HIV resource needs, efficient allocation and resource mobilization for the Republic of Belarus

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This report presents the results of resource tracking and costing of specific HIV activities providing the basis for a comprehensive estimate of resources needed to sustain the national AIDS response in Belarus. This project is an initiative of the Ministry of Health of the Republic of Belarus, supported by the development partners, UNAIDS and UNDP country offices. Costing was led by Anna Yakusik with input from Carlos Avila. Epidemic projections and resource optimization were conducted by Cliff Kerr and David Wilson. Resource mobilization strategies were developed by David Wilson, Anna Yakusik and Carlos Avila.

Executive summary

- **Withdrawing international aid due to economic crises requires establishment of transitional funding mechanisms to domestic sources** – National health programs are developing innovative financing mechanisms to take full leadership of the strategies and funding of HIV/AIDS programs and identifying opportunities to increase value for money.
- **HIV incidence is not yet declining** – The HIV epidemic in Belarus is in an expansion phase. There has also been a shift in the primary mode of transmission from injecting to sexual. Approximately 60-80% of new infections are now due to sexual transmission
- **Critical services need to be scaled up to save lives** – (a) earlier diagnosis is required with 80% unaware of their infection; (b) treatment and care scale-up is a high priority; and (c) prevention among most-at-risk populations needs to be scaled up.
- **Opportunities exist to optimize investments** – A disproportionately high amount of money is being spent on non-targeted programs. If current budget amounts were allocated more optimally among key interventions then overall HIV incidence would reduce by over 25%. Financing health care facilities rather than disease-specific programs in Belarus may mean strategic redirection of priority focus areas at the site-level is necessary.
- **Getting to zero –** It is possible to reduce HIV incidence among the most-at-risk populations by 50% with currently available funds by shifting resources to interventions for priority populations. Defunding facilities may not be viable, in which case additional resources are necessary for interventions for priority groups. Earlier diagnosis and treatment of people living with HIV, under ideal conditions, and at an estimated cost of at least US$10.8 million per year in addition to current resources would be necessary to reduce overall HIV incidence by 50%.
- **It is essential to invest now –** Acting strategically now can avert 5 800 HIV infections over 5 years; delaying by three years would lead to an unnecessary additional 3 000 infections.
- **Smart responses yield return on investments** – Each infection averted saves approximately US$35 000 in future healthcare expenditure. A return of twice the investment in HIV/AIDS is possible in saved healthcare expenditure in the future (e.g. wise spending of the current annual budget of US$20 million, over 5 years, can return $200 million in total).
- **Government leadership –** The Belarus government has shown leadership to commit to filling the gap from funding withdrawals.
- **Funding required** – An extra US$3.2 million per year is required to fill the gap among most-at-risk populations and could reduce HIV incidence by 50% in these groups. The additional annual resources required to also have an enhanced response to reduce incidence in these groups and improve ART coverage is $5.9 million per year.
- **Mobilizing additional resources** – An airline levy (US$2-3 on departing flights) or telecommunications levy (utilizing 2.5% of a recently imposed levy on mobile phones) provides the revenue for financing HIV/AIDS.

1. Why is this report needed?

Shortfalls in domestic funding

- The Belarusian economy was hit by an economic crisis in recent years resulting in a three-fold devaluation of the Belarusian ruble.
- This has reduced government revenues and has led to high risk of underfinancing of social and health care programs.
- There are foreseen shortfalls in the government's ability to invest in HIV prevention and treatment.

HIV response is heavily dependent

- Belarus has been heavily reliant on international aid in recent years with ~50% of HIV/AIDS program funds from external sources in 2011, primarily the Global Fund to fight AIDS, Tuberculosis and Malaria (GFATM).

How can we best strive to achieve the 'getting to zero' goal without many of the current sources of funding?

International aid is withdrawing

- The economic crisis in North America and Western Europe has limited the growing tendency that international aid enjoyed in the past.
- Withdrawal of GFATM grants by the end of 2015, which provide primary support for key prevention programs and care and treatment programs, leads to concern around the sustainability of the HIV/AIDS response.
- Donors are increasingly supporting countries to establish transitional funding mechanisms from international to domestic sources, including innovative financing systems.

Objectives of this report

- Calculate the costs of HIV prevention and treatment interventions and activities.
- Assess modes of transmission and project future epidemic trajectories for the period 2015-2020.
- Identify specific strategies that are likely to have greatest potential for achieving the 'getting to zero' goal.
- Calculate the resources required to implement these strategies.
- Develop recommendations and a framework for resource mobilization.

2. How much is spent on HIV and where does the money come from?

HIV response has been heavily dependent on foreign aid

- National AIDS Spending Assessment (NASA) was conducted for the period 2008-2011.
- Around US$ 20 million has been invested annually in the HIV/AIDS response in Belarus (Table 1, Figure 1).

Around 50% of HIV/AIDS funding for Belarus is from the Global Fund

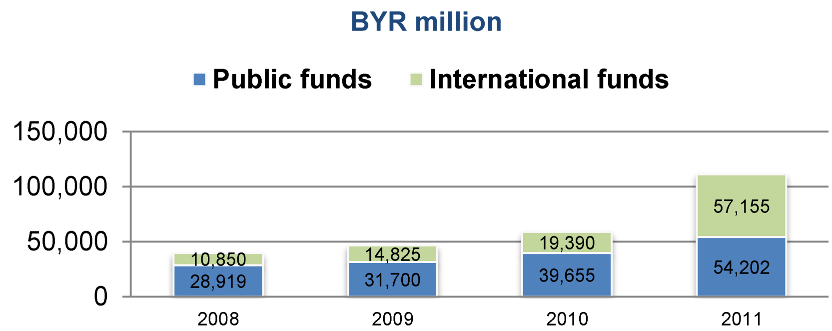
- HIV funding from the international community has increased, more than double the investment in 2008, and has now surpassed domestic spending.
- Domestic investments in HIV/AIDS almost doubled during 2008-2011 (Figure 1a).
- The GFATM has been the major donor. Its share increased and accounted for about 96% of the international donor funding by 2011.

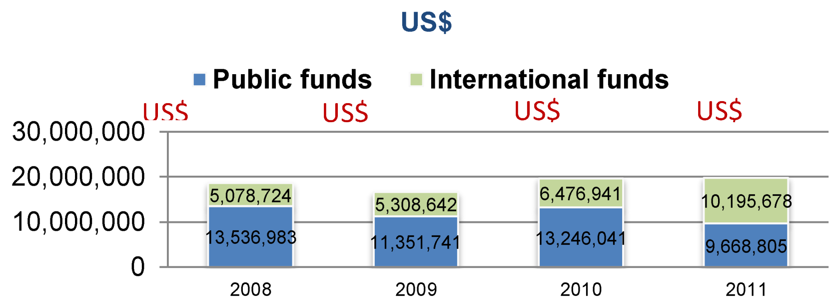
Domestic HIV/AIDS spending has been steadily increasing

Table 1: Investments in national HIV/AIDS response and funding sources, 2008-2011

	2008	2009	2010	2011
Total estimated investments in HIV/AIDS response, BYR million (US$ million)				
Total domestic & international funding	BYR 39,768 m (US$ 18.6 m)	BYR 46,525 m (US$ 16.7 m)	BYR 59,045 m (US$ 19.7 m)	BYR 111,357 m (US$ 19.9 m)
Funding sources (%)				
Domestic	72.72%	68.14%	67.16%	48.67%
International	27.28%	31.86%	32.84%	51.33%
Key intervention areas as a percentage of total investments in HIV/AIDS response				
Prevention	66.42%	60.36%	66.88%	54.53%
Care & treatment	13.85%	17.14%	14.30%	18.27%
Orphans and vulnerable children	0.50%	0.60%	0.00%	0.00%
Program management	10.80%	14.22%	8.86%	18.86%
Human resources	3.48%	4.42%	7.34%	4.86%
Social protection and social services	1.75%	1.69%	0.99%	1.03%

Figure 1: HIV/AIDS investments in Belarus by source of funding, 2008-2011





Breakdown of funding to programs

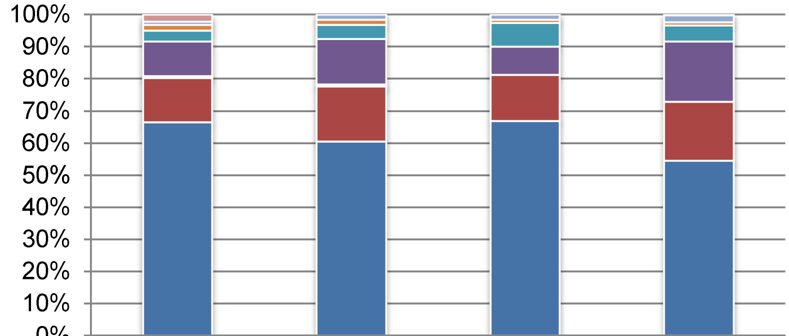
- The majority (55-65%) of all HIV/AIDS spending has been on prevention (Figure 2).
- The interventions receiving the greatest funding have been non-targeted - for the general population or undefined interventions not to the most-at-risk populations (Figure 3).
- There was a large increase and larger amount invested in interventions targeting injecting drug users (IDUs) than programs for men who have sex with men (MSM) and female sex workers (FSWs) (Figure 4). PMTCT also increased over time.
- There was an average annual spending on prevention of US$16.30 per IDU, $4.04 per MSM and $5.36 per FSW (based on National Sentinel Surveillance estimates of 75,000 IDUs, 50,000 FSWs and 55,000 MSM). These amounts are considerably less than required to meet international guideline targets for these populations.
- Expenditure on care and treatment has slightly increased between 2008 and 2011.
- Despite over 35 000 PLHIV, around 20% have been diagnosed and alive and only around 3 500 people are on antiretroviral treatment.

Spending on prevention dominates HIV/AIDS budget

HIV/AIDS response for priority interventions is under-funded

Treatment coverage is low

Figure 2: Composition of total HIV/AIDS investments in Belarus, 2008-2011 (US$ million, %)



	2008	2009	2010	2011
HIV-related research	0.4120	0.0054	0.0145	0.0447
Enabling environment	0.1819	0.2553	0.3082	0.4452
Social protection and social services	0.3262	0.2811	0.1957	0.2036
Human resources	0.6487	0.7361	1.4474	0.9653
Program management	2.0098	2.3697	1.7471	3.7456
Orphans and vulnerable children	0.0940	0.0998	0.0000	0.0000
Care & treatment	2.5777	2.8561	2.8202	3.6284
Prevention	12.3654	10.0569	13.1899	10.8316

Figure 3: Composition of total HIV/AIDS investments in Belarus, 2008-2011

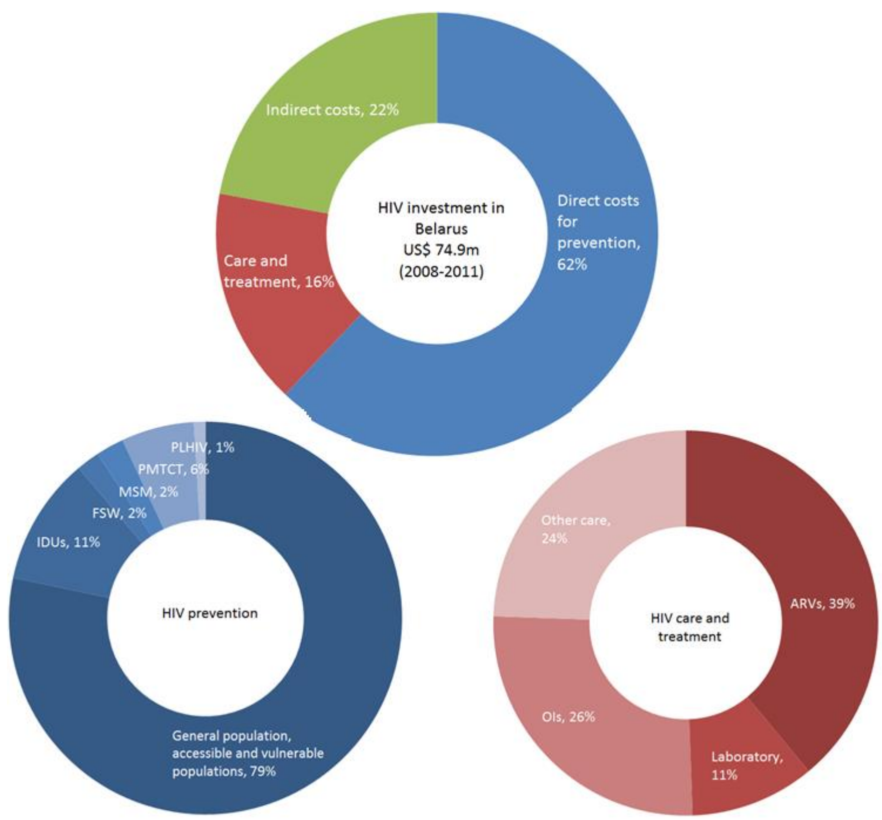
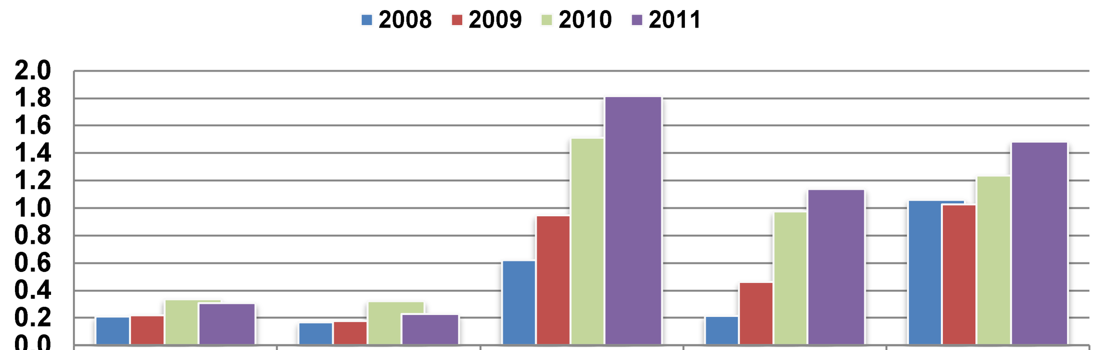


Figure 4: Trends in total investments in key priority interventions (US$ million)



	Prevention programmes for CSWs and their clients	Programmes for MSM	Harm-reduction programmes for IDUs	PMTCT	ART
2008	0.2089	0.1670	0.6189	0.2134	1.0601
2009	0.2193	0.1752	0.9461	0.4605	1.0277
2010	0.3350	0.3217	1.5134	0.9732	1.2346
2011	0.3087	0.2256	1.8147	1.1386	1.4822

Unit costs

- The itemized unit costs of program components are provided in the Supplementary Material.

