PyVIN: An Open Source Hydroeconomic Model for California's Water Supply System

Mustafa S. Dogan, Max Fefer*, Ellie White, Jon Herman, Quinn Hart, Justin Merz, Josue Medellin-Azuara, and Jay R. Lund

UCDAVIS CENTER FOR WATERSHED SCIENCES

Civil & Environmental Engineering, University of California, Davis
*Corresponding author: mafefer@ucdavis.edu,mfefer.github.io

Introduction

PyVIN serves as a cross-platform, extensible model to evaluate California statewide water operations and allow researchers and practitioners to explore long-term scenarios and adaptation strategies. PyVIN is the next generation of the CALVIN model by incorporating CALVIN's structure and data with an open source format using Python and state of the art solvers.

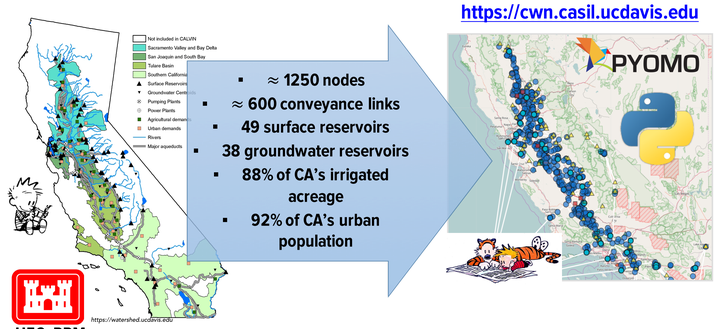


Figure 1: Representation of California water system in PyVIN

PyVIN network flow optimization model

Like CALVIN, PyVIN implements a linear programming network flow model with gains & losses. An abstract model in Pyomo coded in Python was used to allow the model structure, data, and solver to be separate and interchangeable. This allows expansions of PyVIN beyond California's statewide network.

minimize: $$Z = \sum_i \sum_j \sum_k c_{ijk} X_{ijk}$$

subject to: $$\sum_i \sum_k X_{jik} = \sum_i \sum_k a_{ijk} X_{ijk} + b_j \quad \text{for all nodes } j$$

$$X_{ikj} \leq u_{ijk} \quad \text{for all arcs}$$

$$X_{ijk} \geq l_{ijk} \quad \text{for all arcs}$$

Z: total cost
X: flow on the arc
c: unit cost (or penalty)
b: external flow
a: amplitude
l: lower bound
u: upper bound

PyVIN uses freely available state-of-the-art solvers (CPLEX, CBC, GUROBI, GLPK, and others) that significantly outperform CALVIN runtimes. PyVIN results have been verified with prior CALVIN results (example shown in Figure 2). In addition, the PyVIN source code and data are publicly available on Github.

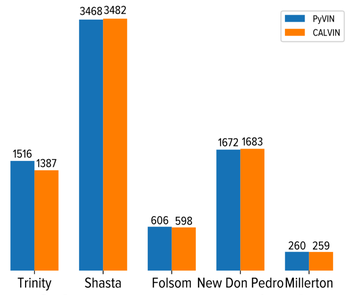
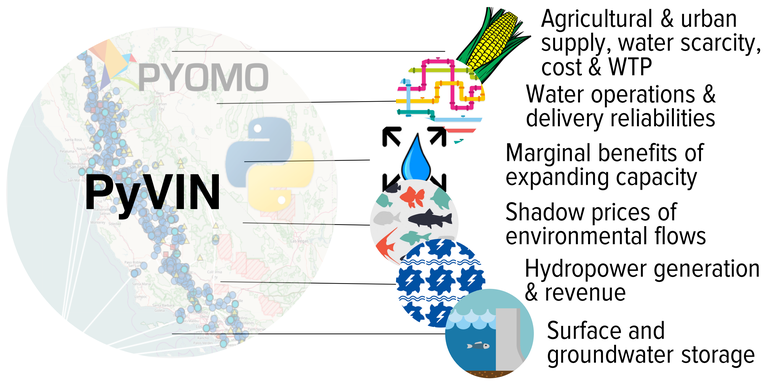


Figure 2: Average storage comparison between CALVIN and PyVIN of selected reservoirs (TAF)

Applications of PyVIN



Solver runtime comparison for different model sizes and solvers

Runs are performed on UC Davis College of Engineering's HPC1 Cluster. CBC, CPLEX and GUROBI are run in parallel, and GLPK is run in serial. All solvers significantly outperform the average CALVIN runtime of 7 days (using HEC-PRM and no initial solution).

