



ENVIRONMENTAL  
INTELLIGENCE LAB



# OPERATIONS ECLIPSE SEQUENCING IN MULTIPURPOSE DAM PLANNING

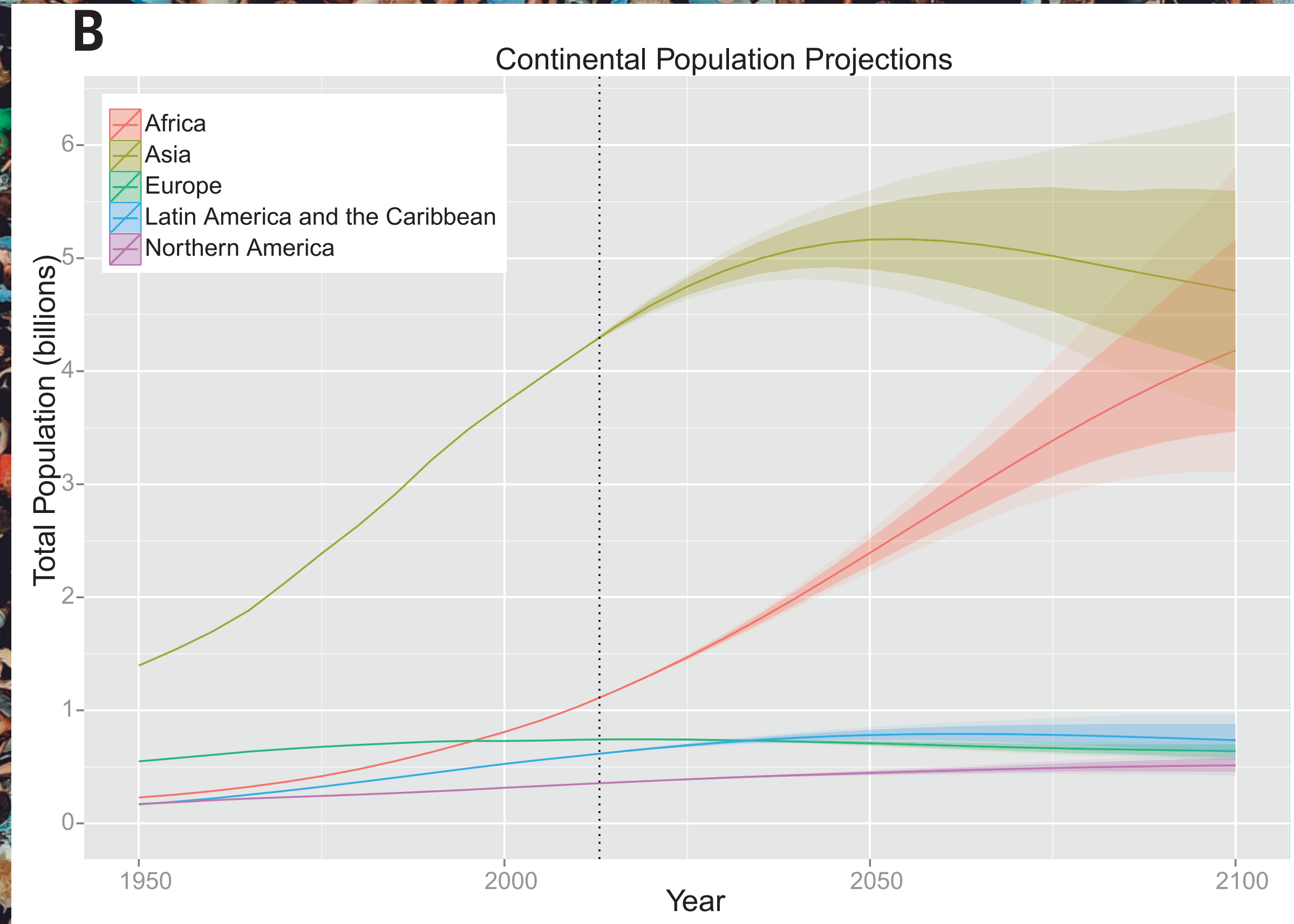
M. Giuliani, W. Arnold, J. Zatarain Salazar, A. Carlino, A. Castelletti



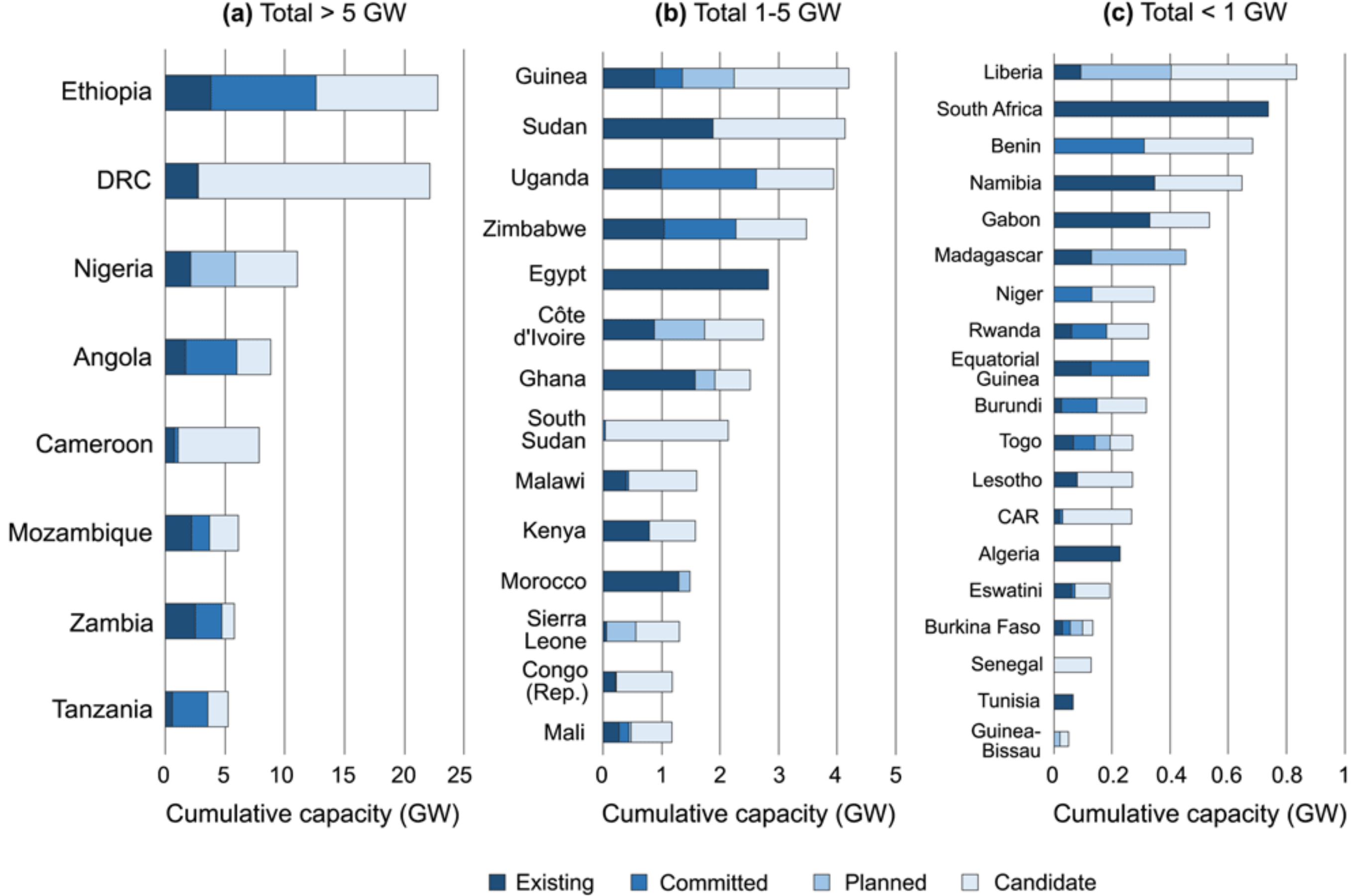
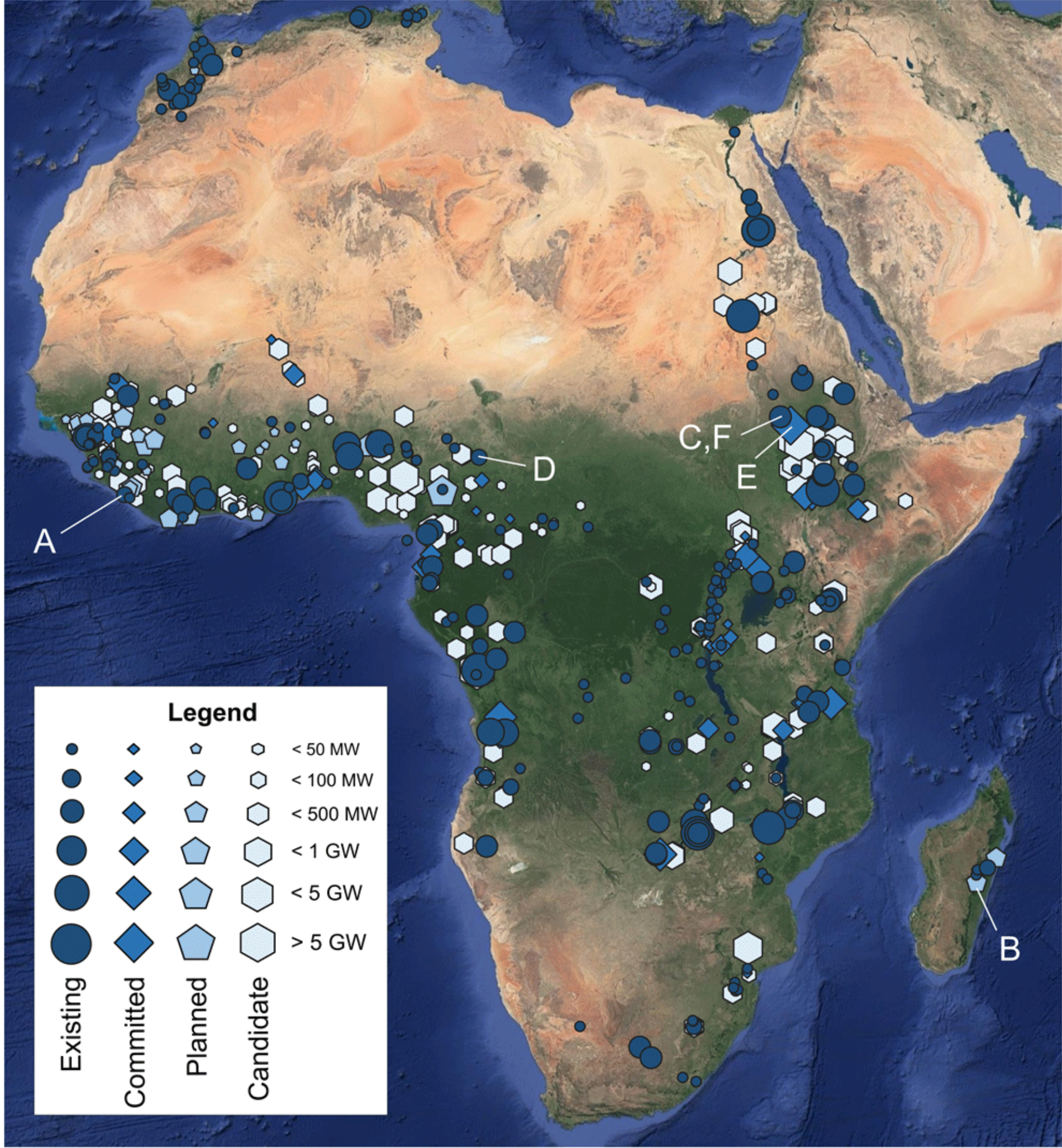
POLITECNICO  
MILANO 1863

G O N E U S

# GROWING POPULATION INCREASES WATER-ENERGY-FOOD DEMANDS



# DAMS ARE OFTEN USED TO SUPPORT ECONOMIC DEVELOPMENT



Source: Sterl et al. (2022)

