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# OPTIMIZING HIV PREVENTION EFFORTS TO ACHIEVE EHE INCIDENCE TARGETS

**Evin U. Jacobson, PhD**[1], **Katherine A. Hicks, MS**[2], **Justin Carrico, BS**[2], **David W. Purcell, JD, PhD**[1], **Timothy A Green, PhD**[1], **Jonathan H. Mermin, MD**[1], **Paul G. Farnham, PhD**[1]

[1]Division of HIV/AIDS Prevention, Centers for Disease Control and Prevention, Atlanta, GA.

[2]RTI Health Solutions, Research Triangle Park, Durham NC

## Abstract

**Background:** A goal of the US Department of Health and Human Services' Ending the HIV Epidemic in the U.S. (EHE) initiative is to reduce annual numbers of incident HIV infections in the United States by 75% within 5 years, and by 90% within 10 years. We developed a resource allocation analysis to understand how these goals might be met.

**Methods:** We estimated current annual societal funding ($2.8B/year) for 14 interventions to prevent HIV and facilitate treatment of infected persons. These interventions included HIV testing for different transmission groups, HIV care-continuum interventions, pre-exposure prophylaxis (PrEP), and syringe services programs (SSP). We developed scenarios optimizing or reallocating this funding to minimize new infections, and we analyzed the impact of additional EHE funding over the period 2021 to 2030.

**Results:** With constant current annual societal funding of $2.8B/year for 10 years starting in 2021, we estimated annual incidence in 2030 of 36,000 new cases. When we added annual EHE funding of $500M/year for 2021–2022, $1.5B/year for 2023–2025, and $2.5B/year for 2026–2030, annual incidence in 2030 decreased to 7,600 cases (no optimization), 2,900 cases (optimization beginning in 2026), and 2,200 cases (optimization beginning in 2023).

**Conclusions:** Even without optimization, significant increases in resources could lead to an 80% decrease in annual HIV incidence in 10 years. However, to reach both EHE targets, optimization of prevention funding early in the EHE period is necessary. Implementing these efficient allocations would require flexibility of funding across agencies, which might be difficult to achieve.

Corresponding Author: Paul G. Farnham, Division of HIV/AIDS Prevention, Centers for Disease Control and Prevention, 1600 Clifton Road NE, MS US8-4, Atlanta, GA 30329-4027, (404) 639-4201 (office); (404) 502-7615 (telework), pgf1@cdc.gov.

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Supplemental Digital Content
Technical Report for the HIV Optimization and Prevention Economics (HOPE) Model, December 2021
EHE Appendix JAIDS_12-01-21.docx

### Keywords

Ending the HIV Epidemic in the U.S.; Resource allocation; HIV incidence; United States


In February 2019, the President announced his administration's goal of ending the HIV epidemic in the United States within 10 years. To do so, the US Department of Health and Human Services (HHS) proposed the *Ending the HIV Epidemic in the U.S.* (EHE) initiative with the goals of reducing annual numbers of incident infections in the United States by 75% within 5 years, and by 90% within 10 years.[1]

The field has converged on a broad consensus that these ambitious goals could be reached with a large influx of resources deployed rapidly to the right populations, in the right geographic areas, for the right interventions. Although many researchers have studied the combination of prevention interventions and interventions influencing the HIV continuum of care to achieve substantial reductions in annual new infections, the estimated reductions were not necessarily sufficient to achieve the EHE targets.[2–6] Others have illustrated the requirements needed to reach EHE targets for certain cities.[7–9]

We wanted to better understand the conditions under which the EHE incidence reduction goals could be met. To do this, we analyzed the effects of the optimization of societal spending by the healthcare and public health systems on HIV prevention and care-continuum interventions compared with current funding allocations, fixed increases in federal funding, and the associated costs to assess whether it is feasible to decrease annual HIV incidence in the United States to less than 9,300 cases in 5 years and less than 3,000 cases in 10 years, and thus achieve the HHS EHE incidence targets.[10] Our analysis is based on published work exploring the optimal allocation of public and private spending on HIV prevention in the United States to prevent the most new cases of HIV.[11]

## Methods

### HOPE Model

We applied the HIV Optimization and Prevention Economics (HOPE) model, a dynamic, compartmental model that simulates that portion of the U.S. population aged 13 and over that is sexually active or drug injecting.[11–16] Our analytic time horizon was 2021 through 2030. The population is stratified into 273 subpopulations by sex, age, race/ethnicity, transmission category, risk level, and circumcision status. There are 24 disease-stage and HIV care-continuum compartments plus 2 death compartments (according as CD4 $< 200$ at death or not) in the model. Both persons with HIV (PWH) as well as those susceptible to HIV, transition among the 24 compartments and move into the model via aging and out of the model via death. The model uses differential equations to represent the progression of persons among the compartments. We built HOPE in MATLAB (MathWorks; Natick, Massachusetts). An extensive description of the model's design, inputs, assumptions, and calibration can be found in the Supplemental Digital Content, Technical Report for the HIV Optimization and Prevention Economics (HOPE) Model, June 2021.