3. What are the results of current investments?

Investments have averted infections

- Modeling of the HIV epidemic in Belarus suggests that if the prevention and treatment programs had not been implemented, then HIV prevalence and incidence would have been even greater (see Supplementary Material).

HIV investment, 2008-2012, averted 3 800 new HIV infections & 1 860 deaths

	2008	2012
Population prevalence	0.2%	0.4%
New HIV infections	4 000	5 000

HIV incidence is not declining

- Unlike most other countries around the world, the annual number of new HIV infections in Belarus is still increasing. This is also reflected in some other countries in Eastern Europe.
- HIV prevalence has sharply increased among FSWs, MSM and in the general population. HIV prevalence has stabilized among IDUs.

Late diagnosis is common

80% of people living with HIV are unaware of their infection

- Self-reported testing rates have decreased.
- The majority (80%) of people living with HIV are still not aware of their infection and ability to transmit to others.
- Late diagnosis also means late initiation of ART which results in poorer clinical outcomes.

	2008	2012
On ART	1 200	3 500

Treatment coverage is 30-40%

- Around 3 500 persons living with HIV are now on ART. This is a 3-fold increase since 2008. However, it is estimated that roughly 10 000 people would be eligible for ART if they were diagnosed and regularly monitored. Hence, only about 1 in 3 is currently being treated. About 50% of all diagnosed and 60-70% of diagnosed treatment-eligible people are receiving ART.

Treatment needs continue to rise

- The absolute numbers of people living with HIV and the AIDS-related mortality continue to increase. The number of people requiring ART has increased by around 200% over the last 4 years and expected to increase steadily in the future, including need for second-line therapies.

4. What will the HIV epidemic look like by 2020?

HIV prevalence and incidence are expected to increase

- Prior to 1996, there was little HIV epidemic in Belarus. An outbreak in two towns, Svetlogorsk and Zhlobin, in 1996-1997, caused 1,021 new known HIV infections within a six-month period. Most HIV infections in this first phase of the epidemic were among young male IDUs.
- Since then, there has been a gradual shift towards other modes of transmission. Typical of HIV epidemics in Asia and Eastern Europe, HIV epidemics among IDUs spread to FSWs, clients of FSWs and to sexual partners of these most-at-risk populations in the general population usually considered to be at low risk. HIV epidemics have also recently emerged among MSM.
- The HIV epidemic among IDUs is at relatively high levels with a prevalence of around 15%. It appears that this sub-epidemic may have peaked, largely due to harm reduction programs and natural epidemic dynamics.

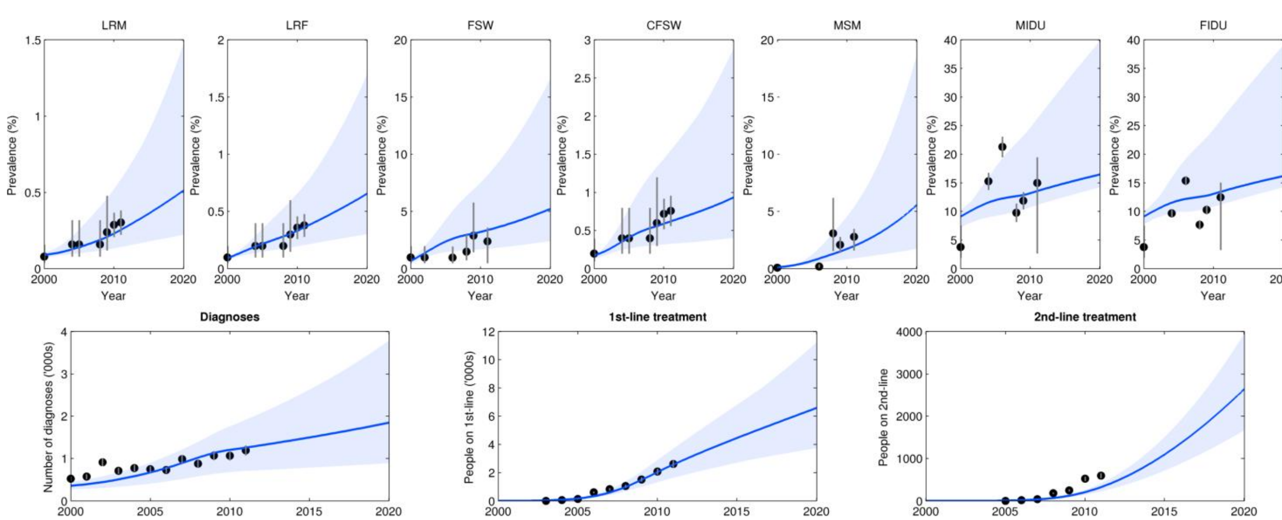
HIV has stabilized to high levels (15%) among IDUs

- HIV epidemics attributable to sexual transmission are in expansion phases (Figure 5).
- HIV prevalence in the general population is expected to increase from 0.4% to 0.6% by 2020 (Figure 5).
- HIV prevalence among FSWs and their clients and among MSM may also increase by relatively large amounts (Figure 5).

HIV prevalence is expected to increase by 50% in the general population

- HIV incidence is expected to increase from 5 000 in 2012 to 5 900 in 2015 to 9 300 in 2020.

Figure 5: Expected trends in HIV prevalence, diagnoses, number of people on ART by 2020. (LRM: low-risk males; LRF: low-risk females; FSW: female sex workers; CFSWs: clients of FSW; MSM: men who have sex with men; MIDU: male injecting drugs users; FIDU: female IDUs)

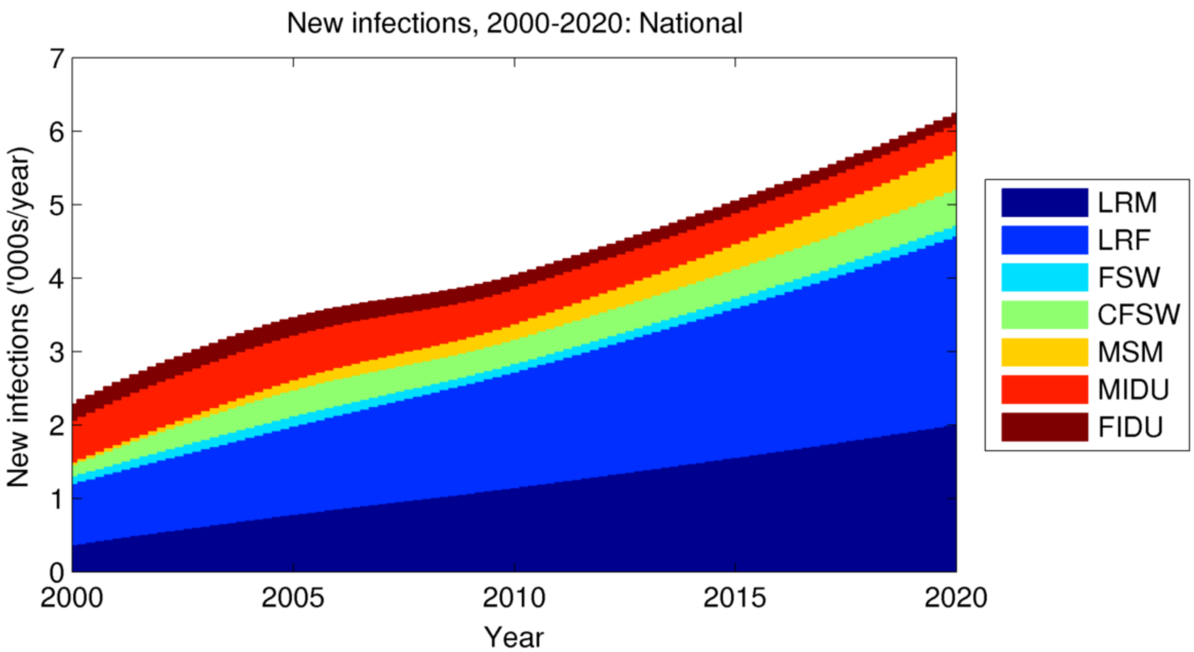


Mode of transmission continuing to shift from injecting to sexual

- Until recently, intravenous drug use was the leading route of HIV transmission in Belarus. HIV continues to spread among IDUs in Belarus but the mode of HIV transmission has been shifting to sexual transmission, which is now dominating and rapidly increasing (Figure 6).

60-80% of new infections are now due to sexual transmission

Figure 6: Expected trends in HIV prevalence, diagnoses, number of people on ART by 2020



Number of people on ART expected to substantially increase

- Current coverage of antiretroviral treatment is relatively low. However, even continuing with the current relative rates of access to treatment for people who are diagnosed and access care would lead to a large increase in the numbers of people on first- and second-line ART (Figure 5).
- Around 7 500 people will be on ART by 2020 according to current rates of uptake.
- An additional 5 800 will be diagnosed and eligible for ART (CD4 < 350 cells/µl) by 2020.
- An additional ~6 000 will be undiagnosed but in need of ART (CD4 < 350 cells/µl).

7 500 people are expected to be on ART by 2020 with current treatment uptake rates

A further 5 800 people will be ready for treatment by 2020

5. What needs to be improved?

More value for money

- **Optimally allocate resources to attain greatest impact**– It is currently unclear how resource allocation takes into account disease burden and potential for impact. There is an important opportunity to ensure resources are allocated to the populations and programs which will result in the greatest impact.

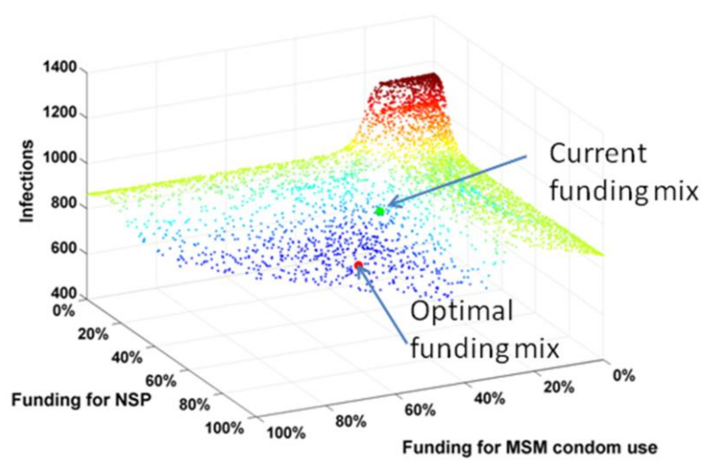
- Allocative efficiency can be considered the allocation of resources in the right mix across various programs to lead to optimal epidemiological outcomes.

Too much money is untargeted, spent on programs with unproven effectiveness

- The NASA activities identified that the greatest proportions of prevention funding were allocated to the general population or were not directed to the key intervention programs for the most-at-risk populations. Most interventions for most-at-risk populations were funded by international sources.

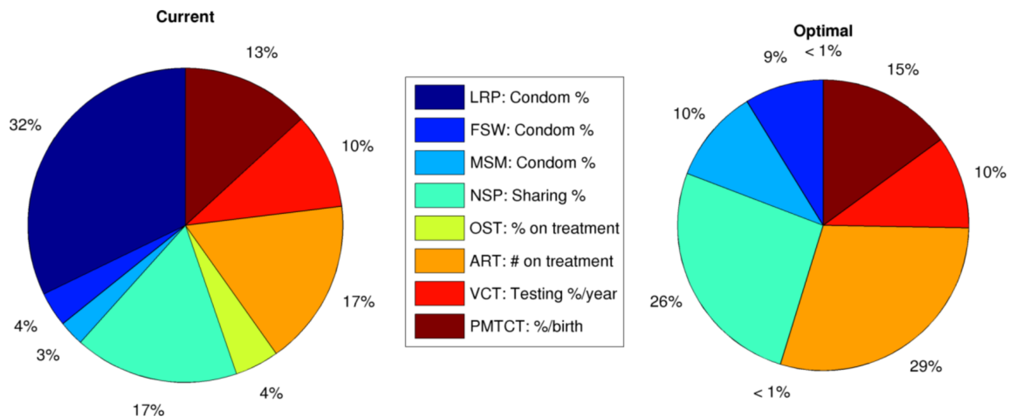
- A formal mathematical optimization procedure surrounded an epidemiological transmission model to calculate the mix of funding across all HIV programs which is likely to result in the least number of new HIV infections over the period 2015-2020 (see Supplementary Material for more detail of the method and Figure 7 for an illustration of the outcome). The model was informed by available epidemiological, behavioral and clinical data, as well as likely program outputs and other outcomes associated with possible funding combinations over all programs.

