Exploration of Resource and Transmission Expansion Decisions in the Western Renewable Energy Zone (WREZ) Initiative

Andrew Mills, Amol Phadke, and Ryan Wiser

Lawrence Berkeley National Laboratory

February 2010

This analysis was funded by the U.S. Department of Energy, Office of Electricity Delivery and Energy Reliability, Permitting, Siting and Analysis Division

Resource and Transmission Expansion Decisions in WREZ: Presentation Outline

1. **Motivation and Scope**
2. **Summary of Key Findings**
3. **Framework for Comparing WREZ Resources**
   a) Bus-bar Costs
   b) Transmission and Line Losses Cost
   c) Market Value Adjustment Factors
   d) Advantages and Disadvantages of WREZ Model and Framework
4. **Results**
   a) Impact of Level of Renewable Energy (RE) Demand
   b) Base Case: WECC-wide 33% RE Delivered to Each Load Zone
   c) Alternative Scenarios with 33% RE Delivered to Each Load Zone
   d) Alternative Scenarios with Tradable Renewable Energy Credits
5. **Conclusions and Future Research**

Project Overview

Motivation: The WREZ Initiative identified renewable resource hubs composed of environmentally preferred, high quality resources sufficient to justify building new high-voltage transmission

- Which WREZ renewable resources might be economically attractive for meeting aggressive renewable energy (RE) targets in the West?
- What transmission might need to be built to access those resources? Who should cooperate in developing the transmission?
- What factors contribute to the costs of meeting renewable energy targets?

Scope: Examine at a screening-level the sensitivity of least-cost **WREZ resource** selection, required transmission expansion, and costs of meeting aggressive Western RE targets to different assumptions and policy decisions

- *How do resource selection and transmission expansion decisions change with assumptions and changes in policies?*
- *What are the important assumptions or factors that should be explicitly considered in more-detailed resource and transmission planning forums?*

Summary of Key Findings

- Increasing renewable energy demands increase costs, as less economically attractive resources are required to meet higher targets
- Wind energy is the largest contributor to meeting WECC-wide renewable energy demands when only resources from the WREZ resource hubs are considered
- Hydropower, biomass, and geothermal contributions do not change significantly with increasing renewable demand or changes to key assumptions
- Key uncertainties can shift the balance between wind and solar in the renewable resource portfolio
- The costs of meeting renewable energy targets within WECC are heterogeneous without Renewable Energy Credits (RECs)
- Transmission investment costs are substantial, but are only a fraction of the costs required to meet a 33% renewable energy target
- Long transmission lines can be economically justified in particular cases, but the majority of transmission lines are found to be relatively short
- Transmission expansion needs and overall WECC-wide costs can be reduced through the use of RECs

Framework for Comparing WREZ Resources: The WREZ Model

Bus-Bar Cost ($/MWh)

+

Transmission Cost ($/MWh)

+

Integration Cost ($/MWh)

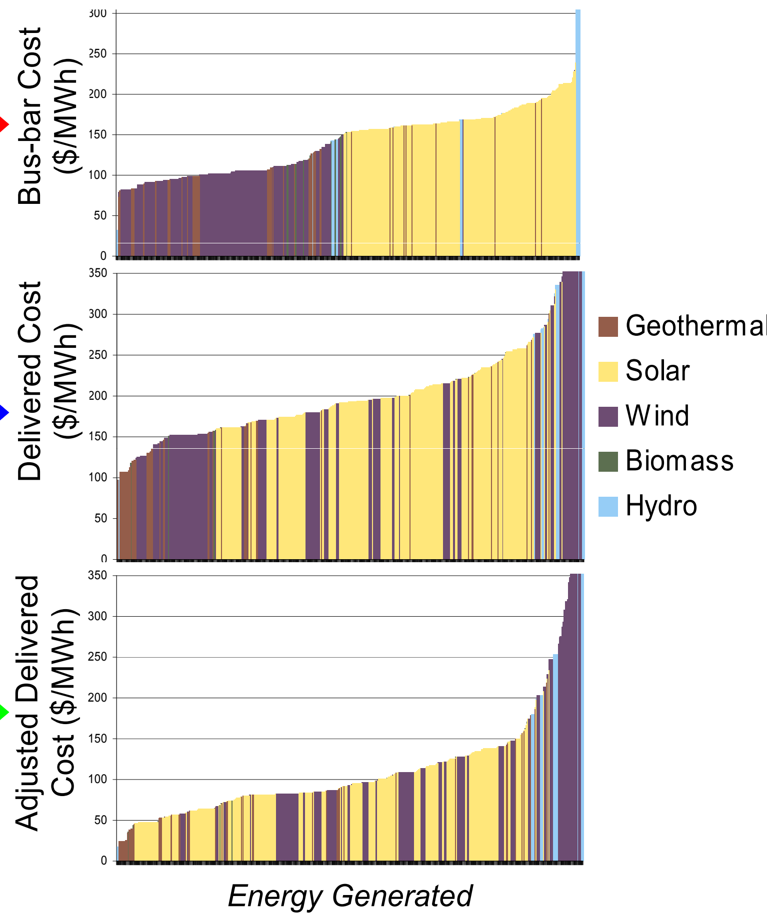
-

Capacity Value ($/MWh)

-

TOD Energy Value ($/MWh)

Renewable Resource Ranking for Southwest Load Zone:



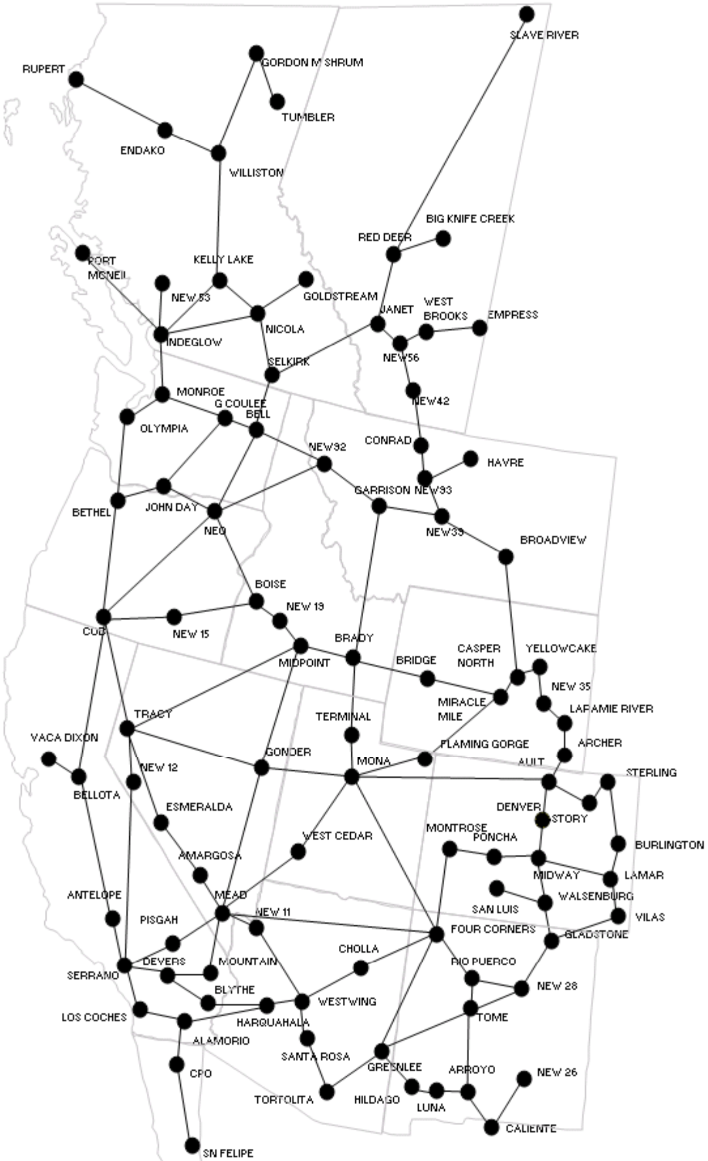
- WECC load is divided into 20 load zones (primarily major metropolitan areas; at least one per state)
- 55 WREZ hubs identified in WECC
- Most economically attractive resources have the lowest adjusted delivered cost
- Limited, high quality resources are allocated to the load zone with the highest economic benefit of procuring that resource

Bus-bar Costs Vary By Technology and Resource Quality

Renewable Technology	Total Capital Cost ($/kW)		Capacity Factor		Bus-Bar Cost with Starting Point Assumptions ($/MWh)	
	Energy-Weighted Median	(10th; 90th Percentile)	Energy-Weighted Median	(10th; 90th Percentile)	Energy-Weighted Median	(10th; 90th Percentile)
Hydro	4,263	(1,106 ; 9,818)	50%	(39% ; 51%)	128	(27 ; 376)
Biomass	3,659	(3,515 ; 3,824)	85%	(85% ; 85%)	115	(109 ; 147)
Geothermal	5,064	(4,355 ; 5,901)	80%	(80% ; 90%)	92	(78 ; 108)
Wind	2,418	(2,396 ; 2,469)	31%	(28% ; 39%)	92	(73 ; 121)
Wet Cooled Solar Thermal with Storage	7,473	(7,465 ; 7,556)	38%	(30% ; 40%)	163	(155 ; 193)
Wet Cooled Solar Thermal without Storage	5,174	(5,165 ; 5,352)	27%	(21% ; 29%)	169	(161 ; 212)
Dry Cooled Solar Thermal with Storage	7,674	(7,665 ; 7,756)	36%	(29% ; 37%)	175	(170 ; 201)
Fixed PV	4,576	(4,565 ; 4,690)	25%	(22% ; 26%)	156	(150 ; 179)

Starting point assumptions from WREZ model include 30% Investment Tax Credit (ITC) for all U.S. resources, a 15-year debt term for all non-solar technologies, and a 25-year debt term for solar technologies; Base solar technology assumed to be wet-cooled solar thermal with storage

Transmission Costs Depend on Distance from Resource to Load Zone



- All WREZ resources are assumed to require new transmission capacity
- Transmission distance is largely based on following existing rights-of-way
- Starting point transmission costs are allocated assuming a pro-rata share of a single circuit 500 kV line
- Transmission utilization is assumed to equal capacity factor of renewable resource
- Transmission losses are 0.7% per 100 miles
- Transmission cost of 500 kV line total an assumed $1,564/MW-mi

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Market Value Adjustment Factors Vary by Technology and Load Combination

	TOD Energy Value Assuming $65/MWh Average Marginal Production Cost ($/MWh)		Capacity Value Assuming $156/kW-yr Resource Adequacy Cost ($/MWh)		Integration Cost ($/MWh)	Market Value Adjustment ($/MWh)
Technology	Median	(10th; 90th Percentile)	Median	(10th; 90th Percentile)	Assumption	Median
Hydro	65.4	(60.9 ; 72.7)	21.7	(5.0 ; 35.4)	N/A	87.0
Biomass	65.0	(65.0 ; 65.0)	17.8	(17.8 ; 17.8)	N/A	82.8
Geothermal	64.4	(63.7 ; 65.0)	13.5	(11.1 ; 20.0)	N/A	77.9
Wind	63.4	(55.7 ; 70.8)	9.7	(5.8 ; 25.7)	5.0	68.1
Wet Cooled Solar Thermal with Storage	71.0	(69.5 ; 73.5)	38.5	(13.7 ; 43.7)	N/A	109.5
Wet Cooled Solar Thermal without Storage	69.0	(67.7 ; 71.4)	30.2	(8.8 ; 40.5)	2.5	96.7
Dry Cooled Solar Thermal with Storage	70.9	(69.4 ; 73.3)	36.1	(14.7 ; 41.3)	N/A	106.9
Fixed PV	68.3	(67.6 ; 70.3)	22.7	(15.6 ; 30.0)	2.5	88.5

