Enhanced Resource Adequacy Representations for Power System Capacity Expansion Planning

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Capacity Expansion and Resource Adequacy

Capacity Expansion Planning

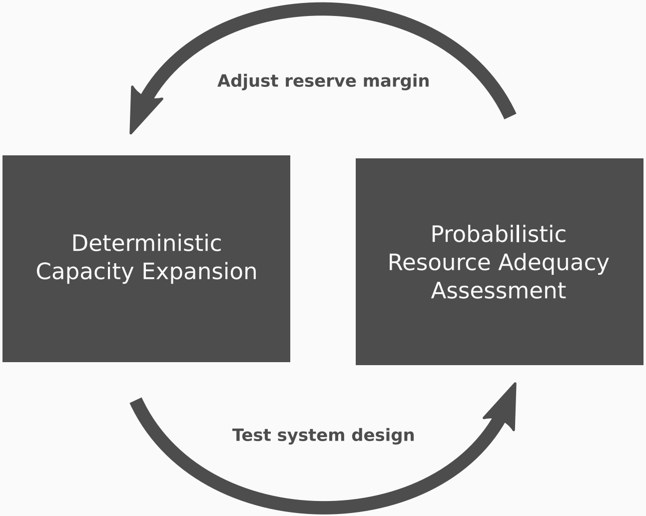
- Longer-term planning optimization
- Computationally demanding, even in the deterministic case
- Usually only considers limited number of representative operating periods
- Resource adequacy is a key constraint

Resource Adequacy Assessment

- Shorter-term operations simulation
- Preferably probabilistic, considering many alternative realizations of future system state
- Every hours matters

How do we reconcile these paradigms to plan economically-efficient, resource adequate systems without sacrificing computational tractability?

Planning Reserve Margin Iteration



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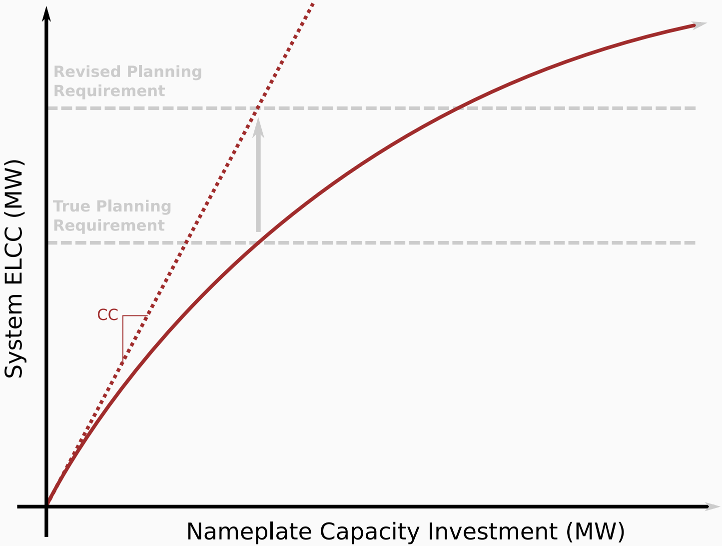
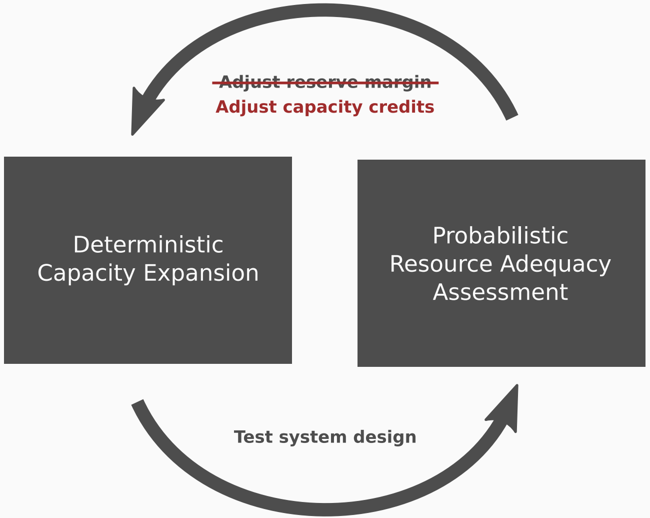
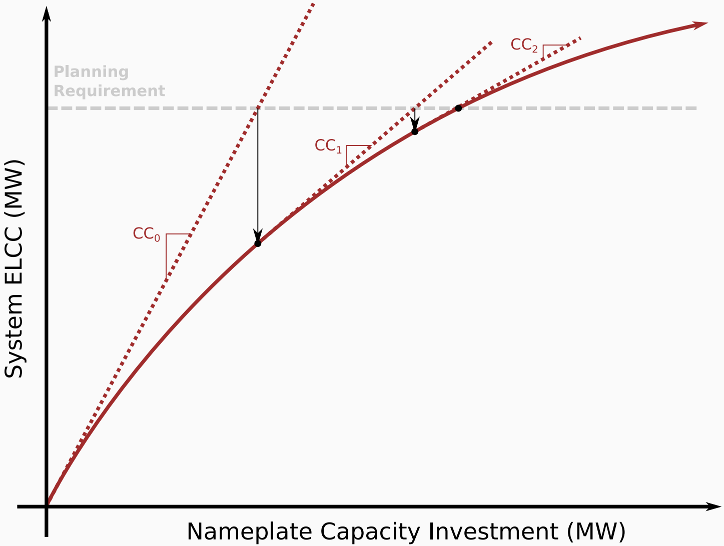


