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Distributed Generation Resources and Implications for Transmission

A study exploring relationships between increasing penetrations of DGs and the long-term need for transmission infrastructure

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ESIG
ENERGY SYSTEMS INTEGRATION GROUP

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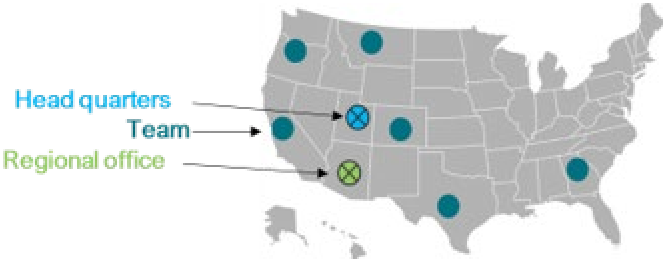
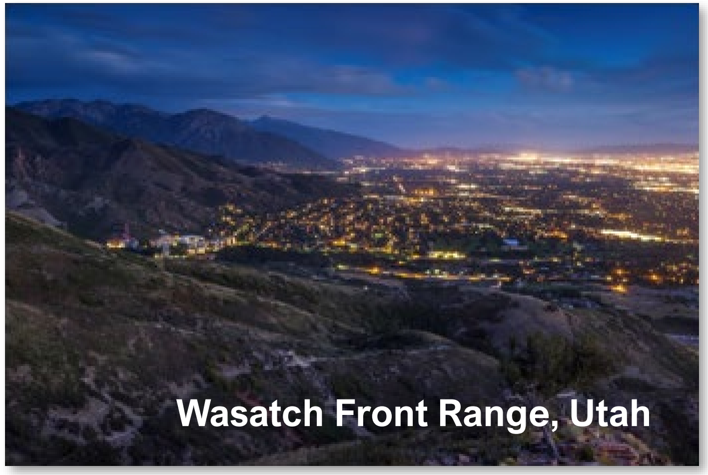
Energy Strategies Overview

- **Founded in 1986, with initial focus on gas deregulation and energy choice for customers**
- **Capabilities and geographic coverage have grown and evolved since. The firm excels at:**
  - Providing market awareness and expertise of large consultancy with trust, access, & insight of small boutique firm or individual consultant
  - Objective and unbiased analysis on complex industry issues – tackle complicated and innovative work
  - Work tailored to client needs – turn-key projects are not the norm for our company although we do retrain proprietary study methods and databases





- **Team consists of ~30 expert consultants that generally have between 5-40 years of experience:**
  - Engineers & power system experts
  - Economists & regulatory/business analysts
  - Data scientist and programmers

Recent project highlights

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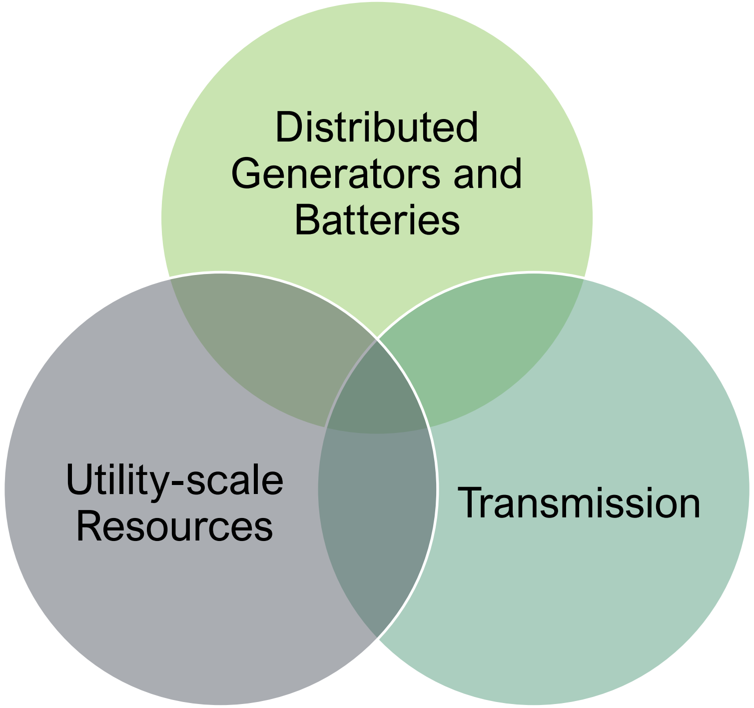
DER-Tx Study Objectives

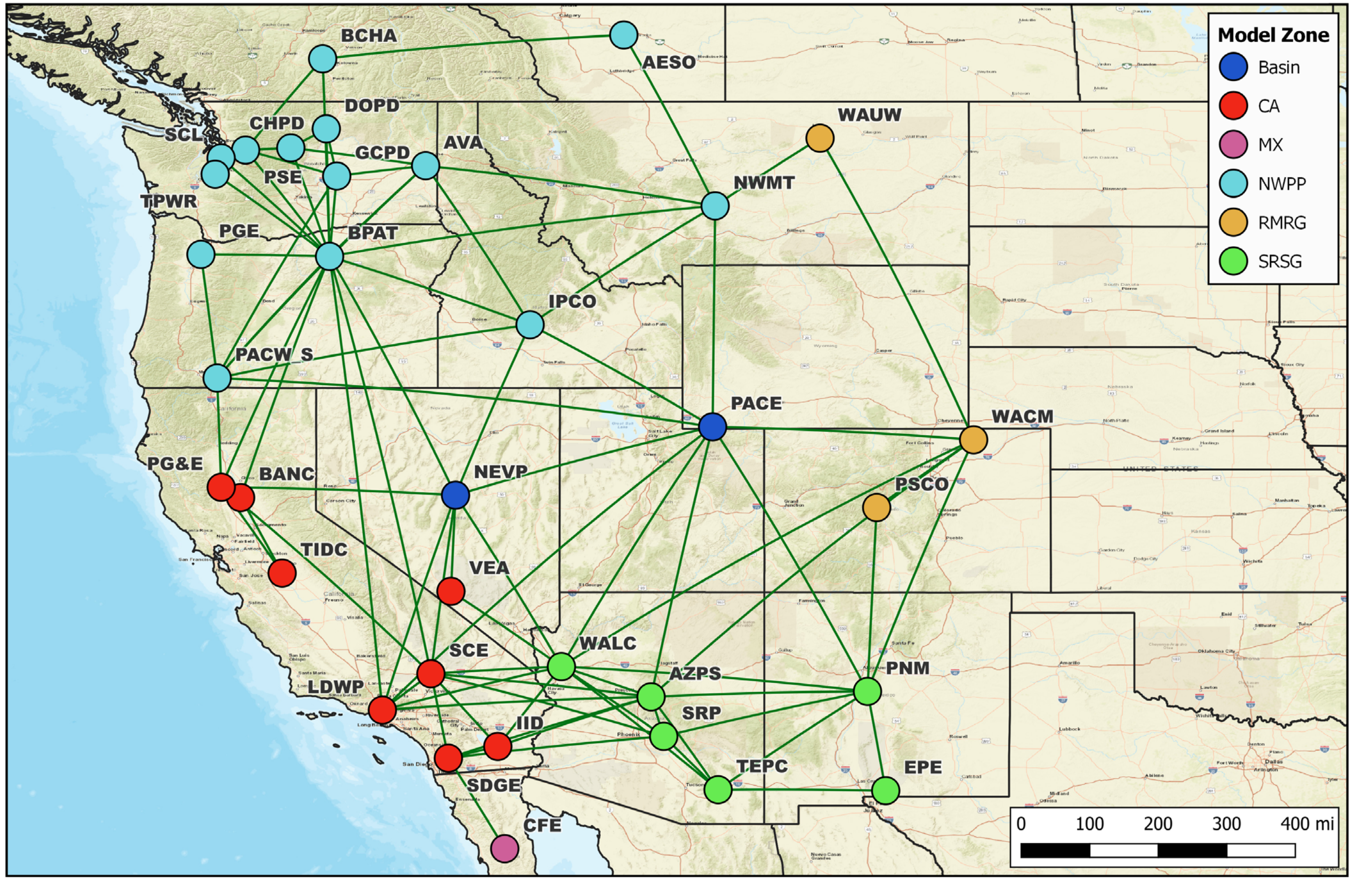
- **Energy Strategies was commissioned by ESIG to investigate the relationship between distributed generators and transmission**
- **Study objectives included:**
  - Explore how increasing penetrations of DERs may impact high-voltage transmission system flows and the need for long-term transmission investment
  - Investigate any synergies or efficiencies between transmission and DER build
  - Quantitatively show how transmission needs change when resources are utility-scale/transmission-connected versus smaller/distribution-connected



