Modeling Workgroup Meeting Quarterly Review

Optimization update

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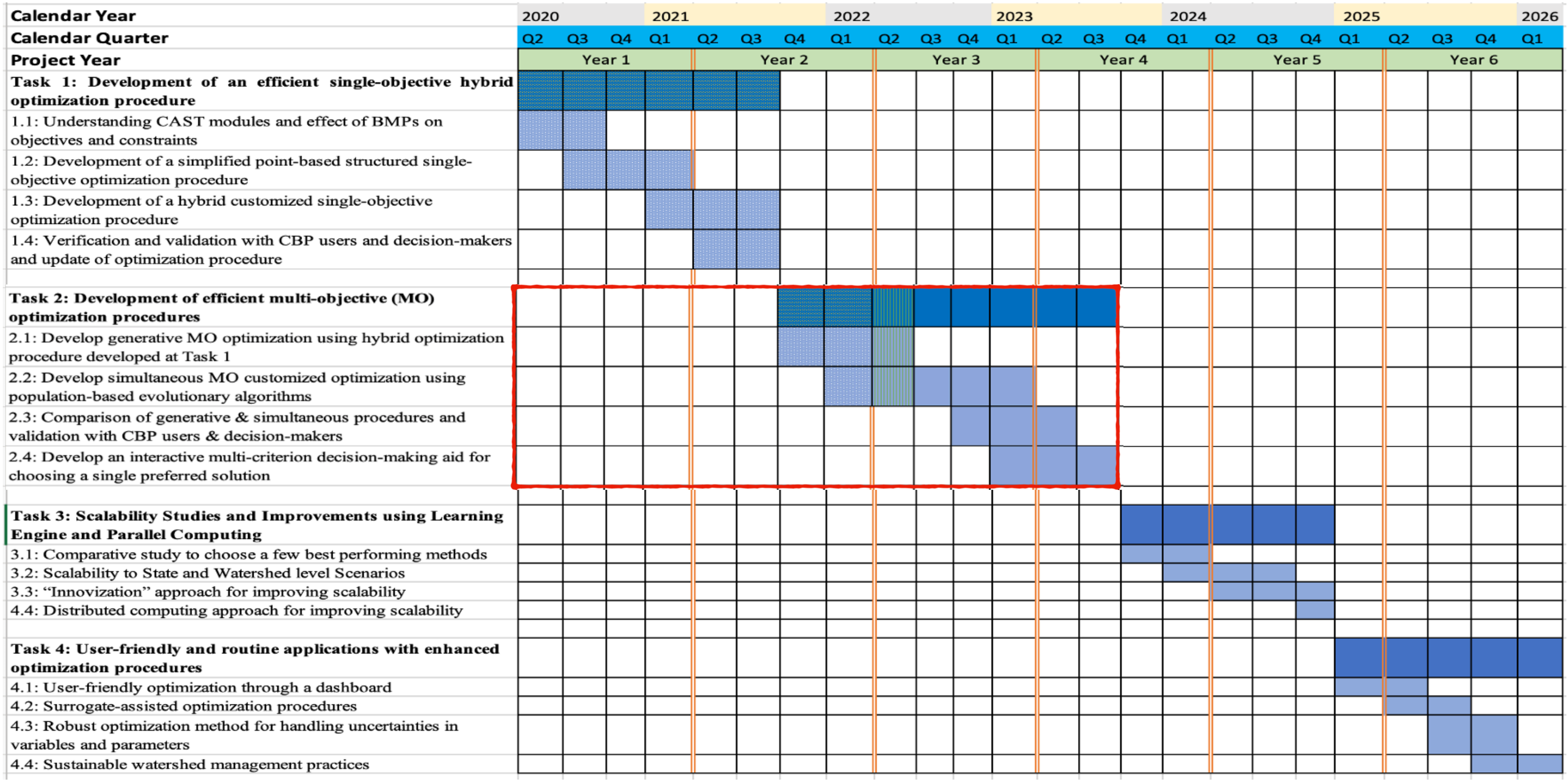
MICHIGAN STATE UNIVERSITY, APRIL 2023