# WHICH DAM TO BUILD? WHEN? AND HOW TO OPERATE THE SYSTEM?

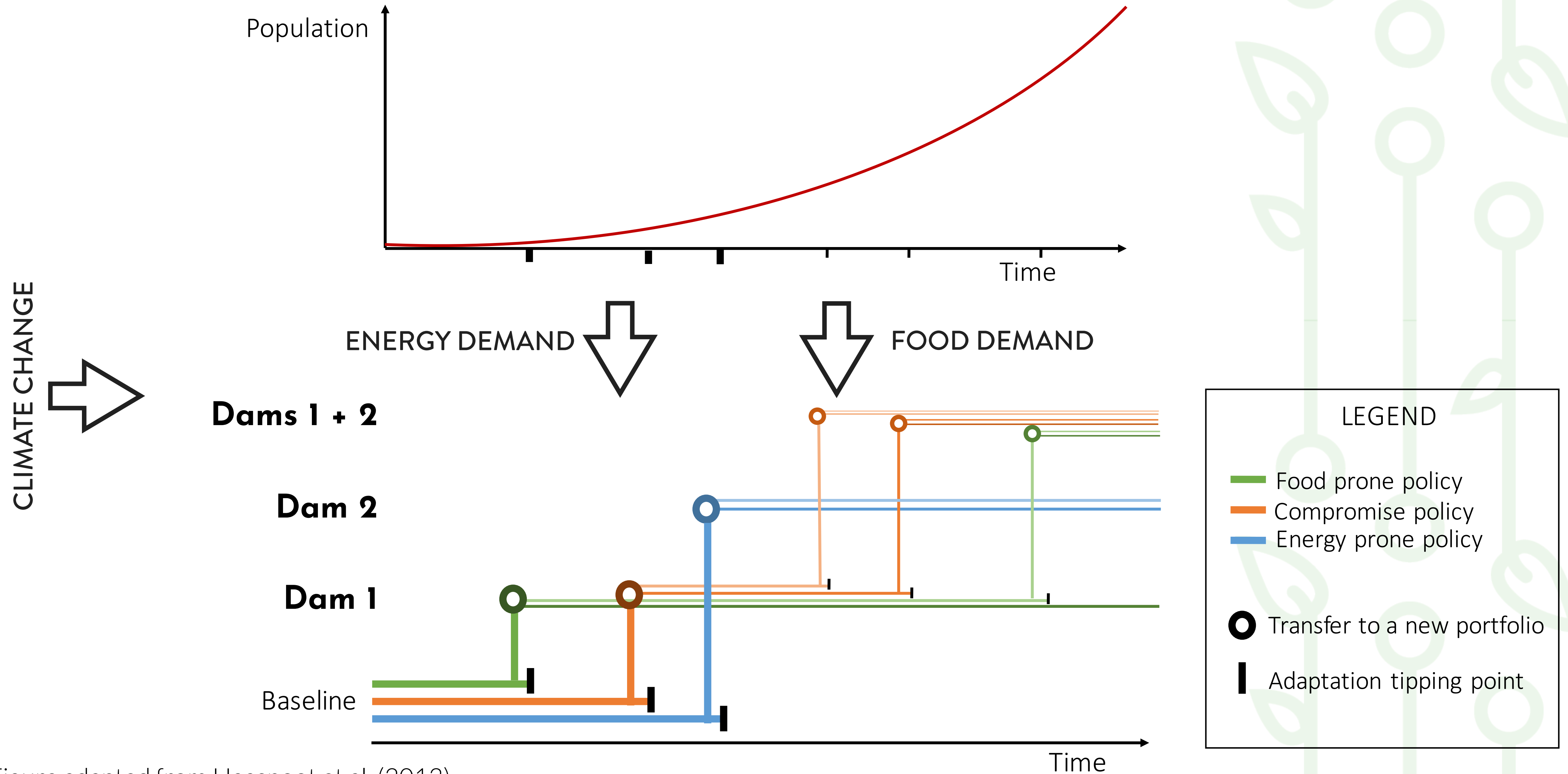
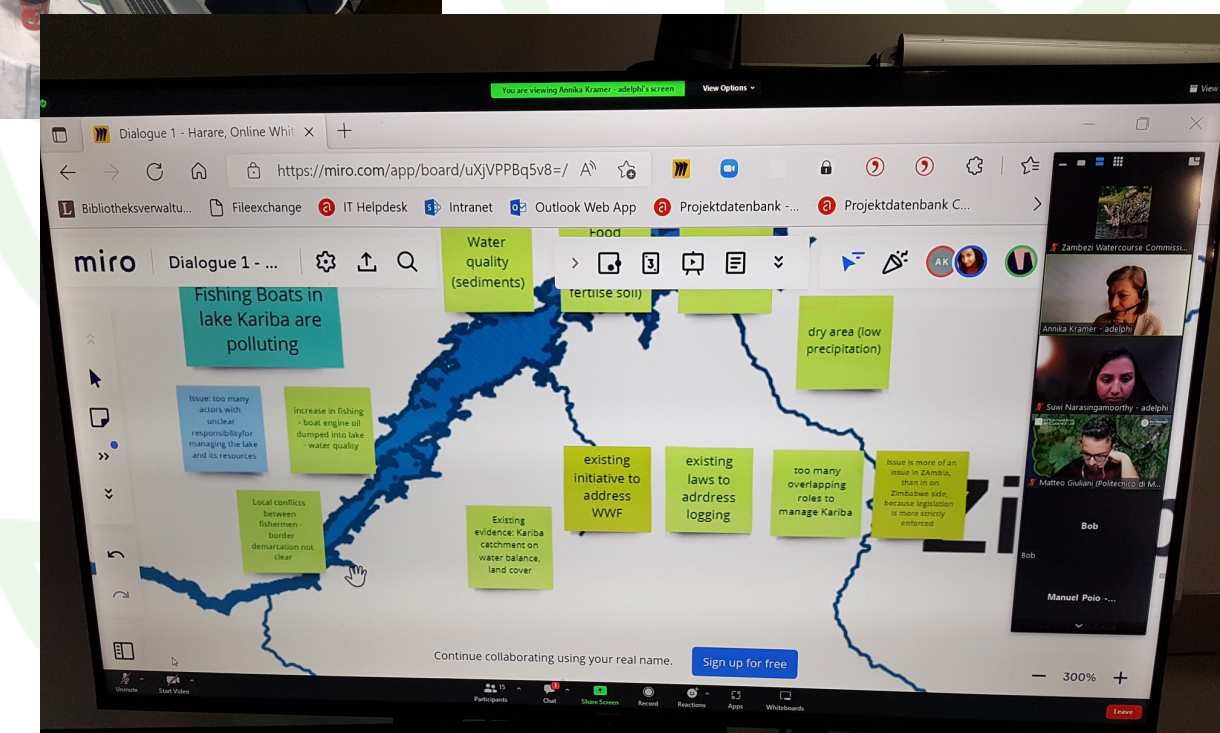
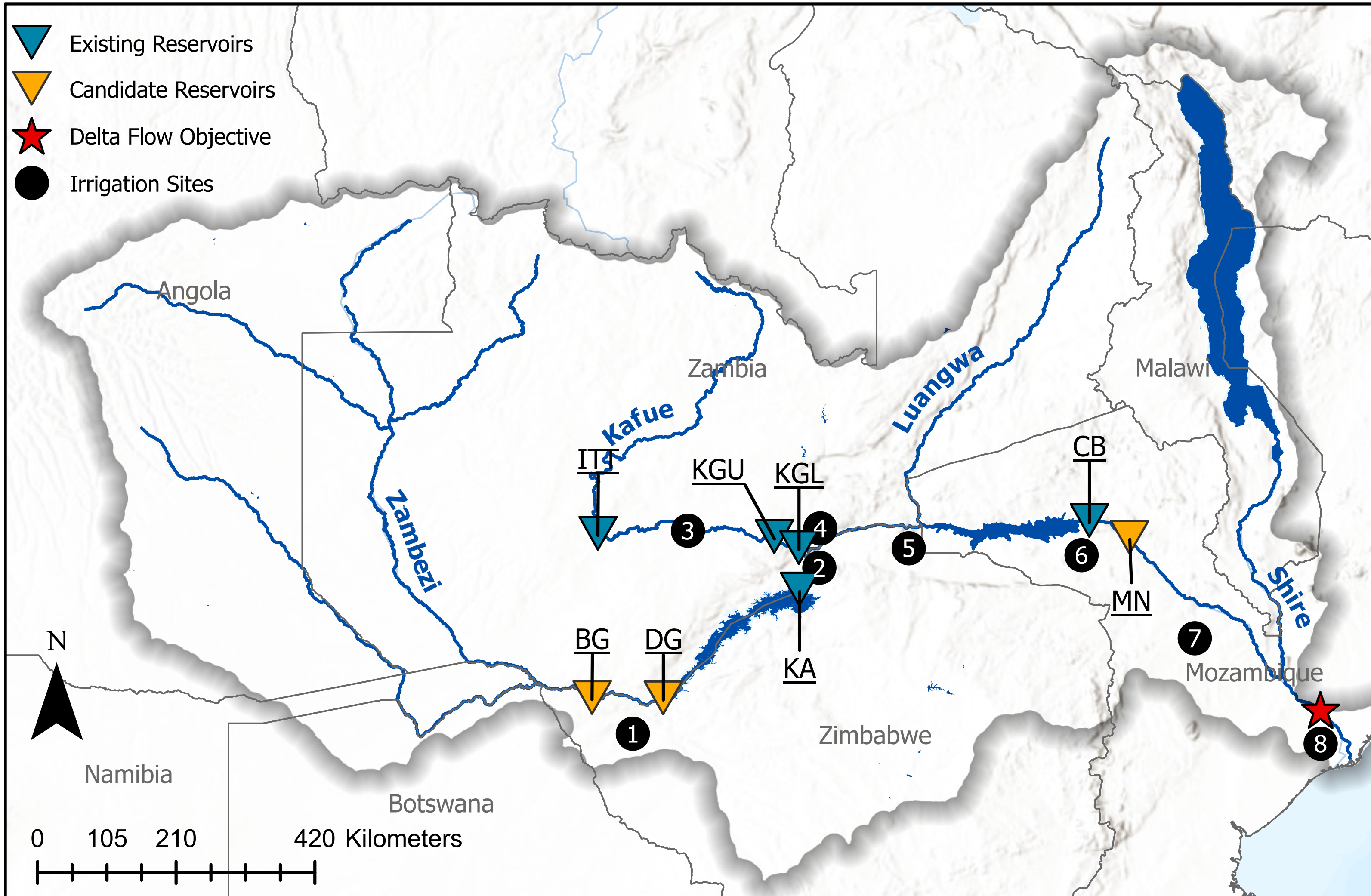


Figure adapted from Haasnoot et al. (2013)

# THE ZAMBEZI WATERCOURSE



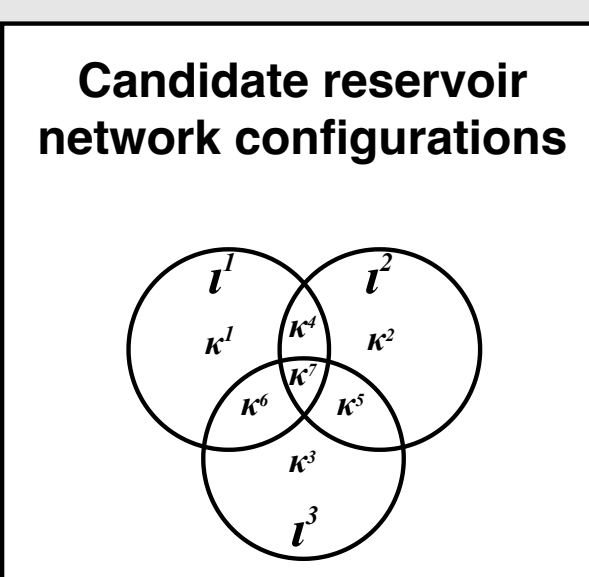
# HOW TO OPTIMIZE DAM SEQUENCING & OPERATION