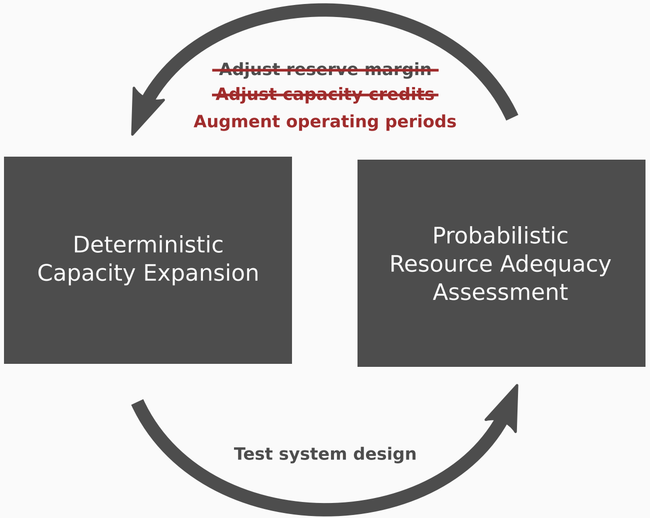
Capacity Credit Iteration



Capacity Credit Iteration

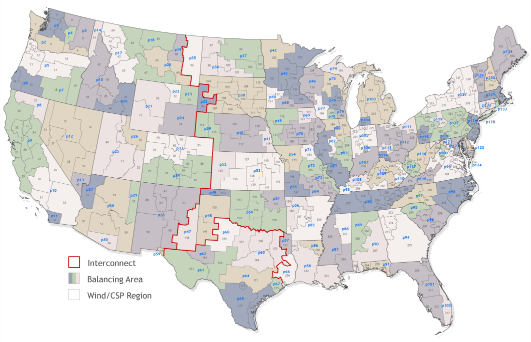


Risk Period Iteration

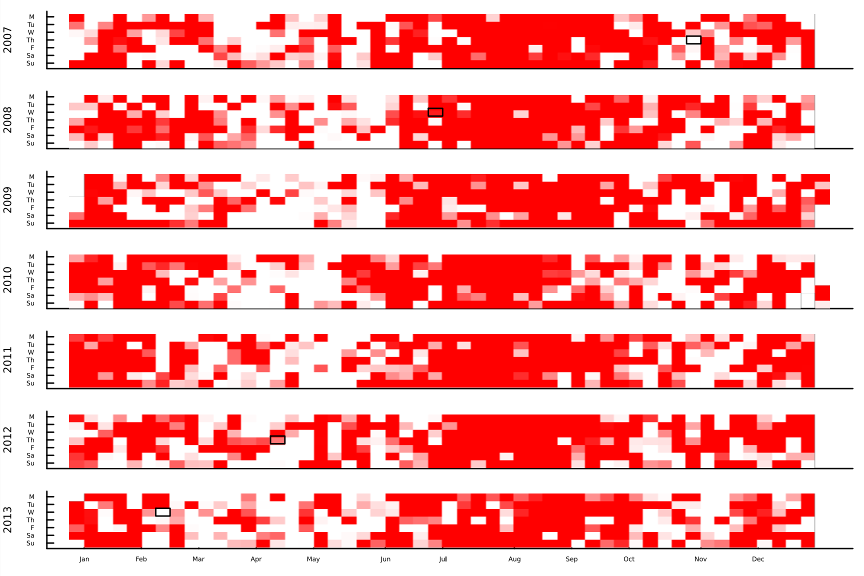


Risk Period Iteration: example application

- Adequacy stress test: plan a greenfield, 100% wind/solar/storage system
- Seven year resource+load dataset with transmission constraints between 134 regions of contiguous U.S. (derived from ReEDS inputs)



