The Value of Distributed Resources in Climate-Resilient Power System Expansion Planning

Conference on Innovations in Climate Resilience

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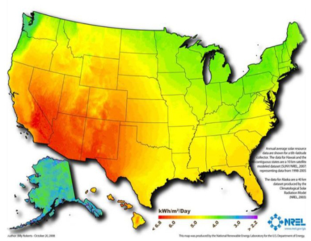
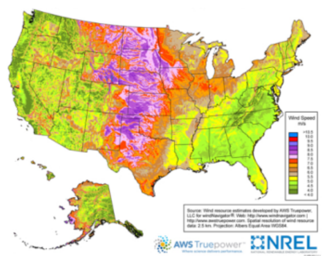
Improved Power System Resilience Starts with Strategic Capacity Expansion Planning

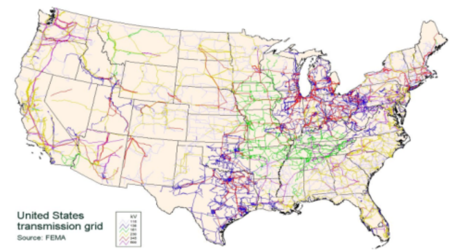
Solar Resources (NREL)



Wind Resources (NREL)

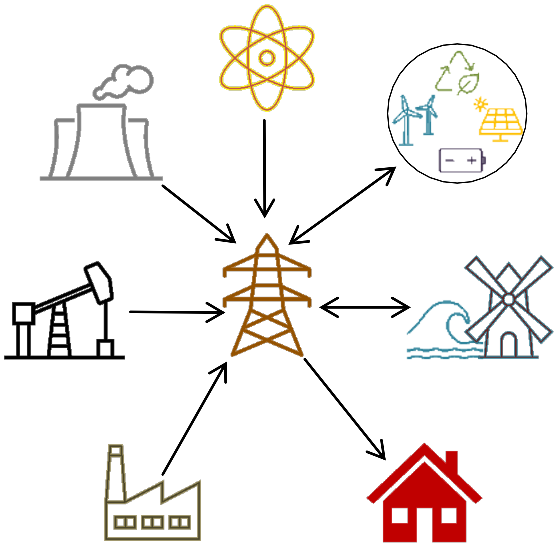


U.S. Transmission System (FEMA)



Population (Census Bureau)

- **The Capacity Expansion** problem identifies most cost-effective combination of **transmission, generation,** and **storage** investments to meet:
  - Forecasted demand
  - Renewable and environmental goals
- Supply, demand, transmission, and storage are affected by future climate and weather
  - We use stochastic programming to optimize across a set of future climate scenarios



Distributed Energy Resources (DERs) should be part of the model

DERs are usually embedded in demand, not modeled explicitly

- DER penetration is much smaller than large-scale plants
- DERs reside where demand resides (at low voltage levels)
- DER behavior is usually linked to demand behavior
- DERs are not directly controllable (neither installation nor operation)

… but we should strive to include them in our models

- DER penetration is rising and expected to continue
- DERs are being included in Integrated Resource Plans as Non-Wire Alternatives to defer investments [1]
- DER behavior is climate and weather-dependent
- Technology improvements and regulations are making DERs increasingly responsive to system signals
  - e.g. FERC Order 2222 opens the market to DER Aggregators [2]

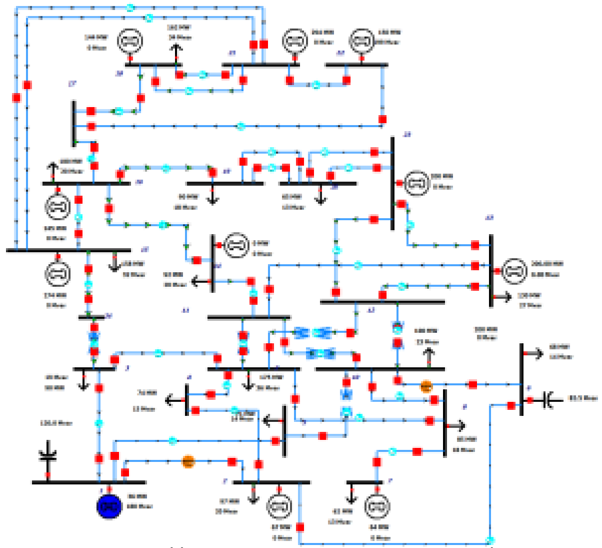
We Adapt Existing Capacity Expansion Models to Include Climate-Related Parameters

