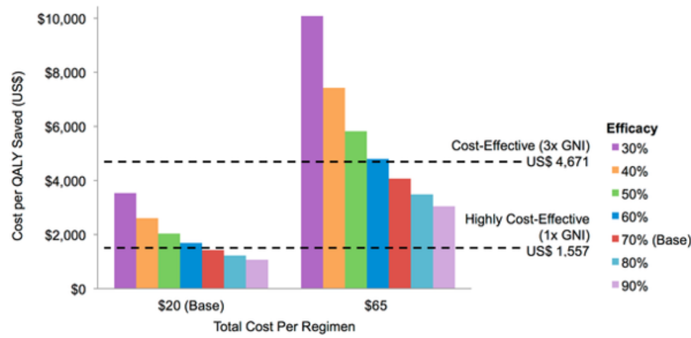
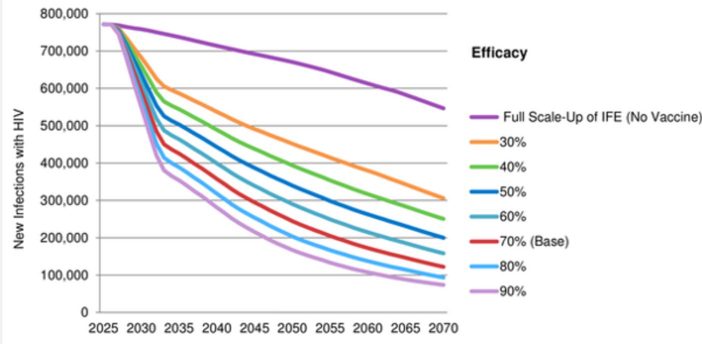
Common Modeling Terminology

Term	Definition	Example
Assumption	A part of the model – either an input or a process or relationship – for which modelers don't have actual data, but that needs to be filled in with something, so they come up with a best guess.	"In this paper, we present the results for a vaccine introduced in 2015 and with 80% coverage reached by 2020, with duration of 20 years. We assume that an HIV test is not a requirement for vaccination. ART coverage is nearly universal in Brazil today and we assumed that would continue in all projections." *Source: Fonseca MGP, Forsythe S, Menezes A, et al. Correction: Modeling HIV Vaccines in Brazil: Assessing the Impact of a Future HIV Vaccine on Reducing New Infections, Mortality and Number of People Receiving ARV. PLoS ONE. 2010:5(8):10.1371/annotation/4rd10061-5a1e-4164-833e-34943a74301c.)*
Calibration	The process in mathematical modeling of changing model inputs and assumptions until the model reproduces observed data.	The mathematical model in the study below was set up to describe the population dynamics of HIV transmission in two rural townships in Liangshan Prefecture of the Shichuan Province of China. The model was calibrated by fitting it to the HIV testing and treatment data from 2005 to 2008. *Source: "A mathematical modeling study of the HIV epidemics at two rural townships in the Liangshan Prefecture of the Sichuan Province of China" by Z Su, C Dong, P Li et al., Oct 2016 1(1) 3-10.* [*https://www.sciencedirect.com/science/article/pii/S2468042716300045*](https://www.sciencedirect.com/science/article/pii/S2468042716300045)
Cost-benefit analysis	A type of economic analysis in which all costs and benefits are converted into monetary (e.g., US$) values, and results are expressed as either the difference between benefits and costs, or the benefits (in dollars) per US$ spent.	"The net benefit of an HIV preventative program is the costs avoided and reduced (the benefit) minus the costs of the program itself. This analysis extended the usual definition to include costs and benefits of treatment and care. (…) On average, these benefits amounted to US$47 per employee for the year 2006." *Source: "Cost Benefit Analysis of HIV Workplace Programmes in Zambia" by Lynn Ilon, Katy Barwise, Saskia Hüsken and Margaret Tembo. Sept 2007; Comprehensive HIV AIDS Management Programme (CHAMP). Available at: pdf.usaid.gov/pdf_docs/Pnadk430.pdf*