In brief, the model requires data to describe HIV risk behaviors and their associated transmission risks, the cost and efficacy of HIV prevention and treatment, and the current transition rates of PWH along the care continuum and across disease stages. To obtain estimated values for most model inputs, we reviewed and summarized the published, peer-reviewed literature and surveillance data. To obtain transition rates along the HIV care continuum, as well as the values of other inputs for which data were limited or uncertain, we calibrated the inputs, constraining their values within bounds informed by published literature, unpublished data, or expert opinion. We calibrated these inputs so that model outcomes matched surveillance data for one or multiple time points from 2016 to 2018, the most current data available at the time of the analysis. The matched outcomes included HIV incidence by transmission category and gender, HIV prevalence for the United States as a whole, and the proportion of PWH estimated to be in each continuum stage (Section 10 of the Supplemental Digital Content).

## Estimation of societal funding for HIV prevention and care-continuum interventions

PWH who, through treatment, are able to achieve and maintain a viral load of <200 copies/mL, hereafter referred to as viral suppression, have effectively no risk of sexual transmission.[17–20] As a result, important HIV care-continuum strategies include early diagnosis, prompt linkage to care, rapid initiation of antiretroviral therapy (ART), and maintenance in care and treatment. In addition, pre-exposure prophylaxis (PrEP)[21–23] and syringe services programs (SSPs)[24–26] are effective tools to prevent infection in persons at high risk of acquiring HIV (Figure 1). Thus, we first estimated current spending by the healthcare and public health systems on 14 interventions in the following categories: HIV testing (for gay, bisexual, or other men who have sex with men [MSM] at high and at low risk of infection, heterosexuals at high and at low risk, and persons who inject drugs [PWID], all of whom we define as high-risk; 5 interventions), HIV care continuum (linkage to care at and after diagnosis, prescription of ART, adherence to care and treatment to achieve viral suppression and to maintain viral suppression; 5 interventions), PrEP (for high-risk MSM, high-risk heterosexuals, and all PWID; 3 interventions), and SSPs. See Sections 8 and 9 of the Supplemental Digital Content for further details about each of these interventions and the populations targeted by each.

We derived current total annual societal (public and private) funding overall and for each intervention by multiplying the cost per person served by the annual number served. We did not estimate the funding from any specific governmental or private agency. We used model calibration to determine the average annual number of persons moving along each step of the continuum, so that the modeled number for each step matched the most recent published HIV surveillance data on the care continuum. Per-person costs from the funders' perspective were based on published studies of interventions (Tables 8.1, 8.2, 9.1, 9.2., 9.3, and 9.4 in the Supplemental Digital Content). We based the per-person PrEP cost on the annual drug cost plus an annual monitoring cost for a total of $14,268 (in 2019 dollars). We estimated the per-person cost for SSPs by using data on the median annual number of syringes used by PWID and the cost of injection equipment. This process resulted in an estimation of current annual societal funding to each of the 14 interventions, which totaled $2.8B. We assumed constant intervention costs over the 10-year time period, and that the current estimated annual societal funding ($2.8B) remained constant for each year of the analysis.

We assumed everyone linked to care received care, and those prescribed ART received ART, unless they dropped out of care. The per-person annual cost for ART used in the model was $25,059 (2019 dollars). We observed the care and treatment expenditure as an output of the model, stratified by disease stage and progress along the HIV care continuum. In addition to the ART-related costs for persons who were prescribed ART, the care and treatment expenditure included HIV-related healthcare resource utilization (inpatient, emergency department, outpatient) for all PWH. For persons linked to care, it also included opportunistic illness prophylaxis prescriptions; CD4, viral load, genotype, and phenotype tests; and medications specifically required by PWH but not related to ART or opportunistic illness prophylaxis, such as medications to treat opportunistic illnesses resulting from HIV infection.

## Scenarios

We then used the model to estimate key outcomes over the 10-year period for 4 scenarios. Under the current funding scenario, we assumed that the current percentage allocation to each intervention of the total annual societal HIV funding of $2.8B remained fixed from 2021 through 2030.