## Two-part optimization of reservoir network expansion sequencing and operations

Part 1

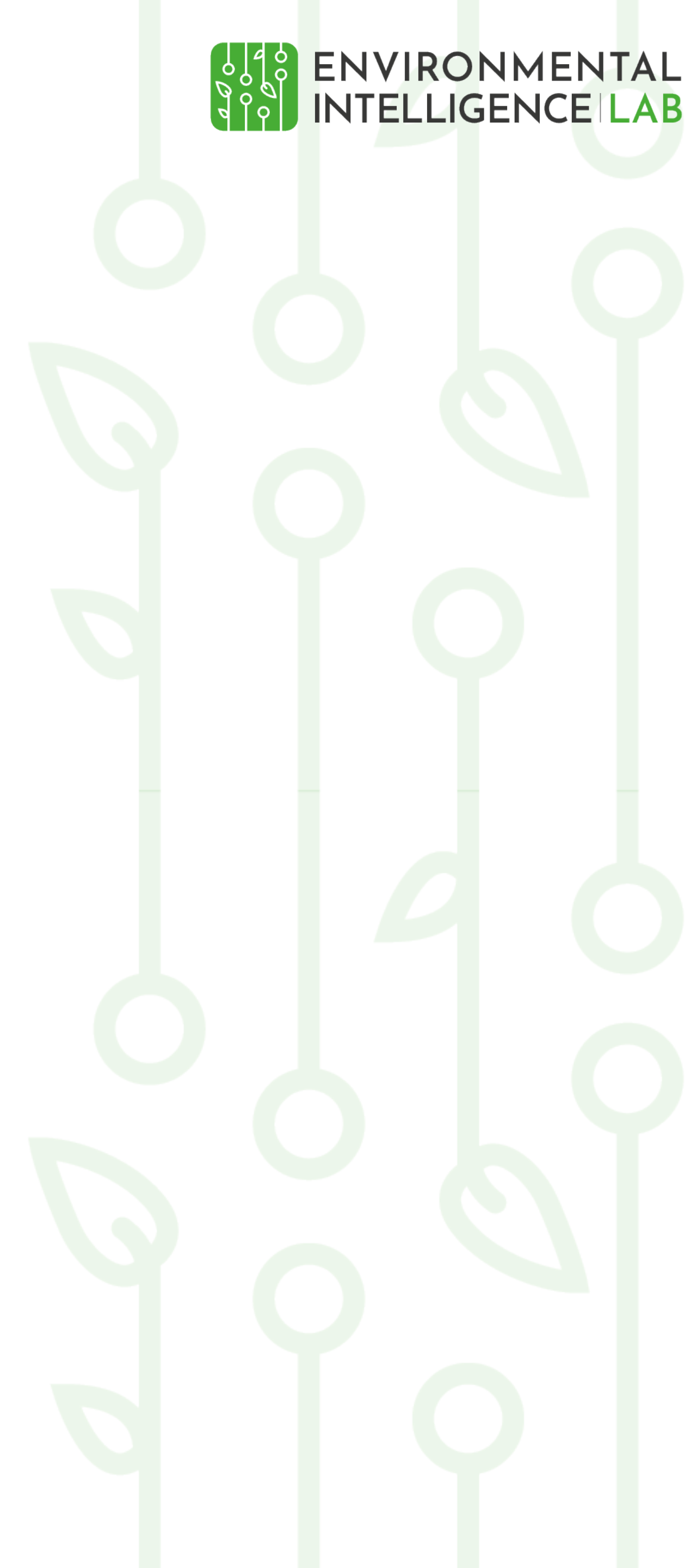
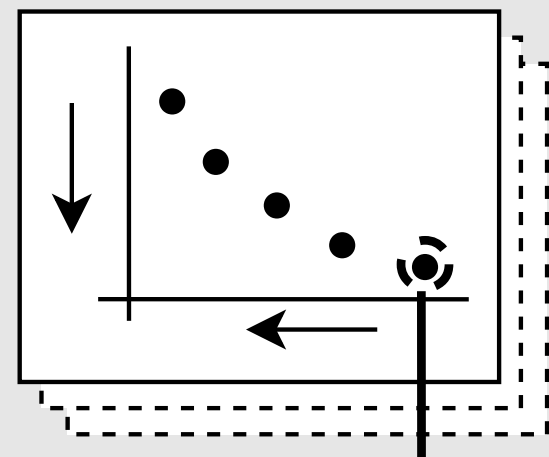
**Reservoir network operations**  
**Objectives:** Water, energy, and food indicators  
**Variables:** Operating policies  
(EMODPS)

×

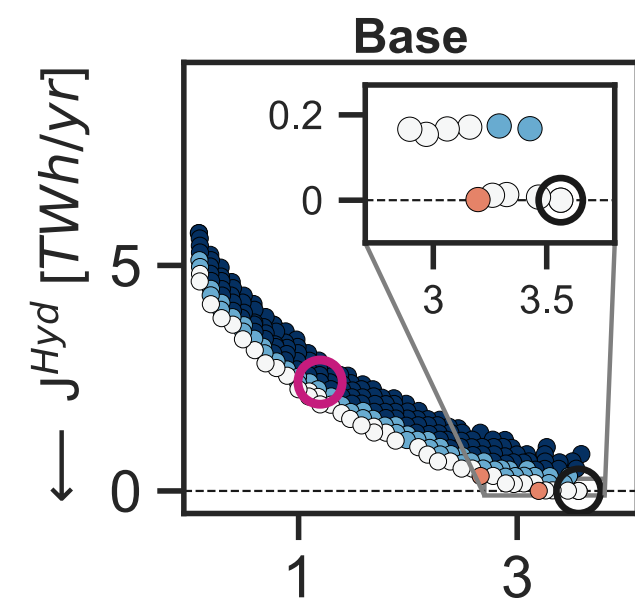
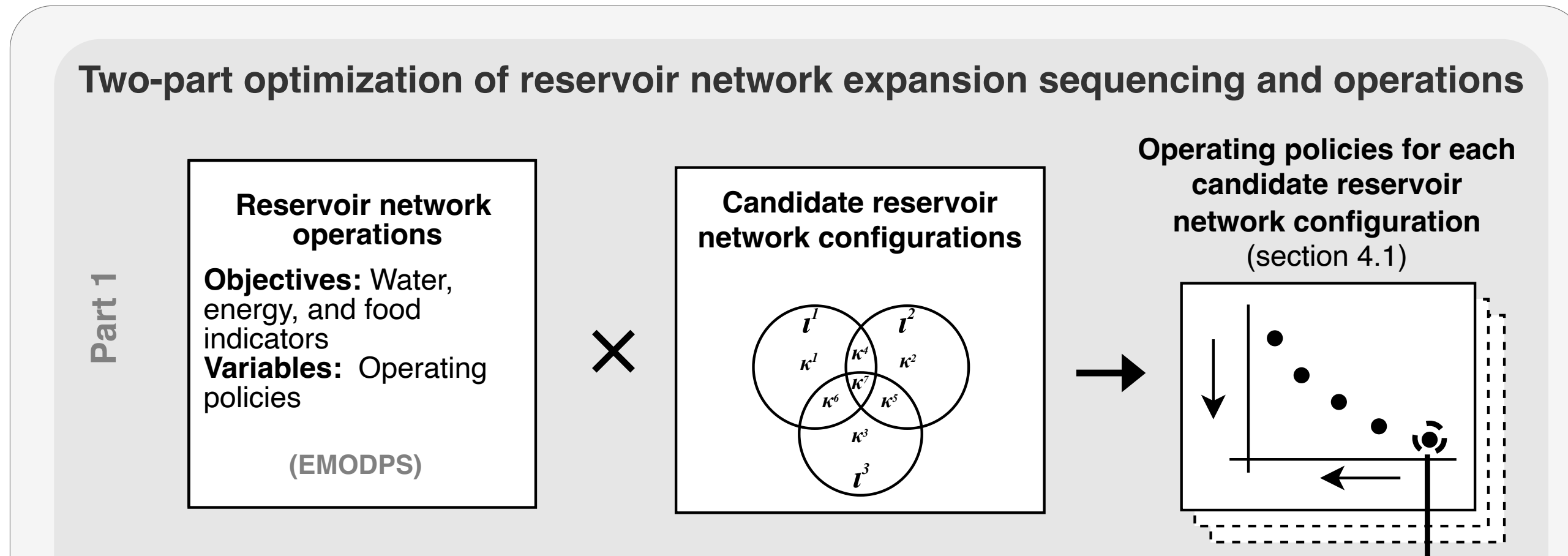


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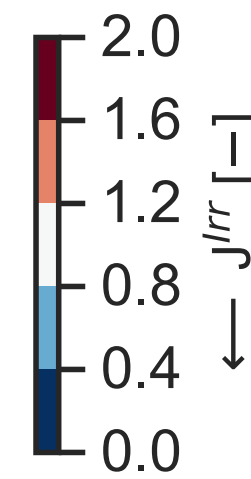
**Operating policies for each candidate reservoir network configuration**  
(section 4.1)



# HOW TO OPTIMIZE DAM SEQUENCING & OPERATION



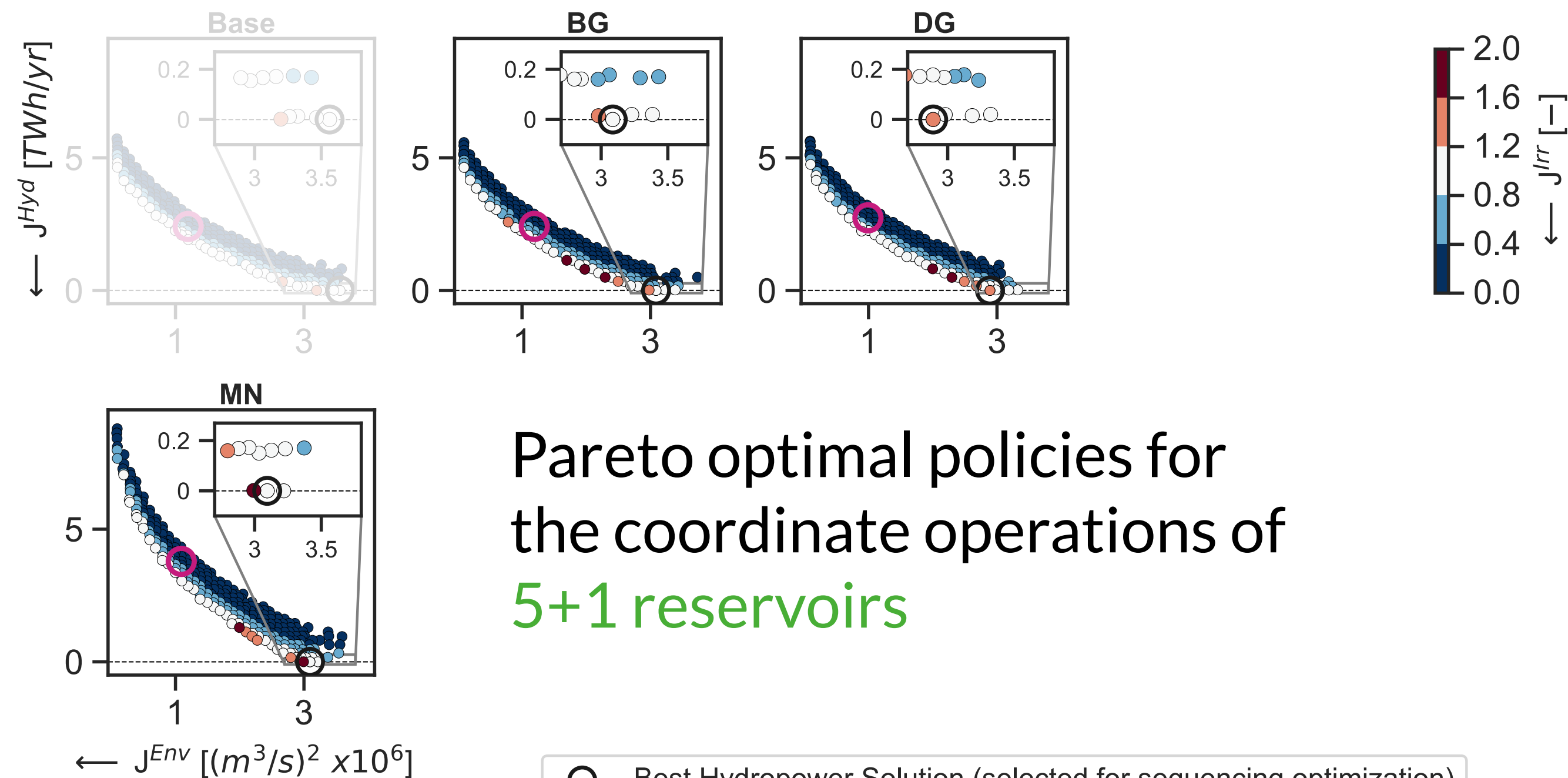
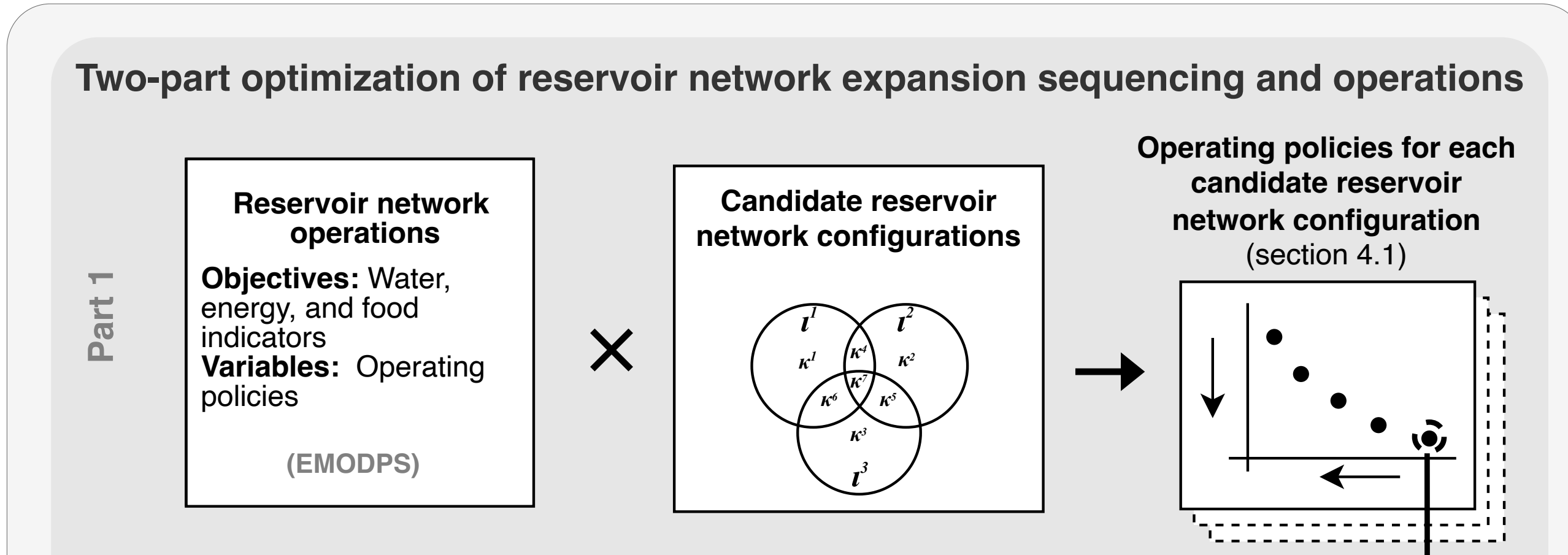
Pareto optimal policies for the coordinate operations of the 5 existing reservoirs



