

***Modeling Workgroup  
Meeting Quarterly Review***

**Optimization update**

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MICHIGAN STATE UNIVERSITY, APRIL 2023





# Overview

- Objective 2: Development of Efficient Multi-objective Optimization Procedures
  - Oct 1, 2021 to September 30, 2023 (24 months)
- Up-to-date status of the project: Optimization approaches
- Innovization Study (extension)
- Submitted papers in this quarter.
- Conclusions and future work

[illegible]

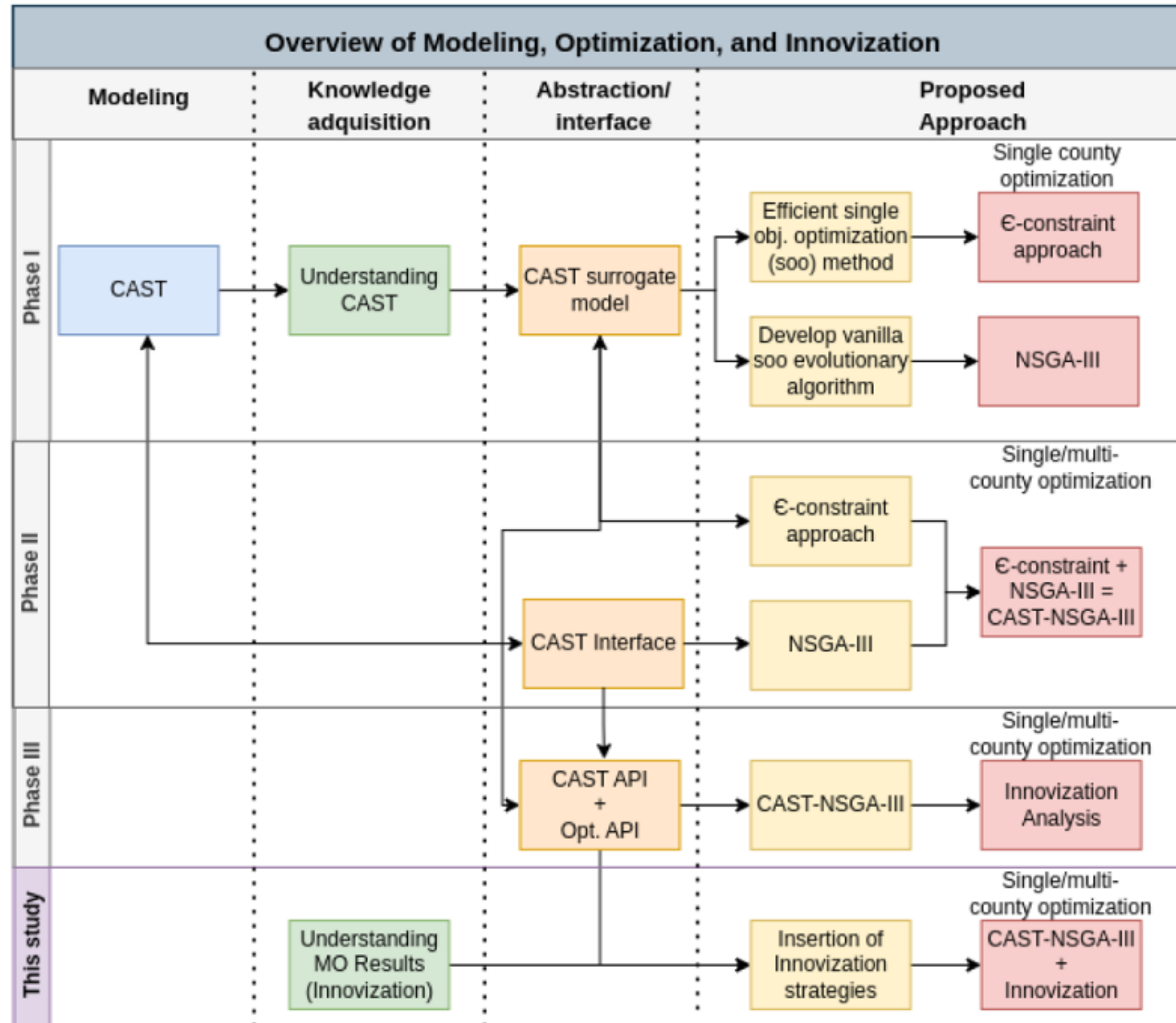
# Current status of the project

[illegible]



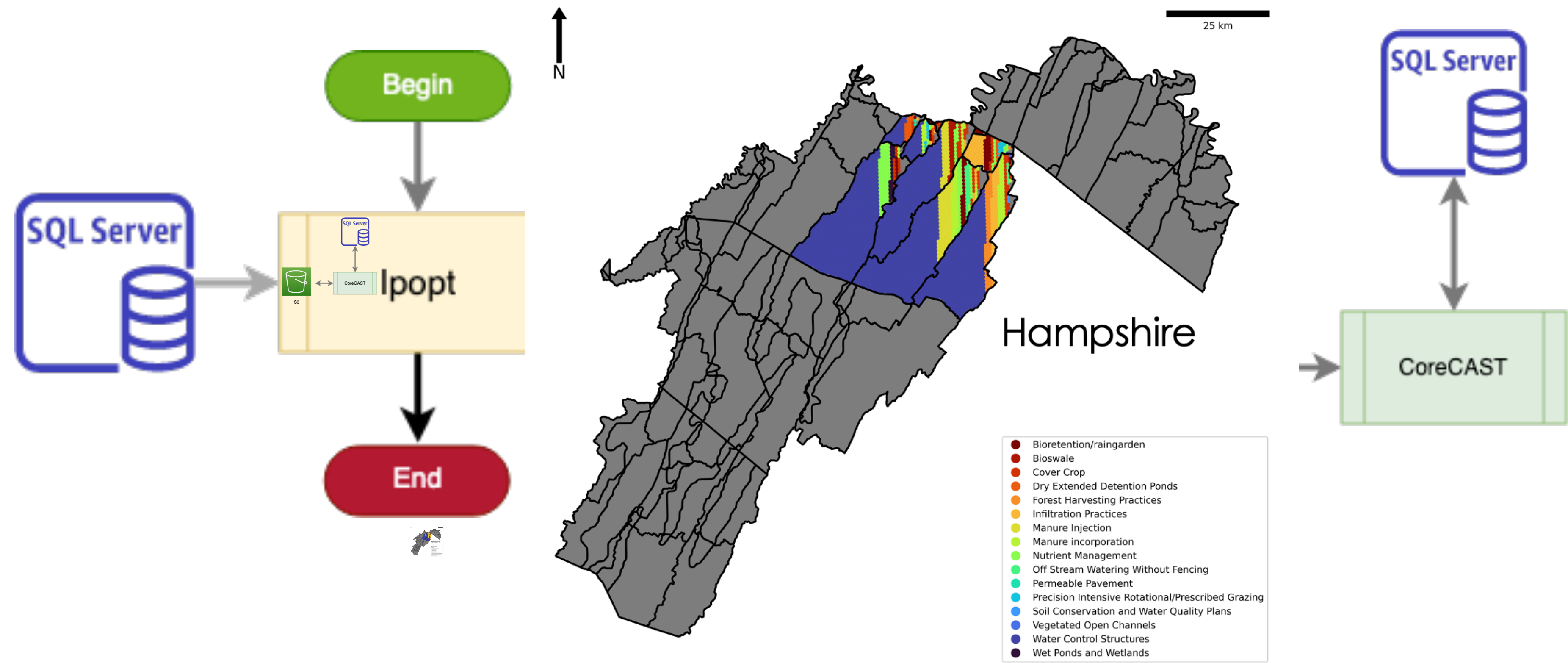
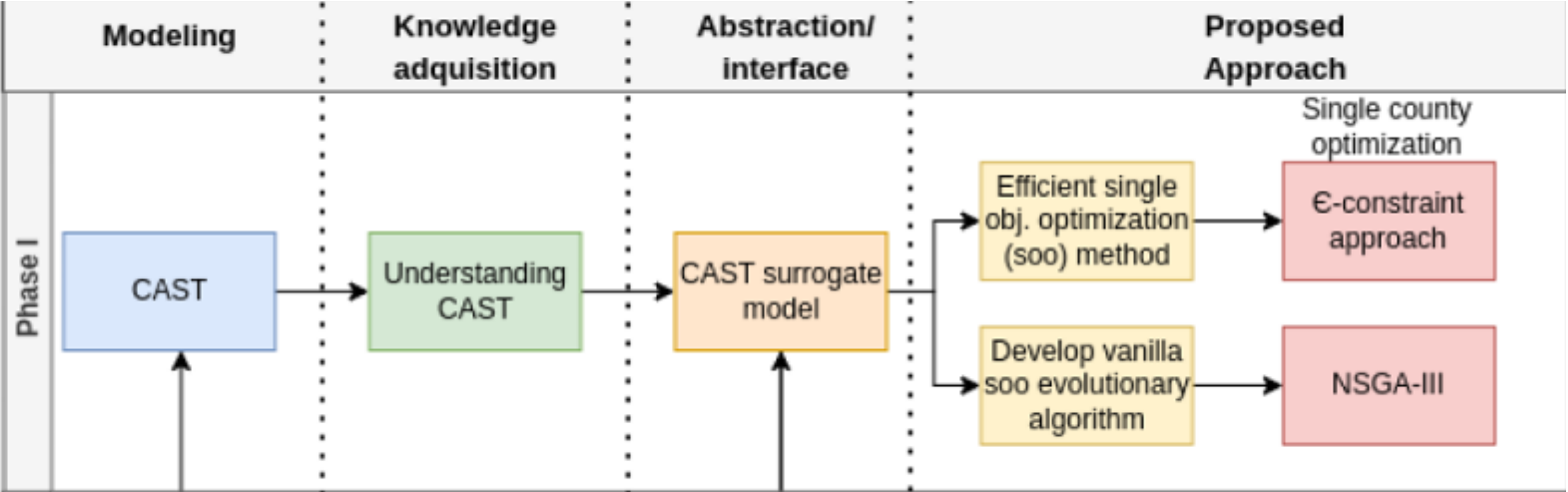
# Algorithm development

## Overview



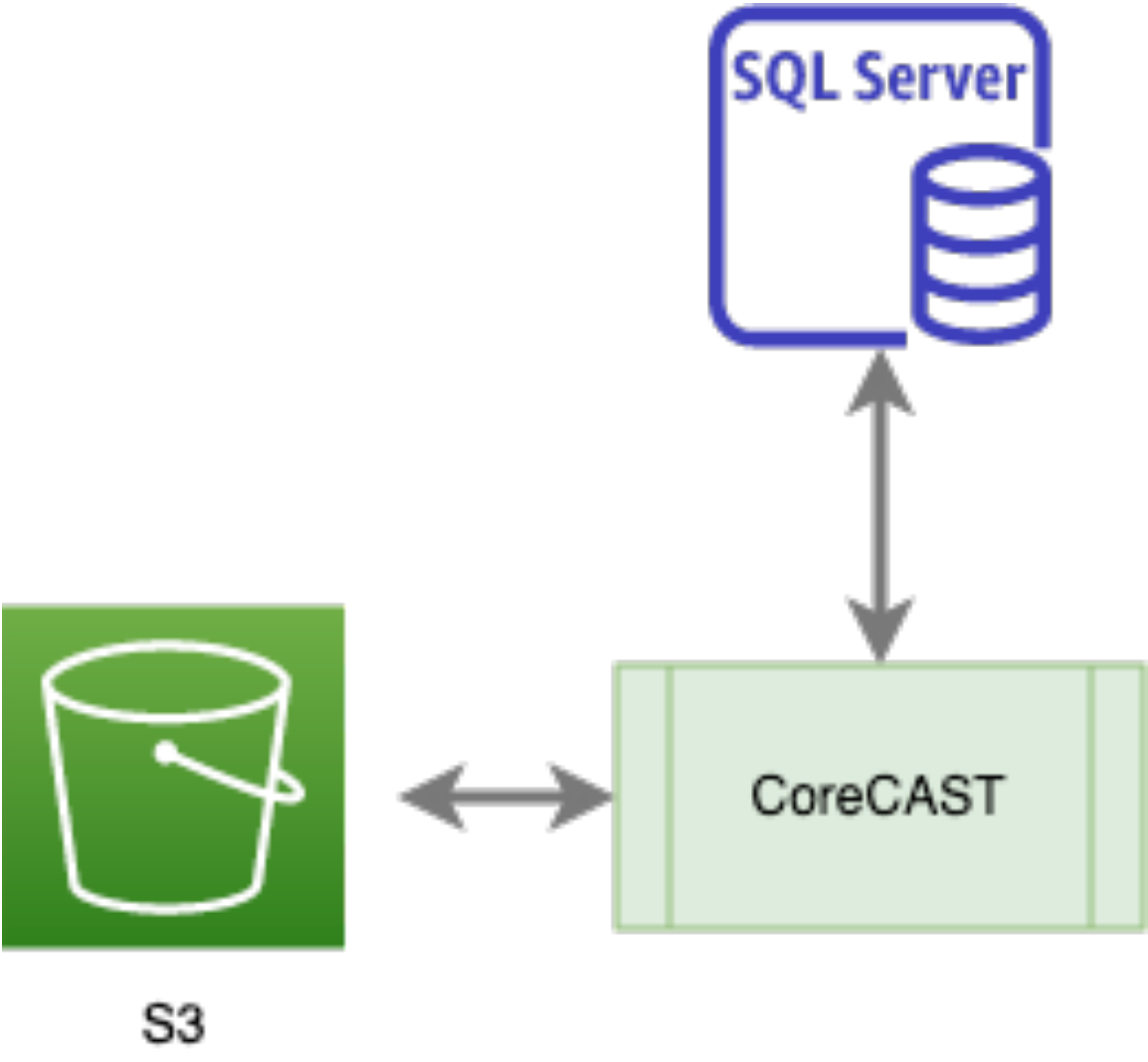
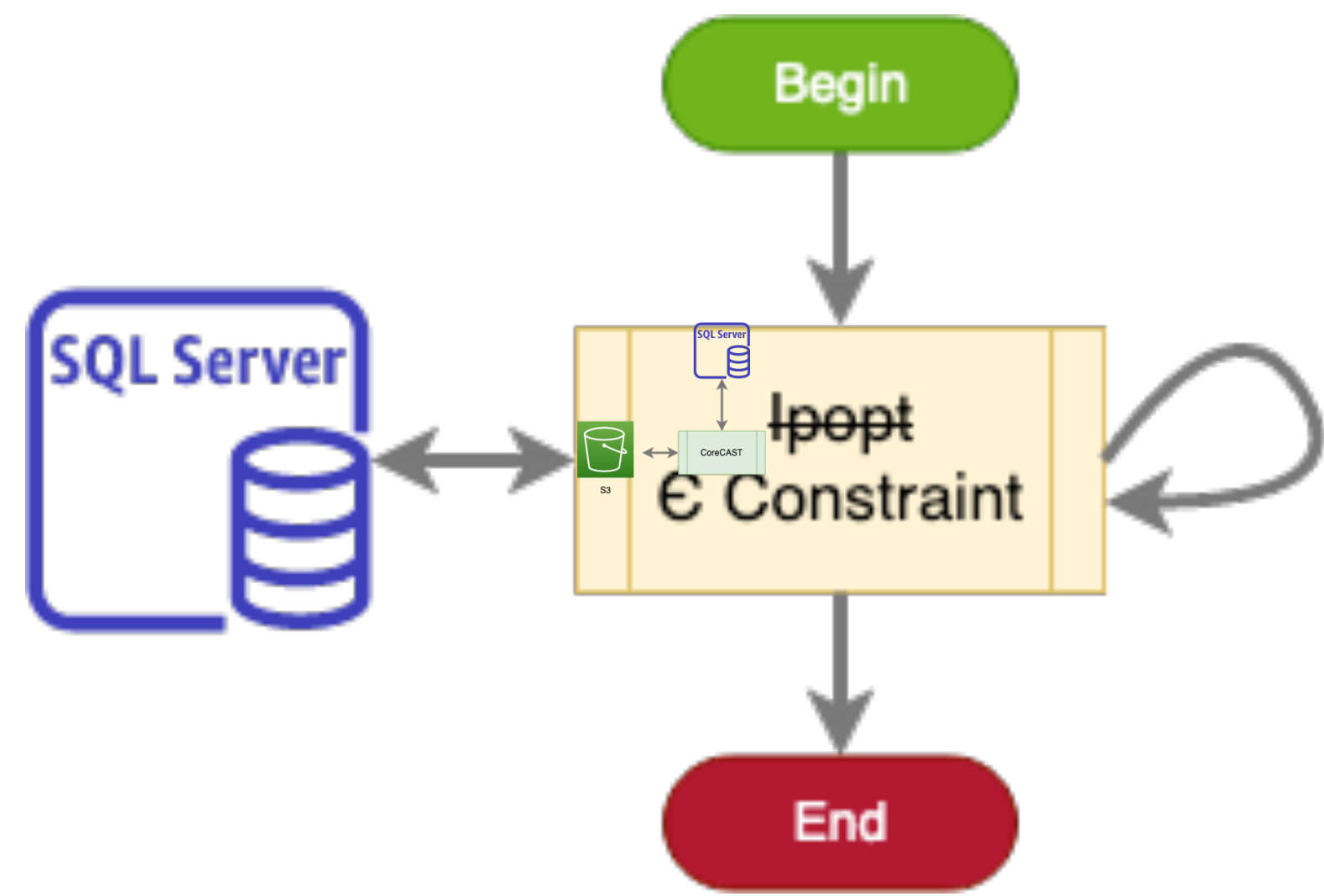
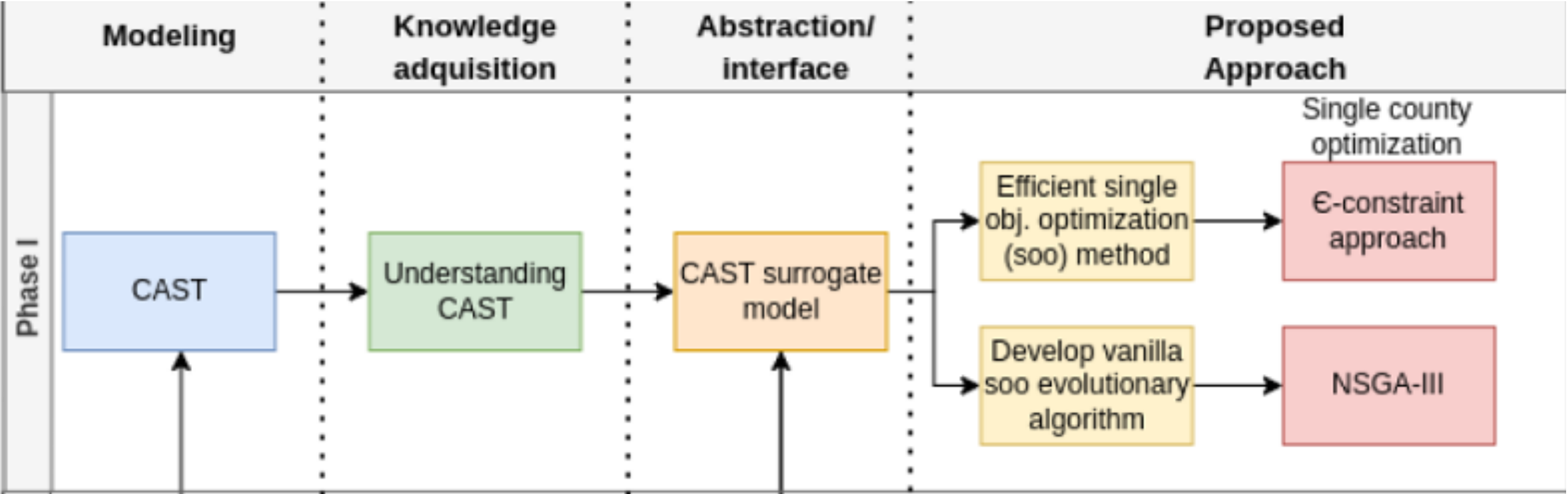
# Project Progress

