Interactions of Energy Efficiency and Demand Response on Power System Costs and Emissions

Andy Satchwell

With contributions from Brady Cowiestoll, Elaine Hale, and Paige Jadun (NREL) and Brian Gerke and Samanvitha Murthy (LBNL)

IRP Contemporary Issues Technical Conference: “Making Utility-Specific Resource Choices in a Changing Regional Market”
September 22, 2022

This work was funded by the U.S. Department of Energy’s Office of Energy Efficiency and Renewable Energy Building Technologies Office under Contract No. DE-AC02-05CH11231.

As demand flexibility grows in importance for the grid, it is important to…

- Take a more integrated approach to energy efficiency (EE) and demand response (DR) program design.
- Avoid unintended competition and promote complementarity between EE and DR.
- Minimize overall building-level and system-level costs and emissions.

Figure source: iStock

How do EE and DR interact with one another on a system cost and emissions basis in different power system configurations?

For system operators…	For utility planners…	For regulators and utilities…
How do EE and DR meet system needs to maintain reliability and service levels, and how does one resource affect the other?	What integrated EE and DR technologies and strategies are most valuable to the power system, and how robust are those valuations across different grid futures?	How should EE and DR program design and valuation frameworks evolve to account for interactive effects?

EE and DR interactions differ by perspective and objective

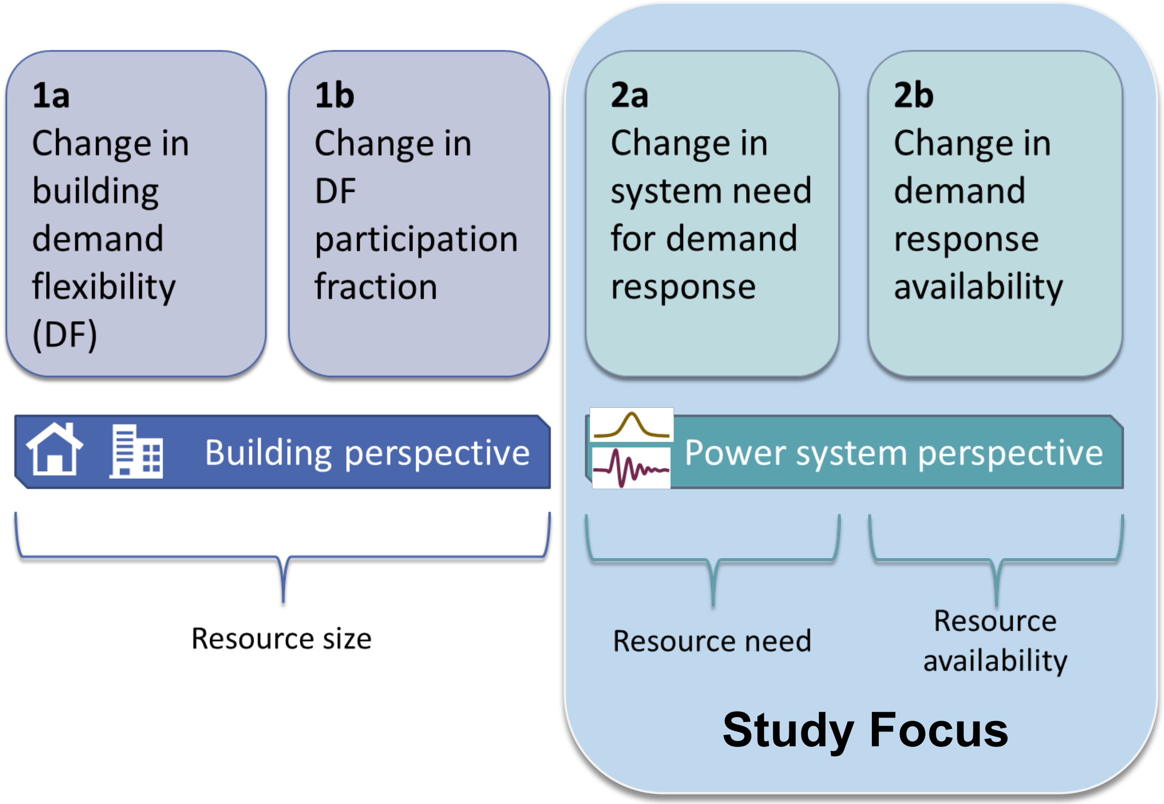


Figure source: Satchwell et al., 2020. Available at:
https://emp.lbl.gov/publications/conceptual-framework-describe-energy