Risk Period Iteration: discovering days to drive adequacy investment



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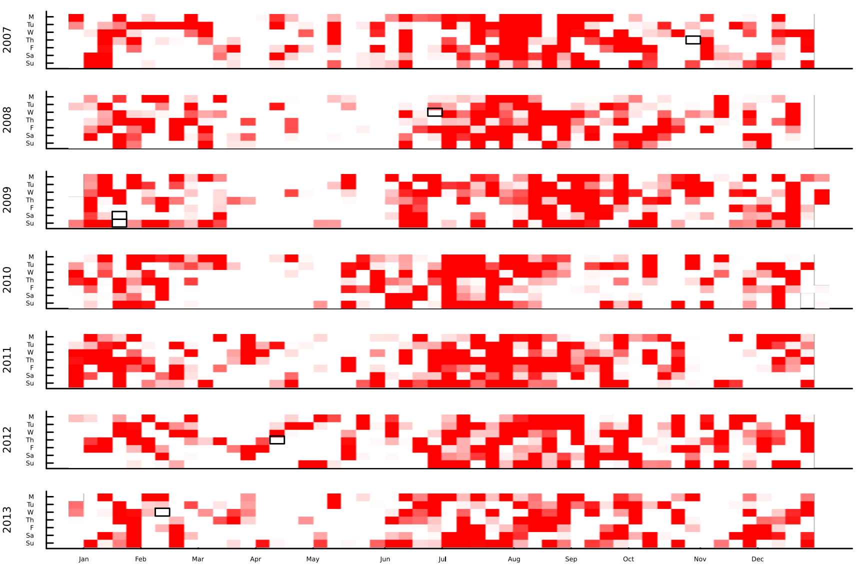

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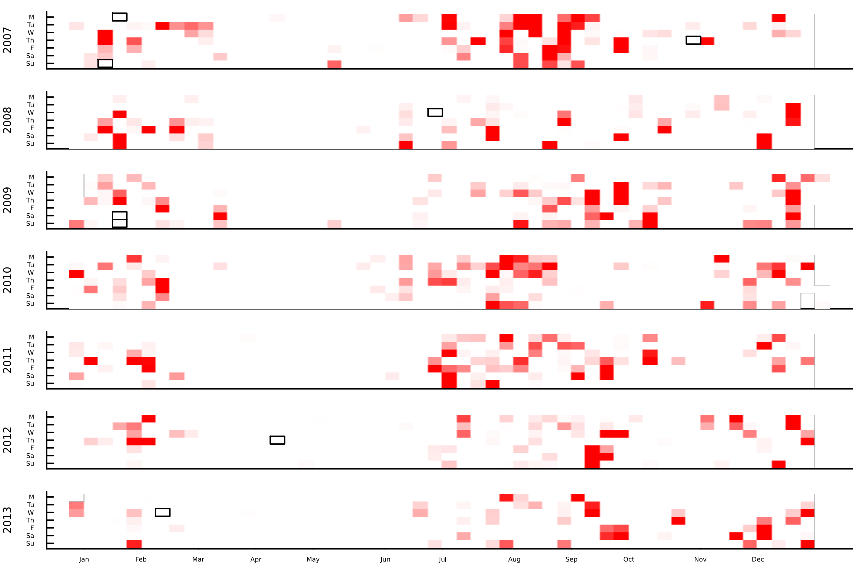

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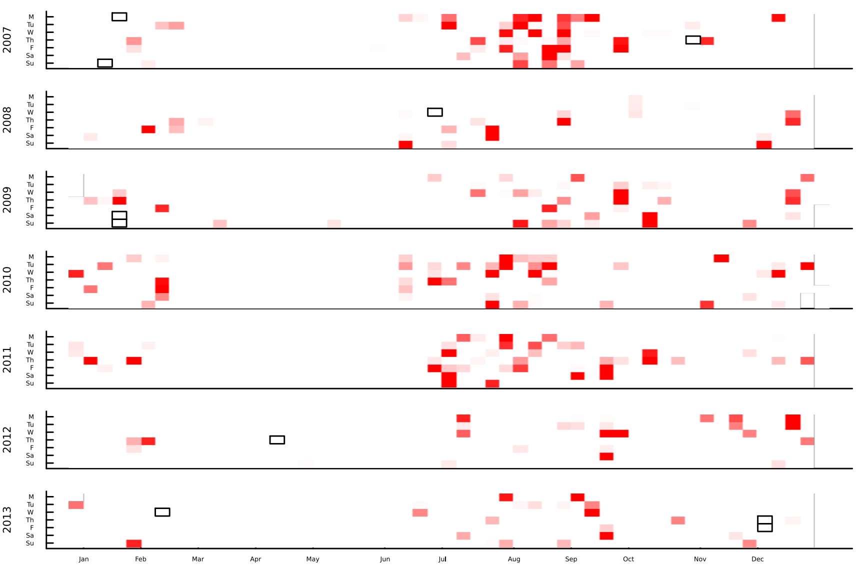

