



Load-Resource Balance in the Western Interconnection: *Towards 2020*

**Complete package based on January 2008 Results
Working Product for the
Western Electric Industry Leaders (WEIL) Group**



*Ren Orans and Arne Olson
Energy and Environmental Economics, Inc.
101 Montgomery Street, Suite 1600
San Francisco, CA 94104
415-391-5100*



Presentation Organization

1. Description of Analysis and Scenarios
2. Demand for “Preferred Resources” by Scenario
3. Overview of Resource Supply Curves
4. Energy Costs Under Local Resources Only
5. Energy Value of New Transmission
6. Value of Tradable Renewable Energy Credits

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Overview of the Current Work

- E3 are experts in energy planning and have done work for many western utilities and state agencies over the past 20 years.
- E3 was hired by a subgroup of western utility executives to study high-priority transmission projects in light of new RPS and GHG goals.
- This study is not restricted by existing control area or jurisdictional boundaries. It takes a much broader “regional” perspective capable of sharing the benefits of large new investments in transmission and renewable or low-carbon resources.
- This study is a working product for the WEIL Group. It includes contributions from both E3 and many but not all WEIL companies. The conclusions are preliminary and are not endorsed by any particular Group member.

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Study Specifications

- High-level “screening” study
 - Highlights “long line” transmission links between regions that merit further study
 - Transparent spreadsheet model using publicly available data
 - Does not attempt to provide precise estimates of the costs and benefits of specific projects
- How does this study differ from other efforts?
 - Multi-region study looking at resources across the WECC
 - Supply-curve analysis instead of assumed resource cost and availability

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Summary of Results

- Policies favoring renewable resources can increase the cost effectiveness of many “long lines” proposals.
- New multi-state lines can help high-load states meet policy goals more cost-effectively
 - Most motivated buyers: Arizona-Southern Nevada, California, Colorado, Northwest
 - Most promising sellers: Wyoming, Montana, New Mexico, Nevada, British Columbia
- Tradable RECs produce similar value to a large new transmission line, at a fraction of the cost

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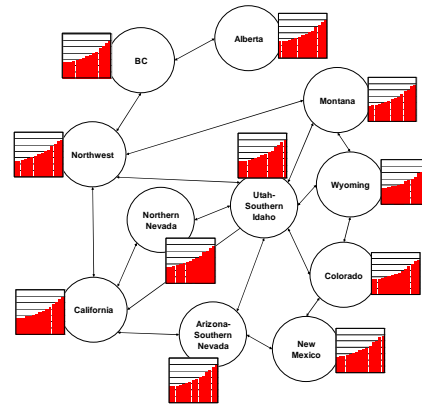
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Description of Analysis and Scenarios



Step 1: Cost of Procuring Energy from Local Resources

- Divide the WECC into 11 regions
- Start with 2008 loads and resources by region
- Grow loads to 2020
- Add least-cost **local** resources on a MWh-for-MWh basis to meet load growth, RPS and GHG requirements



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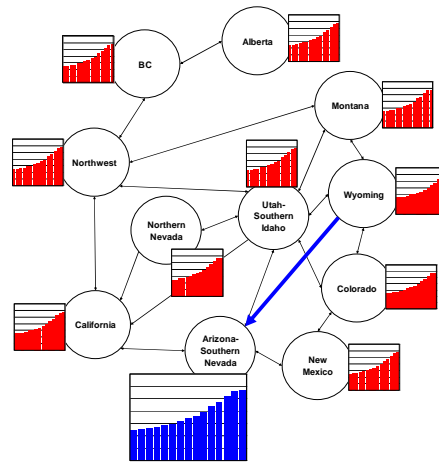
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Notes

- The 11 WECC regions represent “resource zones”, i.e., regions in which new resources can be integrated into the local grid at similar cost.
- The regions roughly line up with state and provincial boundaries, with some exceptions based on the topography of the western transmission grid:
 - Washington and Oregon are in one region
 - Southern Idaho and Utah are in one region
 - Southern Nevada is placed in the same zone as Arizona
- The analysis ignores transmission by adding new resources inside each zone. Region-to-region flows are assumed to remain constant.
- Resources are added to meet load growth and policy requirements on a MWh-for-MWh basis. For example, if load grows by 25,000 GWh, 25,000 GWh of resources are added regardless of the nameplate capacity and regional capacity balance.
- “Preferred resources” -- resources that meet Renewables Portfolio Standard (RPS) or Greenhouse Gas (GHG) targets -- are added first, and conventional resources are added when the RPS and GHG targets are satisfied.

Step 2: Change in Energy Cost from Adding Transmission

- Assume fixed-capacity DC transmission line from one region to another
- Allow resources not selected in “source” region to meet needs in “sink” region
- Calculate change in sink region energy costs



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Notes

- This step analyzes the “change case”: how does the total resource procurement cost change if resources can be added from another region?
- The analysis assumes that a fixed amount of energy can be transferred from one region to another, displacing higher-cost resources in the downstream region. Different transmission line capacities are modeled.
- Load, RPS and GHG requirements are satisfied in the producing region first, before resources are made available to the consuming region. This means that the best renewable resources are dedicated to local loads rather than to exports.
- The transmission line is analyzed on a forward-looking basis: the line is utilized if the “all-in” cost of new resources in the producing region is lower than the “all-in” cost of new resources in the consuming region. If the cost is higher in the producing region, no energy transfers are assumed.
- No benefits are assumed from improved dispatch of existing resources.