## Phase I



# Project Progress

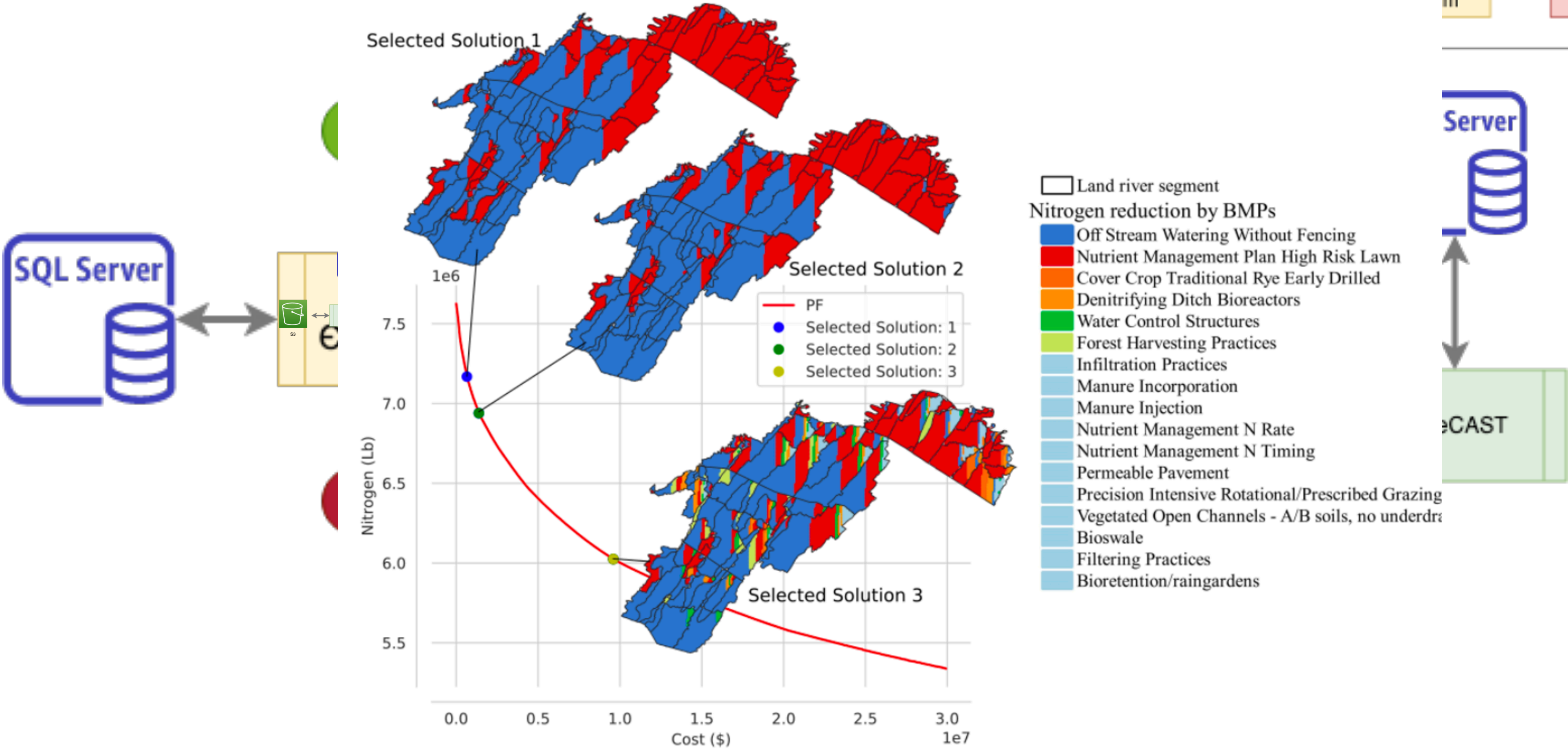
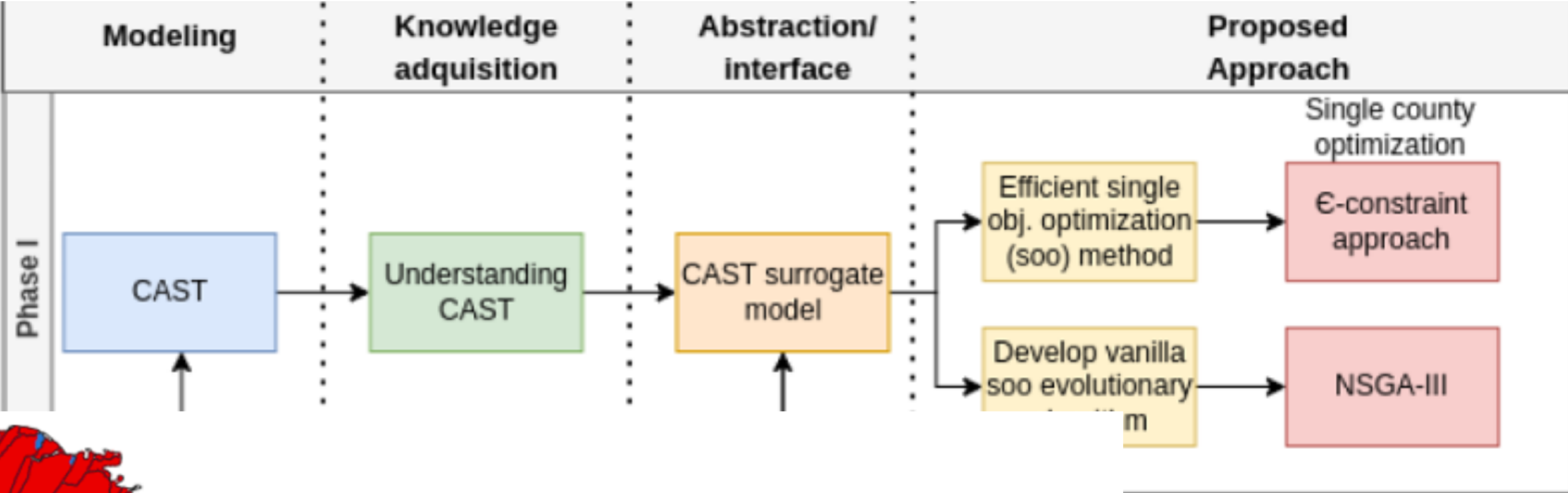
## Phase I





# Project Progress

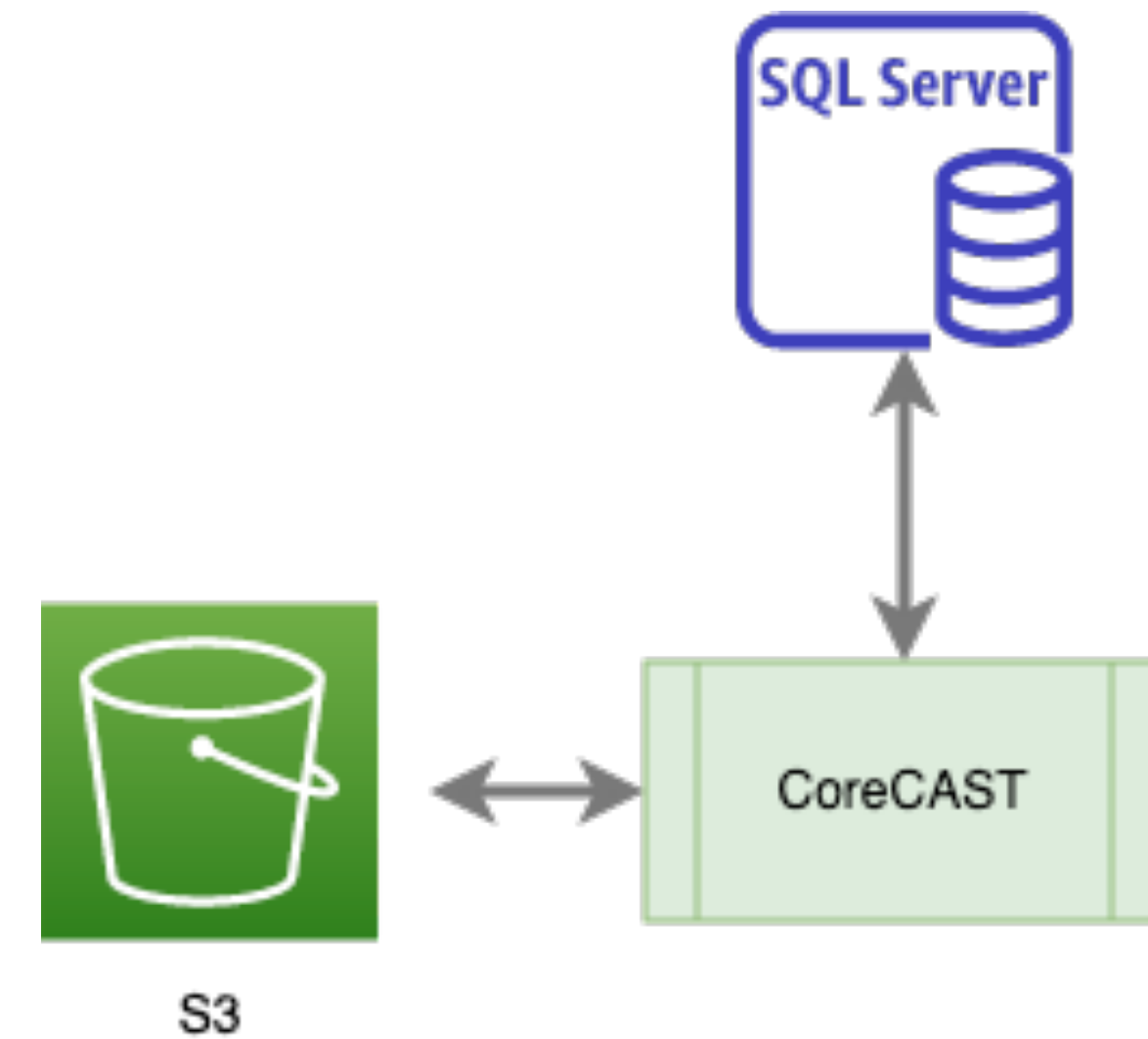
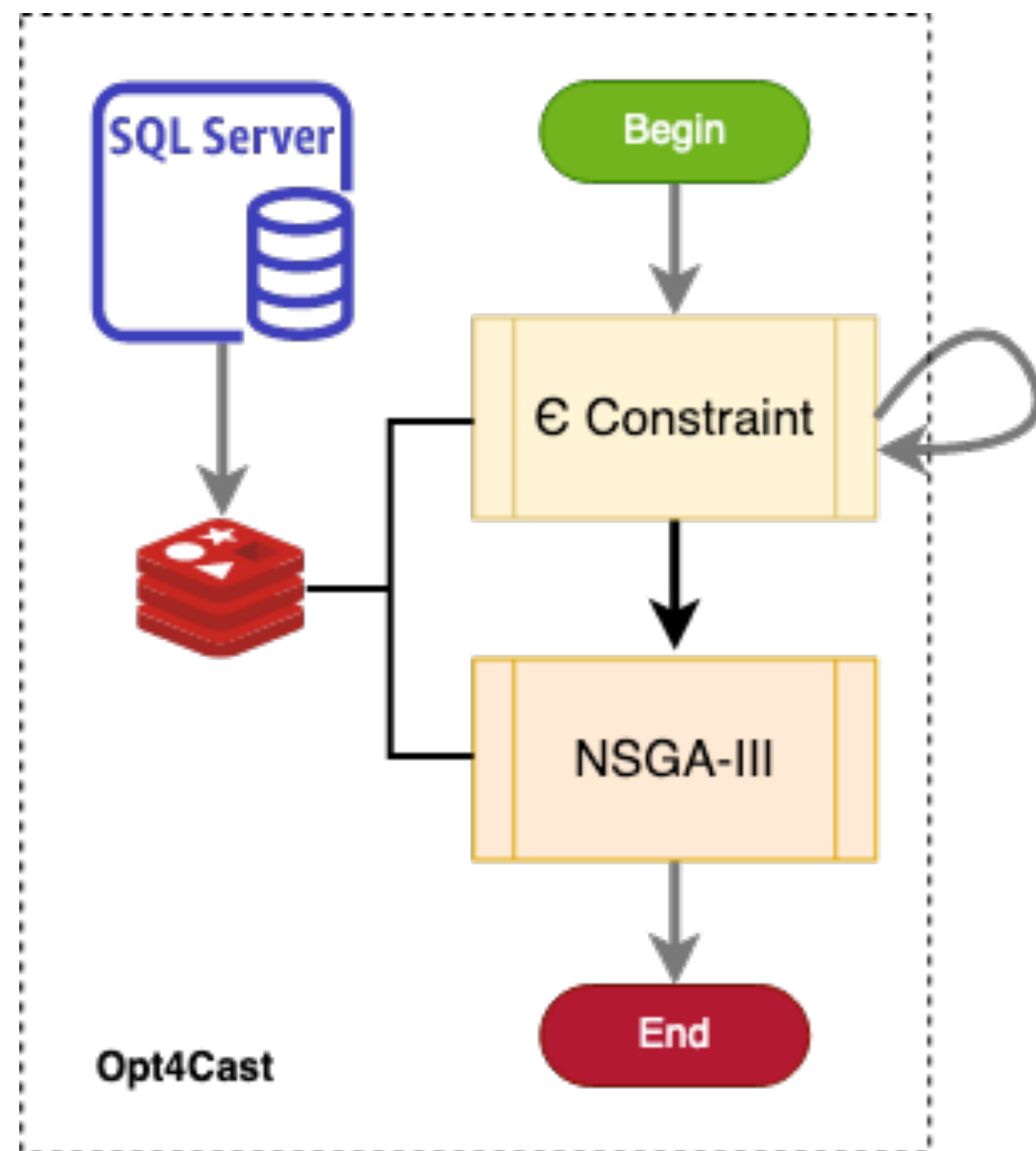
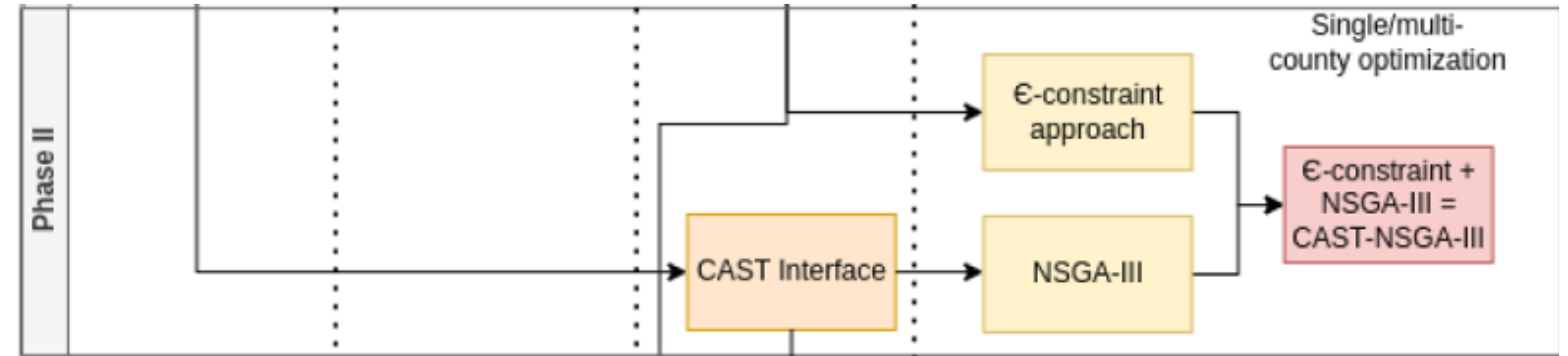
## Phase I