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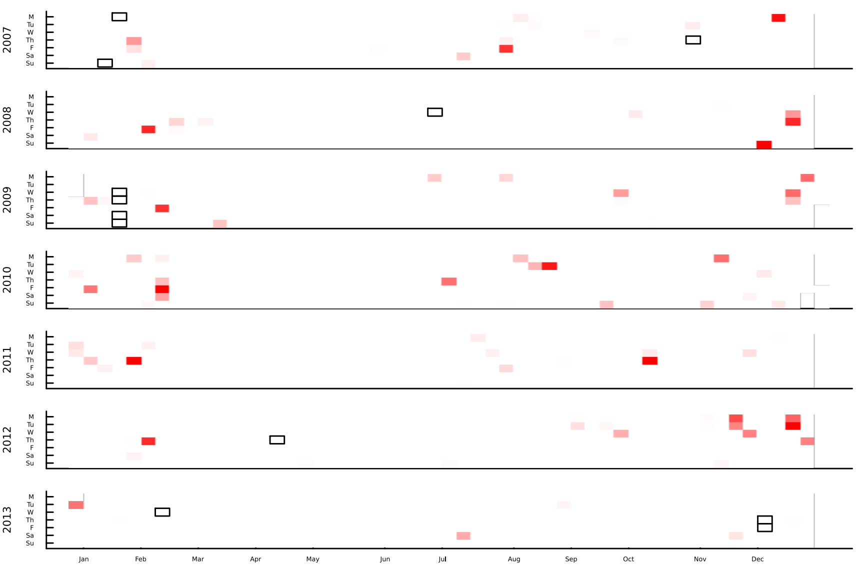

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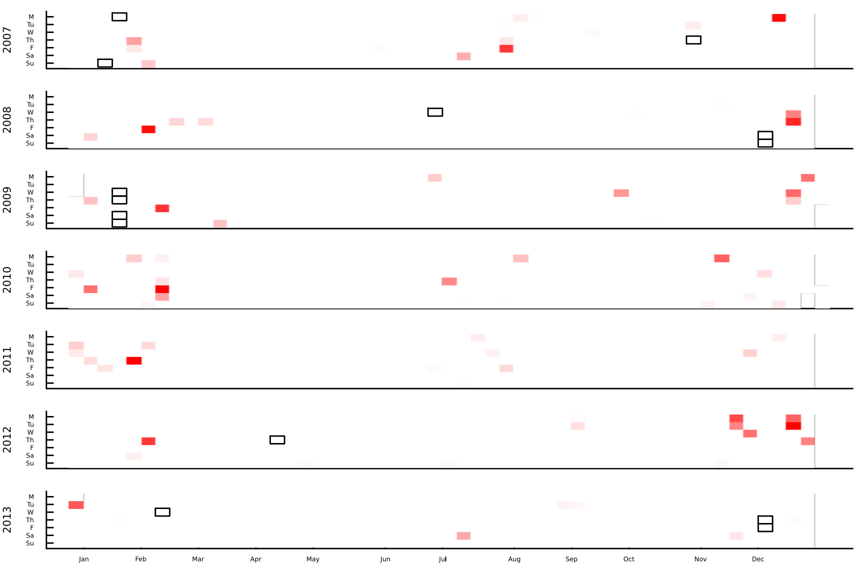

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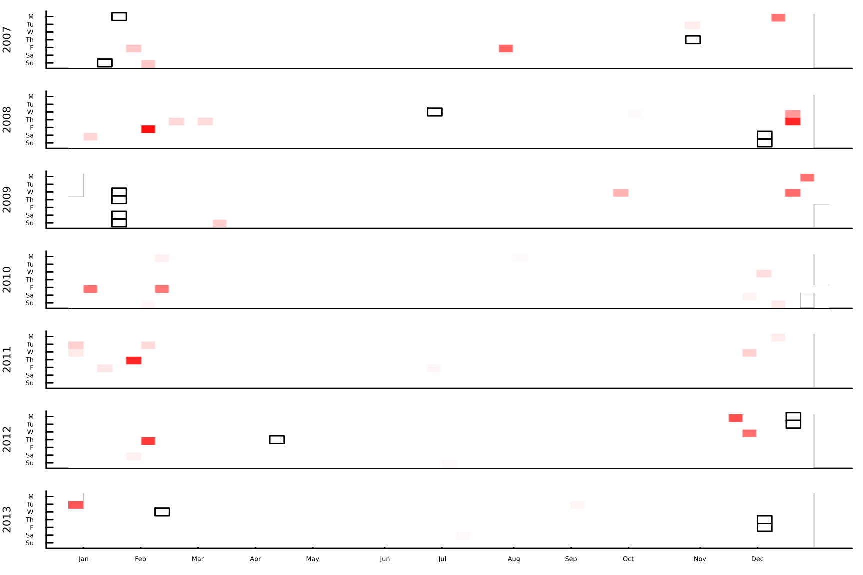

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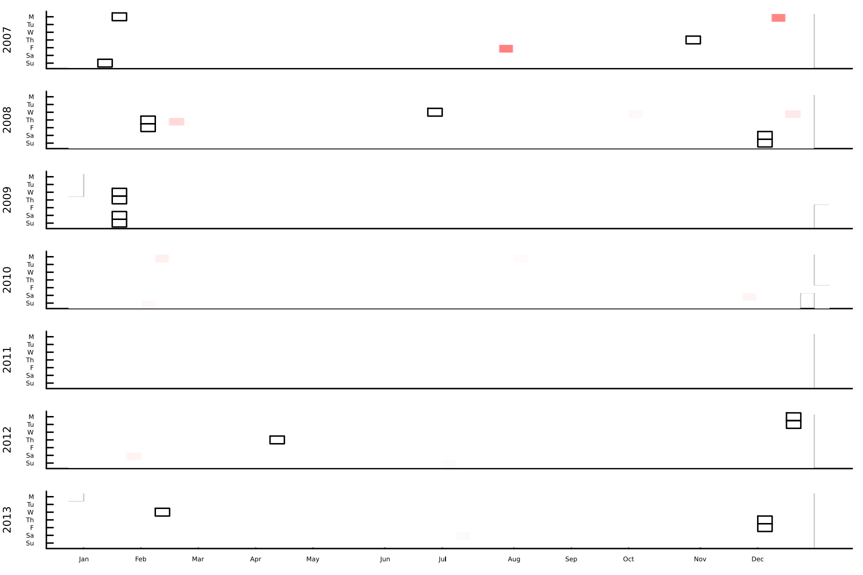