- We incorporate long-term changes in climate
  - Scenarios of hourly resource availability (wind, utility-scale solar and rooftop solar)
  - Scenarios of hourly demand that correlate with scenarios of supply
- Other climate impacts that will be included
  - Specific components disabled or de-rated by extreme events
  - Increased cost of certain technologies through weatherization and/or reduced lifetime
  - Reduced efficiency and maximum potential capacities

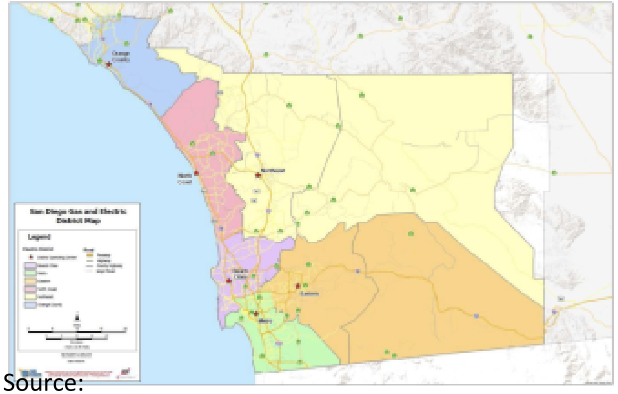



Test Case: Semi-Realistic System in SDG&E Territory

- Electric network data based on IEEE 24-bus system, extended by
  - Assigning generation types to approximate existing mix of SDG&E territory
  - Assigning hourly load and renewable profiles from California Public Utilities Commission (CPUC) data
- Assigning CPUC load to initial system increases load by up to 27%, inducing need for capacity expansion
- New lines and generators can be built in same locations as existing lines and buses, respectively
- Assumes the system is isolated (no transfers with neighboring regions)



Source: https://electricgrids.engr.tamu.edu/electric-grid-test-cases/ieee-24-bus-system/

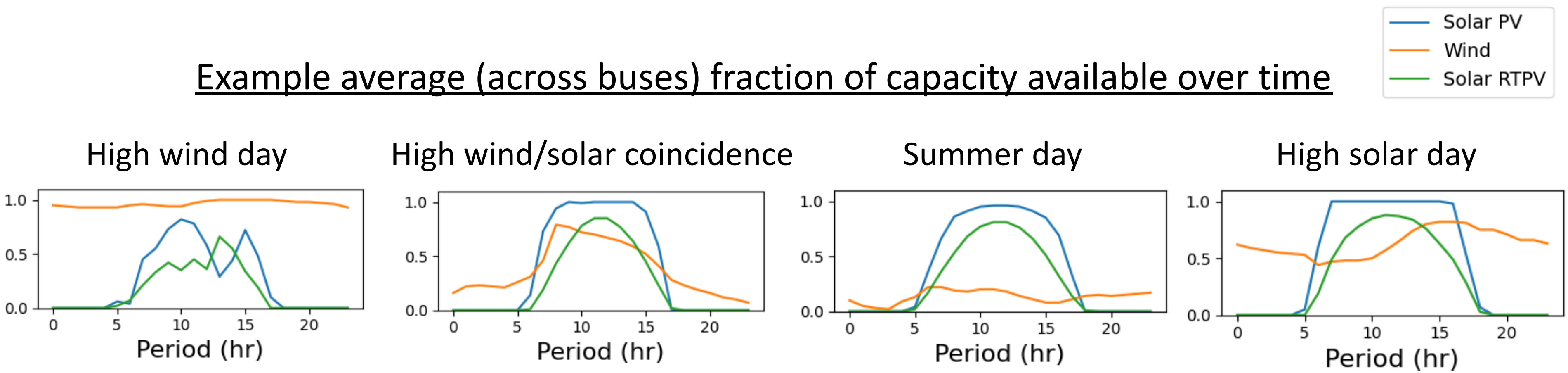


Source: https://www.sdge.com/sites/default/files/SDGE%202019%20Town%20Hall%20-%20120920%20Presentation.pdf

Test Case: Scenarios Considered for the Stochastic Problem

- Modest number of scenarios (10)
  - Seasonal differences
  - High/low wind and solar days
  - High/low wind-solar coincidence
- Scenarios affect
  - Hourly availability of renewable resources
  - Demand
- We run the stochastic program twice
  - Considering DERs fixed
  - Considering DERs decision variables