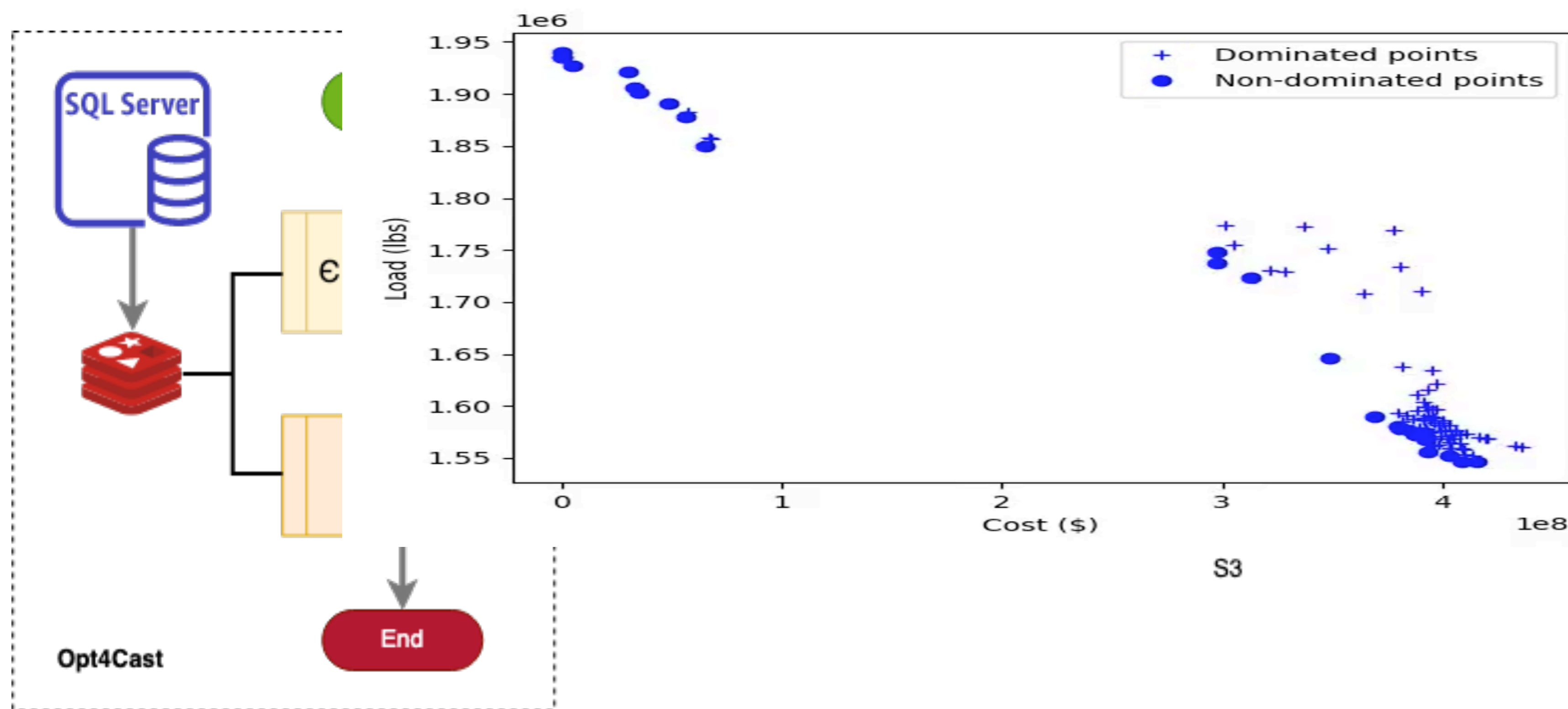
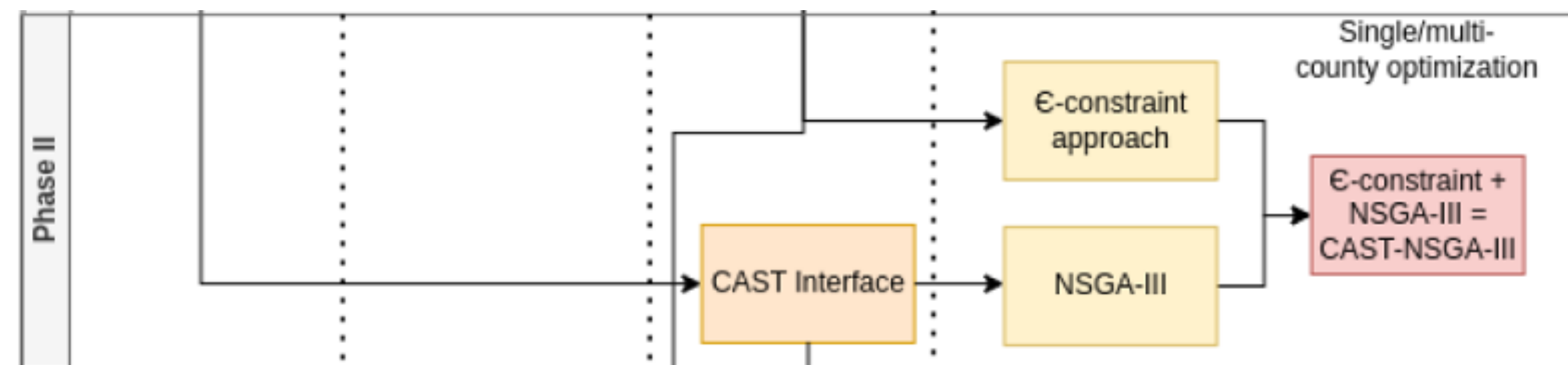
# Project Progress

## Phase II



# Project Progress

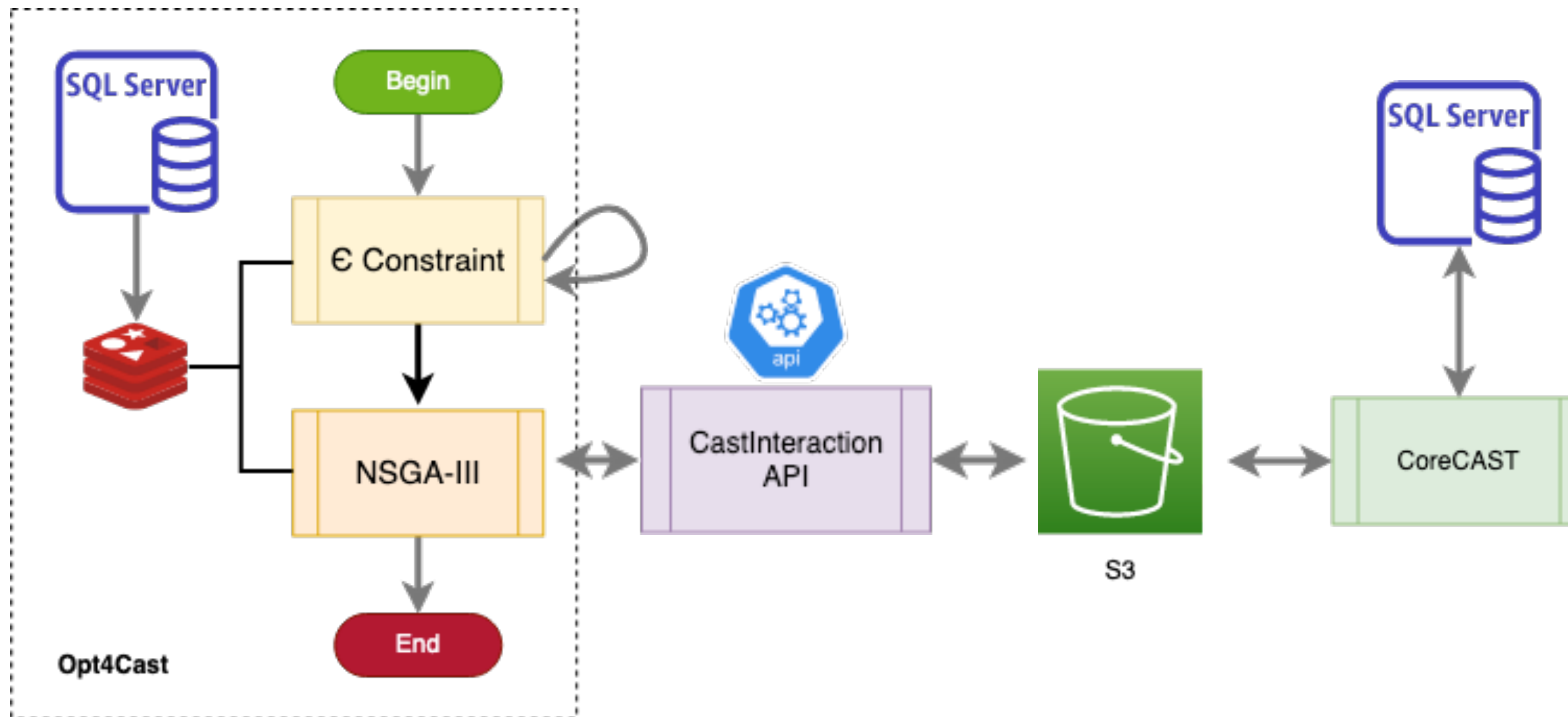
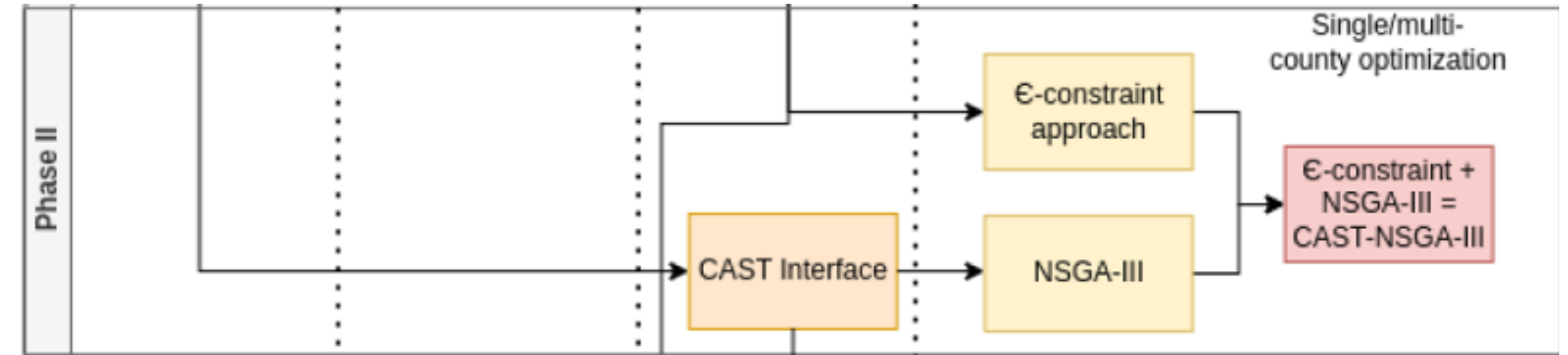
## Phase II





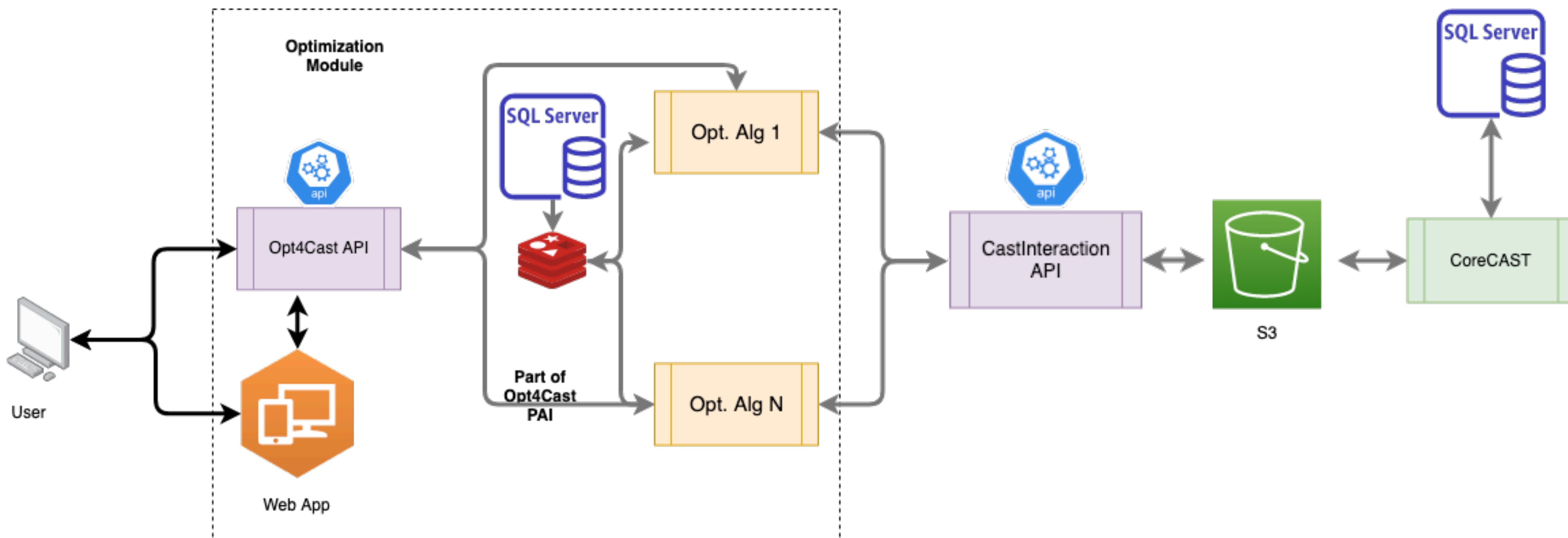
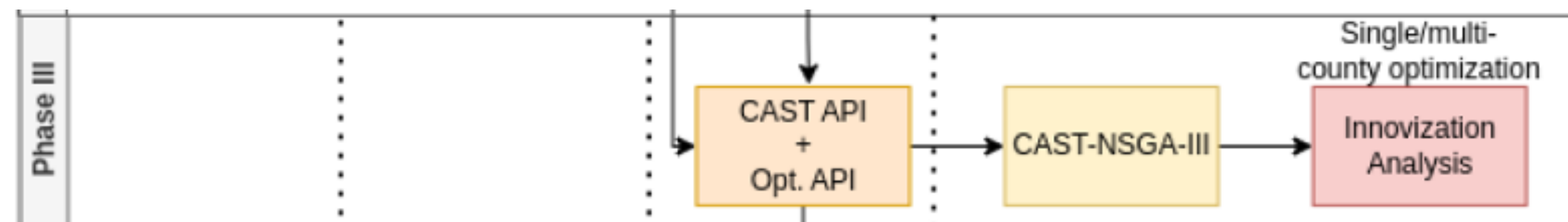
# Project Progress

## Phase II



# Project Progress

## Phase II






# Project Progress

## Phase II

HOME

SCENARIOS

HELP



GREGORIO

1

2

3

4

5

6

Scenario Info

Loads

BMP Selection

Update Costs

BMP Constraint

BMP Constraint Advanced

BMP Constraint (Advanced)

Add your preferences:

Developed

Septic

Natural

Manure Treatment

Animal

Land Conversion

Agriculture

Animal BMPs

BMP

Animal Waste Management System

UNIT

animal unit

ANIMAL GROUP

beef

LOAD SOURCE

Permitted Feeding Space

LOWER BOUND

5

animal unit

UPPER BOUND

10

animal unit

Add

#	BMP	Animal Group	Load Source	Lower Bound	Upper Bound
1	Animal Waste Management System	beef	Permitted Feeding Space	5	10

PREVIOUS

OPTIMIZE

Load (million lbs)

Cost (million \$)

Legend:

- NSGA-III + CoreCAST + eps\_cnstr
- Base Scenario, No BMP implementation

Cost (million \$)	Load (million lbs)	Scenario
0.5	30.5	Base Scenario, No BMP implementation
0.8	29.8	NSGA-III + CoreCAST + eps_cnstr
1.2	29.0	NSGA-III + CoreCAST + eps_cnstr
1.8	28.3	NSGA-III + CoreCAST + eps_cnstr
2.5	27.6	NSGA-III + CoreCAST + eps_cnstr
3.5	26.8	NSGA-III + CoreCAST + eps_cnstr
4.5	26.1	NSGA-III + CoreCAST + eps_cnstr
5.5	25.6	NSGA-III + CoreCAST + eps_cnstr
6.5	25.4	NSGA-III + CoreCAST + eps_cnstr
7.5	25.2	NSGA-III + CoreCAST + eps_cnstr
8.5	24.7	NSGA-III + CoreCAST + eps_cnstr
9.5	24.2	NSGA-III + CoreCAST + eps_cnstr
10.5	23.8	NSGA-III + CoreCAST + eps_cnstr
11.5	23.5	NSGA-III + CoreCAST + eps_cnstr
12.5	22.8	NSGA-III + CoreCAST + eps_cnstr
13.5	22.2	NSGA-III + CoreCAST + eps_cnstr