To model the effect of annual additional EHE funding, we divided the 10-year time frame into three time periods and analyzed hypothetical EHE funding increases of $500M/year for 2021–2022, $1.5B/year for 2023–2025, and $2.5B/year for 2026–2030. We chose the specific hypothetical investment levels with feedback from experts at CDC and HHS to reflect increases over time that were in line with EHE budgetary estimates at the time of the analysis.

We estimated the impact of the additional EHE funding with both the current allocation of funding and an optimized allocation of the same funding. We used mathematical optimization, which is described in Section 8.2 of the Supplemental Digital Content, to determine the level of funding for each HIV intervention in the model that prevents the most HIV infections over a given period. The HOPE model dynamically identifies the number of people who are eligible for, but are not receiving an intervention at any given time, and it assumes that most, but not all of those eligible people would be willing to participate in the intervention. The allocation is then optimized to provide interventions to reach those eligible people as needed, with the assumption of not being able to reach all eligible people. Therefore, the calculation of unmet need is implicitly embedded in the methods.

We varied the time period when the allocation was optimized in three scenarios:

- No optimization (Scenario 1a)
- Optimization starting in year 6 of EHE (2026, Scenario 1b)
- Optimization starting in year 3 of EHE (2023, Scenario 1c)

We allocated the current estimated annual societal funding of $2.8B plus the additional funding for a given year between 2021 and 2030 for each of the three scenarios. For our current funding scenario, we estimated the number of HIV infections that would occur from 2021 through 2030 if the current annual societal funding and the allocation of that funding remained fixed throughout that period. For the no-optimization scenario (1a), we estimated the number of HIV infections if the additional EHE prevention funding was distributed proportional to the current allocation of total HIV prevention funding from 2021 through 2030. Then, assuming the same amount of funding as Scenario 1a, we used optimization techniques (from MATLAB's Optimization Toolbox) and the HOPE model to estimate the 2026–2030 allocation for Scenario 1b, and the 2023–2025 and 2026–2030 allocations for Scenario 1c, that would prevent the most HIV infections from 2021 through 2030.

We constrained the maximum percentage of eligible persons who could be reached by each of the 14 interventions annually in the optimization scenarios. The estimates of the maximum percentage of eligible persons who could be reached annually by each intervention, which reflected expanded efforts to serve such persons, were informed by CDC subject matter experts and were similar to those applied in the limited-reach scenario of Sansom and coauthors[11] and to the "ideal implementation" coverage levels in the analysis led by Nosyk et al.[8] The estimates for maximum annual reach by each intervention were 50% for testing, PrEP and SSPs, 65% for linkage to care after diagnosis, 90% for linkage to care at diagnosis and ART prescription, and 95% for ART adherence. We also note that because these limits are applied annually, the cumulative effects over time are such that much higher percentages of PWH overall will have progressed along each step along the continuum.

Our key research question was whether a given increase in prevention funding was sufficient to achieve EHE incidence targets. In addition to our key outcome of HIV incidence, we observed other outcomes including HIV prevalence, the percentage of PWH whose infection has been diagnosed, and the percentage of persons virally suppressed among those diagnosed. We also estimated changes in average annual HIV prevention funding and treatment spending.

To conduct the uncertainty analysis for this study, we examined how using 10 sets of alternate values for the model's calibrated inputs changed the optimal allocation of the two allocation periods for Scenario 1c, in which public and private funds were optimized starting in 2023. The available budget in each allocation period was the same as in the initial Scenario 1c analysis. We used the model to estimate the expected incidence in 2025 and 2030 under each of the 10 sets and the identified optimal allocation of funds corresponding to each. We then observed the minimum and maximum optimized allocation to each intervention across the 10 sets in each optimized allocation period (2023–2025, 2026–2030), as well as the minimum and maximum HIV incidence outcomes for 2025 and for 2030. Additional details are provided in Section 11 of the Supplemental Digital Content.

## Results

With the current allocation of $2.8 billion annual societal funding that remained the same for 10 years starting in 2021, we estimated total incidence over the period of approximately 347,000 cases. The percentage of those virally suppressed among those with an HIV diagnosis decreased slightly, while HIV prevalence increased slightly. Total prevention funding and treatment spending was approximately $373B over the 10 years (Table 1).