Term	Definition	Example
Cost-effectiveness analysis	A formal methodology for evaluating the value for money of an intervention. Outcomes are usually reported in both costs ($ or other currency) and impact (HIV infections averted, HIV cases detected, quality-adjusted life years gained, etc.).	Fig 6. Cost per QALY gained (2027–2070) according to vaccine efficacy under two cost scenarios in LICs (discounted at 3% per year) when a vaccine is added to Full Scale-up of IFE.  With a vaccine that costs $20, the vaccine was projected to be cost-effective at when vaccine efficacy is as low as 30%, and the vaccine was projected to be highly cost-effective with an efficacy of 70% (red bar). When the vaccine costs $65, it is only cost-effective when efficacy is greater than 60%. *Source: Harmon TM, Fisher KA, McGlynn MG, Stover J, Warren MJ, et al. (2016) Exploring the Potential Health Impact and Cost-Effectiveness of AIDS Vaccine within a Comprehensive HIV/AIDS Response in Low- and Middle-Income Countries. PLOS ONE 11(1): e0146387. Https://doi.org/10.1371/journal.pone.0146387*
Data	Values of quantitative information used in a mathematical model	E.g., HIV prevalence among adults in Nigeria from 1984-2016
Disability-adjusted life-years (DALYs) averted from an intervention	Outcome measure of the burden of a health problem; 1 DALY = 1 lost year of "healthy" life	"At Truvada's current price in China, daily oral PrEP costs $46,813–52,008 per DALY averted and is not cost-effective; on-demand Truvada reduces ICER to $25,057–27,838 per DALY averted, marginally cost-effective; daily generic tenofovir-based regimens further reduce ICER to $3675–8963, wholly cost-effective." *Source: Zhang L, Peng P, Wu Y, et al., (2018) Modelling the Epidemiological Impact and Cost-Effectiveness of PrEP for HIV Transmission in MSM in China. AIDS and Beh Available at* https://doi.org/10.1007/s10461-018-2205-3

Term	Definition	Example
Efficacy	The improvement in health outcome that an intervention can produce in expert hands under ideal circumstances.	Fig 3. Reduction of new annual HIV infections under Full Scale-up of IFE according to vaccine efficacy between 2025 and 2070 (vaccine introduced in 2027).  Red line (base case): With an HIV vaccine of 70% efficacy, the projected number of HIV infections is reduced from in nearly 800,000 in 2025 to slightly more than 100,000 in year 2070. *Source: Harmon TM, Fisher KA, McGlynn MG, Stover J, Warren MJ, et al. (2016) Exploring the Potential Health Impact and Cost-Effectiveness of AIDS Vaccine within a Comprehensive HIV/AIDS Response in Low- and Middle-Income Countries. PLOS ONE 11(1): e0146387. Https://doi.org/10.1371/journal.pone.0146387*
Effectiveness	The improvement in health outcome that an intervention can produce in typical community-based settings.	E.g., the effectiveness of oral PrEP in the iPrEX study was 42%, meaning there was a 42% reduction in HIV incidence among people taking oral PrEP compared with placebo. The efficacy of oral PrEP is now estimated to be above 95% based on follow-up studies. The difference between the effectiveness and efficacy of oral PrEP is attributed to people's adherence – the degree to which PrEP users take the pills as directed.
Incidence	The number of new cases of disease in a defined population initially free of disease.	"In 42 jurisdictions with numerically stable estimates, HIV prevalence in 2012 ranged from 110 per 100,000 persons (Iowa) to 3,936 per 100,000 (District of Columbia)." Source: Hall H I, An, Q, Tang T et al., (2015) Prevalence of diagnosed and undiagnosed HIV infection – United States, 2008-2012. 64(24): 657-662. Available at https://europepmc.org/articles/pmc4584741
Input	Something (e.g., data) that goes into the mathematical model	E.g., HIV prevalence among men who have sex with men, condom use among young women
Mathematical model	A mathematical representation of a situation in the world, from which we can make predictions or test assumptions.	E.g., Goals Model, EMOD, Spectrum, OPTIMA, Resource Needs Model, etc.