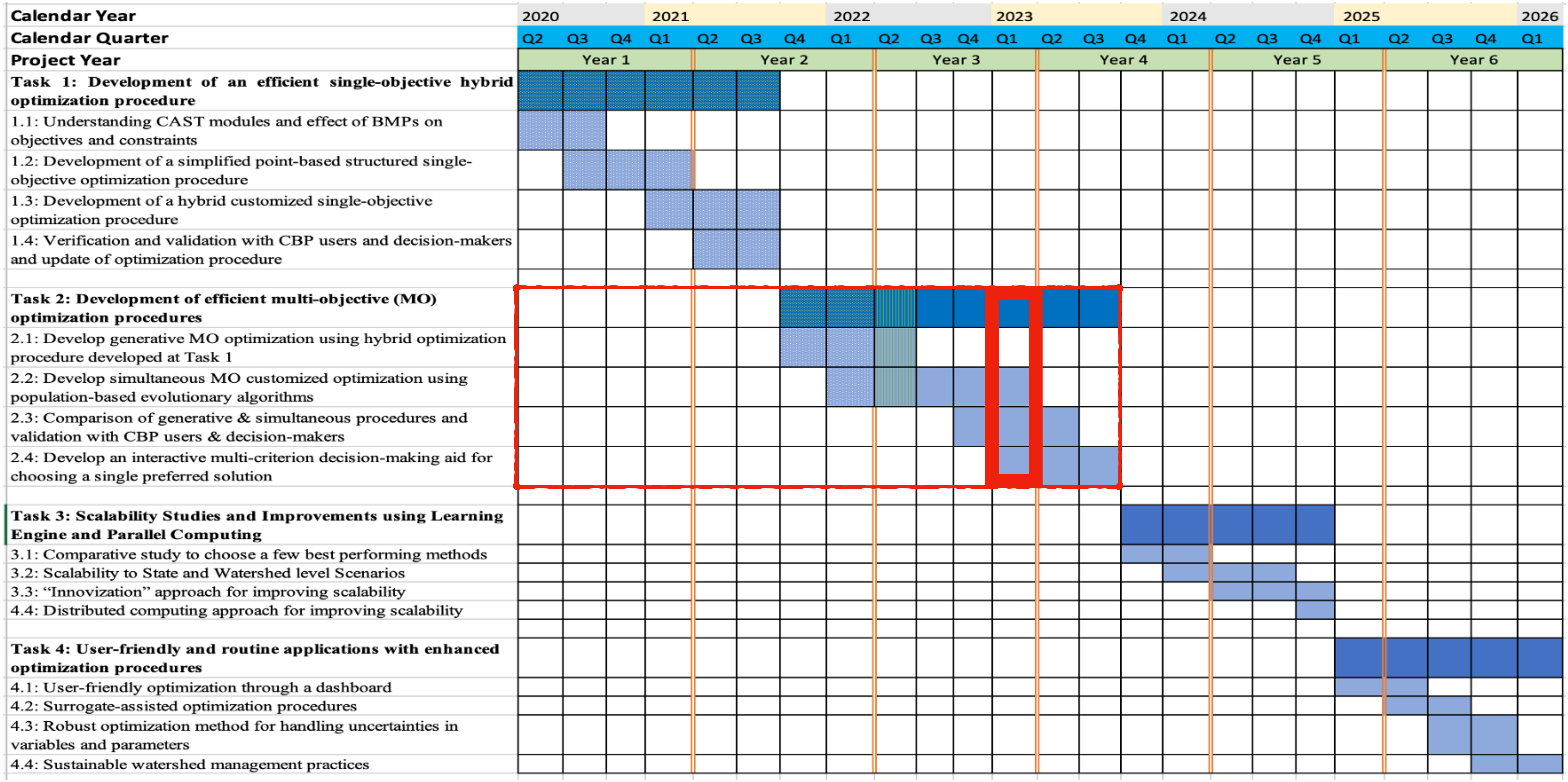
Overview

- 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

Current status of the project

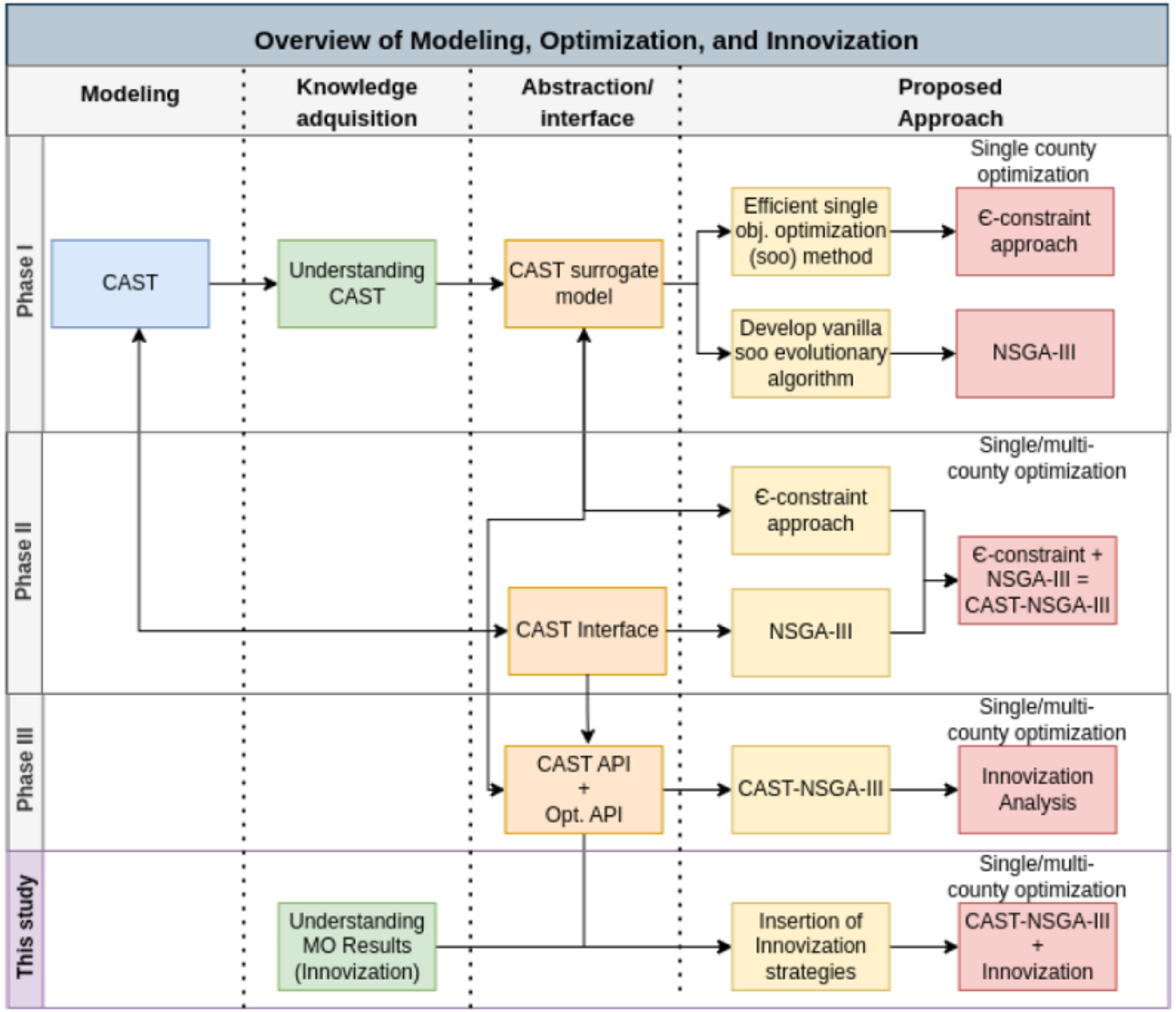
- 

Current status of the project



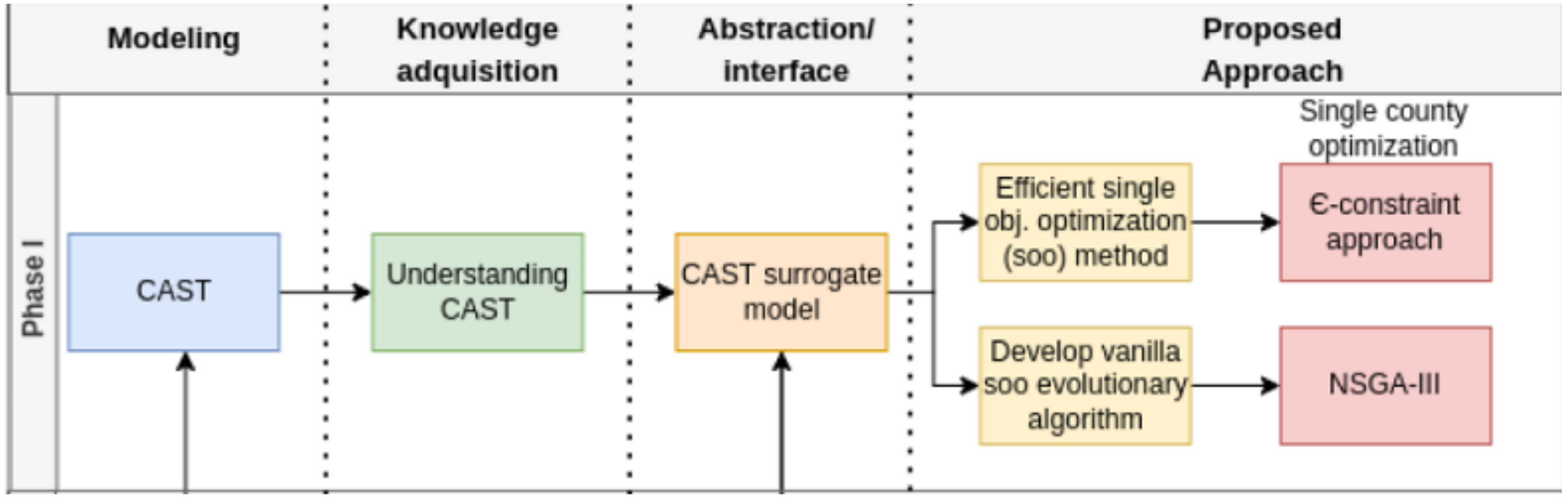
Algorithm development

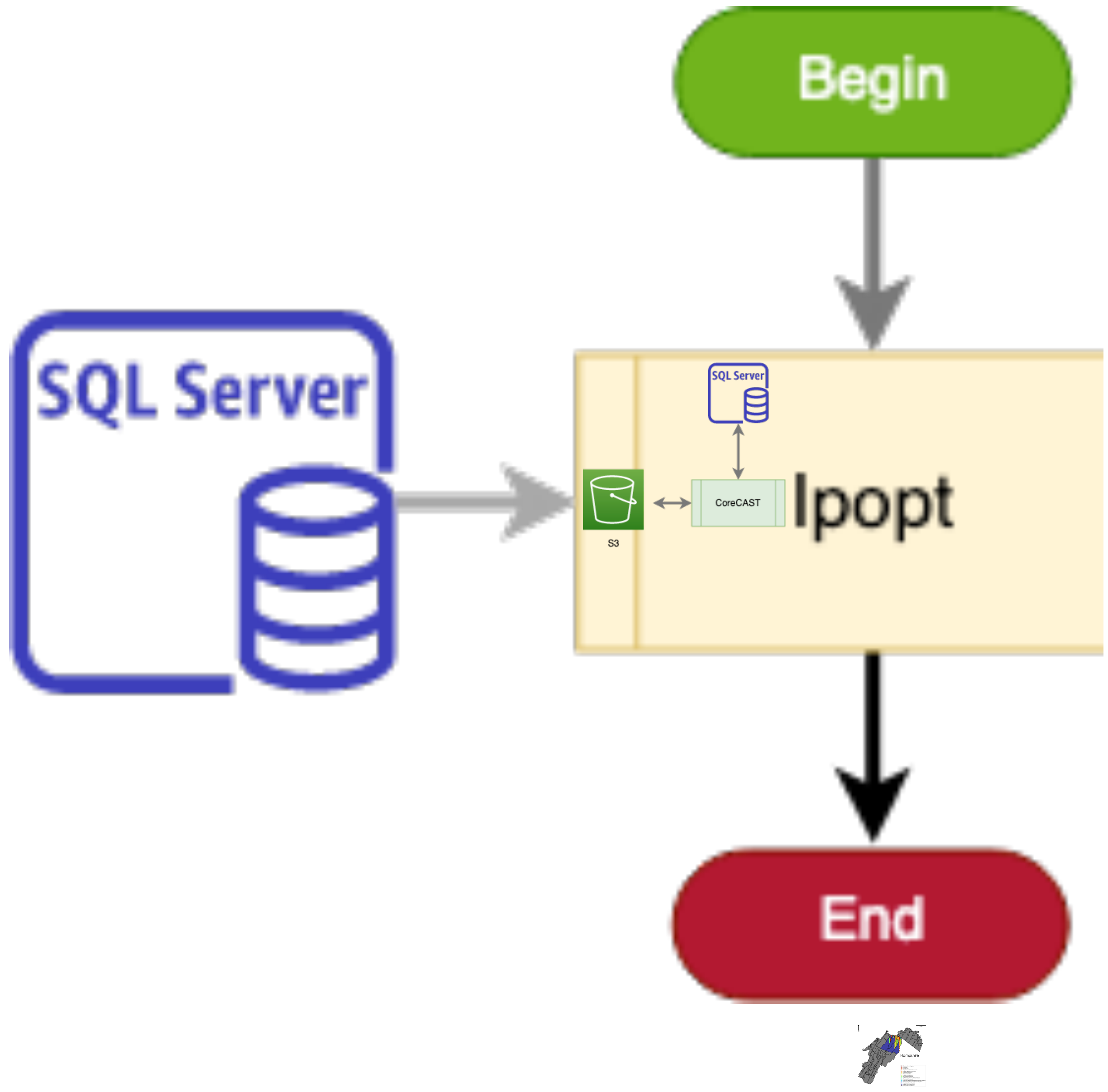
Overview

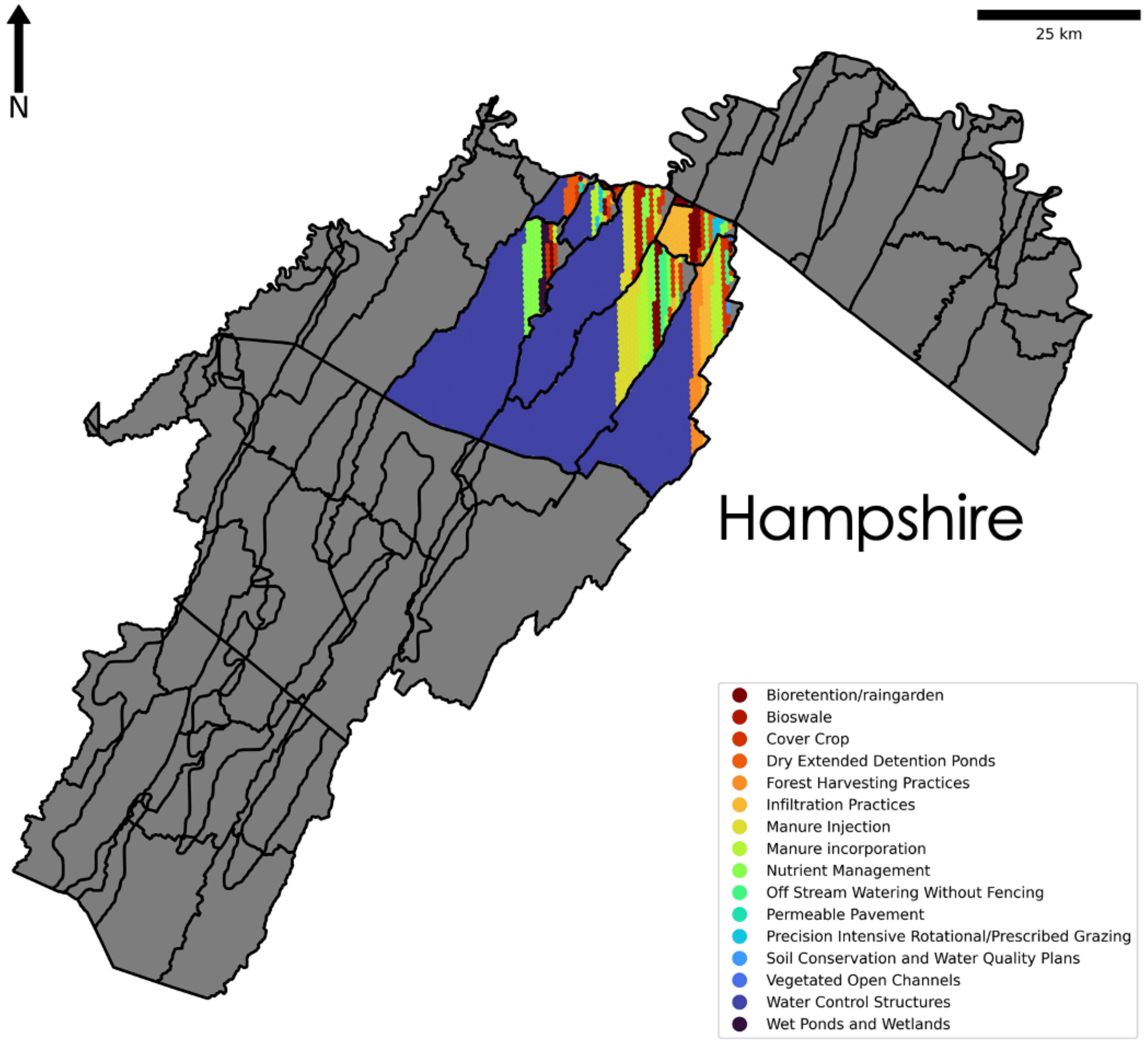


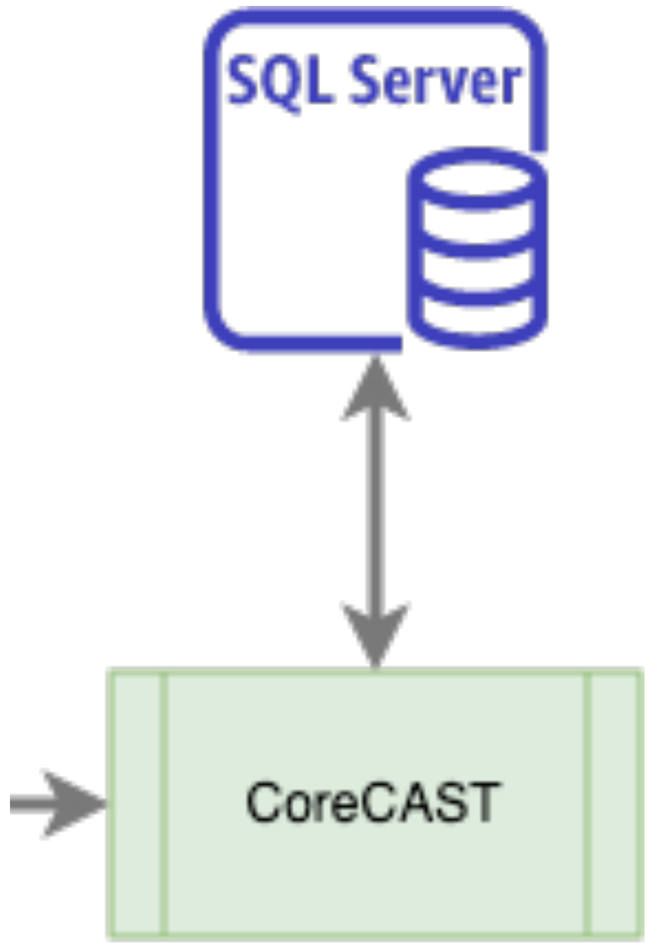
Project Progress

Phase I



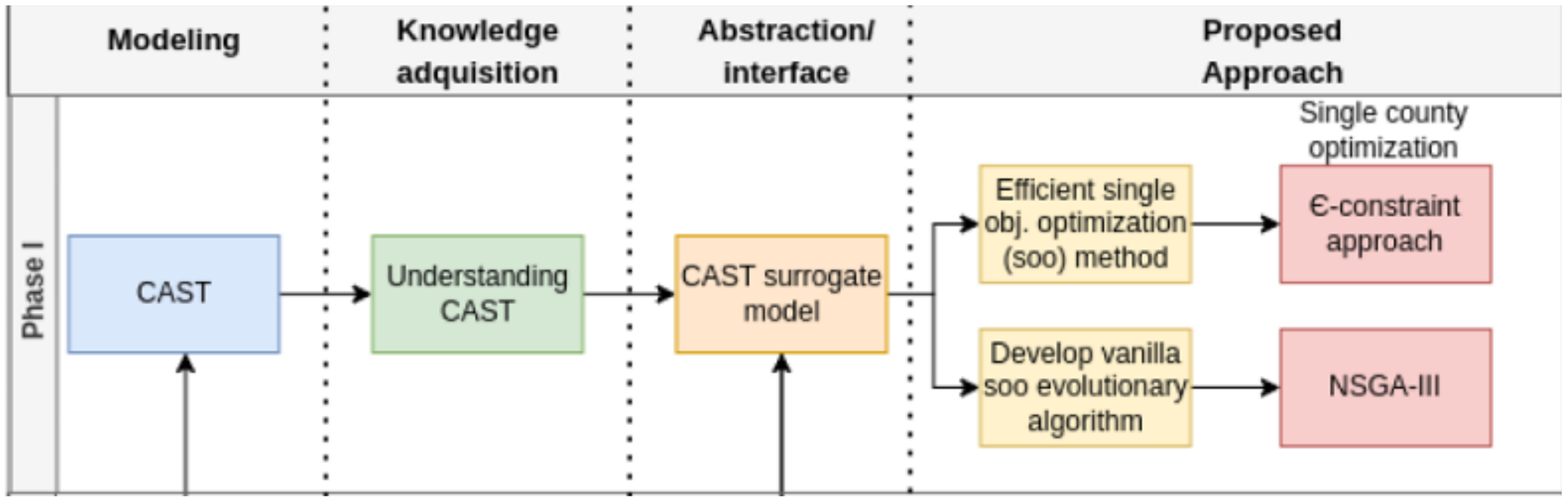


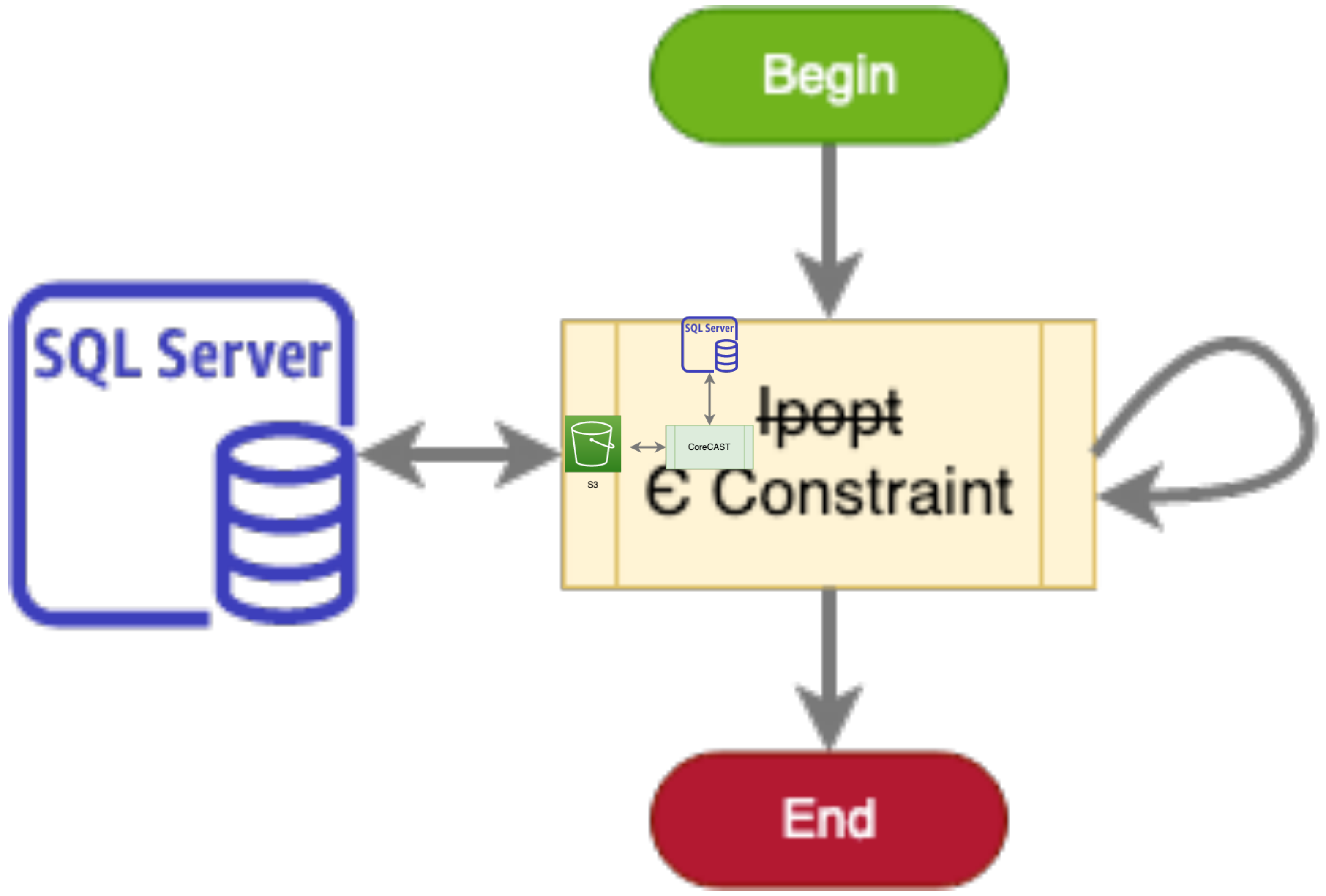