TOD energy value is based on correlation of renewable generation profile and marginal production costs at load zone. ***Capacity value*** is based on renewable generation during top 10% of load hours at load zone. ***Integration costs***–the costs to manage variability and uncertainty–are technology specific and are based on previous wind integration studies.

Advantages and Disadvantages of WREZ Model and Framework

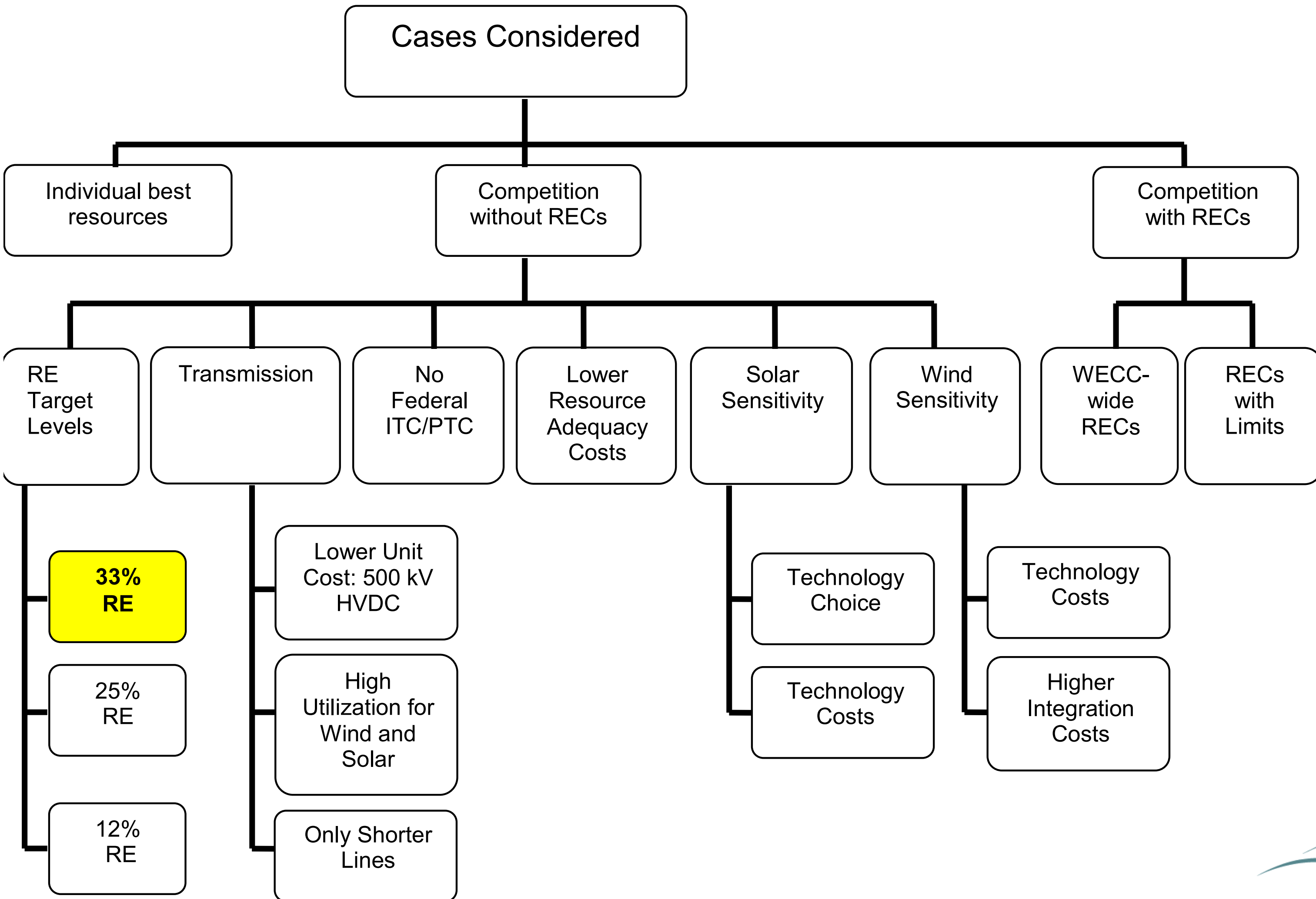
Advantages:

- Simple and transparent
- Broadly accessible: Excel-based
- User can quickly define own input assumptions
- Screening tool identifies factors that should be carefully evaluated in more detailed analysis
- Appropriate tool for understanding policy decisions
- Tool incorporates main drivers of economic attractiveness

Disadvantages:

- Renewable resource database only characterizes resources in WREZ hubs
- Pro-rata allocation of transmission costs ignores lumpiness of transmission
- Market value adjustment factors do not change with renewable penetration level (particularly important for TOD energy and capacity value)
- Assumes no existing transmission capacity and allocates full cost of new transmission to renewable resources

WREZ Model Used to Examine Several Cases Centered Around 33% RE Target



Resource and Transmission Expansion Decisions in WREZ: Presentation Outline

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Increasing RE Targets Increases Costs and Required Transmission Investment