<table>
<tr><th>Term</th><th>Definition</th><th>Example</th></tr>
<tr><td>Outcome measure</td><td>The final health consequence of an intervention that is being measured.</td><td>E.g., HIV infections, patients enrolled in ART</td></tr>
<tr><td>Output</td><td>The results that are generated from a mathematical model</td><td>E.g., AIDS deaths from 2020-2040; number of new HIV infections from 2018-2030</td></tr>
<tr><td>Parameters</td><td>Inputs and assumptions that go into a mathematical model, that do not change</td><td>Ex. Table 1. Parameter Values used to Simulate the Brazilian HIV Epidemic (source: Fonseca et al., 2010).
<table>
<tr><th>Parameter</th><th>Value</th><th>Source</th></tr>
<tr><td>Relative infectiousness compared to asymptomatic stage</td><td></td><td>Pilcher [25]</td></tr>
<tr><td>Primary stage</td><td>8</td><td></td></tr>
<tr><td>Symptomatic stage</td><td>4</td><td></td></tr>
<tr><td>Probability of HIV transmission per act, heterosexual contact</td><td>0.0007</td><td>Powers [26]</td></tr>
<tr><td>Transmission multiplier for MSM contacts</td><td>2.6</td><td>Vittinghoff [27]</td></tr>
<tr><td>Duration of (in years):</td><td></td><td>Fitted</td></tr>
<tr><td>Asymptomatic stage</td><td>10</td><td></td></tr>
<tr><td>Symptomatic stage</td><td>3</td><td></td></tr>
<tr><td>Condom efficacy</td><td>0.8</td><td>Weller [28]</td></tr>
<tr><td>Annual survival on ART</td><td>0.95</td><td></td></tr>
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</td></tr>
<tr><td>Prevalence</td><td>The number of cases of a given disease or condition in a given population at a designated time.</td><td>In 2016 adult HIV prevalence in South Africa was 18.9%.
Source: https://www.avert.org/professionals/hiv-around-world/sub-saharan-africa/south-africa</td></tr>
<tr><td>Quality-adjusted life-years (QALYs) gained from an intervention</td><td>Outcome measure that combines both the quality and the quantity of life lived or gained. 1 QALY = 1 year of perfect health</td><td>"Compared with the existing program (which has no vaccination), the introduction of the HIV vaccination in the general adolescent population resulted in the net cost of US$ 187 representing an 8.68% increase in costs. This translated to 4.36 QALYs gained and an ICER of US$ 43.07 per QALY gained (95% CI: US$ 38.92–47.43). Administering the vaccine to female only yielded a 68% increase in QALYs gained to 6.36 (95% CI: 5.86–6.85) compared with administering to males only."
Source: Moodley N, Gray G, Bertram M. (2016) The case for adolescent HIV vaccination in South Africa. Medicine (Baltimore) 95(4):e2528.
Available at https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5291560/</td></tr>
<tr><td>Scenario</td><td>A situation that a modeler wants to test – a specific combination of model inputs.</td><td>"Three iterations derived from UNAISD IFE were explored as background scenarios: A Current Trends scenario (…); 50% Scale-up of IFE scenario (…); and Full Scale-up of IFE scenario. (…) In the Current Trends scenario, incremental scale-up of existing HIV/AIDS interventions results in an eventual flat trajectory of new infections of around 1.6 million annually in 2070. Full Scale-up of IFE and 50% Scale-up of IPE would reduce the number of new annual HIV infections in 2070 to approximately 550,000 and 1 million, respectively (Fig 1)."</td></tr>
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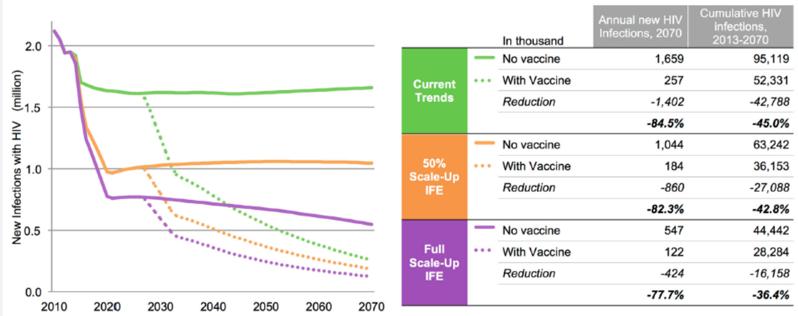

Fig 1. Reduction of new annual HIV infections with and without an AIDS vaccine under different IFE scale-up scenarios between 2010 and 2070. Vaccine and implementation characteristics are outlined in Table 1.