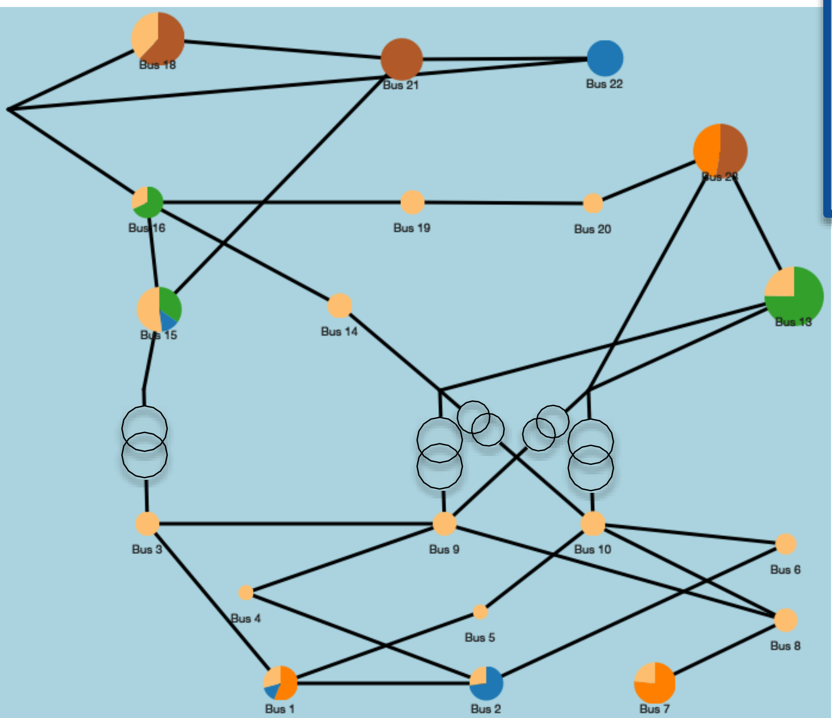
Example average (across buses) fraction of capacity available over time



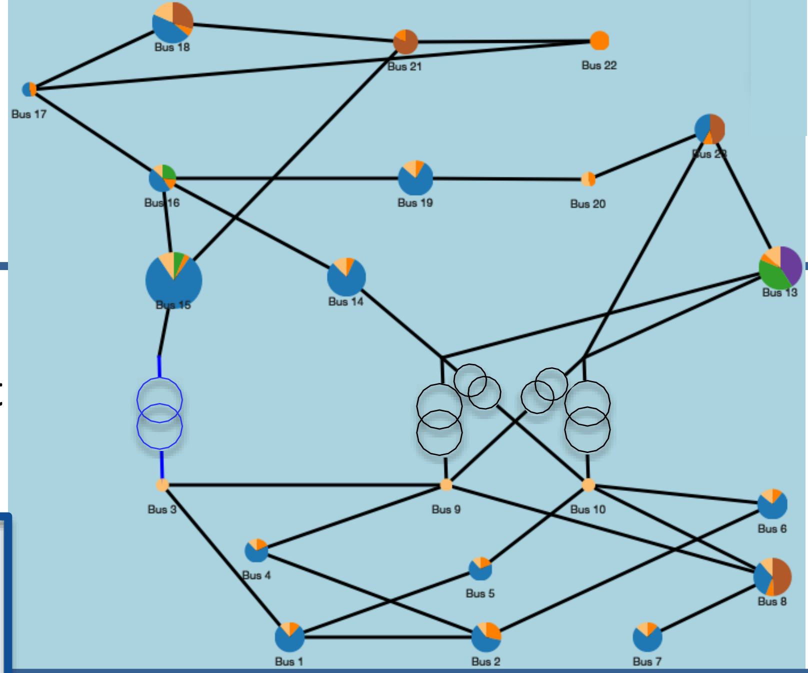
DERs avoid some investments but induce the need for others