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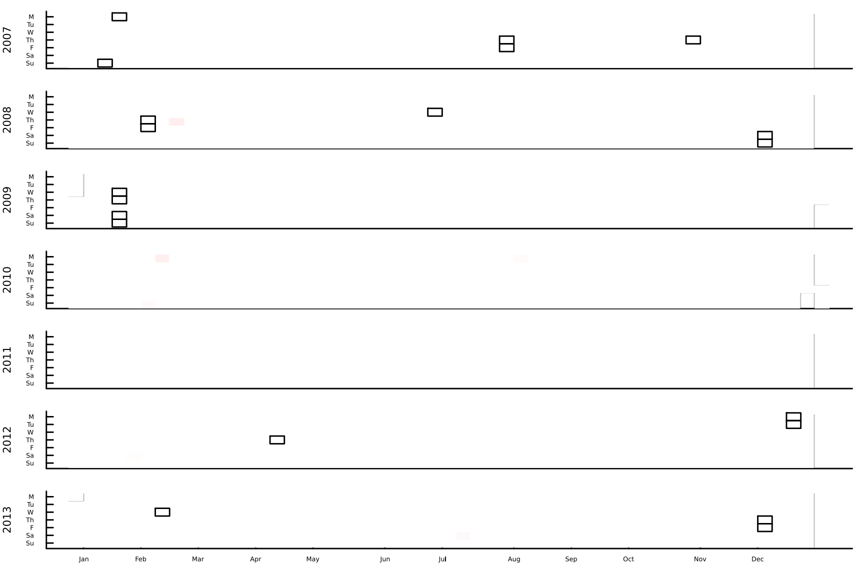

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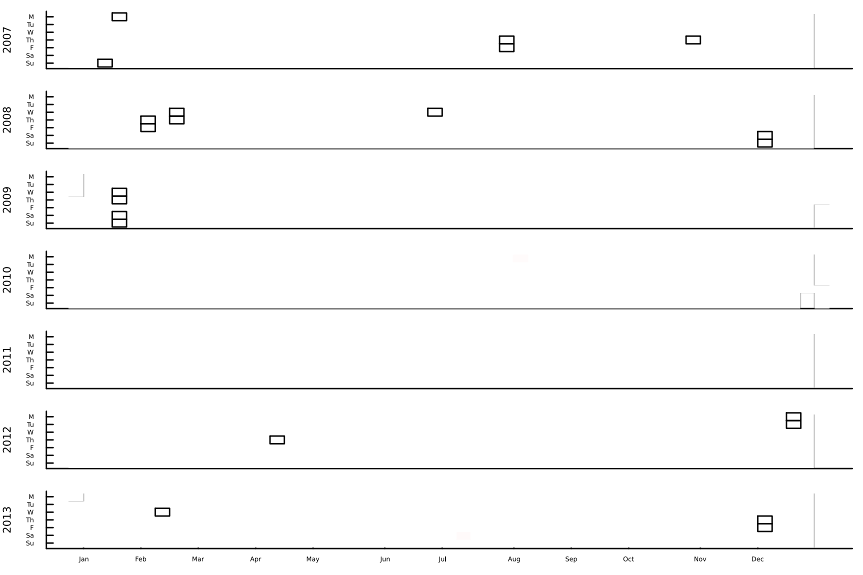