When we added the annual EHE funding of $500M/year for 2021–2022, $1.5B/year for 2023–2025, and $2.5B/year for 2026–2030 to the annual societal HIV prevention funding of $2.8B, the additional prevention funding and treatment spending was approximately $20B higher over the 10-year time period compared to current funding (Table 2). Total infections decreased by approximately 180,000, 200,000 and 230,000 in Scenarios 1a, 1b, and 1c, respectively, compared to the current funding scenario. Only in Scenario 1c did the allocation of funds allow both the 2025 and the 2030 incidence targets to be met. Scenario 1a missed the targets but reduced annual cases to 7,600 in 2030. Scenario 1b met the 2030 target but missed the 2025 target. The reduction in incidence in Scenario 1a compared with the current funding scenario was due to the addition of the EHE funding. The further incidence decreases in Scenarios 1b and 1c resulted from optimizing the allocation of all funding beginning in 2026 (Scenario 1b) and in 2023 (Scenario 1c).

The optimal funding allocations for most interventions changed only slightly compared with the current allocation, except for HET testing, the adherence-related interventions (adherence to care and treatment to achieve and maintain viral suppression) and PrEP funding (Table 3). Funding for low-risk HET testing decreased, while funding for high-risk HET testing increased. For adherence-related interventions, funding for adherence to care and treatment to maintain viral suppression increased, while funding for achieving viral suppression fluctuated in the two time periods. Funding for PrEP increased for high-risk heterosexuals and decreased slightly for high-risk MSM, largely because funding for the continuum interventions reached their maximum constraints, and funding was available for the prevention interventions.

The uncertainty analyses using 10 alternate sets of input values for the model's 280 calibrated inputs produced minimum and maximum allocations for each intervention that varied from the allocations produced by the initial scenario 1c analysis, but in most cases identified optimal allocation strategies that were very similar to those of the initial analysis. Across all calibration sets, the majority of funds were distributed to PrEP (35–50% of overall spending), adherence-related interventions (20–31%), and screening (17–24%) from 2023–2025. Similar trends were observed in 2025–2030, although allocations to adherence-related interventions were more variable (13–38% of overall spending). HIV incidence in 2025 varied from 6,932 to 9,991 across the ten alternate sets (7,980 in the initial analysis). HIV incidence in 2030 varied from 2,034 to 3,065 across the alternate sets (2,223 in the initial analysis).

## Discussion

*Ending the HIV Epidemic in the U.S.* is an ambitious plan announced in 2019 that aims to reduce annual new HIV infections in the United States by 75% in 5 years and 90% in 10 years.[1] To assess whether a given increase in prevention funding was sufficient to achieve EHE incidence targets, we used scenario analyses to investigate the current allocation of HIV funding, an optimal allocation to HIV prevention and care-continuum interventions designed to minimize the number of new HIV infections, the impact of additional EHE funding, and the associated costs at a national level.

All three scenarios that we analyzed resulted in dramatic decreases in annual HIV incidence to fewer than 8,000 cases by 2030. Even without optimization, our model showed that a significant increase in resources leads to significant incidence reductions. In the most realistic and achievable Scenario 1a (increased funding but maintaining the same relative allocation of resources across interventions), annual HIV incidence dropped by almost 80% in 10 years. Thus, the simple addition of significant resources can have a substantial impact on HIV in the United States. However, to reach both EHE targets, optimization of prevention funding early in the EHE period (beginning in 2023 as in Scenario 1c) was necessary. Both scenarios 1b and 1c suggest that some targeting and focusing of resources into the right interventions for the right populations can have an even bigger impact than adding funds alone.

Our optimization analysis showed that the most efficient path toward major reductions in HIV transmission will include greatly enhanced testing among populations at high risk for HIV, and adherence to HIV care and treatment. However, a fully optimal allocation of all societal resources is difficult to achieve in the real world, as it assumes flexibility of funding among various governmental and private agencies, and it would require programs to maximize efficacy of available funding.

Addressing the complexities of intervention implementation will be critical in reducing the spread of HIV and achieving the EHE targets. In this analysis, we assess the “what” (which interventions to fund and to what extent), but not the “how” (the best intervention approaches and implementation strategies). As with other models, the “how” is the purview of creative, experienced program managers and interventional scientists. Our results rely on cost estimates per effectively treated person by evidence-based interventions identified in the scientific literature (Table 8.2 in the Supplemental Digital Content). However, it is beyond the scope of the compartmental model used in this paper to compare various intervention approaches, such as those included in CDC’s Compendium of Evidence-Based Interventions and Best Practices for HIV Prevention (CDC, Compendium) which highlights evidence-based interventions for increasing linkage, retention, and re-engagement in care and improving medication adherence. As the implementation of these interventions improves in practice, their impact would also improve; however, comparing various levels of implementation was also beyond the scope of this paper.