DER-Tx Study Summary

- **The study encompasses 39 balancing authorities in the Western grid, and models a 20-year planning horizon**
  - Started with Energy Exemplar's 2022 WECC Zonal model
  - Region contains generation expansion candidates
  - Zonal transmission expansion options
    - 80 potential transmission candidates included both uprates of existing lines and new lines between zones
    - Allowed one upgrade per path per year; allowed 3 total upgrades per year
- **The study utilizes the PLEXOS capacity expansion and production cost modeling capabilities**
  - Three study scenarios dictate expansion options
  - Each expansion scenario run through 2035 production cost model

WECC Zonal Map



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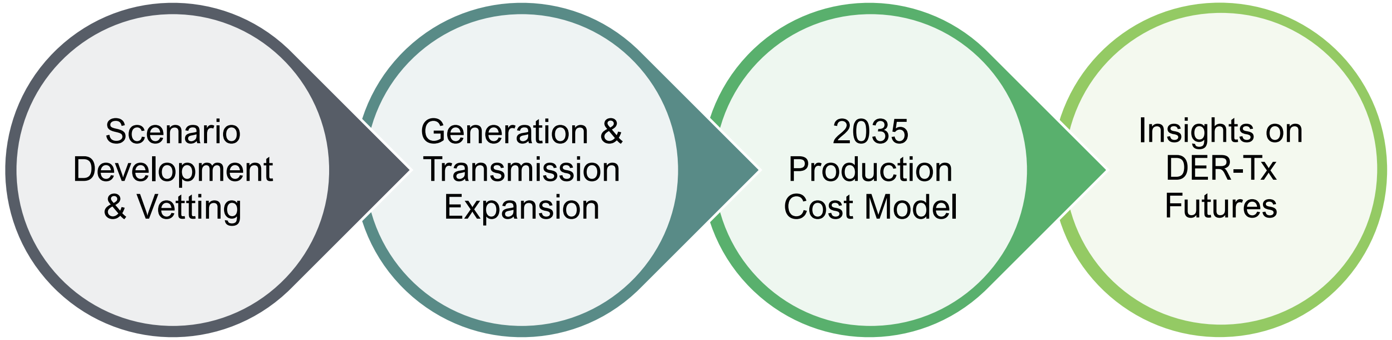

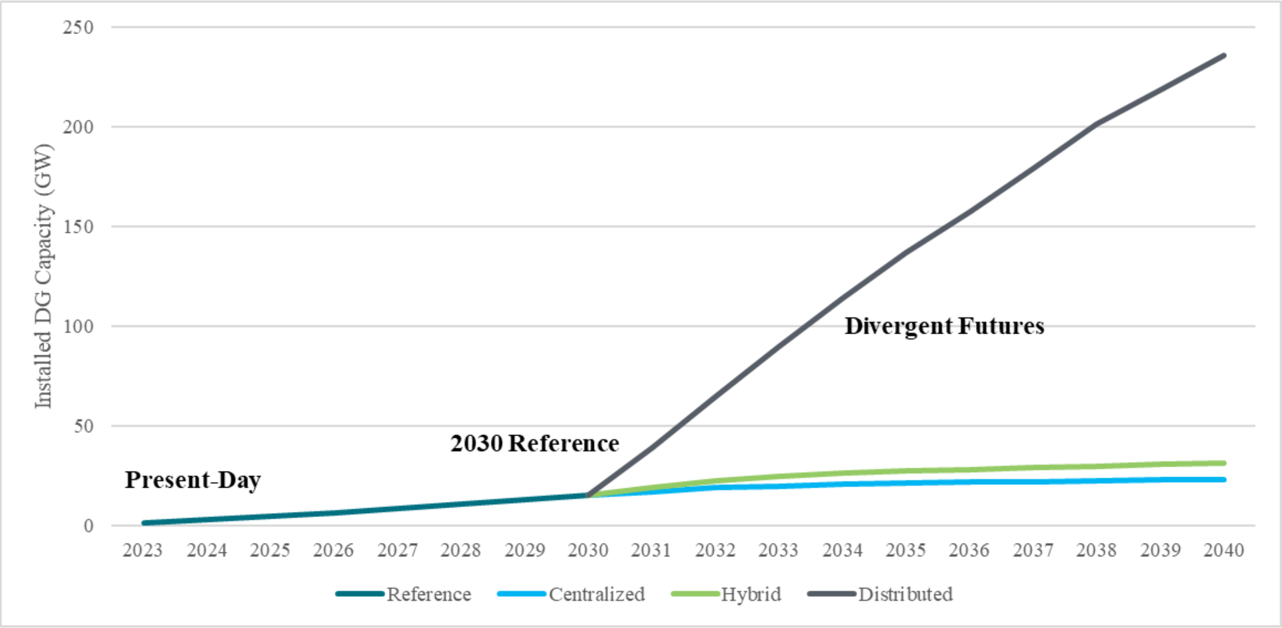

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Study Scenarios

- **Three scenarios for 2030-2040 buildouts:**
  - **Centralized** – adoption of distributed resources consistent with NREL Standard Scenarios; all additional resources are utility-scale
  - **Hybrid** – doubled the adoption rate of distributed resources from the Centralized case; all additional resources are utility-scale
  - **Distributed** – all additional resources are some combination of distributed PV and distributed batteries; also allows pumped hydro storage

Scenario	Started at 2030 Reference	Could Build Transmission	Could Build Utility-Scale Thermal Generators	Could Build Utility-Scale Renewable Generators	Could Build Distributed Generators	Could Build Long-Duration Storage
Centralized	✓	✓	✓	✓	No; fixed at 1x NREL Standard Scenario rate	
Hybrid	✓	✓	No; fixed to centralized builds	✓	No; fixed at 2x NREL Standard Scenario rate	
Distributed	✓	✓	No; fixed to centralized builds		✓	✓

