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2018 SKILLS BUILDING PROGRAM

BIG DATA, ARTIFICIAL INTELLIGENCE AND DECISION SCIENCE IN HEALTH AND NUTRITION

Defining programs, service delivery modalities, parameters, and cost functions

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Learning objectives

- HIV programs including service delivery modalities
- Cost functions
- Data requirements, sources, and concerns
- Currency

Effect of programs on HIV response

To model the effect of HIV programs on the epidemic, the first step is to relate changes in program **spending** to changes in program **coverage**.

Then changes in program **coverage** on **outcome** using **cost functions**.

Overview of HIV programs

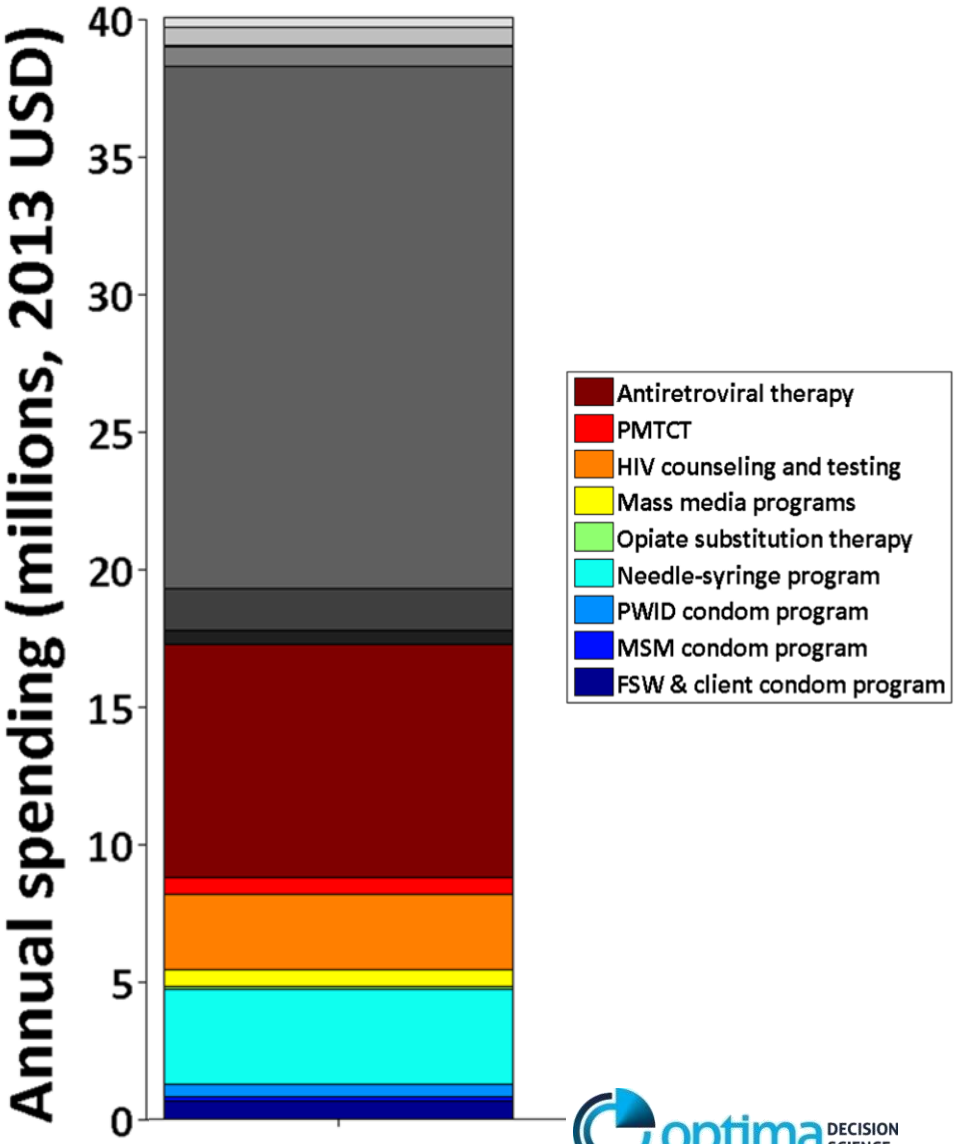
- Optima HIV can accommodate programs that:
  - Directly target HIV response (i.e. diagnostic, treatment, prevention)
  - Less directly target HIV (i.e. behavioral, awareness campaigns)
  - Non-targeted, but included in the budget (i.e. management)

- Each targeted program implemented requires:
  - Coverage (number of people reached)
  - Unit cost
  - Spending
  - Impact on disease

- Program component can include programs not currently implemented, but may be included in the future
- There may be >1 service delivery modalities for each type of program or intervention (e.g. self-testing, mobile testing etc.). These are handled as separate programs in the Optima HIV model

HIV program spending

- Can be reported directly (top-down costing)
- Alternatively, can be reconstructed from unit costs and program coverage (bottom-up costing)



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Cost definitions

- Unit cost
  - Total program cost divided by the number of people covered
  - Total cost/number of people covered
  - E.g. $100/10 = $10

- Marginal cost
  - Cost of covering one more person

Variable unit costs

- Relationships between costs and coverage are generally nonlinear, because costs change depending on the level at which the program is operating

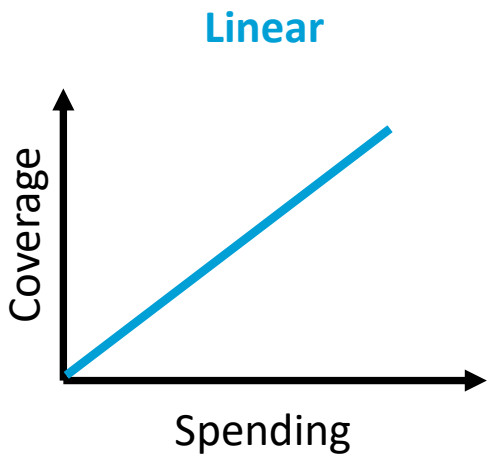
- Optima allows users to **specify** programs with costs that vary depending on coverage

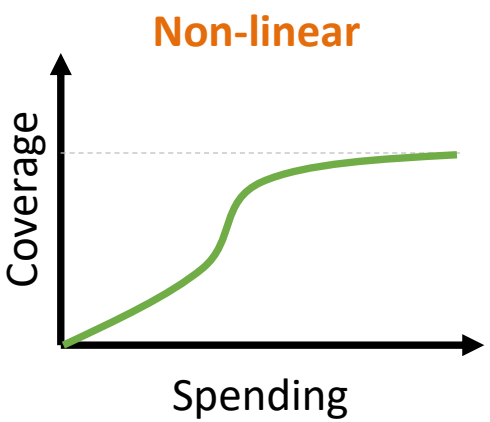
- We expect **increasing marginal costs** as programs **expand coverage** to increasingly hard to reach populations [saturation]

Relating program costs and population coverage

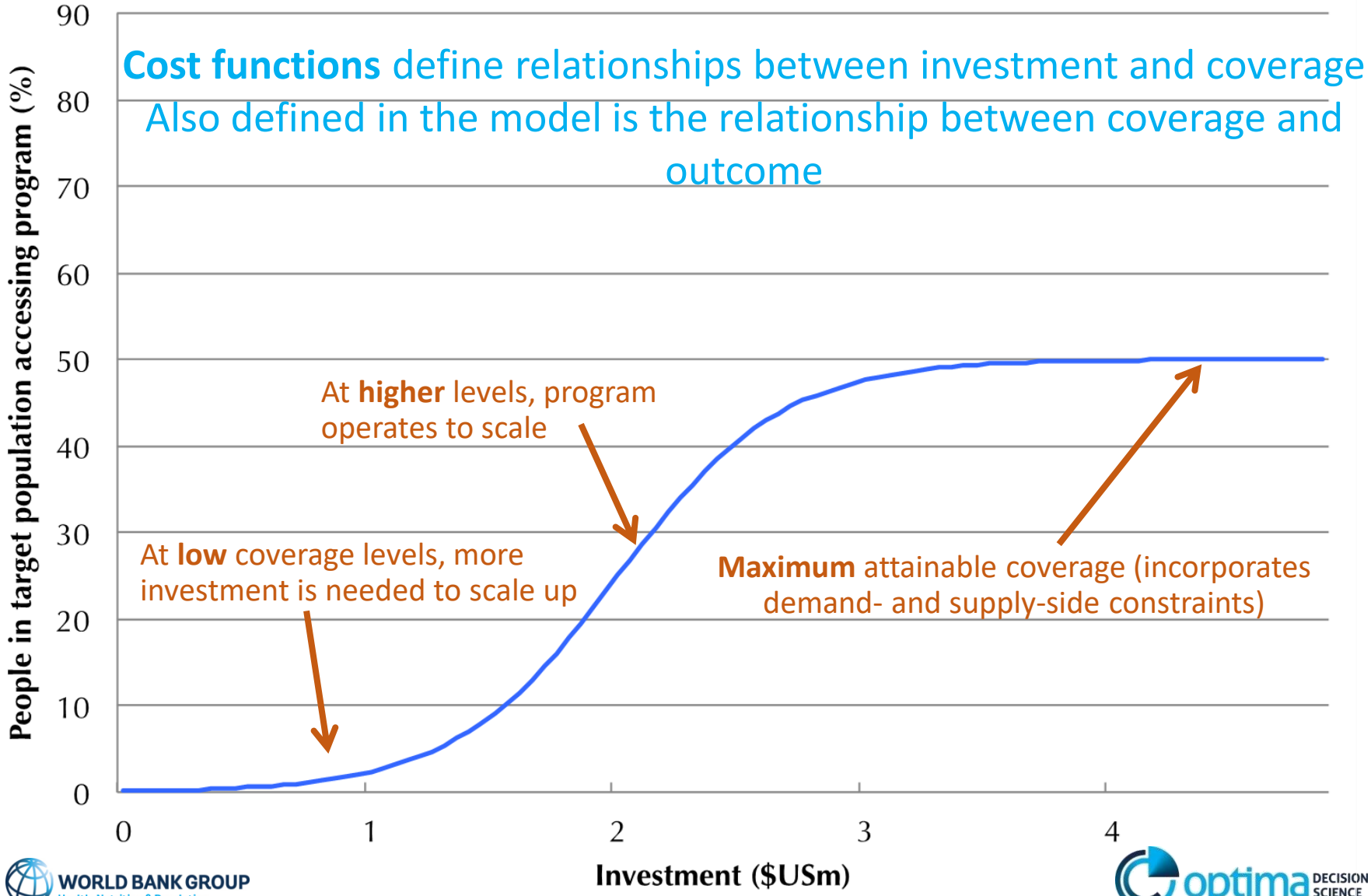
Cost-coverage curves:

- Relates program spending to program coverage
- Cost-coverage curves can be
  - **Linear**: slope represents a single unit cost, or
  - **Non-linear**: slope represent scale-up, stable implementation, and increasing effort in reaching additional people
- In the absence of estimates, **linear** cost-coverage curves are assumed





Cost function curve: spending versus coverage



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Cost functions: requirements and data sources

Data requirements

1. Cost: total spending and unit costs

Data sources

- National AIDS Spending Assessment (NASA)
- PEPFAR/Global Fund expenditures
- Country programme reports
- Other (e.g. Global Health Costing Consortium Unit Cost Repository)

2. Coverage: number of people reached

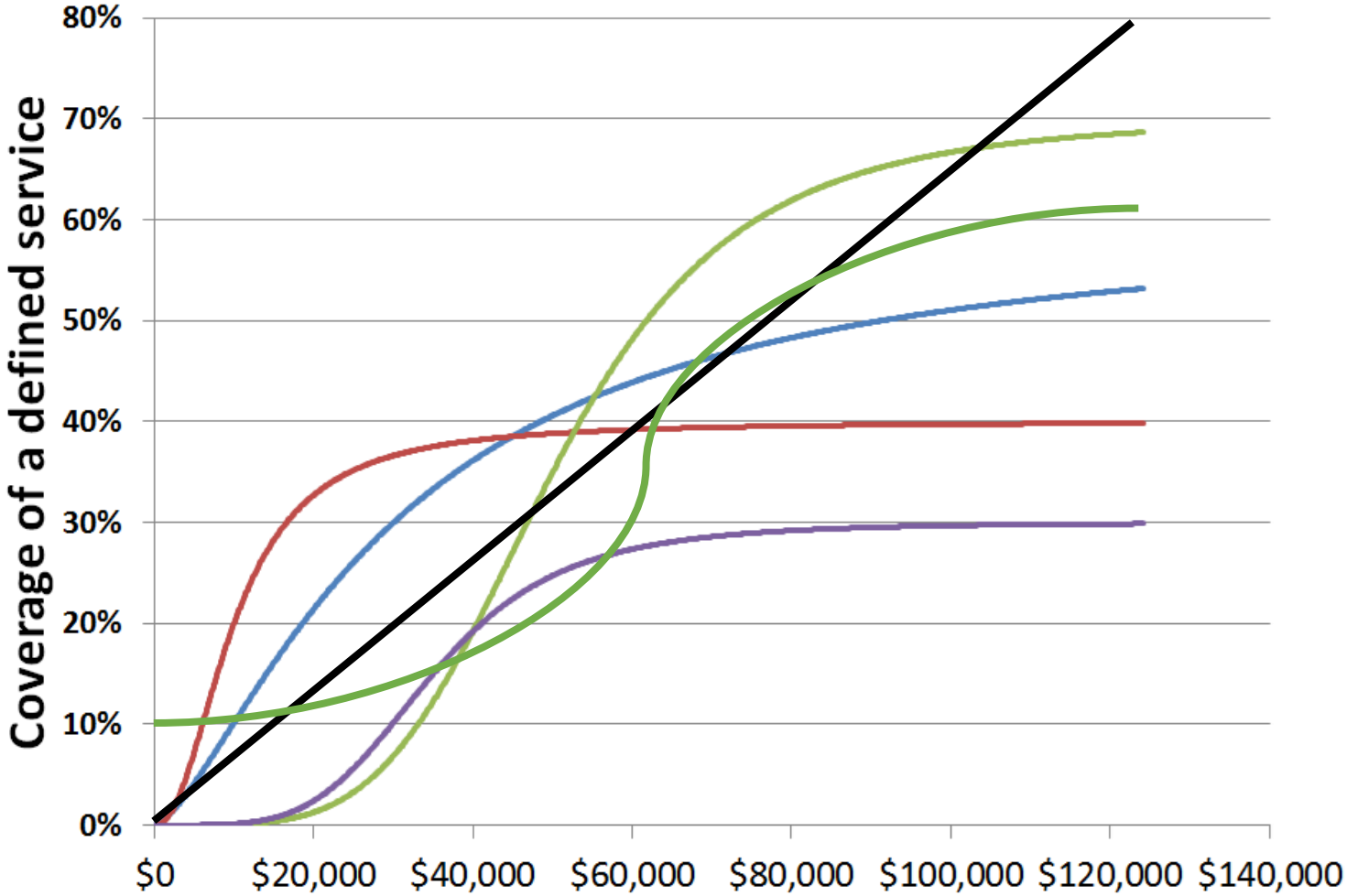
3. Outcomes under:

- Zero spending ($0): in the absence of any programs targeting this parameter
- Maximum attainable coverage (unlimited spending): for each program acting in isolation