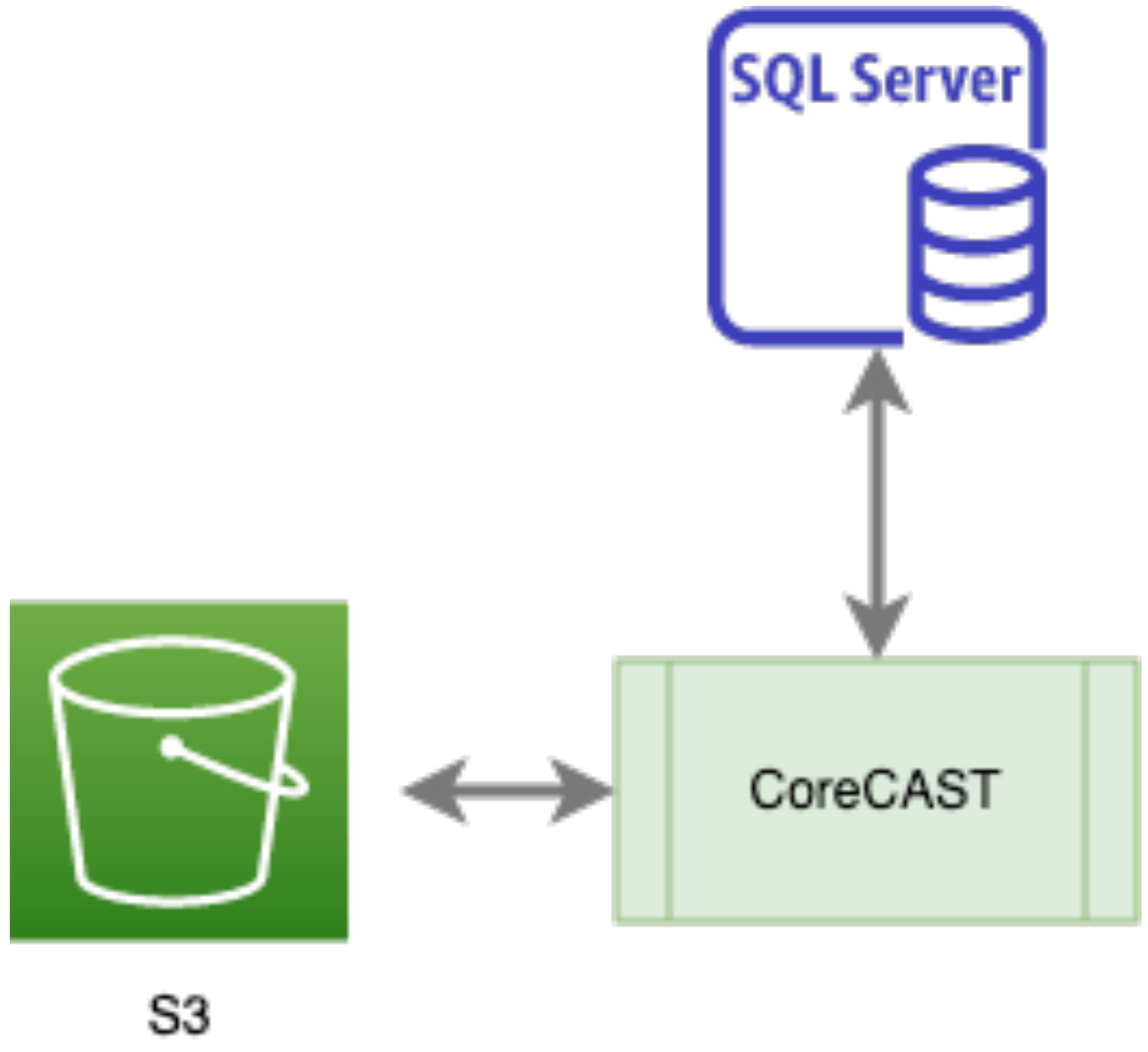


Project Progress

Phase I

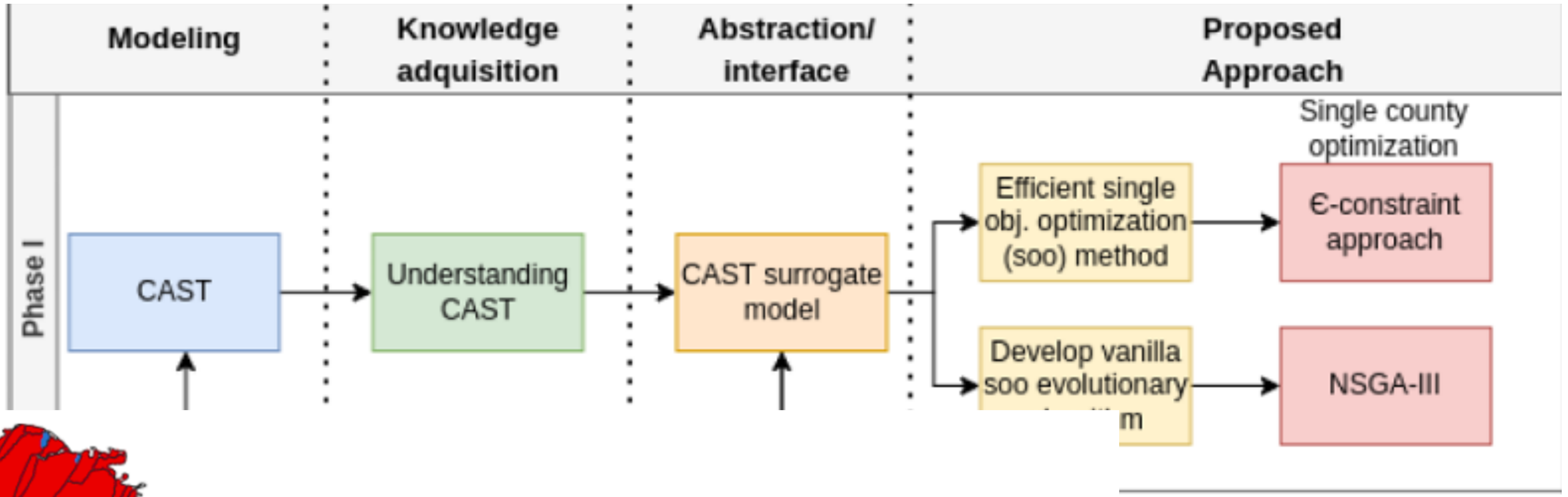


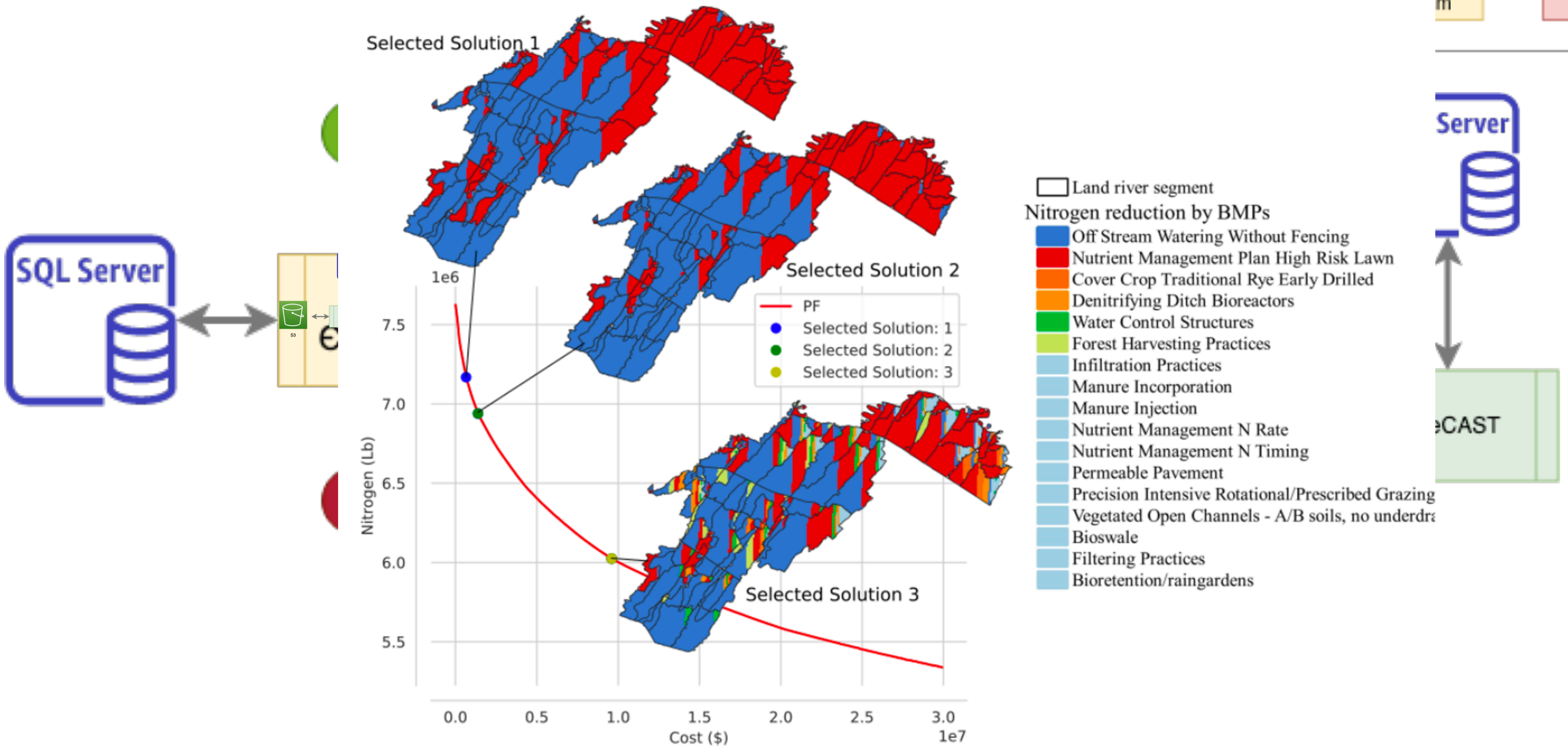




Project Progress

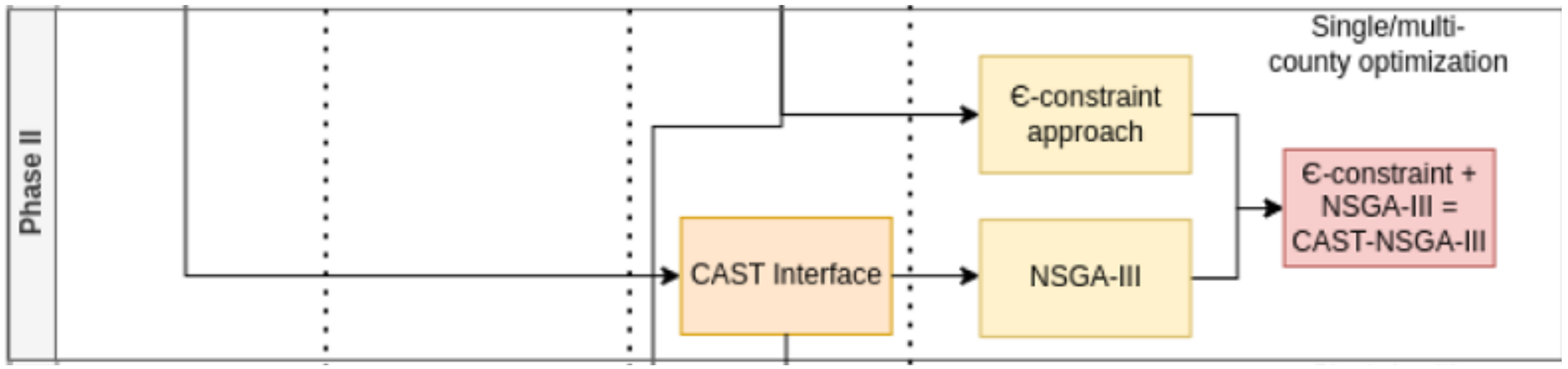
Phase I

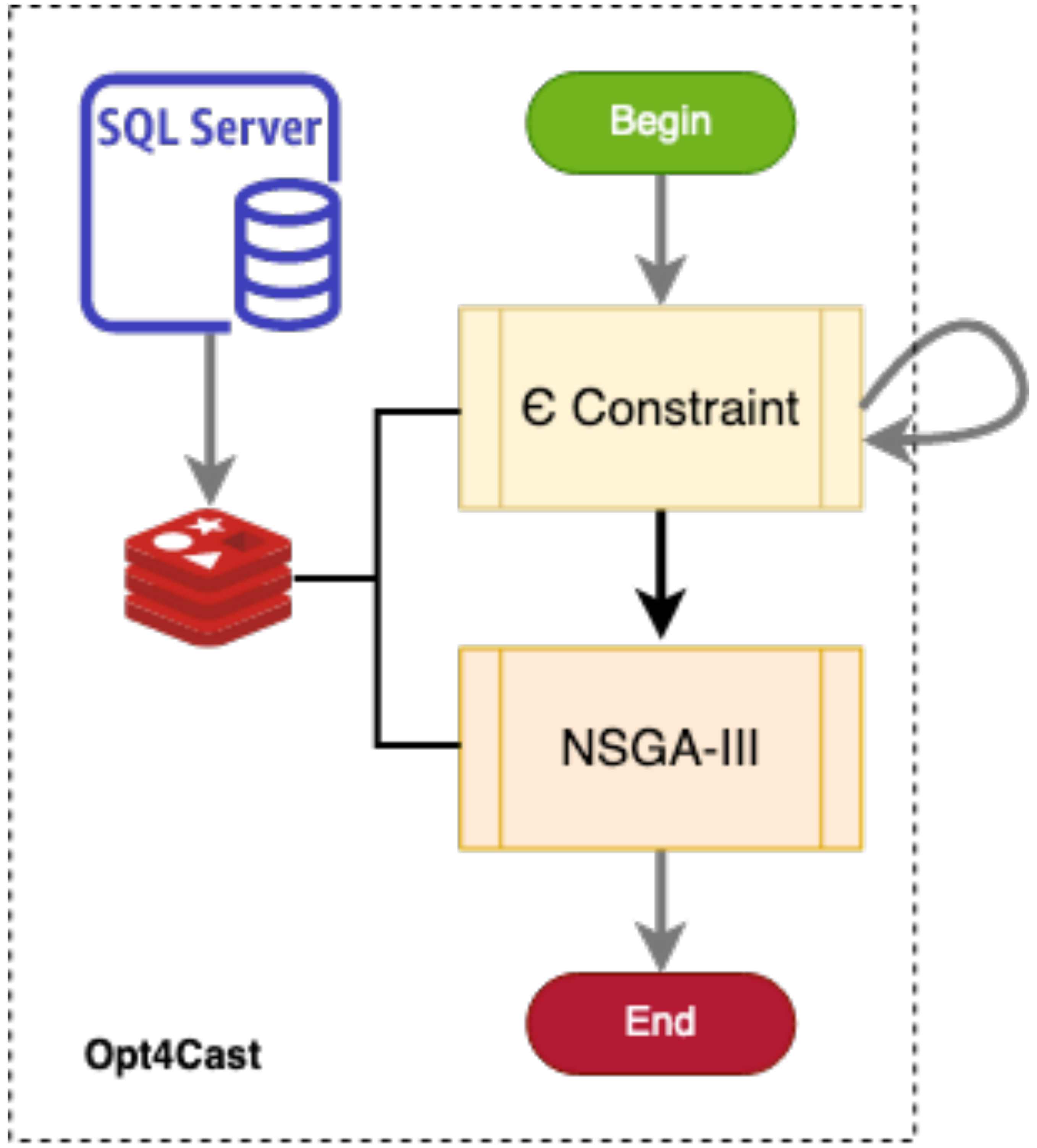


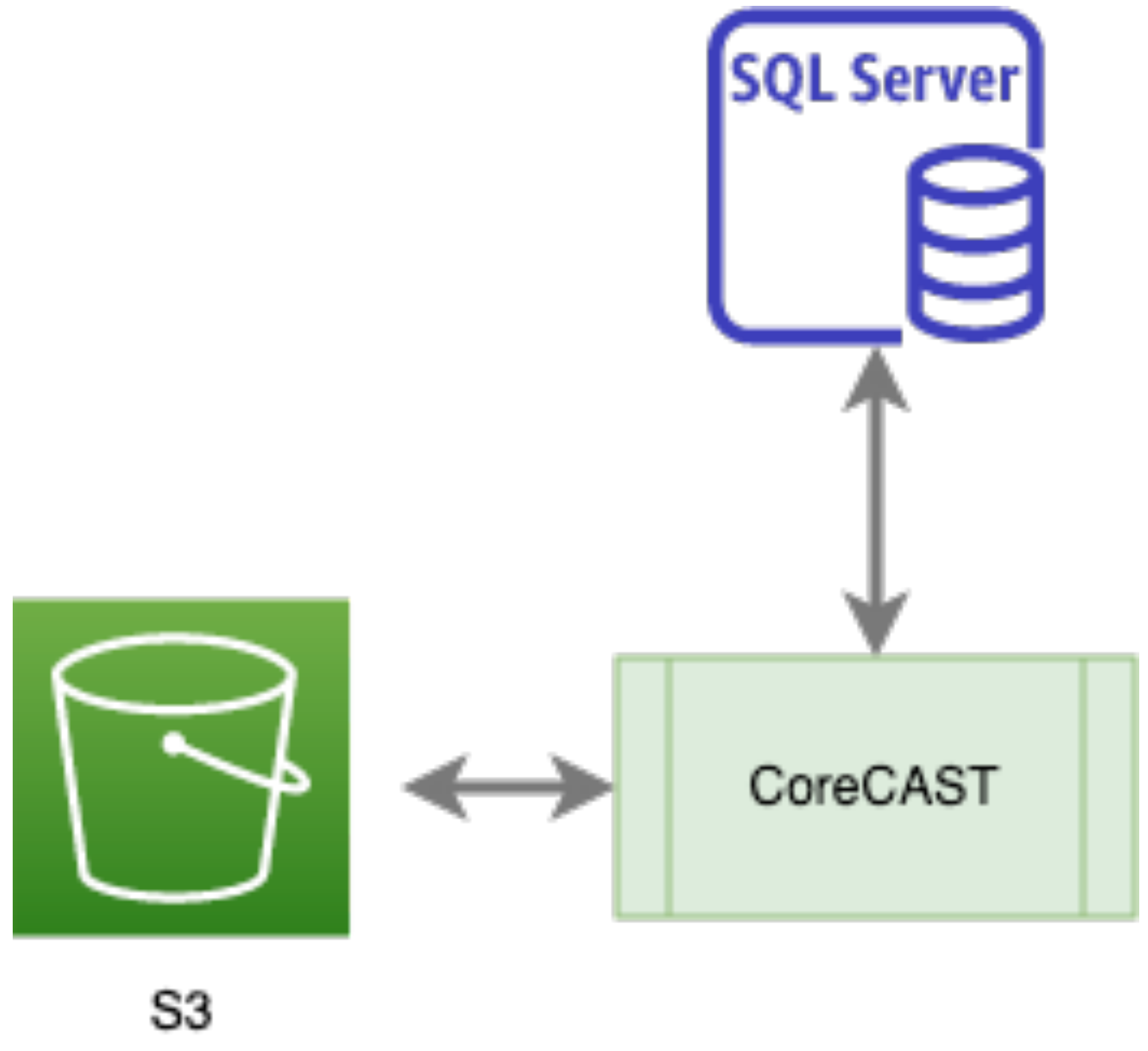


Project Progress

Phase II

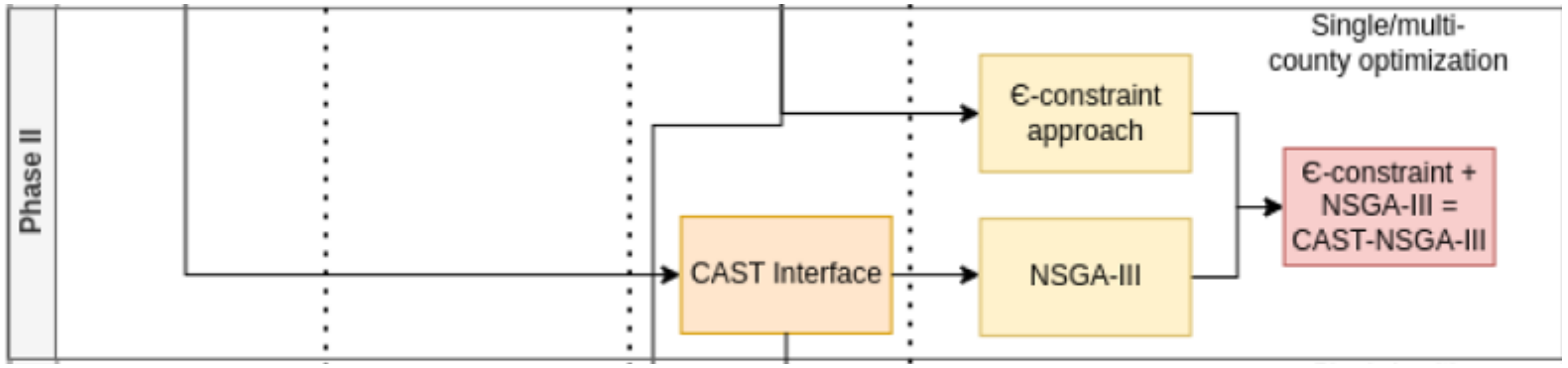


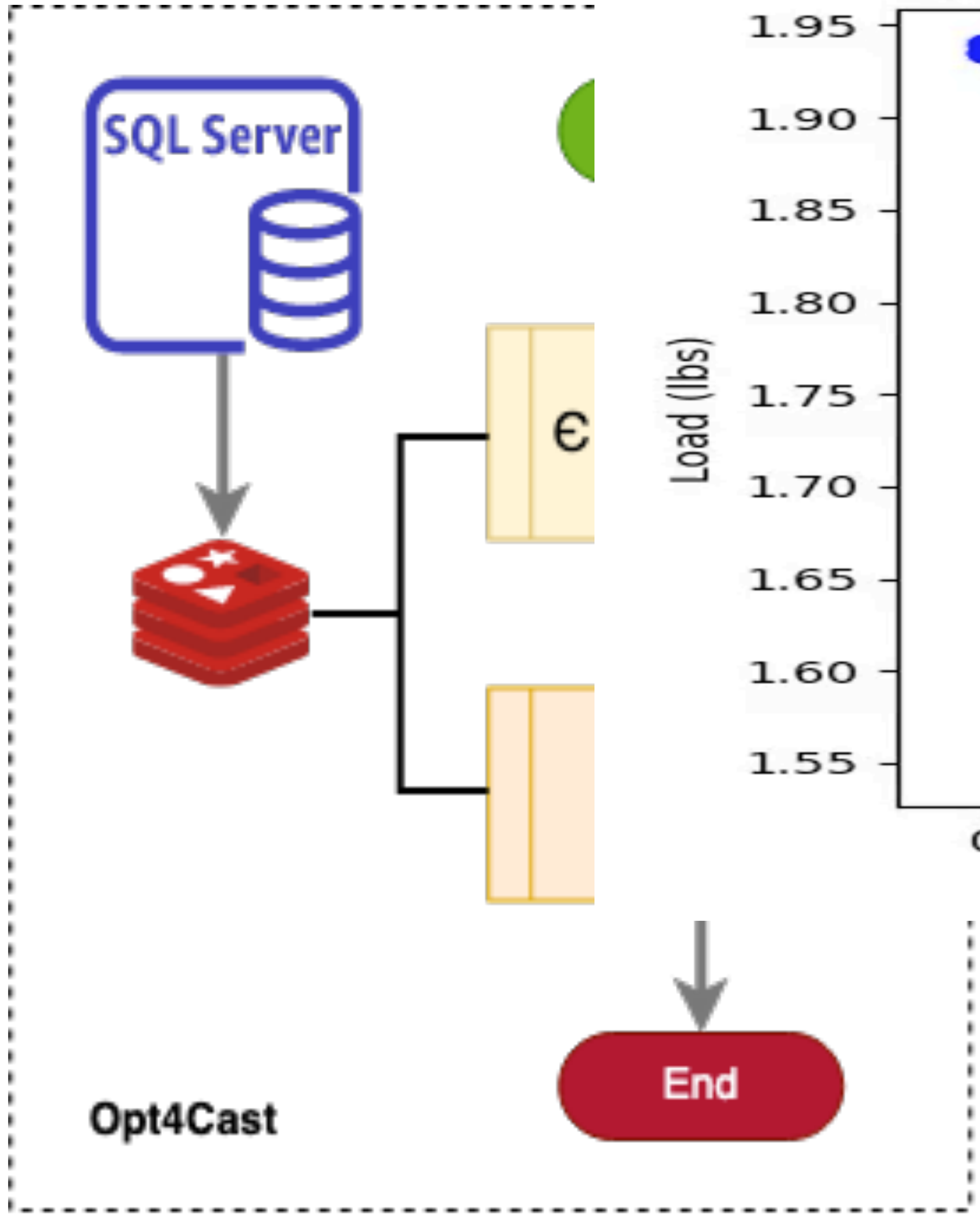


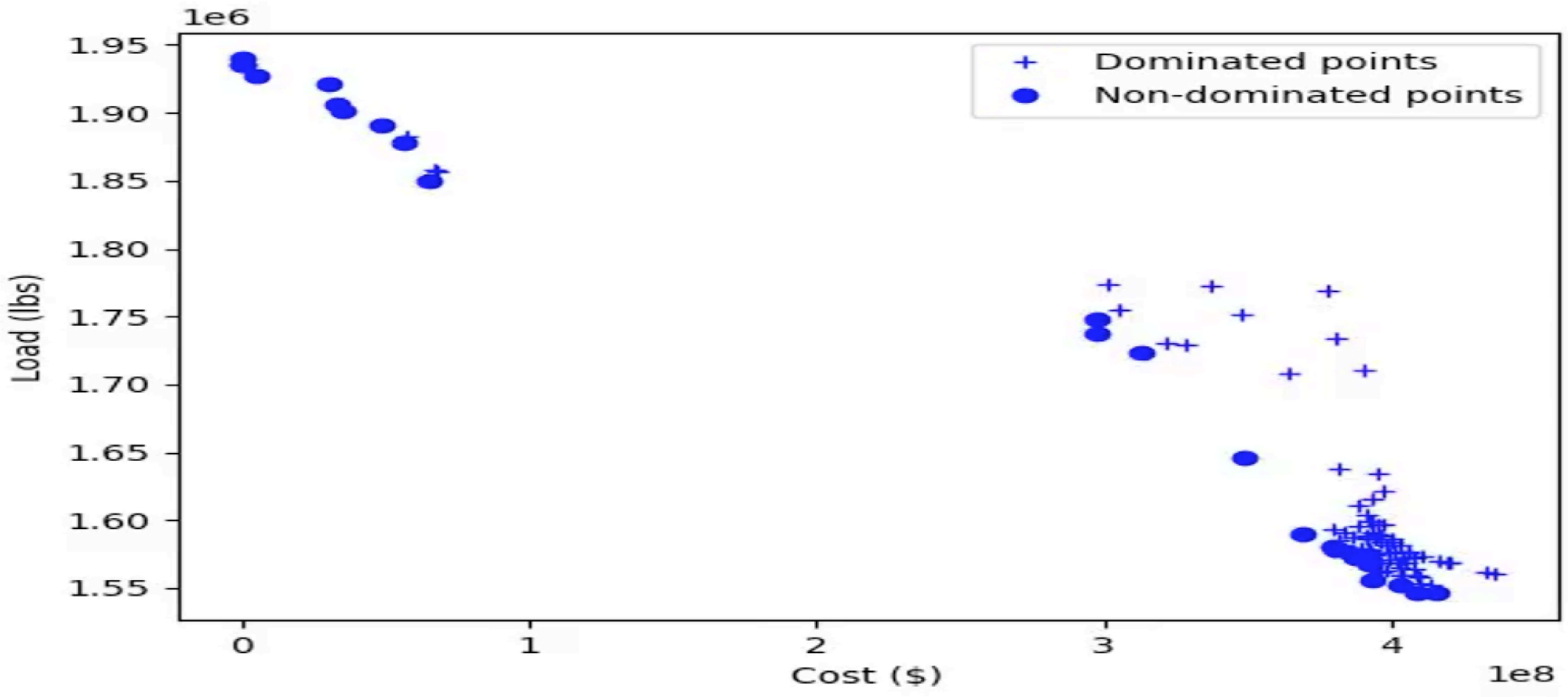


Project Progress

Phase II



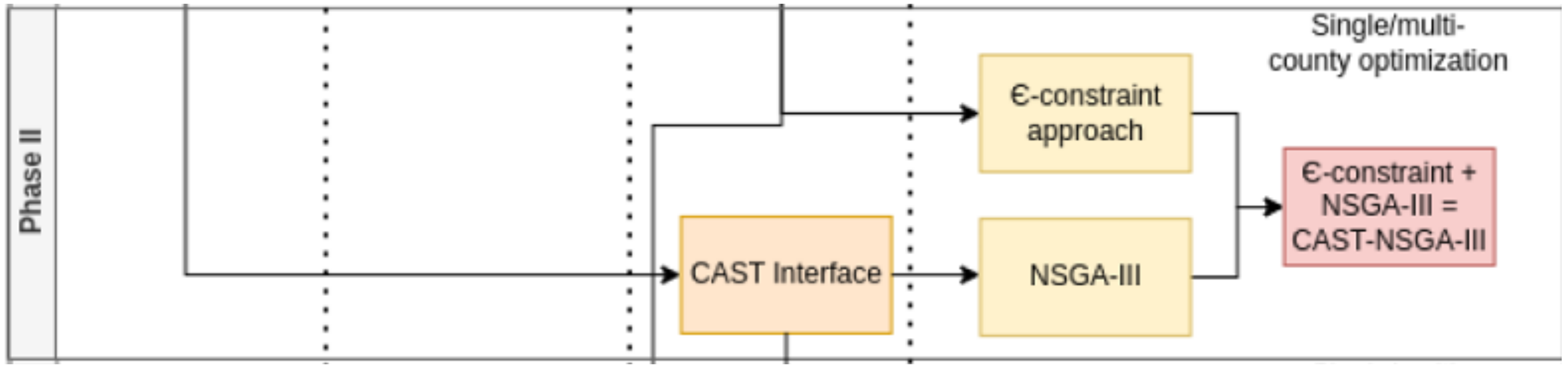