←  $J^{Env} [(m^3/s)^2 \times 10^6]$

- Best Hydropower Solution (selected for sequencing optimization)
- Compromise Solution (selected for re-evaluation)

# HOW TO OPTIMIZE DAM SEQUENCING & OPERATION

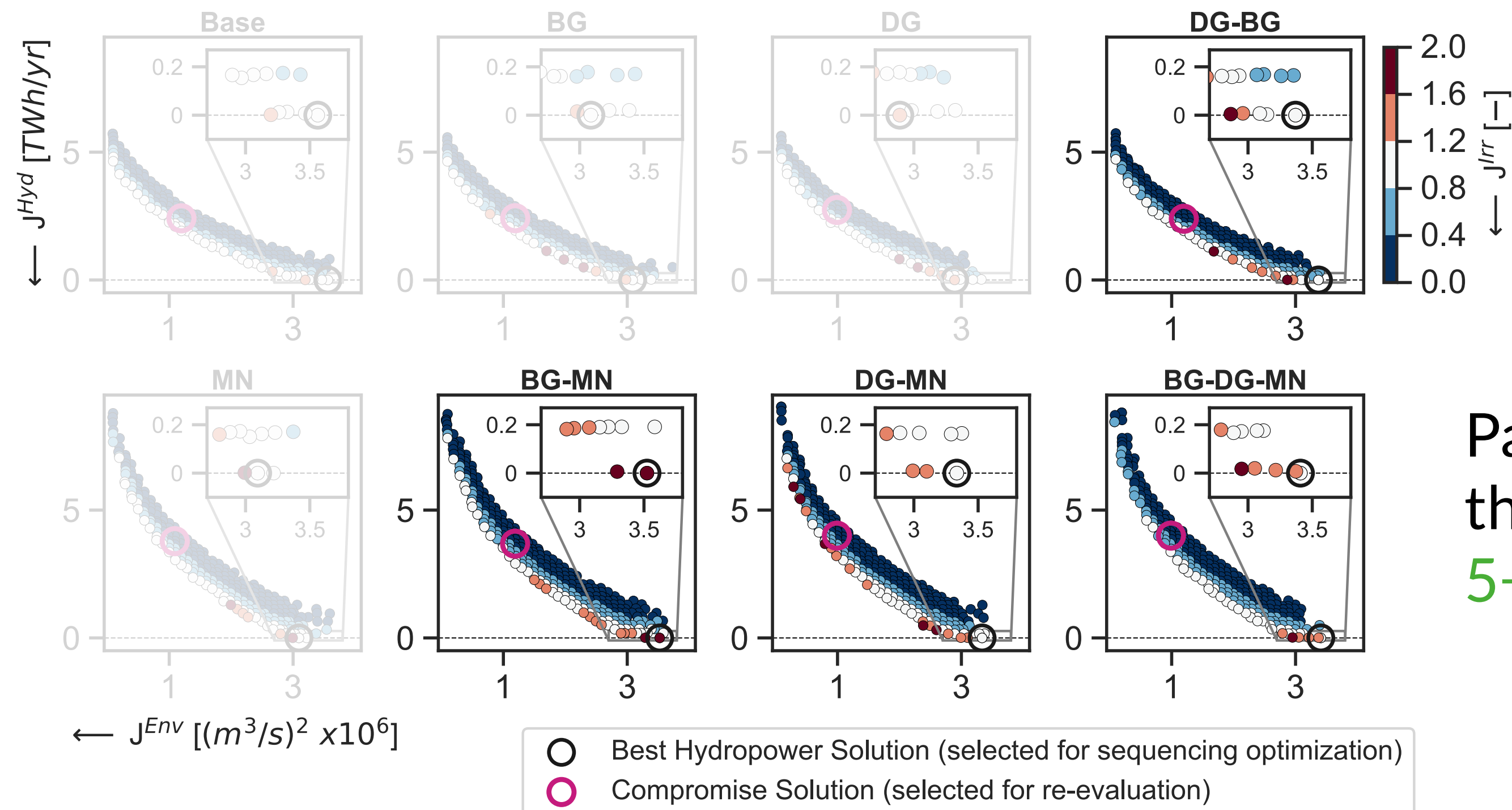
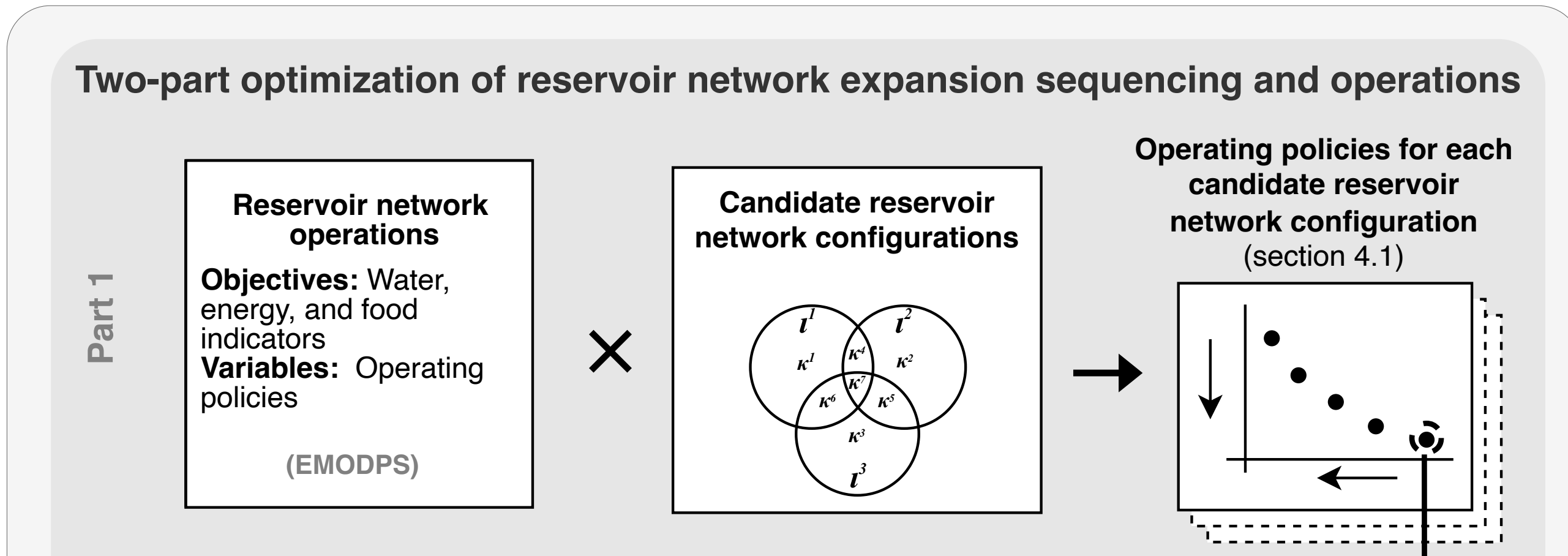


Pareto optimal policies for the coordinate operations of **5+1 reservoirs**

- Best Hydropower Solution (selected for sequencing optimization)
- ◐ Compromise Solution (selected for re-evaluation)

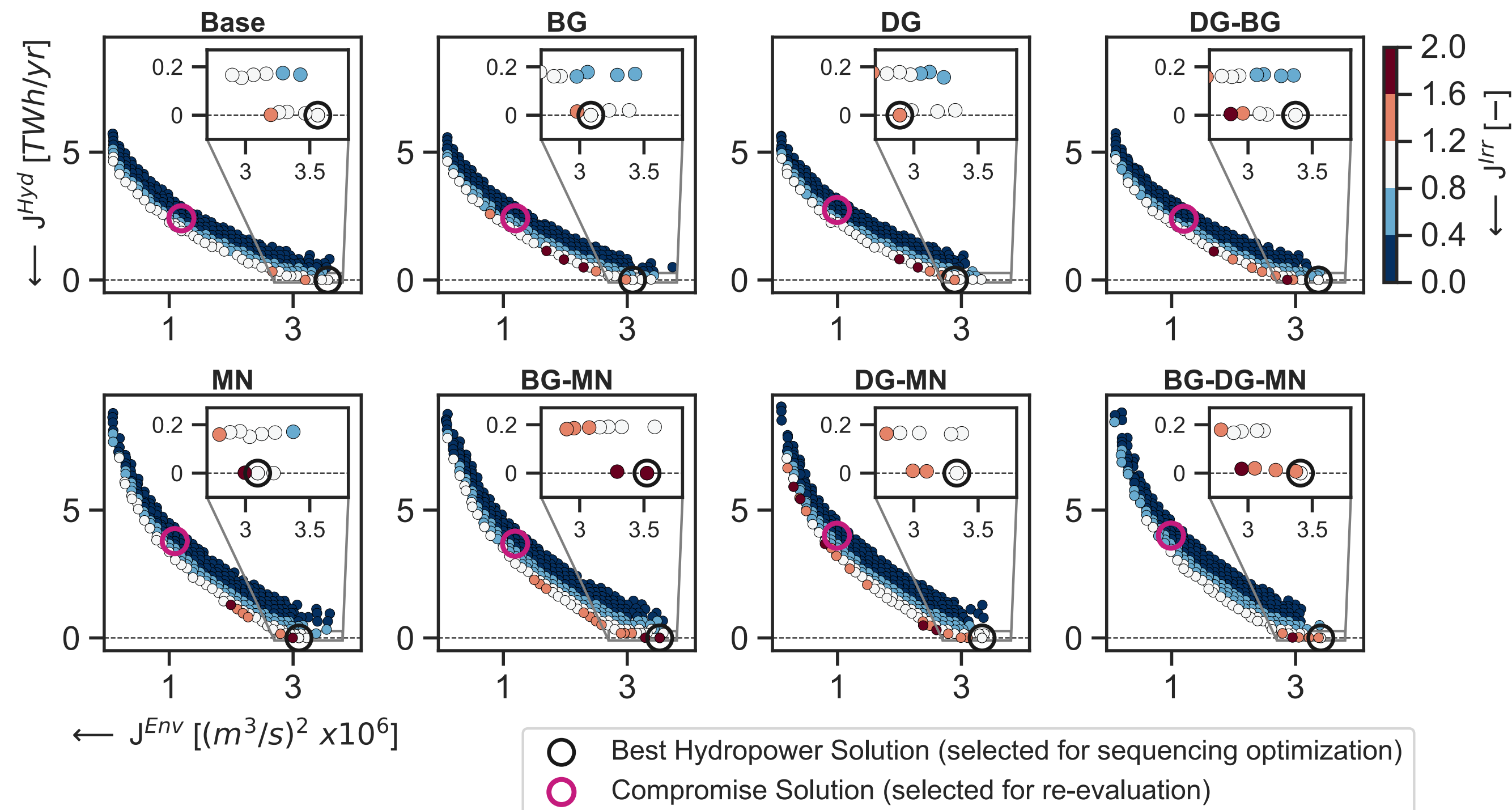
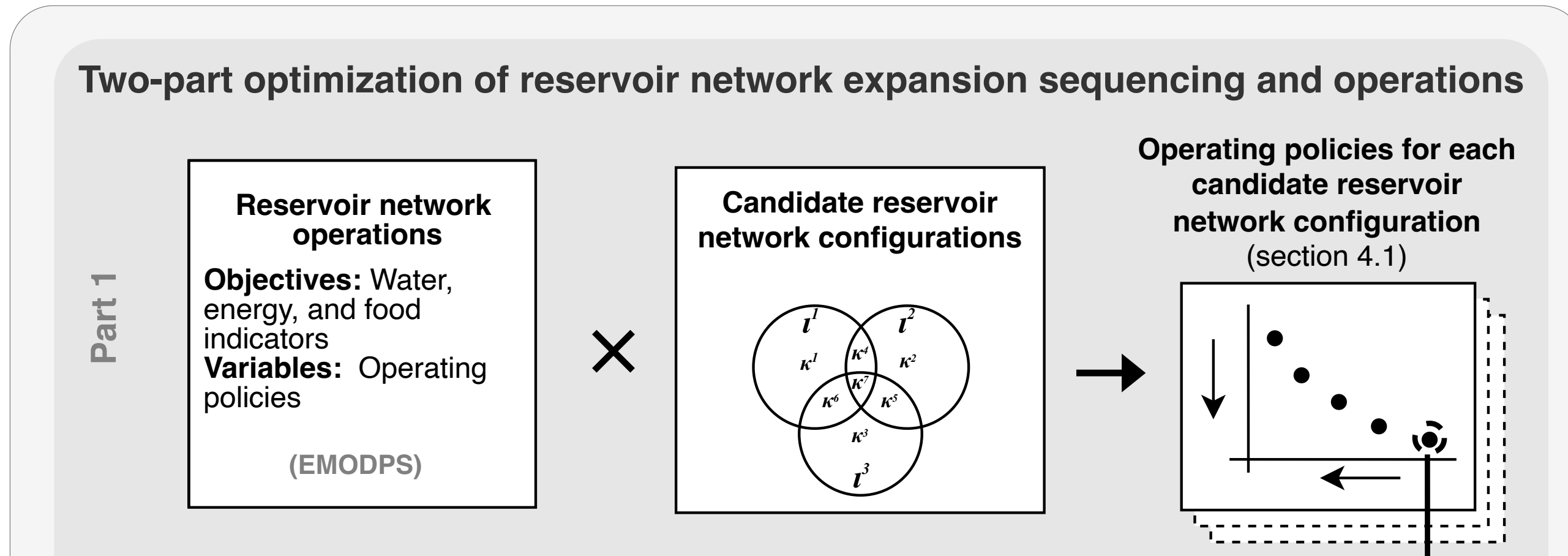