= reinforced transmission branch

Initial system

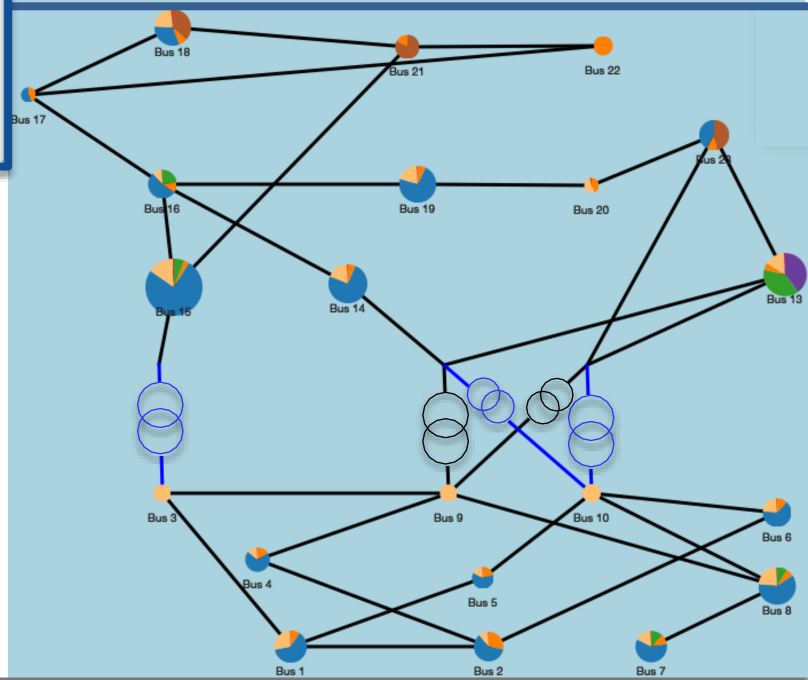


Without DERs



Coal
CCGT
OCGT
Solar PV
Wind
Solar RTPV
Controllable Load
Shiftable Load
Conventional Storage
BESS

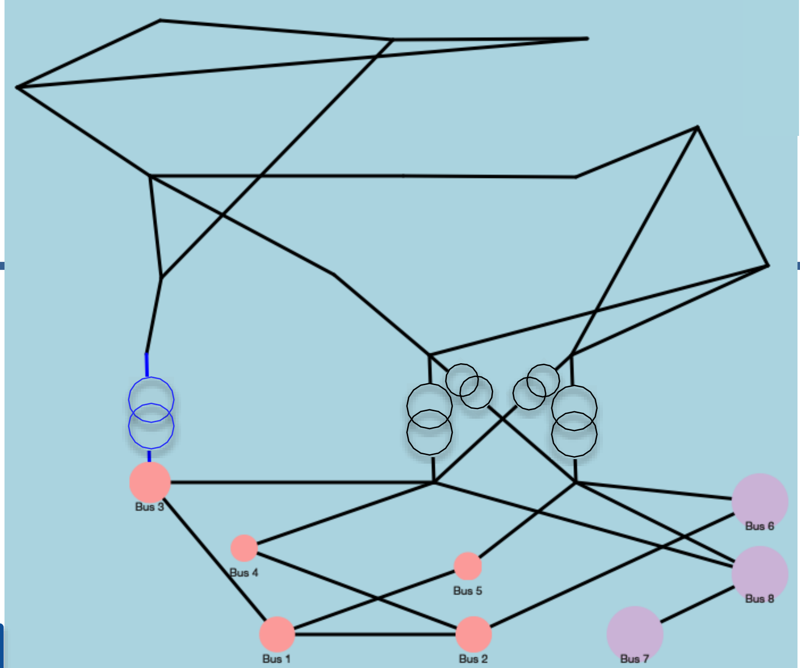
With DERs



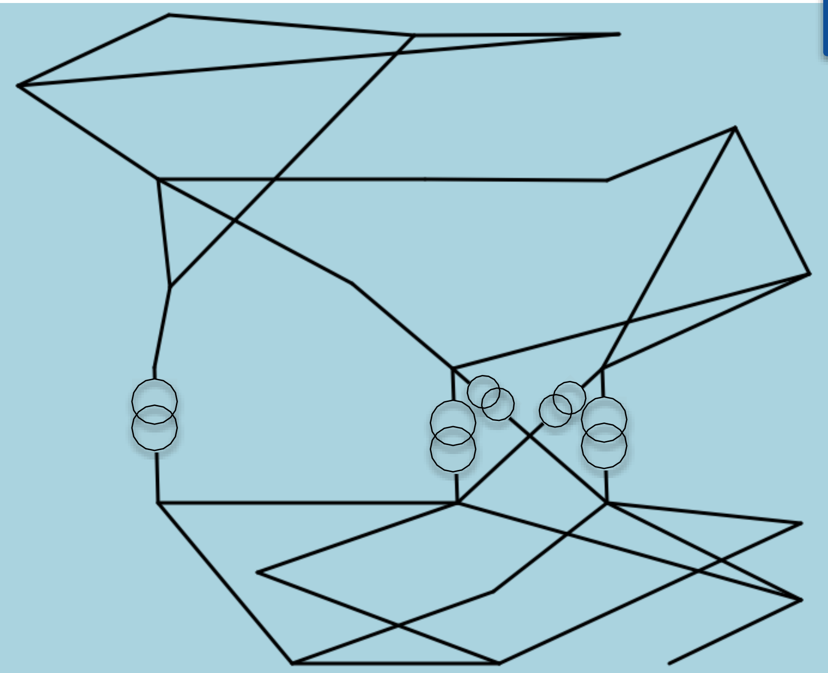
Full DER utilization may require more short-term storage