Data sources

- Global AIDS Monitoring (GAM) reports
- Annual programme/ M&E reports

Cost functions for each program or modality

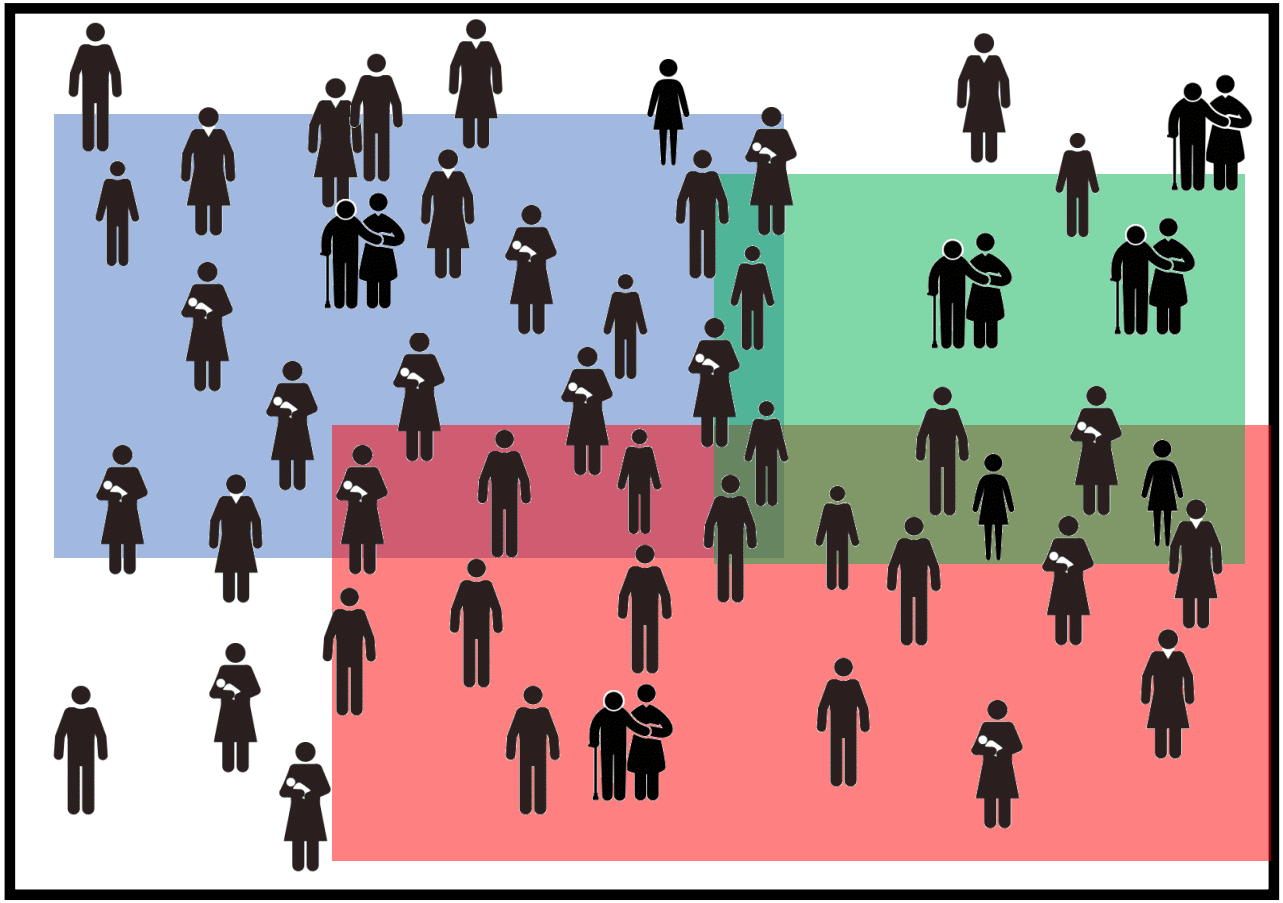


Each program/service modality has it's own **cost-coverage** curve

Spending on different programs/modalities mapped to coverage

$[\$_0, \$_1, \ldots, \$_N] \rightarrow [C_0, C_1, \ldots, C_N]$ ($ maps to coverage)

Entire target population



Coverage reached by program X for $\$_X$

program 1

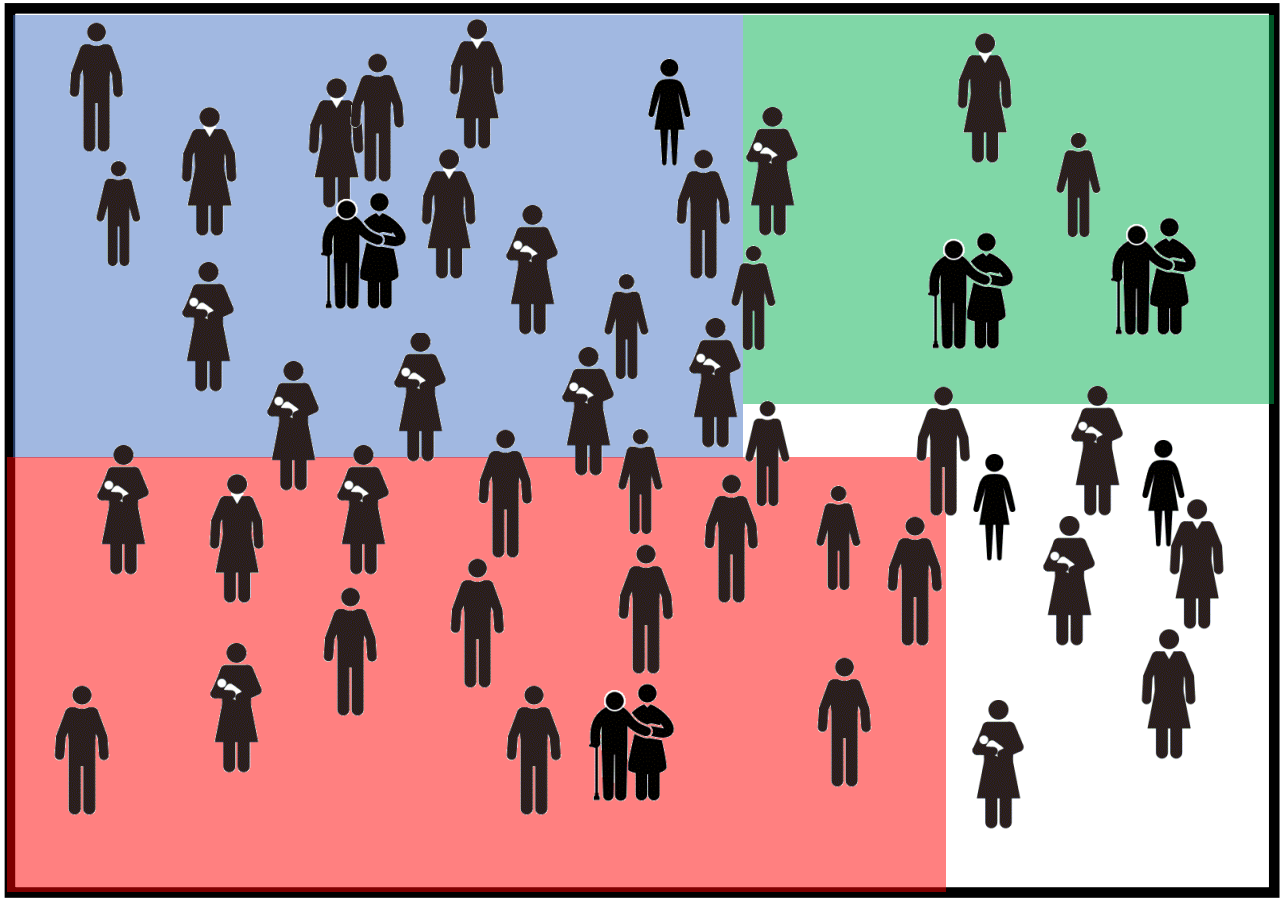
program 2

program 3

For every parameter, the type of program interaction is set

Option 1: **additive** (optional)

Entire target population



Coverage reached by program X for $\$_X$

program 1

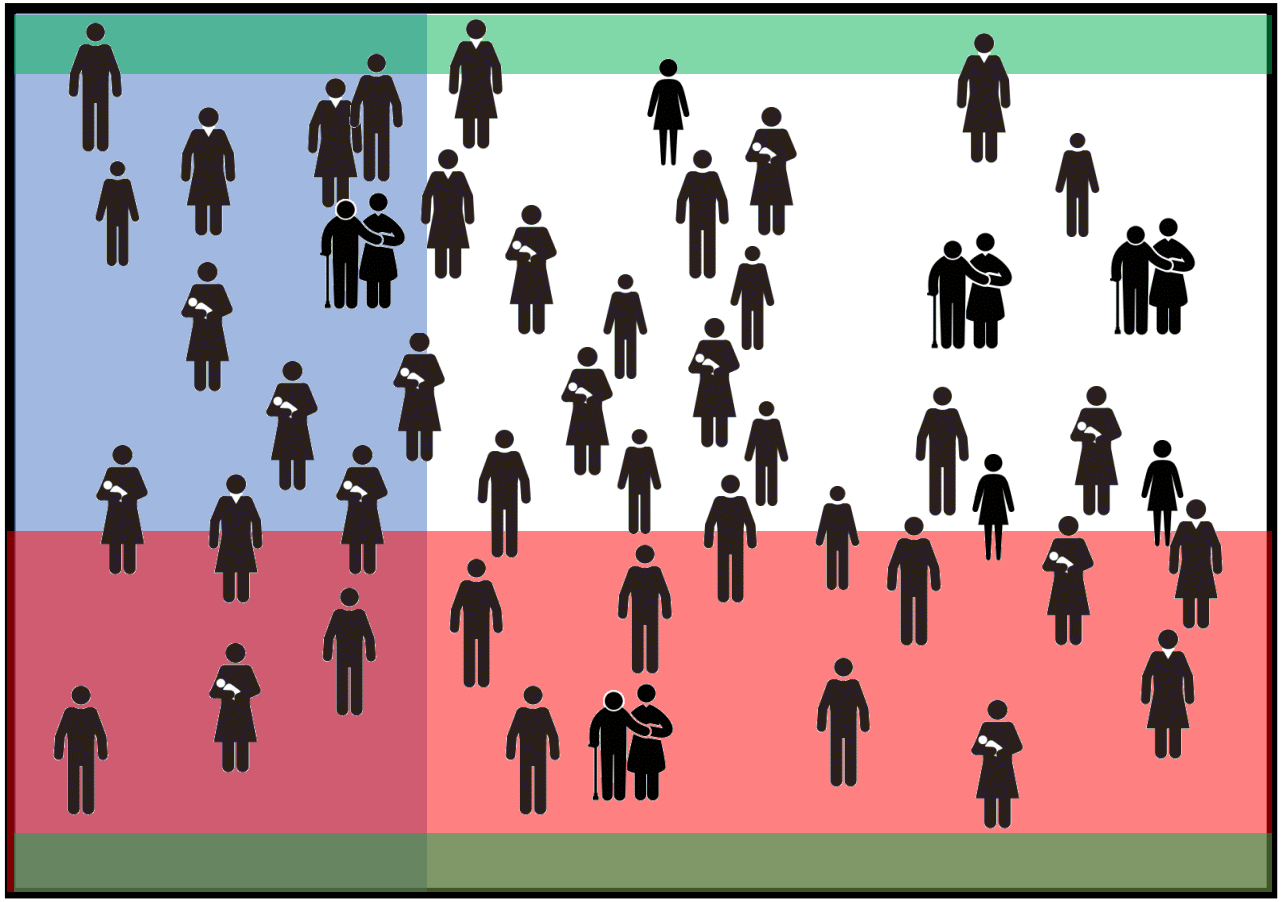
program 2

program 3

For every parameter, the type of program interaction is set

Option 2: **random** (default)

Entire target population



Coverage reached by program X for $\$_X$

program 1

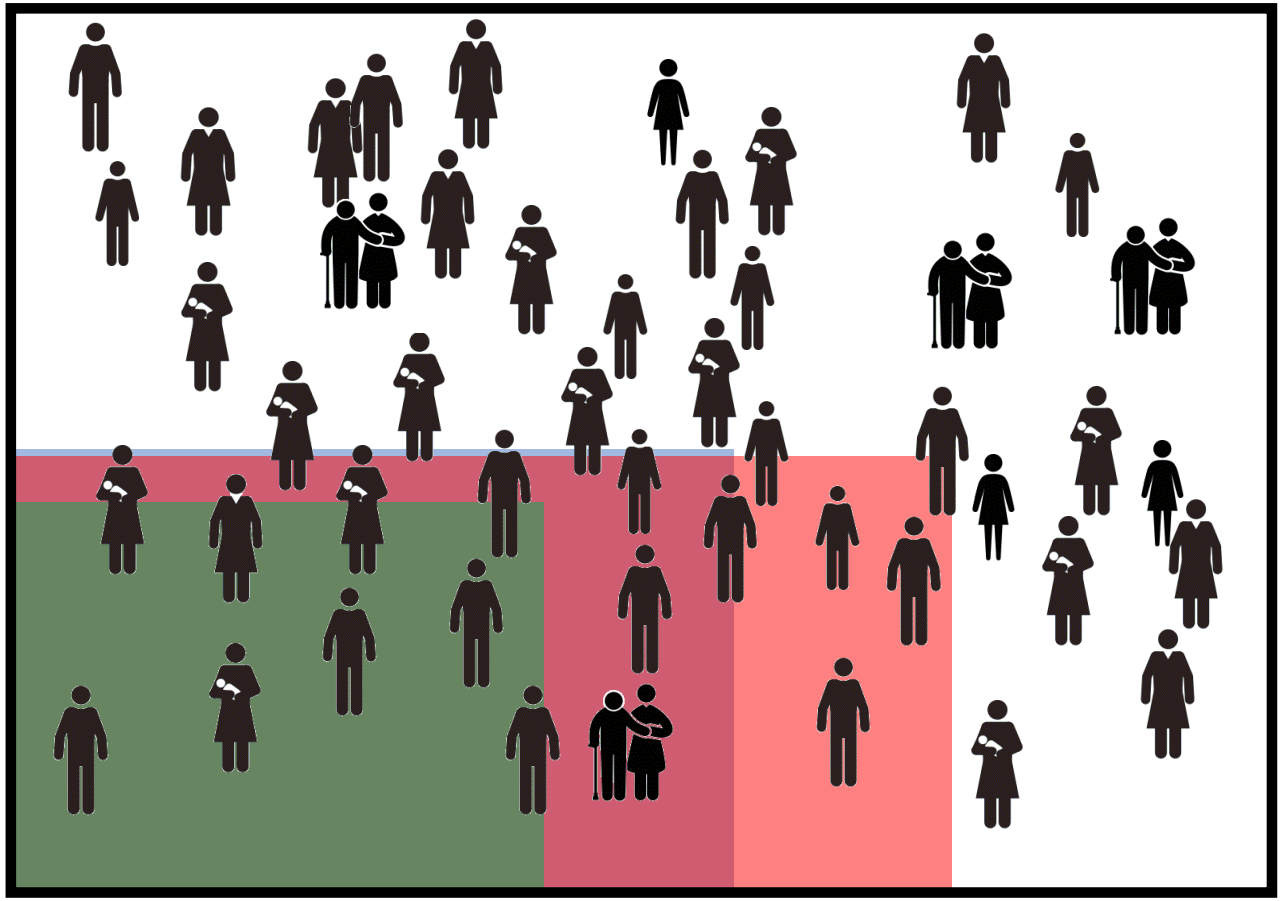
program 2

program 3

For every parameter, the type of program interaction is set

Option 3: **nested** (optional)

Entire target population



Coverage reached by program X for $\$_X$

program 1

program 2

program 3

Reconciliation – a critical step before running an analysis

From the Cost functions, Summary tab, if calibration and coverage values do not match +/-10% as a guide, the modeling team will:

- Check the databook and calibration output for values that might be unrealistic
- Check outcome functions to see if values are realistic:

Define cost functions | Define outcome functions | **Summary**

Year: 2018

Parameter	Population	Calibration value	Coverage value
Condom use for commercial acts	["Clients","FSW"]	0.6900	0.6847
Condom use for commercial acts	["MSM","FSW"]	0.3925	0.3730
Number of people on treatment	tot	700,000.0000	697,668.1332
Number of people on PMTCT	tot	75,165.0000	75,182.2664
Condom use for casual acts	["Clients","Females 20-24"]	0.3755	0.3497
Condom use for casual acts	["Clients","Females 25-49"]	0.3645	0.3497
Condom use for casual acts	["MSM","MSM"]	0.3000	0.2876
Condom use for casual acts	["Males 10-19","Females 10-19"]	0.3965	0.3830
Condom use for casual acts	["Males 10-19","Females 20-24"]	0.4400	0.4079
Condom use for casual acts	["Males 10-19","Females 25-49"]	0.4290	0.3996
Condom use for casual acts	["Males 20-24","Females 10-19"]	0.4630	0.4328

Note: reconciliation does not apply for number of circumcisions

Currency

- Suggested **currency** (for consistency): USD
- **Any** currency can be used - inform modelling team of currency chosen and ensure the same currency is consistently used across the entire project
- Model does *not apply* inflation or discounting
  - These adjustments to spending output can be made outside the model

Practice

Defining programs, service delivery modalities, parameters, and cost functions

QUESTIONS?