Study boundaries

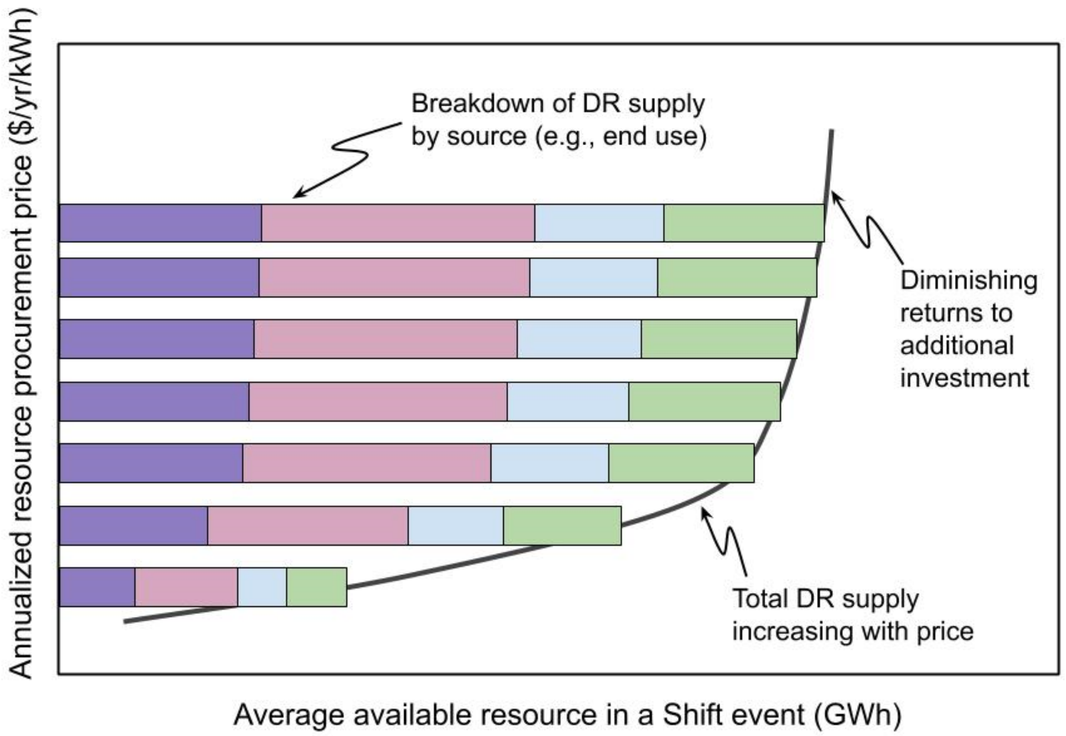
This study is *not*…	Instead, our intent is to…
An EE or DR potential study	Assess change in DR value under different EE packages and the most valuable combinations of EE and DR
Representative of "typical" or average EE savings and DR capacity amounts	Use aggressive energy savings packages reflecting high-efficiency technologies and aggressive estimates of DR availability to create identifiable impacts
A cost-benefit analysis	EE hourly load impacts are determined outside the least-cost expansion model; DR is selected by the model and is economic based on grid needs; Typical historical weather is assumed
Capturing all operational factors (e.g., transmission constraints) and/or 8760 dispatch costs	Identify key factors driving EE and DR interactions from power system perspective using a reduced-order national-scale model

EE Packages → DR Resource & Supply Curves → Capacity Expansion Modeling → Power System Scenarios → Power System Impacts

- Characterized by NREL ResStock and ComStock baseline and more efficient load shapes representing typical EE measures under fairly aggressive performance assumptions and at high customer adoption levels.
- EE measures were grouped into four portfolios (see figure at right) and draw on key EE and DR interactive attributes from the conceptual framework.