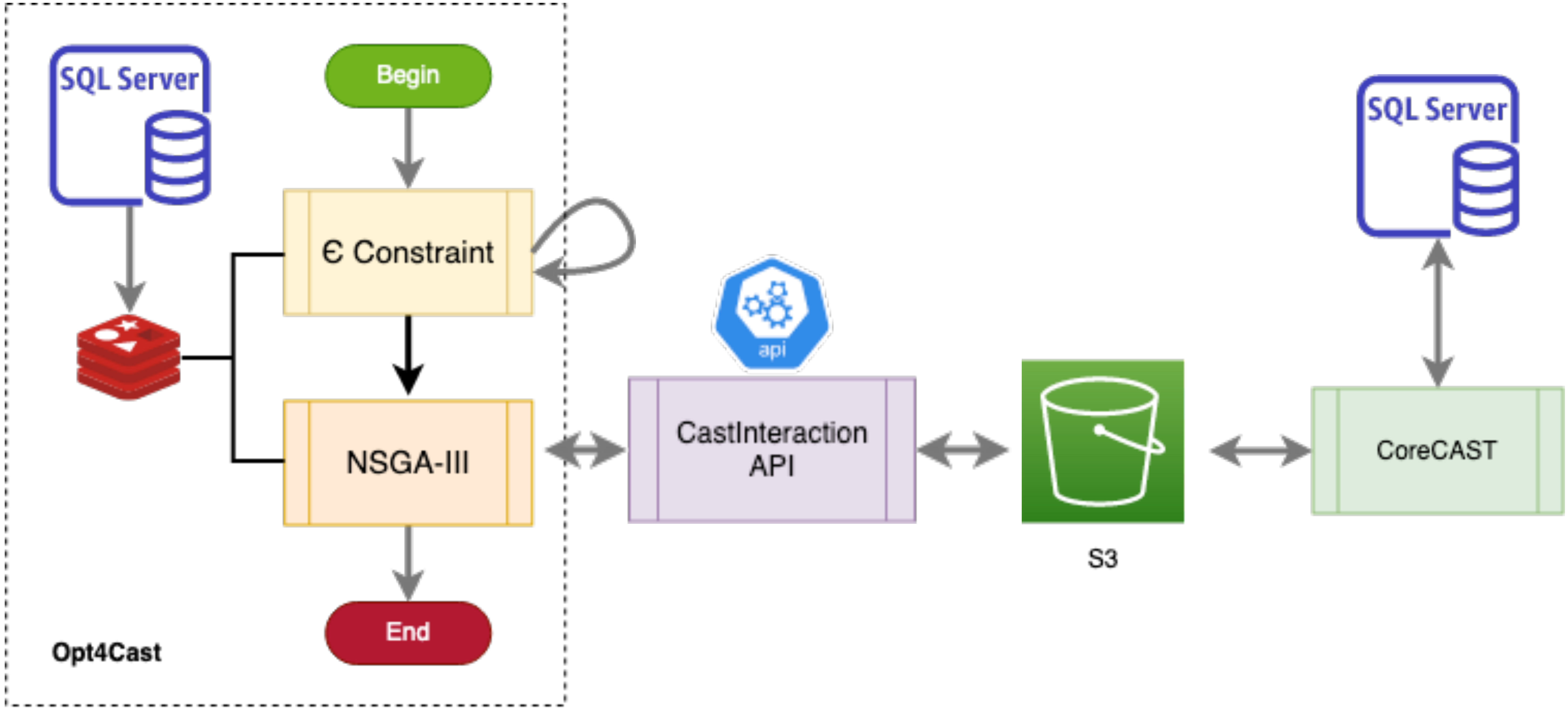


S3

Project Progress

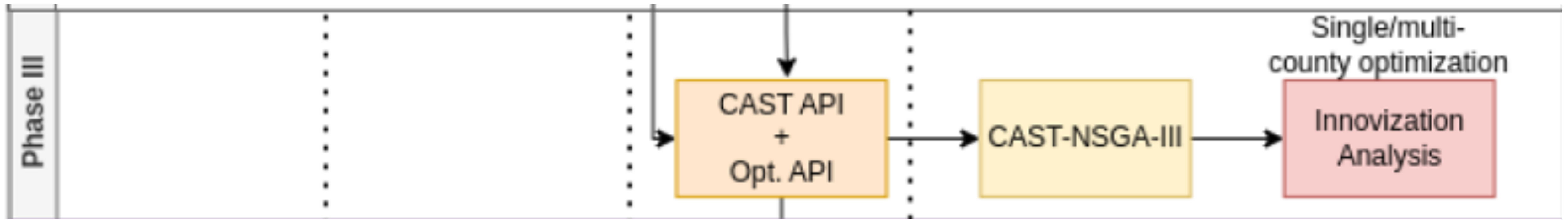
Phase II

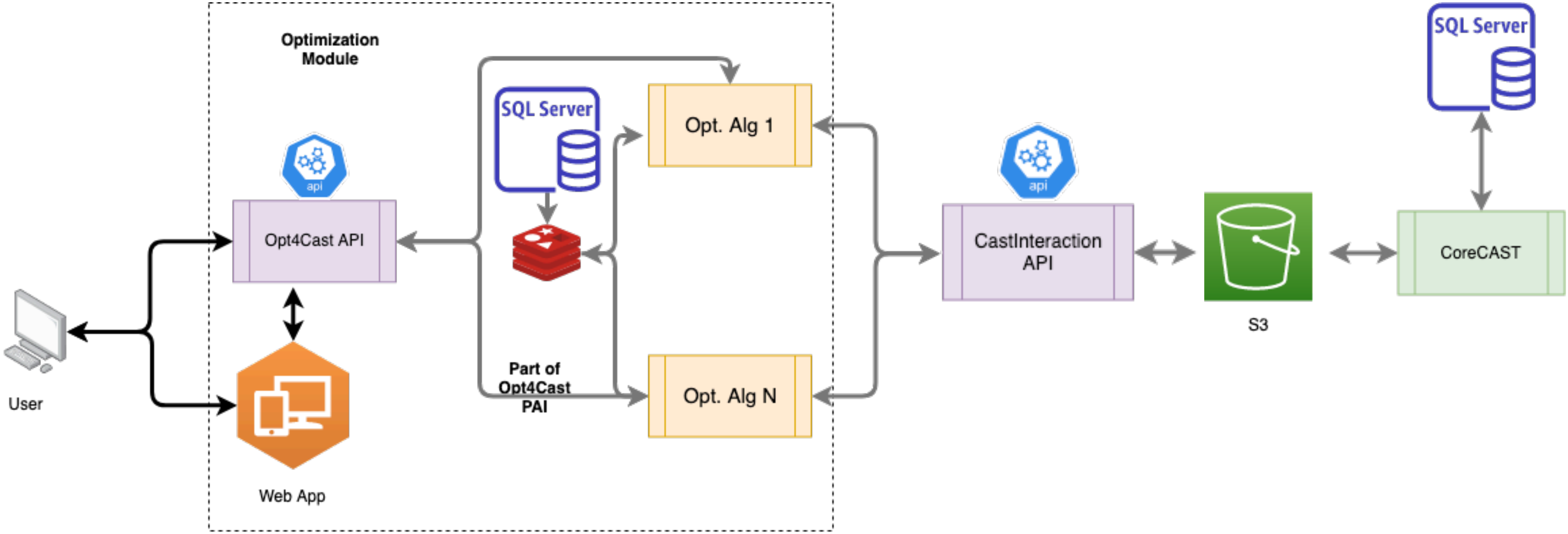




Project Progress

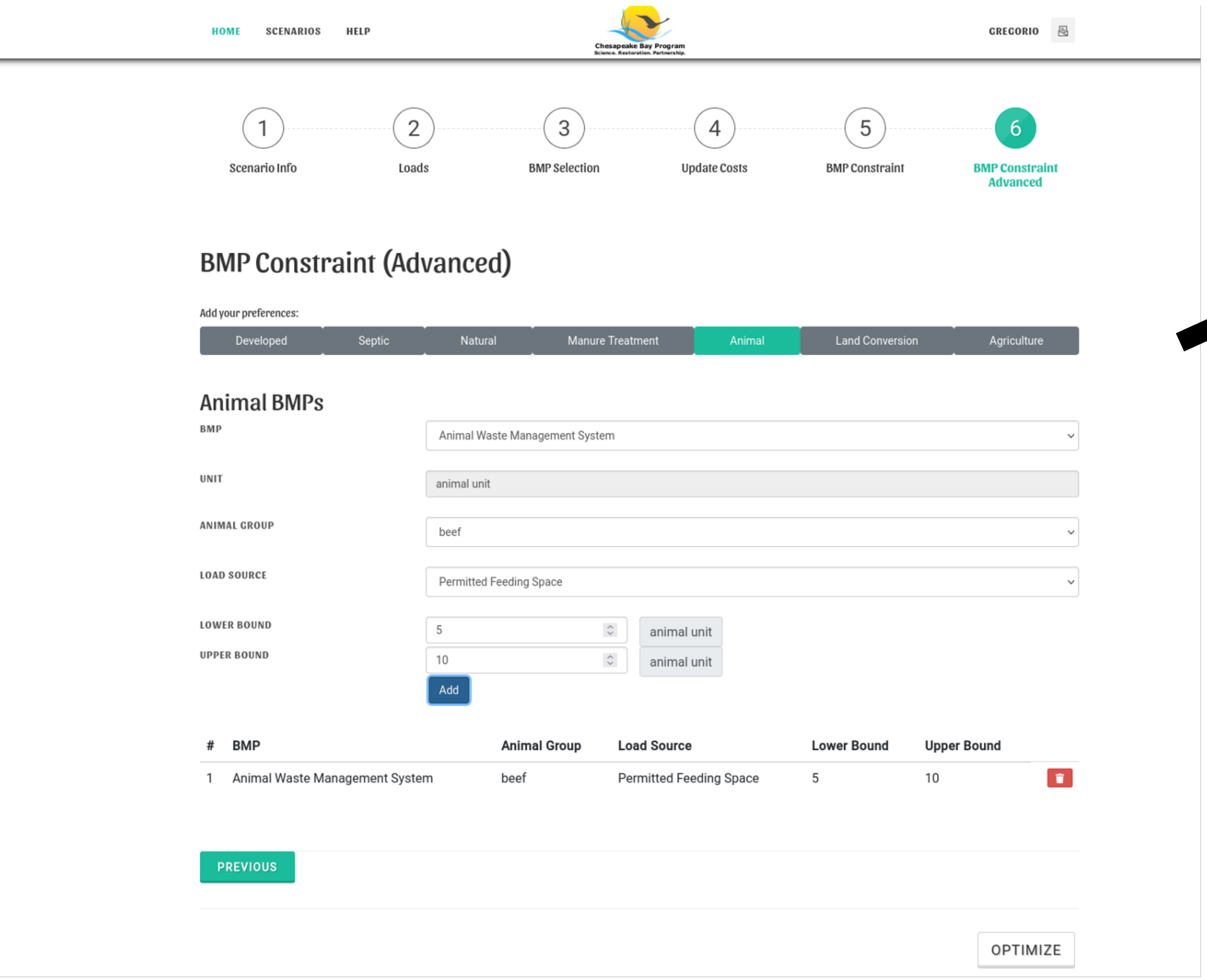
Phase II

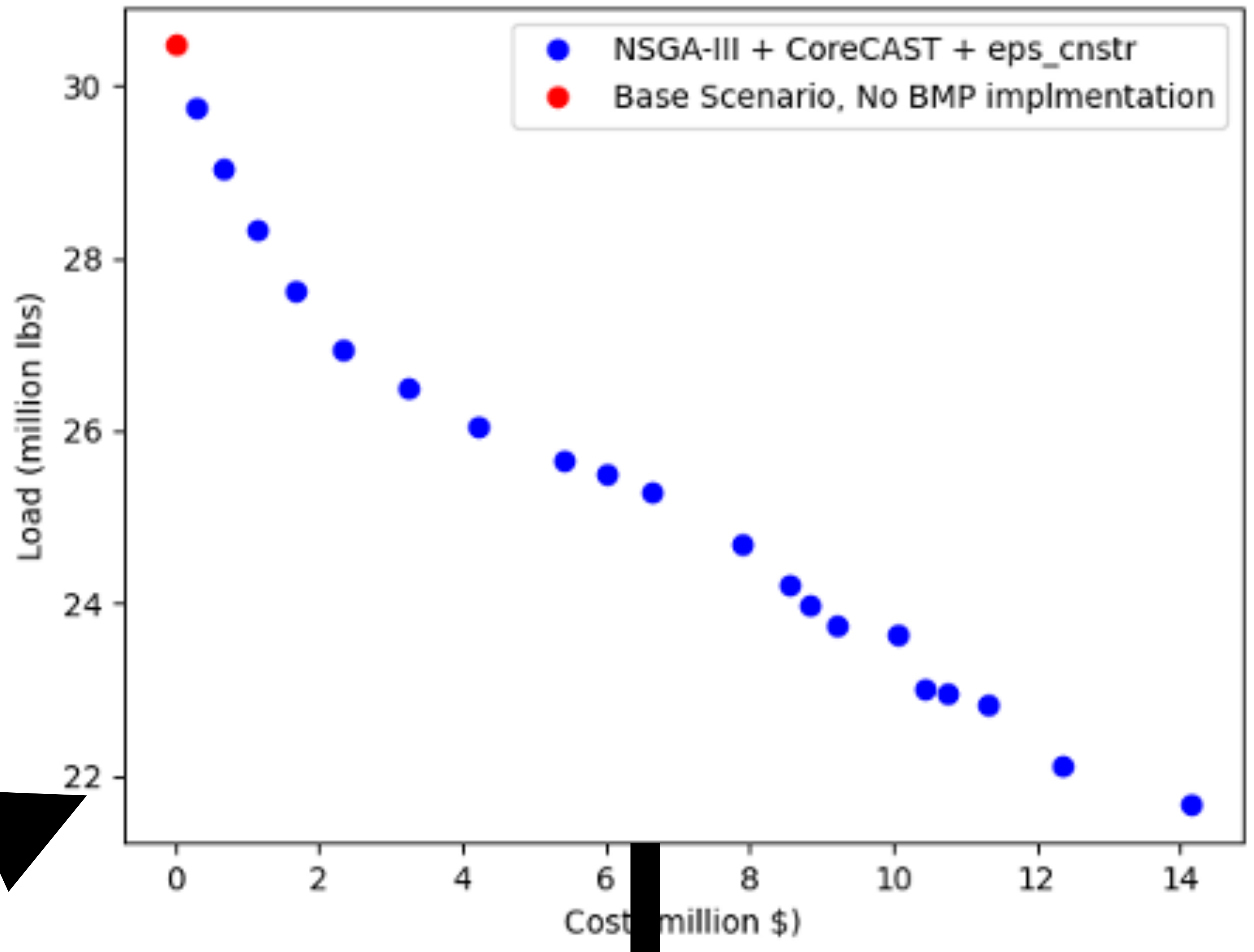


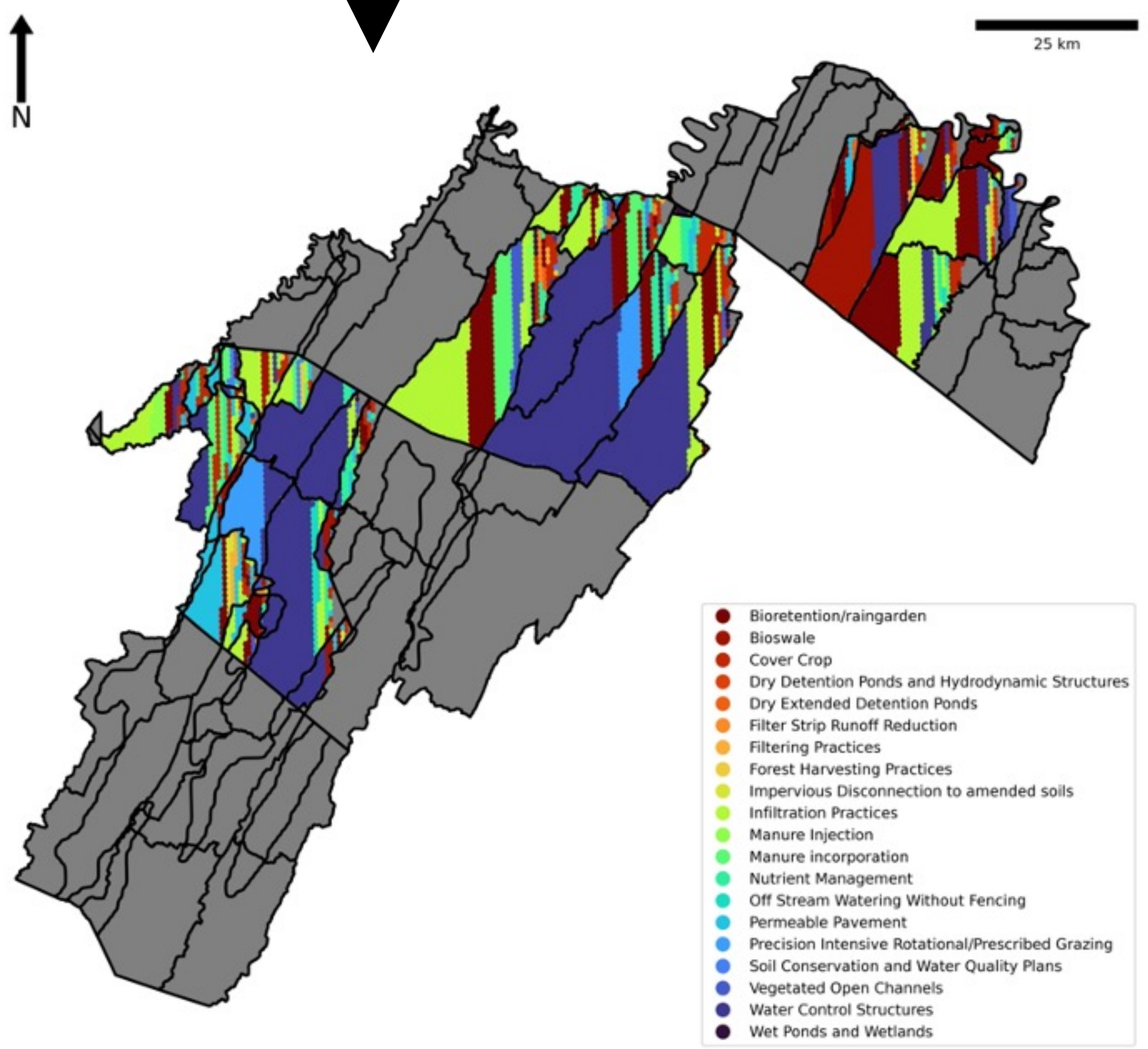


Project Progress

Phase II

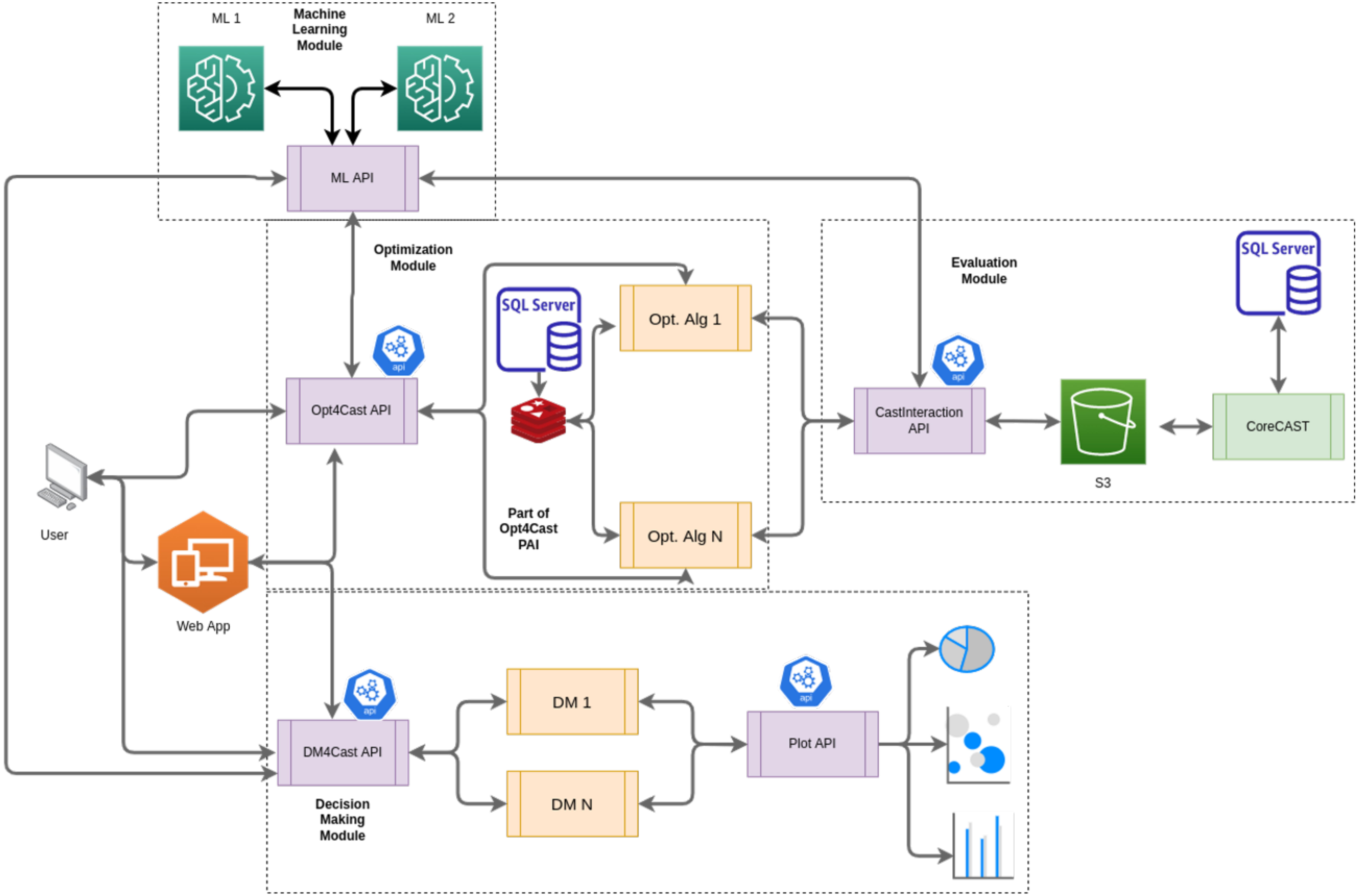






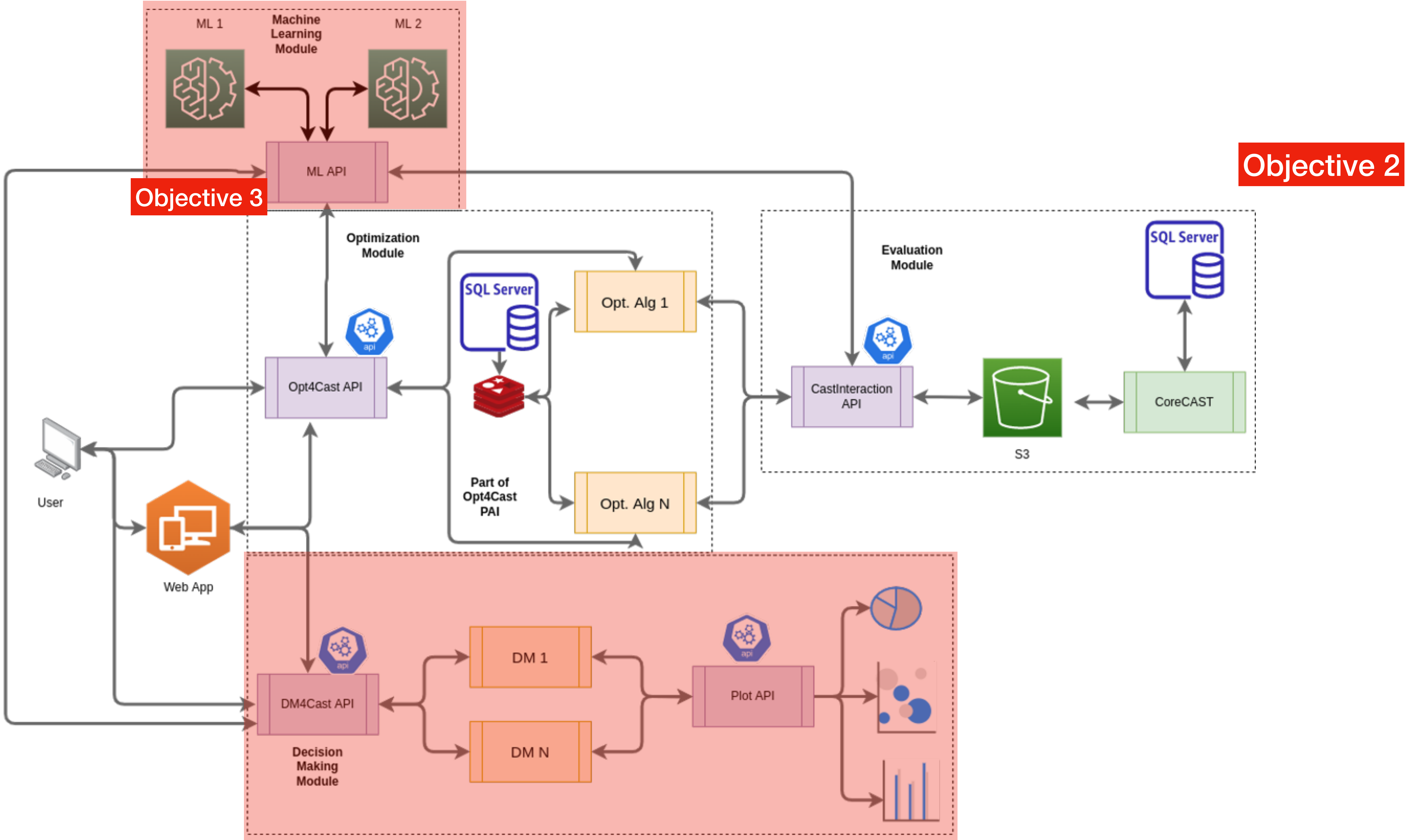
Projected Project Development

Phase II



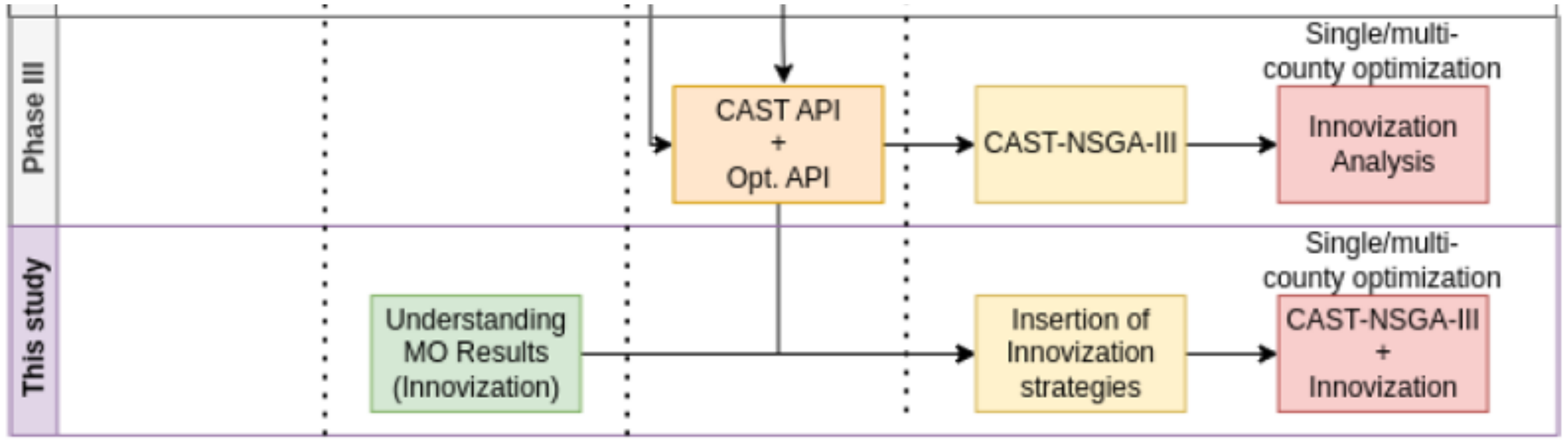