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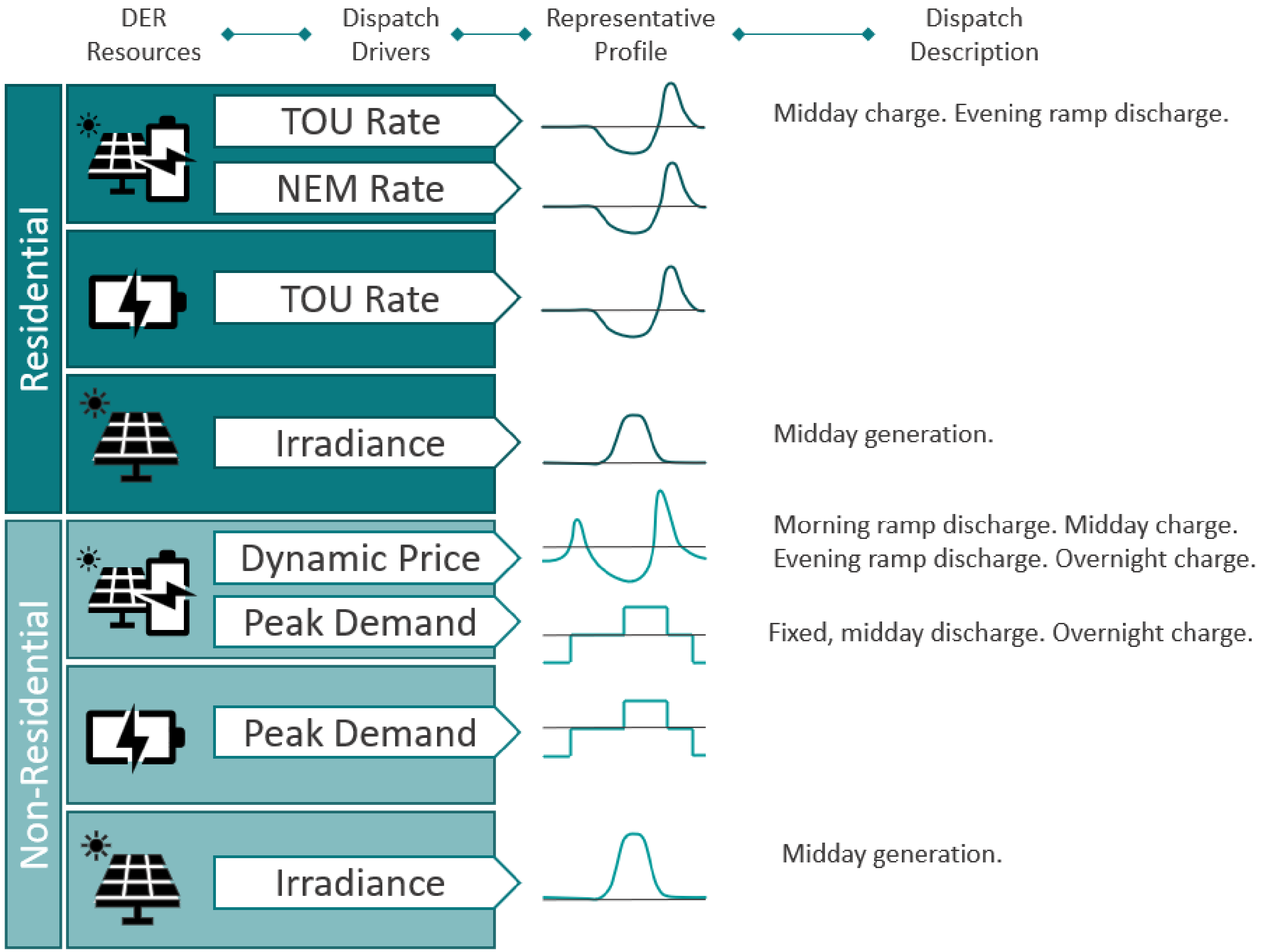
Modeling Distributed Generators and Batteries

- **Literature review performed to define 8 unique DER expansion candidate resource types**
  - Shown in graphic
- **Baseline capacity determined from NREL standard scenarios**
  - Modeled in PLEXOS as generators
  - Included time-of-day price modifiers to model non-optimal dispatch of DER hybrids & batteries (generation-only DGs simply dispatched)
  - DGs could be curtailed if necessary



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Other Capacity Expansion Considerations

- **Included set of "planned" transmission projects in all study scenarios**
- **Study utilizes a zonal planning reserve margin of 15%. Capacity accreditations to account for:**
  - Resource type
  - Seasonal de-rates
  - Forced & planned outage rates
  - Seasonal load peaks
  - ELCC saturation for VERs and batteries
- **Renewable Portfolio Standards & Net-Zero Constraints**
  - In the LT phase, enforced west-wide clean energy constraint getting model to 68% clean by 2035 and 78% clean by 2040
- **Updated capital costs consistent with NREL ATB 2023 & to reflect IRA ITC**

Production Cost Modeling Load

- **Hourly load profiles scaled to represent load electrification**
  - Performed analysis to determine 12x24 load scalars to represent a variety of electrification technologies in 2035
  - Increases load peaks (MW) and energy (MWh) by ~30% and ~12%, respectively
- **2035 PCM included detailed operating reserve modeling**
  - BA-level regulation reserves
  - Spinning reserves held at a reserve-sharing group footprint

NREL Electrification Futures Scenarios

Adoption Scenarios (future report) ↓ Increasing Electrification	Sensitivity Cases (this report): Slow Technology Advancement Sensitivity Case (Slow Advancement)	Sensitivity Cases (this report): Moderate Technology Advancement Sensitivity Case (Moderate Advancement)	Sensitivity Cases (this report): Rapid Technology Advancement Sensitivity Case (Rapid Advancement)
Reference	Slow Advancement, Reference Adoption	Moderate Advancement, Reference Adoption	Rapid Advancement, Reference Adoption
Medium	Slow Advancement, Medium Adoption	Moderate Advancement, Medium Adoption	Rapid Advancement, Medium Adoption
High	Slow Advancement, High Adoption	Moderate Advancement, High Adoption	Rapid Advancement, High Adoption