Figure 7: Illustration of the distribution of funding and number of HIV infections. This is shown across just two dimensions/programs in multi-dimensional space for visualization.



- The most cost-effective programs are those which have proven effectiveness in reducing risk behaviors and/or reducing biological transmissibility and are targeted to groups of people at greatest risk of acquiring or transmitting HIV.

Figure 8: Comparison of current and optimal budget allocations to reduce new infections



- It was identified that current resource allocations are inefficient because they are being used on programs with lower impact than more effective programs which are not fully implemented to scale (Figure 8, Table 2).
- Optimal resource allocation (Figure 8) of the currently available investment amount would:

Shift funds away from the general population at lower risk and towards programs targeted to the MARPs. However, if this is not possible due to the facility-based funding model in Belarus then the following still need to be achieved but with additional resources.

Programs targeting MARPs are much more effective & cost-effective than general population programs

Slightly expand VCT and PMTCT.

Increase spending on needle-syringe programs until saturation is reached.

Triple the amount of spending on MSM programs.

Double the amount of spending on FSW programs.

Substantially increase ART coverage to meet current needs.

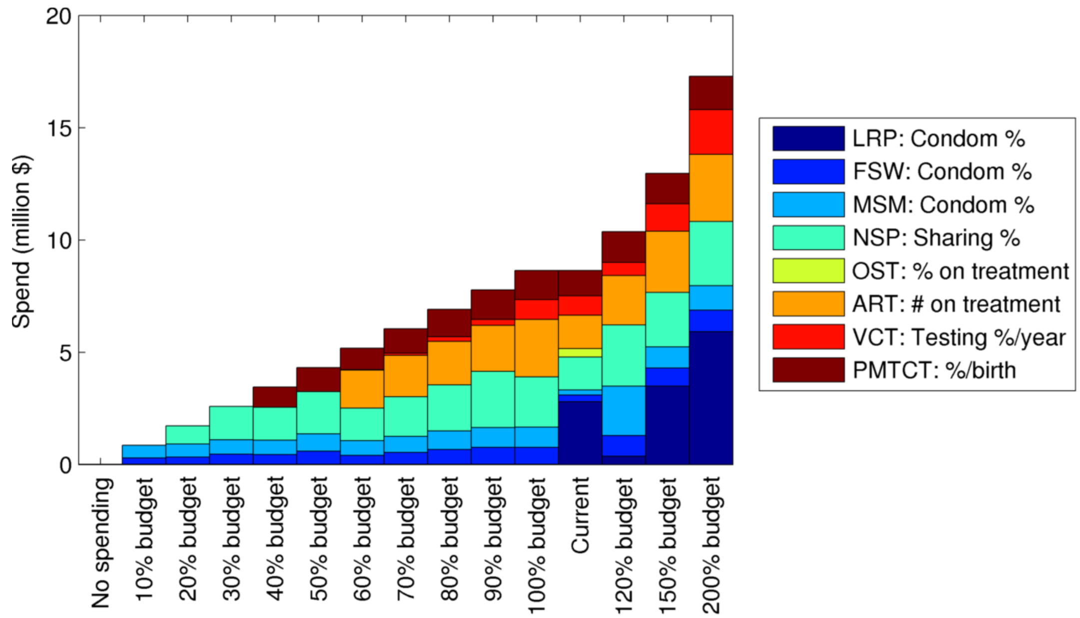
Table 2: Distribution of funding across broad program areas (excludes undefined funding).

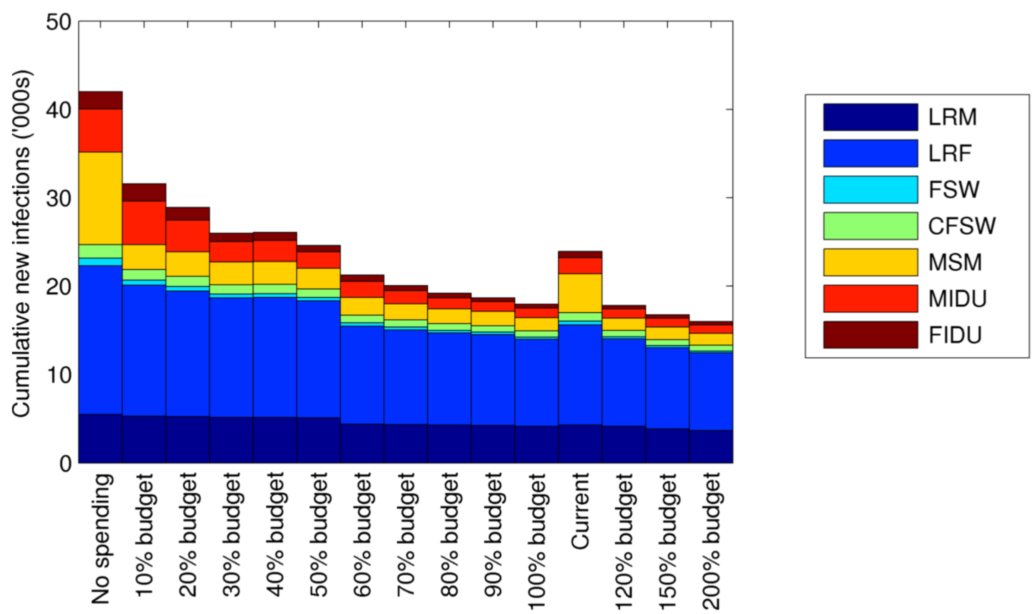
Target population / program	Current budget	Optimized 50% budget	Optimized 80% budget	Optimized 100% budget	Optimized 150% budget
General	$2,782,400	$0	$0	$0	$3,494,726
FSW	$308,728	$591,676	$676,484	$758,323	$802,132
MSM	$225,570	$762,214	$823,192	$900,170	$943,799
NSP	$1,459,844	$1,884,611	$2,050,020	$2,251,182	$2,424,978
OST	$388,571	$0	$0	$0	$0
ART	$1,482,192	$0	$1,929,687	$2,546,401	$2,717,054
VCT	$854,280	$0	$212,252	$891,946	$1,229,778
PMTCT	$1,138,600	$1,081,592	$1,220,512	$1,292,161	$1,347,811

- Without increasing any extra resources, but allocating funds to more effective programs, it is possible to have a noticeable impact on HIV epidemics (Figure 9).

Spending the same amount of money smarter can reduce the number of new infections by 27%

Figure 9: Comparison of current budget allocations and optimal budget allocations for different overall HIV/AIDS budget amounts to reduce new infections, 2015-2020





Focus on investing into key population prevention

- The optimal allocation of resources was calculated for various amounts of total funding (Figure 9). This identifies the priorities for HIV programming for incremental scale-up of resources and the associated expected number of new HIV infections.

  The most important programs to implement initially are foundational condom promotion programs for FSWs and MSM but then needle-syringe programs for IDUs are to be scaled up towards saturation. Then, PMTCT is to cover all HIV-infected pregnant women and then large increases in ART coverage for people living with HIV. FSW and MSM programs could continue to be steadily scaled-up. VCT must also be available to cover testing requirements. If more resources than currently available are mobilized and the prevention programs targeting MARPs have reached saturation, only then should additional resources be allocated to the general population. It is substantially more difficult to reach program coverage levels among the low-risk population that will have impact.

Resource optimization reveals prioritization of key intervention scale-up to saturation, base programs for other MARPs and general population prevention only when there are extra resources

Investing more in treatment

- The majority of HIV/AIDS investments have been on HIV prevention and program management. Overall treatment coverage remains low. Both prevention and treatment need to continue to grow. Treatment also significantly contributes to prevention.

Antiretroviral treatment saves lives, restores health and is one of the few prevention approaches with proven efficacy

- **Treatment and care scale-up** – There is a large gap between current coverage and the number of people living with HIV in Belarus who could benefit from ART. The number in need of ART will also increase substantially over the next few years. Increased investments are required to purchase drugs, improve infrastructure and expand skilled labor, and strengthen the supply chain, among other elements.
- **Prevention of mother-to-child transmission of HIV** – PMTCT is the first priority for ART scale-up (Figure 9). Universal coverage must be sustained.

Better coverage and frequency of HIV testing

- **HIV testing is the cornerstone of prevention for HIV-uninfected people and for entry to care and treatment for HIV-infected people.** Important indicators of HIV testing specify that rates of testing have decreased (e.g., HIV testing was reported among 85% of sex workers in 2009 but only 77% in 2011; testing decreased from 80% to 75% among MSM; and 57% to 54% among IDUs over this period).

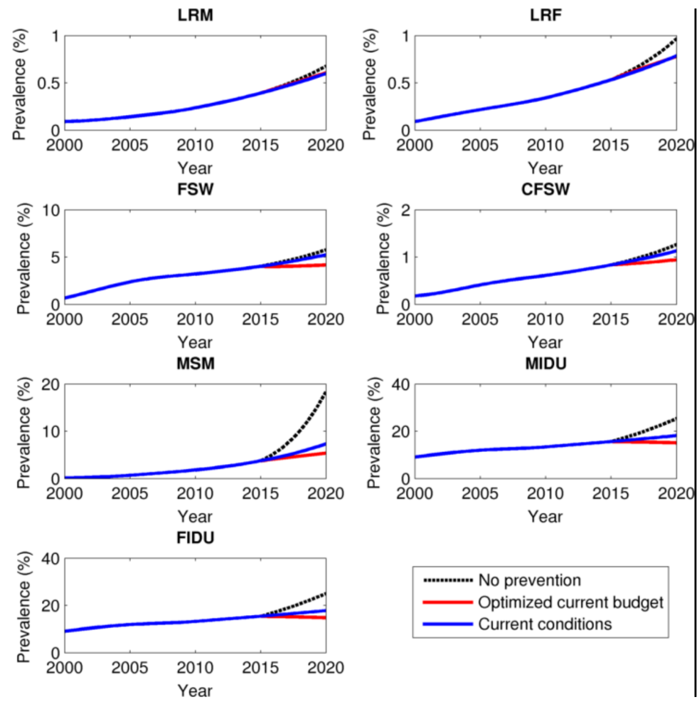
6. How much money will be needed for HIV in the future?

- **Defunding HIV programs would be disastrous:** The expected impact of no prevention and treatment would be large increases in HIV prevalence and incidence in all population groups (Figure 10). Resources which are not optimally allocated still have a major impact on HIV epidemics.
- The amount of money needed for HIV in the future firstly depends on the objective one would like to achieve. UNAIDS has set the target of zero new infections under the 'getting to zero' strategy. The WHO elimination threshold is less than one new case per 1000 people per year in each major population group.
- In practice, an ambitious target for Belarus considering the currently increasing epidemic is to firstly reverse increasing trends towards stabilization and then to achieve:

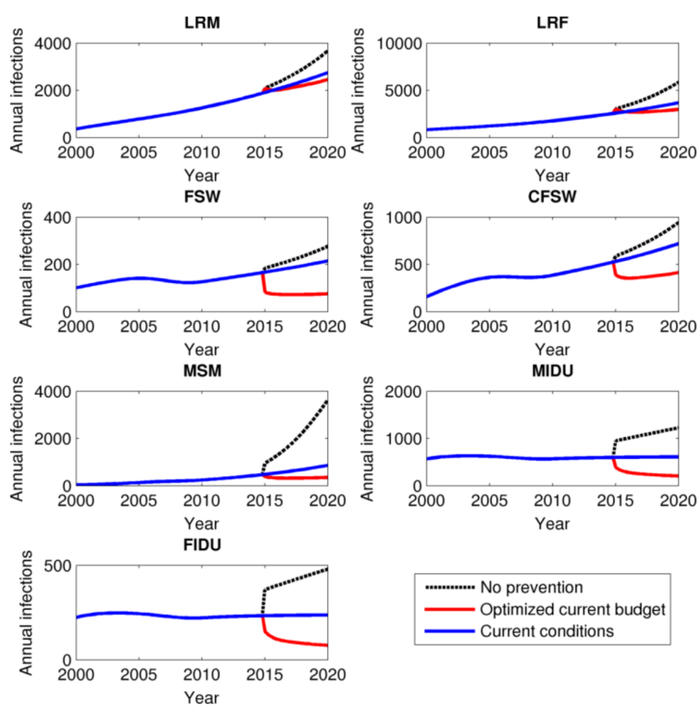
  the UN political declaration target of 50% reduction in incidence among all population groups.
- **Resources required to achieve target among MARPs:** The HIV epidemic in Belarus is concentrated among the MARPs. Mitigating HIV incidence among the populations of IDUs, MSM and FSWs will also prevent infection spreading more broadly. Using the HIV epidemic transmission model (see Supplementary Material), it was estimated that a 50% reduction in incidence among these priority populations can almost be achieved with currently available resources by shifting money away from general population programs and optimally allocating funds to programs targeting the MARPs (Figures 9, 10). A full reduction in HIV incidence by one-half can be achieved with a 50% increase in resources. However, there is close to diminishing returns with the increase from current levels, allocated optimally, and therefore the target can be roughly achieved with ~US$20 million per year allocated optimally and only to programs targeting MARPs.