Projected Project Development

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:

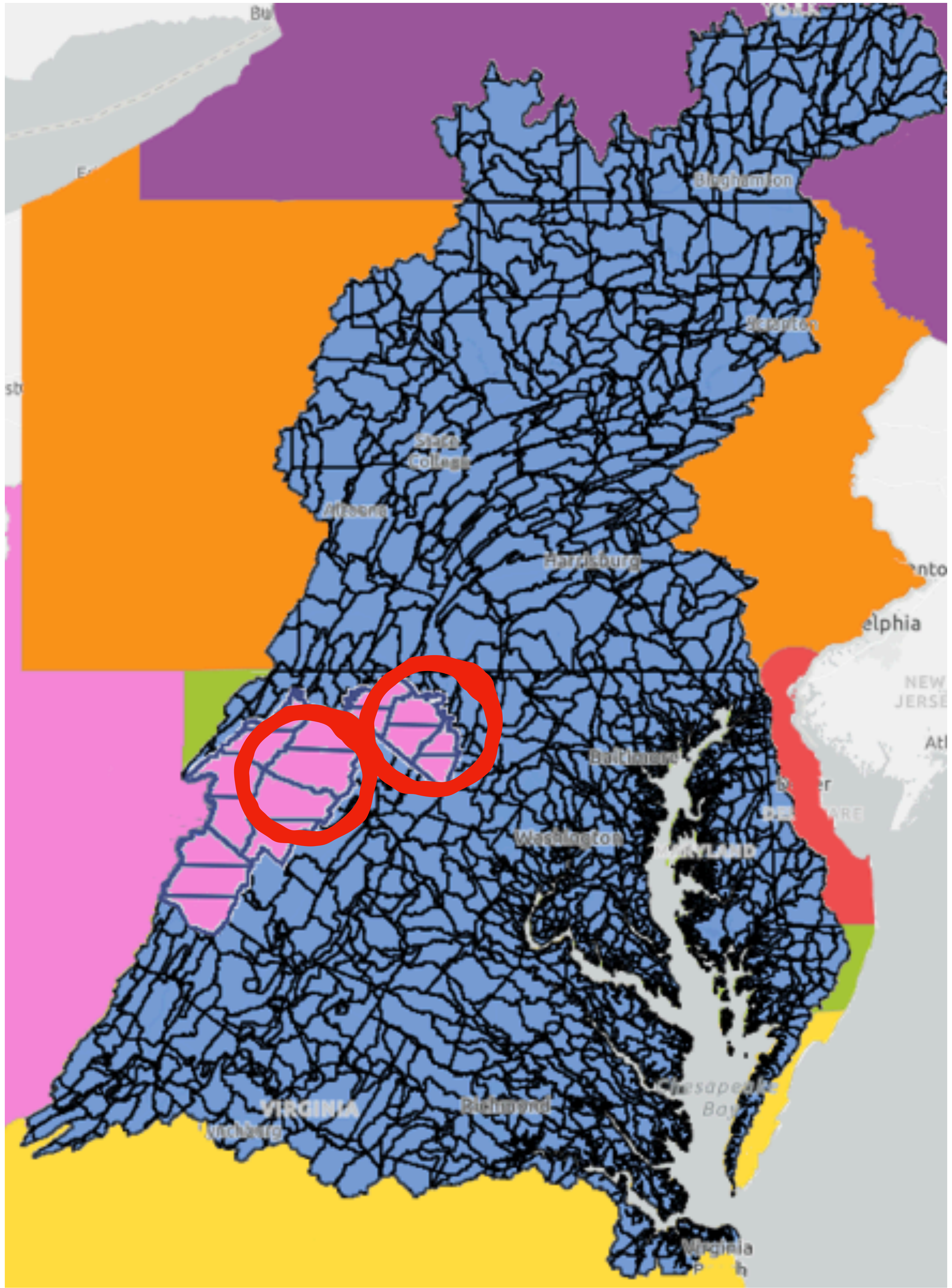
  A. Examine different ranking methodologies to **identify the top BMPs**,
  B. Identify the **similarities and differences** between top-ranked BMPs,
  C. Provide recommendations to **improve the optimization process.**

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.

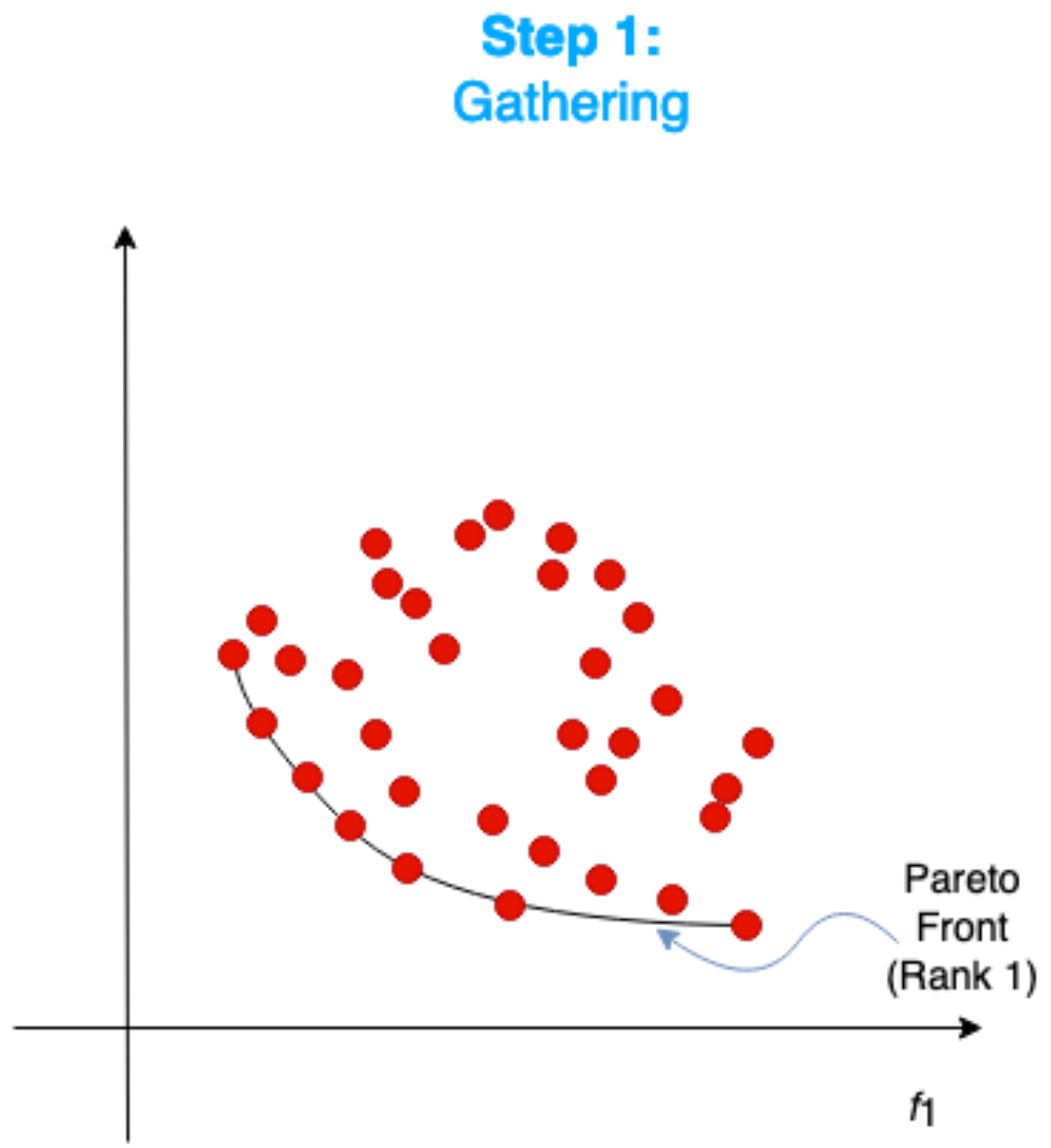
•(Berkeley and Mineral): Urban dominated
•(Jefferson and Hardy): Agricultural dominated