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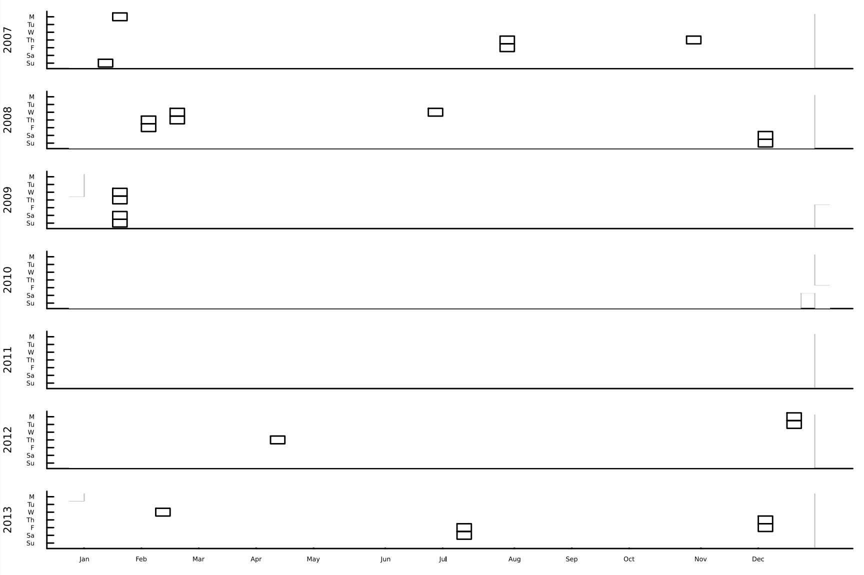
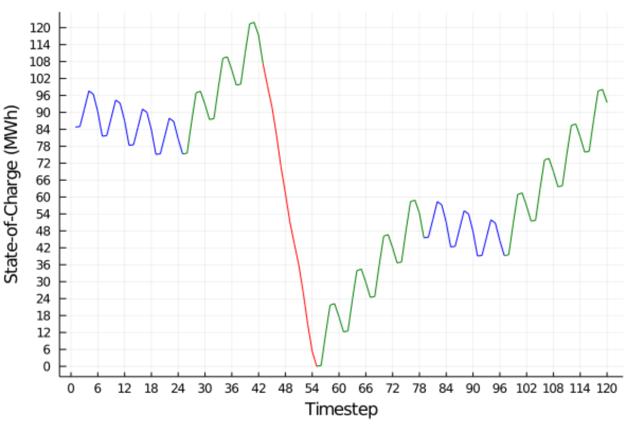


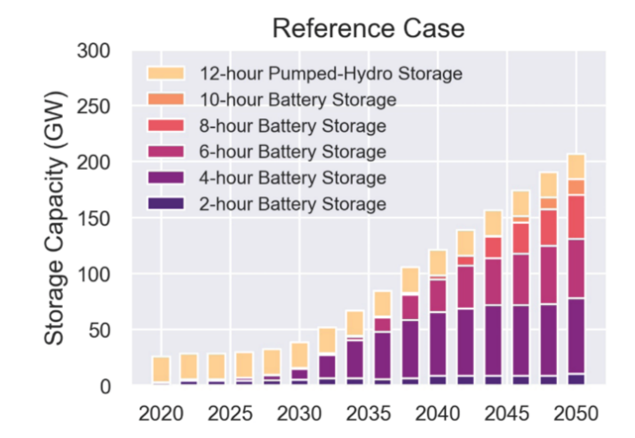
Considering Energy Limited Resources

- Full "sparse" chronology repeats representative days in temporal sequences with minimal impact on problem size
- Risk periods can be explicitly represented within overall chronology



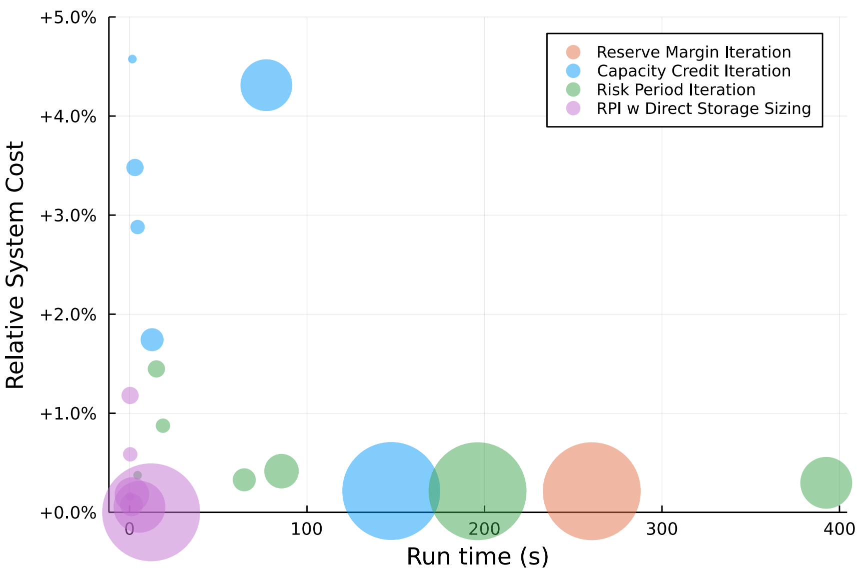
Considering Energy Limited Resources

- Capacity credit-based frameworks require arbitrarily partitioning energy-limited technologies into subclasses
- With a direct risk period representation, resources can be sized flexibly to system needs



Blair, Nate, Chad Augustine, Wesley Cole, et al. 2022. Storage Futures Study: Key Learnings for the Coming Decades. Golden, CO: National Renewable Energy Laboratory. NREL/TP-7A40-81779. https://www.nrel.gov/docs/fy22osti/81779.pdf

Adequacy Framework Performance Comparison (RTS-GMLC)



Stay in touch!