= reinforced transmission branch

Without DERs

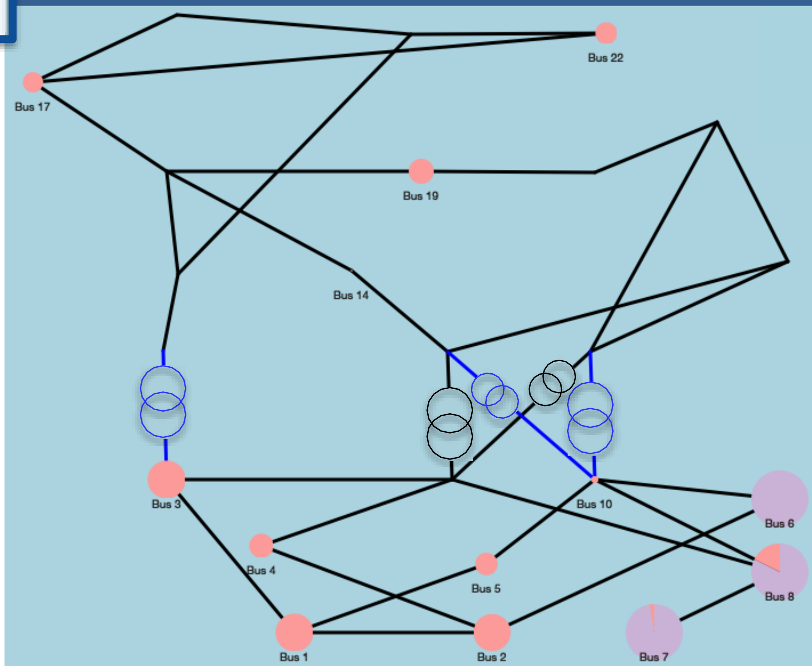


Initial system

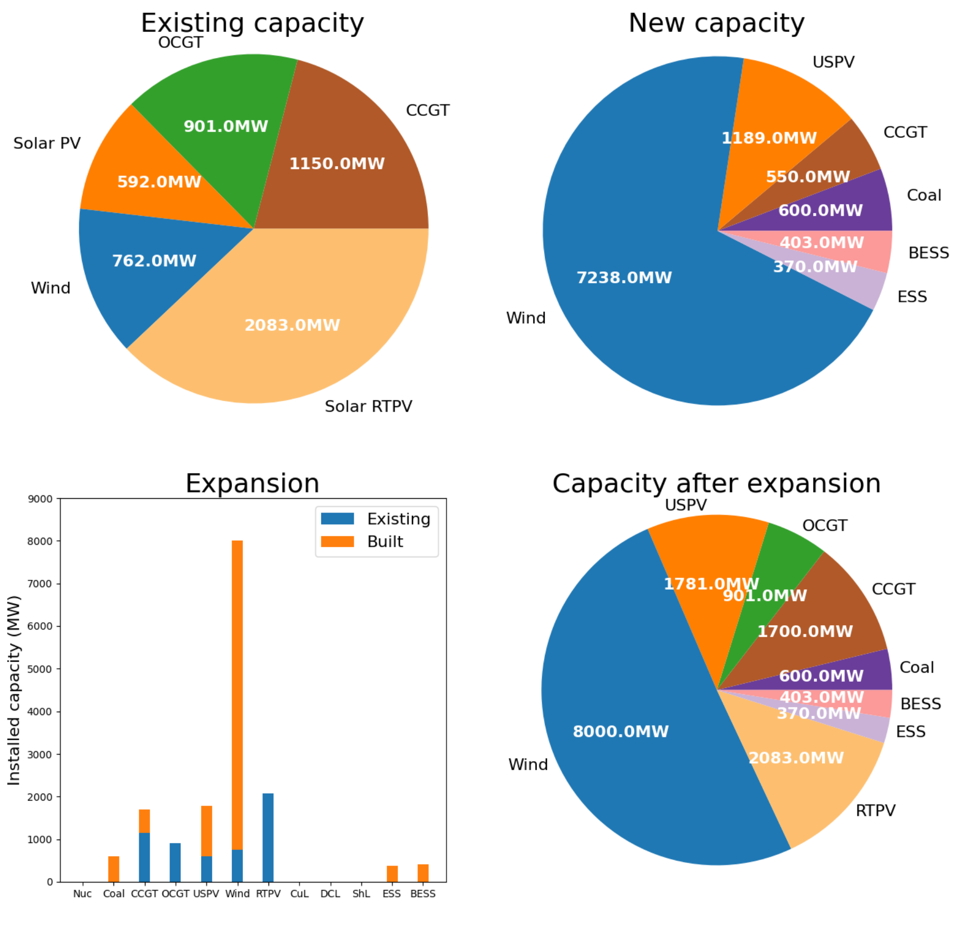


Conventional Storage