Increasing Load Efficiency →

Medium Scenario Load Scalar

Hour

Month	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	1.06	1.06	1.05	1.06	1.06	1.07	1.08	1.10	1.11	1.11	1.11	1.13	1.14	1.15	1.16	1.21	1.25	1.28	1.23	1.15	1.12	1.11	1.10	1.08
2	1.08	1.06	1.06	1.06	1.05	1.06	1.08	1.10	1.10	1.10	1.11	1.12	1.14	1.14	1.16	1.20	1.25	1.28	1.23	1.15	1.11	1.10	1.10	1.09
3	1.07	1.06	1.06	1.06	1.06	1.06	1.08	1.10	1.11	1.11	1.12	1.14	1.16	1.17	1.18	1.23	1.29	1.29	1.24	1.16	1.17	1.15	1.14	1.11
4	1.08	1.05	1.05	1.05	1.05	1.06	1.08	1.11	1.12	1.11	1.12	1.14	1.15	1.15	1.16	1.21	1.26	1.31	1.25	1.22	1.19	1.17	1.14	1.12
5	1.05	1.04	1.03	1.04	1.03	1.05	1.08	1.11	1.11	1.11	1.11	1.13	1.14	1.14	1.15	1.19	1.24	1.28	1.23	1.14	1.12	1.10	1.08	1.06
6	1.04	1.04	1.03	1.03	1.03	1.04	1.07	1.10	1.11	1.10	1.11	1.12	1.13	1.13	1.14	1.18	1.22	1.25	1.21	1.16	1.13	1.11	1.09	1.07
7	1.04	1.03	1.03	1.03	1.03	1.04	1.07	1.10	1.11	1.10	1.10	1.11	1.12	1.12	1.13	1.16	1.21	1.24	1.20	1.12	1.10	1.08	1.06	1.05
8	1.05	1.03	1.02	1.03	1.03	1.04	1.07	1.10	1.10	1.10	1.10	1.11	1.12	1.12	1.13	1.16	1.20	1.23	1.19	1.13	1.11	1.10	1.09	1.07
9	1.05	1.03	1.03	1.03	1.03	1.04	1.07	1.10	1.11	1.10	1.10	1.11	1.12	1.12	1.13	1.17	1.21	1.24	1.20	1.12	1.09	1.08	1.07	1.06
10	1.05	1.04	1.03	1.03	1.03	1.05	1.08	1.11	1.12	1.11	1.11	1.13	1.14	1.14	1.15	1.18	1.23	1.26	1.21	1.13	1.11	1.10	1.09	1.06
11	1.09	1.07	1.06	1.05	1.05	1.06	1.08	1.11	1.12	1.11	1.12	1.14	1.15	1.15	1.16	1.20	1.27	1.31	1.25	1.17	1.14	1.12	1.13	1.12
12	1.06	1.06	1.05	1.06	1.06	1.07	1.09	1.11	1.12	1.11	1.12	1.14	1.15	1.16	1.17	1.21	1.26	1.29	1.24	1.18	1.15	1.12	1.11	1.09

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Summary of Generator Assumptions

Site Type	Unit Type	Dispatch Driver	Contributes Toward Clean Energy Constraints	Contributes Firm Capacity	Regulation Up	Regulation Down	Spin Up Reserve
Utility-scale	Gas/coal	Wholesale price		✓	✓	✓	✓
	Nuclear	Wholesale price	✓	✓	✓	✓	✓
	Biomass/geothermal	Wholesale price	✓	✓	✓	✓	✓
	Hydro	Load-following	✓	✓	✓	✓	✓
	Wind	None; fixed profile	✓	Partial; diminishing	✓	✓	✓
	Standalone PV	None; fixed profile	✓	Partial; diminishing	✓	✓	✓
	PV+battery (PV)	None; fixed profile	✓		✓	✓	✓
	PV+battery (battery)	Wholesale price		✓	✓	✓	✓
	Standalone battery	Wholesale price		✓	✓	✓	✓
Residential	Standalone PV	None; fixed profile	✓	Partial; diminishing	✓	✓	✓
	Standalone battery	Time-of-use		✓	✓	✓	✓
	PV+battery (PV)	Net Energy Metering	✓		✓	✓	✓
	PV+battery (battery)	Net Energy Metering		✓	✓	✓	✓
	PV+battery (PV)	Time-of-use	✓				
	PV+battery (battery)	Time-of-use		✓	✓	✓	✓
Nonresidential	Standalone PV	None; fixed profile	✓	Partial; diminishing	✓	✓	✓
	Standalone battery	Demand charge		✓	✓	✓	✓
	PV+battery (PV)	Demand charge	✓				
	PV+battery (battery)	Demand charge		✓	✓	✓	✓
	PV+battery (PV)	Demand pricing	✓		✓	✓	✓
	PV+battery (battery)	Demand pricing		✓	✓	✓	✓

Results

Summary of buildouts during 2030-2040

	Generation	Storage	Transmission
Centralized	431 GW	252 GWh 63 GW battery	238 GW-miles 18 GW
Hybrid	418 GW	328 GWh 82 GW battery	166 GW-miles 12 GW
Distributed	537 GW	1090 GWh 255 GW battery 7 GW pumped hydro	526 GW-miles 16 GW

Tradeoff between storage and transmission

Distributed resources can reduce some transmission investments

Transmission buildouts 2030-2040

	Generation	Storage	Transmission
Centralized	431 GW	252 GWh 63 GW battery	238 GW-miles 29 GW
Hybrid	418 GW	328 GWh 82 GW battery	166 GW-miles 23 GW
Distributed	537 GW	1090 GWh 255 GW battery 7 GW pumped hydro	526 GW-miles 26 GW

But taken further, if you try to decarbonize with significant distributed resources, both transmission and storage needs skyrocket

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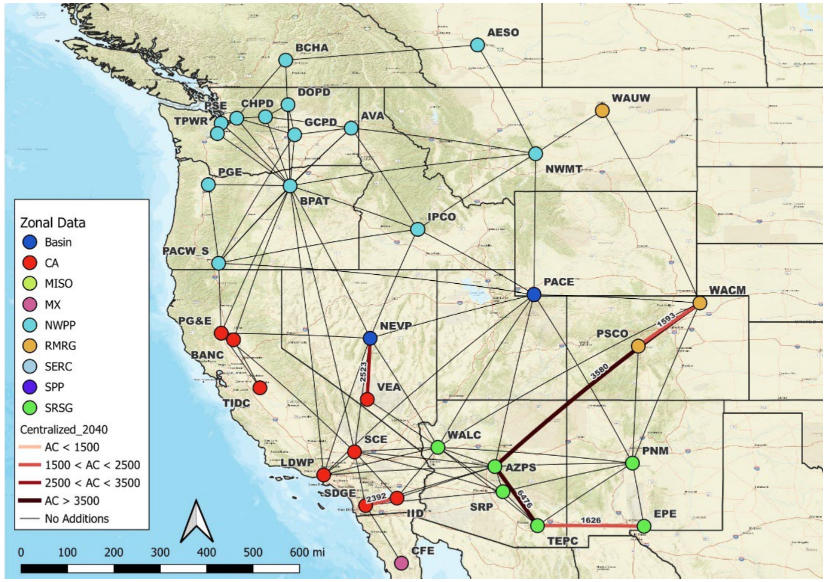
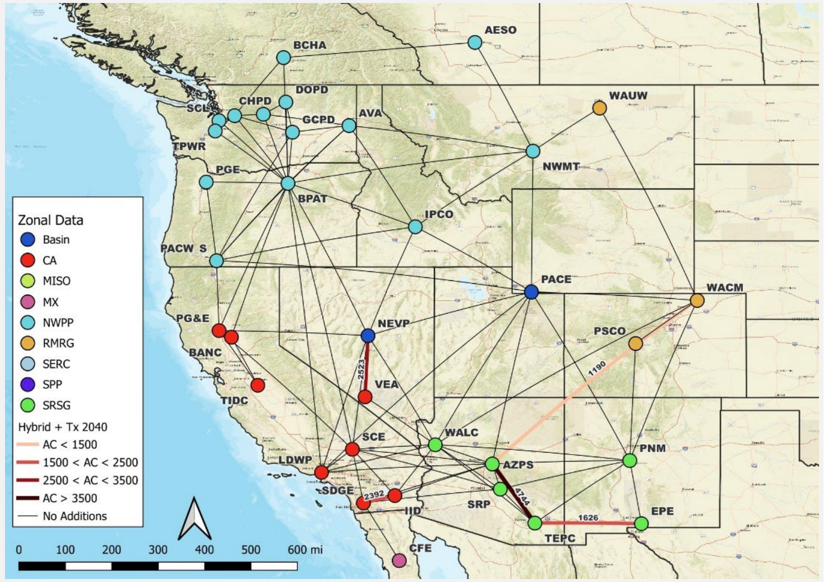
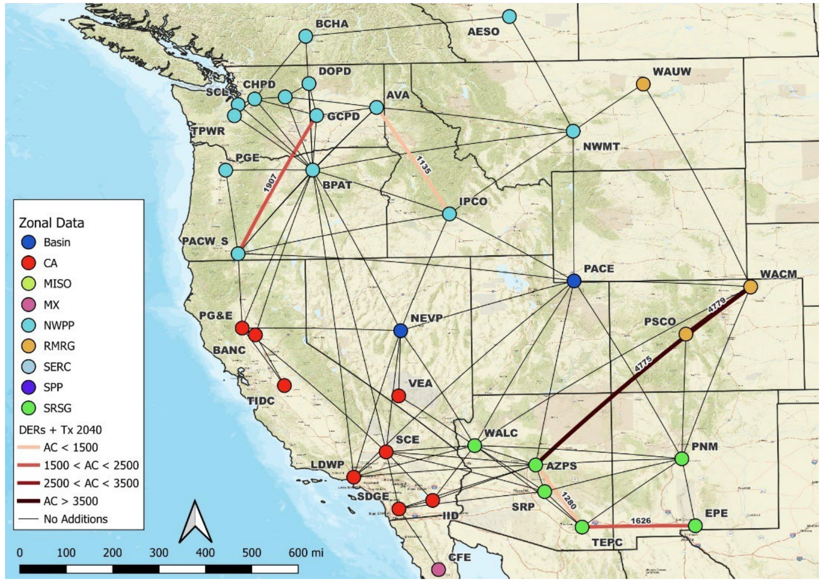
Transmission buildouts 2030-2040