Figure 10: Epidemic trajectories of (a) HIV prevalence and (b) HIV incidence by population group according to no HIV programs, funding according to the status quo, and optimized resource allocation of currently available amount, 2015-2020

(a) **Prevalence**



(b) **Incidence**



- **Resources required to achieve target among all populations:** As identified in the previous section, programs targeting the general population should only be implemented once programs for MARPs achieve saturation. The analyses of this study indicate that the 50% incidence reduction target cannot be achieved among the general population under realistic assumptions according to current environments and infrastructure. Traditional prevention programs may be able to achieve the target according to large socio-cultural shifts (e.g. large increases to consistent condom use among heterosexual regular sexual partners) which are considered unrealistic in the foreseeable future. The approach considered most viable to achieve a 50% reduction in incidence in the general population is 'test and early treatment'.

  It could be assumed that treatment reduces transmission risk by as much as 96% based on the HPTN-052 clinical trial setting (Cohen et al NEJM 2011).

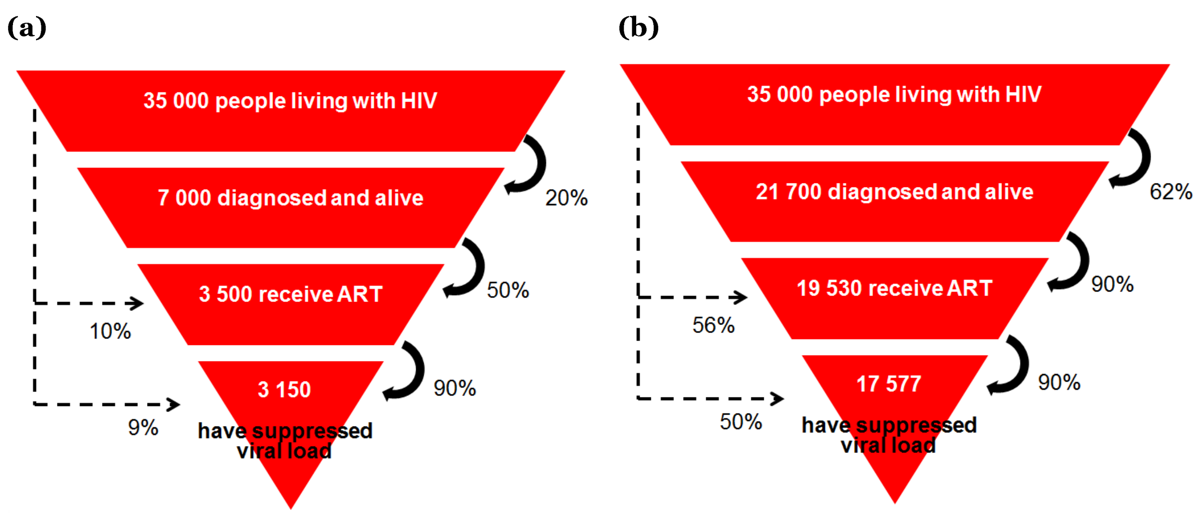
  Expanded coverage of ART also requires early presentation with HIV. Counseling around HIV diagnosis tends to reduce risk of onward transmission; it is assumed that this is associated with a 25% relative reduction.

  The estimated continuum of HIV care and treatment in Belarus is shown in Figure 11. Based on this state and the above assumptions, it can be inferred that a typical undiagnosed person would infect an average of 0.18-0.195 new persons per year (or cause one new transmission every 5-5.5 years).

  Assuming that the maximum attainable coverage of ART uptake among diagnosed individuals is 90%, reducing HIV incidence in the general population by one-half would require a minimum of 62% of people to be diagnosed. This would mean around 19 500 people would be on ART, a 5.6-fold increase from current levels. However, if ART reduces transmission risk by an amount closer to 26%, as observed in an observational cohort study of serodiscordant couples in China (Jia et al Lancet 2012) then it would not be possible to reduce incidence by 50%.

  Sentinel surveillance suggests that 16.5% of people at risk of HIV who do not belong to a MARP group are tested for HIV in the last 12 months. Testing rates would need to increase to around 60% to achieve this level of diagnosed infections.

Figure 11: Treatment cascade for Belarus: (a) current; (b) for 50% reduction in incidence



Conservatively assuming that current infrastructure and healthcare personnel are sufficient to provide the amount of testing and treatment required and that program expenses to recruit people to frequent testing and treatment commencement are negligible compared to the cost of the test (rapid whole blood and confirmation PCR test for positives) and cost of ARVs (and CD4/viral load monitoring), a minimum total of US$10.8 million would be required per year to achieve this level of testing and treatment uptake. This is in addition to the cost for programs targeting MARPs.

US$20 million will be needed per year, allocated optimally among MARPs, and at least an additional $10.8 million for the general population = $30.8 million per year to achieve 50% reduction in overall incidence

- **Resources required without defunding any programs and achieving 50% incidence reduction target among all populations:** The strategy identified to achieve a 50% reduction in incidence among MARPs and the general population would result in defunding some programs, including opioid substitution therapy (OST) and programs for the general population, vulnerable and accessible populations, youth-in-school, youth-out-of-school.

  These programs have much broader benefits than minimizing the risk of HIV infection. For example, the primary purpose of OST is not reduction in risk of HIV acquisition but abstinence from drug use and greater integration into society.

  At current implementation levels, these programs cost $3.2 million per year.

- **Recommended resources required to maintain programs, control incidence, and attain universal treatment coverage:** Approximately 3 500 people are currently diagnosed and not on ART. The majority of these people will have CD4 cell counts less than 350 cells per μl and are eligible for treatment. This number is expected to increase to 5 800 by 2020 without any increase in the rate of HIV testing. Attaining 'universal coverage of ART', defined as 80% on ART, will lead to an additional 4 600 people on ART by 2020 at an average additional annual cost of US$870 000. If people living with HIV generally presented with HIV infection early enough for timely initiation of treatment, universal coverage would cost around $4.5 million per year. A mid-estimate between these amounts is assumed to be aspirational but realistic.

It is recommended that US$25.9 million is needed per year to maintain current programs, expand key interventions for MARPs, and achieve universal coverage of ART

7. What is the funding gap?

- The Belarusian central government is committed to take over 100% funding of ART by the end of 2015. In 2013, it is funding 40% of ART costs. UNDP currently procure ARVs on behalf of the Ministry of Health (MoH) and supply ARVs to the MoH. It is presumed that only people who meet treatment-eligibility criteria according to WHO guidelines will receive funding under this framework.
- The government is committed to take over funding of current prevention programs through revenue of local governments (i.e. regional/municipal budgets). These programs will be implemented in collaboration with local NGOs. An adjustment to legislation was enacted in 2013 to facilitate this transition.

The Belarus government has shown leadership to commit to filling the gap from funding withdrawals

- The government of the Republic of Belarus has demonstrated committed leadership to ensure that the resource gap is funded from public domestic sources. However, if Belarus will be eligible for GFATM grants in the future then funding applications will be submitted in order to ease the domestic burden.
- The current HIV/AIDS budget in Belarus is around US$20 million per year. If the Belarus government funds the resource gap due to withdrawal of international funding from 2015 then, according to our recommendations, there is a further resource gap of $3.2 million per year to ensure sufficient spending on programs targeting MARPs such that HIV incidence in these groups can reduce by 50%. There could be a total additional resource gap of $5.9 million per year to achieve this outcome and also improve ART coverage. However, with government commitment to cover ART costs for those in need, the additional annual resources required for an enhanced response is $3.2 million.

An extra $3.2 million per year, along with optimal allocation of all resources, would enable an enhanced recommended response

8. What impact does waiting to invest in prevention have?

- Continued investments are essential.

  If there was no investment in prevention and treatment over 2015-2020 then an additional 10 800 HIV infections could be expected (Figure 12, 13).

- Making potentially difficult political but smart decisions in shifting funding away from some programs and towards more effective interventions, for an optimal allocation, would have a very clear impact on the evolution of the epidemic and its public health implications.

  An optimal allocation of the same amount of resources can avert 5 800 new HIV infections compared to current allocations (Figure 12, 13).

Defunding HIV response would result in 10 800 additional HIV infections over 5 years

Acting strategically now can avert 5 800 HIV infections over 5 years

- Delaying the decisions to shift strategies leads to worse long-term outcomes.

  Delaying a shift from current allocations to optimal allocations by one year would reduce the expected number of infections averted to 4 800; delaying by three years would reduce the infections averted to 2 800 (Figure 12, 13).

- Investing smartly and timely will result in substantial returns on investment.

  Assuming current rates of access to health care, timely initiation of first-line ART and availability of second-line ART with death 40 years after infection, the average lifetime healthcare costs associated with one person's HIV care and treatment in Belarus is approximately US$ 35 000.

  Each infection saved leads to less HIV-related care and treatment expenditure in the future (Figure 13).

  For US$ 20 million per year over 5 years ($100 million in total), if allocated optimally compared to continuing according to the status quo, a total return of around $200 million, twice the investment, in saved healthcare expenditure in the future is possible.

Lifetime healthcare costs are around US$35 000. Each infection averted saves thousands of dollars in future health expenditure.

Acting smartly and timely will yield substantial financial returns on investment

Figure 12: Impact of delaying investment: annual incidence and numbers of people living with HIV

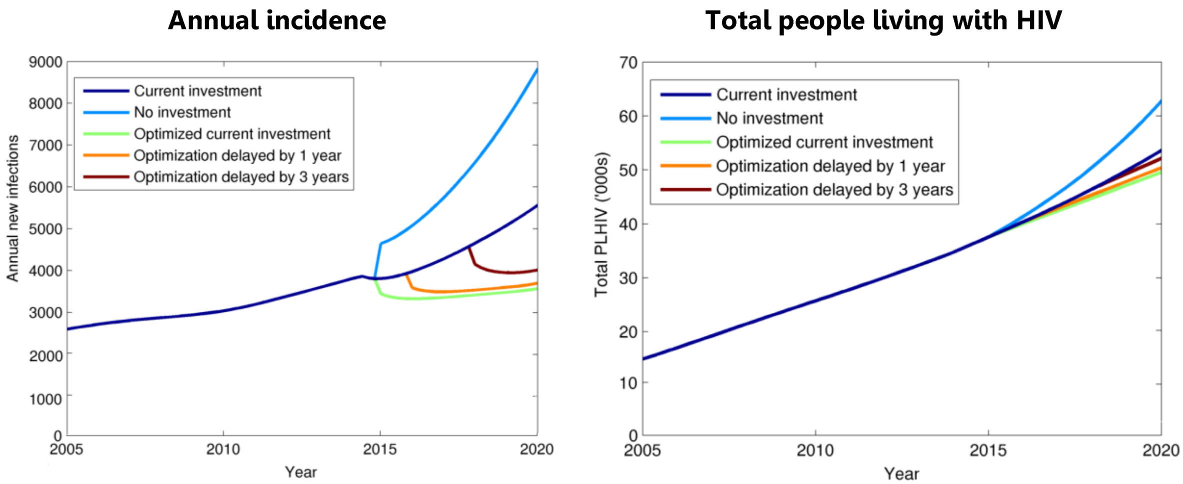
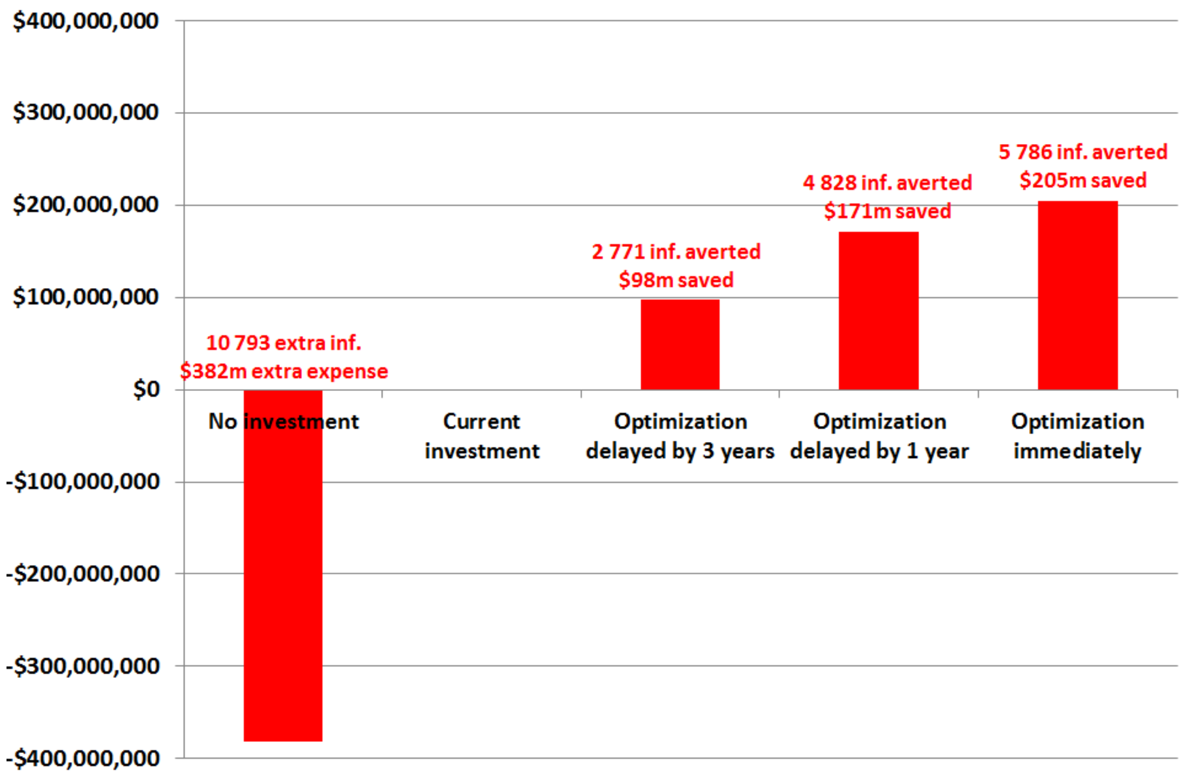


Figure 13: Expected future healthcare savings (HIV-related care and treatment expenditure not required) due to different strategies over the period 2015-2020.