25 km

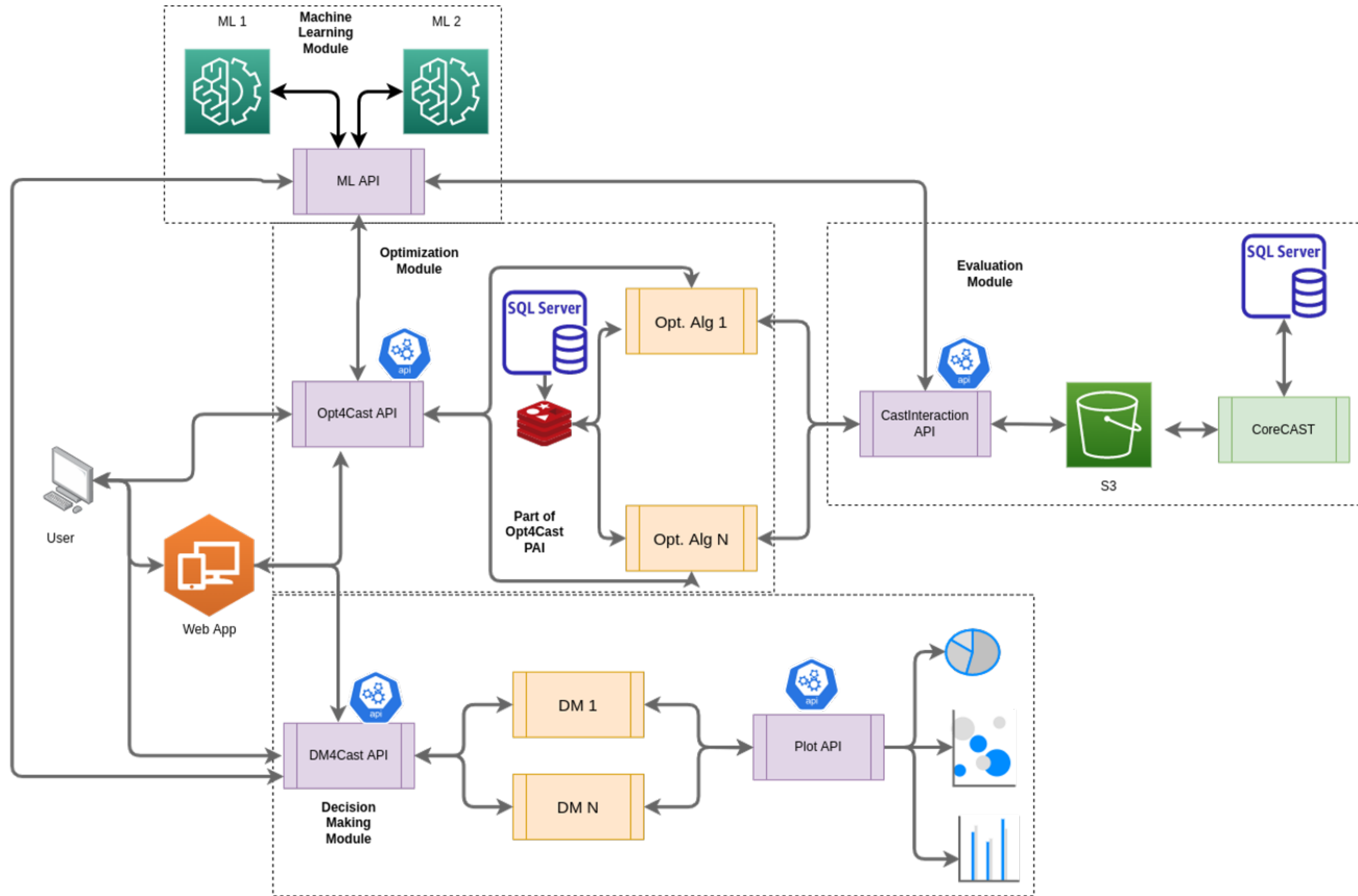
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Legend:

- Bioretention/raingarden
- Bioswale
- Cover Crop
- Dry Detention Ponds and Hydrodynamic Structures
- Dry Extended Detention Ponds
- Filter Strip Runoff Reduction
- Filtering Practices
- Forest Harvesting Practices
- Impervious Disconnection to amended soils
- Infiltration Practices
- Manure Injection
- Manure incorporation
- Nutrient Management
- Off Stream Watering Without Fencing
- Permeable Pavement
- Precision Intensive Rotational/Prescribed Grazing
- Soil Conservation and Water Quality Plans
- Vegetated Open Channels
- Water Control Structures
- Wet Ponds and Wetlands

# Projected Project Development

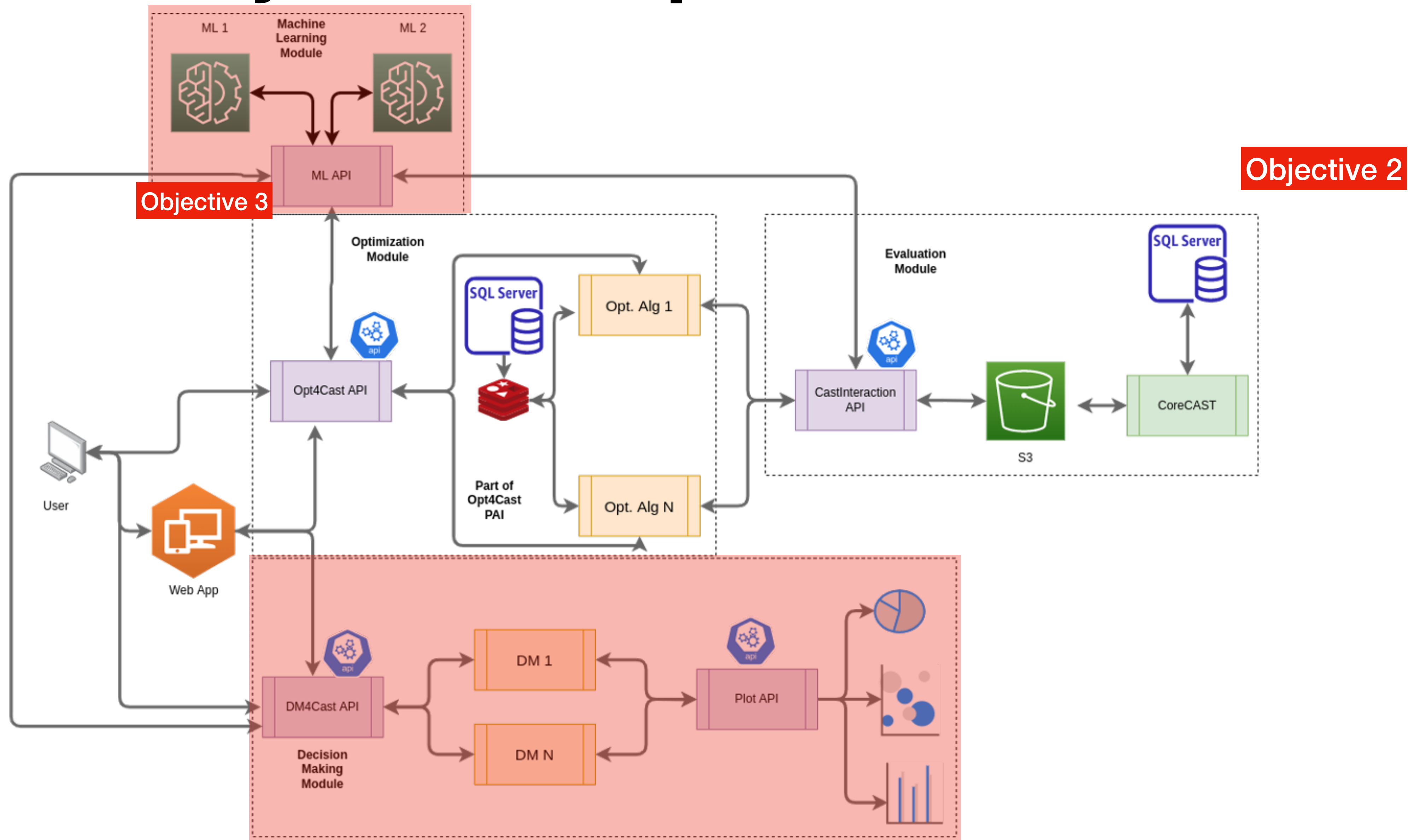
## Phase II





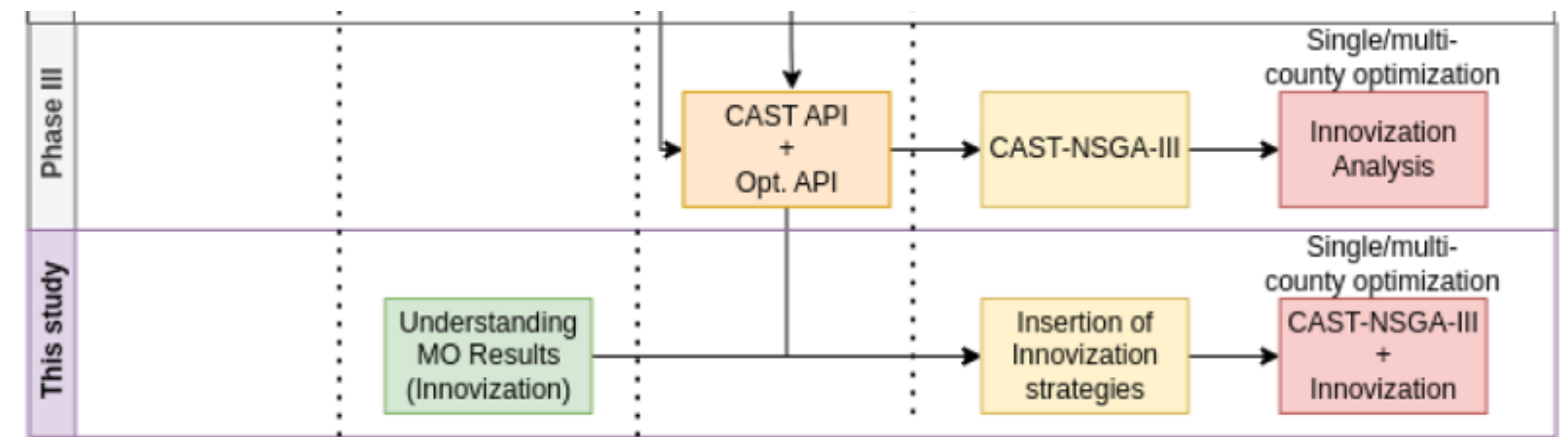
# Projected Project Development

## Phase II



# Phase III

What are the benefits of optimization?



- Identify the **best solutions** for the problem at hand.
- **Generate knowledge** to solve future problems.



# Innovization Analysis

- **What is innovization?**

Learning from optimization results and introducing new ideas, products, and services different from the existing ones.

## **What Innovization can do to CBPO?**

- Provide information for better decision-making for BMP selections (**farmers**)
- Identify the high priority areas for BMP implementation (**regulators**)
- Help with resources allocation (**policymakers**)

# Innovization Experiment

**BMP Selection ranking methodology based on Land use**

- **Overall goal:** learn from optimization results to:

- A. Examine different ranking methodologies to **identify the top BMPs**,
- B. Identify the **similarities and differences** between top-ranked BMPs,
- C. Provide recommendations to **improve the optimization process**.

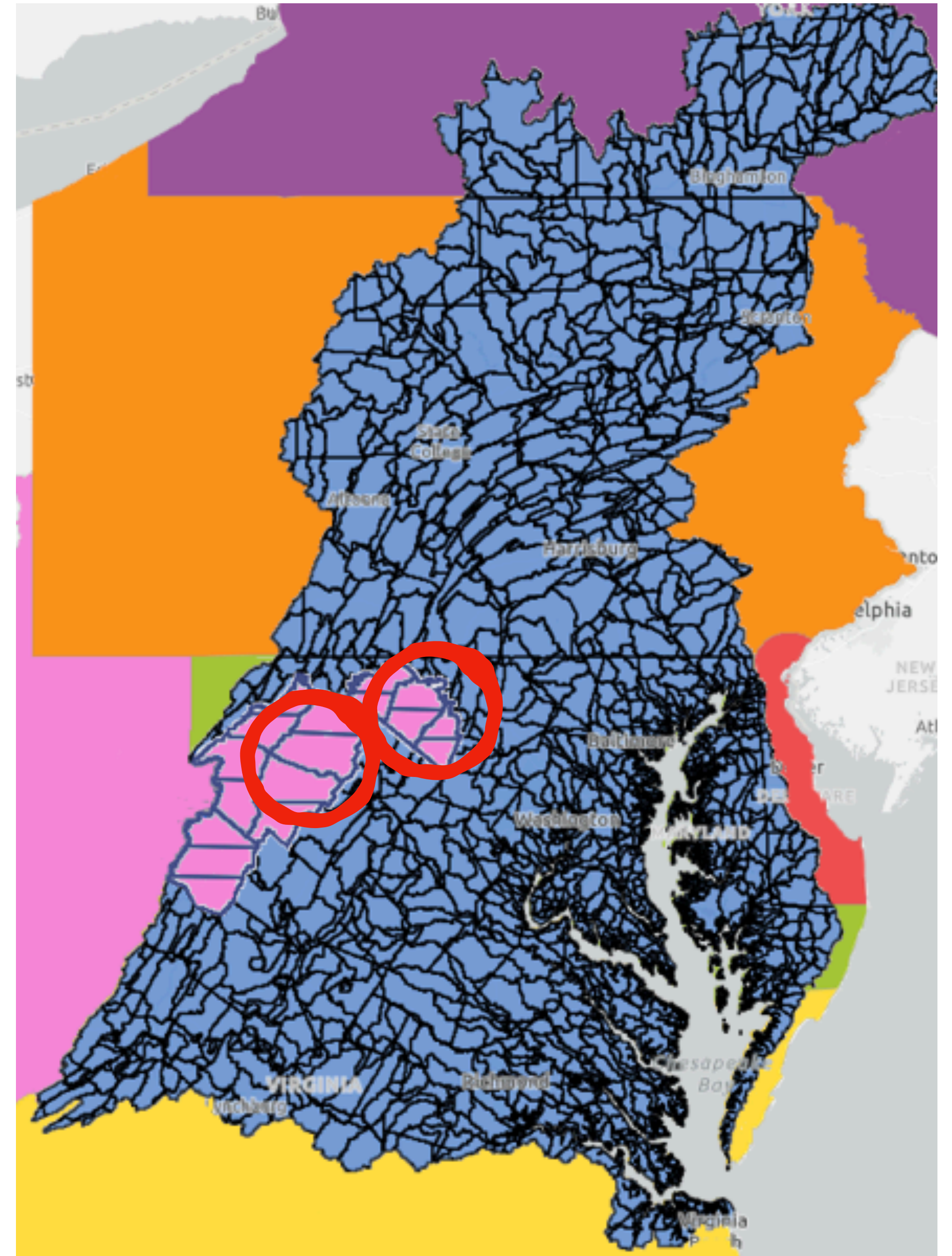


# Innovization experiment

## BMP Selection ranking methodology based on Land use

In **West Virginia**, we identified the top two counties with the highest areas of urban and agricultural land uses.

- (Berkeley and Mineral): Urban dominated
- (Jefferson and Hardy): Agricultural dominated

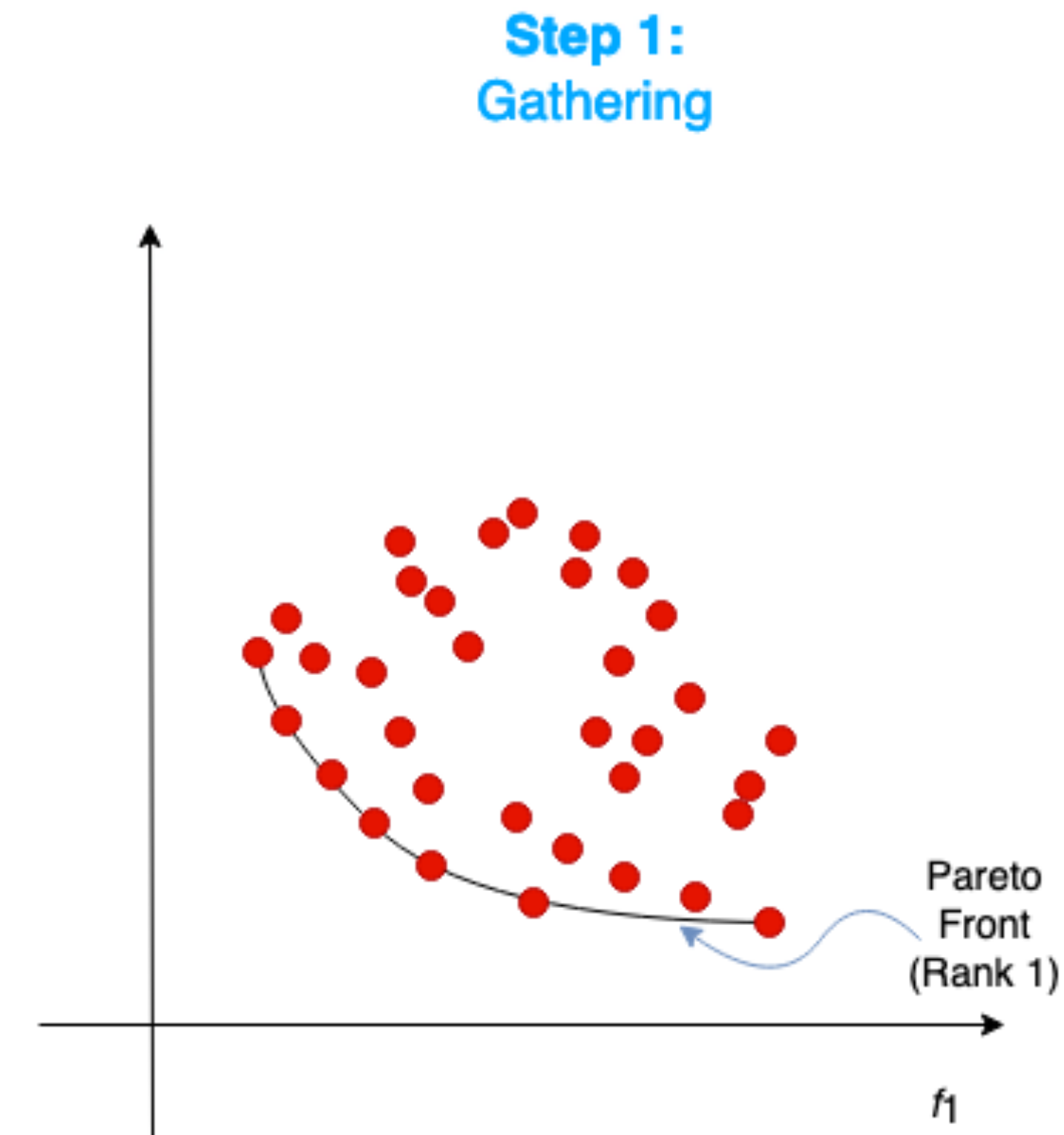




# Innovization Experiment

## BMP Selection ranking methodology based on Land use

- We performed 11 runs of our CoreCAST-optimization algorithm.
- Each run evaluated 3,000 scenarios (1,000 scenarios epsilon constraint +. 2000 scenarios NSGA-III)
- The output solution of each execution consists of 20 solutions.
- We gathered all 220 solutions (from the 11 runs)