Baseline	Standard ResStock and ComStock inputs for present-day building stock and assuming 2012 actual meteorological year (AMY)
Controls	Include programmed HVAC controls, lighting occupancy sensors, demand-controlled ventilation, and advanced power strips.
Envelope	Upgrade windows, roof materials, and attic/wall/floor insulation; improve air sealing.
Equipment	Upgrade HVAC equipment, water heating equipment, appliances, lighting, electronics.

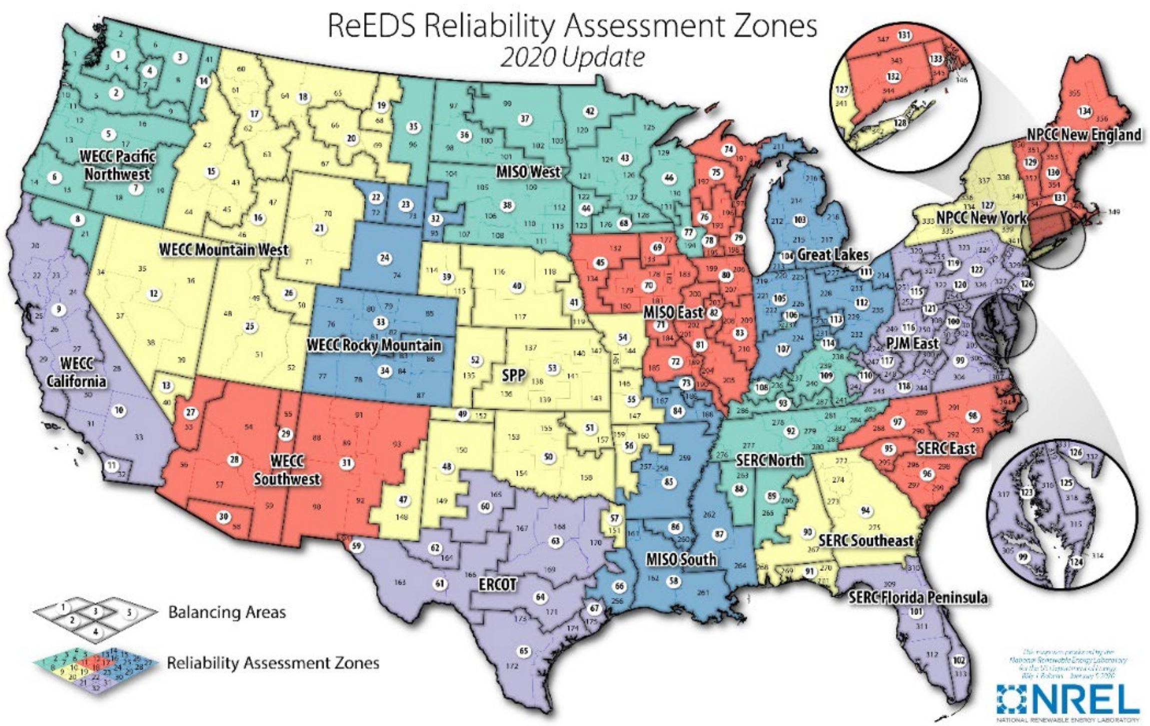
- LBNL's DR-Path model estimates the available DR resource by building type and end-use.
- The available DR resource was represented in the capacity expansion model as hourly profiles of load shedding and shifting availability procurable by the utility at discrete cost levels (i.e., supply curves that maximize the amount of DR resource that is available in each procurement cost bin, starting with the lowest cost bin).



For more on DR-Path, see the Phase 3 CPUC DR Potential Study, available at: https://eta.lbl.gov/publications/california-demand-response-potential

EE Packages → DR Resource & Supply Curves → **Capacity Expansion Modeling** → Power System Scenarios → Power System Impacts

- The study uses NREL's Regional Energy Deployment System (ReEDS) capacity expansion model.
- EE is modeled in ReEDS as a change in hourly load that is added onto the standard load profiles used in ReEDS for each modeled year. EE is therefore not an economic investment decision but rather an exogenous assumption affecting the ReEDS power system investment decisions.
- DR is incorporated in ReEDS as an economic investment decision and represented by DR-Path supply-curves disaggregated into individual DR end uses. In our study, DR can reduce or shift energy an also provide firm capacity to the system.