9. How can the resources be mobilized?

Increasing government spending

- Further increase in the contribution of the government is essential to fund the response to HIV in Belarus.

  The government has expressed leadership in committing to cover the substantial treatment and prevention gap that will be left after withdrawal of international donor funding. This will effectively lead to a doubling of the domestic investment in the HIV/AIDS response.

  Leadership needs to be mobilized at all levels.

  A financial sustainability plan needs to be developed which contains clear targets.

- It is recommended that the HIV response in Belarus

  maintains existing programs,

  aims to control incidence by reducing new infections by 50% among most-at-risk populations by 2020, and

  attain universal treatment coverage among people in need.

- The resources required to achieve this are estimated to be an additional US$3.2 million per year. All HIV/AIDS resources would need to be allocated optimally among key intervention programs.

Innovative financing

Several countries are now experimenting with innovative financing to fund the gaps in HIV responses. Innovative approaches could also be considered in Belarus, including the following.

- **A national, regional or global tax or levy** - The levy would be a very small tax but on a large number of sales. This could include the following.

  Levy on airline ticket sales: Enacting a small fee on all outbound flights from Belarus. The amount levied could depend on class of ticket (e.g. France has a €1 tax on a domestic economy ticket and a €10 tax on a domestic first class ticket), whether the flight is domestic or international (e.g. Niger has a US$1.20 tax on a domestic economy ticket and a US$4.70 tax on an international economy ticket), or length of flight. Several other countries including Botswana, Burkina Faso, Cameroon, Gabon and Malawi are investigating an airline levy specifically for AIDS financing.1

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[1] http://www.unaids.org/en/media/unaids/contentassets/documents/epidemiology/2012/20120718_investmentchallengesupplement_en.pdf

Tax on sale of tobacco products: In the Philippines, 2.5% of the tax on alcohol and tobacco products is used to fund universal health care coverage and disease prevention. In Thailand, a 2% surcharge on alcohol and tobacco is pooled in the Thai Health Promotion Fund. In Indonesia, 2% of total government revenue from tobacco products can be used for health and social welfare programs.

Telecommunications levy: Several countries, including Rwanda and Uganda, impose a levy on the use of mobile phones to fund health programs. Gabon applies a 10% tax on mobile phones for health care of low-income groups.

Tax on financial transactions: A Currency Transactions Tax on foreign exchange transactions or a Financial Transactions Tax on the sale of shares/bonds/derivatives.

General taxation: Zimbabwe's AIDS levy has generated more than US$ 26 million in 2011. Chile uses 1% of its VAT to fund health (total rate 19%); Ghana introduced an additional 2.5% to fund its National Health Insurance Scheme (total rate 15%) Similar steps are being considered in Kenya and Zambia.

- **Lotteries** - Sales from existing or new lotteries could be directed to fund health programs.

  National: a lottery conducted by the government or a company, with a percentage of sales distributed to health and social programs including HIV responses.

  Regional: a lottery conducted in several countries and coordinated regionally (e.g. by a Eastern European Lottery Board) or run by a single organization, with the pooled revenues distributed to health programs in different countries. Existing regional European lotteries (e.g. EuroMillions, Eurojackpot) could be considered as a model.

- **Impact investment funds** – using private sector investors who desire to make a social impact and potentially a minimal financial profit. This could be conducted through debt-financing (i.e. the government borrows from the investment fund and repays a fixed rate of return); or social impact bonds, where the government pays a return based on results (such as numbers of people initiating ART).

- **Voluntary consumer donations** – Systems can be established to provide consumers of specific goods or services the option to make a voluntary donation as an additional amount for HIV or another health cause. This can work effectively as a recurring donation on a subscription service (e.g. utilities service).

The total HIV expenditure for 2008-2011 was almost US$ 20 million each year according to the NASA activities. This equates to $1.80-2.20 per capita. The overall health expenditure in Belarus over this period was US$311-373 per capita. Therefore, HIV expenditure accounts for 0.51-0.66% of the health budget.

A levy on airline ticket sales or a mobile phone levy may be the most viable options for generating more funds for HIV. Because the HIV epidemic in Belarus is concentrated and not a major concern or issue for the typical citizen, a levy could be considered as either (i) an HIV levy or (ii) a more general

An airline or telecommunications levy could have a modest impact on citizens but enable an enhanced HIV response and strengthen broader health systems and programs

healthcare levy from which funding could be used to cover HIV as well as other areas of health. Greater levies will be imposed on people according to the second option but it may be more acceptable and sustainable in the longer term and enable greater strengthening of broader health systems and programs.

Imposing an airline ticket levy

The number of airport passengers departing Belarus per year is around 1.4-1.8 million (Table 3). An airline levy of US$ 2 on outbound flights provides the amount of revenue for financing HIV/AIDS that is recommended for addressing the most-at-risk populations (Table 4). This levy is comparable to airline levies applied in other countries for financing HIVAIDS. This option could also be a reliable financing strategy and is based on conservative estimates of no growth in passenger movement in the coming years despite a 30% increase in the last calendar year. This strategy also constitutes a relatively small charge on the cost of an airfare and is not a tax on the poor. A US$ 3 levy would also finance improvements in ART coverage.

Table 3: Number of air passenger departures from Belarus

	2011	2012
Air passengers	1,400,000	1,821,000

Source: Belarus Bureau "PRIME-TASS", publications on tut.by

Table 4: Estimate of annual revenue generation from airline levy 2015 - 2020 (US $)

Projected number of passengers	$1 Levy	$2 Levy	$3 Levy	$5 Levy
1,821,000	$1,821,000	$3,642,000	$5,463,000	$9,105,000

A $2 levy on airline departures could cover the recommended gap in HIV resourcing. A $3 levy would also allow improved ART coverage

Imposing a telecommunication levy

The main mobile phone operators in Belarus consist of:

- MTS with 47% of the market share;
- Velcom with 44% of the market share; and
- MTL with ~9% of the market share.

The number of mobile phone subscribers is relatively stable at over 10 million (Table 5), and covers 99.7% of the population. The average phone bill per month is approximately US$ 6 (Table 6). There has recently been a 20% levy issued on mobile phone bills. This may be perceived as high already and therefore there may be limited opportunity for increasing this levy. If this source of revenue is targeted then it should be from existing levies charged rather than the introduction of new ones. Therefore, the recommended resource gap could potentially be sourced from 2.5% of the revenue generated from the existing levy (Table 7).

Table 5: Number of mobile phone subscribers

	2011	2012
Mobile phone subscribers	10,701,034	10,347,900

Source: National Statistical Committee of the Republic of Belarus

Table 6: Average phone bill per user per month

	2011	2012
MTS	US$5.27	US$5.70
Velcom	€3.5 (US$4.48)	€4.90 (US$6.27)

Source: MTC 2012 and Velcom 2011

Table 7: Source of finance from mobile phone levy

Total phone charges ($6 × 12 months × 10 million)	$720 million			
Income from existing levy (20%)	$144 million			
Percentage of existing levy	**1%**	**2%**	**2.5%**	**4%**
Potential revenue for HIV/AIDS	$1.44m	$2.88m	$3.6m	$5.76m

Enabling factors must also be supported

- **Partnership with communities:** International experience has provided evidence that true partnerships between government, communities, program implementers and other stakeholders provide the most effective approaches to HIV/AIDS responses. Mobilization of affected communities can largely contribute to effective prevention and treatment. Civil society organizations working with groups at higher risk, key vulnerable populations and PLHIV in Belarus have been entirely supported by international aid. Therefore, it is essential that domestic funding streams be directed to supporting community-based organizations.
- **Capacity building:** Leadership, implementation, evaluation and strategy will all need to be conducted by local members. It is essential that capacity is developed in-country to respond most effectively in every component of the HIV response.
- **Synergies with development sector:** Comprehensive and efficient programs must integrate with relevant systems and structures. It is essential that linkages and referrals occur between relevant programs directly within the HIV program response, within the broader health system, and across the social system. There is also need for strengthening information systems and minimizing management overheads.

Supplementary Information

Summary of costs and unit costs

National spending on AIDS in Belarus was examined by major funding sources with the use of national statistics, sector reports, and data reported by public health service institutions for the years between 2008 and 2011. Standard accountancy estimation methods were used to generate a complete dataset of national spending on AIDS. Costs were broken down by financing sources, agents, service providers, AIDS spending categories, and beneficiary populations using functional NASA classifications and definitions. Data collection covered spending on AIDS response funded from domestic public and international funding sources.

Table S1: Summary costs on most-at-risk populations, PMTCT, ART and other prevention, care and treatment programs from all sources, NASA 2008-2011

Notes / References	Spending item		Amount spent in US$ million			
Related AIDS Spending Categories (ASC) – see NASA funding matrixes	Abbreviation	**HIV spending TOTAL overall**	2008	2009	2010	2011
1.01-1.06; 1.11; 1.12	GP/VAP/YIS/YOS	Programs for general populations (GP), vulnerable and accessible populations (VAP), youth-in-school (YIS), youth-out-of-school (YOS)	2.1604	1.4788	2.2674	2.7824
1.10	IDUs	Harm-reduction programs for injecting drug users, including needle and syringe exchange programs and methadone maintenance therapy	0.6189	0.9461	1.5134	1.8147
1.09	MSM	Programs targeting MSM	0.1670	0.1752	0.3217	0.2256
1.08	FSW/Clients	Programs targeting sex workers and their clients	0.2089	0.2193	0.3350	0.3087
1.17	PMTCT	PMTCT	0.2135	0.4605	0.9732	1.1386
1.07	PLHIV	Prevention of HIV transmission PLHIV	0.1261	0.0951	0.0539	0.1645
1.15; 1.16; 1.19; 1.22; 1.98; 1.99	Other prevention	Other prevention activities *	8.8706	6.6818	7.7254	4.3970
1		**Total estimated annual expenditure on 'Prevention'**	**12.3654**	**10.0568**	**13.1900**	**10.8316**
2.01.03	ART	Antiretroviral therapy	1.0601	1.0277	1.1472	1.3950
2.01.05	CD4, VL tests	Specific HIV-related laboratory monitoring	0.1819	0.2934	0.2698	0.4995
2.02.01	OI	Inpatient treatment of opportunistic infections (OI)	0.8523	0.9126	0.6496	0.6885
ASC related to 'Care & Treatment', except 2.01.03 and 2.01.05	Other care & treatment	Other outpatient and inpatient care services	0.4834	0.6224	0.7536	1.0454
2		**Total estimated annual expenditure on 'Care & Treatment'**	**2.5777**	**2.8561**	**2.8202**	**3.6284**

Table S2: Cost of components of selected HIV-related activities for sex workers and their clients

HIV activities	Components of HIV activities	Average costs of the component / program 2010, US$	Cost of the component / program 2011, US$
Reduce sexual transmission of HIV among SW and their clients	HIV testing - HIV rapid test (whole blood)	2.00	1.00
	HIV testing - HIV rapid test (saliva)	5.75	5.00
	HIV testing - HIV diagnosis test (PCR)	7.90	7.15
	HIV testing - HIV confirmation test (PCR)	10.33	10.40
	Hepatitis C rapid test	1.26	1.20
	Hepatitis B rapid test	1.10	0.75
	condom standard	0.03	0.05
	lubricant - 4ml sachet	0.01	0.07
	lubricant - 100 ml	1.90	5.80
	hygiene pads	0.34	0.34
	hygiene sets (HIV testing motivation)	9.30	9.16
	TOTAL COST of the programs targeting sex workers and their clients, US$ million	0.335	0.309

Table S3: Cost of components of selected HIV-related activities for people who inject drugs

HIV activities	Components of HIV activities	Average costs of the component / program 2010, US$	Cost of the component / program 2011, US$
Prevent HIV among IDUs	HIV testing - HIV rapid test (whole blood)	2.00	1.00
	HIV testing - HIV rapid test (saliva)	5.75	5.00
	HIV testing - HIV diagnosis test (PCR)	7.90	7.15
	HIV testing - HIV confirmation test (PCR)	10.33	10.40
	Hepatitis C rapid test	1.26	1.20
	Hepatitis B rapid test	1.10	0.75
	Syringes	0.34	0.90
	Alcohol pads	0.01	0.01
	OST - average treatment cost per patient	164.98	167.02
	rapid drug test	5.00	5.00
	condom standard	0.03	0.05
	lubricant - 4ml sachet	0.01	0.07
	lubricant - 100 ml	1.90	5.80
	hygiene sets (HIV testing motivation)	9.30	9.16
	hygiene pads	0.34	0.34
	Total cost of needle and syringe exchange programs (NSPs), US$ million	0.815	1.460
	Total cost of opioid substitution treatment program (OST), US$ million:	0.426	0.389
	including cost of Methadone (Methadone HCl 5mg/ml o.sol.), US$ million	0.083	0.127
	TOTAL COST of harm reduction programs, including NSPs and total cost of OST program, US$ million	1.513	1.815