# HOW TO OPTIMIZE DAM SEQUENCING & OPERATION



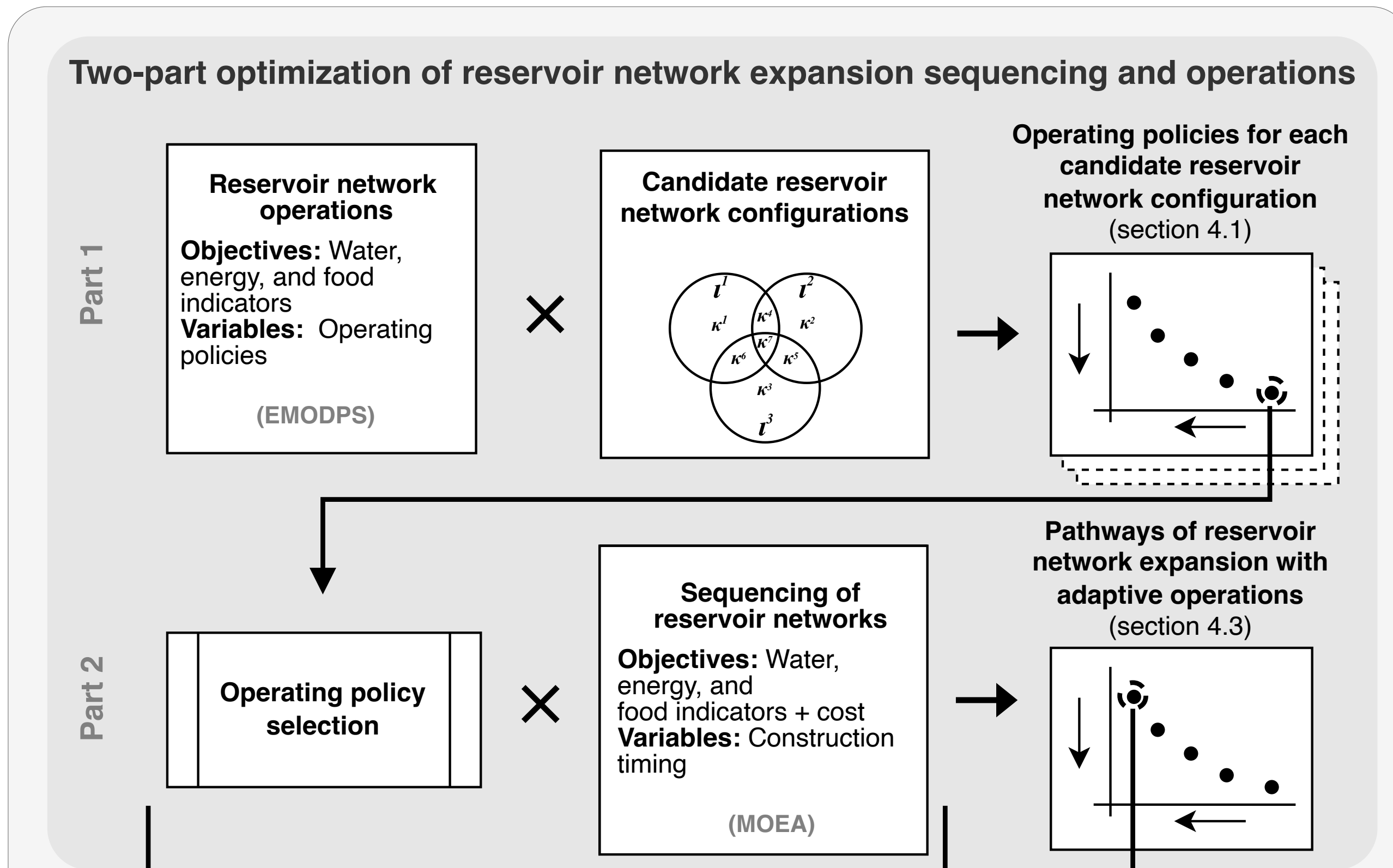
Pareto optimal policies for the coordinate operations of 5+2 and 5+3 reservoirs

# HOW TO OPTIMIZE DAM SEQUENCING & OPERATION



Archive of 2000+ optimal operating policies

# HOW TO OPTIMIZE DAM SEQUENCING & OPERATION



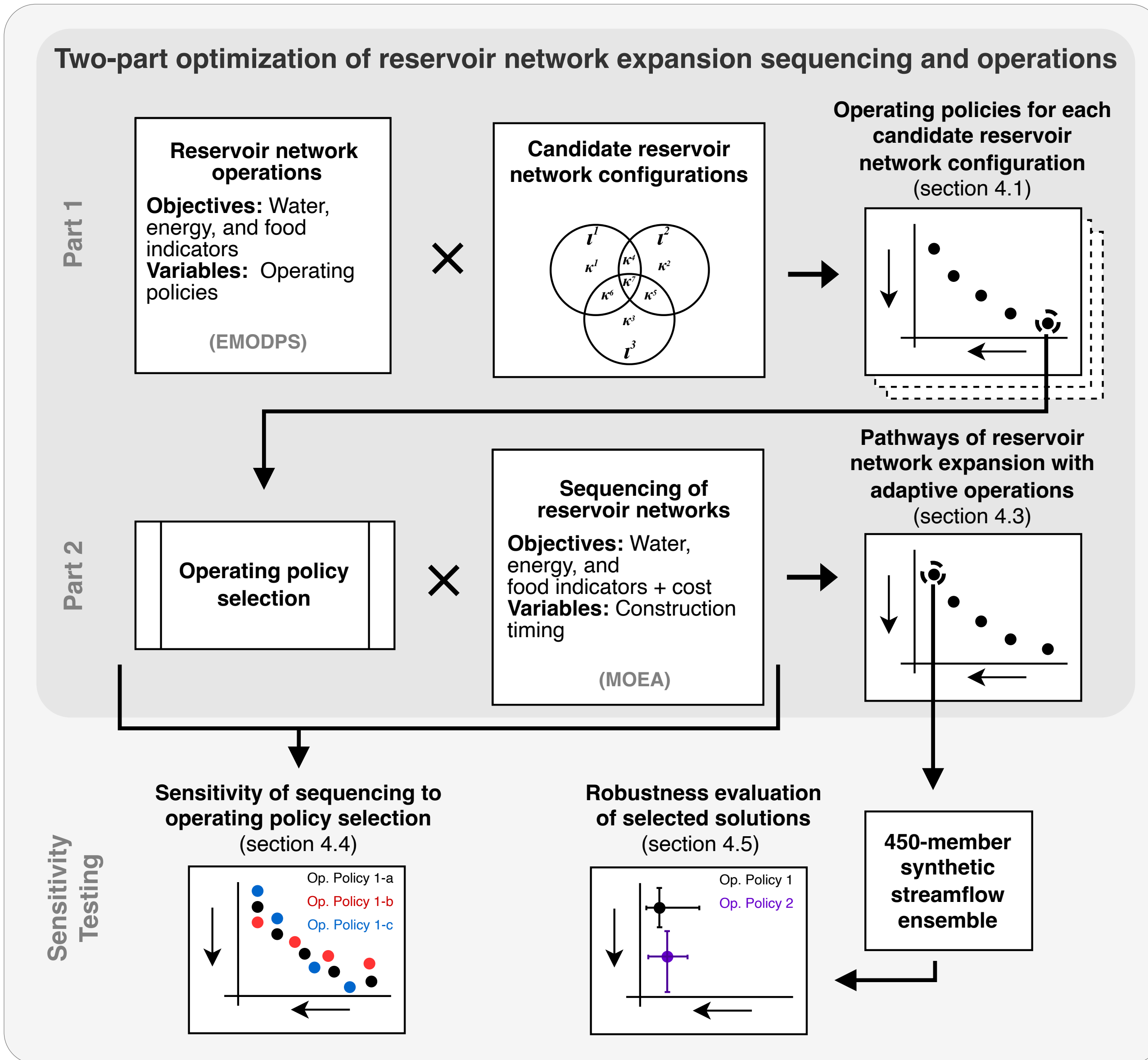
Sequencing problem:

if  $t > T$ :

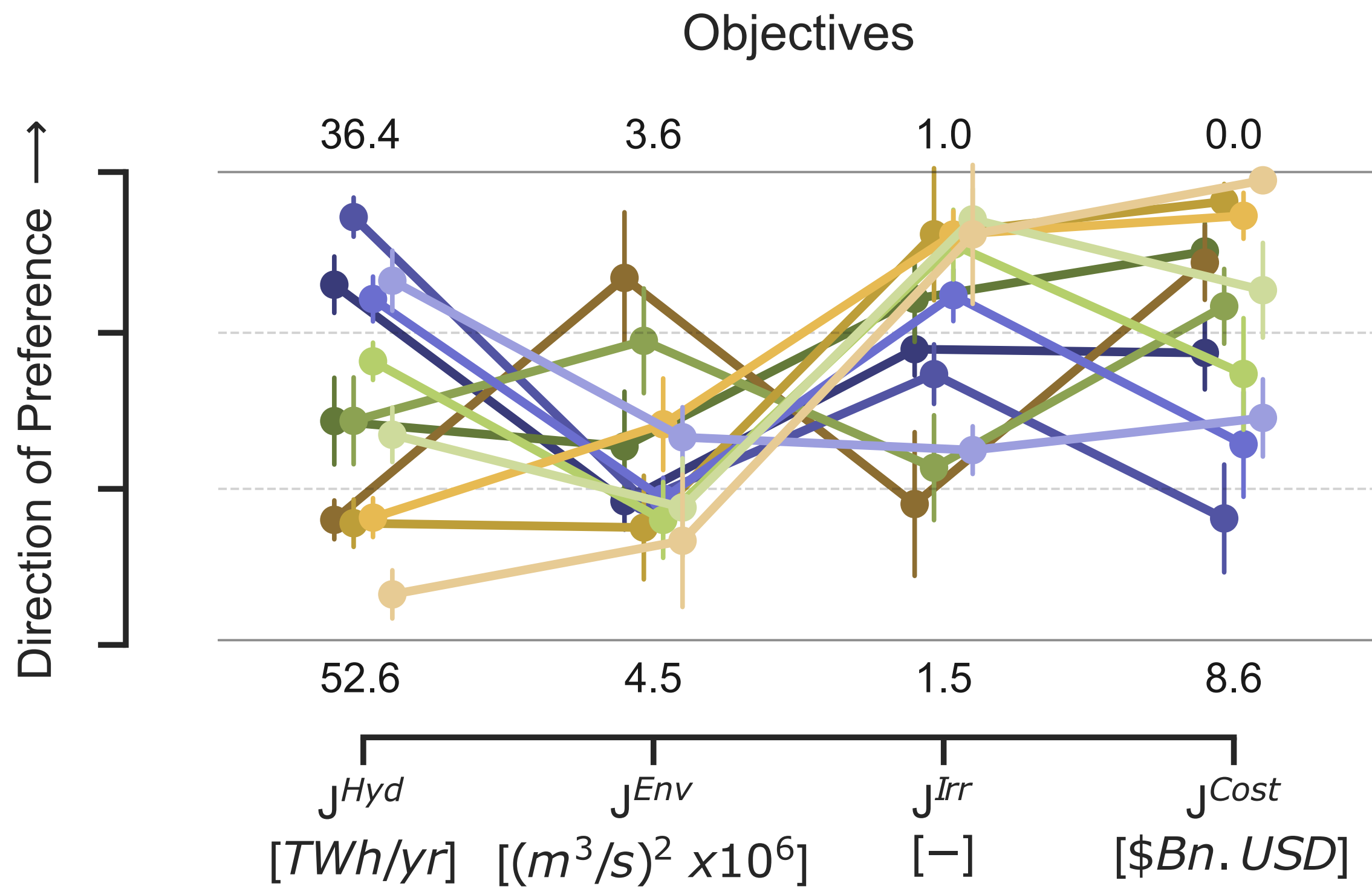
build  $DAM_i$

...