Models are limited by the assumptions and inputs that go into each model and each scenario. With few published data on intervention costs or how funders’ costs change depending on the subpopulation served or how they change as there are fewer of any population left to be served, we have considerable uncertainty about intervention costs and did not increase intervention costs for historically vulnerable populations or when higher percentages of eligible persons were reached. For these reasons, the full costs of HIV elimination in the United States are likely higher than our estimates. Moreover, our costs for PrEP are likely underestimated because we did not include costs associated with increasing PrEP outreach and other support services, a topic for future research. In addition, we have not tried to include the effects of COVID-19 on funding and resource allocation, as there are limited data and guidance available to quantify these effects. Models, such as this one, are meant to provide direction to the allocation of resources over the long run and are only one input that policy makers should consider when making decisions.

This analysis uses a national-level model. In reality, the HIV epidemic varies across local jurisdictions. The conclusions of the analyses should be considered with that limitation in mind. We note that this and other published analyses[8, 9] consistently support two key elements to any successful effort to impact the trajectory of HIV in the United States -- interventions to achieve or maintain viral suppression and expansion of current prevention efforts. Local decision-makers will have to consider how those two elements are most successfully implemented in their jurisdictions.

Implementing the allocations suggested by our model will require careful planning over time, so that implementation is done in accordance with community input, governing rules, laws, and ethics.

The EHE initiative has the potential for reaching the ambitious goal of a 90% reduction in annual incidence in 10 years with the dedication of significant funding increases across all 10 years of the initiative, as well as making the most efficient use of societal resources beginning in the early years of the initiative. Even without optimization, a significant increase in resources can have a substantial impact on ending the HIV epidemic in the United States.

## Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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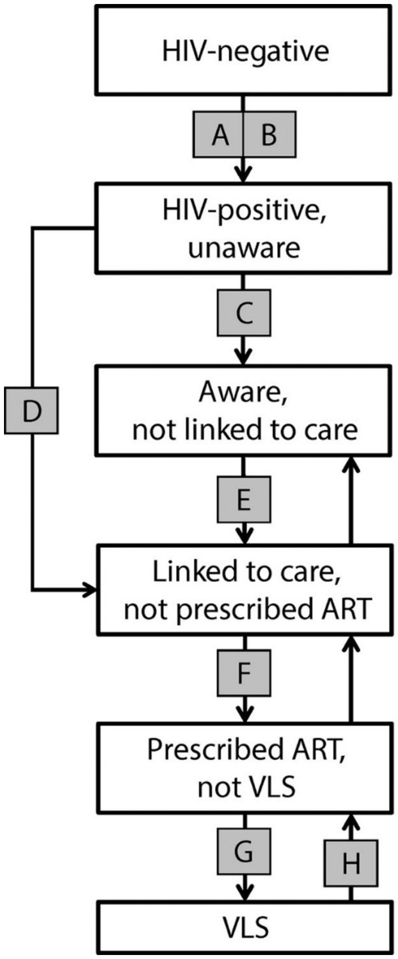
## References

1. Fauci AS, Redfield RR, Sigounas G, Weahkee MD, Giroir BP. Ending the HIV Epidemic: A plan for the United States. JAMA. 2019;321(9):844–845. doi:10.1001/jama.2019.1343 [PubMed: 30730529]
2. Gopalappa C, Sansom SL, Farnham PG, Chen Y-H. Combinations of interventions to achieve a national HIV incidence reduction goal: insights from an agent-based model. AIDS (London, England). 2017;31(18):2533–2539. doi:10.1097/QAD.0000000000001653
3. Birger RB, Hallett TB, Sinha A, Grenfell BT, Hodder SL. Modeling the impact of interventions along the HIV continuum of care in Newark, New Jersey. Clinical infectious diseases : an official

publication of the Infectious Diseases Society of America. 2014;58(2):274–284. doi:10.1093/cid/cit687 [PubMed: 24140971]