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Learning objectives

- How to define scenarios
- How to run scenario analyses, view, and export results

Scenario analysis in Optima HIV

- Explore the impact of past spending
- Compare the impact of theoretical changes to the epidemic
- Compare the impact of different program assumptions
- Compare different model assumptions
- Many other factors can be examined using scenario analysis

Budget and coverage scenarios

- Specify spending or coverage amounts for each program within the scenario (compared to baseline ”business as usual”)

- Results can be used to inform **policy analyses**

Active	Scenario name	Parameter set	Program set	Scenario type	Manage
☑	90-90-90/95-95-95	Treatment fixed	default	parameter	
☑	Status quo	Status quo	default	parameter	

Run scenarios from 2000 to 2030

Add parameter scenario | Add budget scenario | Add coverage scenario

Setting up a scenario analysis in Optima HIV

Optima HIV

Projects

Active	Scenario name
☑	90-90-90/95-95-95
☑	Status quo

Run scenarios from 2000

CREATE OR EDIT A PARAMETER SCENARIO

Name

90-90-90/95-95-95

Parameter set:

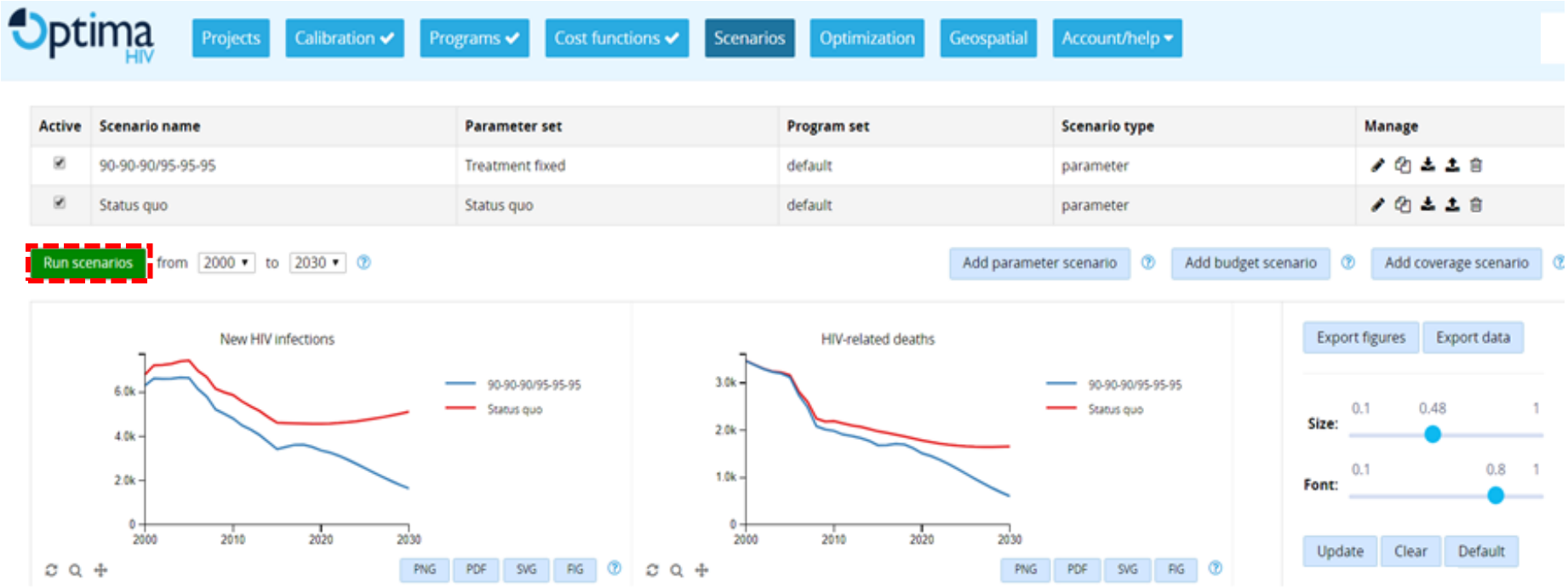
Treatment fixed

Model parameters	Population	Start year	Final year	Start value	Final value
Proportion of PLHIV aware of their status	Total Populati	2015	2020		0.9
Proportion of PLHIV aware of their status	Total Populati	2020	2030	0.9	0.95
Proportion of diagnosed PLHIV in care	Total Populati	2015		1	
Proportion of PLHIV in care on treatment	Total Populati	2015	2020		0.9
Proportion of PLHIV in care on treatment	Total Populati	2020	2030	0.9	0.95
Proportion of people on ART with viral suppres	Total Populati	2015	2020		0.9
Proportion of people on ART with viral suppres	Total Populati	2020	2030	0.9	0.95

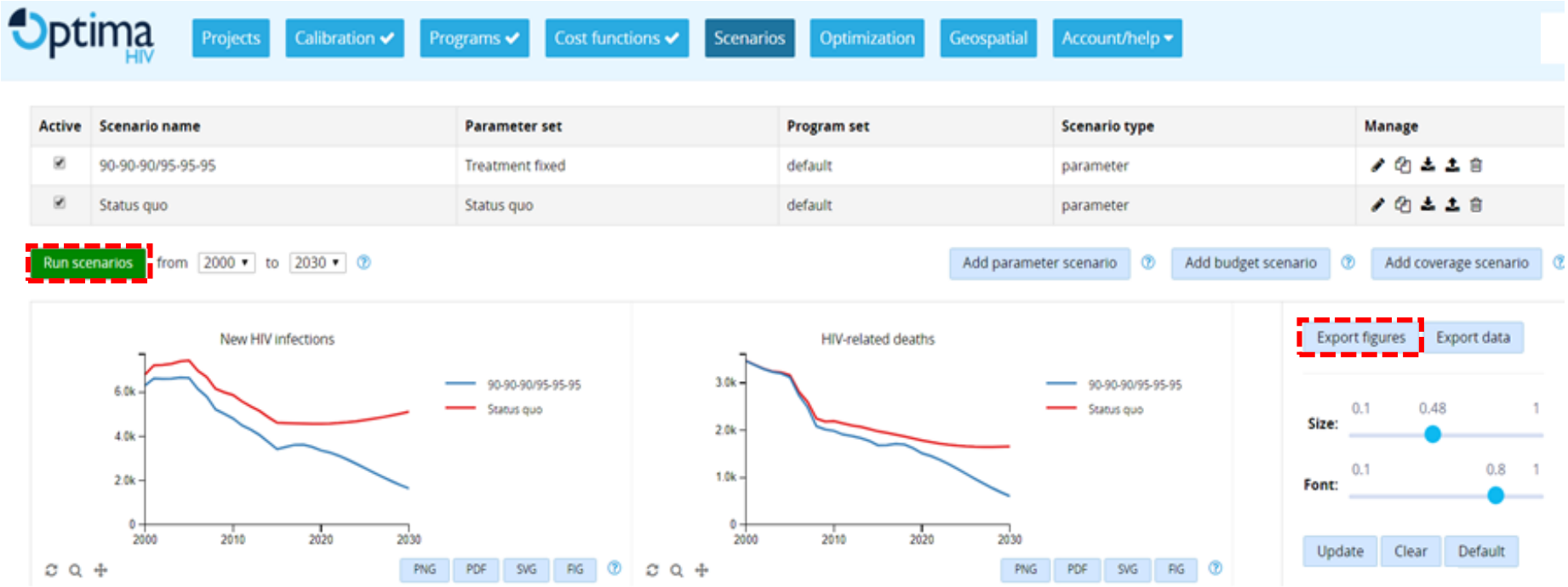
Add parameter

Cancel Save

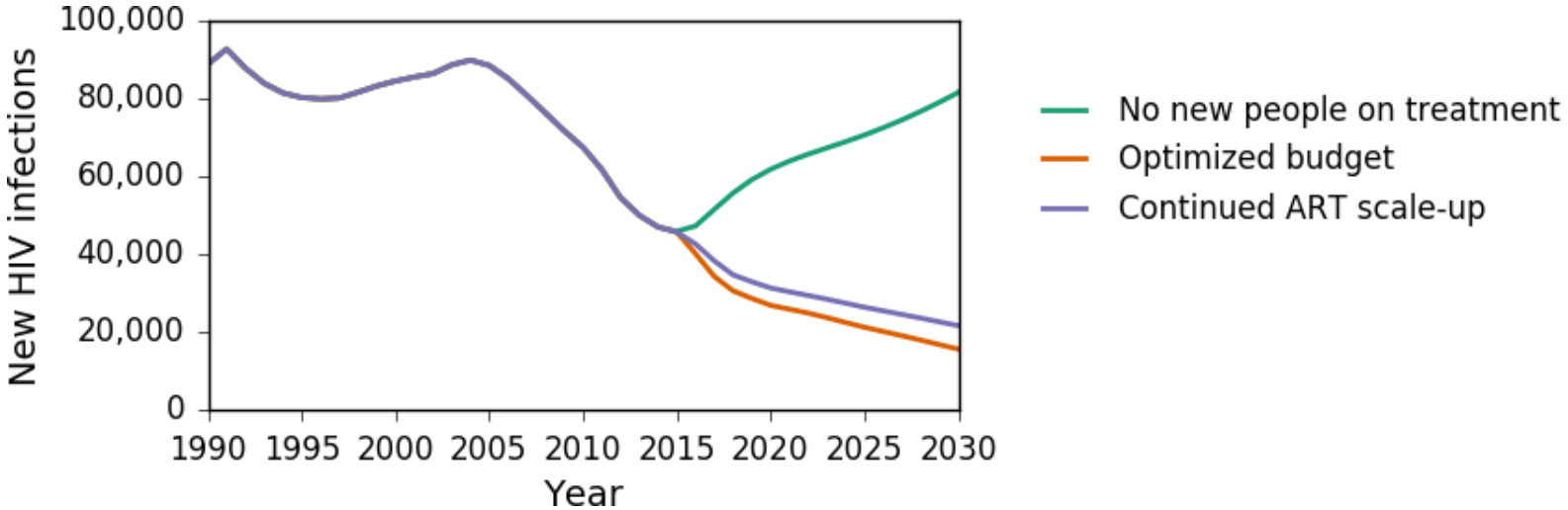
Run a scenario in Optima HIV

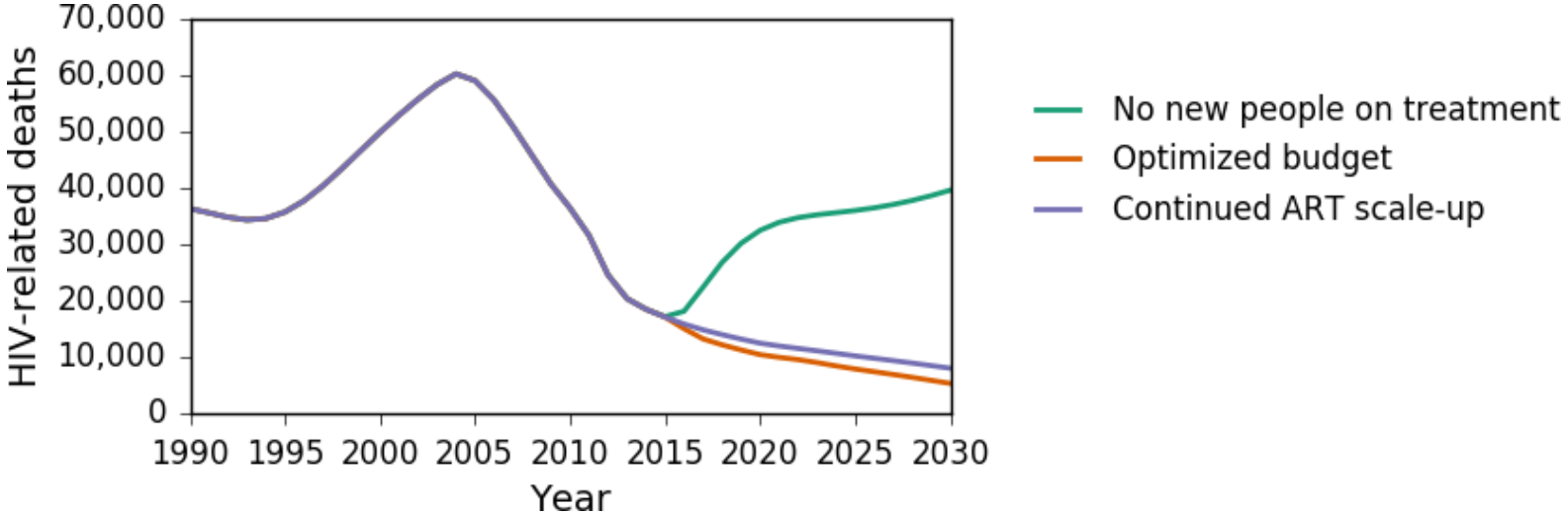


Exporting figures



Example from Malawi - prioritize diagnosis and treatment scale-up





Practice

Running Optima HIV scenario analyses, viewing, and exporting results

QUESTIONS?

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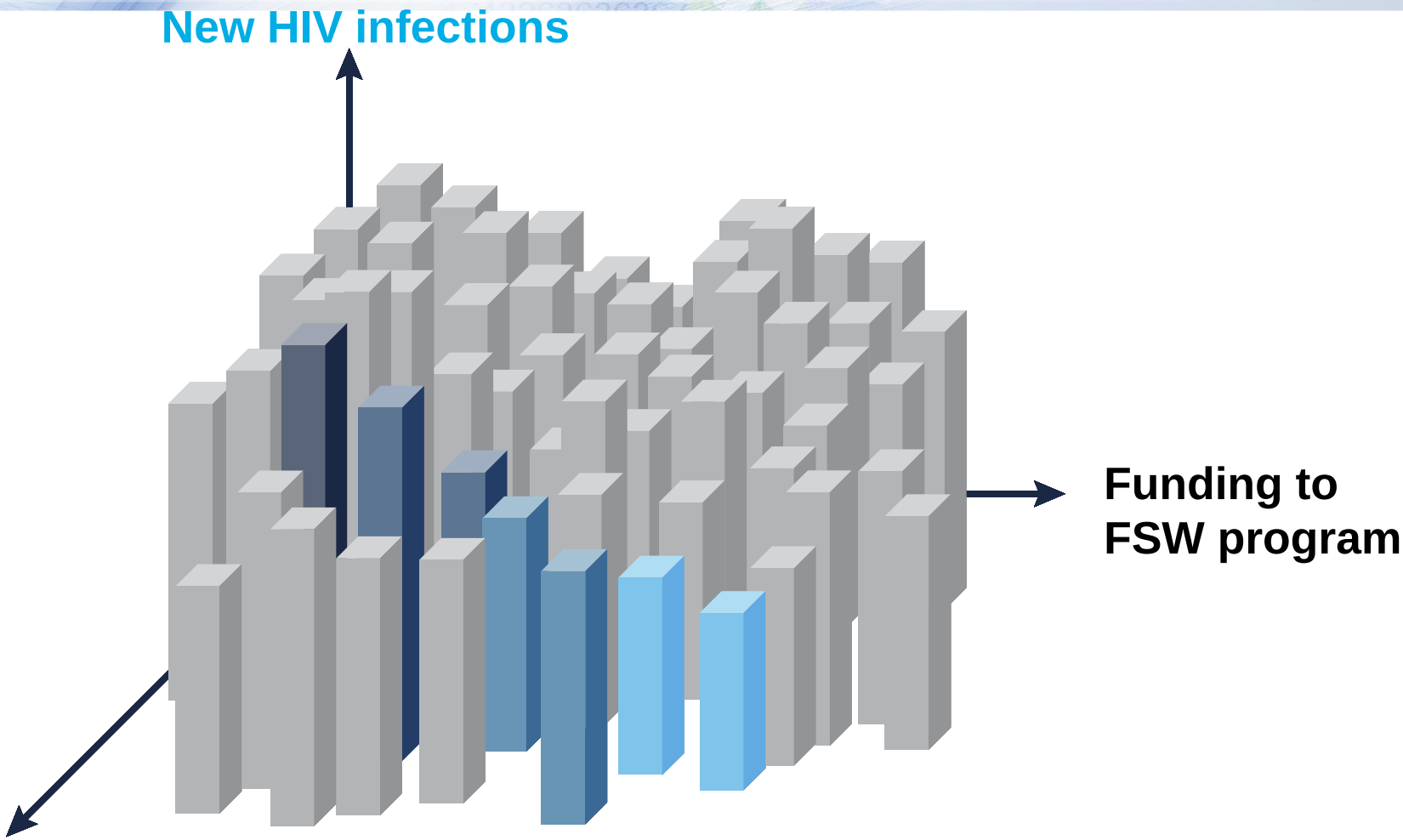
Learning objectives

- How mathematical optimization is achieved
- Description of the Optima HIV optimization algorithm

Optimize resource allocation to best meet objectives

How should the budget be allocated amongst these ‘n’ programs, modalities, and delivery options, considering their interactions with synergies and limitations?

