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# Designing Flexible Electric Generation Portfolios with Reinforcement Learning


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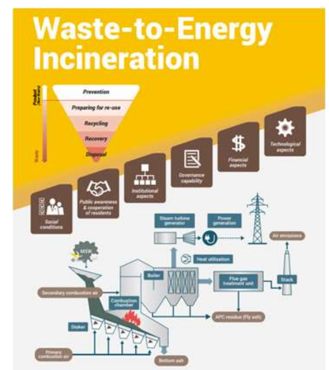
# Designing flexibility in electricity generation





# Challenges in planning for the future

- Uncertainties
  - Demand
  - Costs (investment, fuel)
  - Requirements for using renewable sources
  - Future carbon emission limit
- Planning for very long time horizons (~40 years)
- Need to make decisions at different stages

Monte Carlo simulation can integrate the uncertainties but making decisions with these uncertainties encounters curse of dimensionality

# Dynamic decision making with reinforcement learning

R. Giahi, "Sequential decision making and simulation-optimization for the design of complex engineering systems"

- Decisions made at different stages
- Monte Carlo simulation used to evaluate objective function at each stage
- Deep-Q reinforcement learning algorithm
- Proof of concept (capacity expansion problem over 5 stages)

Research goal: Apply reinforcement learning algorithm to dynamic decision problem for electricity generation

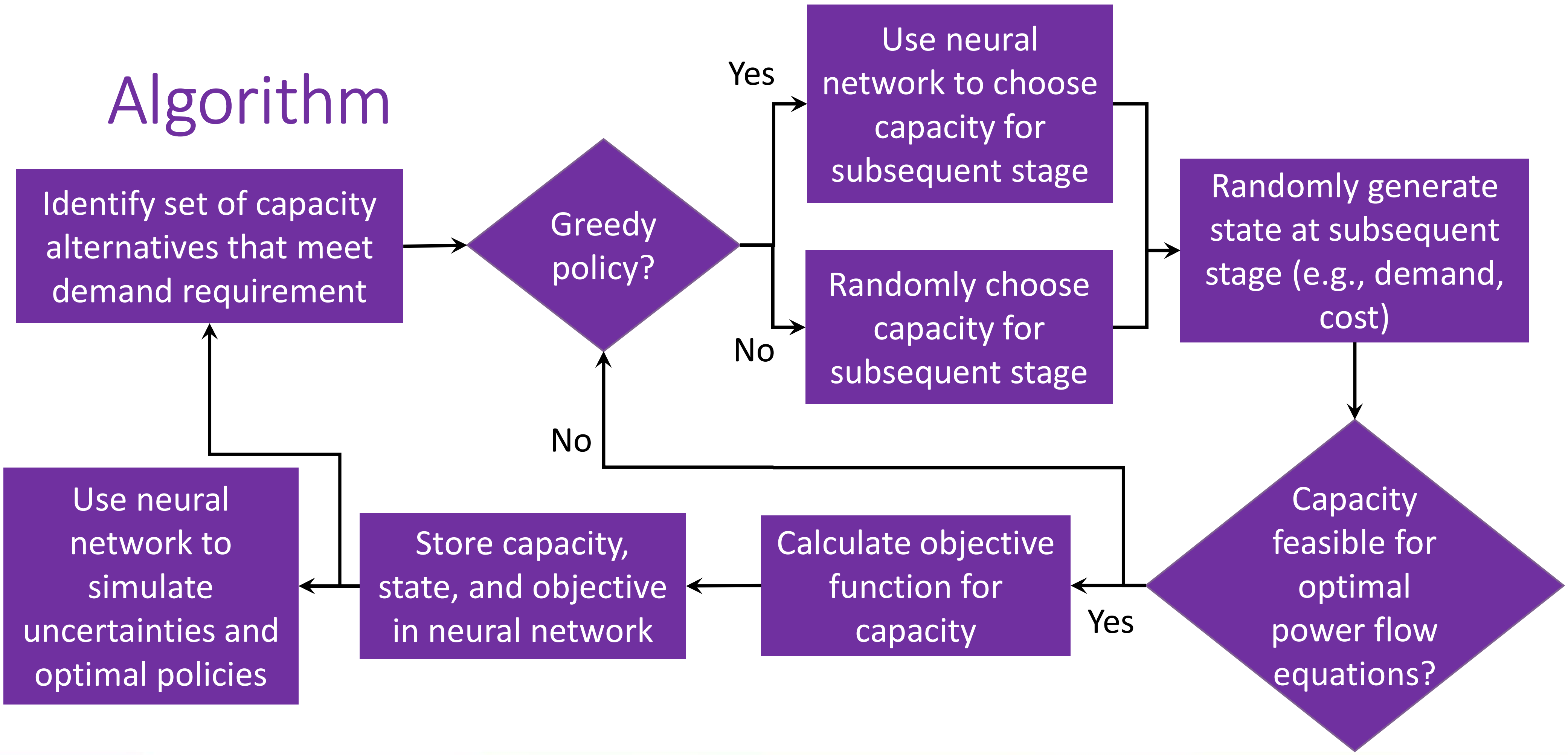
R. Giahi, 2020. "Sequential decision making and simulation-optimization for the design of complex engineering systems." PhD Dissertation, Iowa State University. https://lib.dr.iastate.edu/etd/18317/