4. Jenness SM, Johnson JA, Hoover KW, Smith DK, Delaney KP. Modeling an integrated HIV prevention and care continuum to achieve the Ending the HIV Epidemic goals. AIDS. Nov 15 2020;34(14):2103–2113. doi:10.1097/qad.0000000000002681 [PubMed: 32910062]
5. Holtgrave D, Young P, Mayer R, Maulsby C, Kim J. Employing resource allocation modeling to inform HIV prevention planning for the state of Iowa. AIDS Education and Prevention. 2013;25(5):423–429. [PubMed: 24059879]
6. Holtgrave D, Maulsby C, Kim J, Cassidy-Stewart H, Hauck H. Using resource allocation modeling to inform HIV prevention priority setting for Baltimore-Towson, Maryland. Progress in Community Health Partnerships: Research, Education, and Action. 2016;10(1):133–139.
7. Zang X, Jalal H, Krebs E, et al. Prioritizing additional data collection to reduce decision uncertainty in the HIV/AIDS response in 6 US cities: A Value of Information Analysis. Value in Health. 2020/12/01/ 2020;23(12):1534–1542. doi:10.1016/j.jval.2020.06.013 [PubMed: 33248508]
8. Nosyk B, Zang X, Krebs E, et al. Ending the HIV Epidemic in the USA: an economic modelling study in six cities. The Lancet HIV. 2020/07// 2020;7(7):e491–e503. doi:10.1016/s2352-3018(20)30033-3 [PubMed: 32145760]
9. Krebs E, Zang X, Enns B, et al. The impact of localized implementation: determining the cost-effectiveness of HIV prevention and care interventions across six United States cities. AIDS (London, England). 2020/03// 2020;34(3):447–458. doi:10.1097/qad.0000000000002455
10. AHEAD. America's HIV Epidemic Analysis Dashboard. https://ahead.hiv.gov/data
11. Sansom SL, Hicks KA, Carrico J, et al. Optimal allocation of societal HIV prevention resources to reduce HIV incidence in the United States. American Journal of Public Health. 2021;111(1):150–158. doi:10.2105/ajph.2020.305965 [PubMed: 33211582]
12. Uzun Jacobson E, Hicks KA, Tucker EL, Farnham PG, Sansom SL. Effects of reaching national goals on HIV incidence, by race and ethnicity, in the United States. J Public Health Manag Pract. Jul/Aug 2018;24(4):E1–e8. doi:10.1097/phh.0000000000000717
13. Khurana N, Yaylali E, Farnham PG, et al. Impact of improved HIV care and treatment on PrEP effectiveness in the United States, 2016–2020. J Acquir Immune Defic Syndr. Aug 1 2018;78(4):399–405. doi:10.1097/qai.0000000000001707 [PubMed: 29683993]
14. O'Leary A, DiNenno E, Honeycutt A, et al. Contribution of anal sex to HIVprevalence among heterosexuals: a modeling analysis. AIDS Behav. Oct 2017;21(10):2895–2903. doi:10.1007/s10461-016-1635-z [PubMed: 28058564]
15. Klein PW, Cohen SM, Uzun Jacobson E, et al. A mathematical model to estimate the state-specific impact of the Health Resources and Services Administration's Ryan White HIV/AIDS Program. PLoS One. 2020;15(6):e0234652. doi:10.1371/journal.pone.0234652 [PubMed: 32569330]
16. Shiels MS, Islam JY, Rosenberg PS, Hall HI, Jacobson E, Engels EA. Projected cancer incidence rates and burden of incident cancer cases in HIV-infected adults in the United States Through 2030. Ann Intern Med. Jun 19 2018;168(12):866–873. doi:10.7326/m17-2499 [PubMed: 29801099]
17. Bavinton BR, Pinto AN, Phanuphak N, et al. Viral suppression and HIV transmission in serodiscordant male couples: an international, prospective, observational, cohort study. Lancet HIV. Aug 2018;5(8):e438–e447. doi:10.1016/s2352-3018(18)30132-2 [PubMed: 30025681]
18. Cohen MS, Chen YQ, McCauley M, et al. Antiretroviral therapy for the prevention of HIV-1 transmission. N Engl J Med. Sep 1 2016;375(9):830–9. doi:10.1056/NEJMoa1600693 [PubMed: 27424812]
19. Rodger AJ, Cambiano V, Bruun T, et al. Risk of HIV transmission through condomless sex in serodifferent gay couples with the HIV-positive partner taking suppressive antiretroviral therapy (PARTNER): final results of a multicentre, prospective, observational study. Lancet. Jun 15 2019;393(10189):2428–2438. doi:10.1016/s0140-6736(19)30418-0 [PubMed: 31056293]
20. Rodger AJ, Cambiano V, Bruun T, et al. Sexual activity without condoms and risk of HIV transmission in serodifferent couples when the HIV-positive partner Is using suppressive antiretroviral therapy. Jama. Jul 12 2016;316(2):171–81. doi:10.1001/jama.2016.5148 [PubMed: 27404185]