Optimization: **consider just two dimensions**



*Apply an efficient **A**daptive **S**tochastic **D**escent algorithm*

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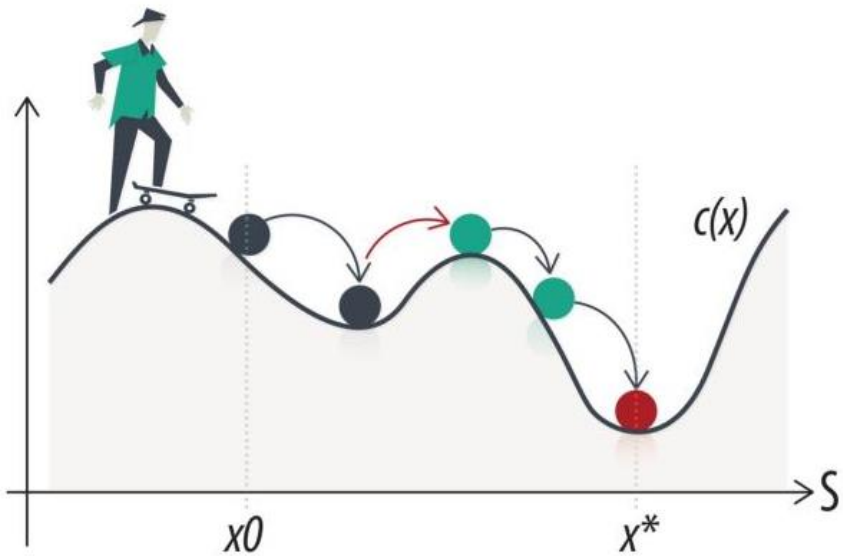
Source: Kerr et al 2016

Which optimization algorithm?

Traditional algorithms (e.g., simulated annealing) require many function evaluations—**slow**



Optima's optimization algorithm

Adaptive **s**tochastic **d**escent

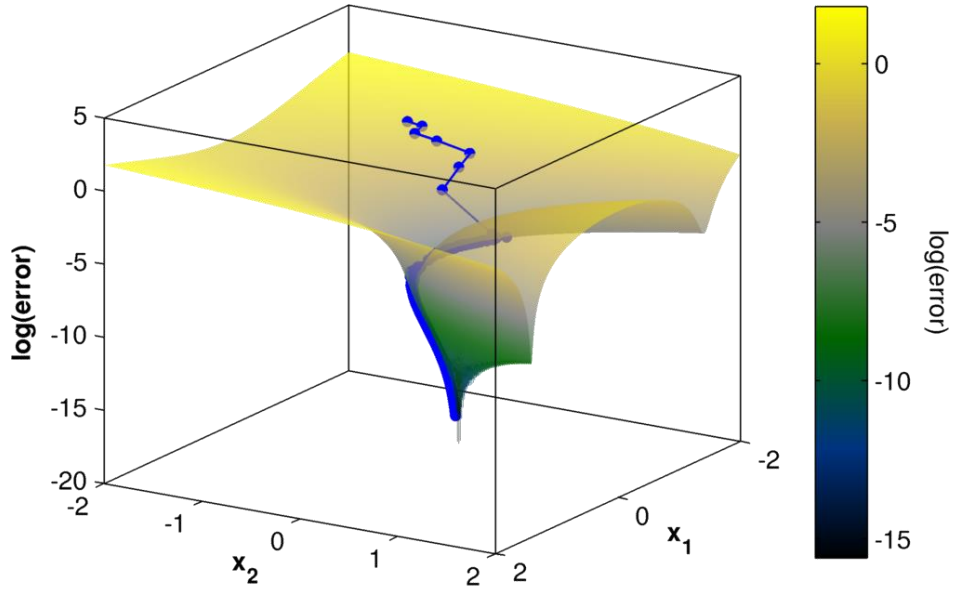
- **Adaptive:** learns probabilities and step sizes
- **Stochastic:** chooses next parameter to vary at random
- **Descent:** only accepts downhill steps

Theory of optimization

Aim: For a given amount of money, what's the best outcome we can achieve?

"Best" could mean:

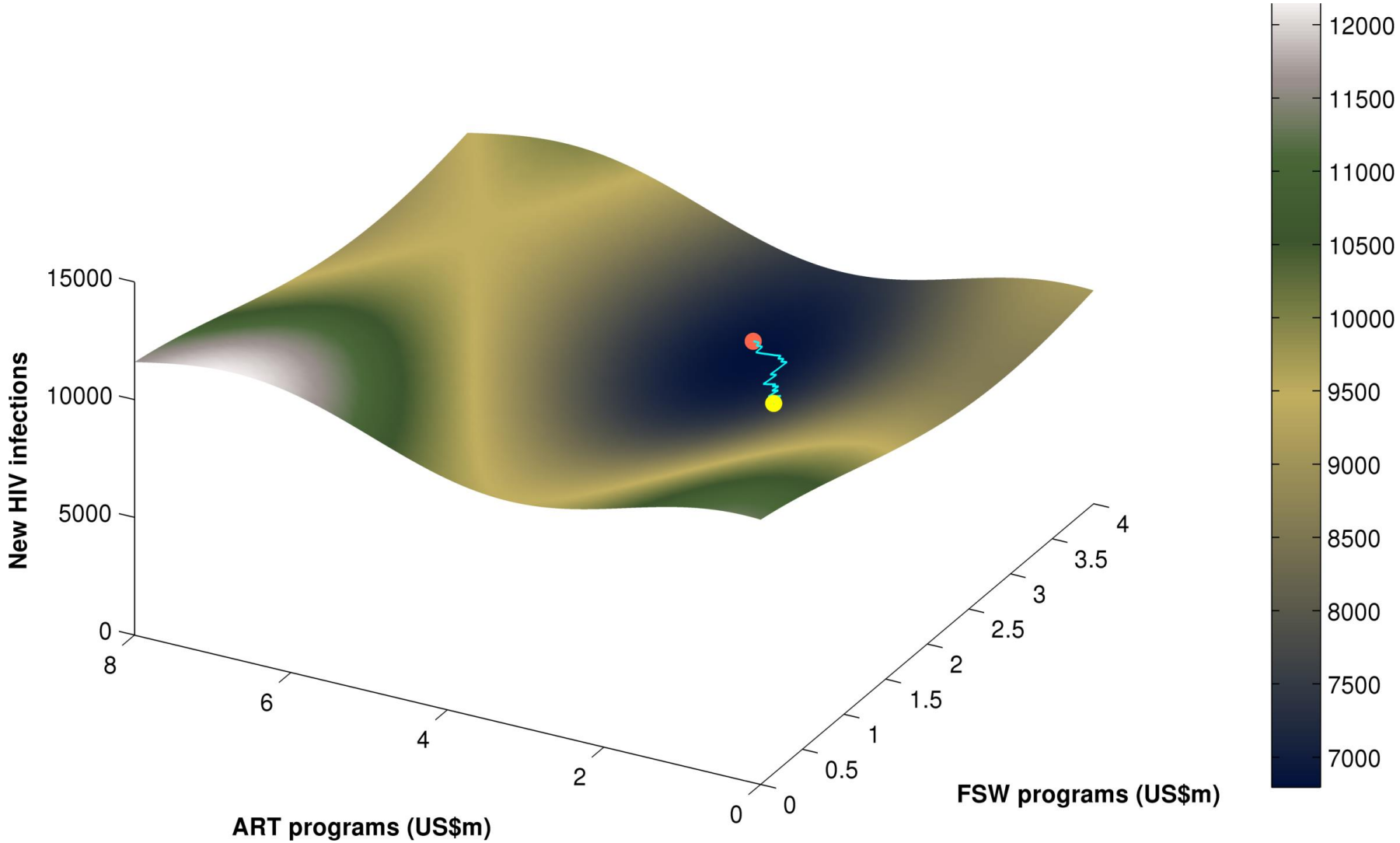
- Fewest infections
- Fewest deaths
- Lowest costs
- All of the above



Formally:

For resource vector $\mathbf{R}$ such that $\sum \mathbf{R} = \text{const.}$ and outcome $O = f(\mathbf{R})$, find $\mathbf{R}$ that minimizes O.

Different outcomes lead to different results



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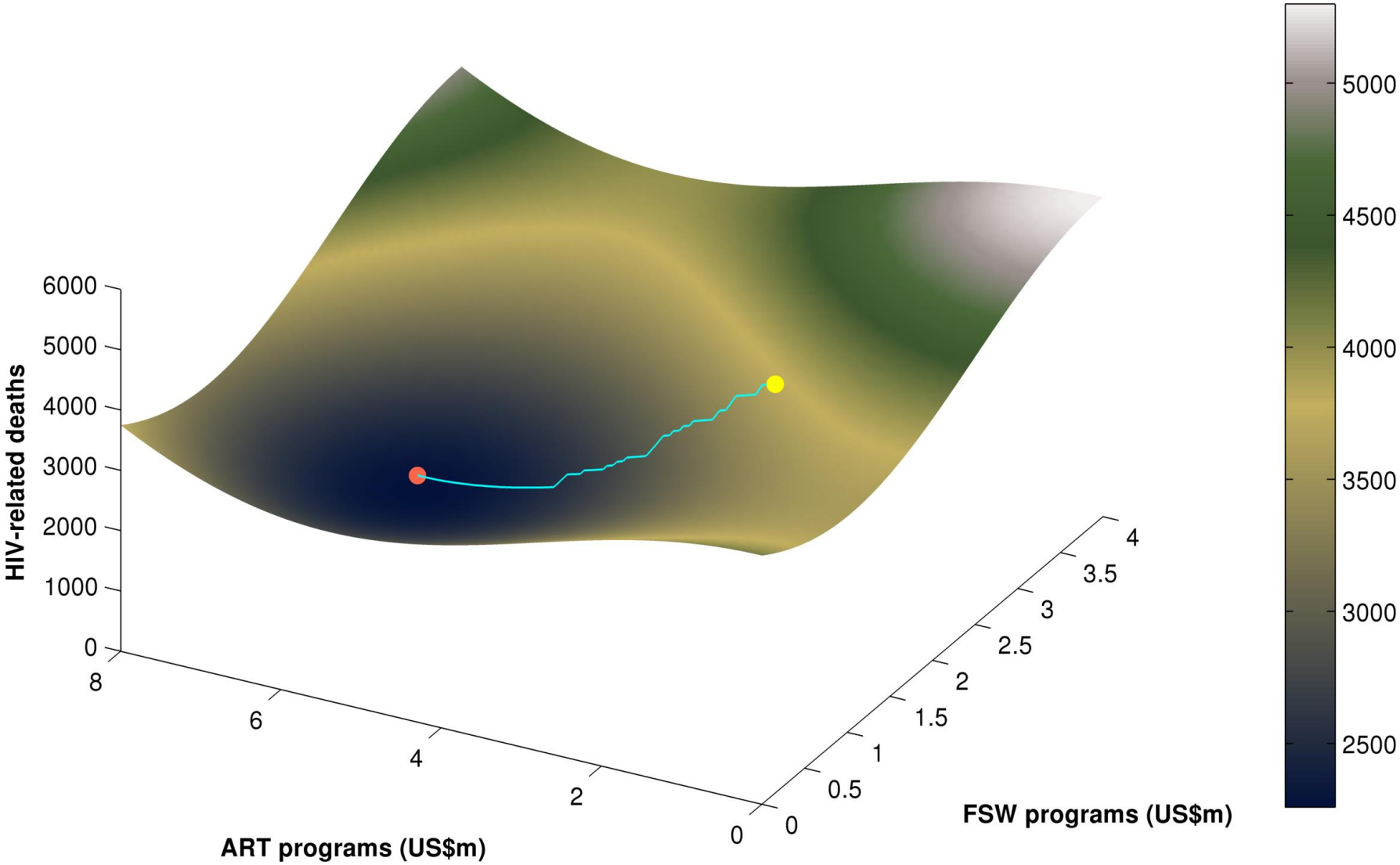
Different outcomes lead to different results



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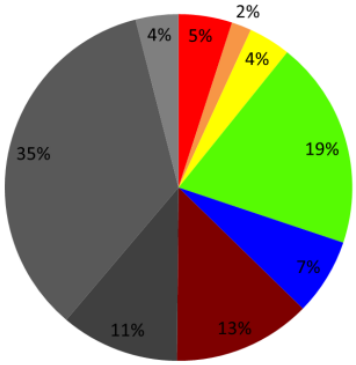
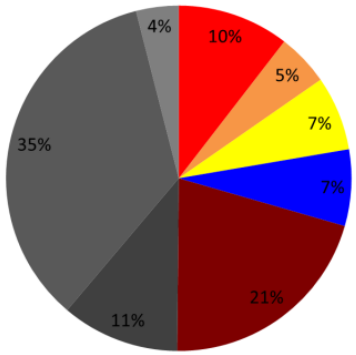
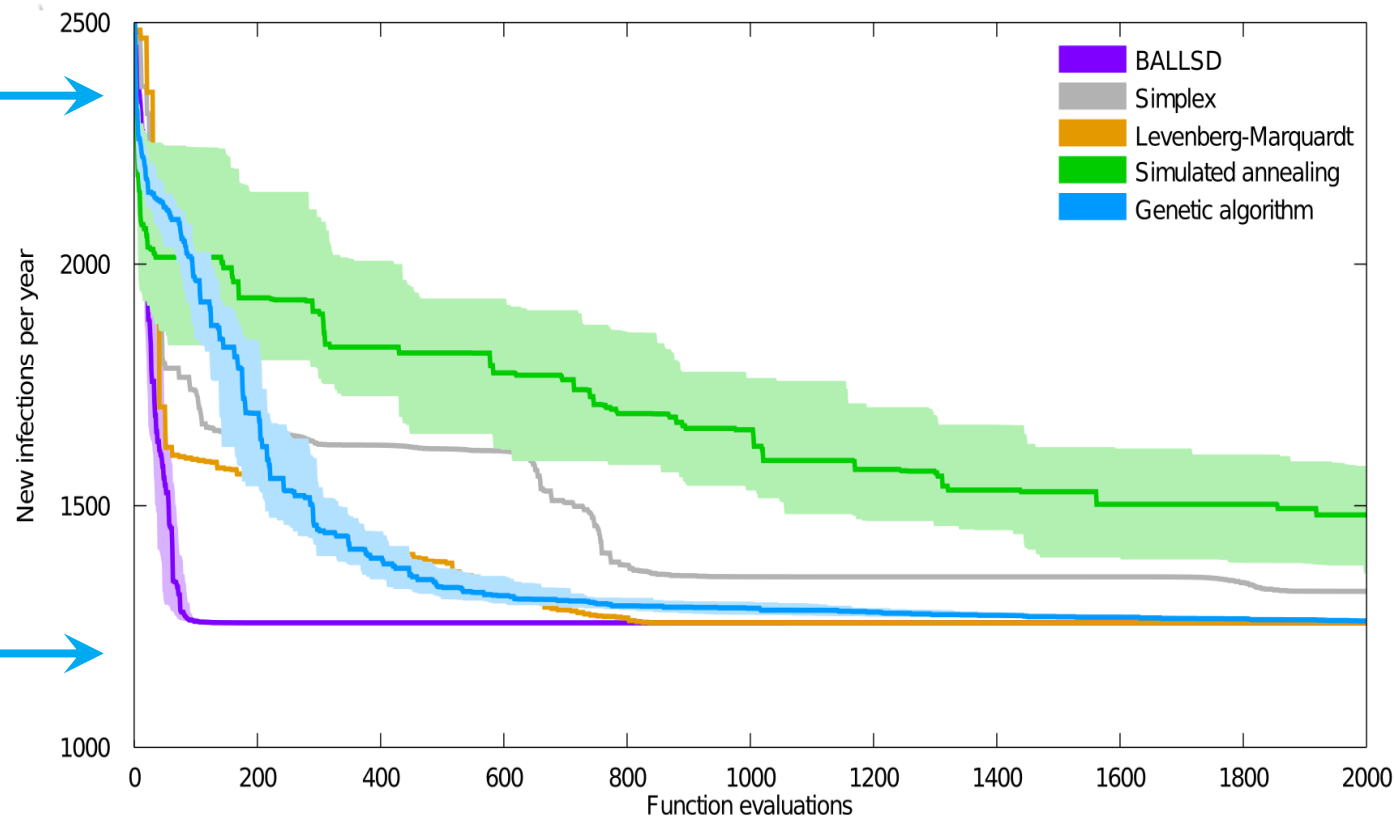
Example: reducing incidence in Sudan