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)

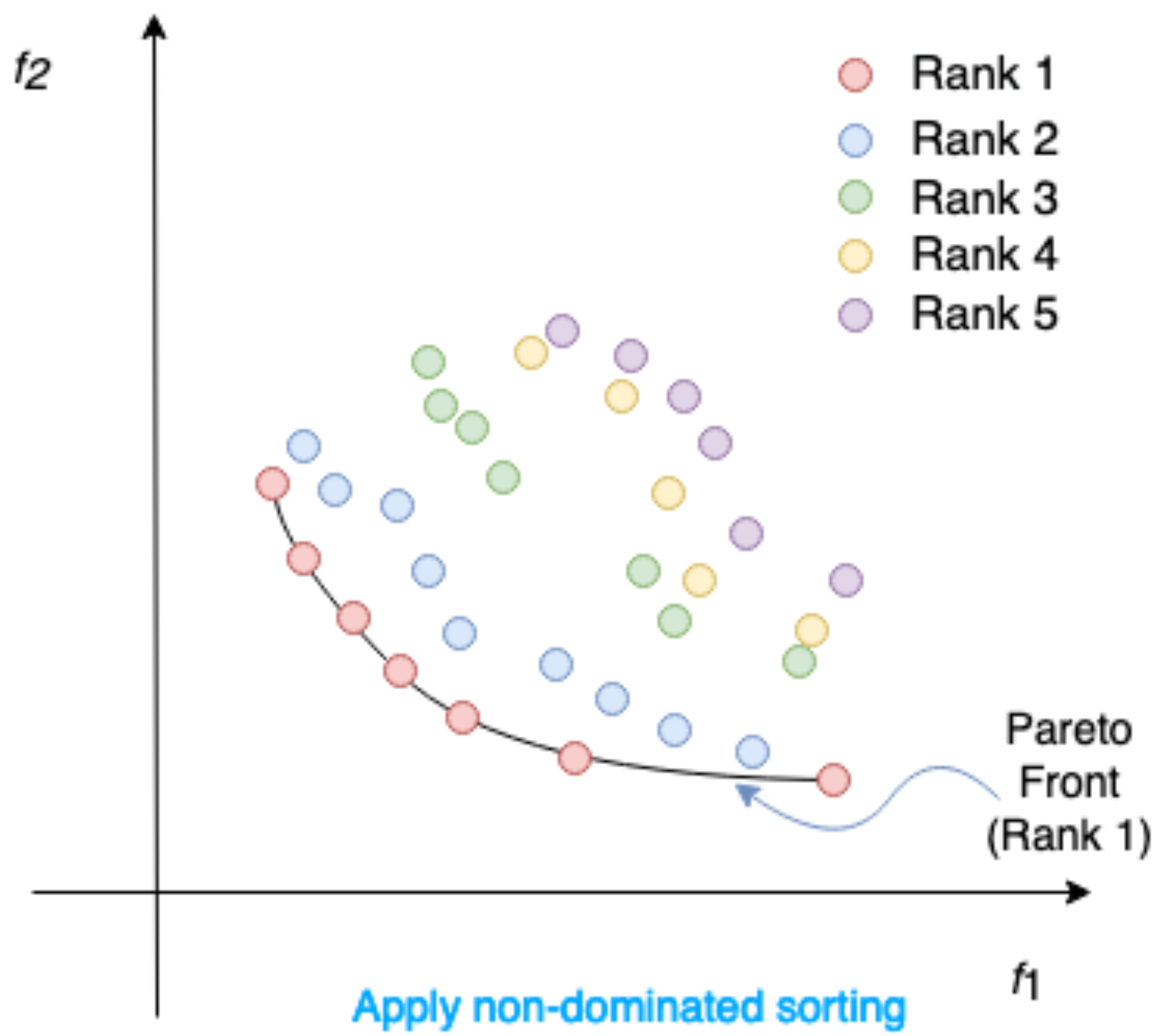


Innovization Experiment

BMP Selection ranking methodology based on Land use

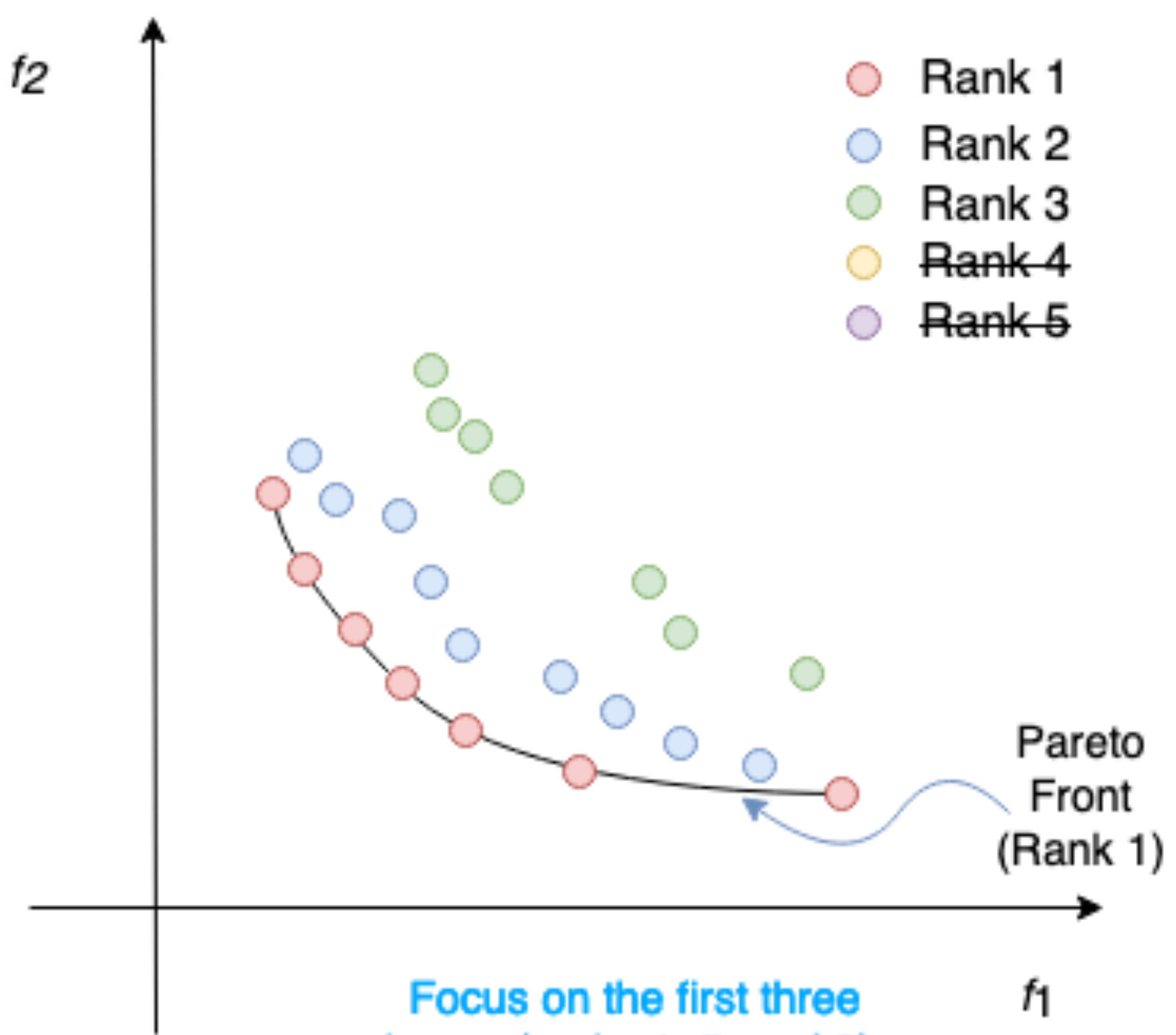
- We filtered the solutions regarding non-dominance layers

Step 2:
Apply non-dominated sorting



Apply non-dominated sorting and label solutions according to their rank layer

Step 3:
Discard lower ranks



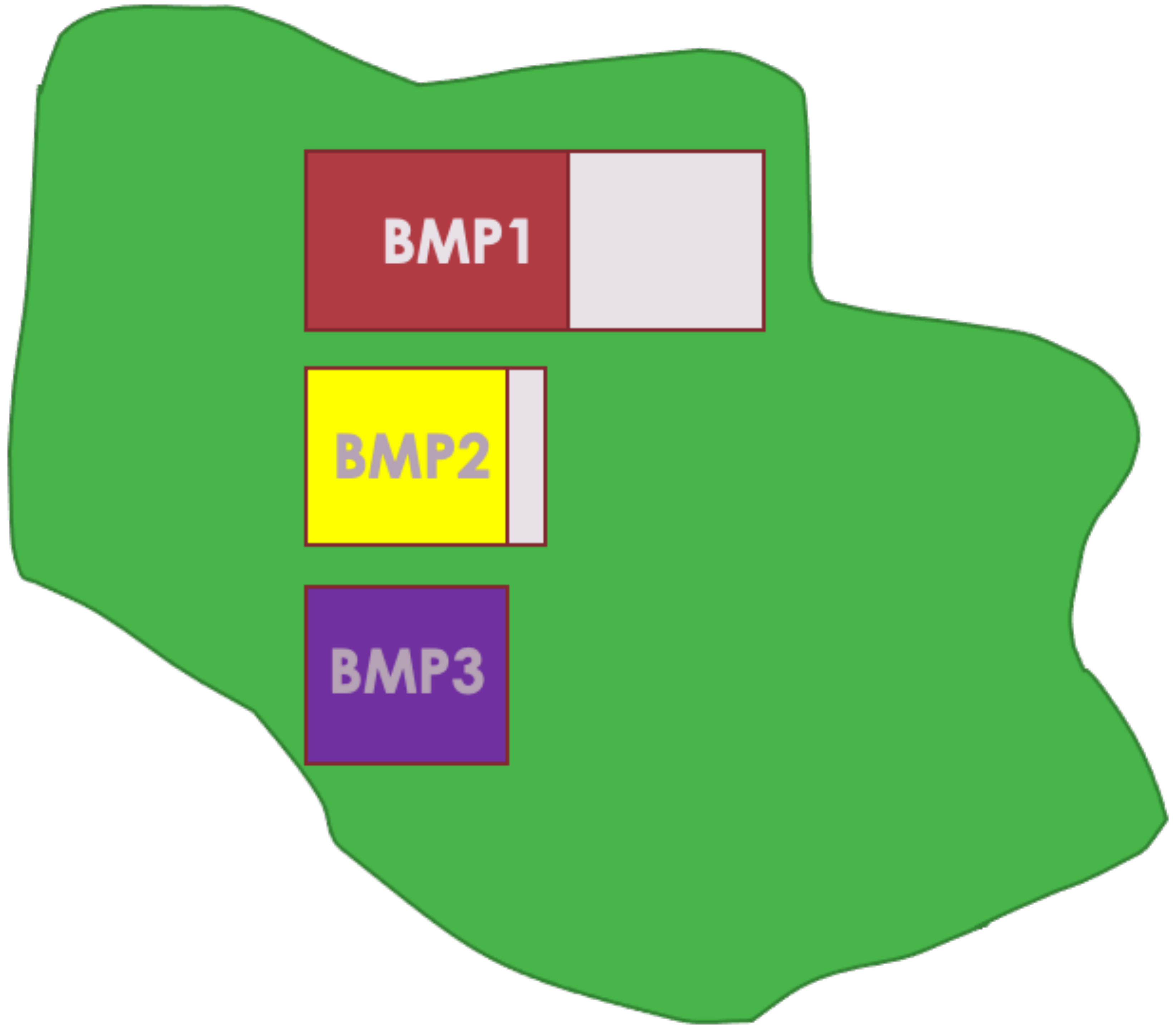
Focus on the first three layers (ranks 1, 2, and 3), discarding any solution beloging to lower ranks

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:

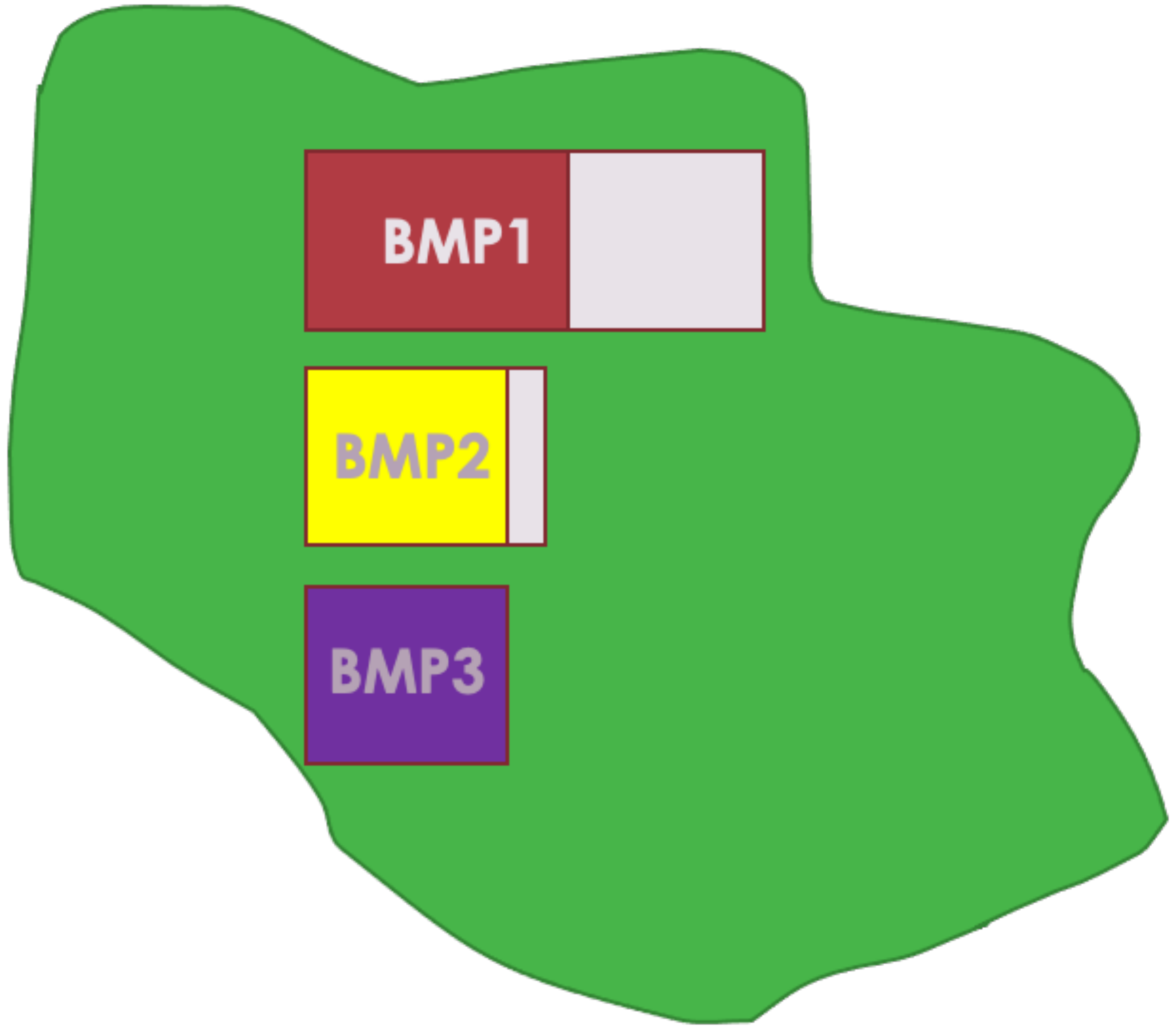
BMP1
BMP2
BMP3

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:

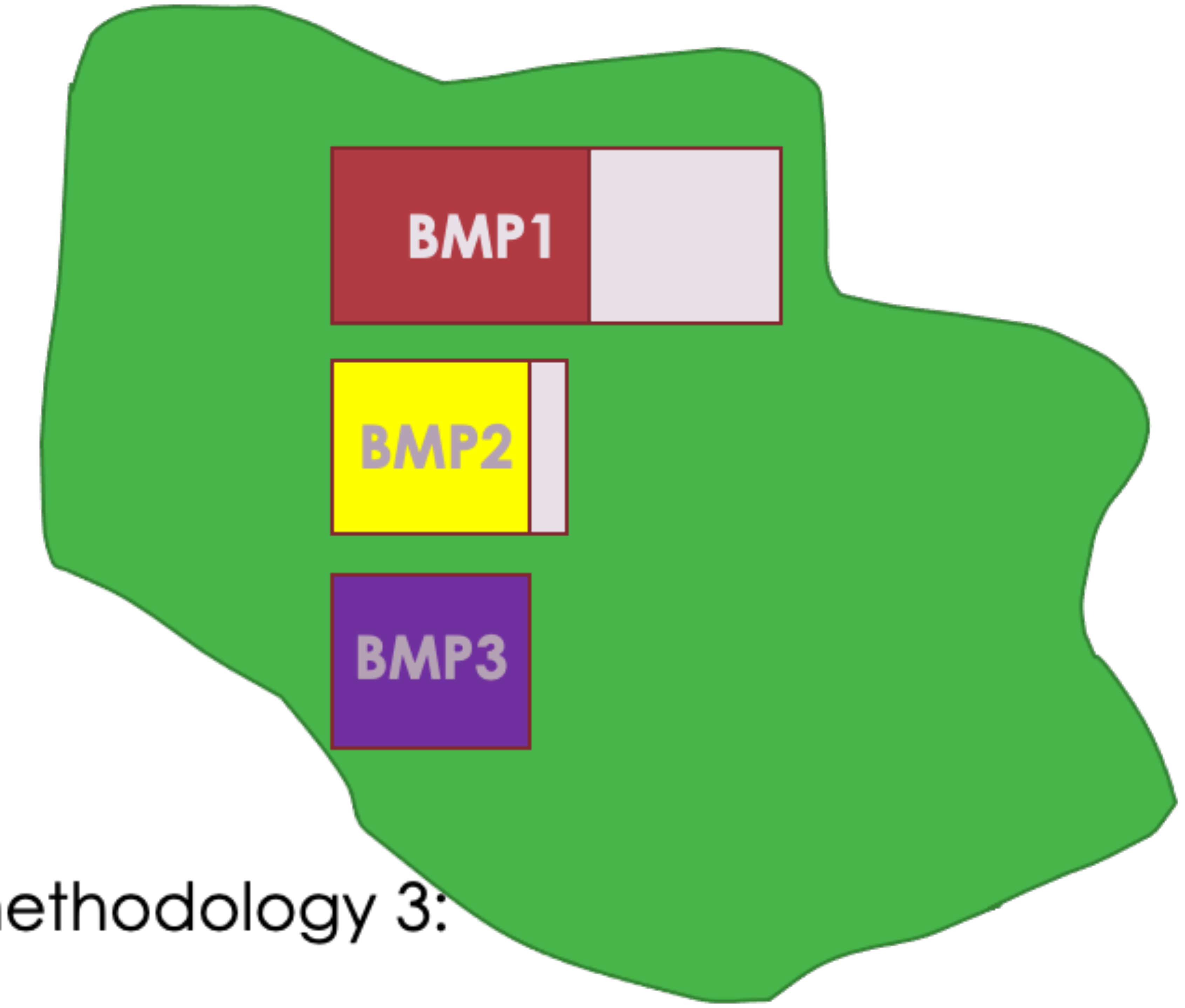
BMP3
BMP2
BMP1

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:

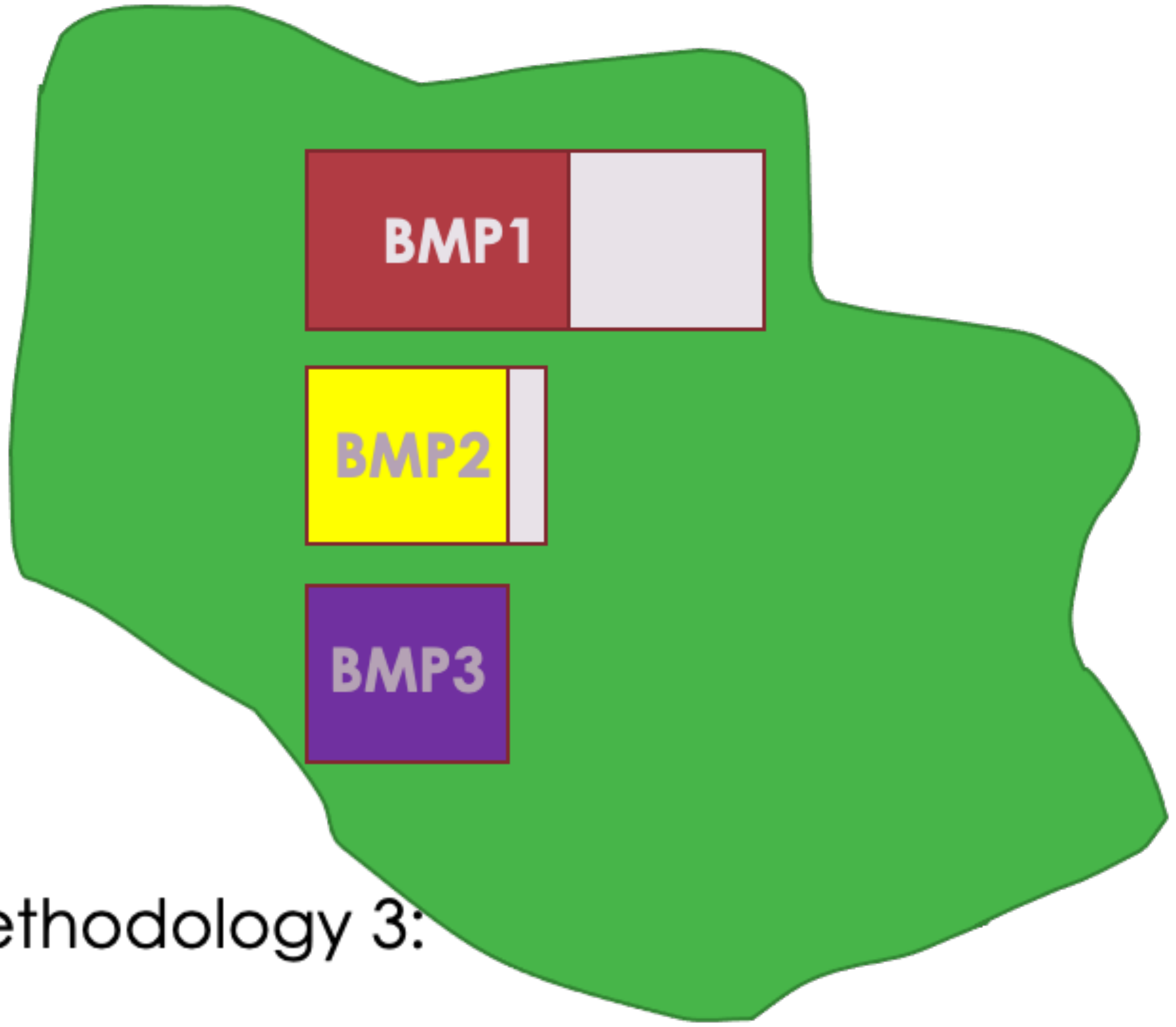
BMP2 ($12/lb N)
BMP3 ($15/lb N)
BMP1($24/lb N)

Methodology

BMP Selection ranking methodology based on Land use

Three ranking strategies from the combined Pareto front:

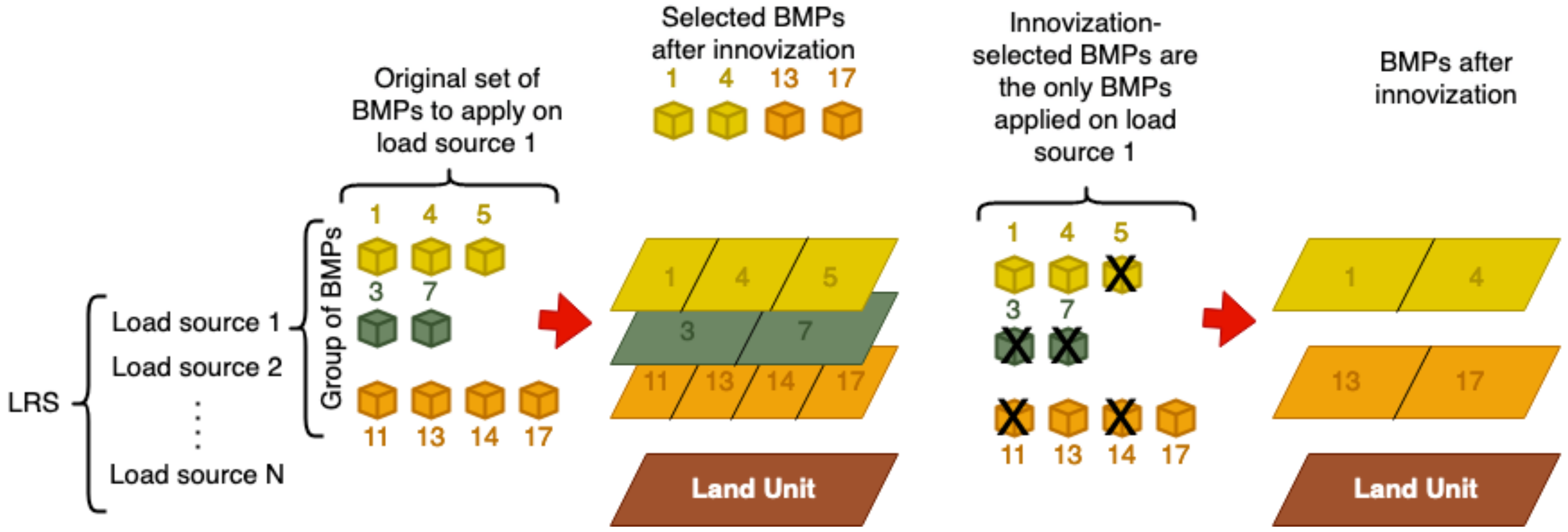
- **Strategy 1:** Rank the top BMPs based on the **implementation acreages**;
- **Strategy 2:** Rank the top BMPs based on the percentage of **maximum allowable acreages**;
- **Strategy 3:** Rank the top BMPs based on the amount of **nitrogen reduction per dollar spent.**



Ranking methodology 1:	Ranking methodology 2:	Ranking methodology 3:
BMP1	BMP3	BMP2 ($12/lb N)
BMP2	BMP2	BMP3 ($15/lb N)
BMP3	BMP1	BMP1($24/lb N)

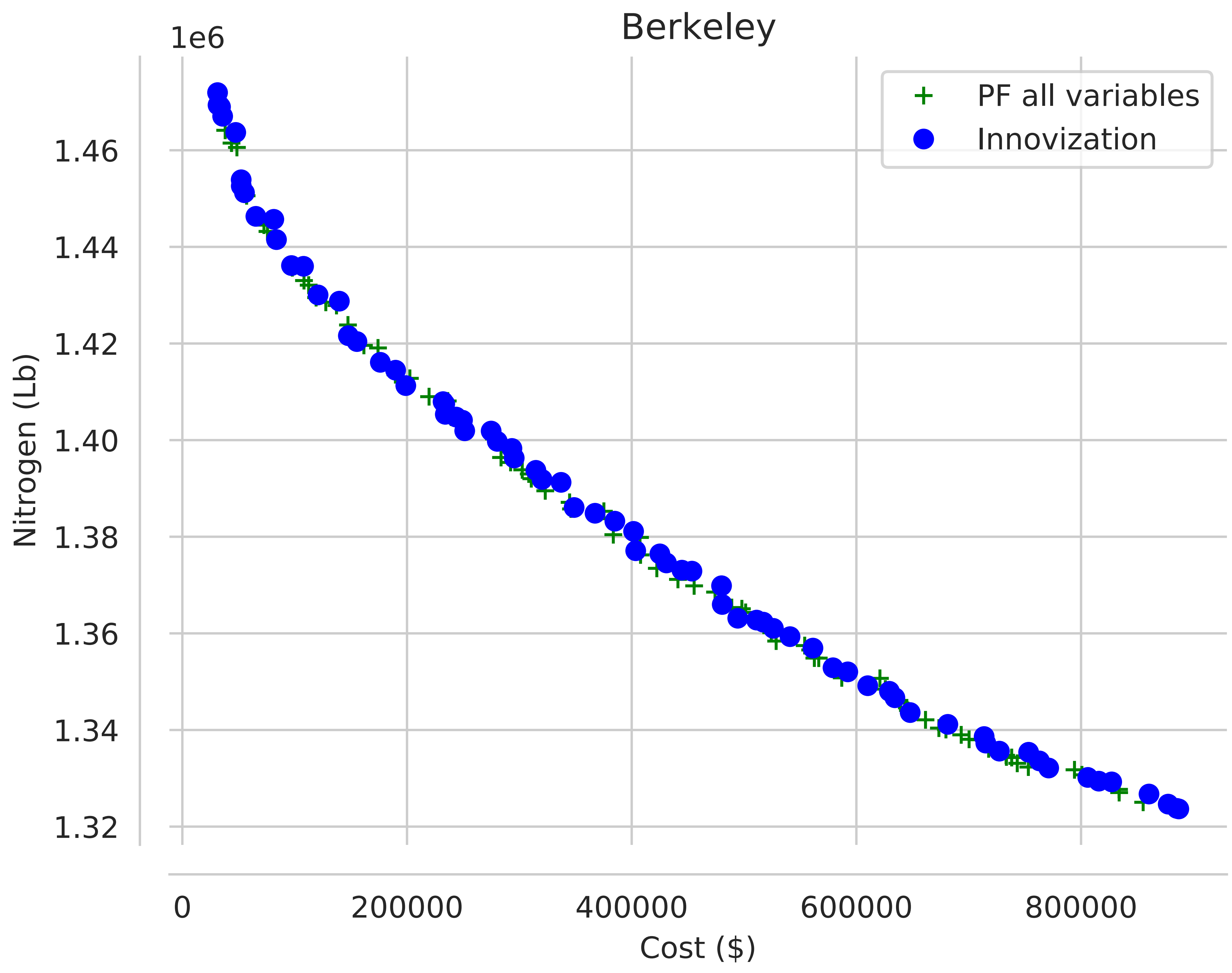
Re-optimization

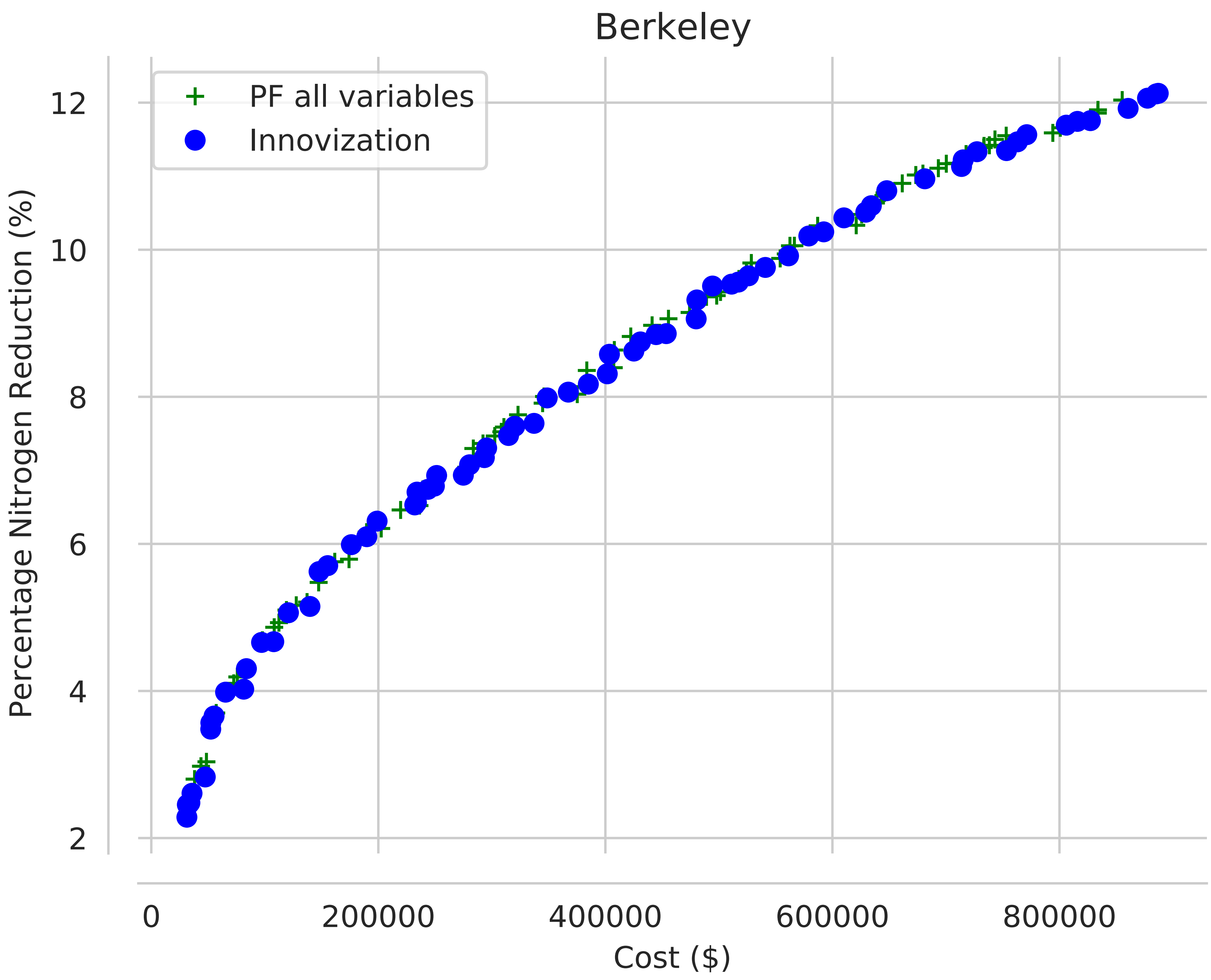
Example of method to use a re-optimization-based innovization



Results for Berkeley County

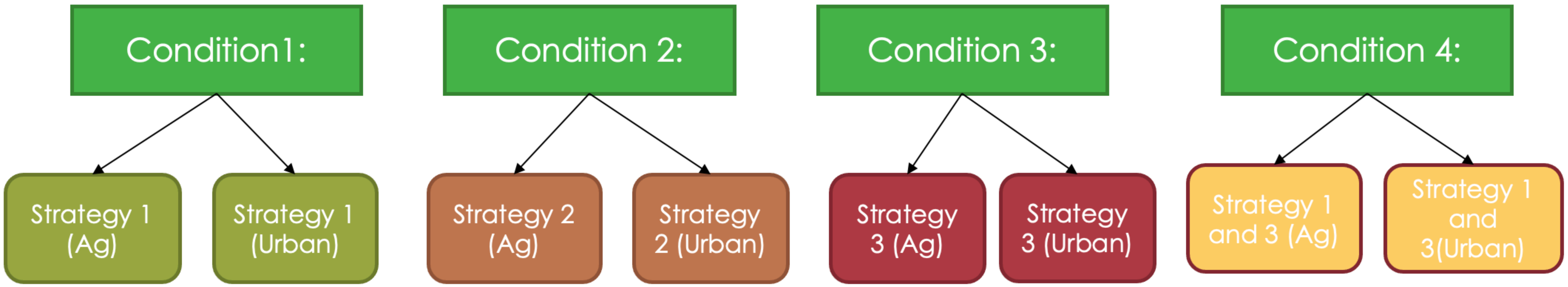
Variable reduction of 30%





Four Conditions for Re-Optimization

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

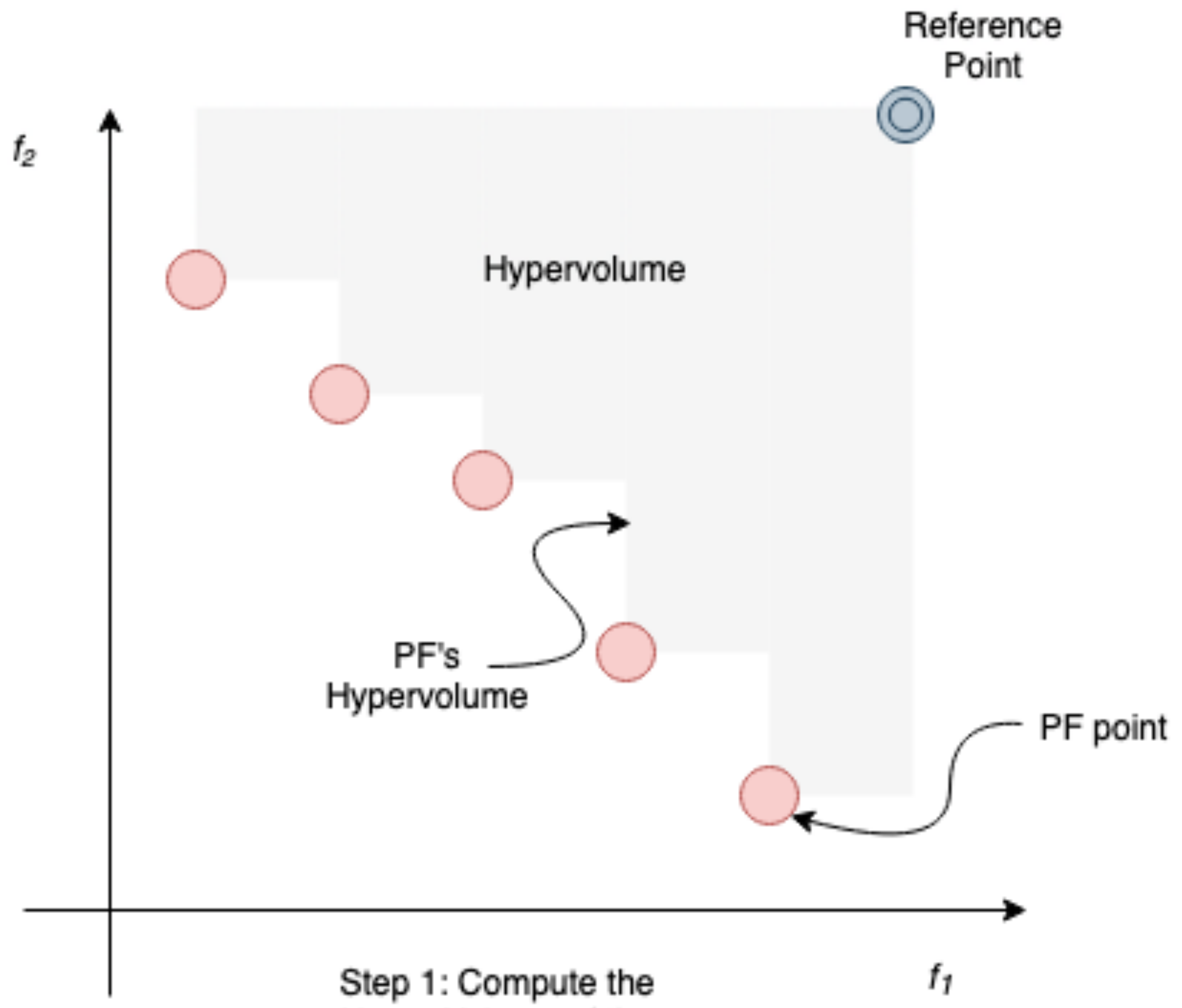


Variable reduction.