# Problem outline

- Decision variables: Choose capacity for each electricity technology at each stage
- Objective: Minimize total discounted cost
  - Investment
  - Operations and maintenance
  - Cost of fuel generation
  - Salvage value
- Constraints
  - Capacity greater than demand
  - Power flow equations
  - Requirement that X% comes from renewable resources
  - Limit on carbon emissions
  - Limit on natural gas

Could be uncertain

# Algorithm


Identify set of capacity alternatives that meet demand requirement
Greedy policy?
Yes
Use neural network to choose capacity for subsequent stage
No
Randomly choose capacity for subsequent stage
Randomly generate state at subsequent stage (e.g., demand, cost)
Capacity feasible for optimal power flow equations?
No
Yes
Calculate objective function for capacity
Store capacity, state, and objective in neural network
Use neural network to simulate uncertainties and optimal policies

# Application

Mejia-Giraldo and McCalley, “Maximizing future flexibility in electric generation portfolios”

- ~~5 regions~~ 1 region
- ~~14 generation technologies~~ 2 technologies: natural gas and wind
- ~~40-year time horizon divided into 20 stages~~ 5 stages
- ~~10 representative scenarios (clustering algorithm~~)

  10,000 scenarios (reinforcement learning and neural network)

D. Mejia-Giraldo and J.D. McCalley, 2014. “Maximizing future flexibility in electric generation portfolios,” *IEEE - Transactions on Power Systems* 29(1): 279-288.

# Uncertainties

- Demand: increases each year but two different rates of increase
- Cost of fuel generation for gas: increases each year but two different rates
- Cost of investment for wind: decreases each year but two different rates

*All units in gigawatts*

| Stage 1 (Gas, Wind) | Stage 2 Demand | Stage 2 (Gas, Wind) | Stage 3 Demand | Stage 3 (Gas, Wind) | Stage 4 Demand | Stage 4 (Gas, Wind) | Stage 5 Demand | Stage 5 (Gas, Wind) |
|---|---|---|---|---|---|---|---|---|
| (34, 20) | 130 | (0, 2) | 132 | (0, 2) | 133 | (0, 2) | 135 | (0, 2) |
| | | | | | | | 136 | (0, 3) |
| | | | | | 134 | (0, 3) | 136 | (0, 2) |
| | | | | | | | 137 | (0, 4) |
| | | | 133 | (0, 3) | 134 | (0, 2) | 136 | (0, 2) |
| | | | | | | | 137 | (0, 4) |
| | | | | | 136 | (0, 4) | 137 | (0, 2) |
| | | | | | | | 139 | (0, 3) |
| | 131 | (0, 3) | 133 | (0, 2) | 134 | (0, 2) | 136 | (0, 2) |
| | | | | | | | 137 | (0, 4) |
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| | | | | | | | 139 | (0, 3) |
| | | | 134 | (0, 4) | 136 | (0, 2) | 137 | (0, 2) |
| | | | | | | | 139 | (0, 3) |
| | | | | | 137 | (0, 3) | 139 | (0, 2) |
| | | | | | | | 140 | (0, 4) |

# Preliminary conclusions and future work

- Preliminary conclusions
  - Incorporating optimal power flow conditions into dynamic decision making with uncertainty presents significant challenges (computational time)
  - Myopic policy seems optimal
  - Demand is only uncertainty that influences capacity decisions
- Future challenges
  - Problem scale → more decision variables, uncertainties, stages
  - Improve algorithm efficiency
  - Verify algorithm produces optimal solution
  - Demonstrate usefulness compared to existing stochastic programming solutions

# Acknowledgements


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