Centralized	Hybrid	Distributed







Transmission provides more cost-effective dispatch across regions, sharing of firm capacity across regions, and reduces curtailment of renewables.

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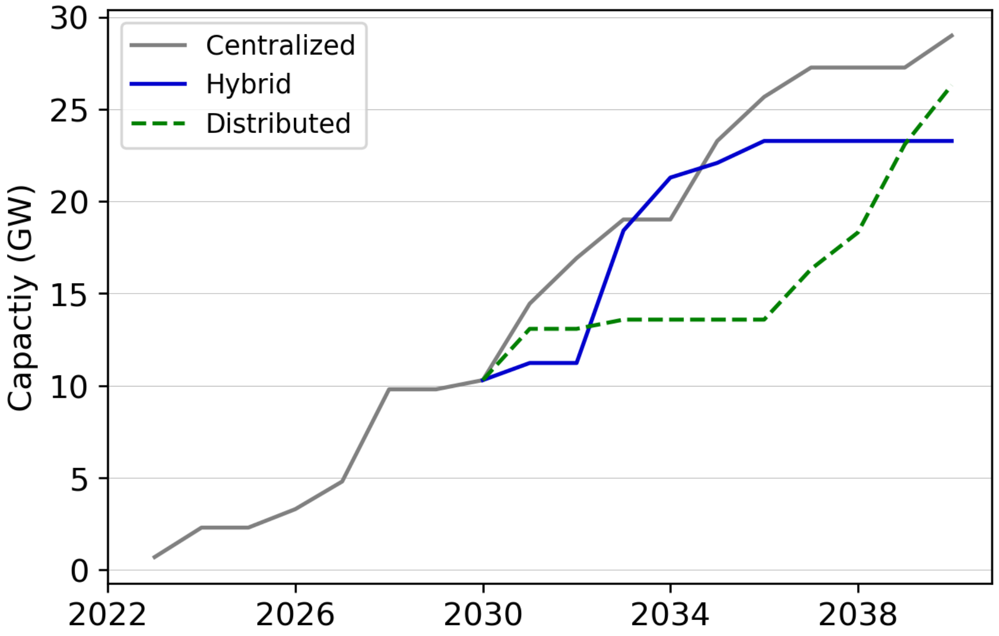
Transmission buildouts 2030-2040

Scenario	Lines Built	GW-Miles Added	Total GW Added since 2023
Centralized	11	238 GW-miles	18 GW
Hybrid	8	166 GW-miles	12 GW
Distributed	11	526 GW-miles	16 GW



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Commonalities of lines across scenarios

Compare	Lines Built*	Shared Lines	Unique Lines	GW Shared	GW Unique	% Shared	% Unique
Distributed vs. centralized	17	5	12	8 GW	18 GW	29%	71%
Distributed vs. hybrid	16	3	13	4 GW	20 GW	19%	81%
Centralized vs. hybrid	11	8	3	12 GW	6 GW	73%	27%

*Note: Counts the total number of unique lines among the two cases compared. Overlap among the transmission buildouts in each scenario indicates some common geographic transmission needs. The buildouts in the Centralized and Hybrid scenarios are mostly alike

ID	Hybrid Scenario	Distributed Scenario
1	Deferred	Deferred
2	Avoided	Avoided
3	Installed sooner	Avoided
4	Deferred	Deferred
5	Same in-service date	Avoided
6	Same in-service date	Avoided
7	Same in-service date	Avoided
8	Installed sooner	Avoided
9	Deferred	Installed sooner
10	Avoided	Deferred
11	Avoided	Same in-service date
12		Added
13		Added
14		Added
15		Added
16		Added
17		Added