For more on ReEDS, see the model documentation, available at: https://www.nrel.gov/docs/fy21osti/78195.pdf

EE Packages → DR Resource & Supply Curves → Capacity Expansion Modeling → **Power System Scenarios** → Power System Impacts

Mid Case	• Uses mid-line generation, storage, and transmission cost assumptions and technology parameters for the US bulk power system.
Limited Transmission	• Assumes higher transmission costs and only allows transmission builds between BAs *within* the same RTO with limited expansion options compared to the Mid Case assumptions.
High RE	• Assumes lower costs for renewable technologies along with more aggressive technology advancements than the Mid Case assumptions.

EE Packages → DR Resource & Supply Curves → Capacity Expansion Modeling → Power System Scenarios → **Power System Impacts**

Firm Capacity

- Resource adequacy (RA) is a key driver of capacity build decisions by ensuring the system has enough capacity that can be depended on during times of system stress to meet expected peak demand plus a reserve margin.
- ReEDS estimates firm capacity contributions for DR as fractions of nameplate capacity that could be relied upon at different times of the year and contribute to seasonal RA requirements.

Power System Costs

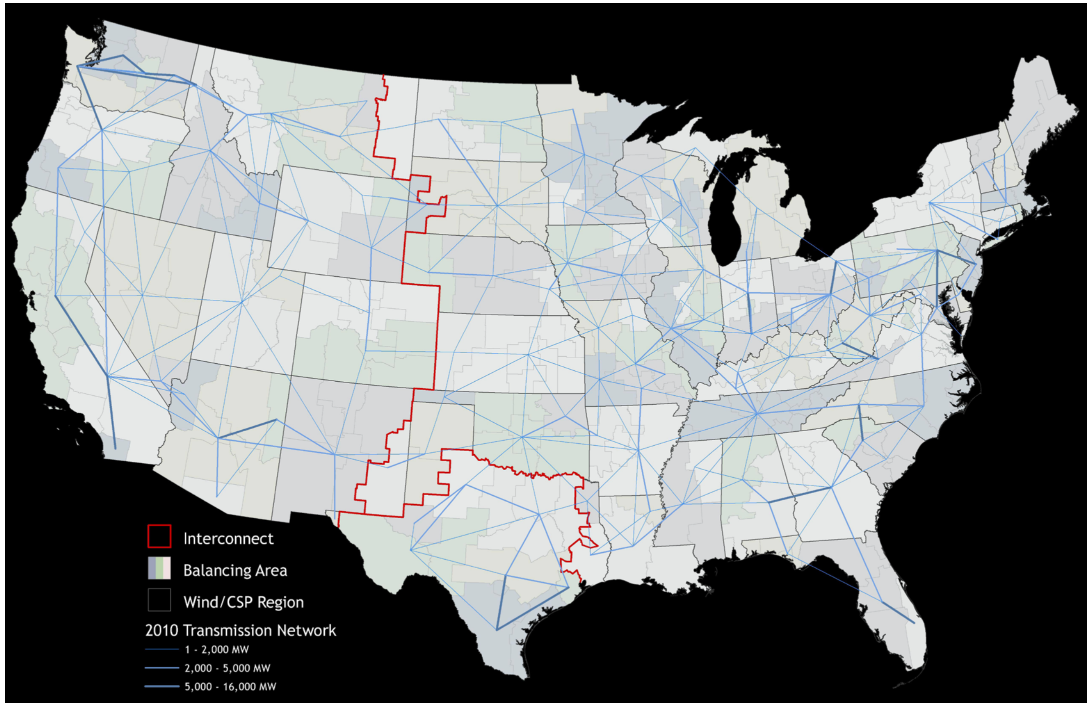
- Total system costs capture the new generation, storage and DR investments (capacity costs); new transmission investments or upgrades to ensure all generation can reach load (transmission costs); and fuel and operations and maintenance (O&M) costs for new and existing resources (variable costs) that are incurred during operation of the generation fleet.