Table S4: Cost of components of selected HIV-related activities for men who have sex with men

HIV activities	Components of HIV activities	Average costs of the component / program 2010, US$	Cost of the component / program 2011, US$
Reduce sexual transmission of HIV among MSM	HIV testing - HIV rapid test (whole blood)	2.00	1.00
	HIV testing - HIV rapid test (saliva)	5.75	5.00
	HIV testing - HIV diagnosis test (PCR)	7.90	7.15
	HIV testing - HIV confirmation test (PCR)	10.33	10.40
	Hepatitis C rapid test	1.26	1.20
	Hepatitis B rapid test	1.10	0.75
	condom - ultra strong	0.41	0.16
	lubricant - 4ml sachet	0.01	0.07
	lubricant - 100 ml	1.90	5.80
	hygiene sets (HIV testing motivation)	9.30	9.16
	hygiene pads	0.34	0.34
	TOTAL COST of the programs targeting MSM, US$ million	0.322	0.226

Table S5: Cost of components of selected HIV-related activities for vulnerable populations

HIV activities	Components of HIV activities	Average costs of the component / program 2010, US$	Cost of the component / program 2011, US$
Selected preventive activities aimed on prisoners	HIV testing - HIV rapid test (whole blood)	2.00	1.00
	HIV testing - HIV rapid test (saliva)	5.75	5.00
	HIV testing - HIV diagnosis test (PCR)	7.90	7.15
	HIV testing - HIV confirmation test (PCR)	10.33	10.40
	Hepatitis C rapid test	1.26	1.20
	Hepatitis B rapid test	1.10	0.75
	condom standard	0.03	0.05
	lubricant - 4ml sachet	0.01	0.07
	lubricant - 100 ml	1.90	5.80
	hygiene sets (HIV testing motivation)	9.30	9.16
	hygiene pads	0.34	0.34
Programs for general population, vulnerable (prisoners) and accessible populations (VAP), youth-in-school (YIS), youth-out-of-school (YOS)	**TOTAL COST of the programs targeting GP/VAP/YIS/YOS, US$ million**	2.267	2.782

Table S6: Cost of components of selected HIV-related activities for PMTCT, care and treatment

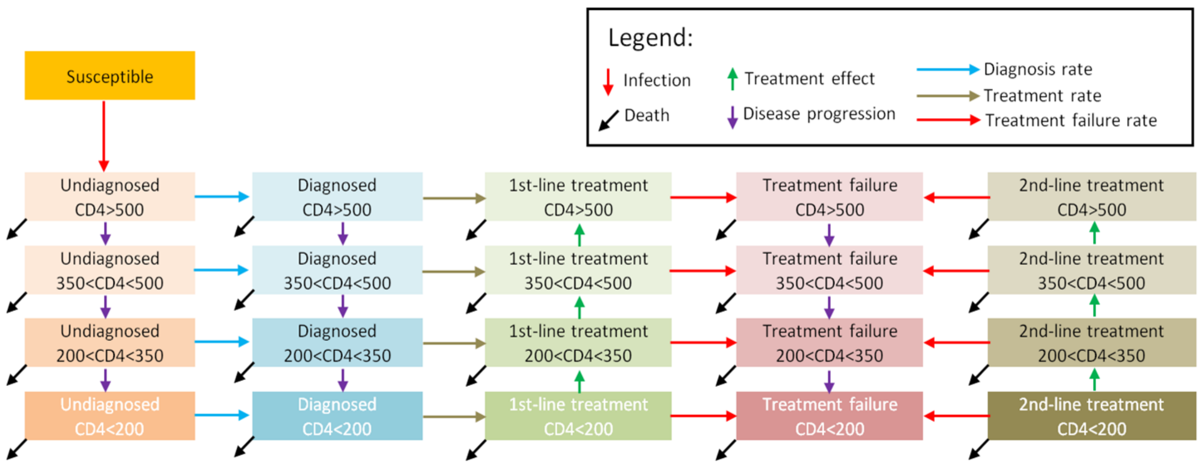
HIV activities (PART 5)	Components of HIV activities	Average costs of the component / program 2010, US$	Cost of the component / program 2011, US$
Selected activities to prevent MTCT	HIV testing - HIV rapid test (whole blood)	2.00	1.00
	HIV testing - HIV rapid test (saliva)	5.75	5.00
	HIV testing - HIV diagnosis test (PCR)	7.90	7.15
	HIV testing - HIV confirmation test (PCR)	10.33	10.40
	TOTAL cost of milk formulas, US$ million	0.030	0.037
	TOTAL COST of PMTCT, including safe infant feeding practices, US$ million	0.973	1.139
Access to HIV treatment - pharmaceuticals	antiretrovirals (ARVs) - average price of the first line ARV regimen	228.55	233.65
	antiretrovirals (ARVs) - average price of the first line ARV regimen	1,269.86	1,305.35
	TOTAL COST of antiretrovirals (ARVs), US$ million	1.147	1.395
Access to specific HIV-related laboratory monitoring	CD4 cell count - CD4 test (quantitative) - Flow Cytometer	30.00	38.60
	viral load (VL) determination - Viral load test (RNA-HIV)	15.00	10.70
	testing for drug resistance - HIV Resistance	338.89	305.21
	TOTAL cost of specific HIV-related laboratory monitoring (CD4,VL), US$ million	0.270	0.500

Overview of analytical methods

To assess HIV epidemic trends, resource needs, the cost-effectiveness of past programs, and the impact of potential future programs, we developed a detailed mathematical model of HIV transmission and disease progression, called the Projection and Evaluation Tool (Prevtool).

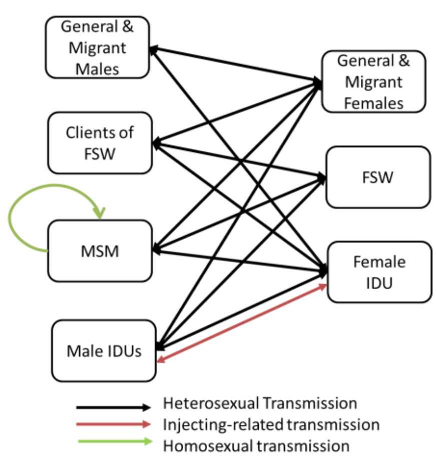
Prevtool is an extremely flexible population-based HIV model. The basic disease progression implemented in the model is shown in Fig. S1. This is the only aspect of model structure that is fixed, and specifies it as being an HIV model instead of a universal epidemic model.

Fig. S1: Schematic diagram of model structure. Each compartment represents a single population group with the specified health state, while each arrow represents the movement of individuals between health states. All compartments except for *Susceptible* represent individuals living with HIV. Death includes all causes of death.



In contrast to most other HIV models, the population groups used in Prevtool are not fixed. Instead, up to 14 user-defined population groups may be used. A typical example for a concentrated HIV epidemic, such as used in Belarus, is shown in Fig. S2. Here, seven population groups are used, including low-risk ("general") males and females, sex workers and their clients, male and female injecting drug users (IDUs), and men who have sex with men (MSM).

Fig. S2: Example population groups and interactions in Prevtool.



Data are entered into Prevtool by means of an Excel spreadsheet, as shown in Fig. S3. Data entry is flexible, allowing everything from a separate data point for every population for each year, or a single data point for all populations over the entire time period.

Fig. S3: Example of data entry spreadsheet for a concentrated epidemic (in this case, Belarus). In addition to best-estimate data, upper and lower bounds are provided (or estimated) for each point.

	A	B–C	D	E	F	G	H	I	J	K	L	M	
1			2000		2001		2002		2003		2004		
2		Low-risk males	2,522.393	2,648.513	2,510.536	2,636.063	2,498.735	2,623.672	2,486.990	2,611.339	2,475.299	2,599.064	2,5
3				2,396.274		2,385.009		2,373.798		2,362.640		2,351.534	
4		Low-risk females	2,629.521	2,760.997	2,617.161	2,748.020	2,604.860	2,735.103	2,592.617	2,722.248	2,580.431	2,709.453	2,6
5				2,498.045		2,486.303		2,474.617		2,462.986		2,451.410	
6		Direct FSW	24.784	26.688	24.668	26.564	24.552	26.439	24.437	26.316	24.323	26.192	
7				22.879		22.772		22.665		22.559		22.454	
8		Indirect FSW											
9													
10		Clients of FSW											
11													
12		MSM	62.383	72.366	62.091	72.027	61.801	71.690	61.512	71.355	61.224	71.021	
13				52.401		52.156		51.912		51.669		51.427	
14		Bisexual MSM											
15	Population size (thousands)												
16		Transgender											
17													
18		Male high-risk IDUs	30.224	31.377	30.082	31.230	29.941	31.083	29.800	30.937	29.660	30.792	
19				29.070		28.934		28.798		28.663		28.528	
20		Female high-risk IDUs	11.695	12.142	11.641	12.085	11.586	12.028	11.532	11.972	11.477	11.915	
21				11.249		11.197		11.144		11.092		11.039	
22		Male low-risk IDUs											
23													
24		Female low-risk IDUs											
25													
26		High-risk males											
27													
28		High-risk females											
29													
30													
31													
32													

The model uses a coupled system of ordinary differential equations to track the movement of people between health states. The overall population is partitioned in two ways: by group and by health state. Individuals are assigned to a given population based on their dominant risk; however, to capture important cross-modal types of transmission (e.g., FSW becoming infected via injecting drug use), relevant behavioral parameters can be set to small but nonzero values (e.g., male IDUs occasionally engage in commercial sex; MSM occasionally inject drugs).

The rate at which uninfected individuals in each population group become infected is determined by the force-of-infection for that population. This depends on the number of risk events an individual is exposed to in a given period of time and the infection probability of each event. Sexual transmission risk depends on the number of people in each HIV-infected stage (that is, the prevalence of infection in the population of partners), the average number of casual, regular, and commercial homosexual and heterosexual partnerships per person, the average frequency of sexual acts per partnership, the proportion of these acts in which condoms are used, the efficacy of condoms, the extent of male circumcision, and the prevalence levels of ulcerative STIs (which increase transmission probability) and HIV. The stage of infection (chronic, AIDS-related illness/late stage, or on treatment) for the HIV-positive partner in a serodiscordant couple also influences transmission risk due to different levels of infectiousness in each infection stage. Intravenous transmission risk depends on the number of injecting partners per person per year, frequency of injecting per year, frequency of sharing injecting equipment and percentage of shared syringes that are cleaned before re-use and the efficacy of cleaning.

Mathematically, the force-of-infection is given by: ( )

where is the force-of-infection, is the transmission probability of each event, and n is the effective number of at-risk events (thus n gives the average number interaction events with infected people where HIV transmission may occur). The value of the transmission probability is based n average viral load of people in different stages of infection and transmissibility differs by mode of transmission (intravenous drug injection, heterosexual intercourse, and homosexual intercourse), and may be modified by behavioral interventions (for example, condom use or circumcision). The number of events n not only incorporates the total number of events, but also other factors that moderate the possibility that these events are capable of transmitting infection, such as condom use or circumcision. There is one force-of-infection term for each type of interaction (for example, casual sexual relationships between low-risk males and indirect female sex workers), and the force-of-infection for a given population will be the sum of overall interaction types.

In addition to the force-of-infection rate, in which individuals move from uninfected to infected states, there are seven other means by which individuals may move between health states. First, individuals may die, either due to the background death rate (which affects all populations equally), due to injecting behavior, or due to HIV/AIDS (which depends on CD4 count). Second, in the absence of intervention, individuals progress from higher to lower CD4 counts. Third, individuals can move from undiagnosed to diagnosed states based on their HIV testing rate, which is a function of CD4 count (for example, people with AIDS symptoms have a higher testing rate) and population type (for example, FSWs usually get tested more frequently than low-risk males). Fourth, diagnosed individuals may move onto treatment, at a rate which is dependent on CD4 count. Fifth, individuals may move from treatment to treatment failure, and sixth, from treatment failure onto second-line treatment. Finally, while on successful first- or second-line treatment, individuals may progress from lower to higher CD4 count and they will have reduced infectiousness.

In total, the model can accommodate up to 294 compartments (14 populations each with 21 health states), and the change in the number of people in each compartment is determined by the sum over the relevant rates described above multiplied by the compartments on which they act. For example, the number of individuals in the compartment corresponding to undiagnosed female sex workers with a CD4 count between 200 and 350 cells/μL changes according to the following equation:

( )

where is the current population size of people with undiagnosed HIV and with a CD4 count between 350 and 500 cells/μL, is the population size of the compartment with lower CD4 count (200-350 cells/μL), is the disease progression rate for the given CD4 count, is the death rate, and is the HIV testing rate. (Note: this example does not consider movement between populations, such as female sex workers returning to the low-risk female population and vice versa.) Each compartment (Fig. S1, boxes) corresponds to a single differential equation in the model, and each rate (Fig. S1, arrows) corresponds to a single term in that equation.