BESS

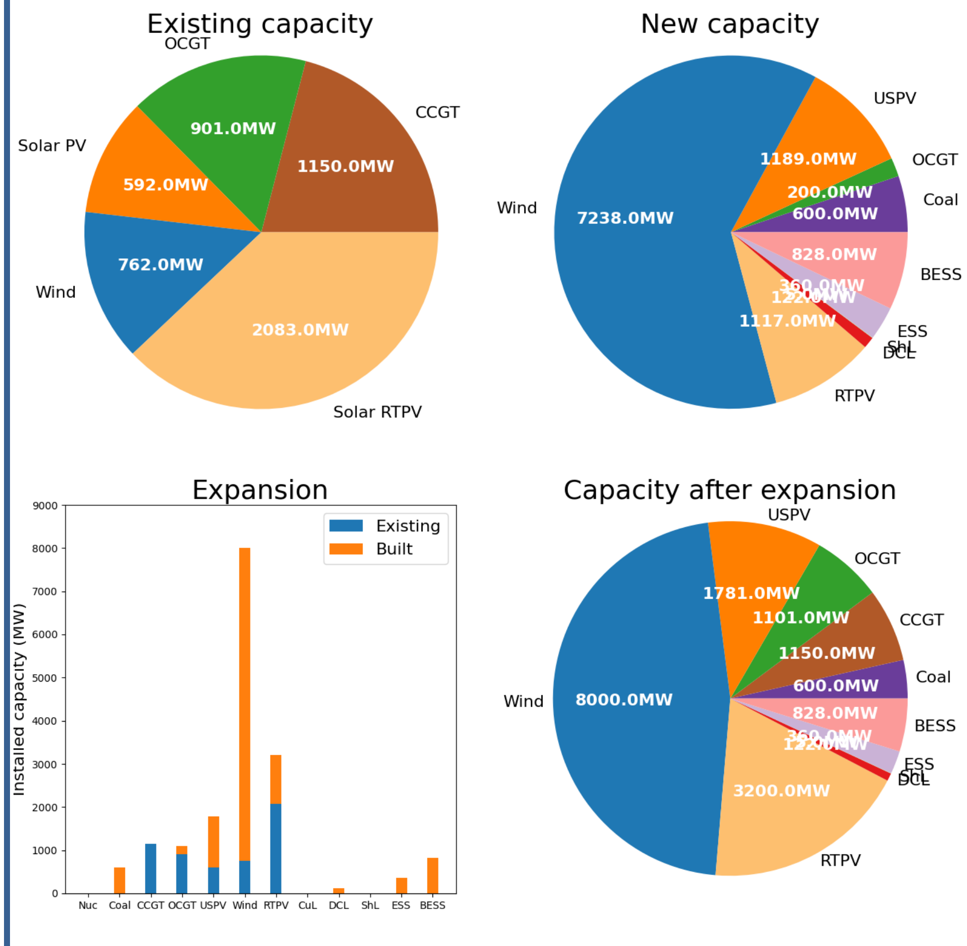
With DERs



If available for construction, DER deployment can avoid some new fossil fuel generation