21. Baeten JM, Donnell D, Ndase P, et al. Antiretroviral prophylaxis for HIV prevention in heterosexual men and women. N Engl J Med. Aug 2 2012;367(5):399–410. doi:10.1056/NEJMoa1108524 [PubMed: 22784037]
22. Grant RM, Lama JR, Anderson PL, et al. Preexposure chemoprophylaxis for HIV prevention in men who have sex with men. N Engl J Med. Dec 30 2010;363(27):2587–99. doi:10.1056/NEJMoa1011205 [PubMed: 21091279]
23. Thigpen MC, Kebaabetswe PM, Paxton LA, et al. Antiretroviral preexposure prophylaxis for heterosexual HIV transmission in Botswana. N Engl J Med. Aug 2 2012;367(5):423–34. doi:10.1056/NEJMoa1110711 [PubMed: 22784038]
24. Adams M, An Q, Broz D, Burnett J, Wejnert C, Paz-Bailey G. Distributive syringe sharing and use of Syringe Services Programs (SSPs) among persons who inject drugs. AIDS Behav. Dec 2019;23(12):3306–3314. doi:10.1007/s10461-019-02615-4 [PubMed: 31512066]
25. Aspinall EJ, Nambiar D, Goldberg DJ, et al. Are needle and syringe programmes associated with a reduction in HIV transmission among people who inject drugs: a systematic review and meta-analysis. Int J Epidemiol. Feb 2014;43(1):235–48. doi:10.1093/ije/dyt243 [PubMed: 24374889]
26. Des Jarlais DC, Nugent A, Solberg A, Feelemyer J, Mermin J, Holtzman D. Syringe Service Programs for persons who inject drugs in urban, suburban, and rural areas - United States, 2013. MMWR Morb Mortal Wkly Rep. Dec 11 2015;64(48):1337–41. doi:10.15585/mmwr.mm6448a3 [PubMed: 26655918]




| | Intervention | How Intervention Affects Model Flow |
|---|---|---|
| A | PrEP | Decreases the number of individuals who become HIV-infected |
| B | SSP | Decreases the number of PWID who become HIV-infected |
| C | Screening | Increases the number of undiagnosed HIV-infected individuals who become diagnosed with HIV |
| D | Linkage to care at diagnosis | Increases the number of undiagnosed HIV-infected individuals who become diagnosed with HIV and are immediately linked to care |
| E | Linkage to care after diagnosis | Increases the number of individuals who are aware of their infection but not in care who are linked to care |
| F | ART prescription | Increases the number of individuals who are prescribed ART |
| G | Adherence to care and treatment to become virally suppressed | Increases the number of individuals who are prescribed ART but are not virally suppressed who become virally suppressed |
| H | Adherence to care and treatment to remain virally suppressed | Decreases the number of individuals who lose their VLS status |

**Figure 1, Diagram of how HIV prevention interventions relate to HIV and the HIV care continuum: United States**

Note. ART = antiretroviral therapy; PrEP = pre-exposure prophylaxis; PWID = persons who inject drugs; SSP = syringe services programs; VLS = viral load suppression.

Source: Sansom SL et al. Optimal allocation of societal HIV prevention resources to reduce HIV incidence in the United States. American Journal of Public Health 2021; 111(1): 150–158, Figure 1. Permission to reprint received May 20, 2021.

**Table 1:**

Current funding results

| Year | Incidence | % Living with diagnosed HIV | % VLS among diagnosed | Prevalence | Total prevention funding and treatment spending ($M) |
|---|---|---|---|---|---|
| 2021 | 35,021 | 87% | 55% | 1,138,730 | $36,201 |
| 2022 | 34,062 | 87% | 55% | 1,146,327 | $36,465 |
| 2023 | 34,041 | 87% | 54% | 1,153,575 | $36,728 |
| 2024 | 34,232 | 88% | 54% | 1,160,792 | $36,988 |
| 2025 | 34,436 | 88% | 53% | 1,168,043 | $37,242 |
| 2026 | 34,588 | 88% | 53% | 1,175,294 | $37,491 |
| 2027 | 34,743 | 88% | 53% | 1,182,538 | $37,733 |
| 2028 | 34,996 | 88% | 53% | 1,189,854 | $37,967 |
| 2029 | 35,311 | 88% | 52% | 1,197,286 | $38,196 |
| 2030 | 35,681 | 88% | 52% | 1,204,868 | $38,418 |
| **Total** | 347,112 | | | | $373,429 |

Source: Authors' analysis of data in the HIV Optimization and Prevention Economics (HOPE) model.