# HOW TO OPTIMIZE DAM SEQUENCING & OPERATION

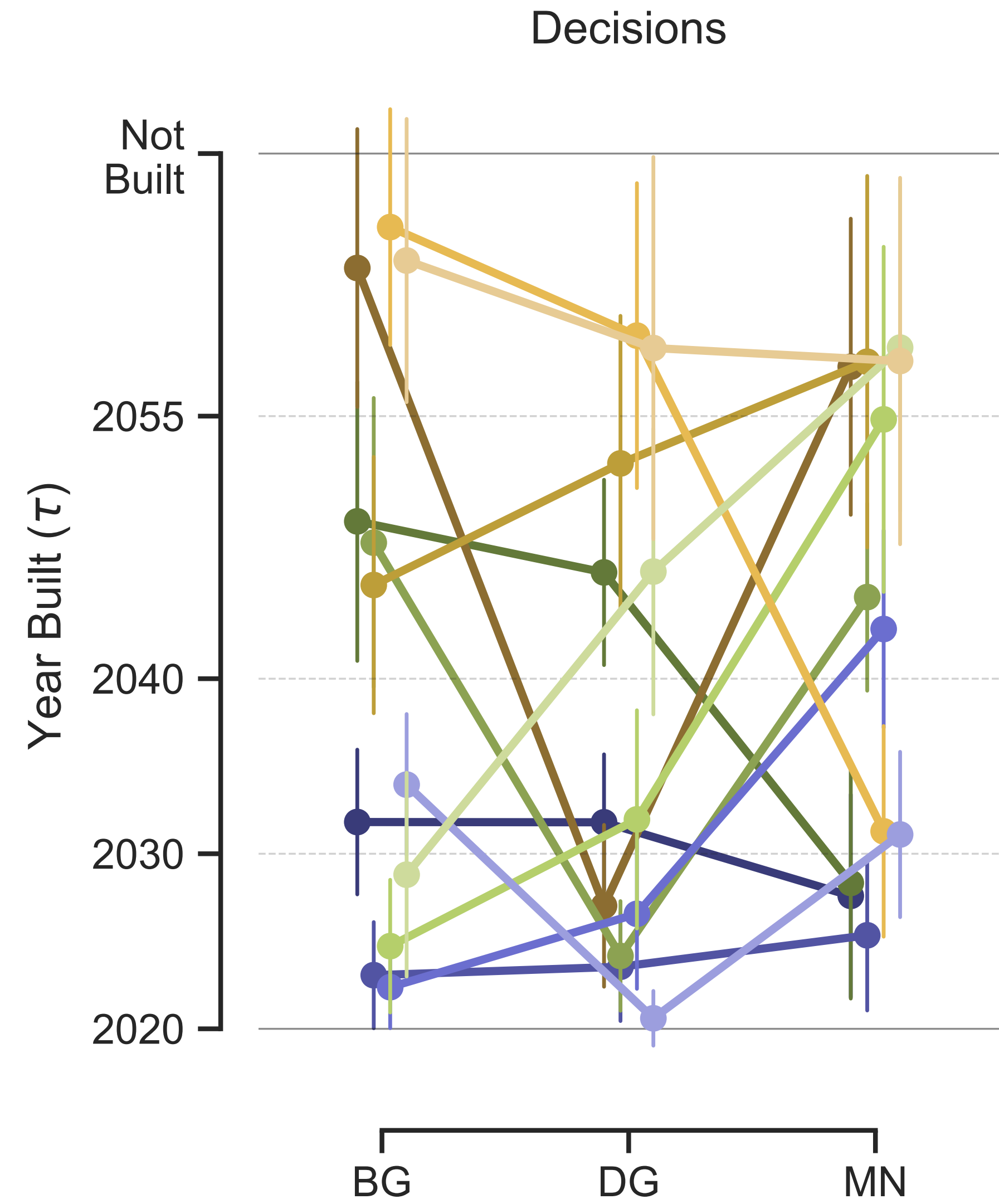


# OPTIMAL PATHWAYS OF DAM EXPANSION

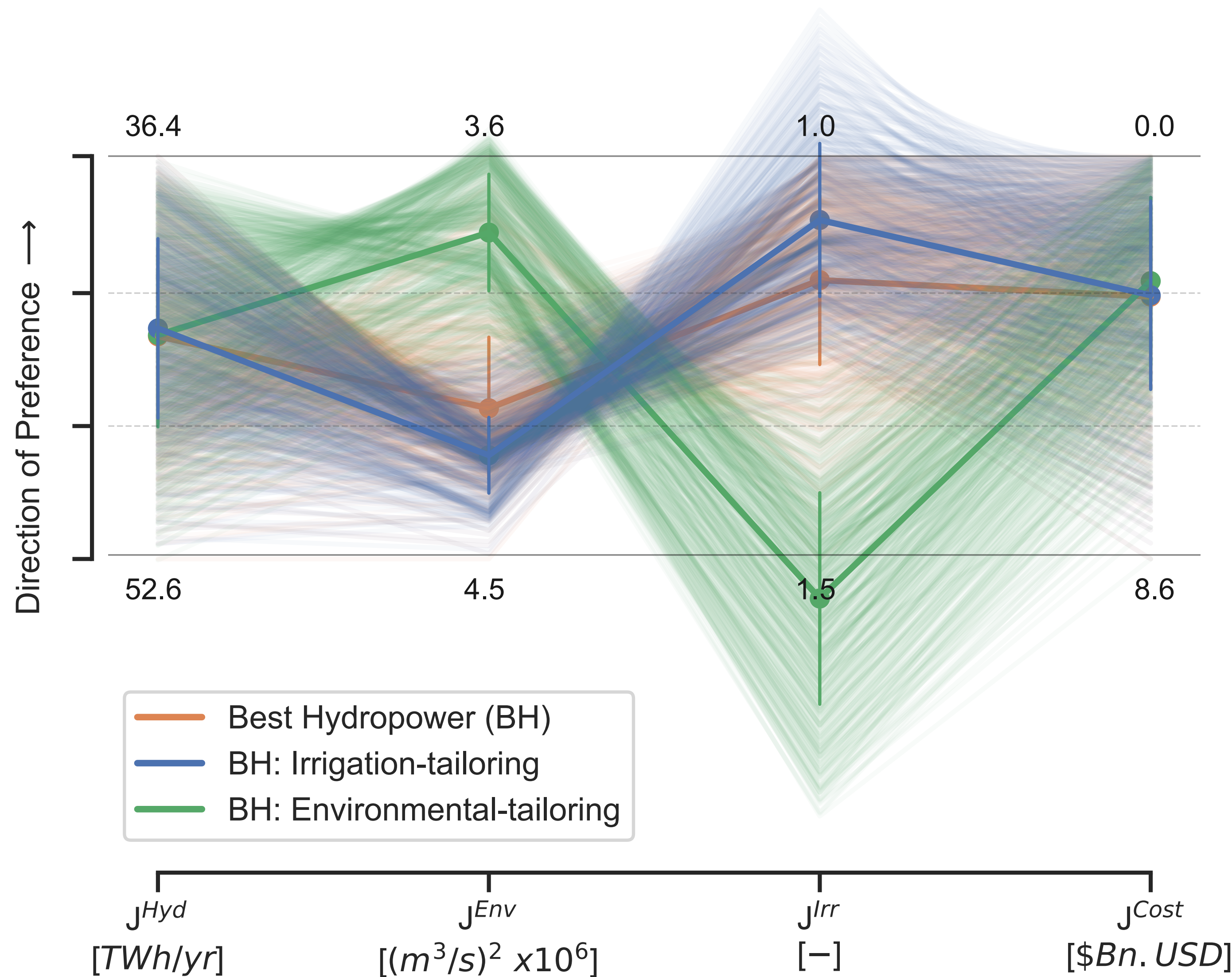


$J^{Hyd}$  Tercile Clusters

Top	Middle	Lower
● A	● A	● A
● B	● B	● B
● C	● C	● C
● D	● D	● D

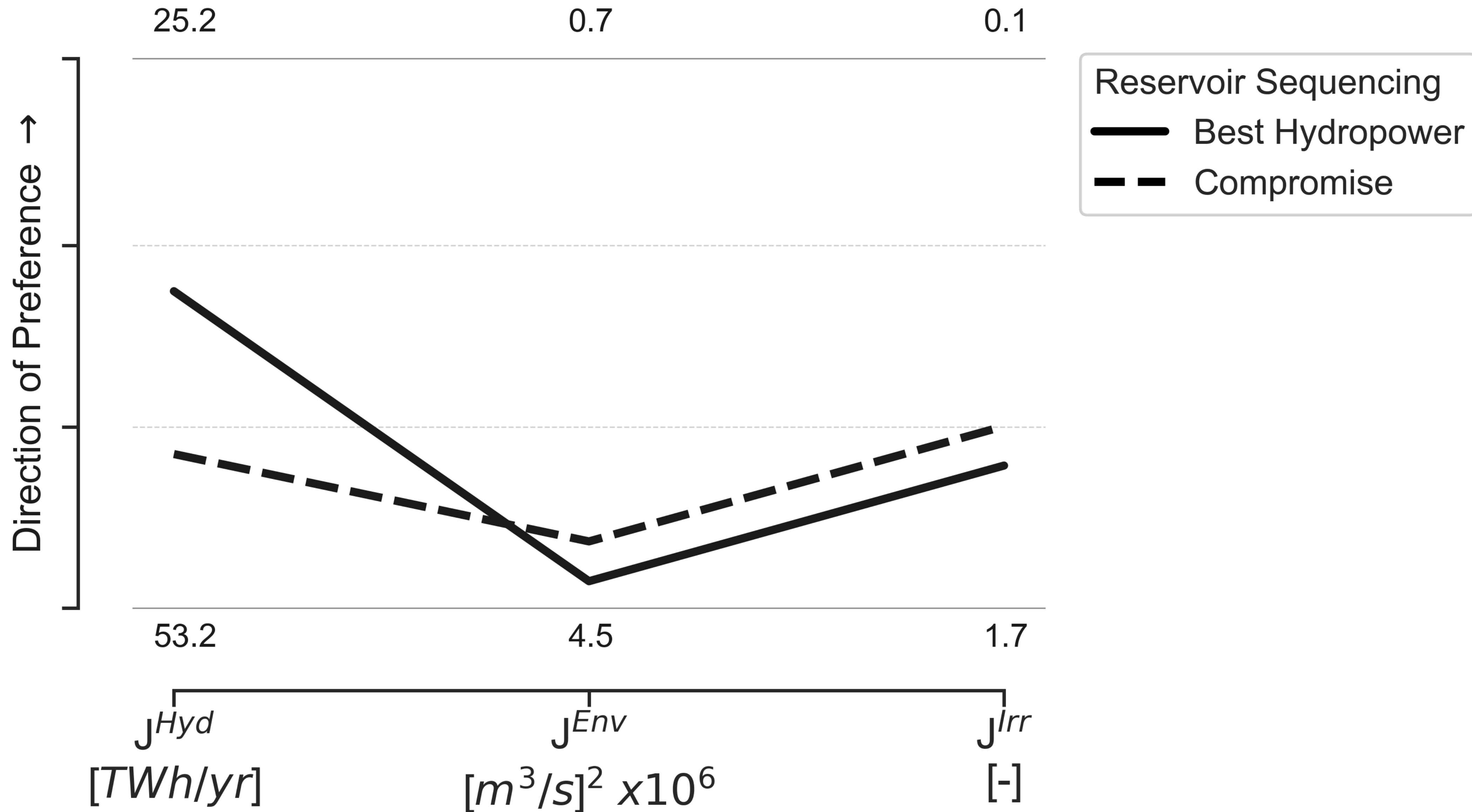


# OPERATING POLICY SELECTION MAY DISTORT TRADEOFFS PERCEPTION IN DAM PLANNING

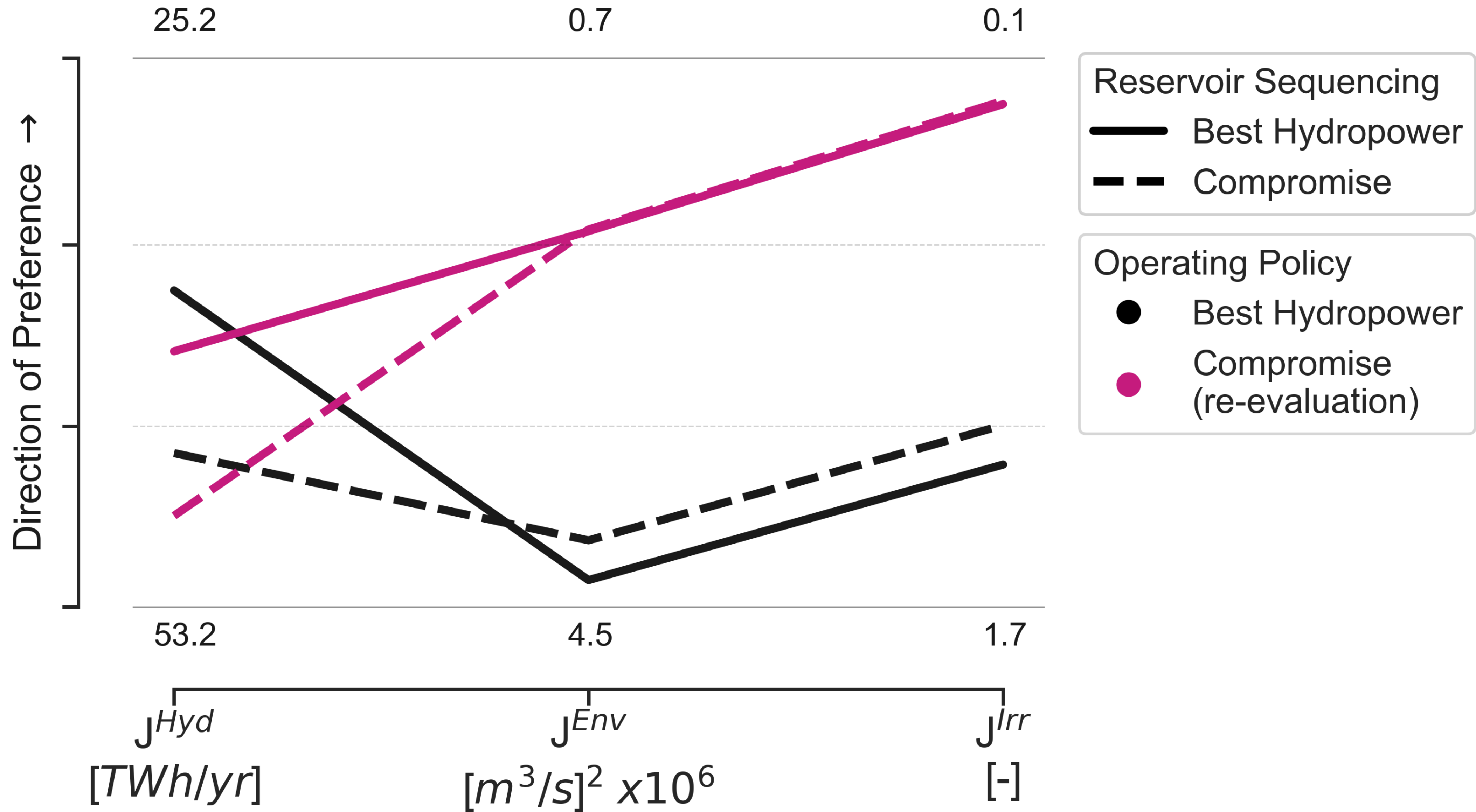


Three selected policies differ in HP less than 0.01 TWh/y

# ROBUSTNESS VIA COMPROMISE OPERATIONS

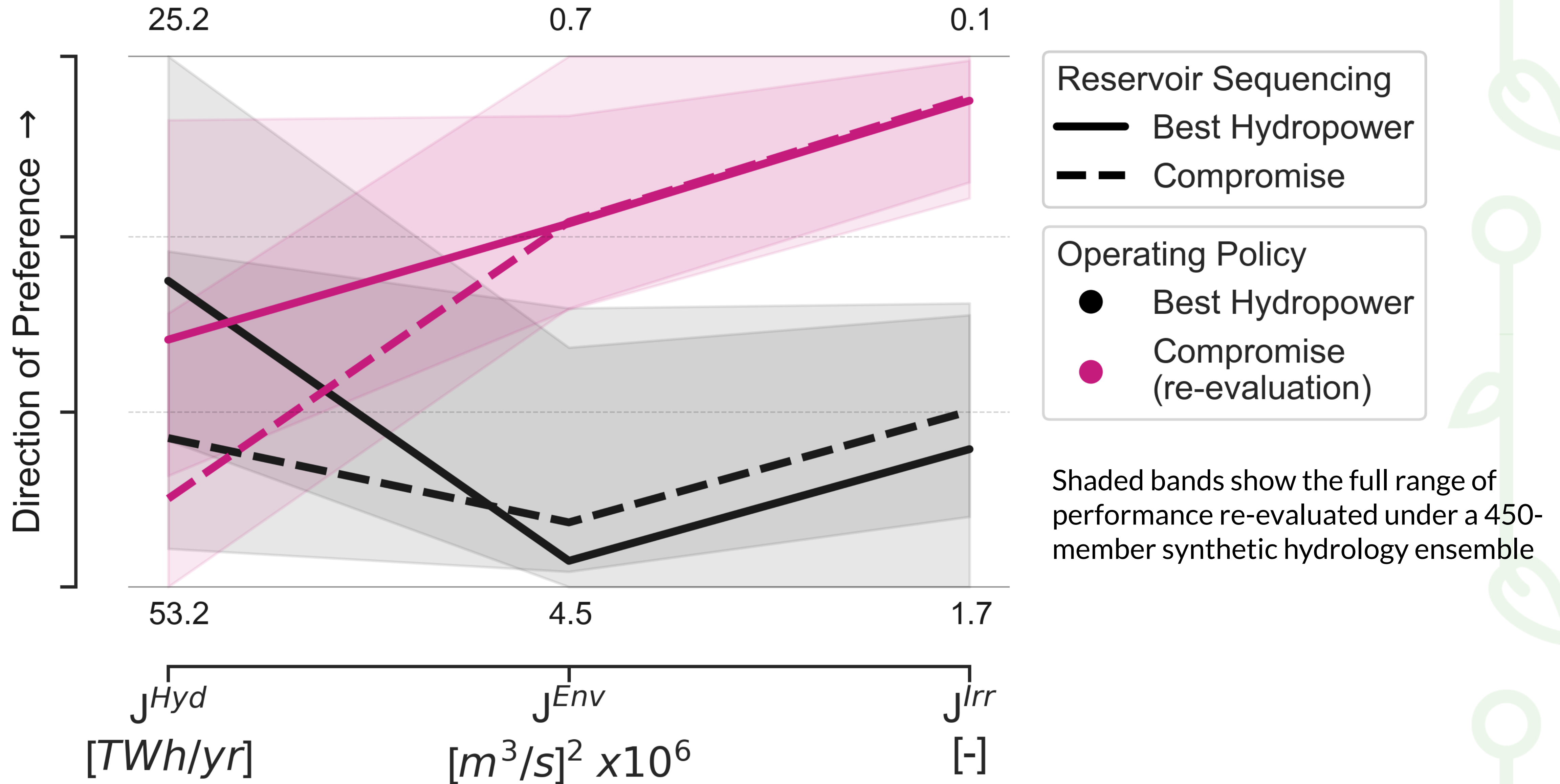


# ROBUSTNESS VIA COMPROMISE OPERATIONS





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# TAKEAWAYS



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- Operating policies eclipse reservoir sequencing in balancing conflicting objectives