Impact		12% Renewables		25% Renewables		33% Renewables	
		(TWh/yr)	(GW)	(TWh/yr)	(GW)	(TWh/yr)	(GW)
Resource Composition	Geothermal	22.7	3.0	28.6	3.9	28.6	3.9
	Biomass	7.9	1.1	17.2	2.3	20.7	2.8
	Hydro	6.5	1.5	12.0	2.7	16.7	3.7
	Wind	42.2	13.2	108.5	36.1	144.3	48.2
	Solar	0.0	0.0	47.1	13.7	85.5	25.0
Costs	Average Adjusted Delivered Cost ($/MWh)		23.6		37.2		43.2
	Marginal Adjusted Delivered Cost ($/MWh)		33.9		54.7		61.5
Transmission Expansion	New Capacity (GW-mi)		4,123		11,958		18,510
	Transmission Investment ($ Billion)		5.9		17.0		26.3
	Transmission and Losses Cost as Percentage of Delivered Cost		16%		14%		15%

- Wind is the largest source of incremental renewable energy when the renewables target increases from 12% to 25%
- Equal amounts of wind and solar (wet-cooled solar thermal with thermal storage) are added when western RE target increases from 25% to 33%
- Increasing the RE target from 12% to 33% WECC-wide increases the average costs of renewable energy by $20/MWh
- Transmission investment costs are substantial, but are only about 15% of delivered cost at all RE target levels

Note: Marginal adjusted cost indicates the cost of the resource that would be procured if the RE target were increased by a very small amount

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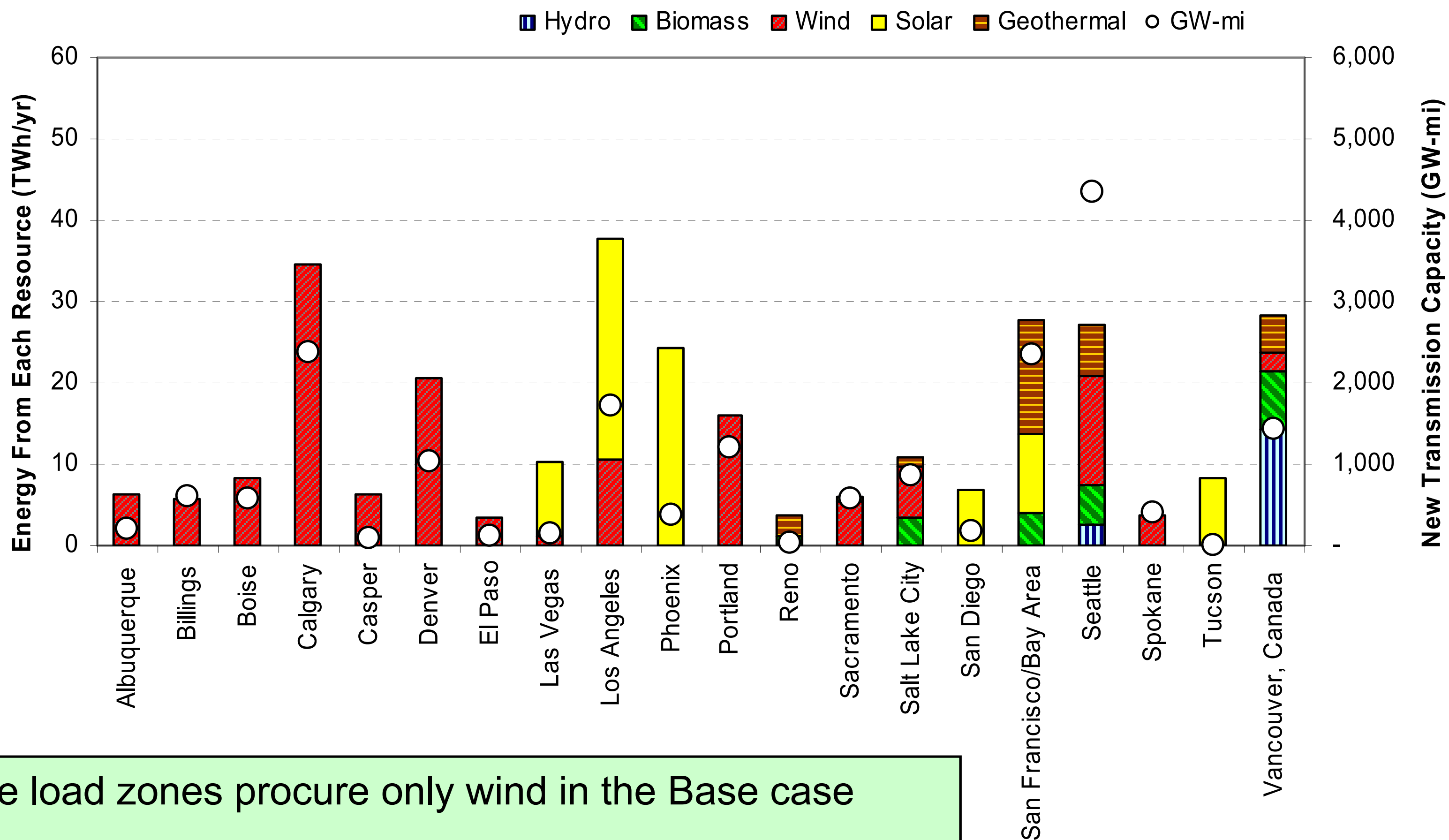
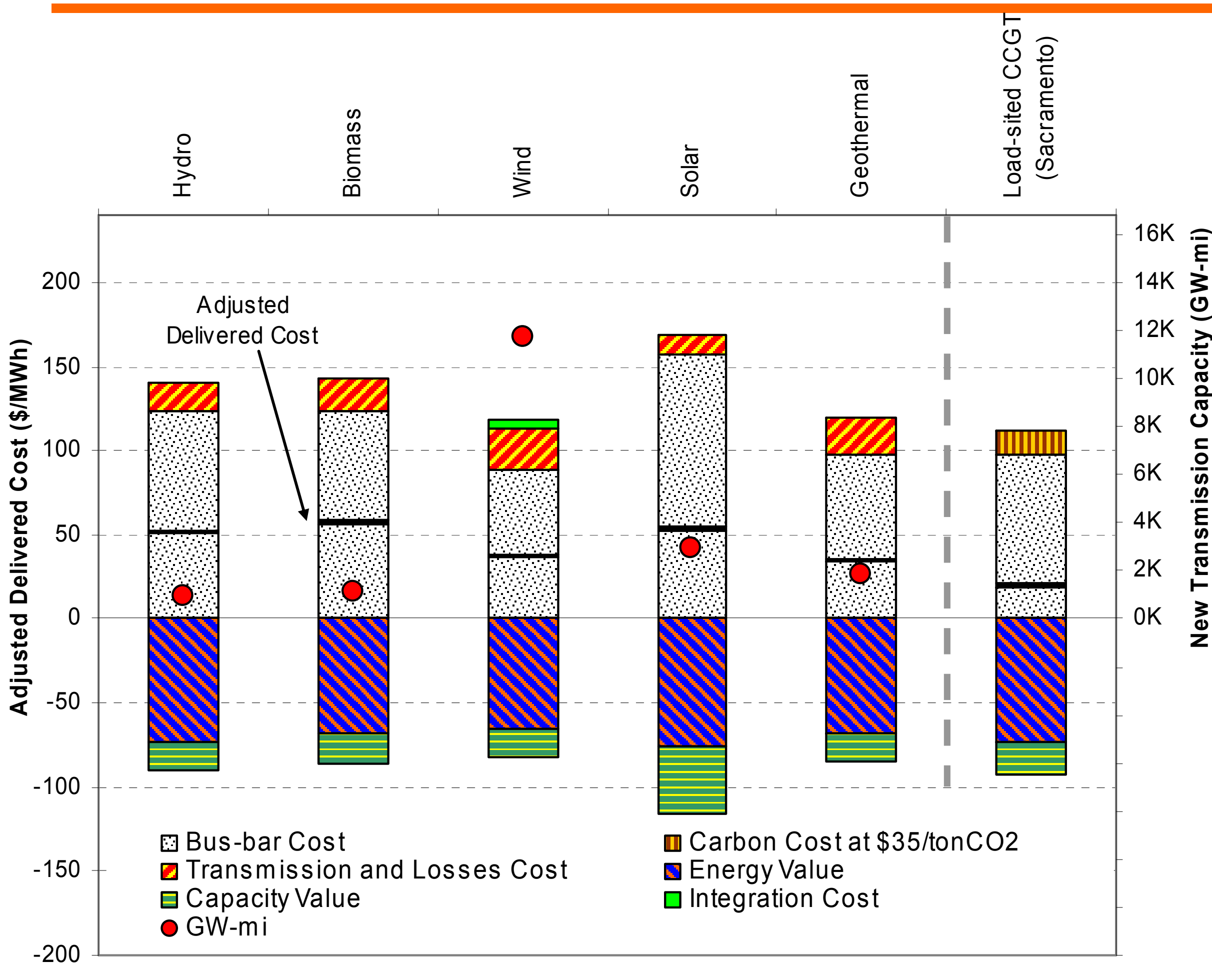
Wind Is the Largest Contributor to Meeting the 33% RE Target with WREZ Resources