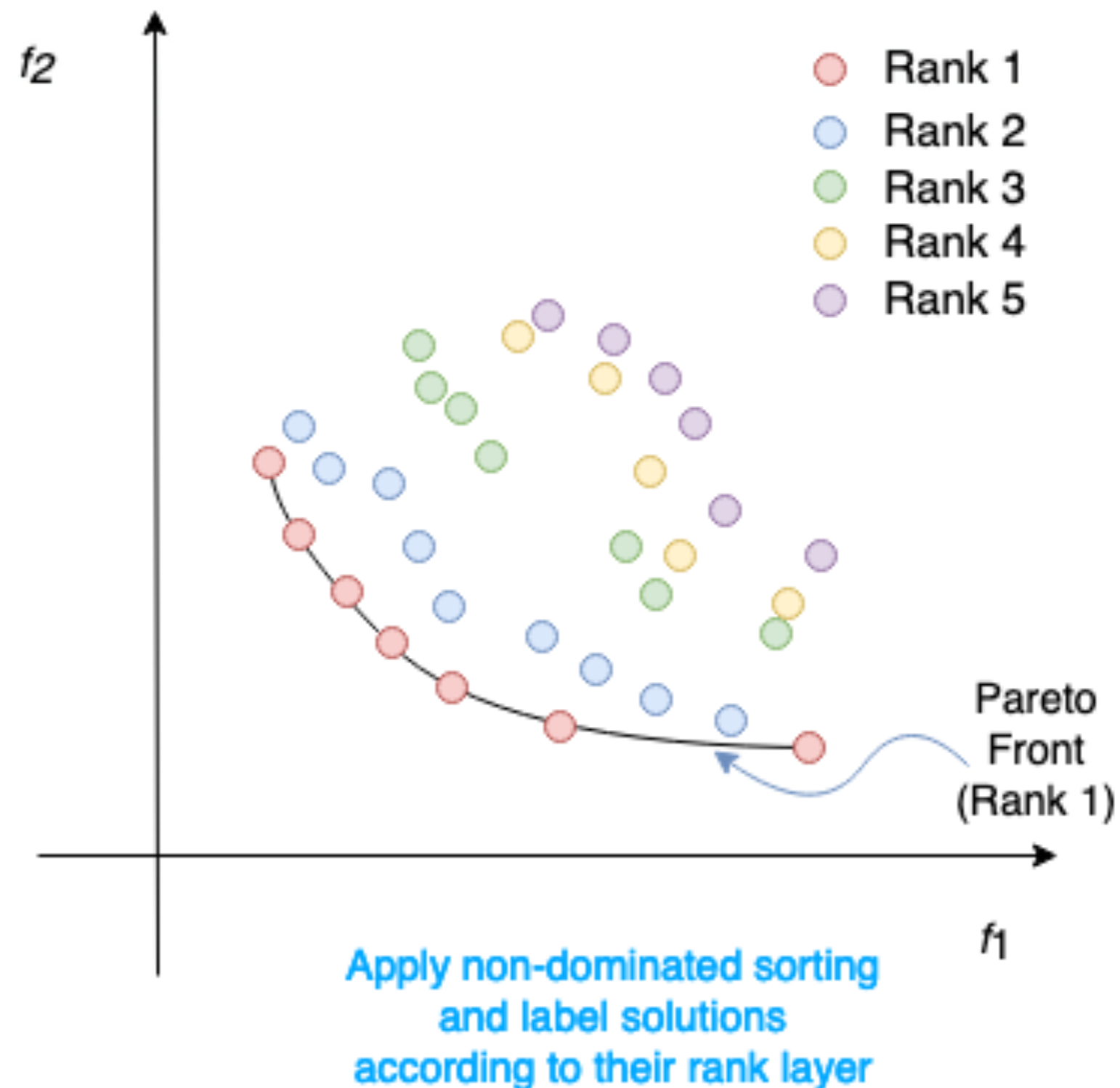


# Innovization Experiment

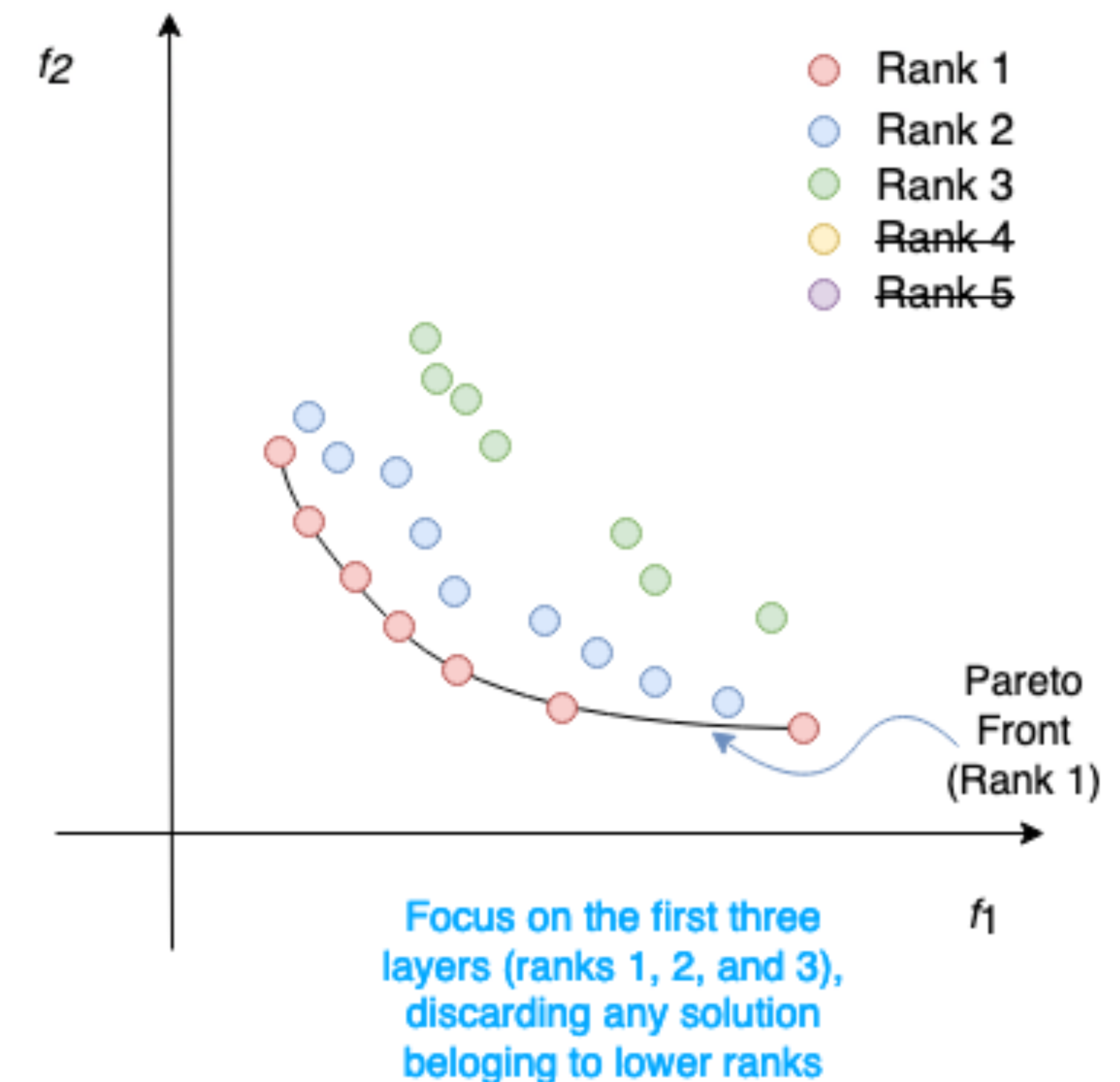
## BMP Selection ranking methodology based on Land use

- We filtered the solutions regarding non-dominance layers

**Step 2:**  
Apply non-dominated sorting



**Step 3:**  
Discard lower ranks



# Methodology

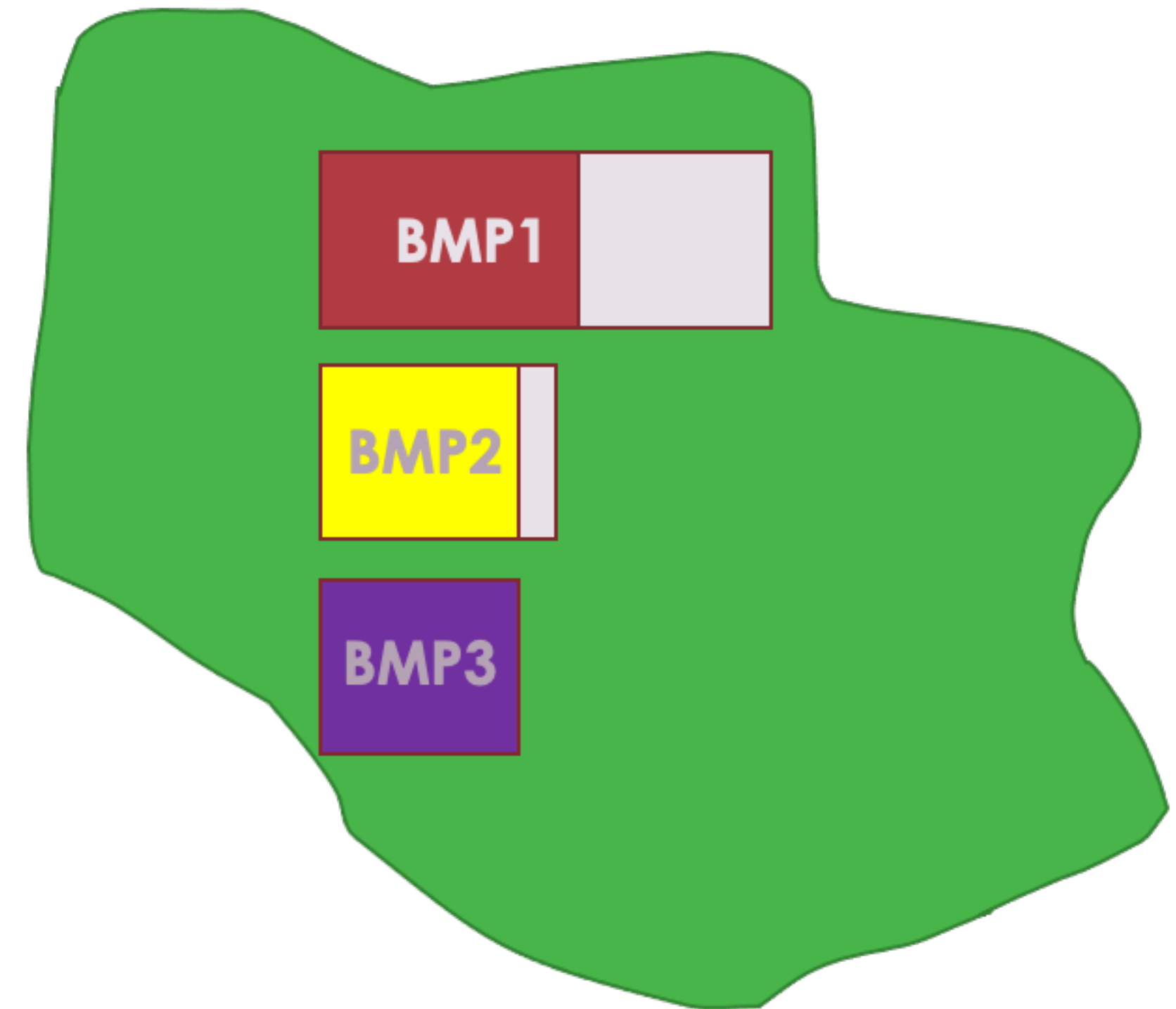
## BMP Selection ranking methodology based on Land use

Three ranking strategies from the combined Pareto front:

- **Strategy 1:** Rank the top BMPs based on the **implementation acreages**;
- **Strategy 2:**
- **Strategy 3:**

Ranking methodology 1:

**BMP1**  
**BMP2**  
**BMP3**





# Methodology

## BMP Selection ranking methodology based on Land use

Three ranking strategies from the combined Pareto front:

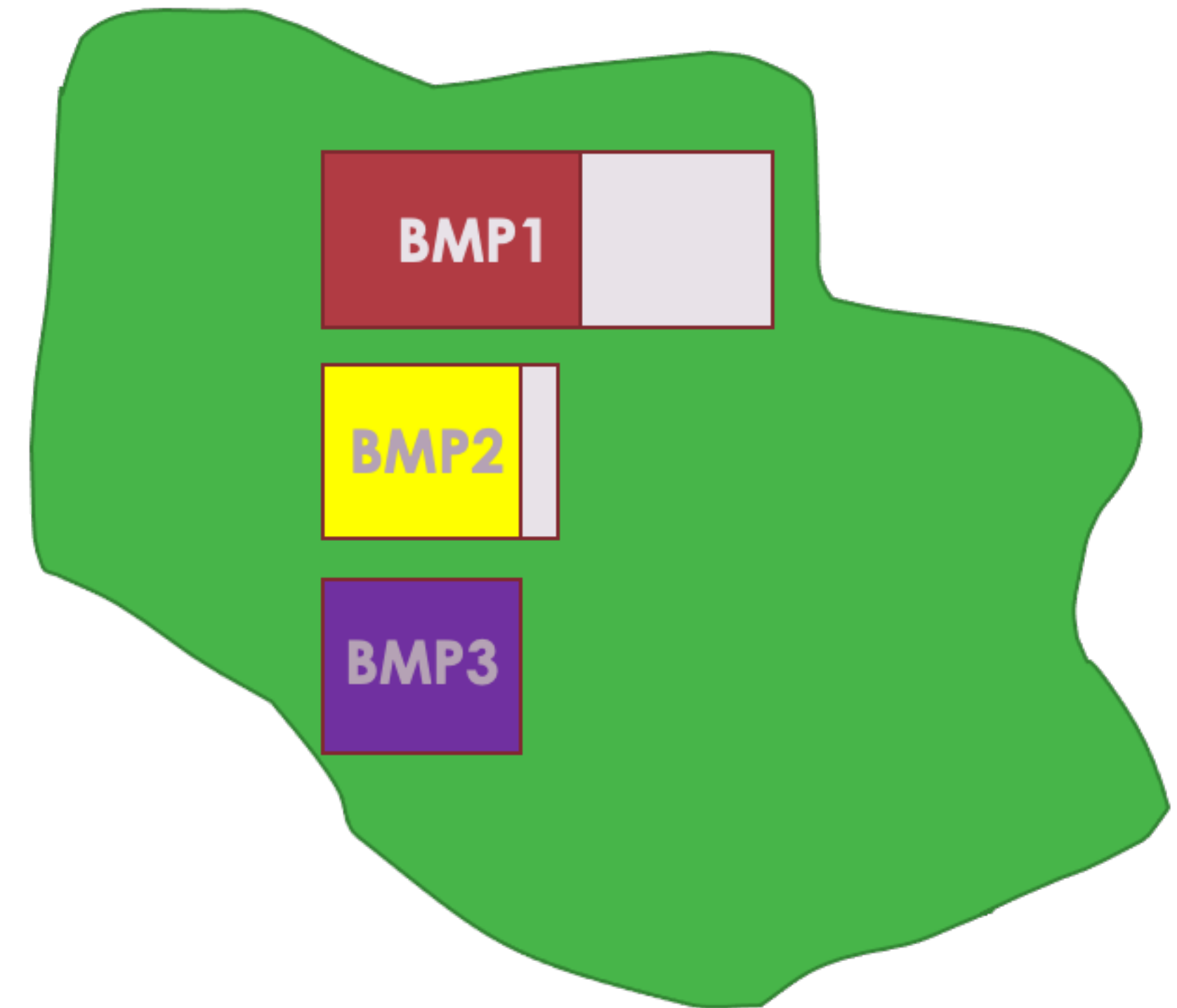
- **Strategy 1:**
- **Strategy 2:** Rank the top BMPs based on the percentage of **maximum allowable acreages**;
- **Strategy 3:**

Ranking methodology 2:

**BMP3**

**BMP2**

**BMP1**

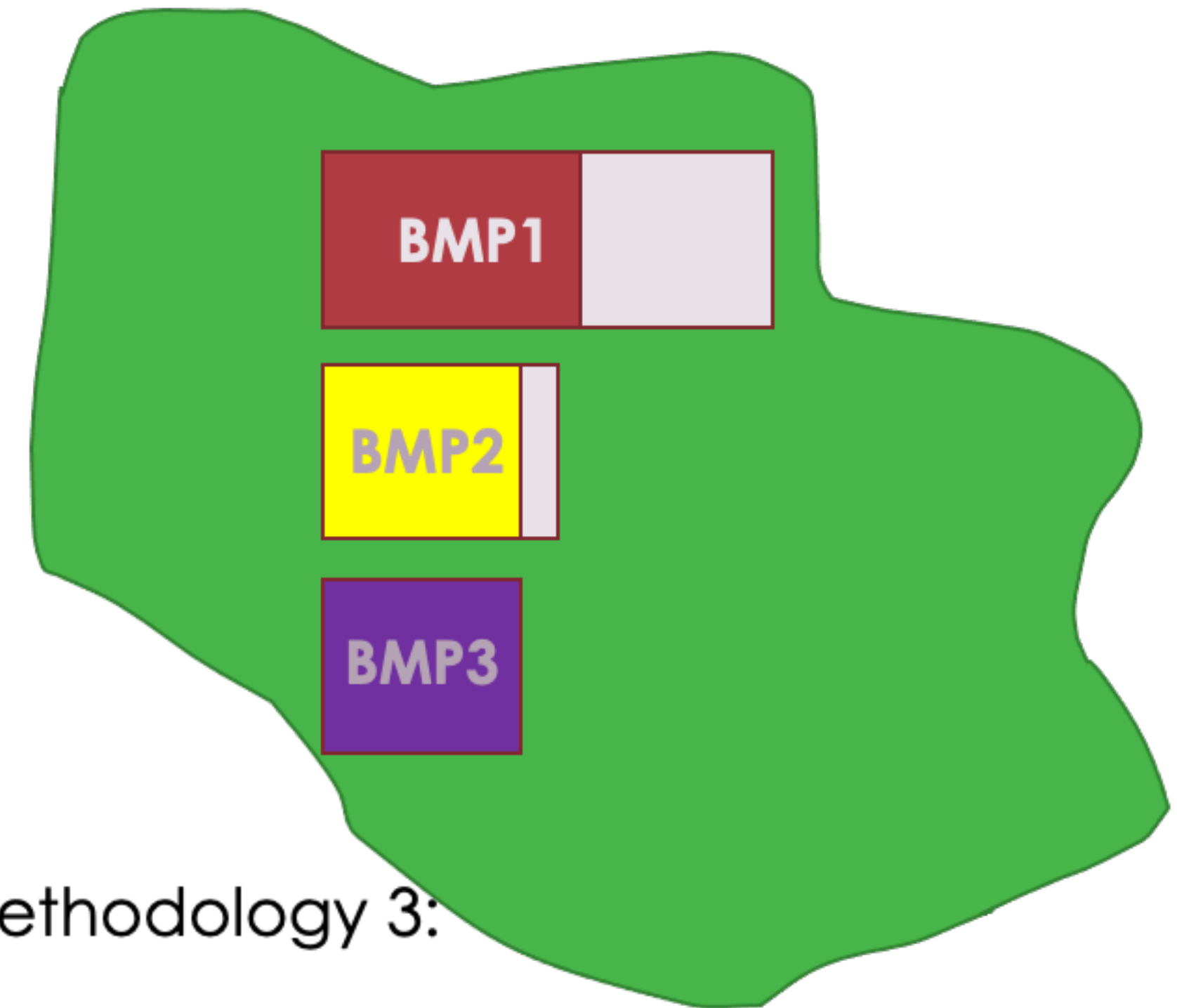


# Methodology

## BMP Selection ranking methodology based on Land use

Three ranking strategies from the combined Pareto front:

- **Strategy 1:**
- **Strategy 2:**
- **Strategy 3:** Rank the top BMPs based on the amount of **nitrogen reduction per dollar spent.**



Ranking methodology 3:

**BMP2 (\$12/lb N)**  
**BMP3 (\$15/lb N)**  
**BMP1 (\$24/lb N)**

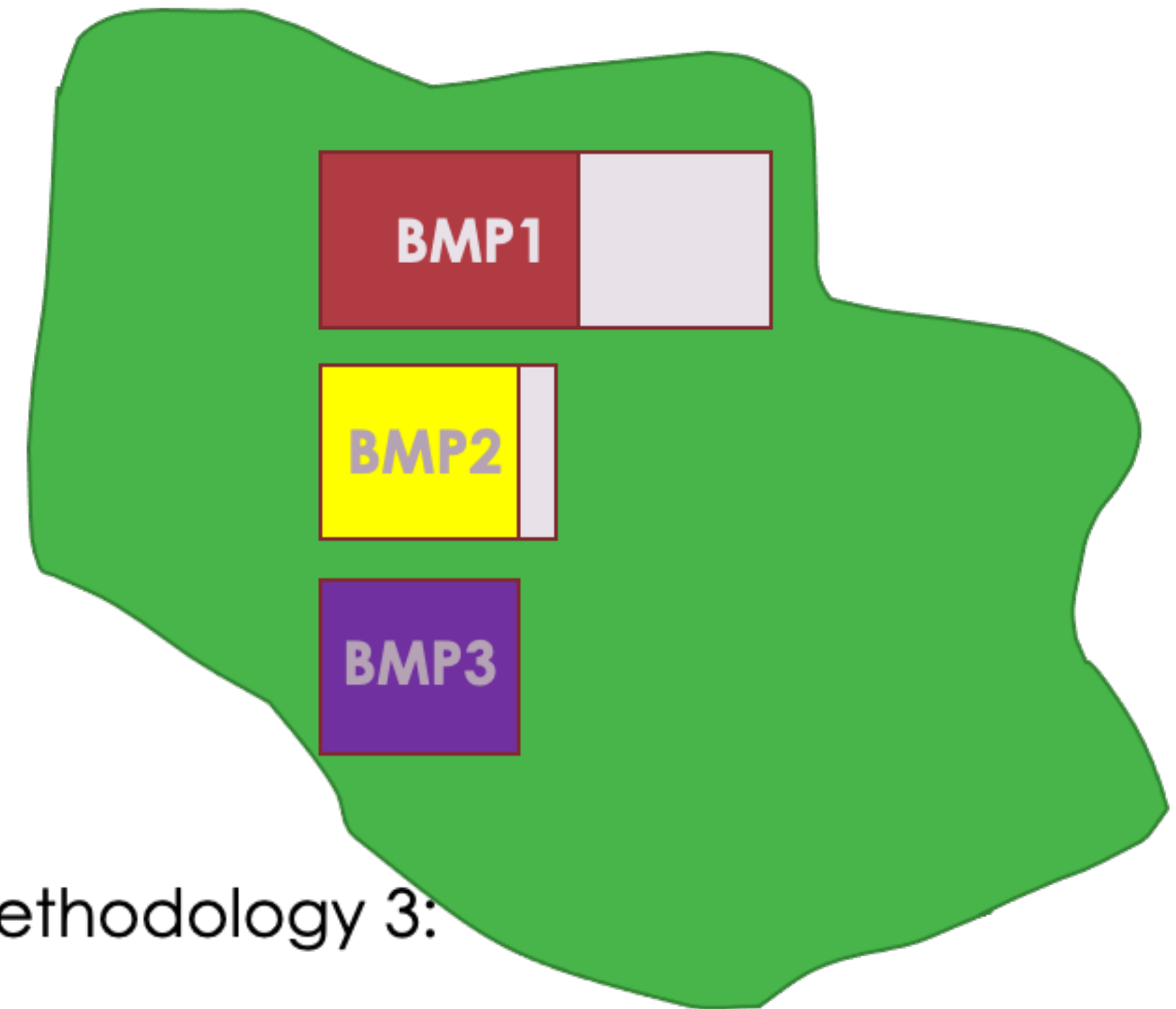


# Methodology

## BMP Selection ranking methodology based on Land use

Three ranking strategies from the combined Pareto front:

- **Strategy 1:** Rank the top BMPs based on the **implementation acreages**;
- **Strategy 2:** Rank the top BMPs based on the percentage of **maximum allowable acreages**;
- **Strategy 3:** Rank the top BMPs based on the amount of **nitrogen reduction per dollar spent**.



Ranking methodology 1:

**BMP1**  
**BMP2**  
**BMP3**

Ranking methodology 2:

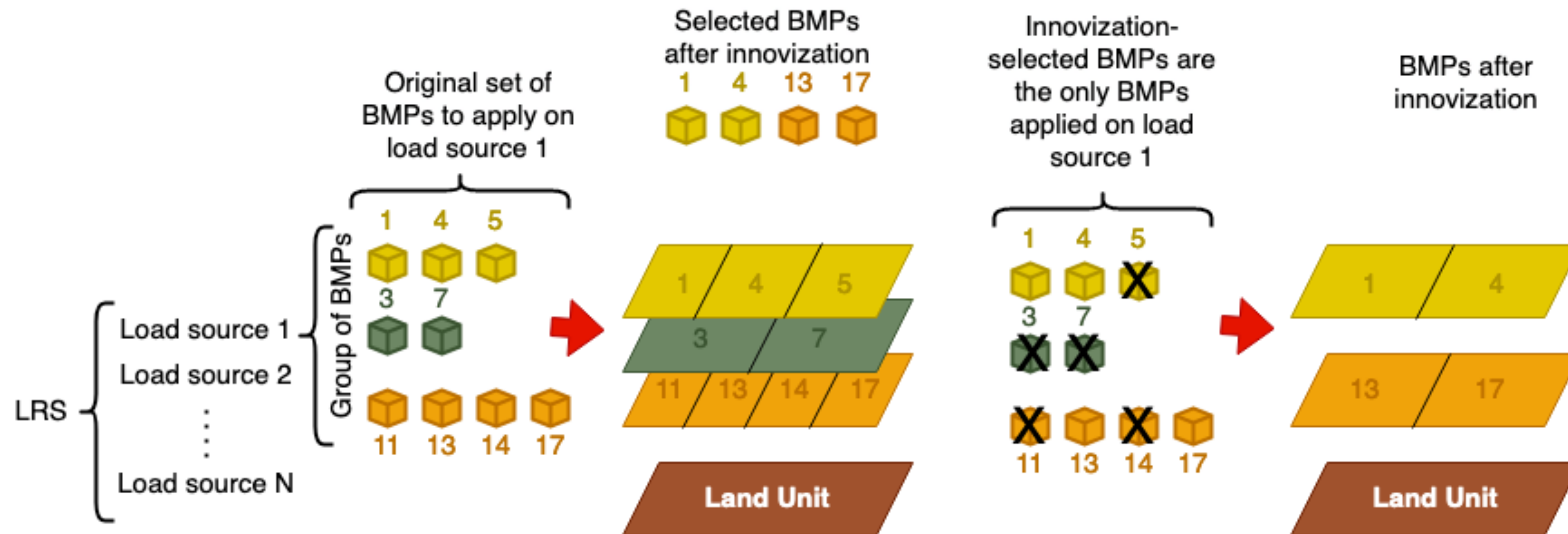
**BMP3**  
**BMP2**  
**BMP1**

Ranking methodology 3:

**BMP2 (\$12/lb N)**  
**BMP3 (\$15/lb N)**  
**BMP1 (\$24/lb N)**

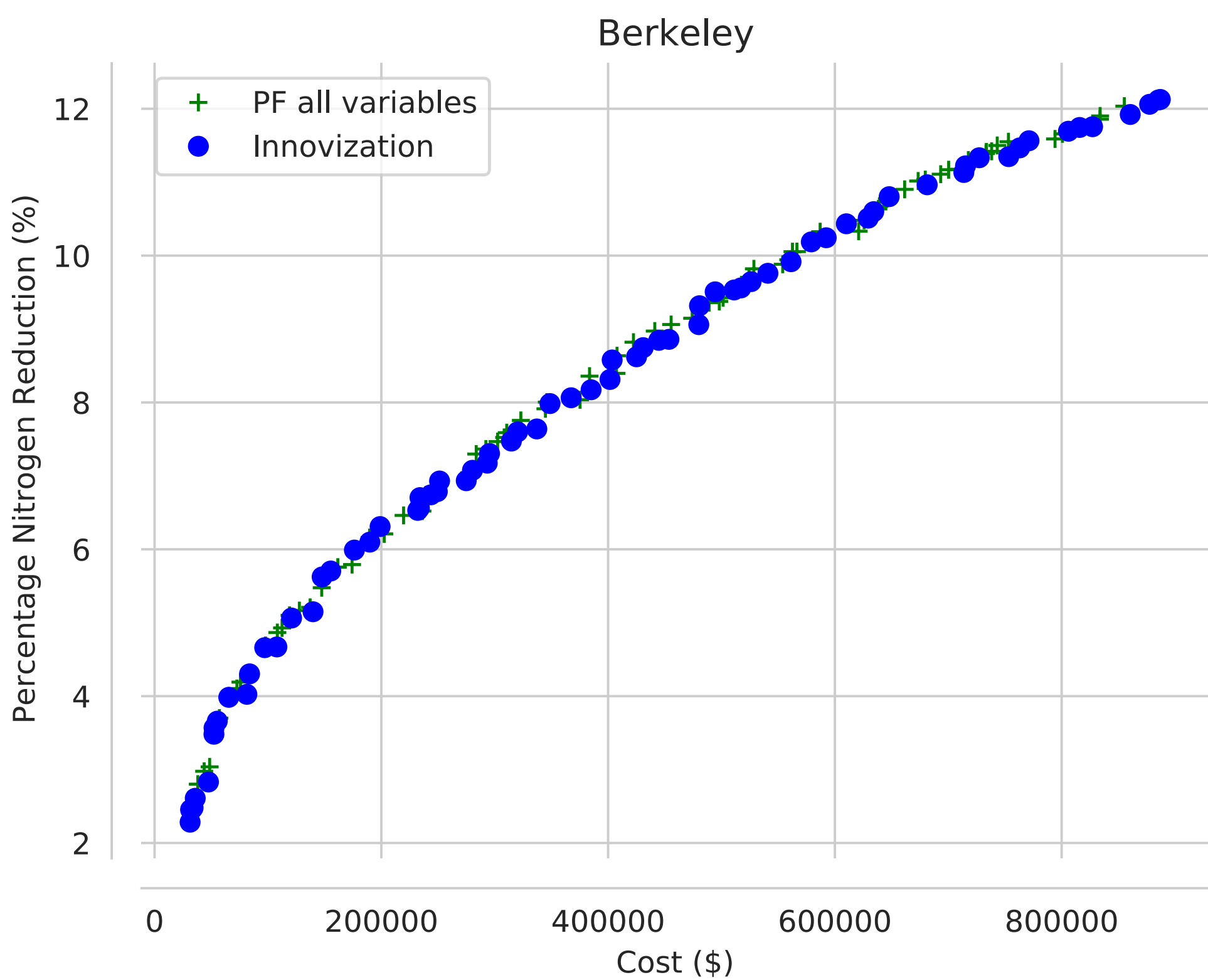
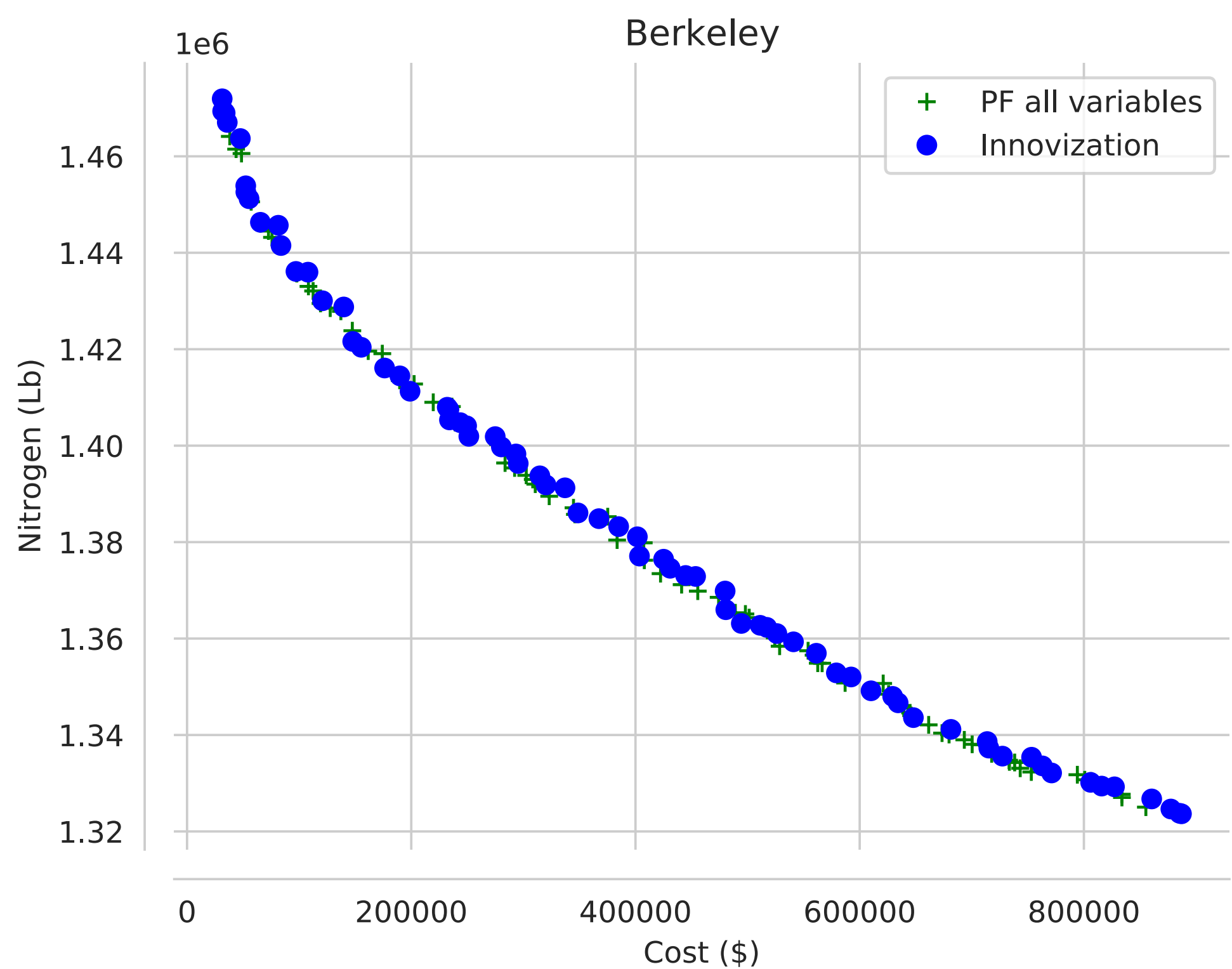
# Re-optimization