Current



Optimal





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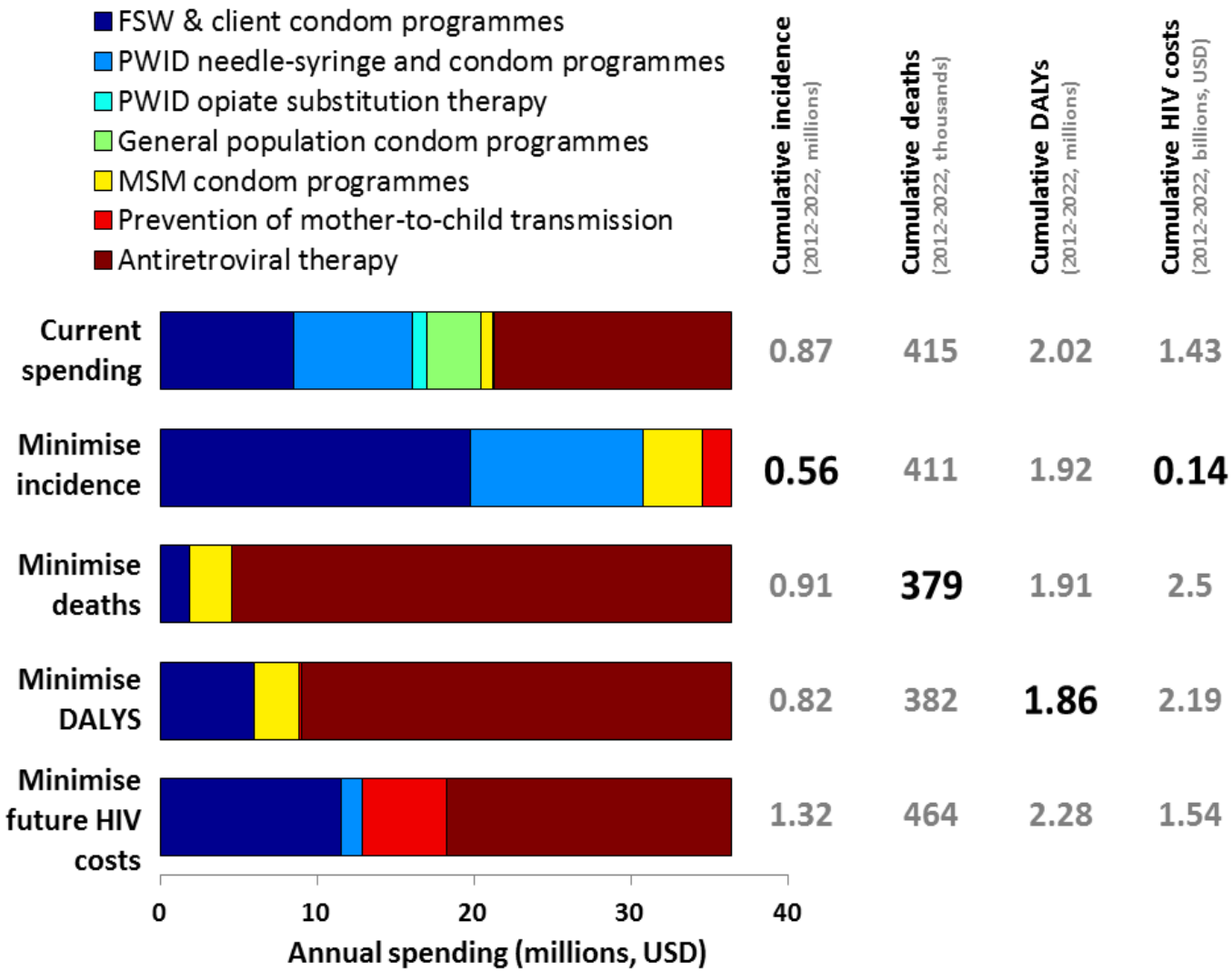
Example: Optima HIV optimization for Indonesia



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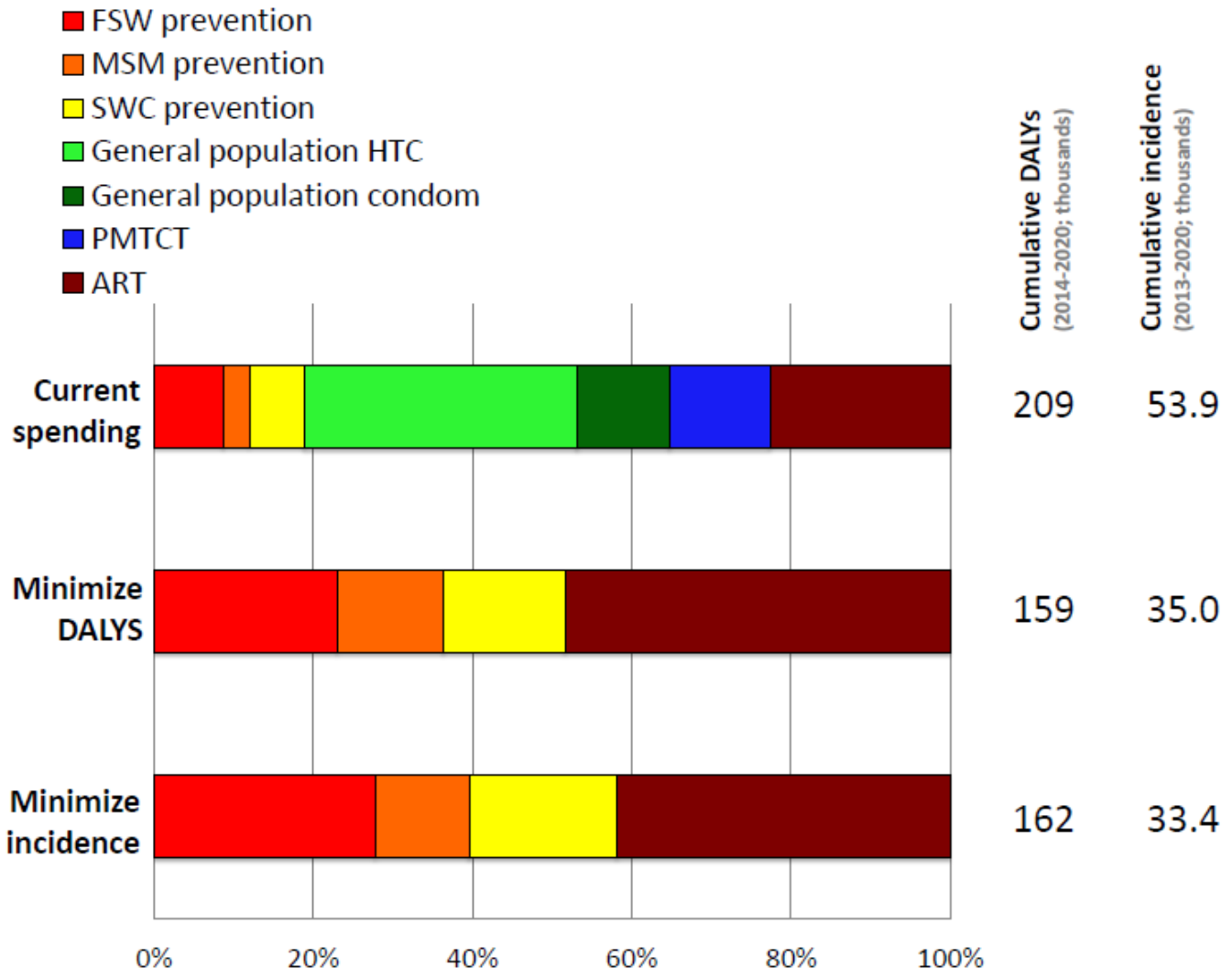
Example: Optima HIV optimization for Sudan



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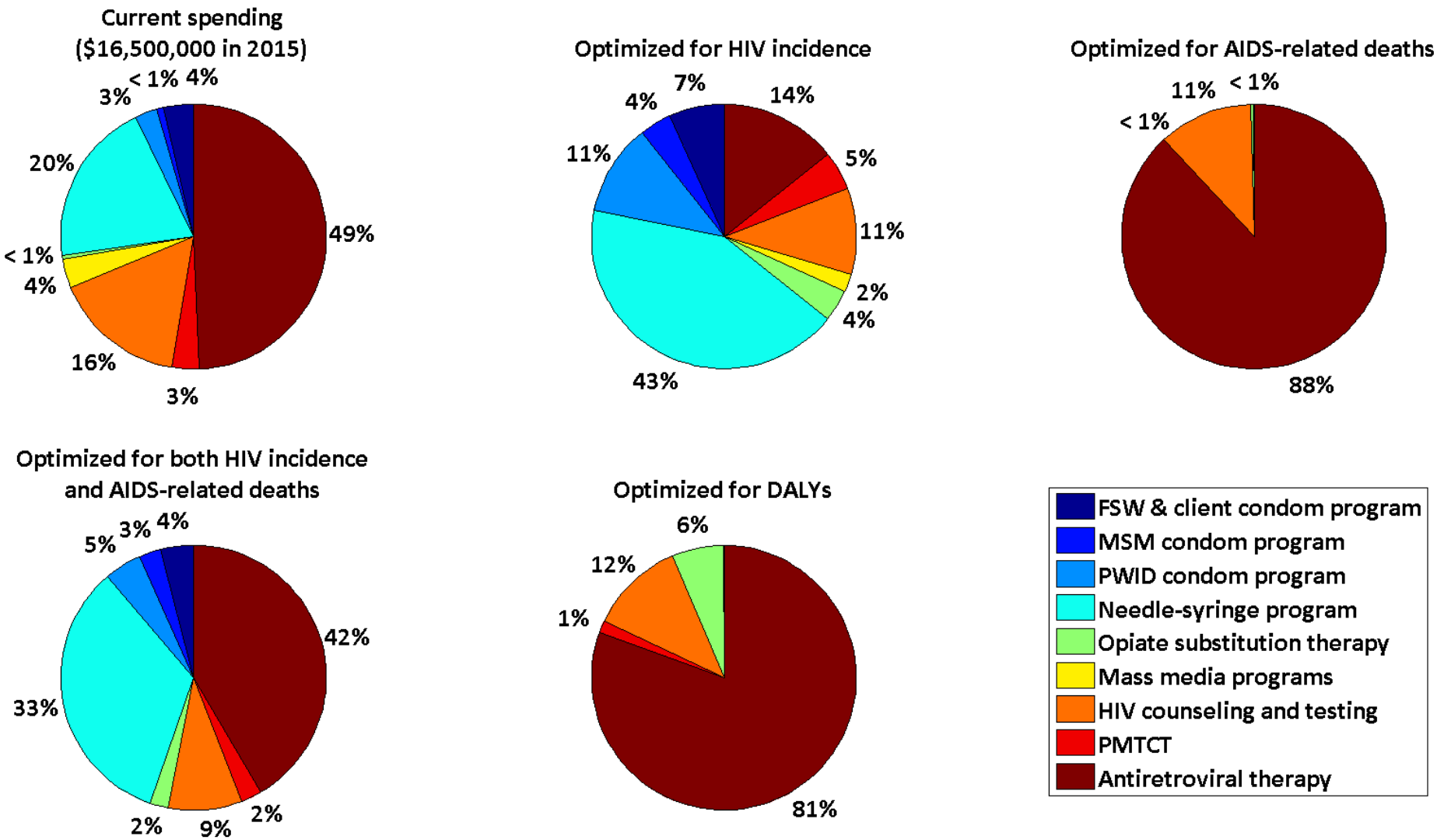
Example: Optima HIV optimization Kazakhstan



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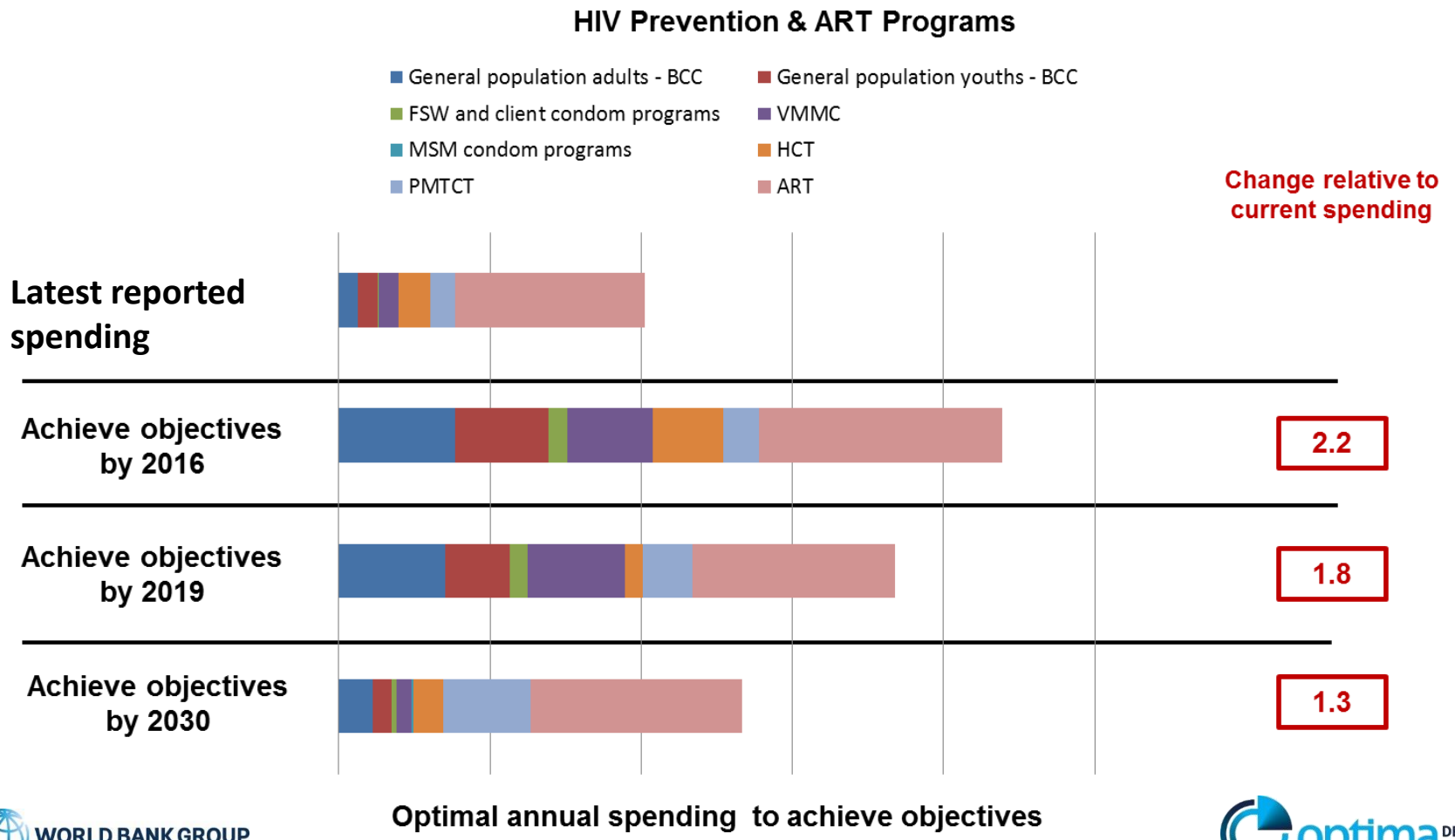
Recommendation: single objective to ease interpretation

- Recommend selecting a single objective with multiple outcomes
  - Identify allocation to minimize **incidence**
  - Identify allocation to minimize **deaths**
  - Identify allocation to minimize **DALYs**

- Highlight or present the optimal allocation for a single objective for a single outcome, e.g. by 2030 reduce HIV incidence by 90% compared with 2010 (End AIDS target)