- Nine load zones procure only wind in the Base case
- Solar thermal is second largest resource and is particularly important in the Southwest
- Transmission expansion driven by Seattle, San Francisco, Calgary, Los Angeles, and Vancouver

High Bus-bar Costs of Solar Are Offset by High TOD Energy and Capacity Value



Note: Load-sited CCGT cost assumes $8/MMBTU gas cost

- Average TOD energy and capacity value of solar thermal with storage procured in Base case is $34/MWh greater than TOD energy and capacity value of procured wind
- Adjusted delivered cost of solar is more sensitive to correlation with loads and avoided resource adequacy costs than other technologies
- Wind provides 49% of the renewable energy but drives 63% of transmission expansion

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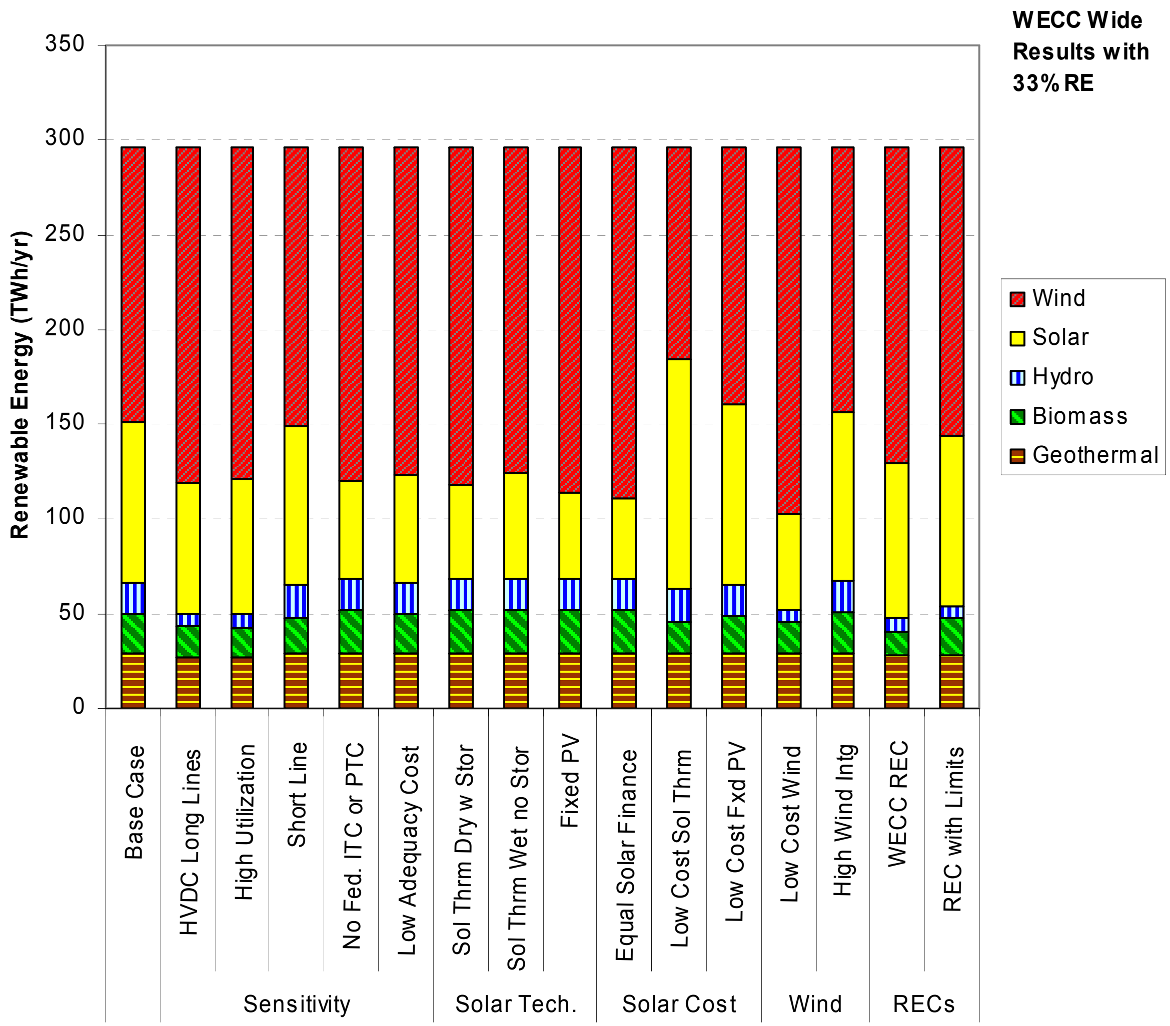
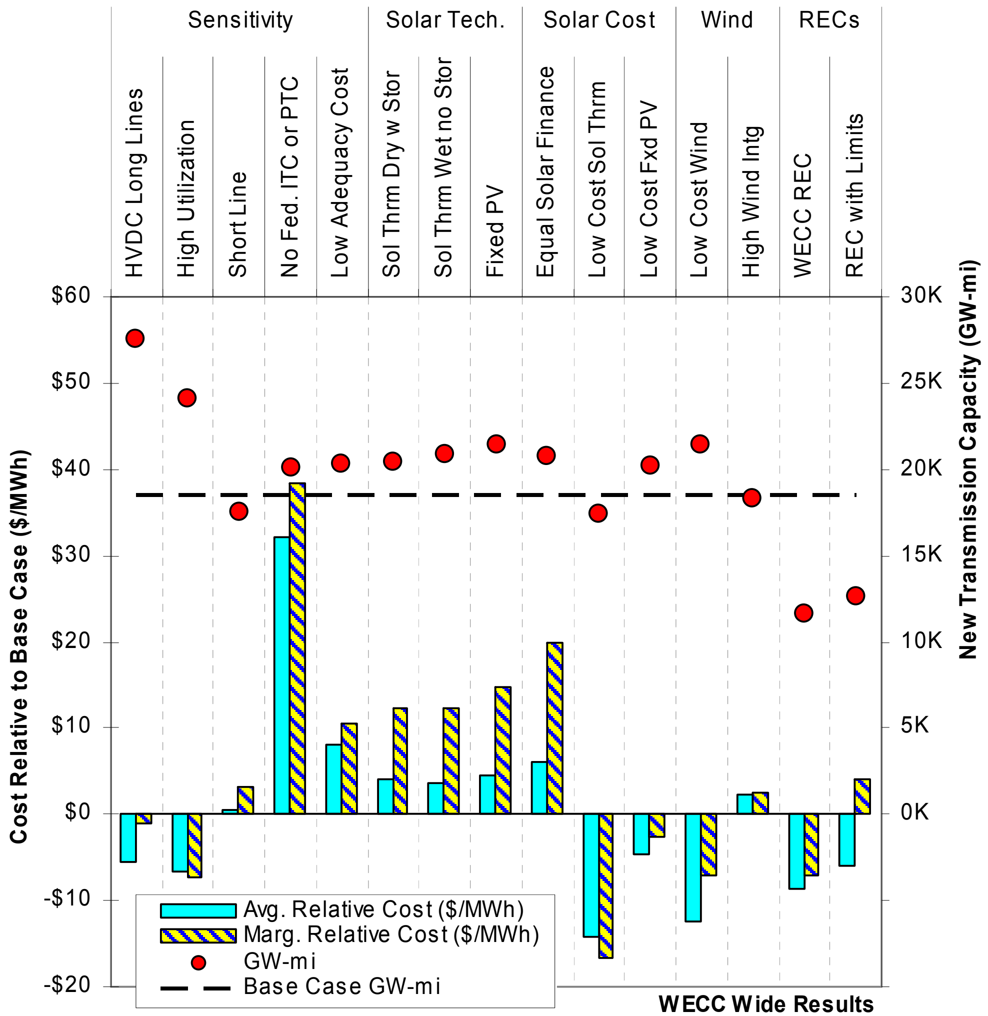
Key Uncertainties Can Shift Balance Between Wind and Solar Procurement