Carbon Emissions

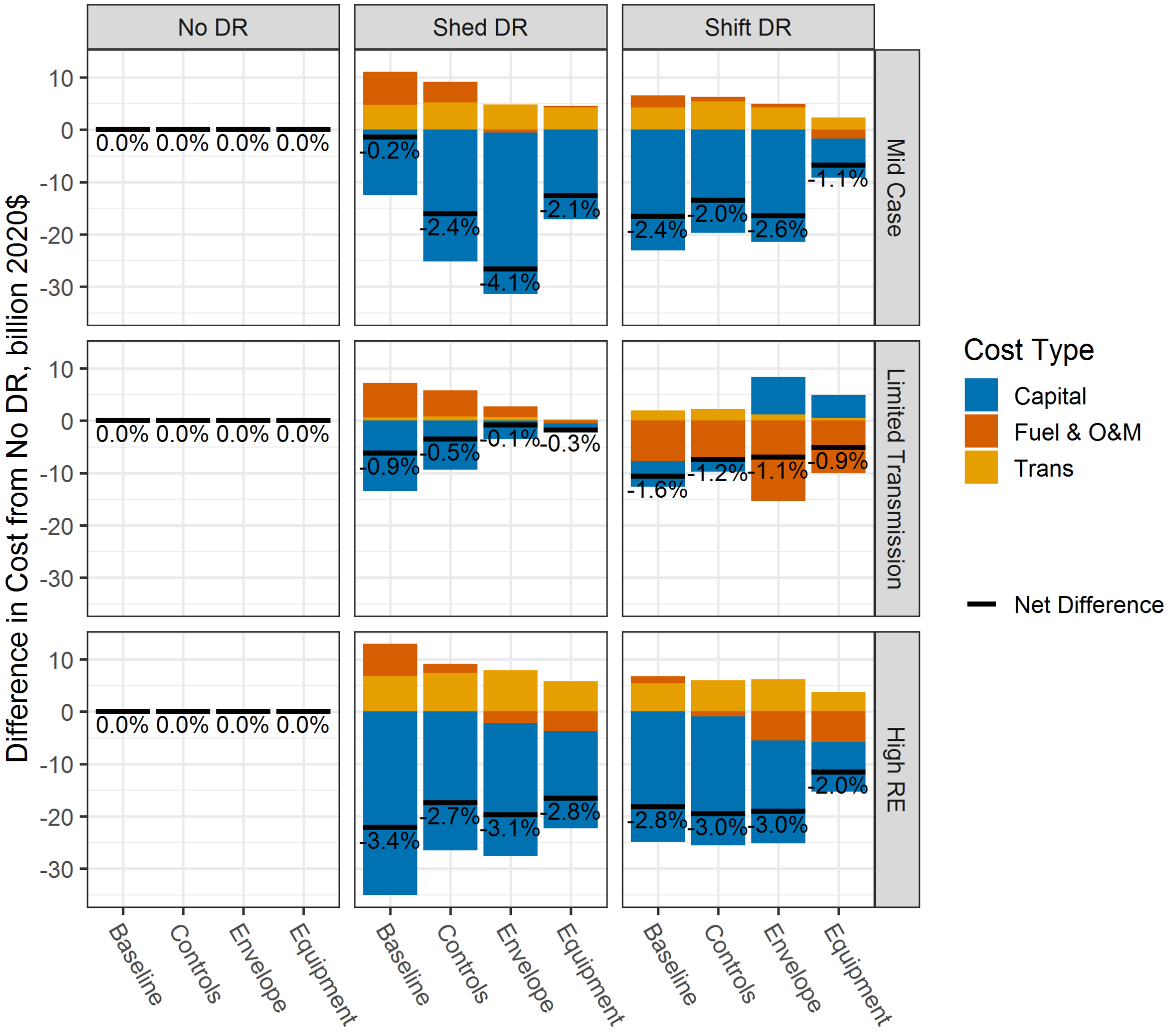
- Cumulative CO_2 emissions over the study period are based on the annual operation of the generation fleet.
- Emissions rates per MWh generation are an outcome of combining coal and gas fuel emissions contents with individual coal and gas plant heat rates.