Time horizons matter

The greatest long-term impacts are affected by different short-term allocations



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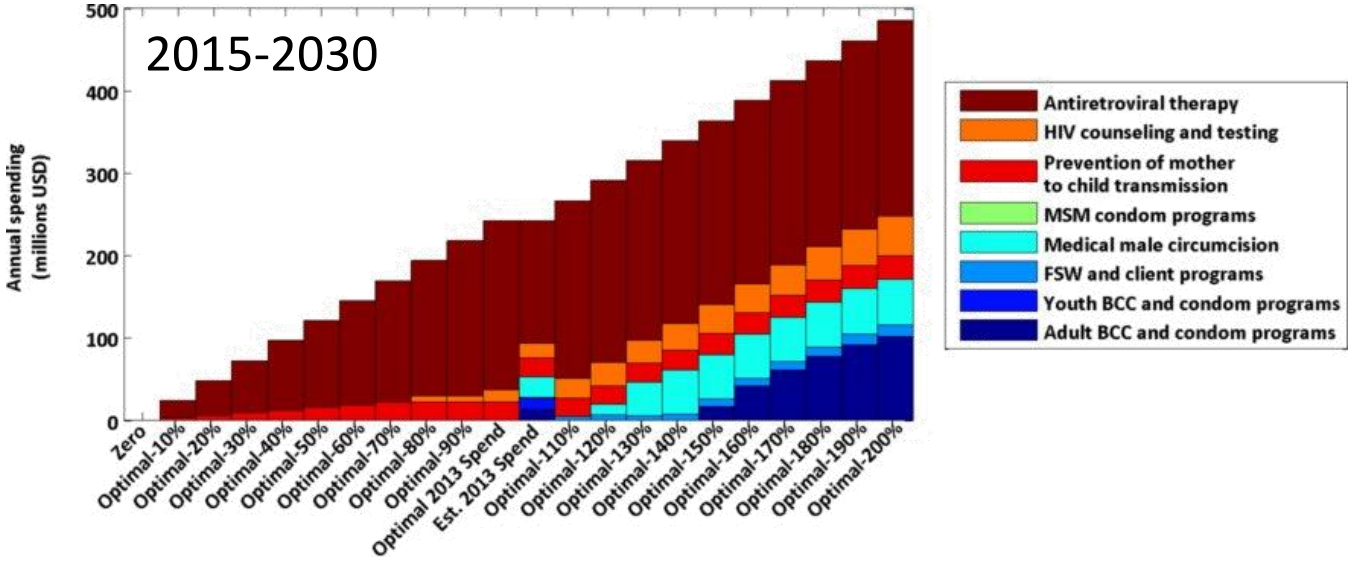
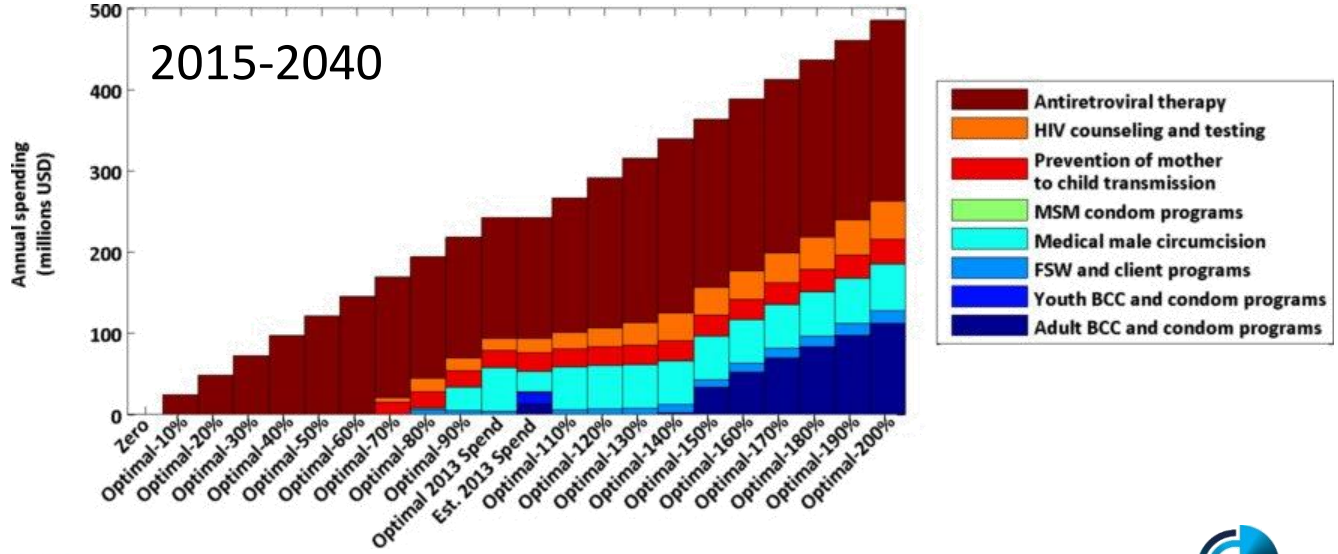
Time horizons matter





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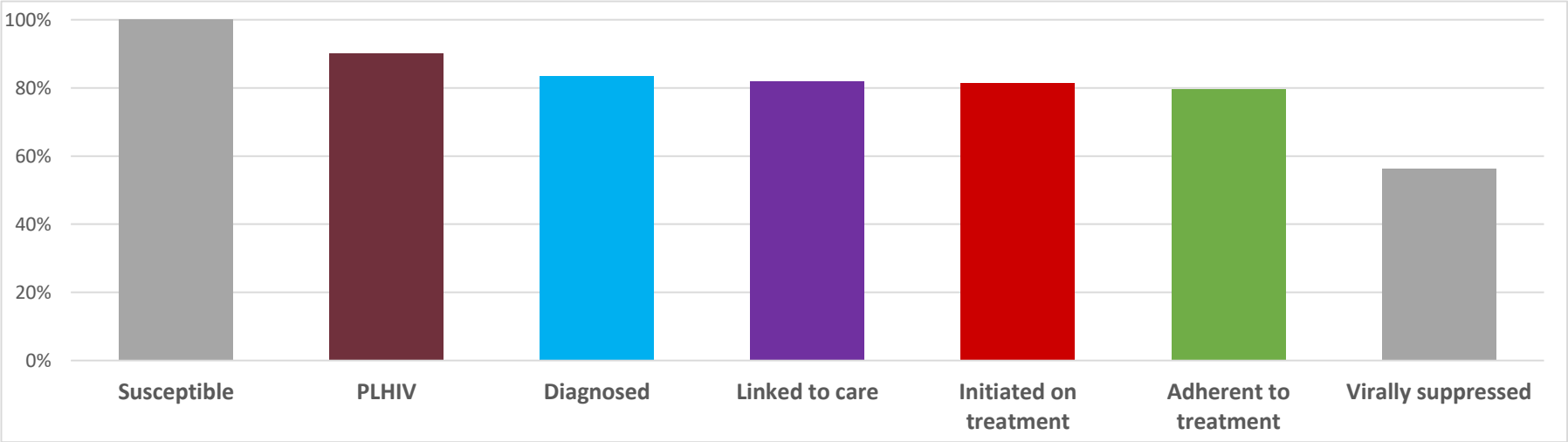
Learning objectives

- The HIV care cascade
- Interventions along the care cascade
- Optima modeling the cascade

HIV care cascade

- The HIV care cascade is used to represent the proportion of people at the different stages of HIV: diagnosis, care, treatment, adherence, and treatment success.
- Various interventions exist to move people across the care cascade to:
  - increase the proportion of PLHIV aware of their status, initiated and retained on treatment, and achieving viral suppression



Optimization of **service delivery cascade** in HIV

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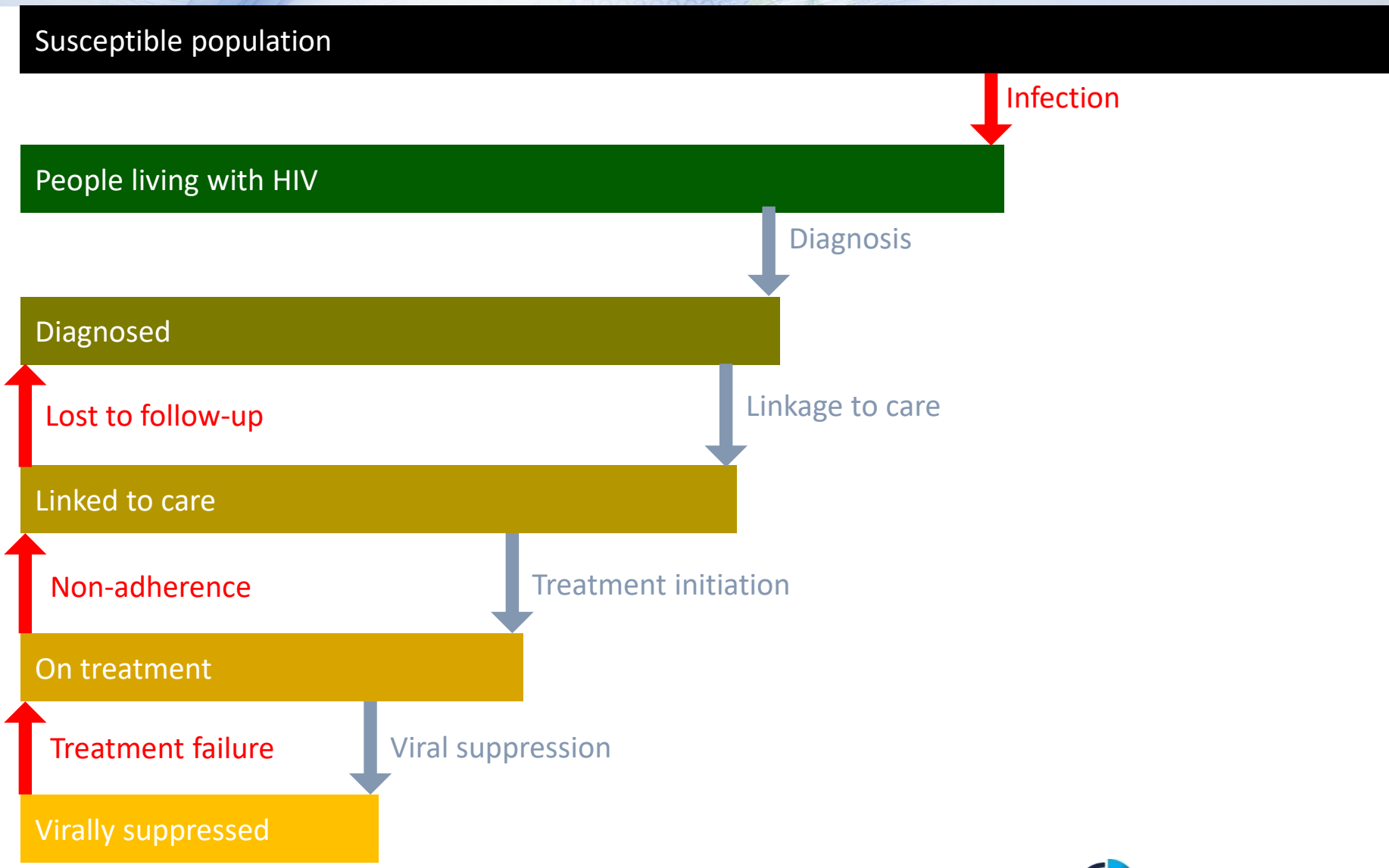
Optima HIV care cascade compartments



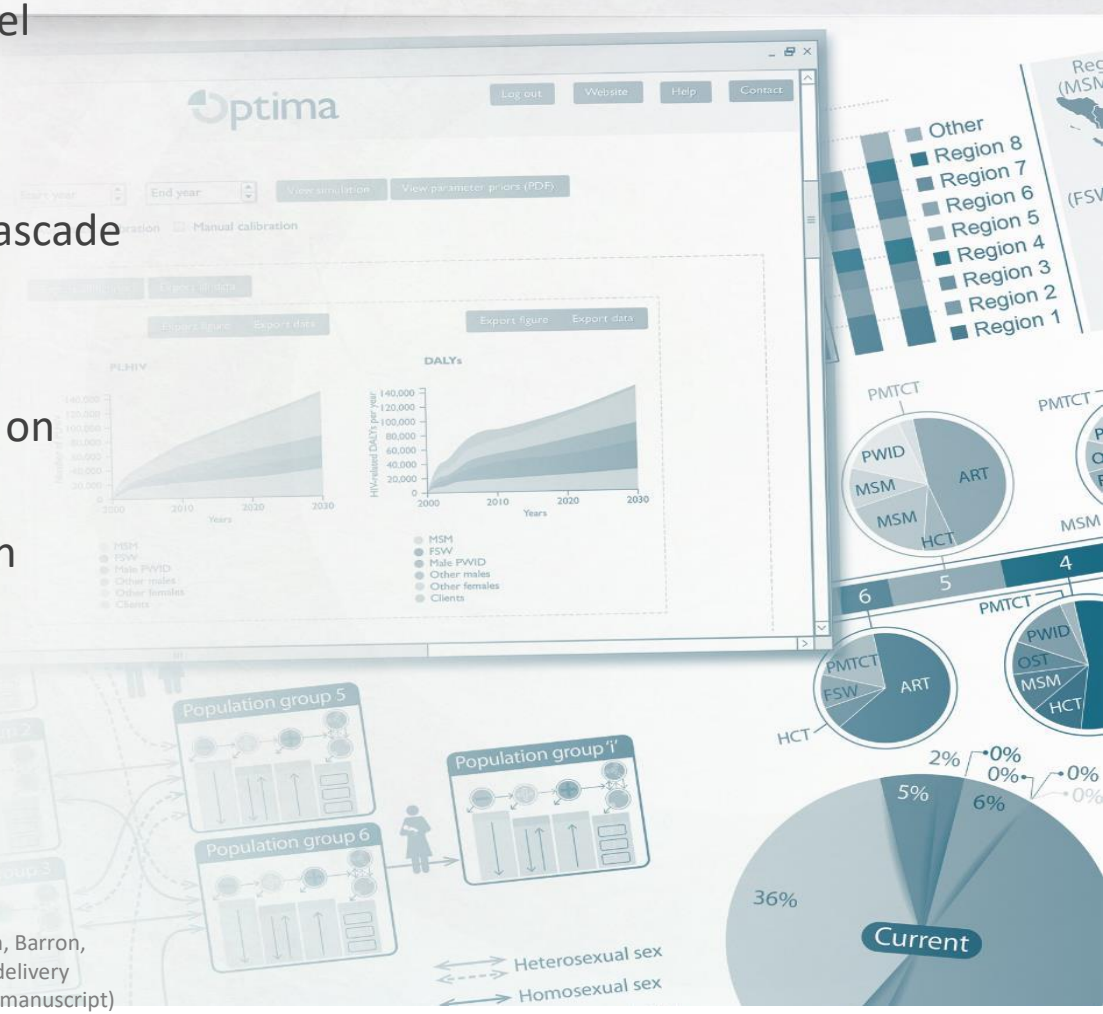
Optima cascade modelling

- The model does not track individuals, so the traditional cohort cascade can not be generated.
- Displays the outcomes for people who are at each stage of the cascade over each year
- Optima HIV can be used to determine the optimal resource allocation across these intervention modalities to achieve best results across the HIV care cascade

How can cascade optimization be done?

Main components*

- Dynamic epidemiological model
- Calibration process
- Optimization function
- Characterized services along cascade
- Understanding of their service delivery modalities
- Understanding of their impact on cascade stages
- Annual per patient cost of each service/intervention
- Target populations for each service/intervention
- Understanding of relationship between cost and coverage



* Based on methodology developed by Shattock, Fraser, Shubber, Muzah, Barron, Pillay, Görgens, Gray & Wilson in: Optimising resources across service delivery modalities to improve the HIV continuum of care in South Africa (draft manuscript)

Examples of service modalities and outcomes along cascade

	SERVICE/MODALITY	EXPECTED OUTCOME (MODEL)
Testing/ Diagnosis	▪ Testing (lab vs. point-of-care) ▪ Testing (workplace/home/self)	Receipt of test results
Linkage/ Enrolment	▪ Community support for linkage ▪ Tracing new cases	Increased linkage to care
Linkage to care	▪ Text messaging ▪ Tracing of lost-to-care ▪ Education/counselling (lay vs. professional counsellors)	Increased retention in care
Treatment	▪ Treatment initiation counselling (conventional vs. fast-track vs same-day)	Timely treatment initiated
Disease control	▪ Treatment initiation counselling ▪ Adherence community support ▪ Text messaging ▪ Enhanced adherence counselling (lay vs. professional) ▪ Drug refill (clinic vs. community)	Treatment adherence (consolidation/maintenance phase)

Methodology: Optimization across a cascade

INTERVENTIONS CAN IMPACT MORE THAN ONE CASCADE STAGE

- **Example: Testing modalities**
  Can have additional effects at latter stages of cascade beyond diagnosis itself
  - On laboratory monitoring compliance (such as post-diagnosis CD4 testing, viral load testing
  - On treatment adherence
- **Example: Counselling/education intervention**
  Can influence behaviours across cascade stages

*The thing that works, that helps people **progress through the cascade** is proper counselling, on everything, from HIV to their treatment to the side effects..."*

Key informant, Limpopo Province, South Africa

CASE STUDY

South Africa

Collaborative work with:

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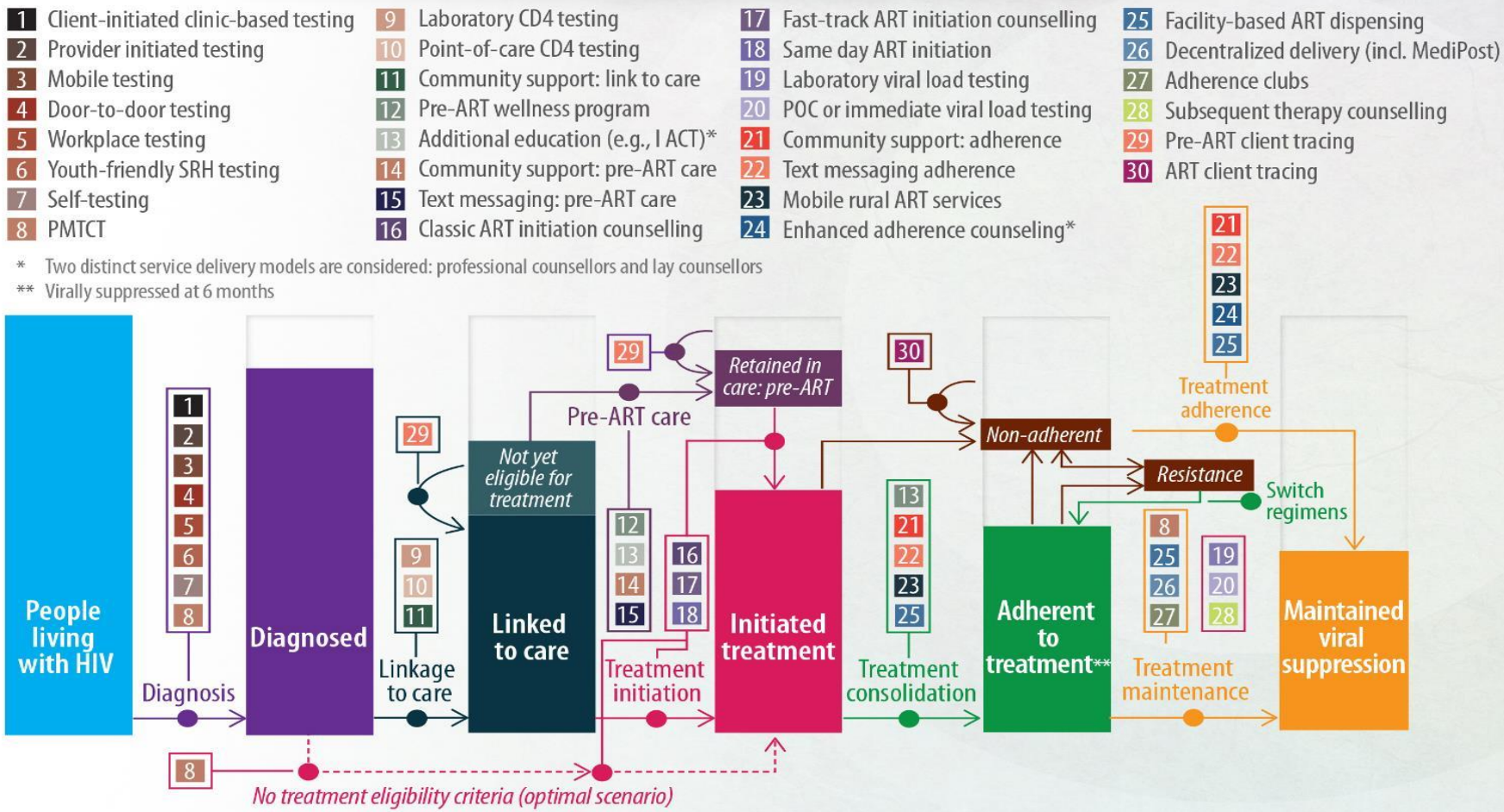
Treatment implementation efficiency in South Africa



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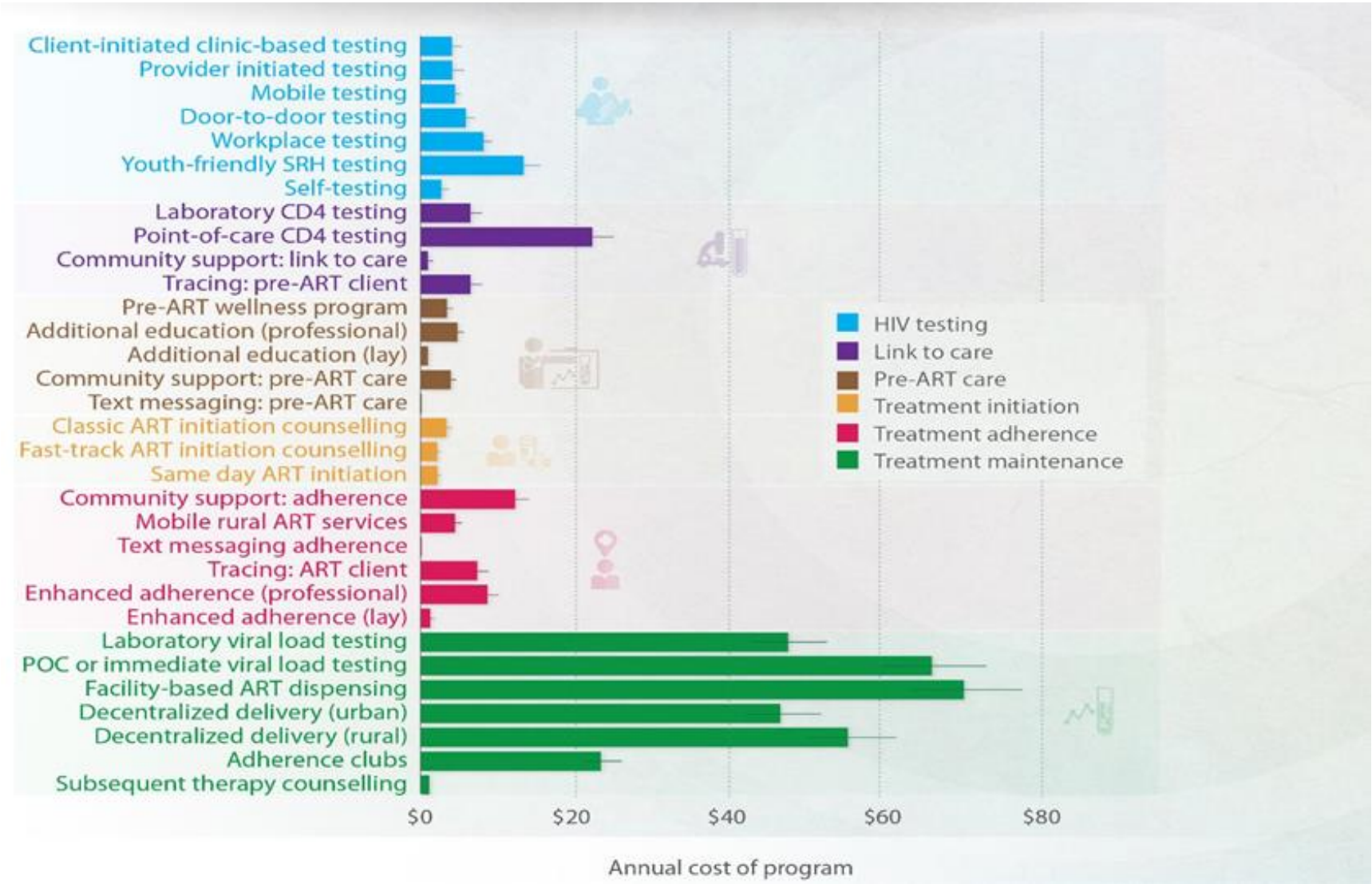
Estimated annual cost of each intervention



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Linked unit cost with data

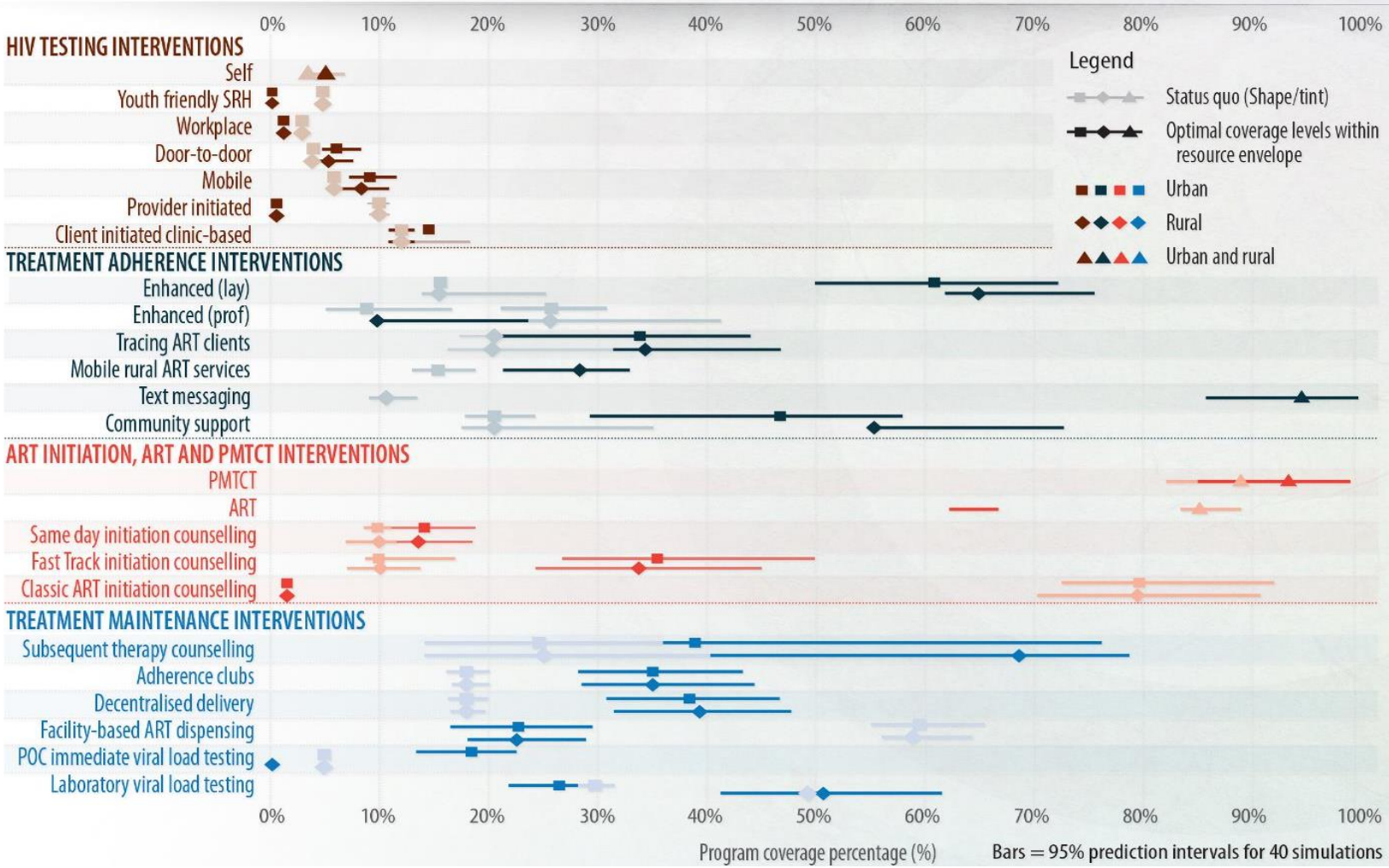
- Linked unit cost with data on program capacity, geographical setting(s) and cascade stages that the services directly impact*

* Excerpt from a longer table

Program (urban and rural setting)	Unit cost (USD, 1 ZAR = 0.0630 USD)	Program Capacity (%)	Cascade flows affected
Client-initiated clinic-based testing	$5.20	88	Diagnosis, linkage to care
Provider initiated testing	$5.73	88	Diagnosis, linkage to care
Mobile testing	$6.05	87	Diagnosis, linkage to care
Door-to-door testing	$7.44	80	Diagnosis, linkage to care
Workplace testing	$9.68	67	Diagnosis, linkage to care
Youth-friendly SRH testing	$14.74	62	Diagnosis, linkage to care
Self-testing	$4.41	87	Diagnosis, linkage to care
Laboratory CD4 testing	$8.28	80	Linkage to care
Point-of-care CD4 testing	$23.76	80	Linkage to care
Community support: link to care	$2.66	80	Linkage to care
Tracing: pre-ART client	$8.18	60	Linkage to care, pre-ART care
Pre-ART wellness program	$5.00	80	Pre-ART care
Additional education (prof)	$6.30	80	Pre-ART care, treatment consolidation
Additional education (lay)	$1.26	80	Pre-ART care, treatment consolidation
Community support: pre-ART care	$5.32	80	Pre-ART care

Service coverage over 2017–20

* Excerpt from a longer table



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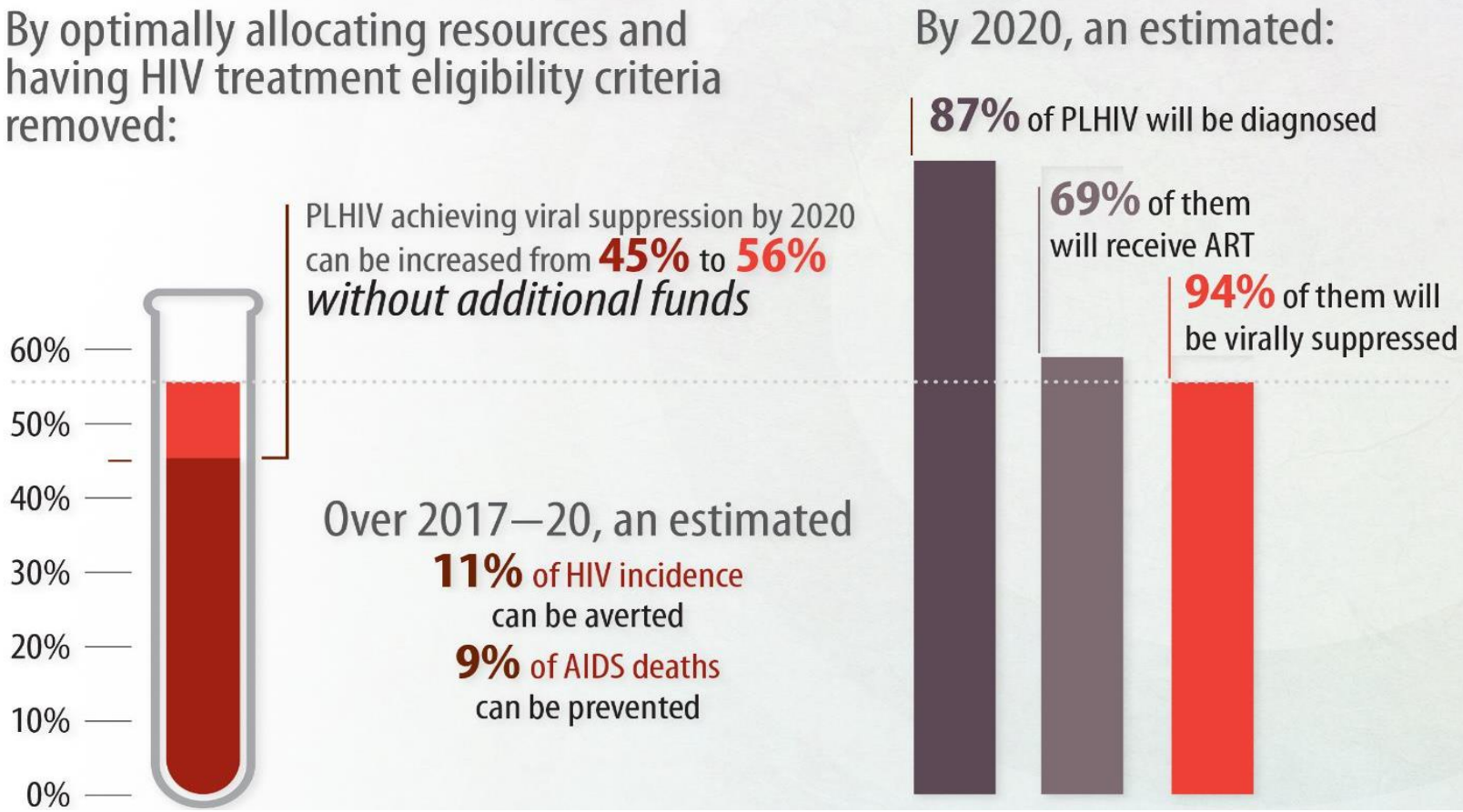
Findings


By optimally allocating resources and having HIV treatment eligibility criteria removed:
PLHIV achieving viral suppression by 2020 can be increased from 45% to 56%
without additional funds
60%
50%
40%
30%
20%
10%
0%
Over 2017—20, an estimated
11% of HIV incidence can be averted
9% of AIDS deaths can be prevented
By 2020, an estimated:
87% of PLHIV will be diagnosed
69% of them will receive ART
94% of them will be virally suppressed

QUESTIONS?

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2018 SKILLS BUILDING PROGRAM

BIG DATA, ARTIFICIAL INTELLIGENCE AND DECISION SCIENCE IN HEALTH AND NUTRITION

Defining objectives and constraints in Optima HIV

In partnership with

datasciencedojo — data science for everyone

Burnet Institute — Medical Research. Practical Action.

UCL

techemergence

symphony

UNIVERSITY OF COPENHAGEN

WORLD BANK GROUP ca

iDSI — Better decisions. Better health.