## Example of method to use a re-optimization-based innovization



# Results for Berkeley County

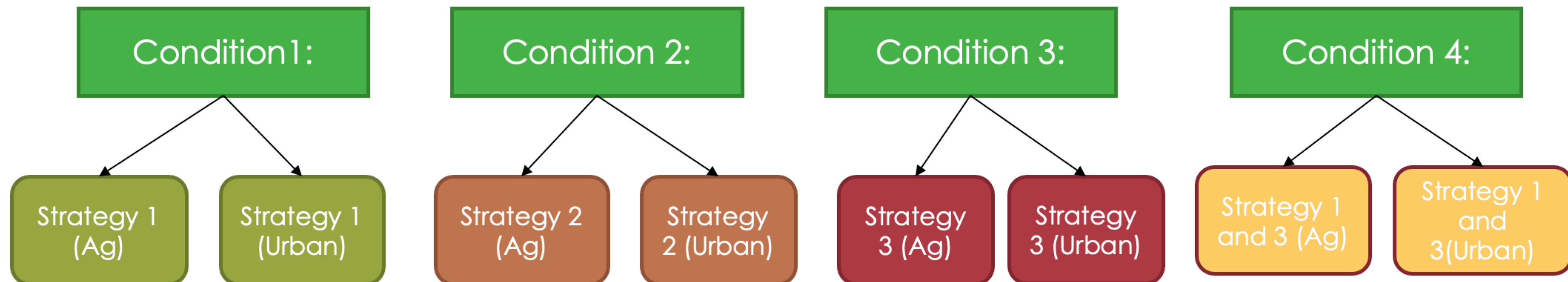
Variable reduction of 30%





# Four Conditions for Re-Optimization

- Strategy 1: Implementation area
- Strategy 2: Max implementation area (available area)
- Strategy 3: Dollar / Nitrogen

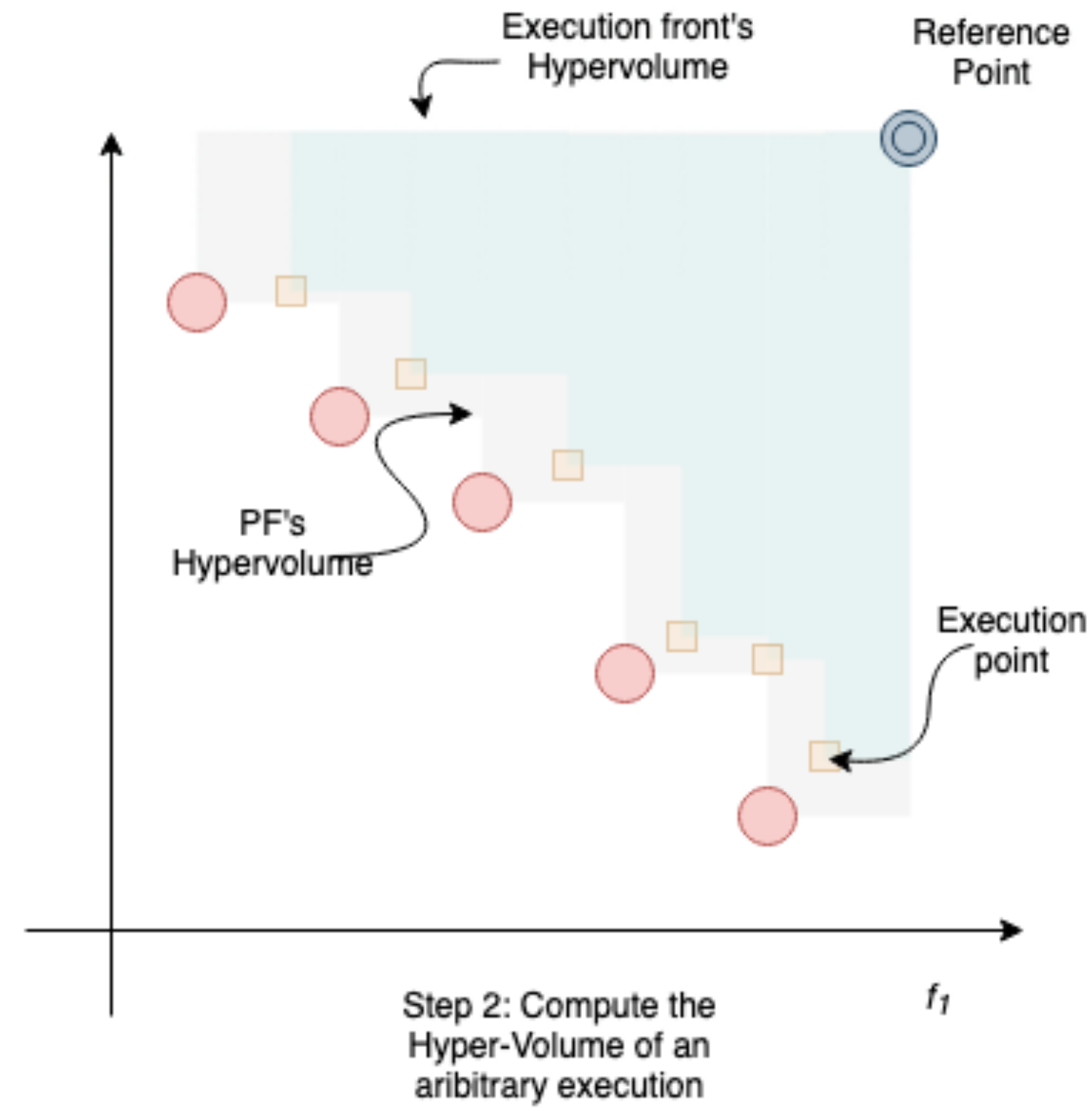
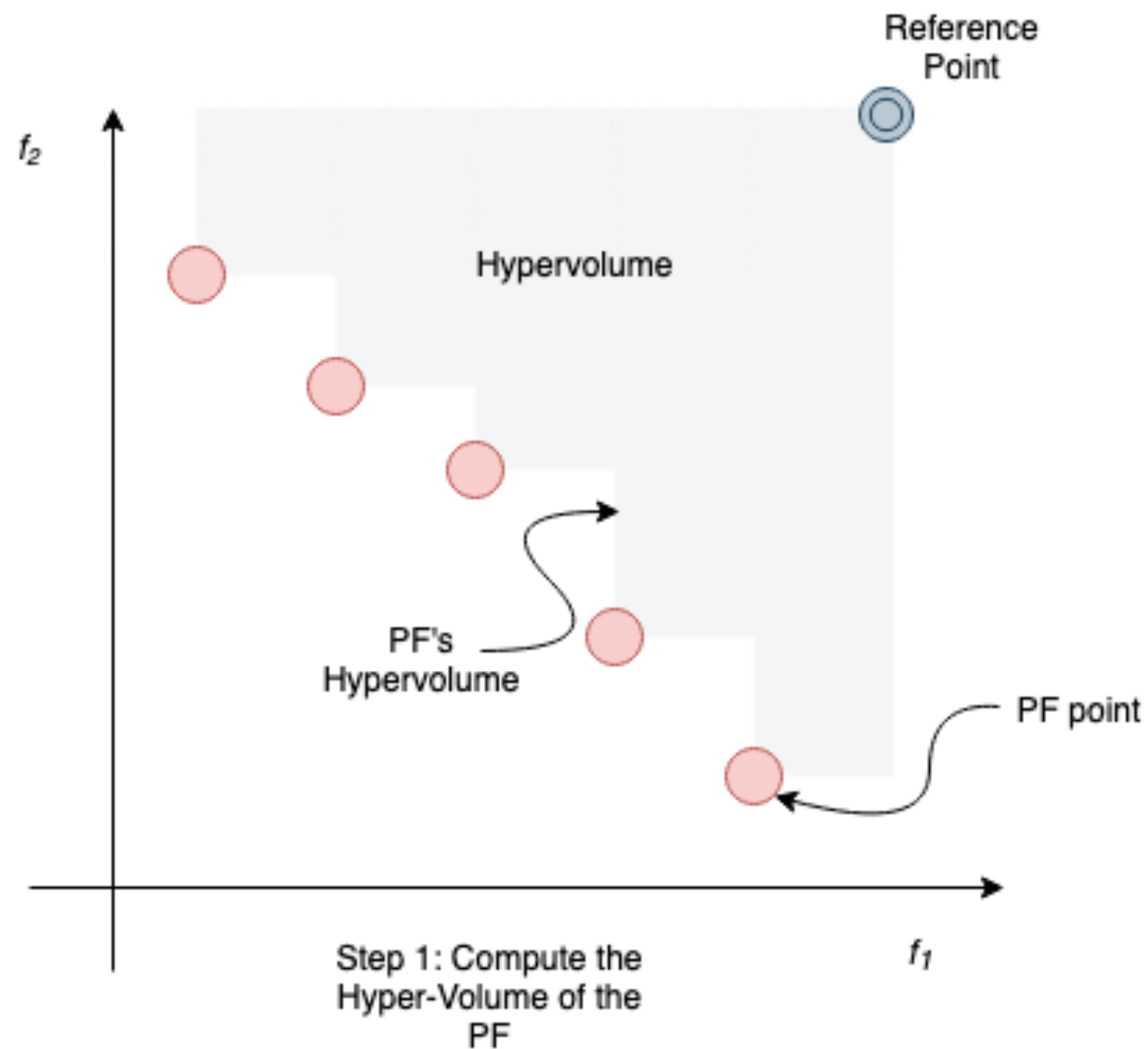


# Variable reduction.

	Berkeley	% of all vars	Mineral	% of all vars	Hardy	% of all vars	Jefferson	% of all vars
All Variables	14090	100	20260	100	18607	100	12303	100
Condition 1	537	3.81	810	4.00	777	4.18	488	3.97
Condition 2	654	4.64	990	4.89	946	5.08	592	4.81
Condition 3	681	4.83	1020	5.03	959	5.15	600	4.88
Condition 4	717	5.09	1080	5.33	1011	5.43	632	5.14

# Performance Measure

## Ratio of the Hypervolume



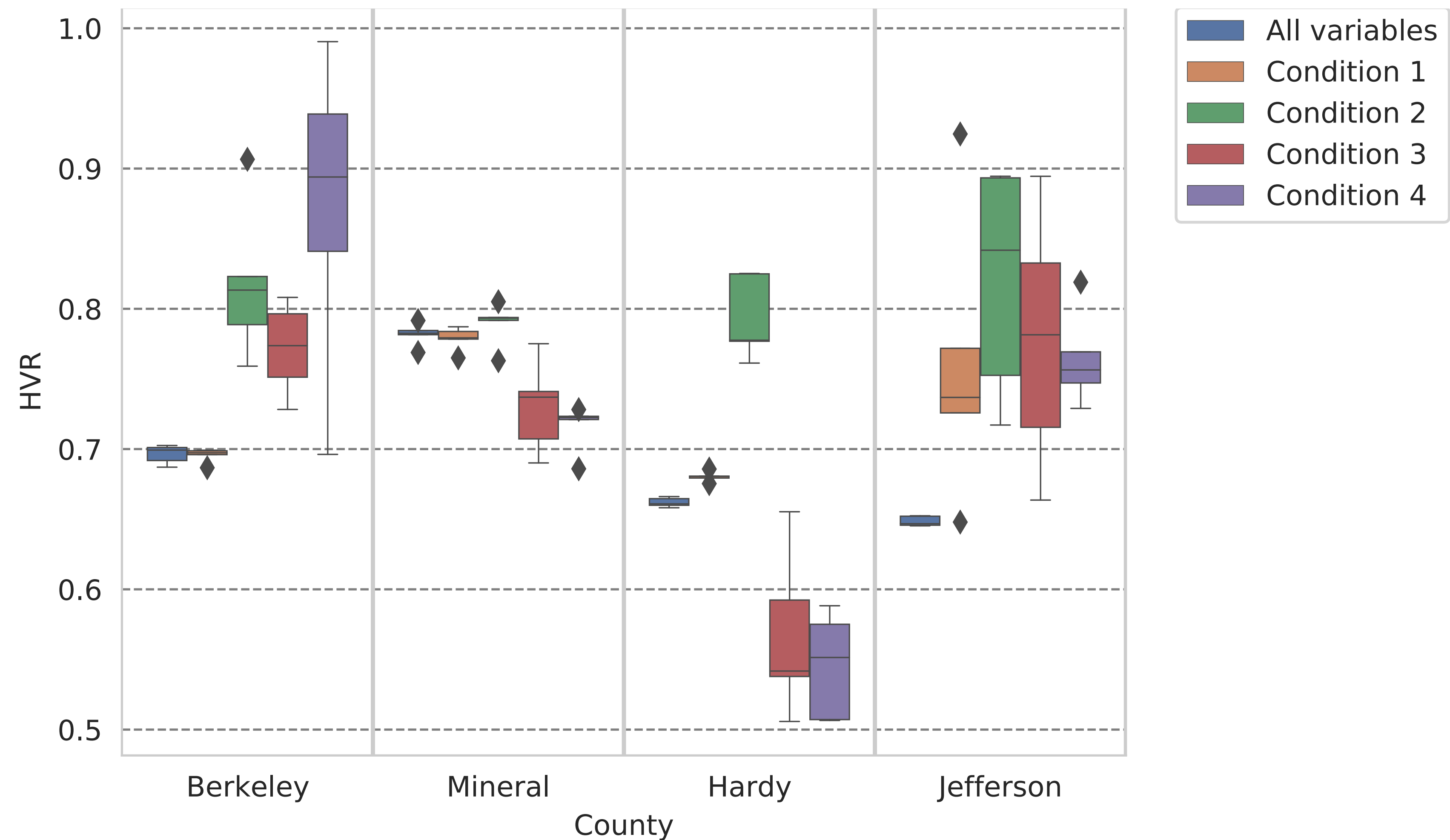
$$\text{Rate of the Hypervolume (HVR)} = \frac{\text{PF's Hypervolume}}{\text{Execution front's Hypervolume}}$$