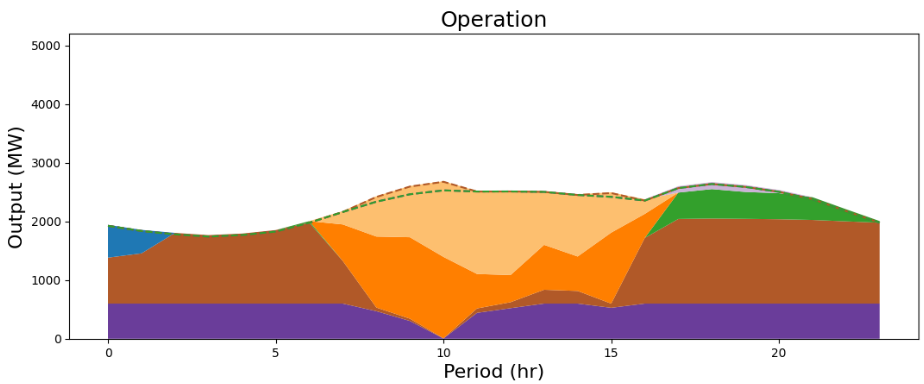
Results of model without DERs

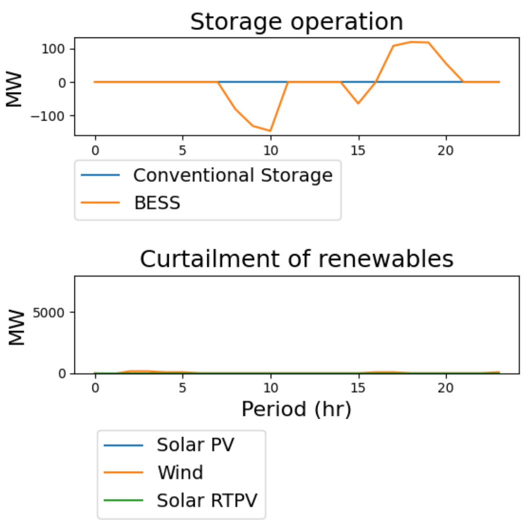


Results of model with DERs

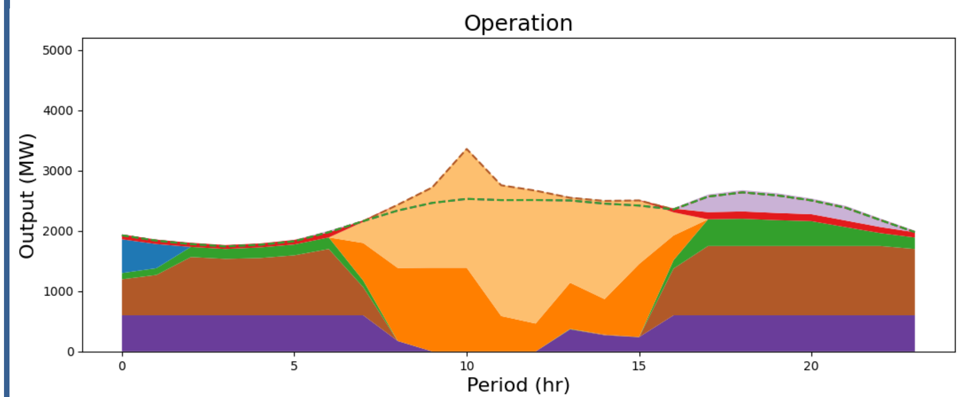
In some days, including DERs results in less utilization of costly, CO_2-emitting resources

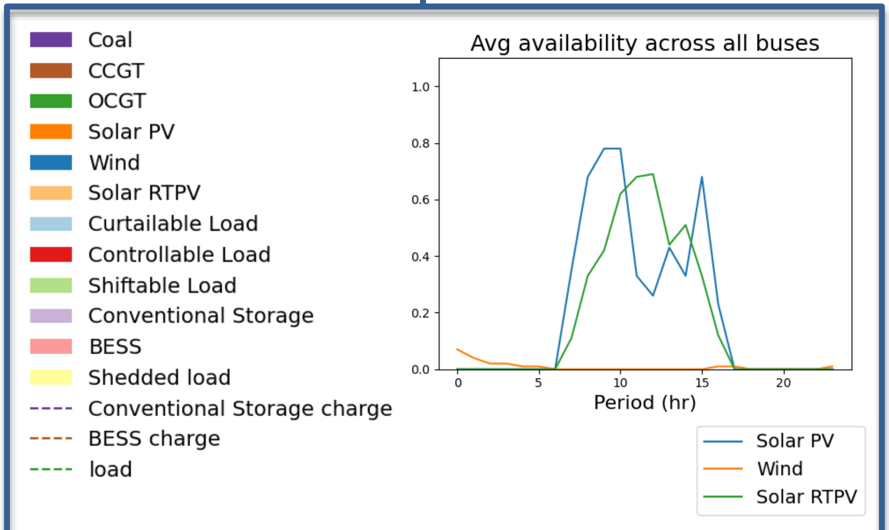
Results of model without DERs - low wind day