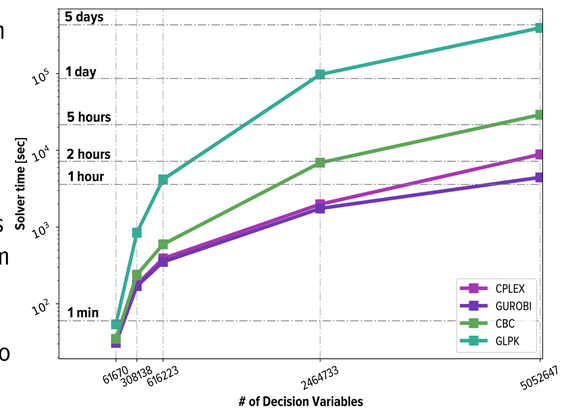


Figure 3: Solver runtime comparison

Model output: Water Supply Portfolio

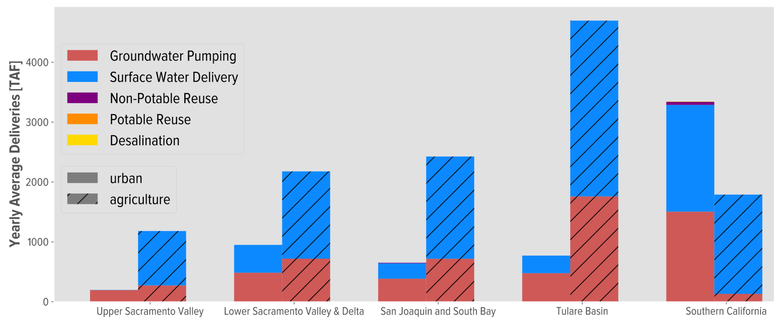


Figure 4: Water supply portfolio across regions

Initial Findings: Drought vulnerability assessment

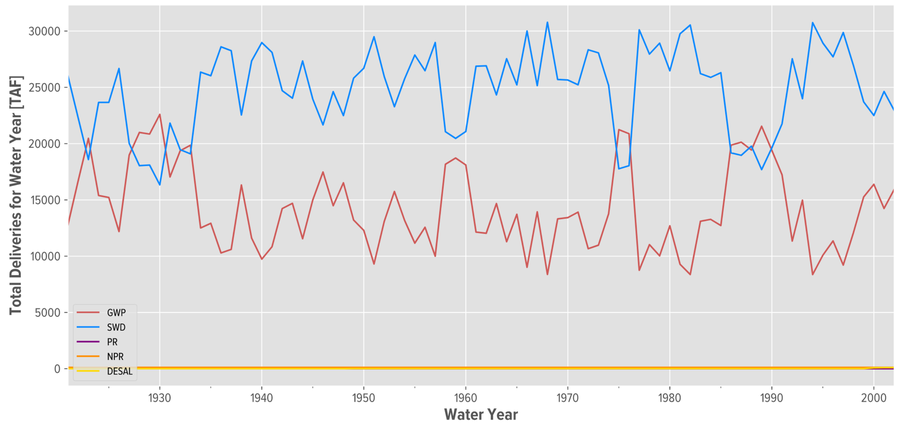


Figure 5: 82 Year PyVIN Run – time series of statewide water supply portfolio

Long-term changes in climate and population are expected to have significant impacts on the management of California's extensive water network, creating a need for hydro-economic models to explore adaptation strategies. The following plots look at how PyVIN allocates water in scenarios with reduced model inflows. Figures 6 and 7 include the initial findings from a 1 year model run (WY 2003).

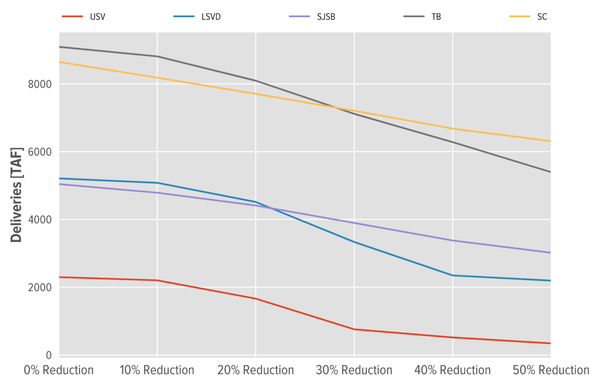


Figure 6: Change in regional deliveries with reduced statewide rim inflows

Drought conditions have brought reservoirs to historic lows and significant overdraft of groundwater basins. Future PyVIN climate studies will incorporate population growth and climate warming. PyVIN can be used to address important policy questions like how groundwater management mandated by SGMA will affect statewide operations and supply portfolio.

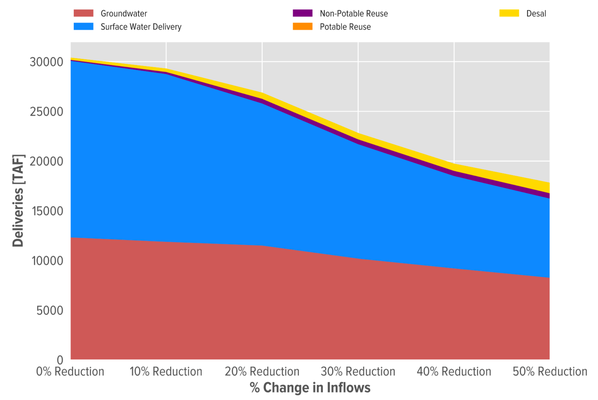


Figure 7: Change in statewide water portfolio with reduced inflows

References & Acknowledgements

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PyVIN repository: https://github.com/msdogan/pyvin
HOBBES repositories: https://github.com/ucd-cws/calvin-network-tools & https://github.com/ucd-cws/calvin-network-data