Step 3: Compute the HVR



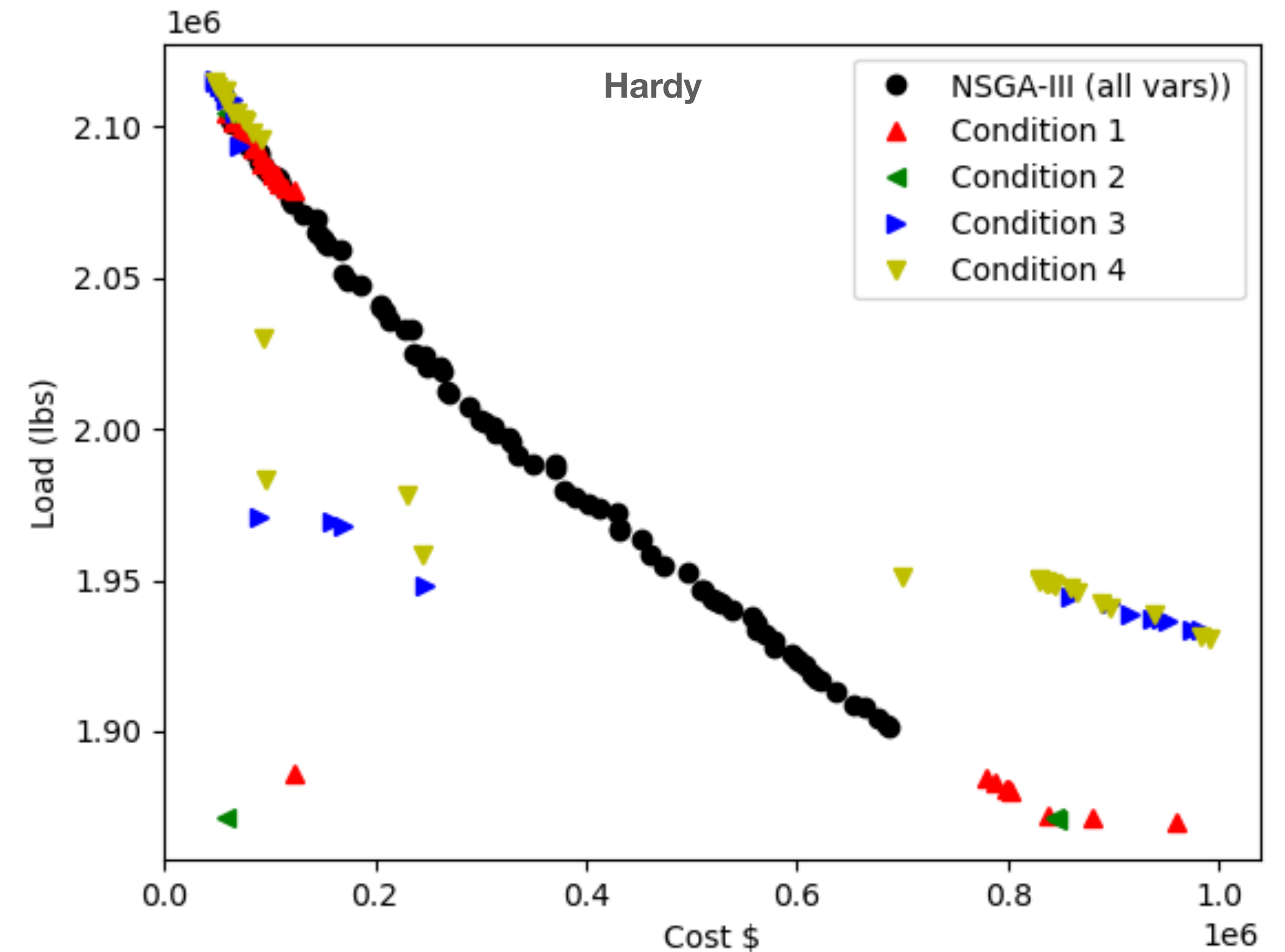
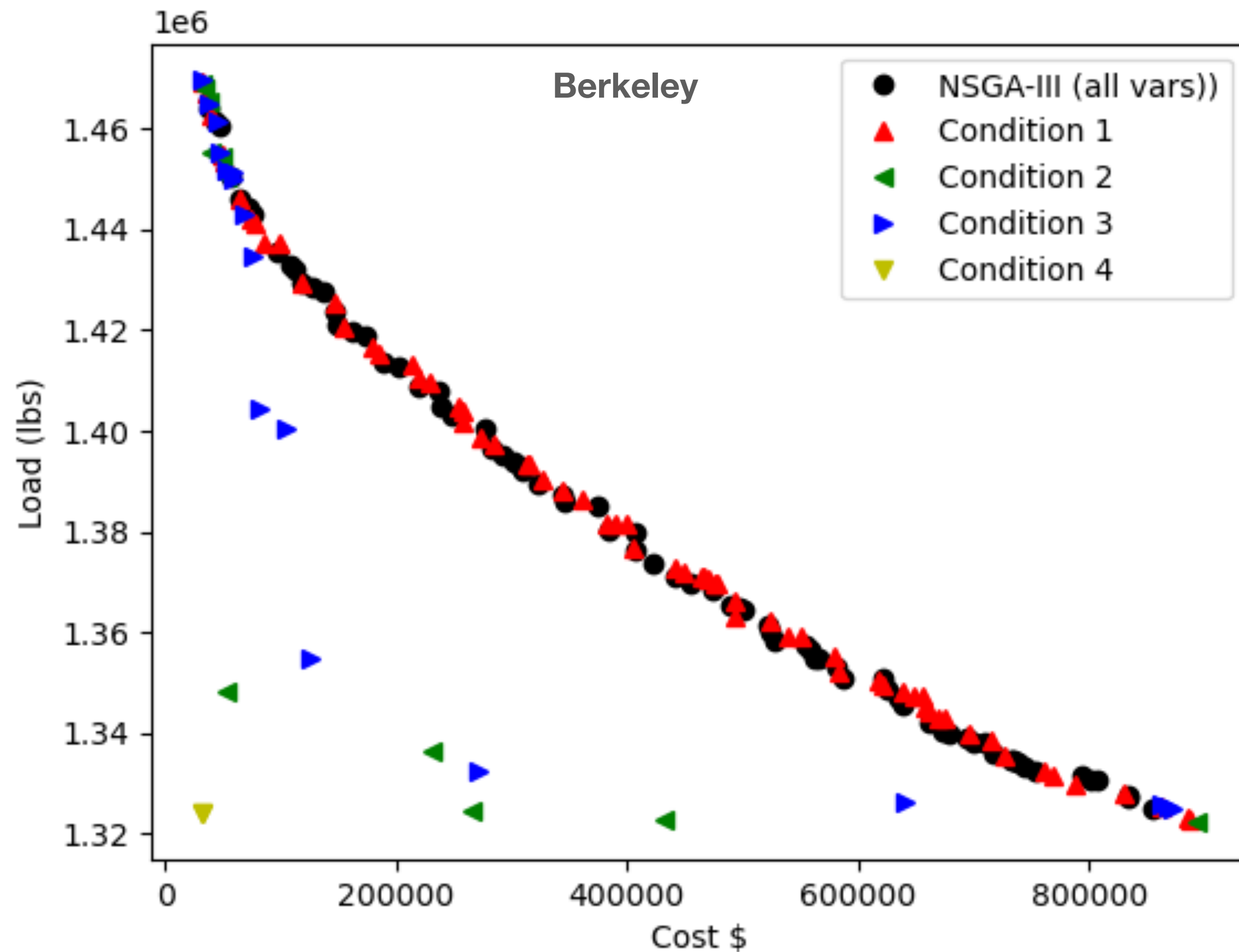
# Performance Measure

## Ratio of the Hypervolume



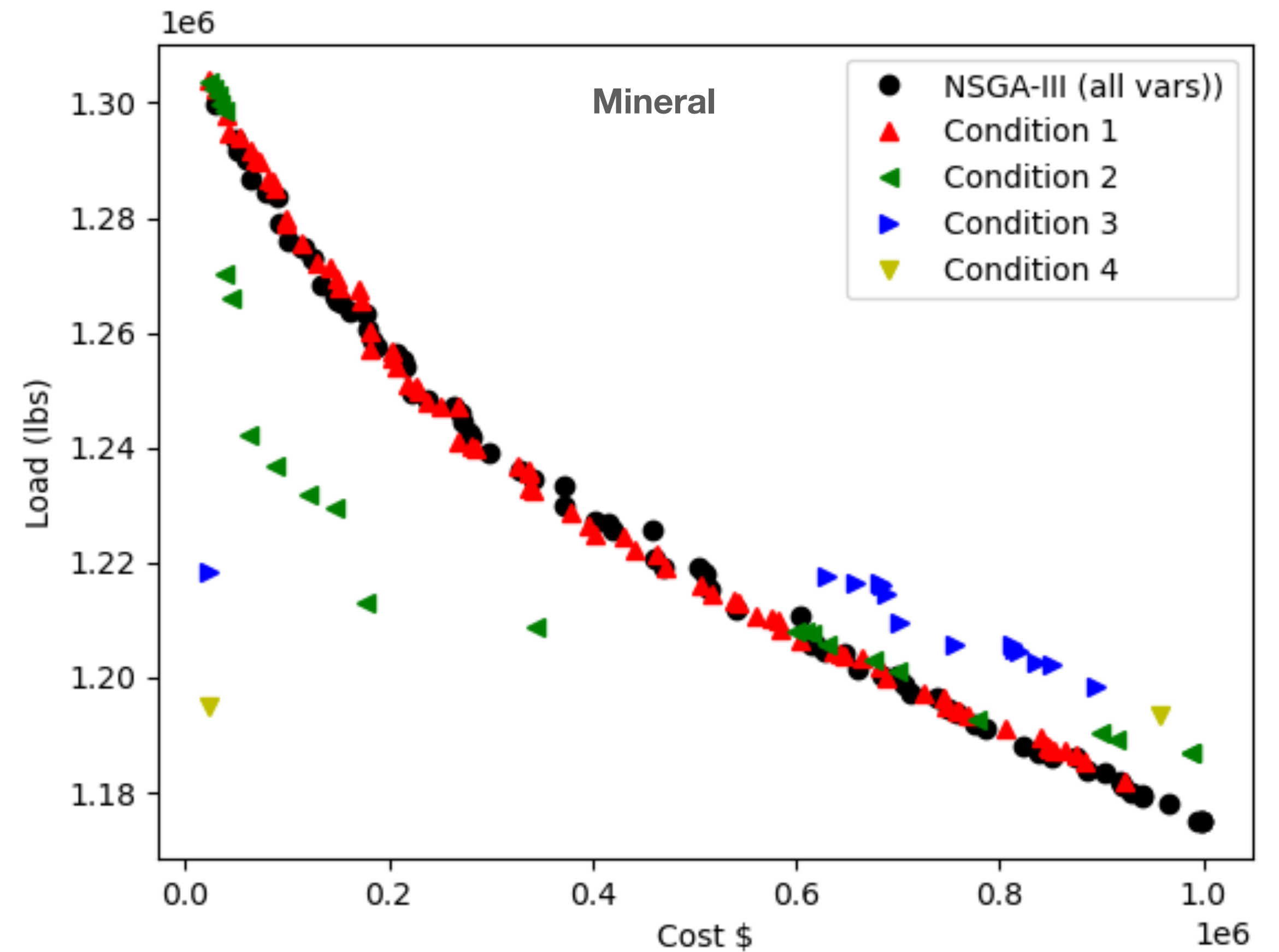
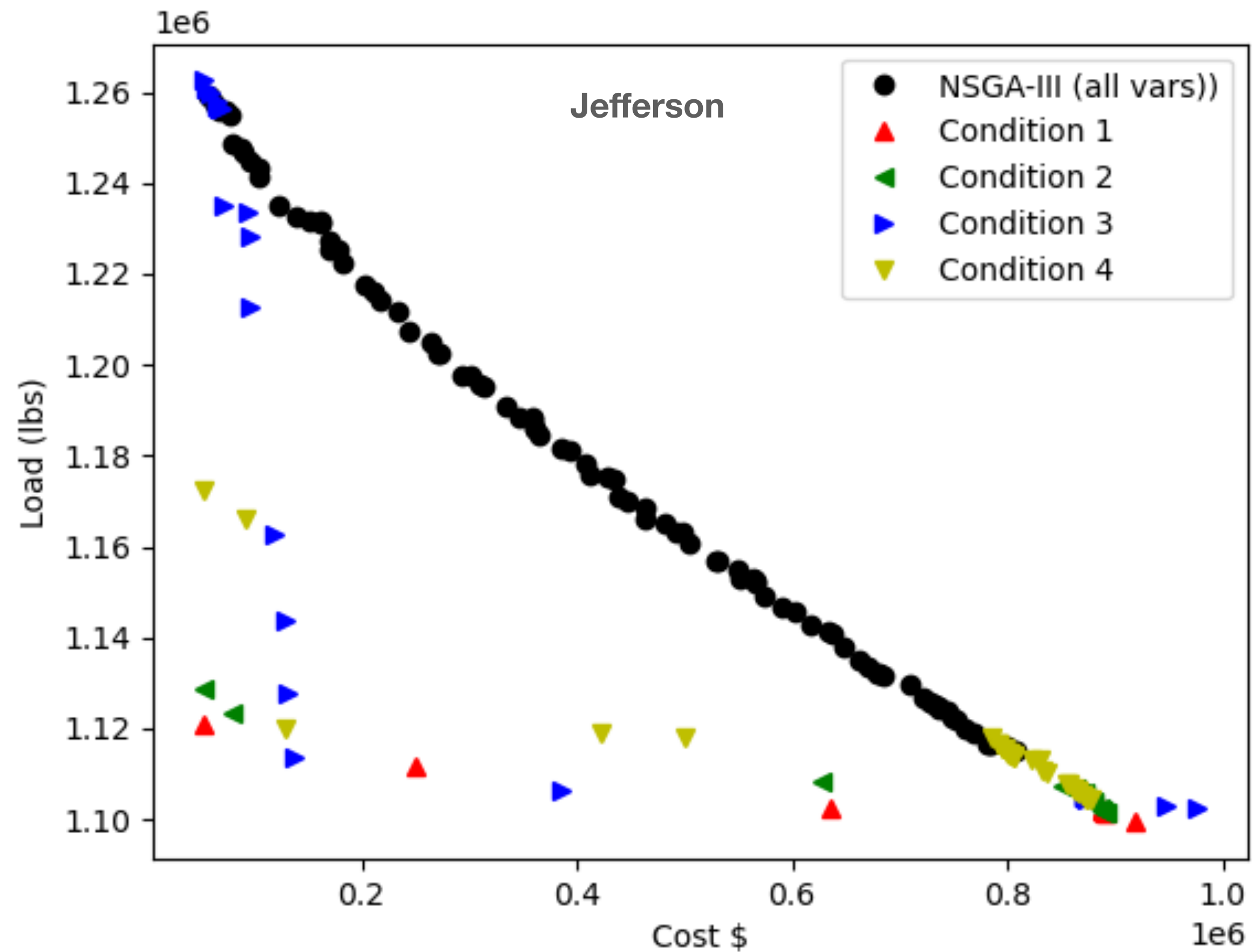
# Re-optimization-based Innovization

## Berkeley and Hardy



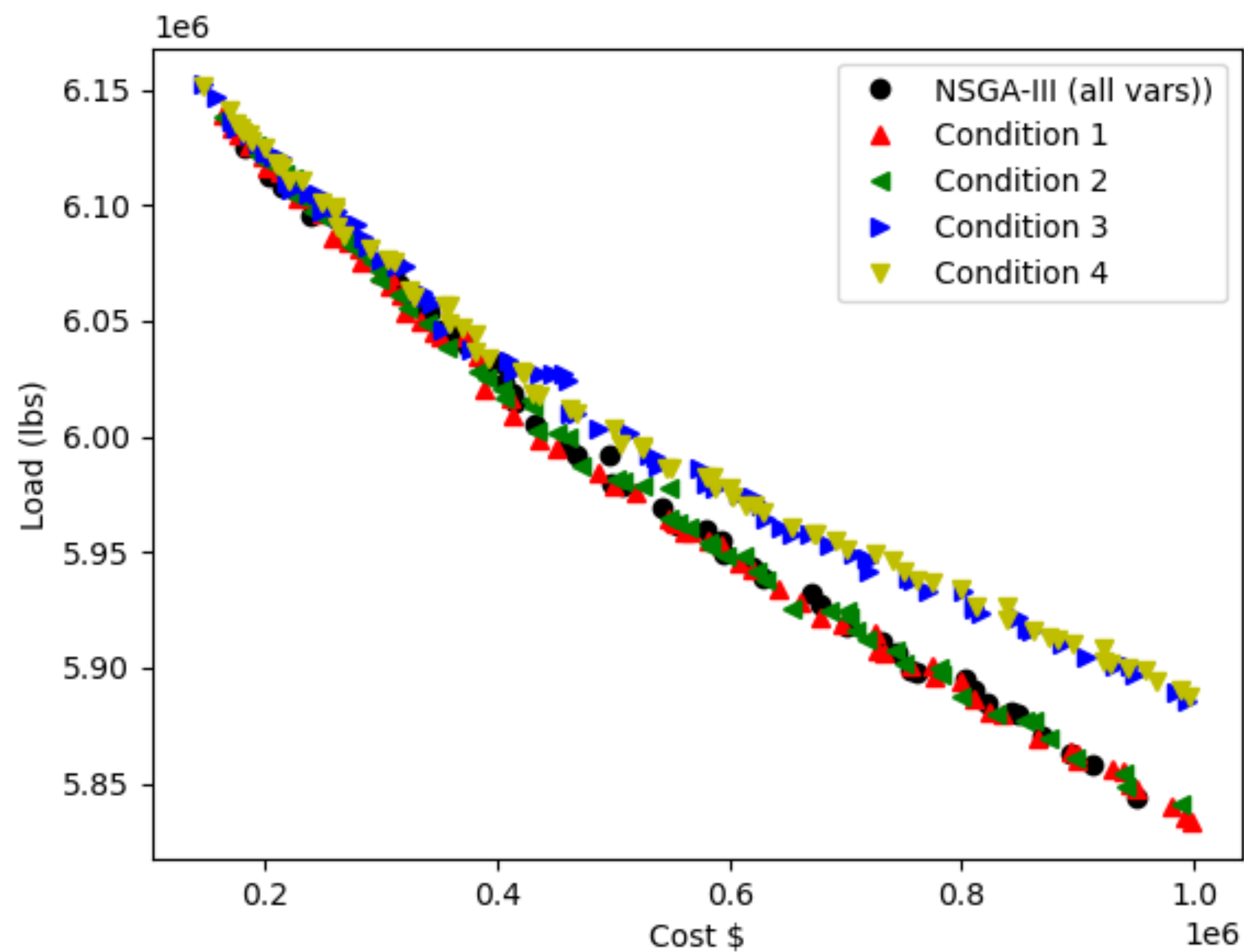
# Re-optimization-based Innovization

## Jefferson and Mineral





# Multi-County Results



# Submission of Papers (this quarter)

- Gregorio Toscano, Juan Hernández, Julian Blank, Pouyan Nejadhashemi, Kalyanmoy Deb, and Lewis Linker. Utilizing Innovization to Solve Large-scale Multi-objective Chesapeake Bay Watershed Problem Efficiently. Submitted to the 2023 Congress on Evolutionary Computation (submitted in January 2023)
- Gregorio Toscano, Hoda Razavi, Pouyan Nejadhashemi, Kalyanmoy Deb, and Lewis Linker, 2023. Large-scale Multi-objective Optimization for Watershed Planning and Assessment. IEEE Transactions on Systems, Man, and Cybernetics: Systems (submitted in March 2023).

# Conclusions and Future Work

- We have developed **multi-objective** methods that accept users' **preferences** and find several **solutions** in a **single run**.
- Such a tool will help us reduce the time to evaluate and analyze our optimization algorithms.
- Innovization can help us to perform more efficient search.
- The results are promising, and we are planning to incorporate these results in the design of our future approaches.
- Replicate study with rest of BMPs.



**Thank you!**