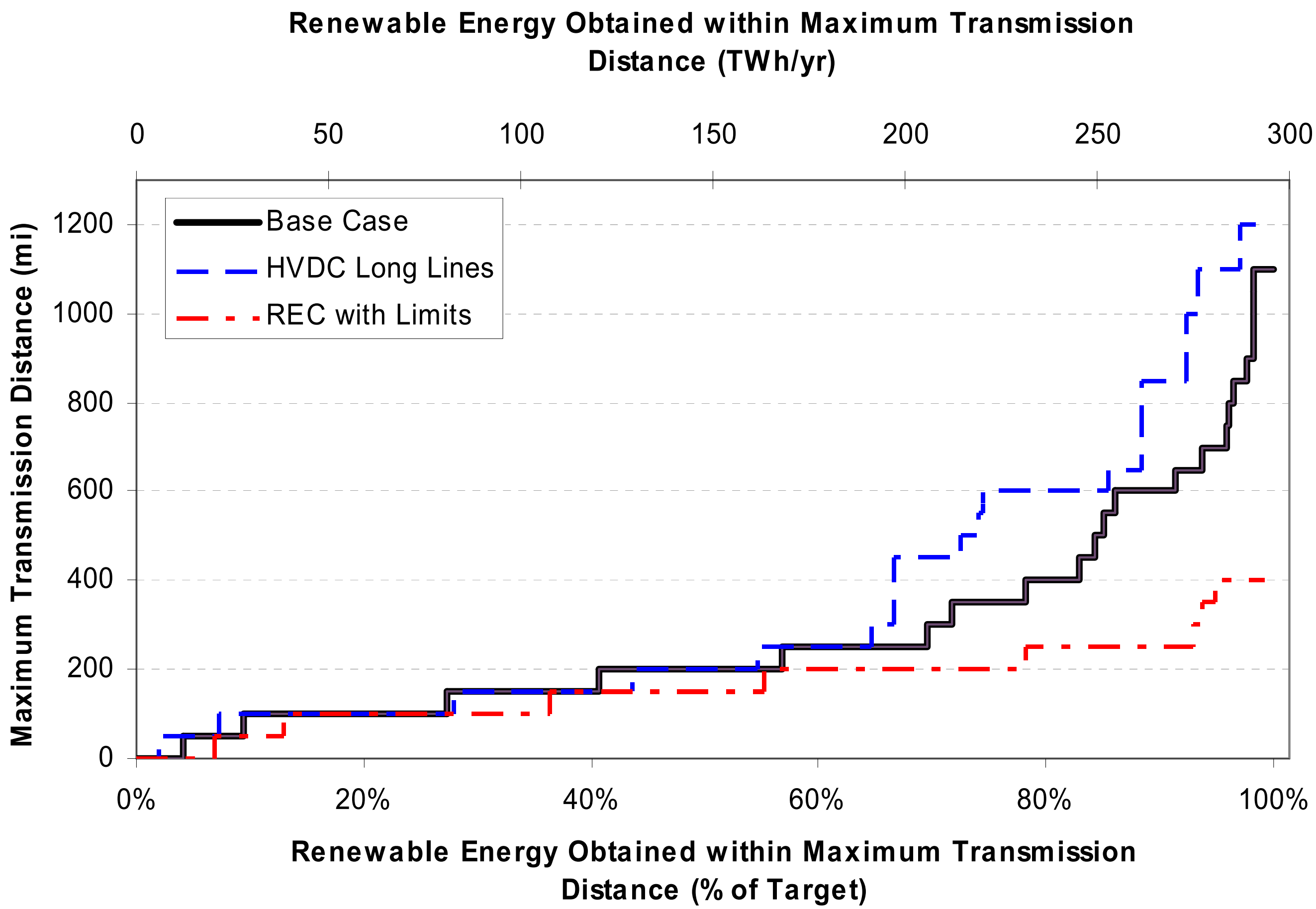
- Biomass, hydro, and geothermal contribute 16-23% of overall portfolio across all cases: supply constrained
- More wind energy is procured when wind costs are low, transmission costs are low, resource adequacy costs are low, or federal tax incentives for RE are allowed to expire
- More solar energy is procured when solar capital costs decline or wind integration costs are assumed to be higher
- Dry-cooled solar thermal, solar thermal without thermal storage, and fixed PV are all less attractive than wet-cooled solar thermal with thermal storage, under starting point assumptions

Transmission Costs with 33% RE Delivered to Each Load Zone Are $22-34 Billion



- Overall cost is most influenced by availability of Federal tax incentives and potential reductions in renewable capital costs
- Transmission expansion is greatest in scenarios with significantly more wind
- Cases with more transmission than Base case sometimes also have overall lower costs than Base case
- Transmission costs are only a fraction of delivered costs: 14-19% in cases that require 33% RE to be delivered to each load zone

Long Trans. Lines Can Be Economically Justified But Most Are Relatively Short



- Lines over 800 miles long can be economically justified in some cases
- Long lines are more prevalent when HVDC is assumed for lines longer than 400 miles
- Average transmission distances are 230-315 miles when 33% RE is delivered to each zone
- Any long distance lines built to access renewable energy in the west would ideally be coupled with an even-greater emphasis on short-distance lines