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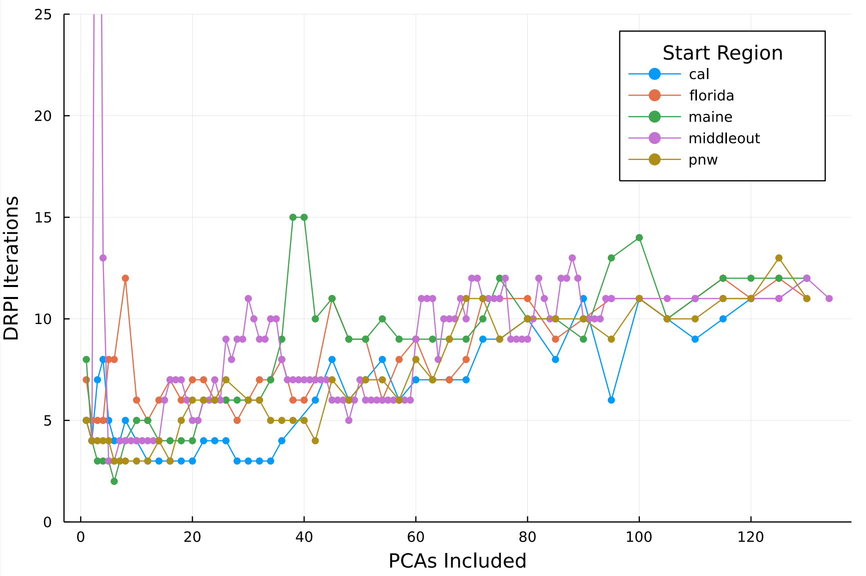
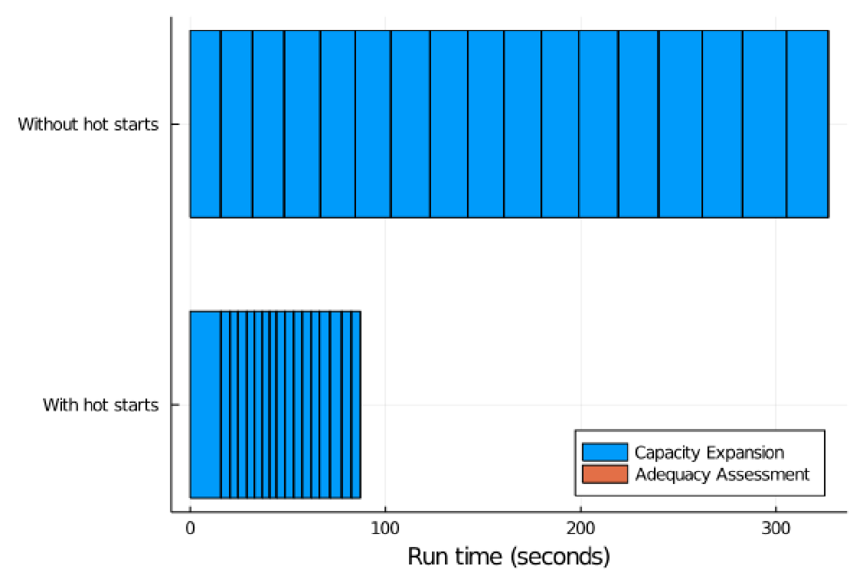
Appendix

Does Risk Period Iteration scale?



Hot-starting Iterative Optimization Solves



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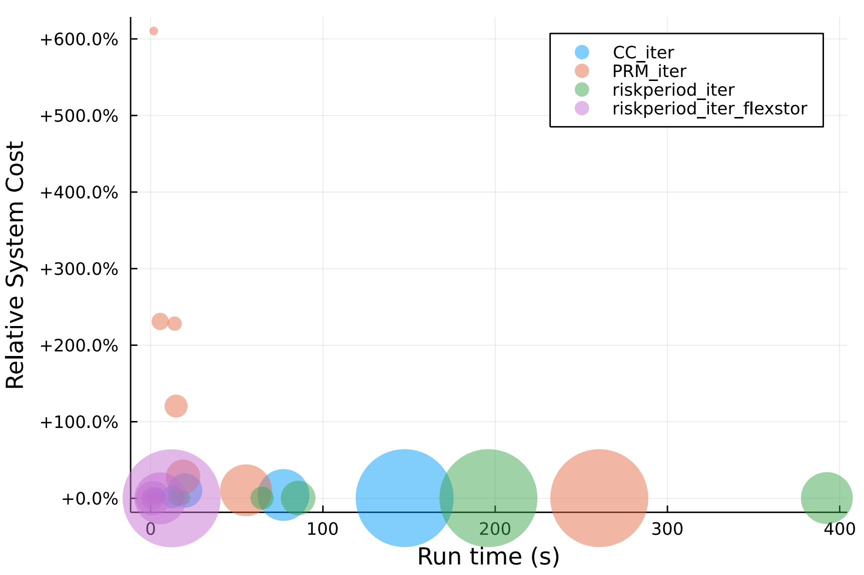