**Table 2:**

Scenario comparisons

| | **Scenarios** | **Current funding*** | **1a[1+]** | **1b[2+]** | **1c[3+]** |
|---|---|---|---|---|---|
| 10-year cumulative | New infections | 347,112 | 166,799 | 146,506 | 115,692 |
| | Decrease in new infections compared to current funding | | 180,313 | 200,606 | 231,420 |
| | Prevention funding ($M) ** | 28,033 | 46,033 | 46,033 | 46,033 |
| | Treatment spending ($M)*** | 345,396 | 347,490 | 347,511 | 347,327 |
| | Prevention funding and treatment spending ($M) | 373,429 | 393,524 | 393,545 | 393,360 |
| | Additional prevention funding and treatment spending compared to current funding ($M) | | 20,094 | 20,115 | 19,931 |
| | 2025 annual new infections (target 9,300) | 34,436 | 16,911 | 16,911 | 7,980 |
| | 2030 annual new infections (target 3,000) | 35,681 | 7,624 | 2,886 | 2,223 |

*Current annual societal HIV prevention funding: $2.8B

**Calculated by multiplying the total annual prevention funding (see last row in Table 3) by the number of years at that annual funding level for years 1 to 10.

***Treatment spending, an outcome of the simulation, is dependent on the number of PWH who are on ART and who utilize healthcare resources for each scenario.

[1]No optimization

[2]Optimization starting in year 6 (2026)

[3]Optimization starting in year 3 (2023)

+Annual additional EHE funding: $500M/year for 2021–2022; $1.5B for 2023–2025; $2.5B/year for 2026–2030

Source: Authors’ analysis of data in the HIV Optimization and Prevention Economics (HOPE) model.

## Table 3:

Funding allocation[+]

| | | | Current allocation[*] ($M) | | | | | Optimal allocation[*] ($M) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Intervention | | | Total annual additional EHE funding over current allocation, by year | | | | | | | | |
| | | | $0M<br>2021–2030 | $500M<br>2021–2022 | $1.5B<br>2023–2025 | $2.5B<br>2026–2030 | %[**] | $1.5B<br>2023–2025 | | $2.5B<br>2026–2030 | |
| | | | Allocation, by year | | | | | | | | |
| Testing | HET | Low-risk | $744 | $877 | $1,143 | $1,408 | 27% | $275 | 6% | $347 | 7% |
| | | High-risk | $57 | $67 | $87 | $108 | 2% | $339 | 8% | $433 | 8% |
| | MSM | Low-risk | $16 | $19 | $25 | $30 | 1% | $34 | 1% | $94 | 2% |
| | | High-risk | $29 | $34 | $44 | $54 | 1% | $93 | 2% | $99 | 2% |
| | PWID | | $28 | $33 | $43 | $54 | 1% | $33 | 1% | $51 | 1% |
| LTC at diagnosis | | | $18 | $22 | $28 | $35 | 1% | $102 | 2% | $81 | 2% |
| LTC after diagnosis | | | $12 | $14 | $19 | $23 | 0% | $97 | 2% | $42 | 1% |
| ART prescription | | | $1 | $1 | $2 | $2 | 0% | $55 | 1% | $3 | 0% |
| Adherence to care and treatment: Remain in care and VLS | | | $205 | $242 | $315 | $388 | 7% | $576 | 13% | $623 | 12% |
| Adherence to care and treatment: Remain in care and become VLS | | | $248 | $292 | $380 | $468 | 9% | $498 | 12% | $370 | 7% |
| SSPs | | | $23 | $27 | $35 | $44 | 1% | $69 | 2% | $67 | 1% |
| PrEP | HETs | High-risk | $167 | $197 | $257 | $316 | 6% | $423 | 10% | $966 | 18% |
| | MSM | High-risk | $1,254 | $1,478 | $1,926 | $2,373 | 45% | $1,708 | 40% | $2,118 | 40% |
| | PWID | | $0 | $0 | $0 | $0 | 0% | $0 | 0% | $2 | 0% |
| Total annual prevention funding | | | $2.8B | $3.3B | $4.3B | $5.3B | 100% | $4.3B | 100% | $5.3B | 100% |

[+]We used the following maximum-reach percentages in the optimization scenarios: Testing, PrEP and SSPs: 50%; LTC at diagnosis and ART prescription: 90%; LTC after diagnosis: 65%; and Adherence to care and treatment: 95%. The optimal allocation is for Scenario 1c.

[*]Current annual societal HIV prevention funding: $2.8B

[**]Percentage distribution is the same for all levels of additional EHE funding under the current allocation.

Source: Authors' analysis of data in the HIV Optimization and Prevention Economics (HOPE) model.