Source: Harmon TM, Fisher KA, McGlynn MG, Stover J, Warren MJ, et al. (2016) Exploring the Potential Health Impact and Cost-Effectiveness of AIDS Vaccine within a Comprehensive HIV/AIDS Response in Low- and Middle-Income Countries. PLOS ONE 11(1): e0146387. Https://doi.org/10.1371/journal.pone.0146387
</td></tr>
<tr><td>Sensitivity analysis</td><td>Answers the question: how much does our model output depend on a specific model parameter? Or: which model parameters have the greatest influence on the model output?
A sensitivity analysis tells you how important a particular model parameter is for the outcome, or which model parameters are the most important.</td><td>
In the table below, the authors performed several sensitivity analyses (year in which a vaccine is introduced (2025 and 2030), vaccine efficacy (30%, 40%, 50%, 60%, 80%, 90%), number of doses, etc.

Table 1. Assumptions.
<table>
<tr><th>Parameter*</th><th>Base assumption</th><th>Variables for Sensitivity</th></tr>
<tr><td>Introduction year</td><td>2027</td><td>2025, 2030</td></tr>
<tr><td>Efficacy</td><td>70%</td><td>30, 40, 50, 60, 80, 90</td></tr>
<tr><td>Doses (primary vaccination)</td><td>3</td><td>2, 4</td></tr>
<tr><td>Booster vaccination</td><td>5 years (returning individual to full modeled efficacy for life)</td><td>3, 10, none necessary (lifetime immunity)</td></tr>
<tr><td>Target coverage–generalized epidemics</td><td>• Routine: 10 year olds: 70%
• Catch up: 11–14 year olds: 60%
• Catch up: 15–17 year olds: 55%
• Catch up: 18–49 year olds: 50%</td><td>+/- 10, 20% for each tier</td></tr>
<tr><td>Target coverage–high risk populations in concentrated epidemics</td><td>50%</td><td>30, 70</td></tr>
<tr><td>Cost per regimen</td><td>• LMICs: US $20 (US $5/dose + US $5 implementation)
• MICs: US $55 (US $15/dose + US $10 implementation)</td><td>See Table 2</td></tr>
<tr><td>Rate at which target coverage is met (both epidemics)</td><td>6 years</td><td>5, 10</td></tr>
</table>

Source: Harmon TM, Fisher KA, McGlynn MG, Stover J, Warren MJ, et al. (2016) Exploring the Potential Health Impact and Cost-Effectiveness of AIDS Vaccine within a Comprehensive HIV/AIDS Response in Low- and Middle-Income Countries. PLOS ONE 11(1): e0146387. Https://doi.org/10.1371/journal.pone.0146387
</td></tr>
<tr><td>Uncertainty analysis</td><td>Answers the question: how much certainty do we have in the model conclusions? When model inputs are based on measured values, these values may be expressed as</td><td>“The uncertainty in the HIV incidence projection for the three provinces with the lowest projected HIV incidence – Western Cape, Limpopo, and Gauteng - leads to uncertainty intervals for HIV treatment cost savings that include zero at a VMMC unit cost of $125. At a VMMC unit cost of $225, the uncertainty interval</td></tr>
</table>

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	a range, such as a mean and standard deviation, so these measured values have some uncertainty to them. An uncertainty analysis examines how the uncertainty in the model inputs leads to uncertainty in the model outputs.	includes zero for the national projection and all provinces except Free State, Mpumalanga, and Northwest." *Source: "Cost and impact of voluntary medical male circumcision in South Africa: focusing the program on specific age groups and provinces" by K Kripke, PA Chen, A Vazzano, et al., July 2016 PloS ONE 11(7): e0157071.*
Validation	Determining if a mathematical model reproduces real-world results well enough to be useful.	The mathematical model in the study below was set up to describe the population dynamics of HIV transmission in two rural townships in Liangshan Prefecture of the Shichuan Province of China. The model was validated by comparing its predicted value of HIV prevalence in 2010 to the prevalence data obtained in the 2010 population wide HIV testing. *Source: "A mathematical modeling study of the HIV epidemics at two rural townships in the Liangshan Prefecture of the Sichuan Province of China" by Z Su, C Dong, P Li et al., Oct 2016 1(1) 3-10.* https://www.sciencedirect.com/science/article/pii/S2468042716300045
Variable	A value within a mathematical model that can be changed.	In a mathematical model with HIV-infected subjects, variables that might be modeled include: CD4 count, viral load, presence of resistance, adherence to treatment, etc.