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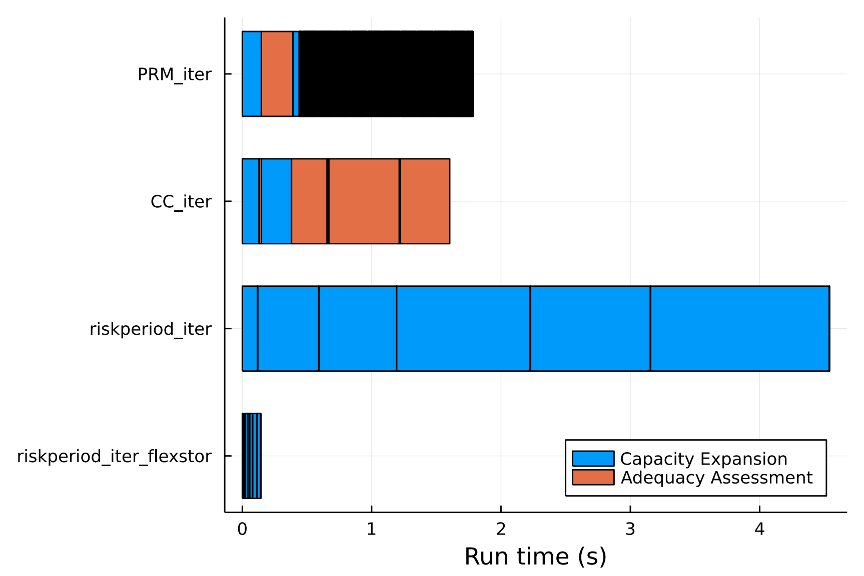

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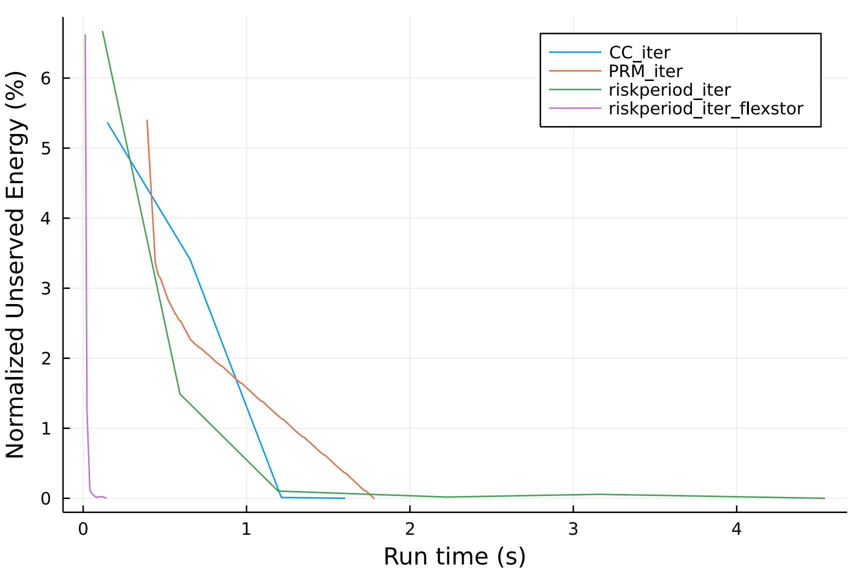

Sparse Chronological Energy Constraints (1/2)

$$\Delta e_d = \sum_{t \in T} p_{td} \quad \forall d \in D \tag{1}$$

$$\lfloor e \rfloor \leq \sum_{i=1..t} p_{id} \quad \forall t \in T, d \in D \tag{2}$$

$$\lceil e \rceil \geq \sum_{i=1..t} p_{id} \quad \forall t \in T, d \in D \tag{3}$$

Sparse Chronological Energy Constraints (2/2)

$$e_{0,p+1} = e_{0,p} + N_p \Delta e_{d_p} \quad \forall p \in P \tag{4}$$

$$0 \leq e_{0p} + \lfloor e \rfloor_{d_p} \quad \forall p \in P \tag{5}$$

$$0 \leq e_{0p} + (N_p - 1)\Delta e_{d_p} + \lfloor e \rfloor_{d_p} \quad \forall p \in P \tag{6}$$

$$e_{0p} + \lceil e \rceil_{d_p} \leq E \quad \forall p \in P \tag{7}$$

$$e_{0p} + (N - 1)\Delta e_{d_p} + \lceil e \rceil_{d_p} \leq E \quad \forall p \in P \tag{8}$$

Sparse Chronological Energy Constraints - Problem Size

- TD dispatch variables (p_{td})
- D state-of-charge evolution variables (Δe_d)
- 2D state-of-charge bounding variables ($\lceil e \rceil_d, \lfloor e \rfloor_d$)
- D state of charge evolution definitional constraints (enforcing the definition of Δe_d)
- 2TD relative minima and maxima inequality constraints (enforcing the definitions of $\lceil e \rceil_d$ and $\lfloor e \rfloor_d$)
- P boundary condition energy variables (e_{0p})
- P boundary condition equality constrants (enforcing the definition of e_{0p})
- 4P state of charge constraints