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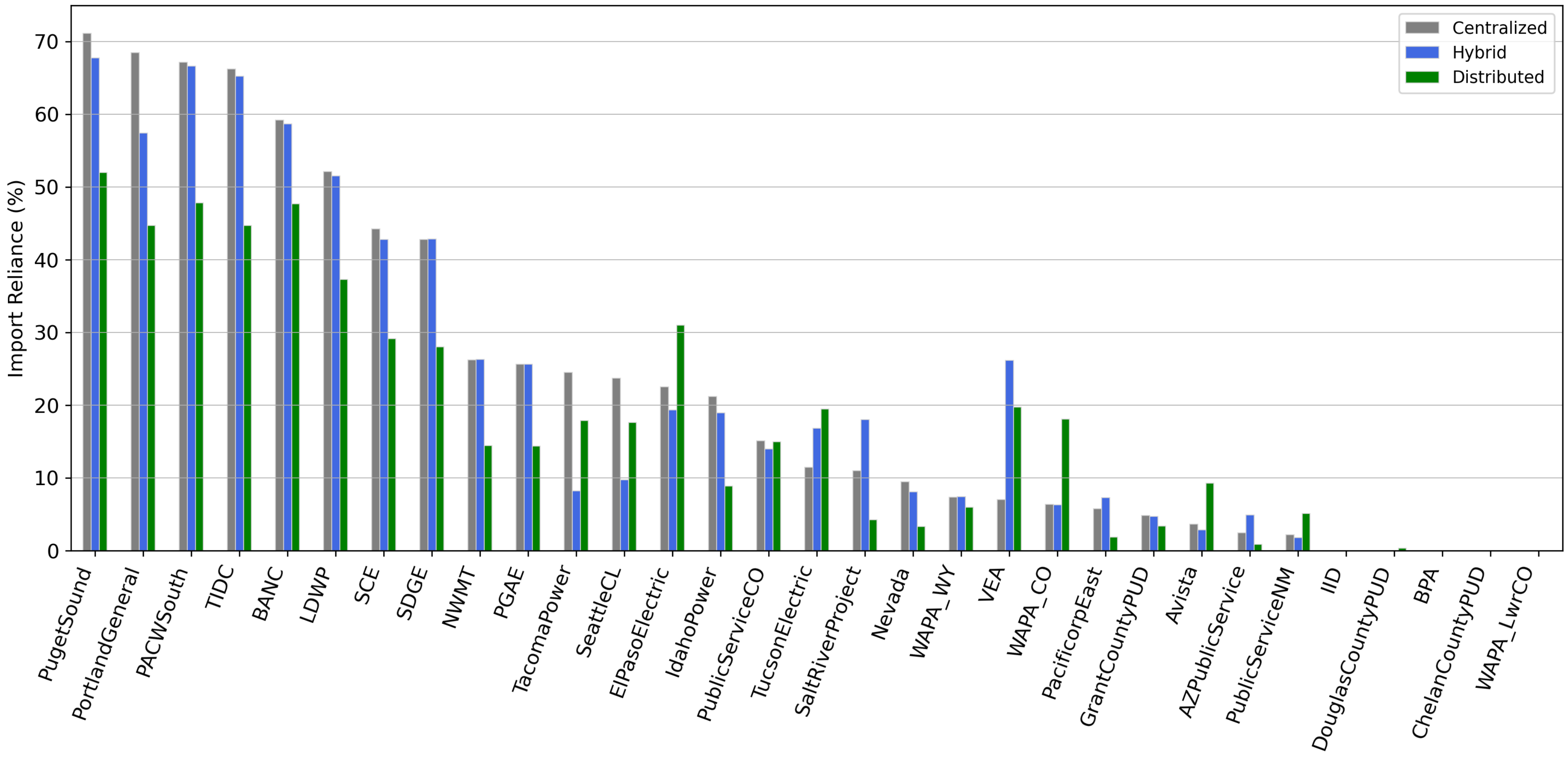
Transmission reliance - Percent of Net Imports to Load



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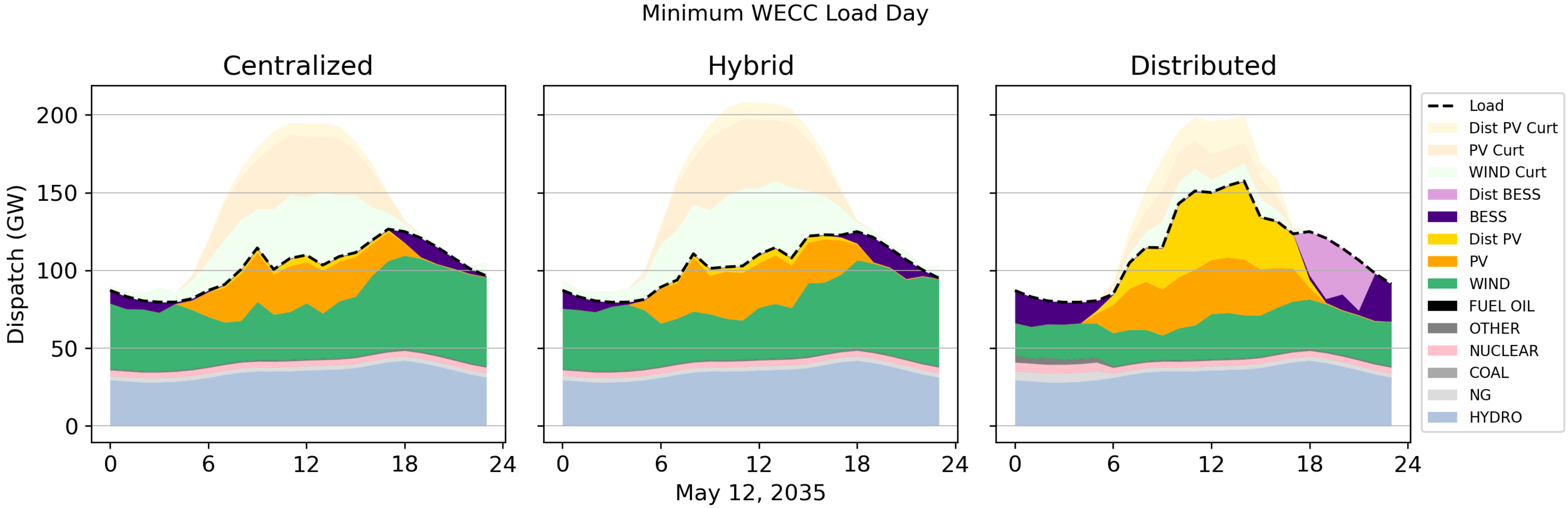
On the minimum load day there is significant charging of storage in the Distributed scenario



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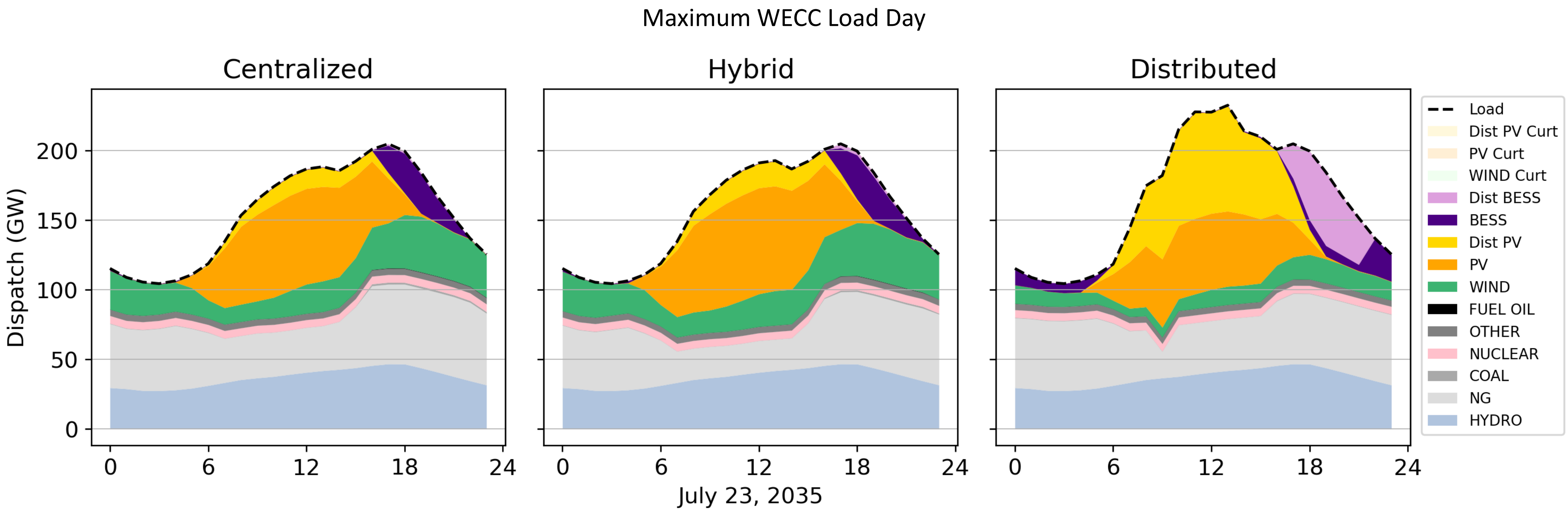
Centralized and Hybrid scenarios depend on wind in the evening; Distributed scenario uses storage