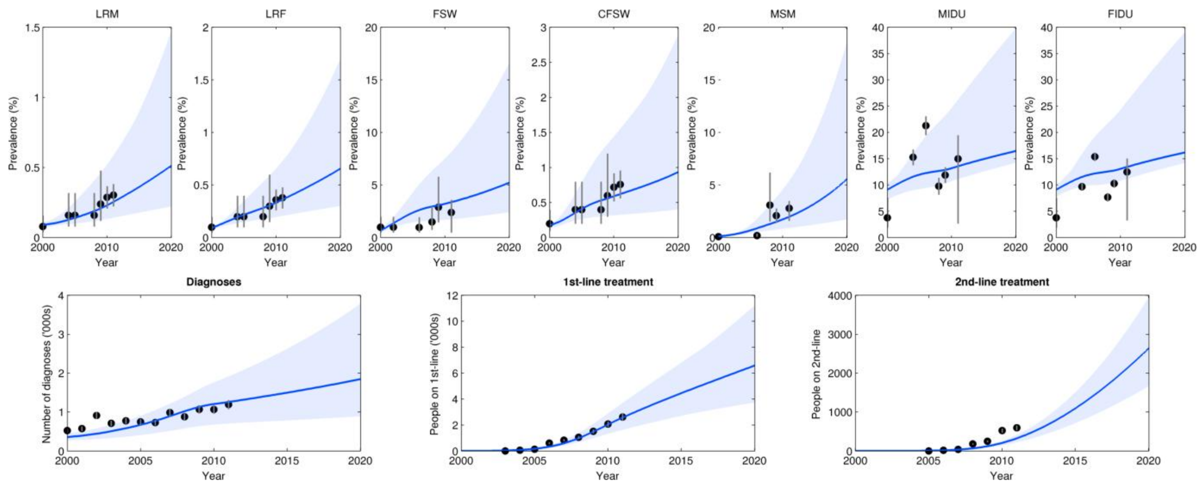
Table S7: Input parameters of the model.

	Biological parameters	**Behavioral parameters**	**Epidemiological parameters**
Population parameters	Background death rate		Population sizes (TP)
HIV-related parameters	Sexual HIV transmissibilities* (H) STI-related transmissibility increase* Condom efficacy* Circumcision efficacy* HIV health state progression rates (H) HIV-related death rates (H)	Number of sexual partners* (TPS) Number of acts per partner* (S) Condom usage probability* (TP) Circumcision probability* (T)	HIV prevalence (TP) STI prevalence (TP)
MTCT parameters	Mother-to-child transmission probability	Birth rate PMTCT access rate (T)	
Injection-related parameters	Injecting HIV transmissibility* Syringe cleaning efficacy* Drug-related death rate	Number of injections* (T) Syringe sharing probability* (T) Syringe cleaning probability* Methadone treatment probability (T)	
Treatment parameters	ART efficacy* ART failure rates	HIV testing rates (TPH)	Number of people on ART (T)

Key: T = parameter value changes over time; P = parameter value depends on population group; H = parameter depends on health state; S = parameter depends on sexual partnership type; * = parameter is used to calculate the force-of-infection.

Most of the parameters in the model are related to calculating the force-of-infection; a list of model parameters is provided in Table S7. Empirical estimates for model parameter values can be interpreted in Bayesian terms as prior distributions. The model must then be calibrated, which is the process of finding posterior distributions of the model parameter values such that the model generates accurate prevalence estimates. Given the challenges inherent in quantifying all known constraints on the epidemic, initial calibration is performed manually, with oversight by and collaboration with in-country stakeholders where possible. This prior distribution is then used in a Monte Carlo Markov chain (MCMC) algorithm, which uses both epidemiological and behavioral data to calculate the log-likelihood for a given set of model parameters. The distribution of parameter values produced by the MCMC is the posterior, which is then used for all epidemiological and economic analyses. An example calibration is shown in Fig. S4.

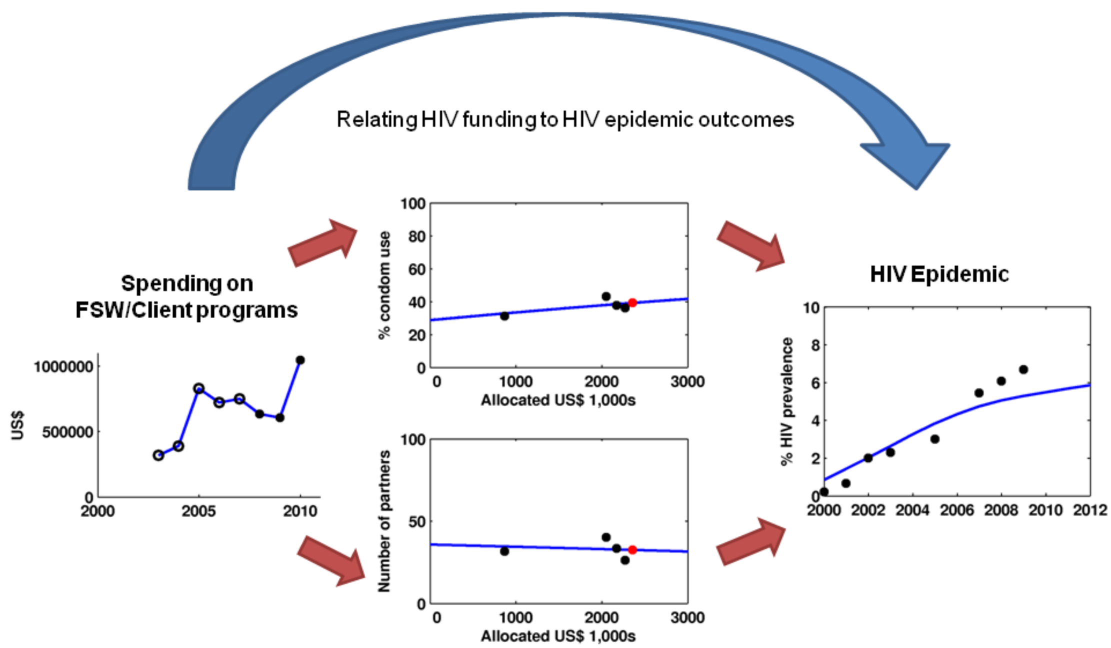
Fig. 4: Calibration of Prevtool to Belarus epidemic data. Dots show data; lines show model. Error bars and shaded regions are 95% confidence intervals (CI). LRM = low-risk males; LRF = low-risk females; FSW = female sex workers; CFSW = clients of female sex workers; MSM = men who have sex with men; MIDU = male injecting drug users; FIDU = female injecting drug users. In almost all cases, model parameters fell well within the 95% CI of the behavioral data (results not shown).



Relationships between spending and risk behaviors

In our analysis, we use a logistic/sigmoid function to describe the relationships between a behavioral parameter affected by a HIV prevention program and the level of spending on that program. Using this function with assumed uncertainties bounds, we obtain logistic curve fits to available datasets for overall program spending and associated behaviours. Indirect costs have no direct impact on HIV transmission parameters; but changes to HIV programs may affect these costs to supply additional condoms, clean syringes, and methadone, for example. Using these relationships, any change in HIV program funding directly affects risk behaviors and changes to the HIV epidemic; an example of this is demonstrated in Fig. S5. The fitted logistic relationships will represent the change in behaviors with spending.

Fig. S5: Example of the relationship between spending on FSW/client programs and the HIV epidemic (numerical values are for illustrative purposes only).

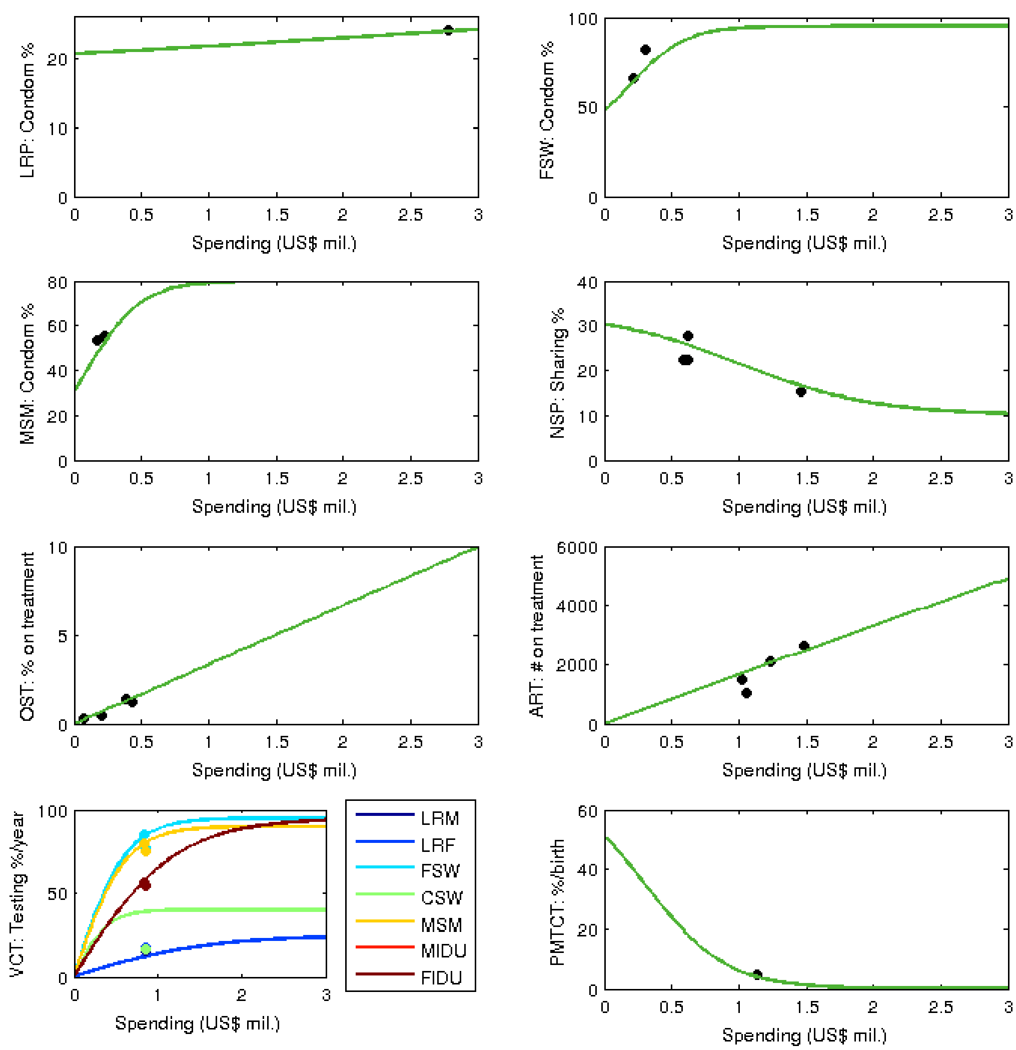


Counterfactual scenarios

Prevtool calculates the cost-effectiveness of past HIV programs by comparing the expected number of new infections and HIV/AIDS related deaths according to current and past conditions with the estimated numbers under counterfactual scenarios in the absence of funding for specific programs.

We simulate counterfactual scenarios using Prevtool based on the assumed effect of the removal or enhancement of specific programs. The calibrated simulations with the programs in place represent the baseline scenario. For each prioritized population, we develop counterfactual scenarios for the behavioral parameters affected by prevention programs prioritizing that population—with the parameters for the other populations remaining at their values obtained through the calibration process. Specific counterfactual scenarios used depend on the implementation and characteristics of HIV prevention programs and the data available. We fit a logistic function to behavioral parameters affected by prevention programs; Fig. S6 shows some example logistic functions for Belarus.

Fig. 6: Example logistic curves for Belarus. Black dots represent empirical data. Green curves represent the assumed relationship between program funding and behavior. To calculate a counterfactual scenario, a funding level is provided, and then the corresponding behavioral parameter is calculated from these curves.



Cost-effectiveness calculations for past evaluations

For each counterfactual scenario, we measure the health benefits of a specific HIV intervention program in terms of HIV infections averted as well as life years and DALYs saved compared to the baseline scenario. We calculate incremental cost-effectiveness ratios (ICERs) to estimate the cost-effectiveness of each program. These are calculated based on the counterfactual scenarios and comparing the spending of each program (discounted annually), as well as estimated annual healthcare costs incurred/saved (using unit health costs and utilities for each country obtained from our data synthesis), with the estimated effectiveness of the programs. Determining whether a past HIV program is cost-effective is dependent on country-specific thresholds. Appropriate thresholds for each country were determined after consultation with in-country stakeholders.

Return on investment calculations

Return on investment (ROI) analyses determines the future healthcare costs saved that are attributable to the past financial investment in HIV/AIDS programs. For this analysis, we consider the two scenarios: (1) the counterfactual scenarios without HIV/AIDS programs and the (2) status quo (with HIV programs). From these two scenarios, we calculate health care costs incurred among individuals infected with HIV (diagnosed, undiagnosed, and on treatment). The ROI in a given year is equal to the total HIV health care costs saved (compared to the status quo scenario) divided by the total investment in a HIV/AIDS program.

Future impact of HIV programs and optimal allocation of resources

To investigate the potential impact of future HIV prevention programs we run model projections for each scenario. Specific program options are investigated but are based on core prevention methods (harm reduction), along with programs based on using antiretroviral treatment as prevention in combination with other programs. We then compare projections where parameters and funding remain at current values and calculate the annual incidence, the number of infections averted, and the total cost required for each scenario.

Prevtool is used to determine the optimal allocation of funding using an adaptive stochastic linear gradient-descent optimization method. This calculates the allocation of funding to programs with the minimum total infections, minimum prevalence, minimum HIV/AIDS deaths, or maximum DALYs saved. It is also possible to invert this analysis and calculate the minimum spend required to achieve a particular target in terms of one of those quantities.