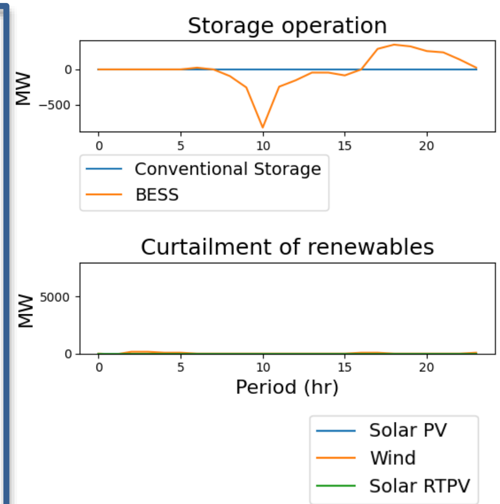




Results of model with DERs - low wind day







Conclusions

- Extended capacity expansion planning model to include climate-related variables and distributed resources
- Ran initial test for various sets of wind and solar scenarios
  - Wind and solar availability, as well as the explicit modelling of DERs, impacted both the capacity expansion and generation output decisions
- We can identify the climate and system data with highest impact on plan output
  - E.g. here, solar potential at key buses in system
- We can identify infrastructure projects that are good candidates for substitution through non-wire alternatives

Future Work

- Solve for more realistic CA test case
- Larger scenario sets incorporating more climate data
- Include extreme events
  - Their effect on availability and de-rating of certain components
- Run on data from Regionally Refined Model
  - Significantly improved resolution of climate data relevant for our expansion model

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Backup: Additional Data Sources

- [1] B. Reid, J. Bourg, D. Schmidt,"Let's Make a Deal", IEEE Power & Energy Magazine, Vol. 20 No. 2, March 2022
- [2] FERC Order No. 2222: Fact Sheet: https://ferc.gov/media/ferc-order-no-2222-fact-sheet
- [3] Eastern Interconnection Demand Response Potential, Oak Ridge National Lab, 2012, https://info.ornl.gov/sites/publications/Files/Pub37931.pdf
- [4] Costs to automate Demand Response - Taxonomy and Results from Field Studies and Programs, 2015, https://www.osti.gov/servlets/purl/1373278
- [5] Assessment of Long-Term, System-Wide Potential for Demand-Side and Other Supplemental Resources,2013-2032 Volume I, https://pscdocs.utah.gov/electric/13docs/13203501/249913PCorpDSMPotVolI1-16-2014.pdf
- [6] Incorporating Demand Response into Western Interconnection Transmission Planning, LBNL, 2013, https://eta-publications.lbl.gov/sites/default/files/lbnl-6381e.pdf
- [7] Lazard's Levelized Cost of Energy Analysis - Version 15.0. October 2021, https://www.lazard.com/media/451905/lazards-levelized-cost-of-energy-version-150-vf.pdf
- [8] 2020 Grid Energy Storage Technology Cost and Performance Assessment, Kendall Mongird, Vilayanur Viswanathan, Jan Alam, Charlie Vartanian, Vincent Sprenkle, Pacific Northwest National Laboratory. 2020. Availabe at https://www.pnnl.gov/sites/default/files/media/file/Final%20-%20ESGC%20Cost%20Performance%20Report%2012-11-2020.pdf Accompanying website: https://www.pnnl.gov/ESGC-cost-performance
- [9] CPUC Datasets: https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/electric-power-procurement/long-term-procurement-planning/2022-irp-cycle-events-and-materials/unified-ra-and-irp-modeling-datasets-2022
- [10] ERA5: https://www.ecmwf.int/en/forecasts/datasets/reanalysis-datasets/era5
- [11] System Advisor Model: https://sam.nrel.gov/
- [12] CMIP6 - Coupled Model Intercomparison Project Phase 6: https://pcmdi.llnl.gov/CMIP6/