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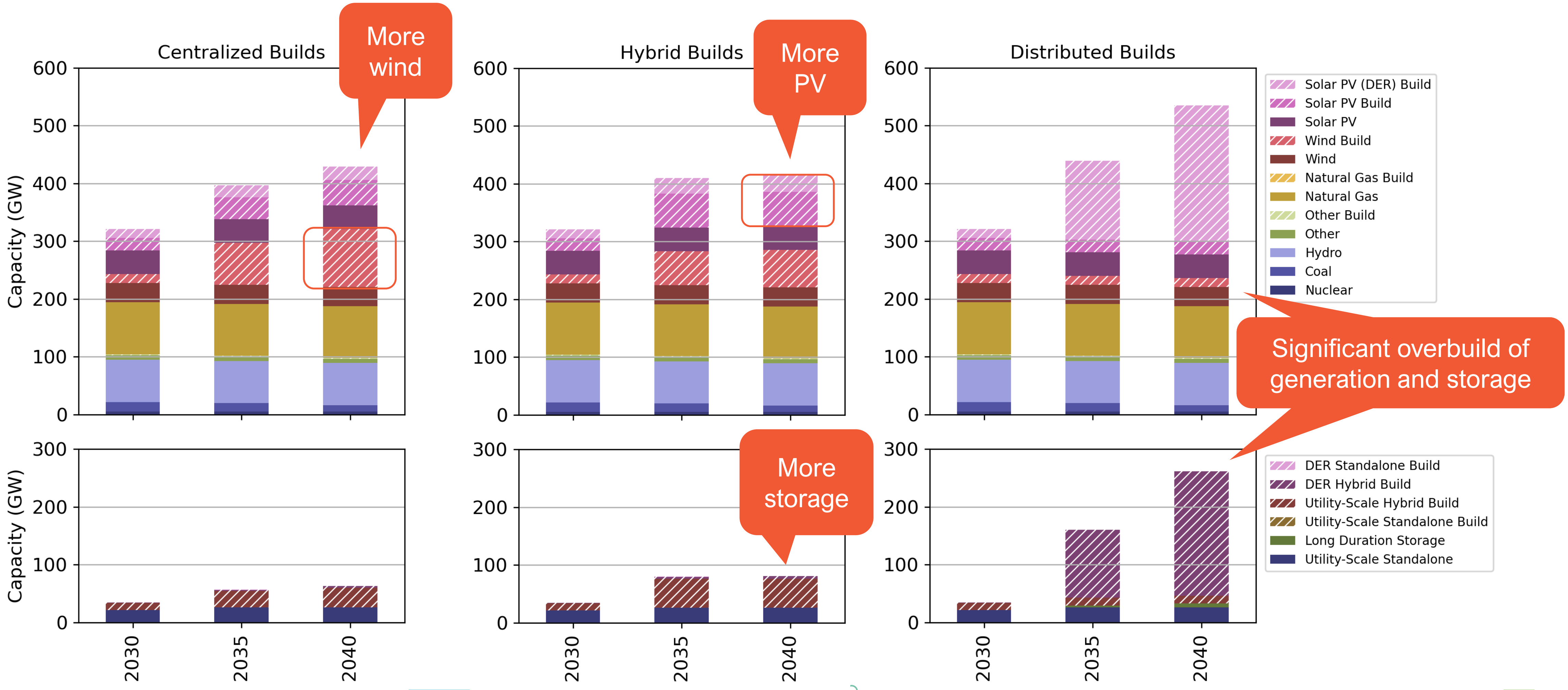
Results of generation/storage for each scenario



