each OW is able to focus on the modalities that they are most skilled in.	Captured in the model as a 15% increase in service delivery costs for all key population programmes representing proposed increase in renumeration for outreach workers plus potential increases in overheads. No impact of implementation efficiencies through improved service delivery was modelled.