GHCC — Global Health Cost Consortium

UNDP

BILL & MELINDA GATES foundation

Learning objectives

- How objectives, constraints, and time horizons are incorporated in Optima
- Specifying settings in Optima to meet objectives and set constraints
- Understanding and interpreting results with respect to objectives, time horizons, constraints, and cost functions

Objectives: achieving maximum impact

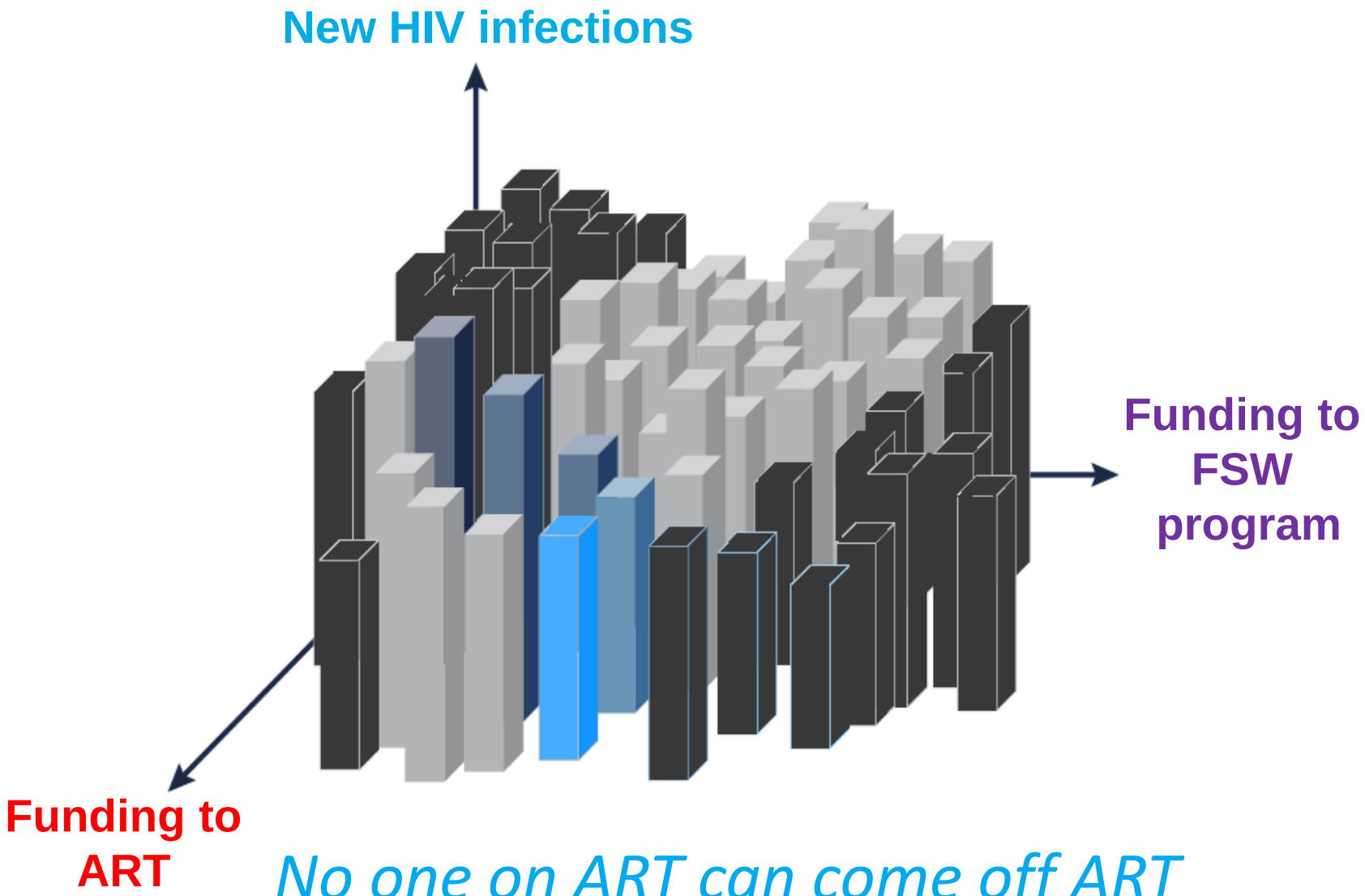
What objective is desired?

- *Minimizing new infections*
  - Funding allocated to most effective HIV prevention interventions
- Minimizing HIV-related deaths
  - All funding would go to saving lives (treatment/care) for a short time horizon
- Minimizing longer-term financial commitments
- Obtain equality in access or impact across groups

Multiple objectives

- National strategic plans can have multiple objectives by end of the strategy timeframe
  - For example:
    - 60% reduction in HIV incidence
    - 50% reduction in HIV-related deaths
    - Virtual elimination of mother-to-child transmission
    - Attain universal treatment coverage
- Simultaneously get as close as possible to all NSP targets with the funding available

Constraints: ethical, economic, logistic, political

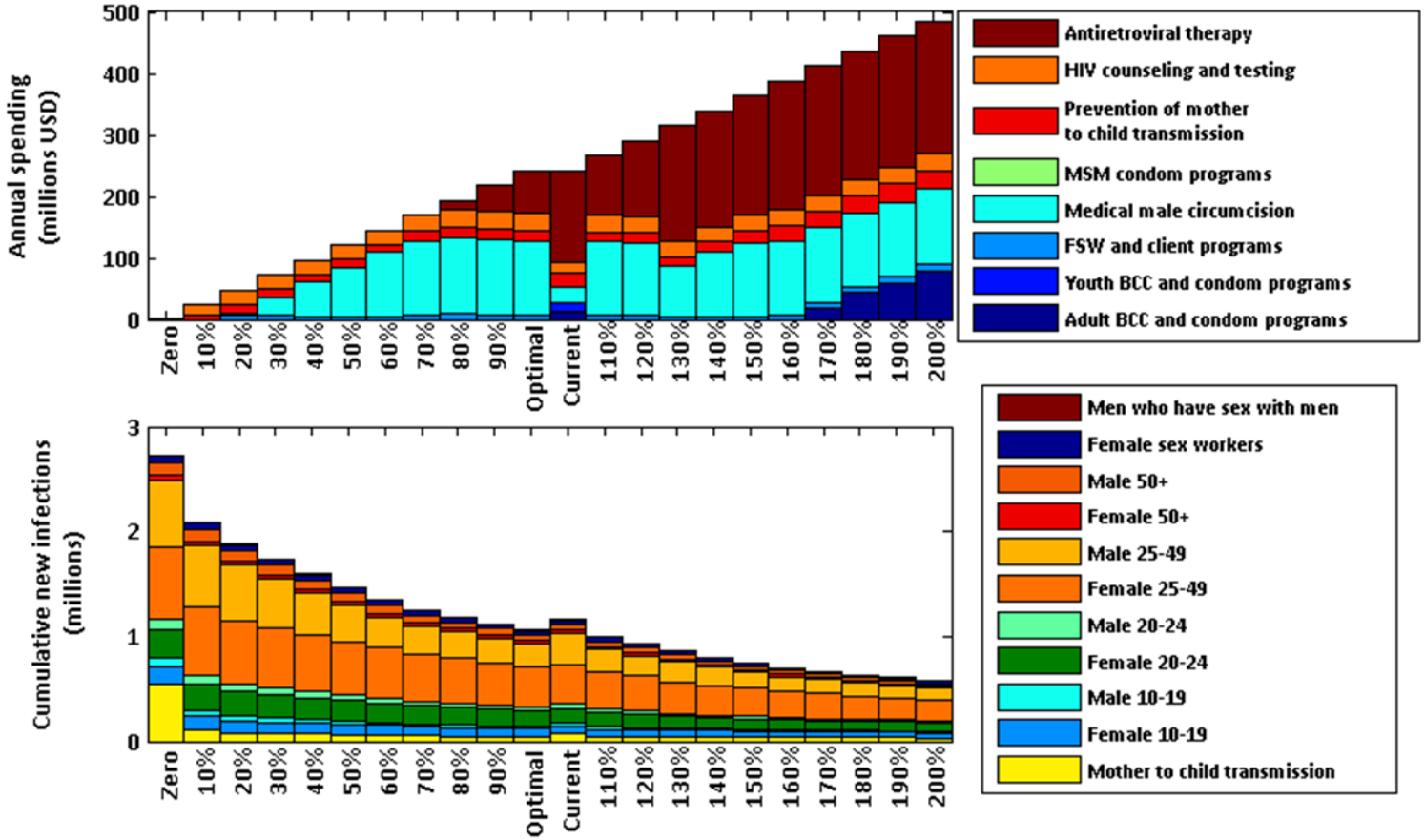


No one on ART can come off ART

Constraints are important, but should be limited

No constraints

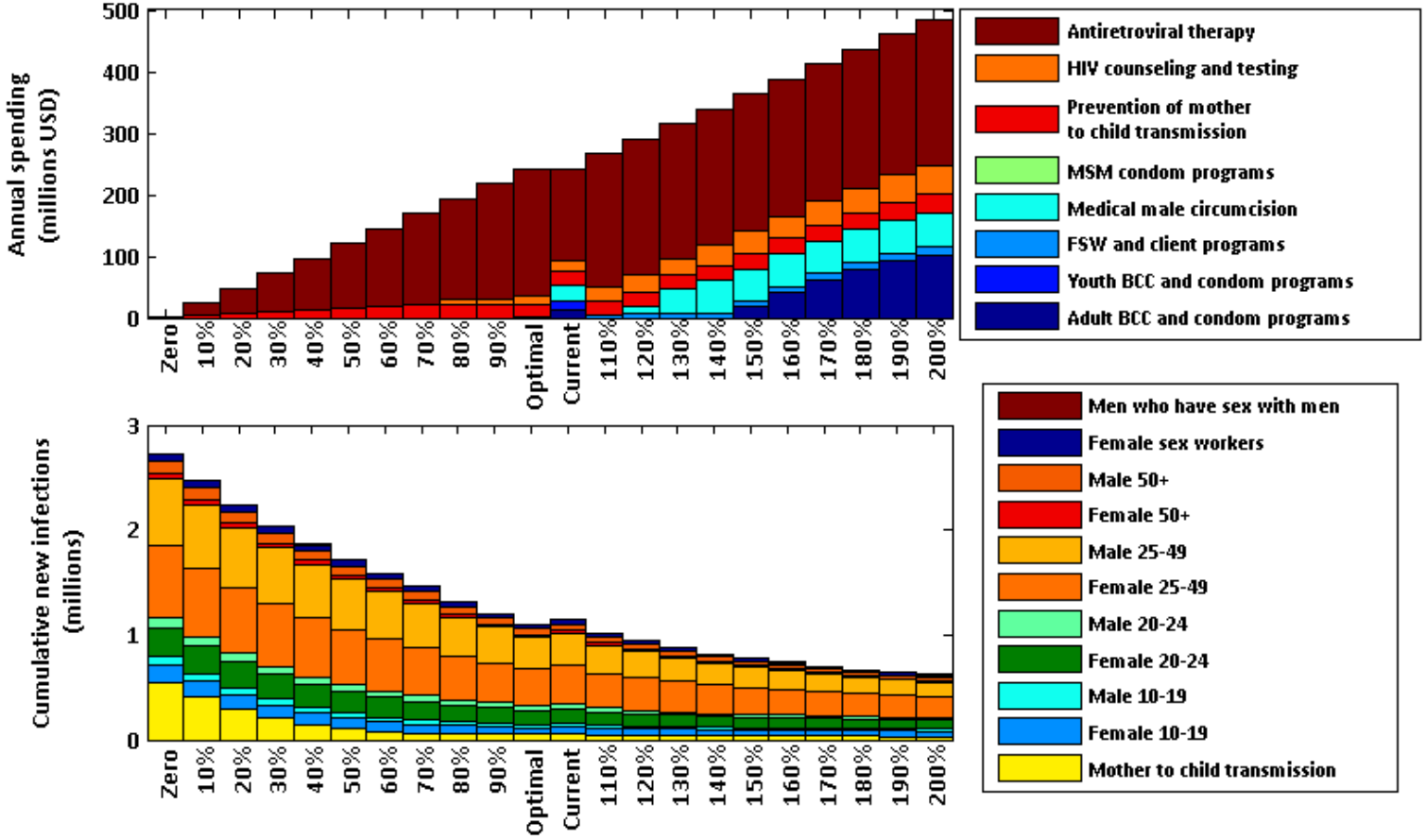
Objective: to minimize new HIV infections



Constraints are important, but should be limited

With constraint

No one who commences ART should be removed from ART



Constraints are important, but should be limited

Most commonly requested constraints:

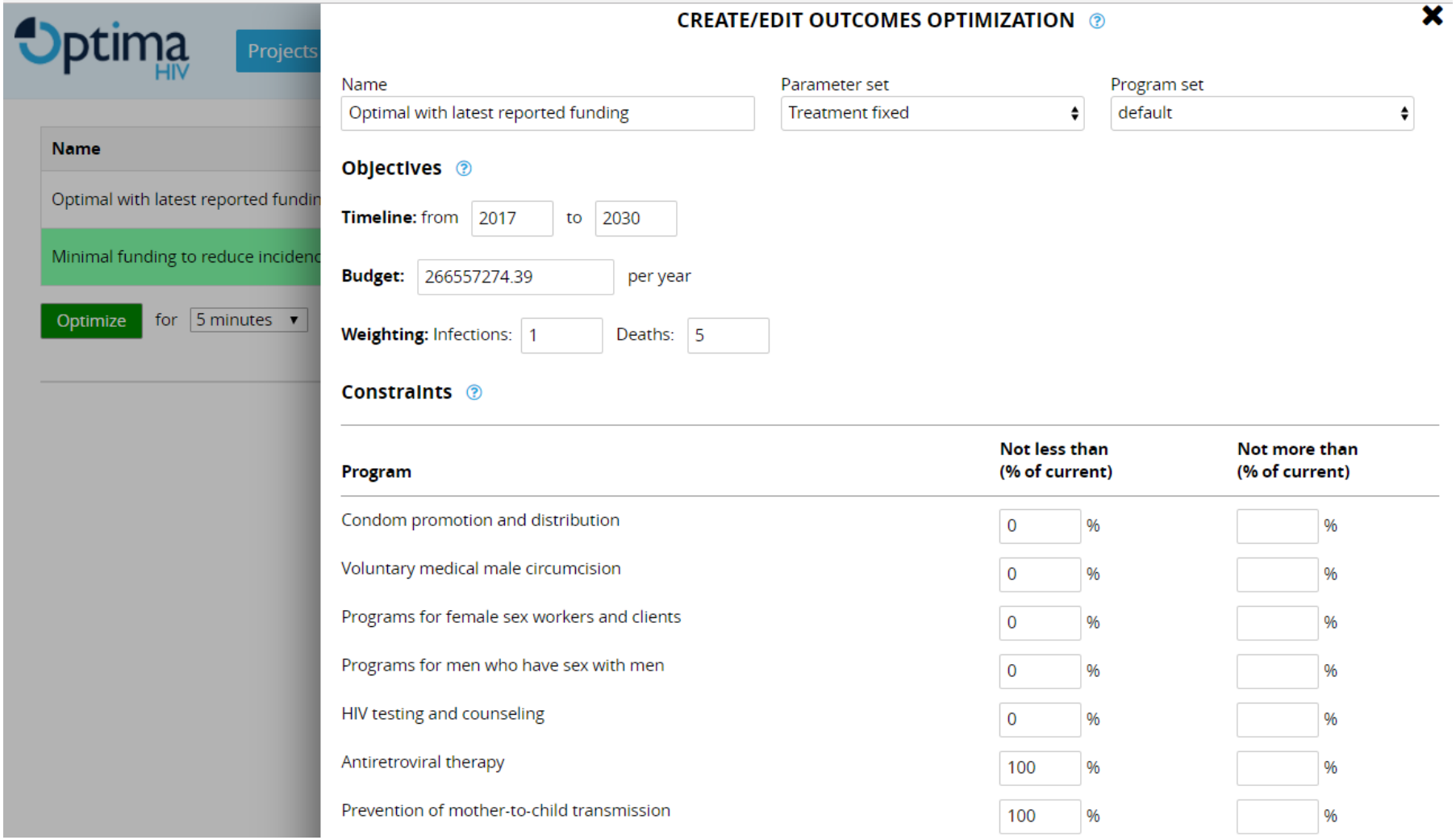
- No one who commences ART should be removed from ART
- PMTCT is important to retain
- OST has many important multi-sectoral benefits and funding must not be decreased
- Programs cannot be scaled up faster than 20% per year
- Programs should not lose more than 30% funding per year in a scale-down period
- Important to maintain some prevention for all populations
- Non-targeted program costs cannot be touched and are not included in the optimization
  - no evidence to affect outcomes
- Keep some programs which are mandatory for the key populations

Constraints are important, but should be limited

- If all commonly requested constraints were incorporated, there would be limited or no change in funding allocation
  - Little to no change towards achieving the objective

- **Recommendations**
  - Analyses be as unconstrained as possible
  - No one on treatment be removed from treatment (ART, PMTCT, OST)
  - Add constraints around funding mechanisms
    - Donor-based program targeting policies
  - Reasonable scale-up/down periods (with allowance for as large changes as possible)

Setting up optimization in Optima HIV including constraints



Practice

Defining objectives and constraints in Optima and performing an optimization analysis, including cascades

QUESTIONS?