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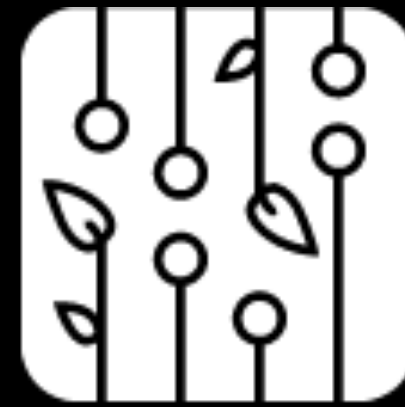
- Operating policies eclipse reservoir sequencing in balancing conflicting objectives
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- Integrating operations into dam planning becomes crucial for addressing multisector tradeoffs

## References:

Arnold, W., Salazar, J. Z., Carlino, A., Giuliani, M., & Castelletti, A. (2023). Operations eclipse sequencing in multipurpose dam planning. *Earth's Future*, 11, e2022EF003186

SCAN ME





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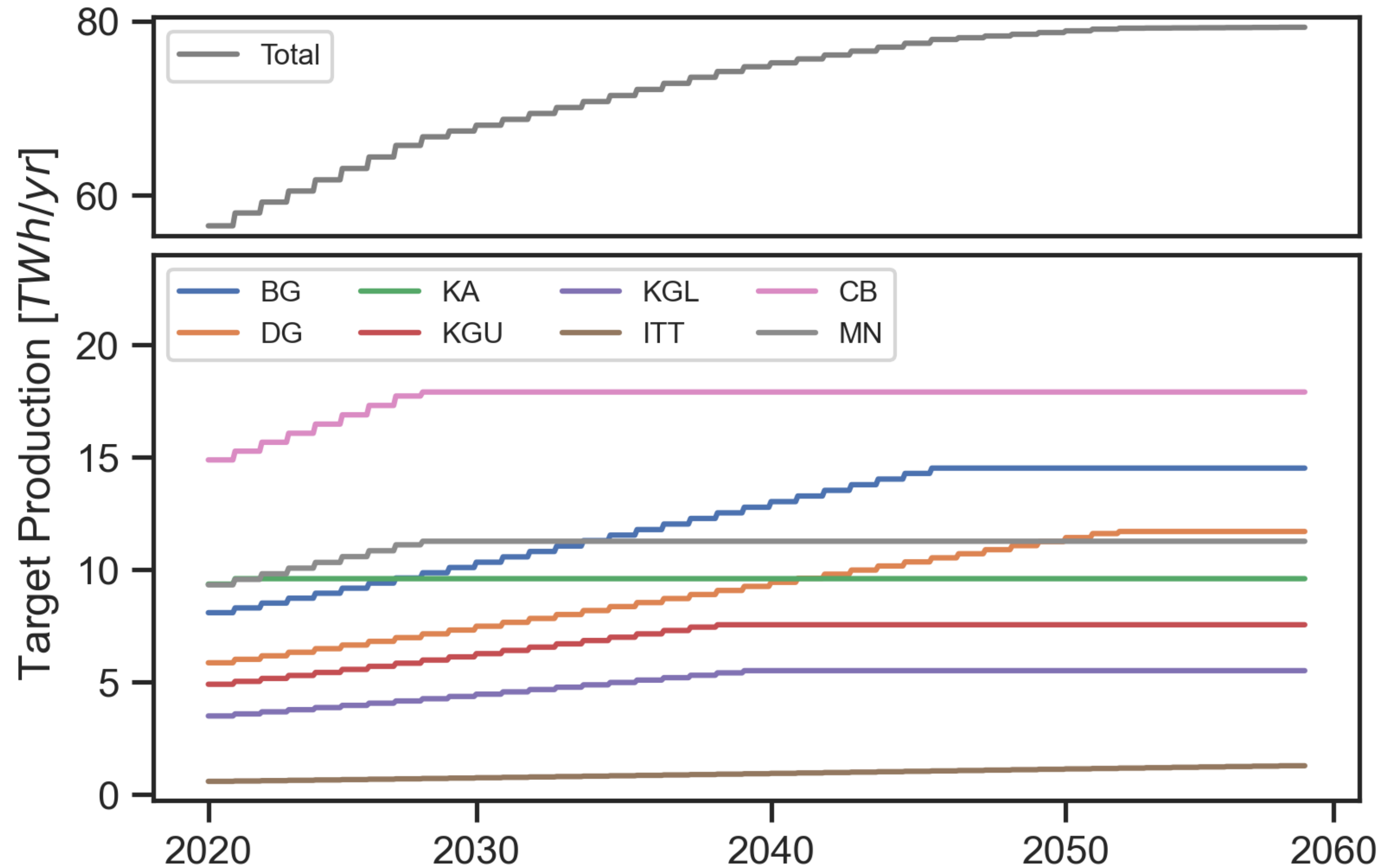
**DEPT. of ELECTRONICS, INFORMATION,  
and BIOENGINEERING**