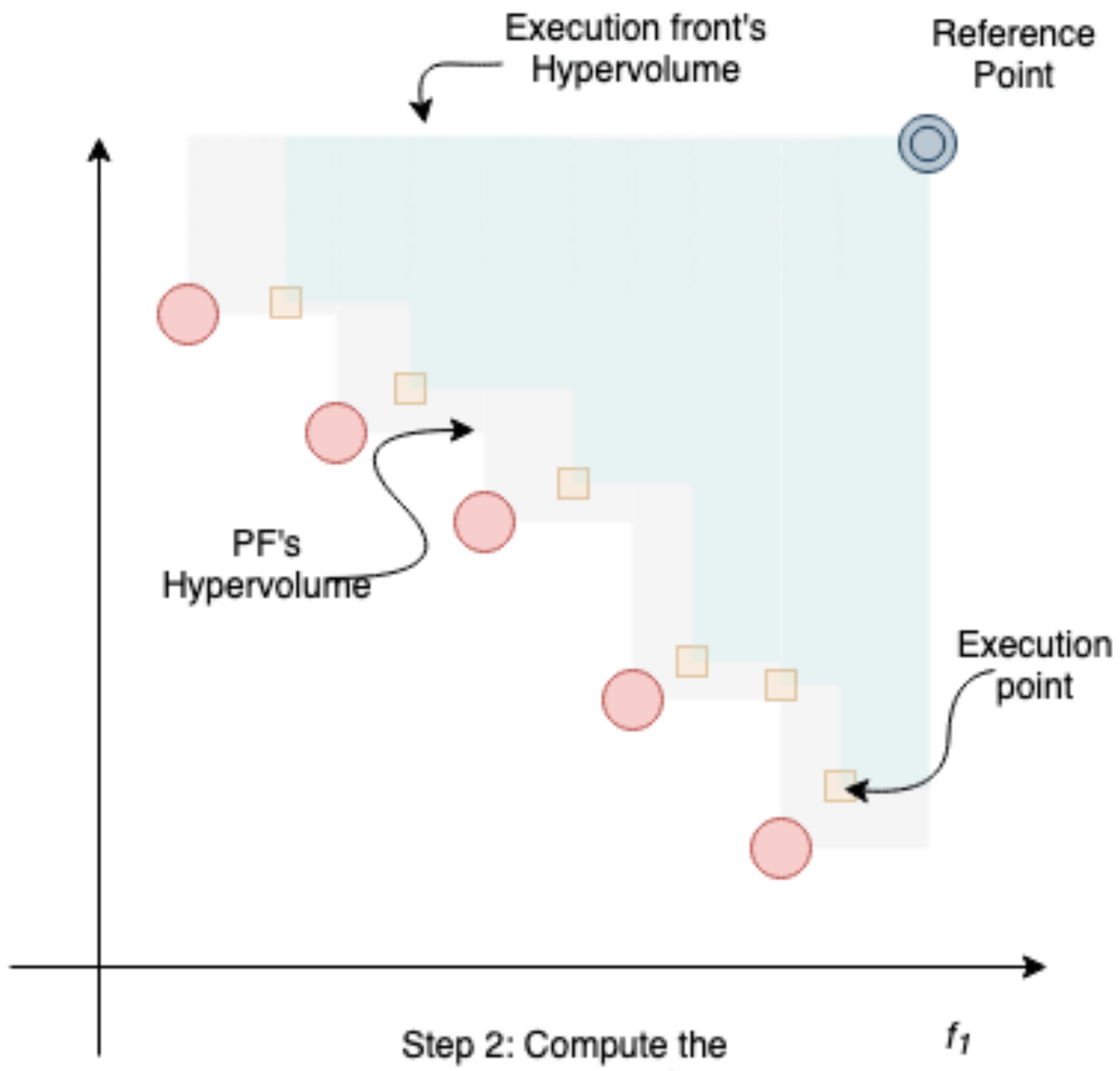
	Berkeley	% of all vars	Mineral	% of all vars	Hardy	% of all vars	Jefferson	% of all vars
All Variables	14090	100	20260	100	18607	100	12303	100
Condition 1	537	3.81	810	4.00	777	4.18	488	3.97
Condition 2	654	4.64	990	4.89	946	5.08	592	4.81
Condition 3	681	4.83	1020	5.03	959	5.15	600	4.88
Condition 4	717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

Performance Measure

Ratio of the Hypervolume



Step 1: Compute the Hyper-Volume of the PF



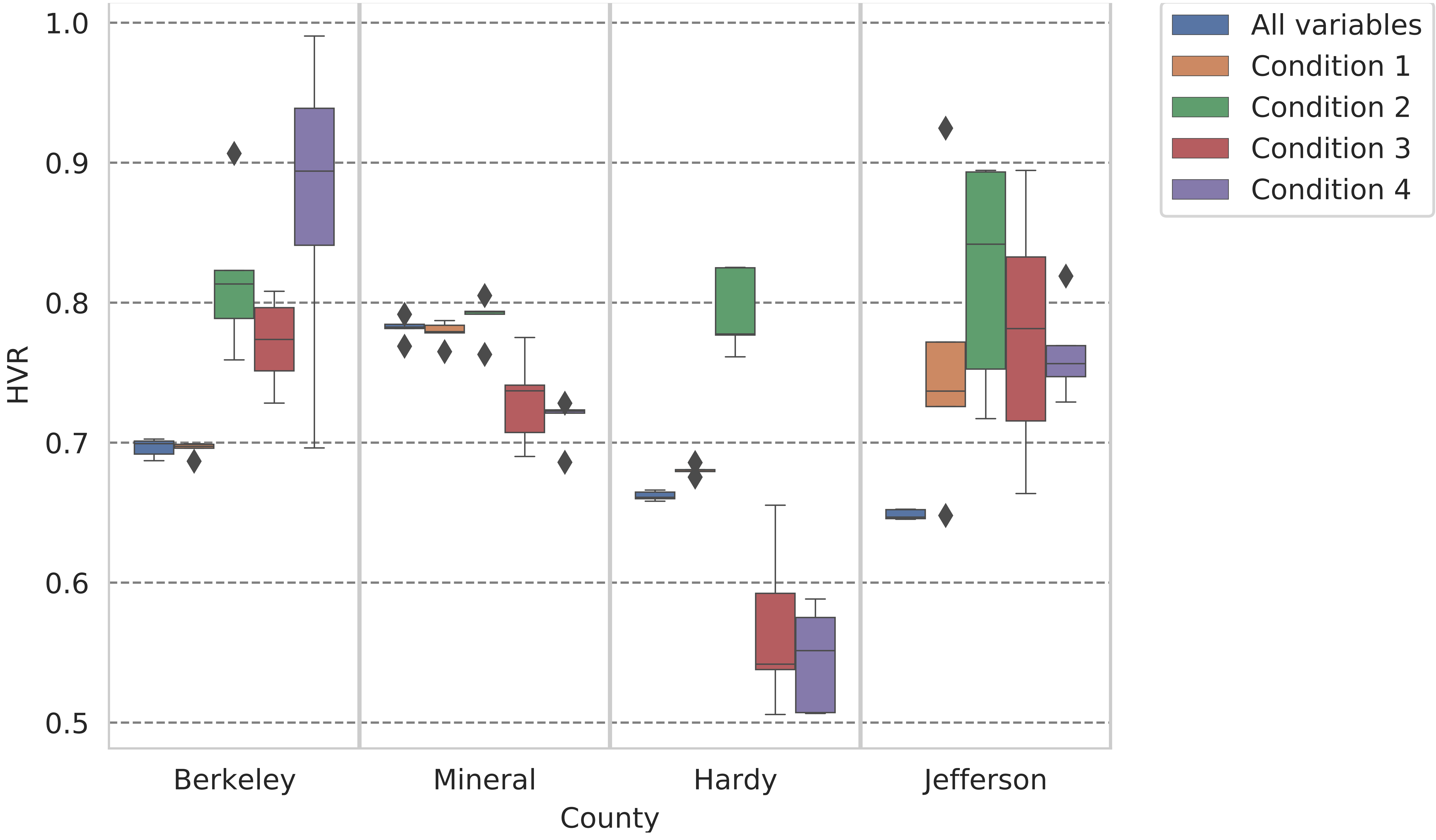
Step 2: Compute the Hyper-Volume of an aribitrary execution

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

Step 3: Compute the HVR

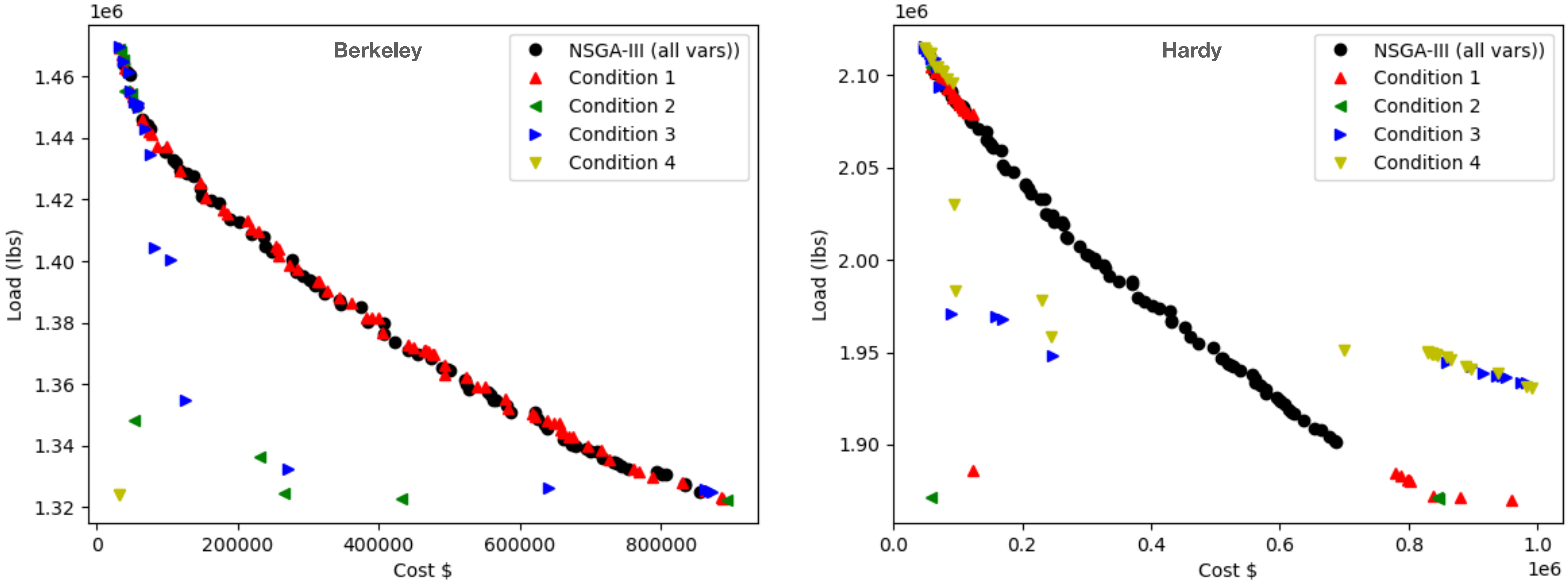
Performance Measure

Ratio of the Hypervolume



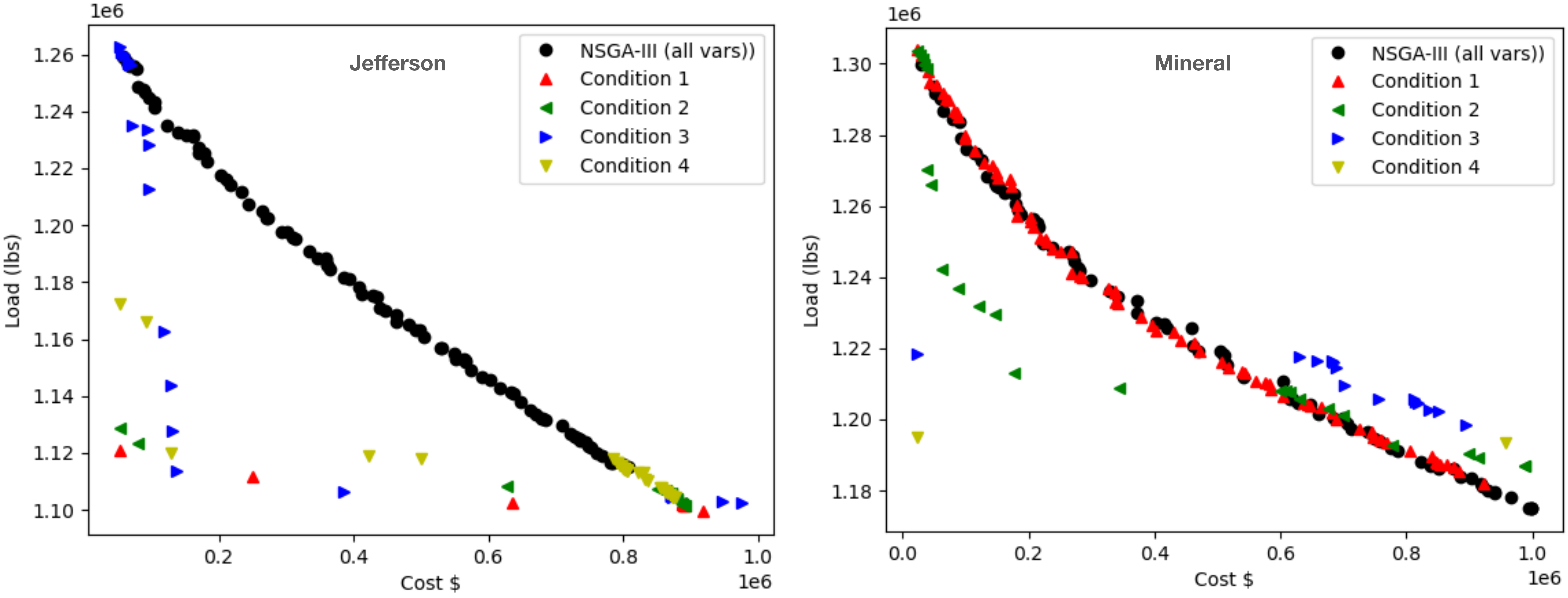
Re-optimization-based Innovization

Berkeley and Hardy

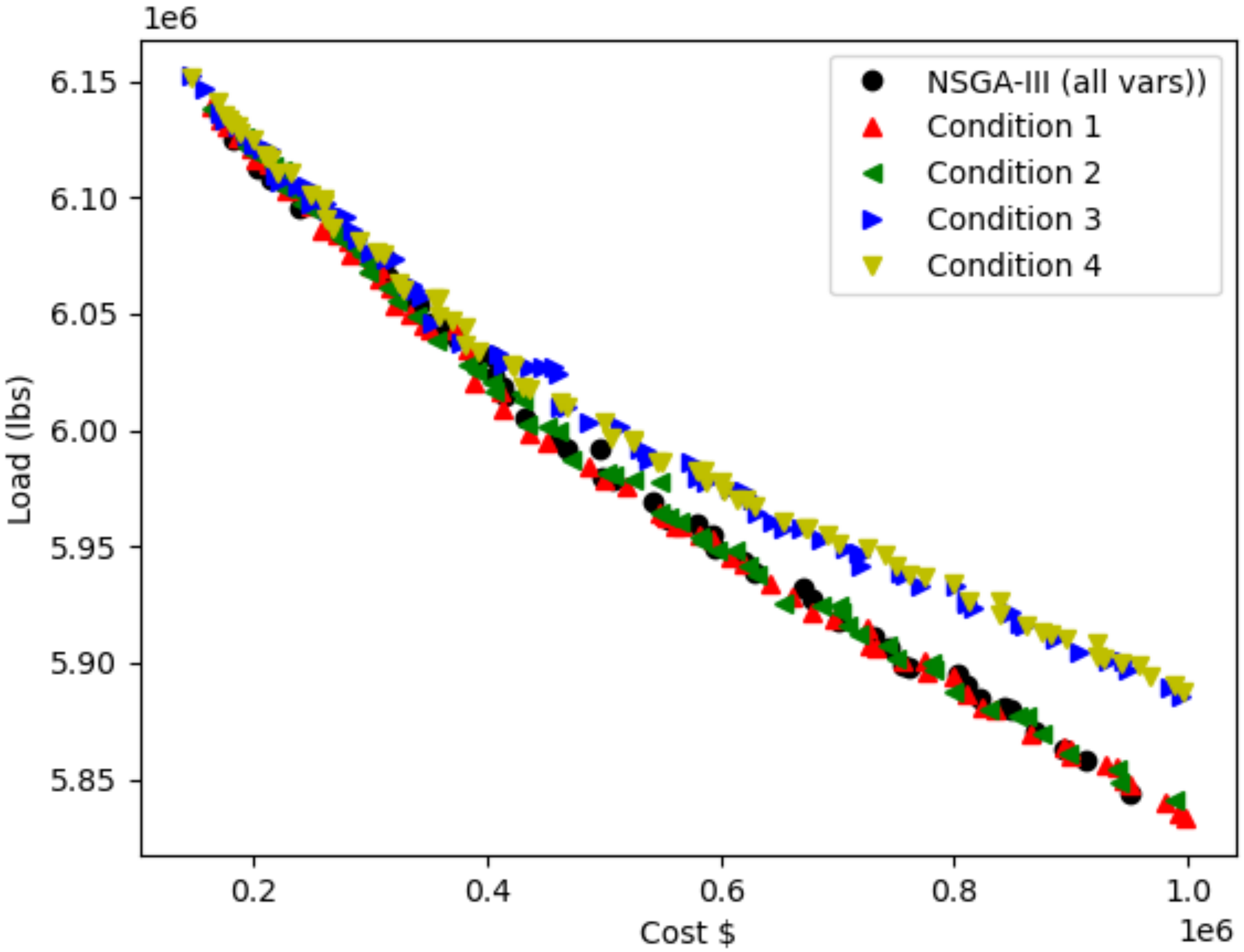


Re-optimization-based Innovization

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!