An important caveat about the following results…

- The study adds EE and DR to CAISO, ERCOT, and ISO-NE and regional connections in ReEDS allow the benefits of demand-side changes to be shared between these regions and other RTOs throughout the continental U.S.
- While ERCOT is connected to other RTOs, these connections are small relative to ERCOT's size.
- We focus our results in ERCOT because it allows us to observe the interactions between EE, DR, and supply-side investment decisions with fewer transmission-related complications.



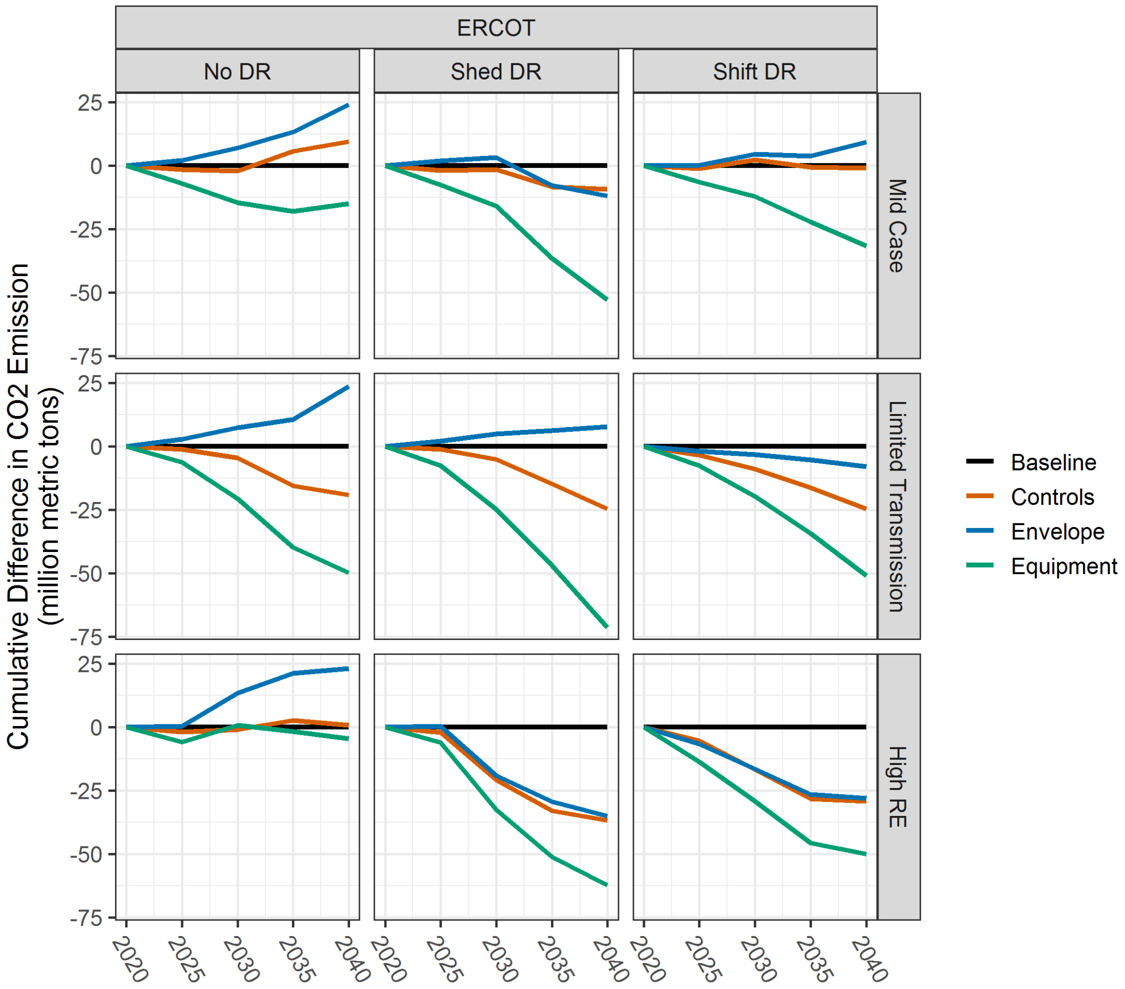
Key finding #1: EE and DR provides value to the power system by reducing bulk power system costs in isolation *and* in combination



- In isolation:
  - EE reduces system costs through annual energy savings and by reducing net-capacity, and also reduces cumulative transmission builds and can support more exports.
  - DR reduces system costs by providing firm capacity and energy shifting, as well as increases transmission export capacity.
- In combination:
  - Power system costs are always lower *on net* compared to without EE and DR (see figure at left).