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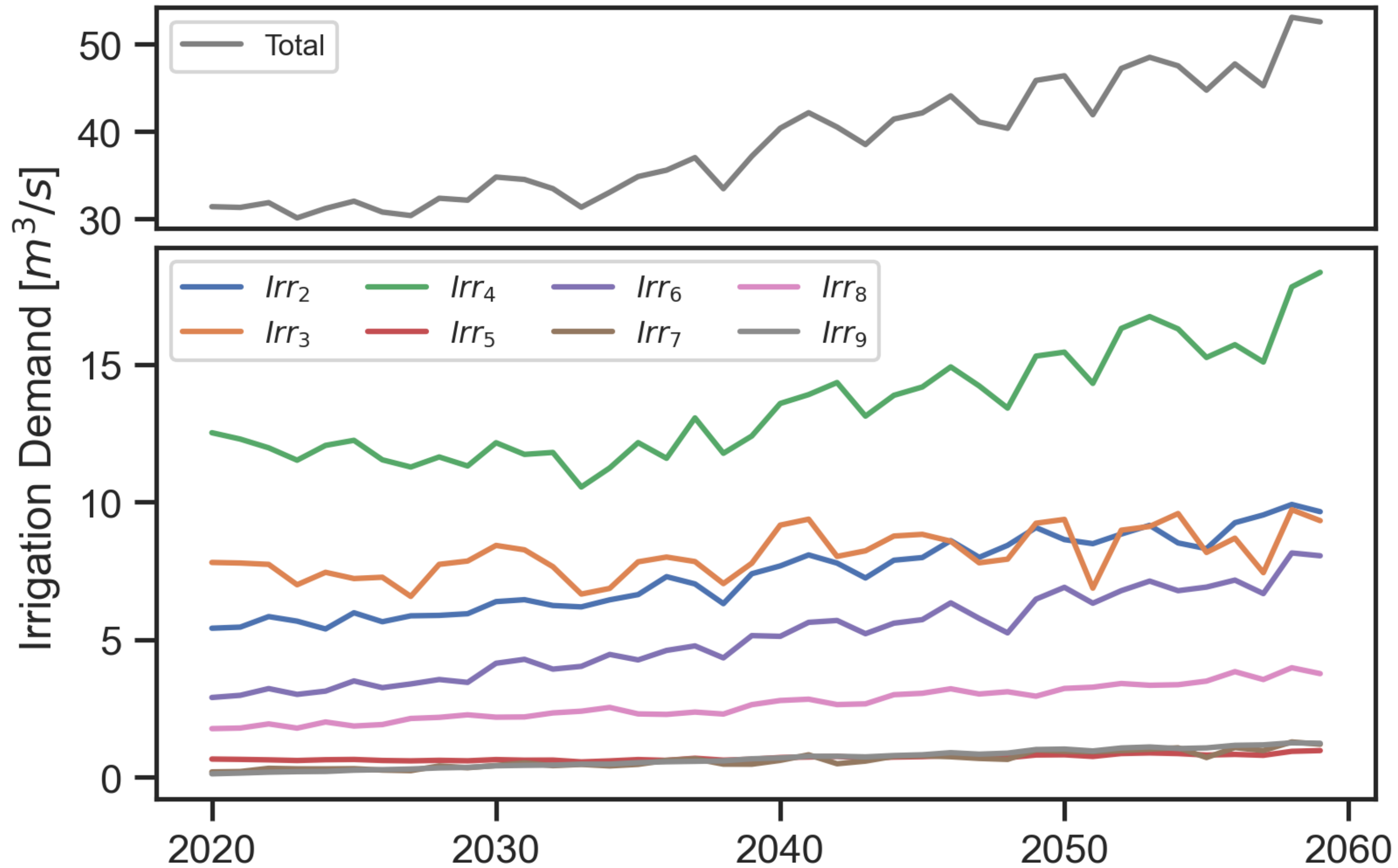
# HP PRODUCTION TARGETS



Osemosys TEMBA model for SAPP using projected energy demand (based on population)

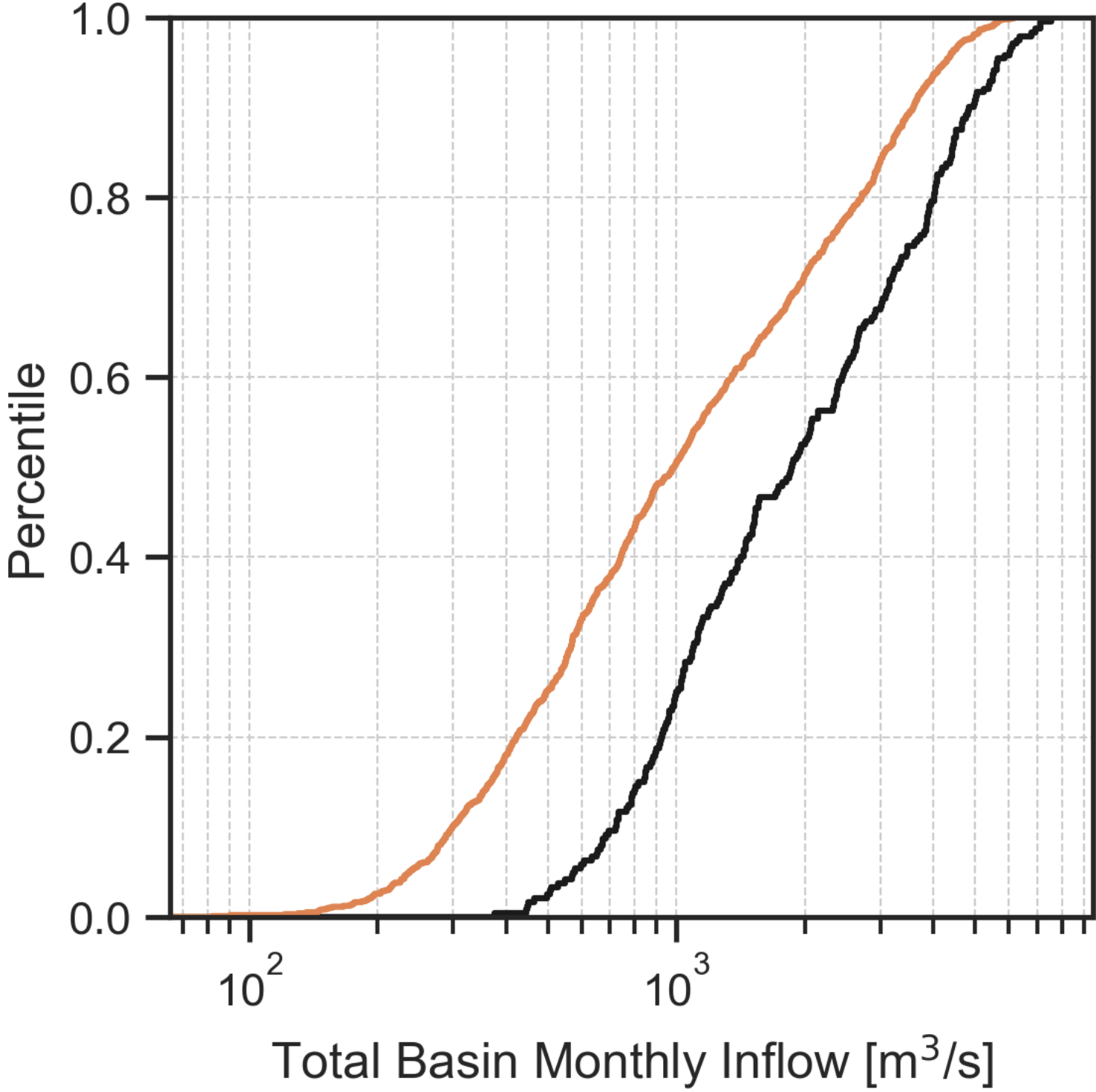


# PROJECTED IRRIGATION DEMANDS



AQUACROP simulation under RCP45 and considering planned irrigation expansions

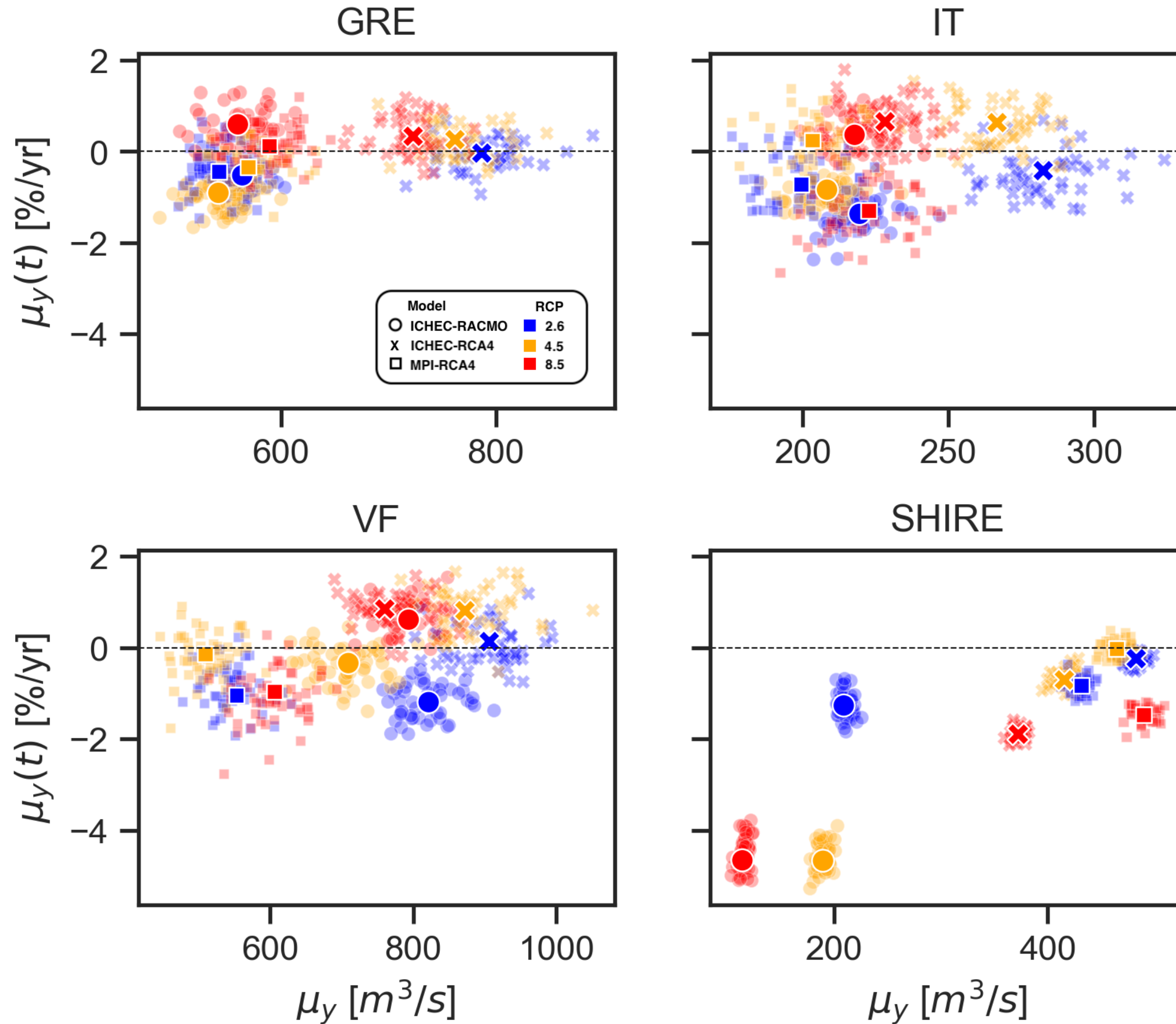
# PROJECTED FLOWS



— Historical (1986-2005)  
— Future



# SYNTHETIC FLOW



1. multimodel, multi-RCP ensemble
2. trend identification and removal
3. 50 synthetic realisations (40Y each) via Cholesky decomposition
4. trend addition to synthetic trajectories