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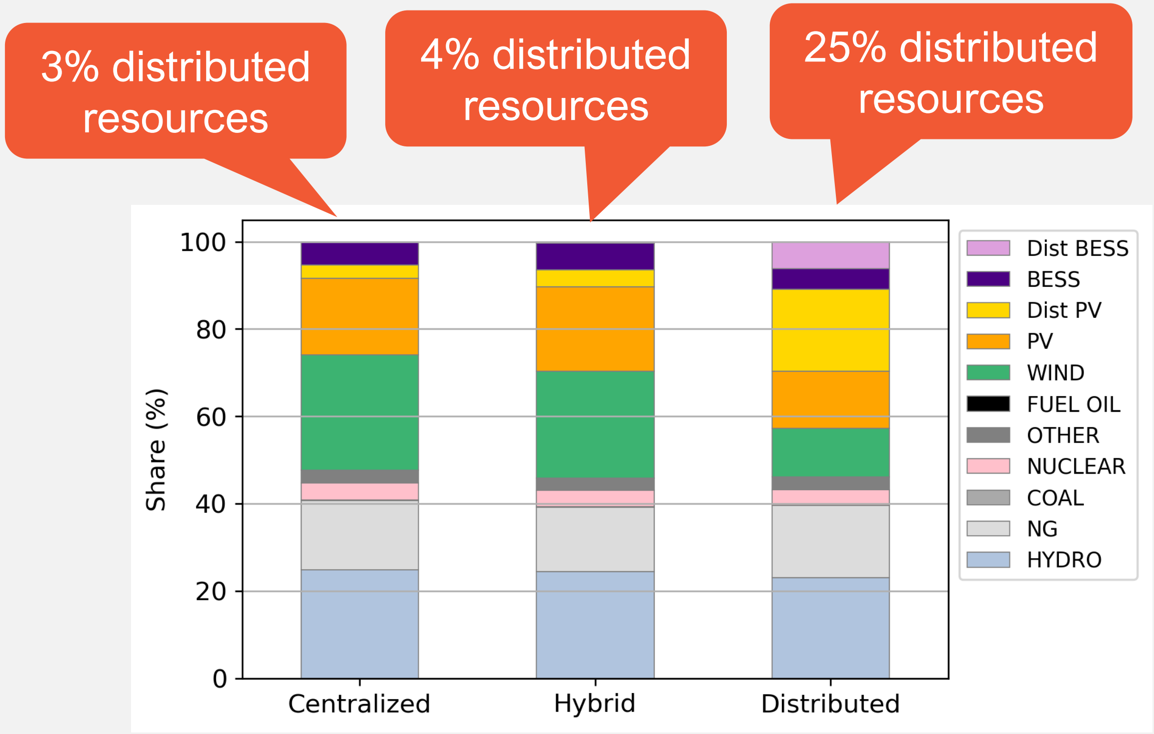
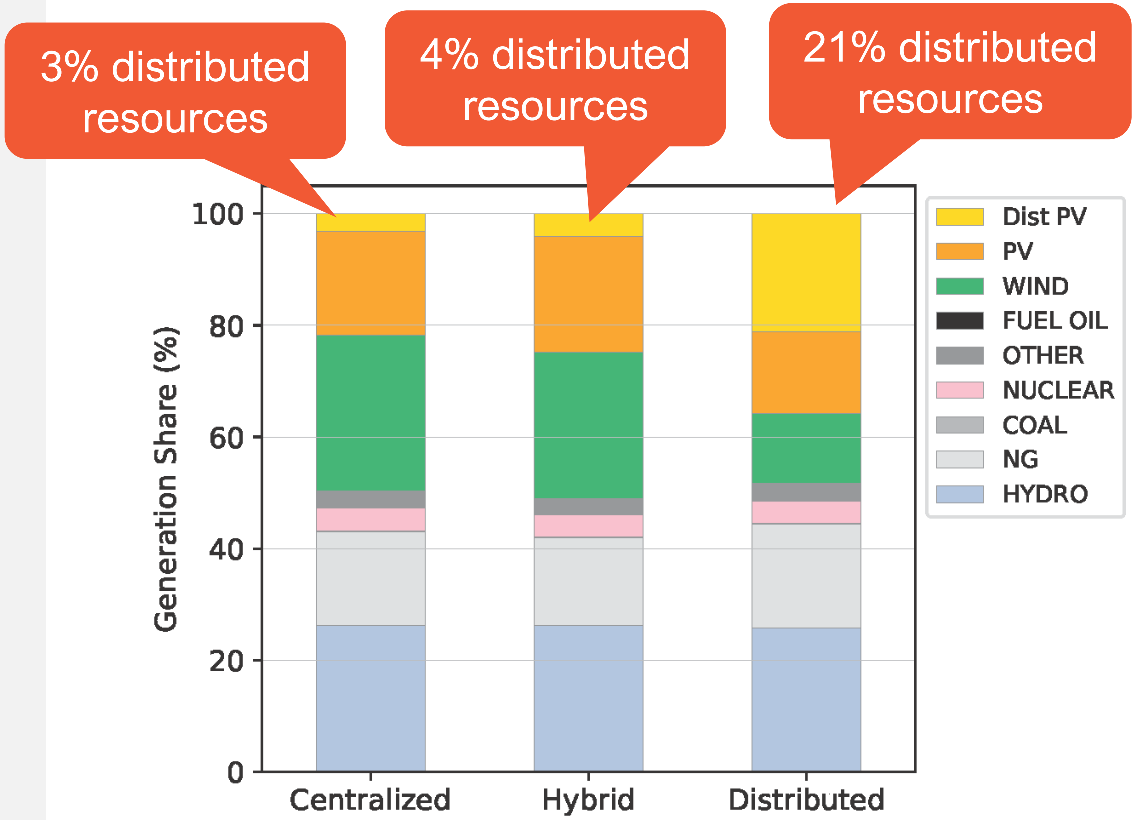
One-fourth of the energy in the Distributed scenario is from distributed resources



Production by type including storage



Generation resources only

Year 2035

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Production costs and curtailment

Scenario	System Production Costs	RE Generation Potential	Total RE Curtailed	Percent RE Curtailed	Peak RE Curtailment Hour
Centralized	$11.28 billion	556.03 TWh	23.93 TWh	4.3%	5/12/2035 1:00 PM
Hybrid	$10.67 billion	589.75 TWh	28.21 TWh	4.8%	5/12/2035 12:00 PM
Distributed	$12.57 billion	538.81 TWh	11.76 TWh	2.2%	5/12/2035 9:00 AM

Centralized and Hybrid scenarios reach higher % of clean energy

Scenario	% clean energy	CO_2 Emissions (million metric tons)	Social Cost of CO_2
Centralized	83.1%	54.5 mmT	$1,199 million
Hybrid	84.2%	50.9 mmT	$1,119 million
Distributed	81.3%	60.2 mmT	$1,325 million

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Study Findings (1 of 2)

- **Distributed generation can significantly impact inter-zonal transmission flows.**
  - The modeled adoption of distributed solar and batteries across the Western Interconnection changed diurnal transmission flow and generation patterns. Specifically, it tended to create a midday nadir in net load, and a need for morning and evening flexibility that must be served by storage and other generators on the system.
- **At moderate levels, distributed generation adoption could cause certain inter-zonal transmission investments to be delayed or avoided.**
  - Relative to the centralized scenario, the hybrid scenario, which has a distributed generation adoption rate doubling our study's status quo (centralized) trajectory from 2031 onward, required about 30% less inter-zonal transmission in terms of both GW and GW-miles as shown in Table ES-1.
  - The hybrid scenario also exhibited a lower overall generation nameplate capacity but required about 30% more storage capacity than the centralized scenario.

	Centralized Scenario	Hybrid Scenario	Distributed Scenario
Zonal transmission expansion candidates	11 projects totaling 18 GW (238 GW-miles)	8 projects totaling 12 GW (166 GW-miles)	11 projects totaling 16 GW (526 GW-miles)
Generation nameplate capacity	431 GW	418 GW	537 GW
Total storage capacity	252 GWh	328 GWh	1,090 GWh

Study Findings (2 of 2)

- **The status-quo (centralized) and accelerated (hybrid) distributed generation adoption scenarios shared many common inter-zonal transmission investments.**
  - Notably, the eight inter-zonal transmission candidates selected in the hybrid scenario were also all selected in the centralized scenario, though often in different years.
  - The centralized scenario required three additional inter-zonal transmission projects—for a total of 11 projects—that were not required in the hybrid scenario. These three projects were avoided in the hybrid scenario during the study horizon because of the increased distributed generation levels in this scenario.

- **High levels of distributed generation could increase the need for inter-zonal transmission investment.**
  - While significant inter-zonal transmission is selected in all three study scenarios, the transmission built in the distributed scenario was almost double that of the centralized scenario as measured by GW-miles. The large increase in transmission GW-miles in the distributed scenario illustrates the need for longer lines to help transport high levels of solar and balance the system between regions where existing inter-zonal capacity is limited.
  - The distributed scenario also required more than four times the storage capacity of the centralized scenario, although these two scenarios met the same system planning and policy requirements over the study horizon.

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Takeaways

- **There is no simple conclusion.**
- **There may be an optimal buildout of distributed vs utility-scale resources but we did not attempt to find that here.**
- **As you increase distributed resources from 3% to 4% of total energy, transmission investments can be reduced, and more storage is required.**
  - More PV and less wind gets built.
  - There are slight (<10%) benefits in production costs and CO_2 emissions.
  - This shows competition between transmission and storage infrastructure.
  - This shows complementarity of transmission with distributed resources.
- **If you increase distributed resources to 21% of total energy, transmission, storage, and generation investments all increase significantly.**
- **There are common transmission builds in the Centralized and Hybrid scenarios, which could be a starting point for “no-regrets” paths.**
- **The need for transmission is sensitive to many other factors related to DGs including time, location, capacity, and participation behavior; also to many other factors not related to DGs.**
  - Location-specific and nodal analyses should be performed to better understand the relationship between DGs and transmission

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Thank You. Questions?

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