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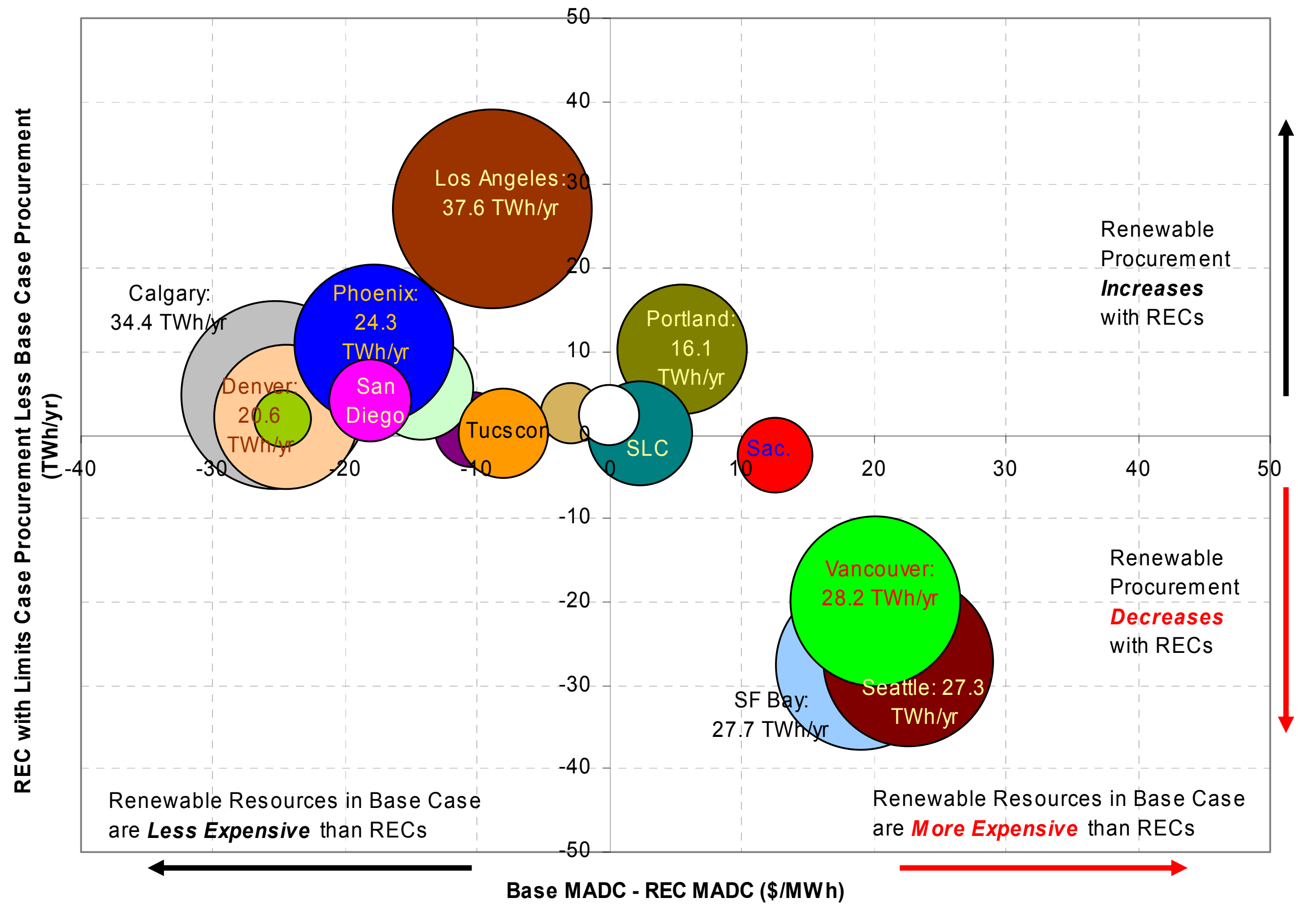
Renewable Energy Credits Can Reduce Transmission Expansion and Overall Costs

- Costs of meeting RE targets are heterogeneous across load zones
- RECs allow loads near high-quality resources to increase procurement and loads distant from resources to decrease procurement
- RECs can reduce transmission costs by $8 billion in 33% RE target scenario
- RECs may potentially reduce average costs of meeting 33% RE target by $6/MWh



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Conclusions

- Assumptions and policies that affect bus-bar costs of renewables have the largest impact on resource selection and transmission expansion
  - Renewable resource capital cost, financing parameters, availability of incentives, and resource quality need careful consideration
- Bus-bar costs are only one piece of the puzzle: transmission and market value assumptions can also be important
- Wind energy is the largest contributor toward a 33% RE target under starting point assumptions, but key uncertainties can shift the balance between wind and solar in the Southwest
- Transmission investment to meet 33% RE with new WREZ resources estimated at $17-34 billion
- Transmission costs are 10-19% of delivered cost of WREZ resources
- Availability of tradable RECs should be explicitly considered in more detailed transmission planning

Future Research

- **Considerable non-WREZ renewable resource potential** exists in the West; the adjusted delivered cost of non-WREZ resources should be compared to the adjusted delivered costs of WREZ resources
- **Market value adjustment factors** will change with penetration levels; more detailed tools should evaluate changes in market value at higher penetration, particularly in identifying the potential role of tradable RECs
- **Higher transmission utilization** increases wind procurement; detailed analysis should evaluate the costs and benefits of approaches to increasing transmission utilization for wind energy

For more information...

Contact the authors:

Andrew Mills, 510-486-4059, ADMills@lbl.gov

Amol Phadke, 510-486-6855, AAPhadke@lbl.gov

Ryan Wiser, 510-486-5474, RHWiser@lbl.gov

Download the full report:

http://eetd.lbl.gov/ea/EMS/re-pubs.html

Download the WREZ model:

www.westgov.org