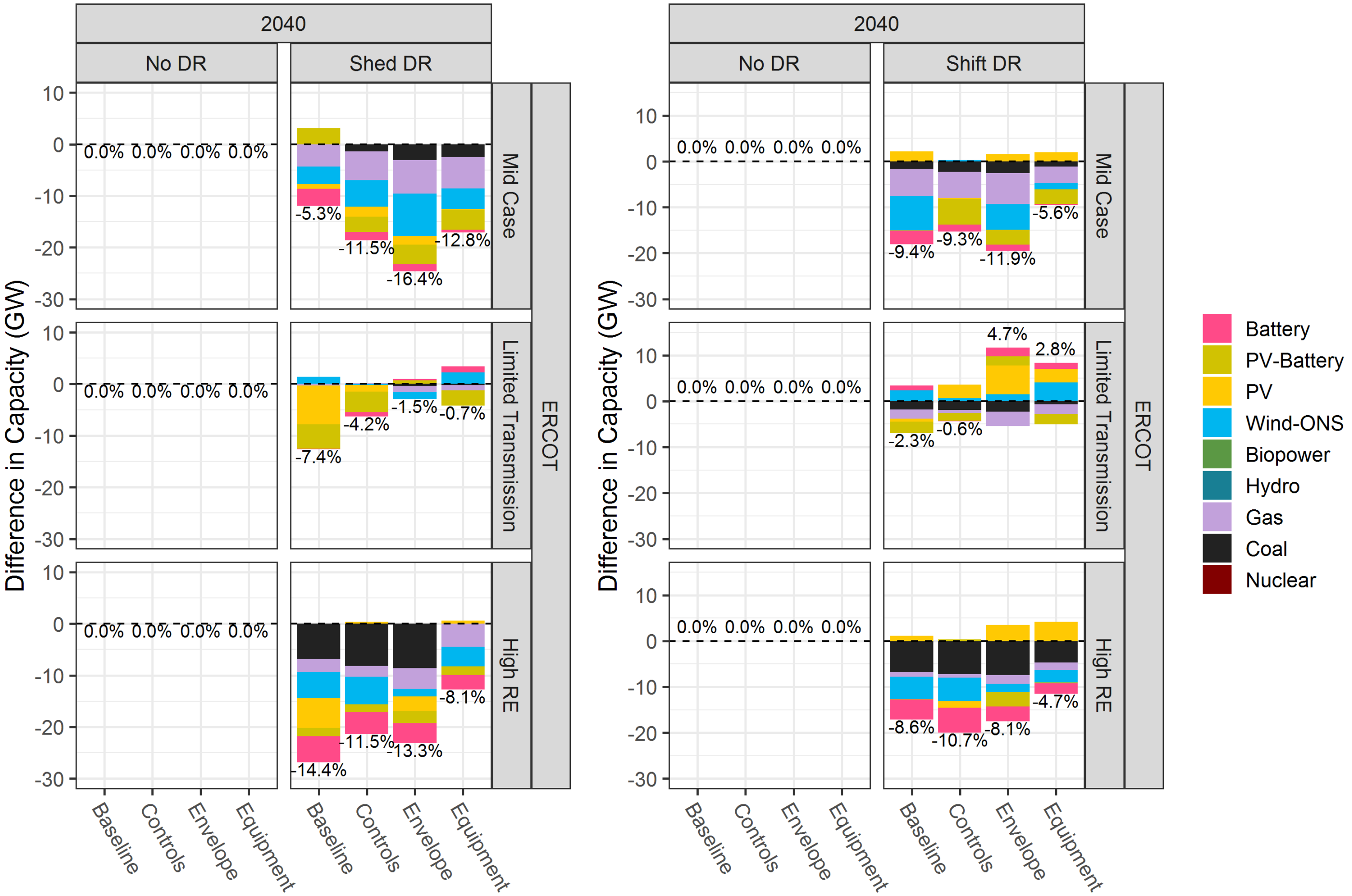
Key finding #2: Adding EE to DR, and vice-versa, reduce generation CO_2 emissions in most cases

- Adding EE to Shed DR or Shift DR results in (sometimes significant) emissions reductions across almost all EE packages (the exception being the Envelope package).
- Emissions impacts of EE alone range from –8% to +6% in the No DR cases to –16% to +2% when EE is added to DR.