Data inputs and assumptions used in analysis

Population size ('000s)

	2000		2001		2002		2003		2004		2005		2006		2007		2008		2009		2010		2011		2012	
Low-risk males	1,999	2,099	2,052	2,154	2,035	2,136	2,025	2,126	2,016	2,116	2,006	2,106	2,528	2,654	1,914	2,010	1,900	1,995	1,892	1,987	1,870	1,964	1,867	1,961	1,861	1,954
		1,899		1,949		1,933		1,924		1,915		1,906		2,401		1,819		1,805		1,798		1,777		1,774		1,768
Low-risk females	2,630	2,761	2,696	2,831	2,681	2,815	2,668	2,802	2,656	2,789	2,643	2,776	2,528	2,654	2,484	2,609	2,478	2,602	2,465	2,588	2,451	2,574	2,439	2,561	2,431	2,553
		2,498		2,562		2,547		2,535		2,523		2,511		2,401		2,360		2,354		2,342		2,328		2,318		2,310
Direct FSW	25	27	25	27	25	26	24	26	24	26	24	26	24	26	51	54	51	54	50	53	50	53	50	53	50	53
		23		23		23		23		22		22		22		48		48		47		47		47		47
Clients of FSW	523	549	536	563	533	560	531	558	528	555	526	552	504	529	502	527	499	524	497	522	495	520	494	518	492	517
		497		509		507		504		502		500		479		477		474		472		471		469		468
MSM	62	72	62	72	62	72	62	71	61	71	61	71	61	70	56	59	56	59	55	58	55	58	55	58	55	58
		52		52		52		52		51		51		51		53		53		52		52		52		52
Male high-risk IDUs	30	31	30	31	37	38	37	38	37	38	37	38	37	37	37	43	42	50	40	48	56	59	53	55	53	55
		29		29		37		37		36		36		36		30		35		33		55		51		51
Female high-risk IDUs	12	12	12	12	14	15	14	15	14	15	14	15	14	15	19	22	13	16	15	18	21	22	24	25	24	25
		11		11		14		14		14		14		14		16		11		12		20		24		23

HIV prevalence (%)

	2000		2001		2002		2003		2004		2005		2006		2007		2008		2009		2010		2011		2012
Low-risk males	0.08	0.16							0.16	0.32	0.16	0.32	0.29				0.16	0.32	0.24	0.48	0.29	0.37	0.30	0.38	
		0.04								0.08		0.08						0.08		0.12		0.21		0.22	
Low-risk females	0.10	0.20							0.20	0.40	0.20	0.40	0.36				0.20	0.40	0.30	0.60	0.36	0.46	0.38	0.48	
		0.05								0.10		0.10						0.10		0.15		0.26		0.28	
Direct FSW	1.00	2.00			1.00	2.00								1.96			1.50	3.00	2.90	5.80			2.40	3.60	
		0.50				0.50								0.49				0.75		1.45				0.50	
Clients of FSW	0.20	0.40							0.40	0.80	0.40	0.80	0.72				0.40	0.80	0.60	1.20	0.72	0.92	0.76	0.96	
		0.10								0.20		0.20						0.20		0.30		0.52		0.56	
MSM	0.10	0.20												0.40			3.10	6.20	2.10	2.80			2.80	3.50	
		0.05												0.10				1.55		1.40				1.60	
Male high-risk IDUs	3.80	7.60							15.30	16.80				23.10			9.80	11.40	11.90	13.40			15.00	19.50	
		1.90								13.80				19.50				8.20		10.40				2.70	
Female high-risk IDUs	3.80	7.60							9.70	10.30				16.20			7.70	8.50	10.30	11.10			12.50	15.10	
		1.90								9.10				14.60				6.90		9.50				3.30	

STI prevalence (%)

	2000		2001		2002		2003		2004		2005		2006		2007		2008		2009		2010		2011		2012	
Low-risk males																			5.40	8.10						
																				3.60						
Low-risk females																			6.60	9.90						
																				4.40						
Direct FSW													39.40	59.10	52.20	78.30			74.80	97.24			64.60	96.90		
														26.27		34.80				49.87				43.07		
Clients of FSW																			5.40	8.10						
																				3.60						
MSM													19.40	29.10	22.20	33.30			53.10	79.65			45.80	68.70		
														12.93		14.80				35.40				30.53		
Male high-risk IDUs													22.40	33.60	29.70	44.55			28.40	42.60			20.80	31.20		
														14.93		19.80				18.93				13.87		
Female high-risk IDUs													22.40	33.60	29.70	44.55			28.40	42.60			20.80	31.20		
														14.93		19.80				18.93				13.87		

Testing & treatment

		2000		2001		2002		2003		2004		2005		2006		2007		2008		2009		2010		2011		2012	
Testing rate per year (%)	Low-risk males															30.50	45.75			16.30	24.45			16.50	24.75		
																	20.33				10.87				11.00		
	Low-risk females															30.50	45.75			16.30	24.45			16.50	24.75		
																	20.33				10.87				11.00		
	Direct FSW													55.00	82.50	62.96	94.44			84.99	101.9			76.80	92.16		
															36.67		41.97				56.66				51.20		
	Clients of FSW															30.50	45.75			16.30	24.45			16.50	24.75		
																	20.33				10.87				11.00		
	MSM													52.00	78.00	53.20	79.80			79.85	95.82			75.16	97.71		
															34.67		35.47				53.23				50.11		
	Male high-risk IDUs													47.00	70.50	49.25	73.88			56.70	85.05			54.10	81.15		
															31.33		32.83				37.80				36.07		
	Female high-risk IDUs													47.00	70.50	49.25	73.88			56.70	85.05			54.10	81.15		
															31.33		32.83				37.80				36.07		
	AIDS stage	0.10	0.15	1.04	1.56	2.30	3.44	4.63	6.94	11.57	17.35	21.70	32.56	36.83	55.25	32.02	48.03	46.31	69.47	45.99	68.98	57.44	86.16	49.33	74.00		
			0.07		0.69		1.53		3.09		7.71		14.47		24.56		21.35		30.87		30.66		38.29		32.89		
Treatment rate per year (%)	CD4(500)	0.10	0.20	0.10	0.20	0.10	0.20	1.00	2.00	1.00	2.00	3.00	4.00	15.00	22.00	20.00	29.00	24.00	24.09	29.00	37.00	51.00	75.00	60.00	80.00		
			0.05		0.05		0.05		0.50		0.50		2.00		11.00		14.00		23.94		23.00		33.00		40.00		
	CD4(350,500)	0.10	0.20	0.10	0.20	0.10	0.20	1.00	2.00	1.00	2.00	3.00	4.00	15.00	22.00	20.00	29.00	24.00	24.09	29.00	37.00	51.00	75.00	60.00	80.00		
			0.05		0.05		0.05		0.50		0.50		2.00		11.00		14.00		23.94		23.00		33.00		40.00		
	CD4(200,350)	0.10	0.20	0.10	0.20	0.10	0.20	1.00	2.00	1.00	2.00	3.00	4.00	15.00	22.00	20.00	29.00	24.00	24.09	29.00	37.00	51.00	75.00	60.00	80.00		
			0.05		0.05		0.05		0.50		0.50		2.00		11.00		14.00		23.94		23.00		33.00		40.00		
	CD4(200)	0.10	0.20	0.10	0.20	0.10	0.20	1.00	2.00	1.00	2.00	3.00	4.00	15.00	22.00	20.00	29.00	24.00	24.09	29.00	37.00	51.00	75.00	60.00	80.00		
			0.05		0.05		0.05		0.50		0.50		2.00		11.00		14.00		23.94		23.00		33.00		40.00		
	Treatment failure																							20.00	30.00		
																									10.00		
No. of HIV diagnoses	Total	527	579.7	578	635.8	915	1007	713	784.3	778	855.8	751	826.1	733	806.3	990	1089	881	969.1	1072	1179	1069	1176	1196	1316		
			474.3		520.2		823.5		641.7		700.2		675.9		659.7		891		792.9		964.8		962.1		1076		
Number of patients on ART	1st-line							11	12.1	68	75	146	160.3	618	679	840	924.3	1,064	1,170	1,524	1676	2,086	2,295	2,624	2886		
									9.9		61		131.1		556		756.3		957		1372		1,877		2362		
	2nd-line											3	4	20	22.44	44	48	185	203.8	252	277	528	580.8	599	659		
													3		18.36		39		166.8		227		475.2		539		

Sexual acts per person per year

Average number of regular sexual acts	Low-risk males	48	96
			12
	Low-risk females	48	96
			12
	Direct FSW	48	96
			12
	Clients of FSW	48	96
			12
	MSM	48	96
			12
	Male high-risk IDUs	48	144
			12
	Female high-risk IDUs	48	144
			12
Average number of casual sexual acts	Low-risk males	12	24
			6
	Low-risk females	12	24
			6
	Direct FSW	12	24
			6
	Clients of FSW	12	24
			6
	MSM	50	100
			10
	Male high-risk IDUs	48	144
			12
	Female high-risk IDUs	48	144
			12
Average number of other sexual acts (e.g. commercial)	Direct FSW	464	1716
			114
	Clients of FSW	47	175
			11
	MSM	2	3
			1
	Male high-risk IDUs	2	3
			1
	Female high-risk IDUs	2	3
			1

Condom usage (% probability per act) and circumcision (% probability per person)

		2000		2001		2002		2003		2004		2005		2006		2007		2008		2009		2010		2011		2012	
Condom use percentage for regular acts	Low-risk males													24	29												
															20												
	Low-risk females													24	29												
															20												
	Direct FSW													25	30	19	22			29	35			27	32		
															21		16				25				22		
	Clients of FSW													24	29												
															20												
	MSM													58	69	67	80			61	74			64	77		
															48		56				51				53		
	Male high-risk IDUs													49	59	59	71			59	71			53	64		
															41		49				50				44		
	Female high-risk IDUs													49	59	59	71			59	71			53	64		
															41		49				50				44		
Condom use percentage for casual acts	Low-risk males															61	73			69	83			64	77		
																	51				58				54		
	Low-risk females															61	73			69	83			64	77		
																	51				58				54		
	Direct FSW															38	46			45	54			62	74		
																	32				37				51		
	Clients of FSW															61	73			69	83			64	77		
																	51				58				54		
	MSM													36	44	32	38			54	64			56	67		
															30		27				45				46		
	Male high-risk IDUs																							53	64		
																									44		
	Female high-risk IDUs																							53	64		
																									44		
Condom use percentage for other acts (e.g. commercial)	General Males																							75	90		
																									60		
	General Females																							75	90		
																									60		
	Direct FSW															38	46			45	54			62	74		
																	32				37				51		
	Clients of FSW																							75	90		
																									60		
	MSM																			66	79			82	98		
																					55				68		
	Male High-risk IDU																			71	86			77	92		
																					59				64		
	Female High-risk IDU																							77	92		
																									64		
Circumcision probability	Low-risk males	1.00	3.00																								
			0.10																								
	Clients of FSW	1.00	3.00																								
			0.10																								

	MSM	1.00	3.00
			0.10
	Male high-risk IDUs	1.00	3.00
			0.10

Drug use parameters

		2000		2001		2002		2003		2004		2005		2006		2007		2008		2009		2010		2011		2012		2013	
Average number of injections per person per year	Male IDUs																							258	700				
																									12				
	Female IDUs																							258	700				
																									12				
Drug use parameters	% of shared injections													22.30	33.45	27.70	41.55			22.40	33.60			15.20	22.80				
															14.87		18.47				14.93				10.13				
	% of IDUs on methadone																							0.20	0.30				
																									0.10				
	% of reused syringes that are cleaned													53.30	79.95	41.50	62.25			40.50	60.75			41.20	61.80				
															35.53		27.67				27.00				27.47				

Biological constants

Interaction-related transmissibility (% per act):	Male & female (insertive)	0.04	0.1
			0.01
	Male & female (receptive)	0.1	0.6
			0.06
	Male & male (insertive)	0.06	0.2
			0.02
	Male & male (receptive)	0.5	2
			0.2
	Injecting	0.3	1
			0.1
Disease-related transmissibility	CD4(500)	1.6	1.8
			1.2
	CD4(350,500)	1	1.2
			0.8
	CD4(200,350)	1	1.2
			0.8
	CD4(200)	3.8	4
			3.6
	Treatment	0.04	0.1
			0.02
Disease progression rate: (% per year)	CD4 (500) to CD4 (350,500)	24.5	26.4
			22.6
	CD4 (350,500) to CD4 (200,350)	51	55
			47
	CD4 (200,350) to CD4 (200)	51	55
			47
Treatment recovery rate: (% per year)	CD4 (350,500) to CD4 (500)	45	93
			14
	CD4(200,350) to CD4 (350,500)	70	111
			29
	CD4 (200) to CD4 (200,350)	36	43
			28
Death rate: (% mortality per year)	Background	1.45	1.96
			0.94
	Injecting	1	1.25
			0.75
	CD4 (500)	0.0515	0.068
			0.035
	CD4 (350,500)	0.128	0.164
			0.092
	CD4 (200,350)	1.1	2
			0.2
	CD4 (200)	50	66
			40
	Treatment (CD4<200)	4	10
			1
Treatment failure rate: (% per year)	1st-line	4.5	6
			3
	2nd-line	4.5	6
			3
Protective efficacy of per-exposure:	Condom (%)	95	99
			85
	Circumcision (%)	60	65
			50
	STI cofactor increase	2	4
			1
Drug use (% efficacy):	Syringe cleaning efficacy	75	80
			70
	Methadone efficacy for people retained in program	95	99
			90