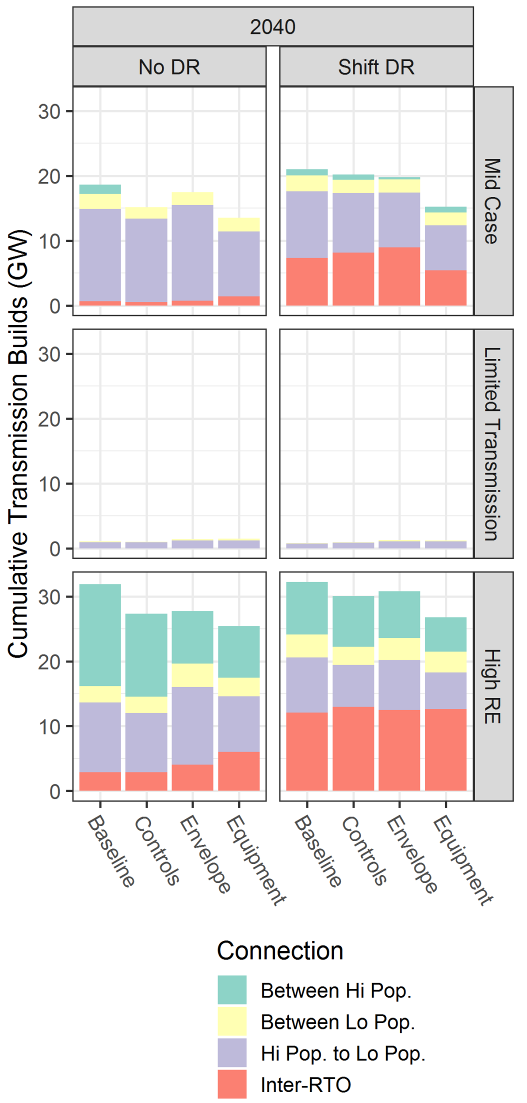
Key finding #3: Results were sensitive to different baseline electricity system characteristics, particularly constraints on new transmission expansion

- One example is in the Mid Case scenario, EE significantly enhances Shed DR value by reducing wind, battery and existing thermal generation capacity relative to Shed DR's impact under Baseline (no EE) conditions. In contrast, in the Limited Transmission scenario the addition of EE results in smaller capacity reductions.



Key finding #4: Certain EE measures can enhance the capabilities and value of DR

- EE controls measures do not substantially compete with DR and enhance the avoided generation cost savings in some instances with Shed DR.
- The EE controls package also increases inter-RTO transmission capacity with Shift DR, which enables more energy exports (see figure at right).
- EE envelope measures exhibit slightly greater complementarity with Shift DR as compared to EE controls measures because the DR shifts generation away from coal in favor of less expensive gas and variable generation resources.



Conclusions

- Concerns about competition between EE and DR may be overstated when considering bulk power system cost and emissions impacts.
- The policy, planning, and regulatory context matters for assessing whether or not EE and DR interactions are important.
- Electricity system characteristics are important in determining precise impacts of EE and DR interactions.
- The power system impact metric, particularly system costs vs. emissions, also matters and the study results suggest valuation frameworks should be comprehensive in order to capture all sources of EE and DR complementarity.

Contact

Andy Satchwell | asatchwell@lbl.gov

Full article available at:

https://emp.lbl.gov/publications/assessing-interactive-impacts-energy

For more information

Download publications from the Electricity Markets & Policy: https://emp.lbl.gov/publications
Sign up for our email list: https://emp.lbl.gov/mailing-list
Follow the Electricity Markets & Policy on Twitter: @BerkeleyLabEMP

This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE -AC36-08GO28308. Funding provided by the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Building Technologies Office. The views expressed herein do not necessarily represent the views of the DOE or the U.S. Government.