Step 3: Repeat for Different Load, RPS, Greenhouse Gas Cases

Scenarios Run for Today's Results

- Base Case: Current state-by-state RPS requirements
- High RPS Case: 30% in CA, 25% everywhere else
- CO2 Reduction Case: Reduce CO2 emissions by 30% below 2008
- Low Solar Cost Case: 20% cost reduction relative to base case

Many Other Sensitivities Possible

- Size of transmission line (1500 - 6000 MW)
- High energy efficiency achievement
- Effect of carbon tax or allowance price

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Notes

- The four cases selected for today's presentations are those that we thought provided the most interesting and useful results. Many additional sensitivities are possible with the spreadsheet tools that we have developed.
- The Base Case reflects current state and provincial renewables requirements, and medium load growth.
- The "High RPS" case assumes 30% RPS in California, 25% RPS in all other regions.
- The CO2 Reduction case eliminates RPS requirements and focuses exclusively on CO2 reduction. The case reduces CO2 emissions by 30% from 2008 levels. The case is similar to a case where emissions are reduced to 1990 levels, but this simplifying methodology avoids the need to calculate a 1990 baseline for each region.
- The Low Solar Cost Case reduces solar thermal costs by 20%. The case assumes the same RPS as the Base Case. This represents an alternative assumption about the cost of solar thermal in 2020.



Model Limitations

- “Screening analysis” based on simple, transparent spreadsheet model
- Model estimates the *energy benefits* of moving electric energy from one region to another
- “Energy model” does not consider reliability benefits, dispatch benefits, or benefits from load/resource diversity
- Does not consider actual power flows
- Simple transmission configuration based on size and line-miles

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Notes

- Our model is a simple, spreadsheet model that ignores real power flows and focuses on resources needed to meet policy goals. The necessary simplifications lead to a number of important limitations that must be understood.
- The most important limitation is that the model calculates only a portion of the benefits of new transmission. Since we only look at part of the benefits picture, we do not attempt to incorporate transmission costs and calculate benefit-cost ratios.
- The regional resource supply curves are the basis for the model results. Key drivers are regional fuel cost differences, capital cost differences, and the quality and availability of renewable resources.

Demand for Preferred Resources under RPS and GHG Scenarios



Base Case RPS Targets by Region

- RPS currently in effect in 8 of 11 regions (shaded green)
- Assume 5% for other regions to reflect known renewables plans
- WECC-wide gap:
 - 120,000 GWh, or
 - 14,000 aMW, or
 - 40,000 MW of wind

Region	Base Case Target	Preferred Resource Gap (GWh)
Alberta	5%	2,753
Arizona-Southern Nevada	13%	18,020
British Columbia	12%	9,414
California	20%	43,801
Colorado	15%	12,395
Montana	15%	829
New Mexico	18%	3,988
Northern Nevada	20%	2,574
Northwest	14%	22,946
Utah-Southern Idaho	5%	3,103
Wyoming	5%	415
WECC Total	15%	120,238

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Notes

- This slide shows the region-by-region RPS targets for our Base Case.
- We estimated the targets by looking at the RPS laws in each state and province.
- Where the goals were stated for years prior to 2020, we used the goal for the year stated (e.g., California's goals is 20% by 2010, so we used 20% for the Base Case).
- Where the goals were stated for years after 2020, we used a linear interpolation to calculate the 2020 goal.
- Where regions cross state boundaries, we calculated a load-weighted average of the targets in the two states (Northwest and Arizona-Southern Nevada).
- Where targets are different for IOUs vs. POUs, we calculated a load-weighted average for each region.
- Our starting point was a 2008 case run using the PLEXOS production simulation model for the entire WECC.
- Our starting point contains some renewable resources, but does not represent an exhaustive catalog of resources online in 2008. This does not negatively affect the model results, since our resource supply curves are also not decremented for existing renewable resources.

High Case RPS Targets

- 30% for California, 25% for other regions
- Gap exceeds growth for most regions
- WECC-wide gap:
 - 252,000 GWh, or
 - 28,000 aMW, or
 - 85,000 MW of wind

Region	High RPS Case Target	Preferred Resource Gap (GWh)
Alberta	25%	18,006
Arizona-Southern Nevada	25%	33,850
British Columbia	25%	19,755
California	30%	80,422
Colorado	25%	20,725
Montana	25%	2,131
New Mexico	25%	6,022
Northern Nevada	25%	3,304
Northwest	25%	45,760
Utah-Southern Idaho	25%	18,031
Wyoming	25%	4,200
WECC Total	27%	252,206

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Notes

- For this case, we assumed aggressive RPS goals in each state/province in the WECC.
- The Preferred Resource Gap exceeds load growth for most regions, which means that the new resources must displace existing resources in order for the regions to remain in load-resource balance.

CO2 Reduction Case Targets

- RPS-like target set for each region to achieve CO2 goal
- Target similar to High RPS Case for BC, CA, NW
- Preferred resources include nuclear & IGCC with carbon capture
- WECC-wide gap:
 - 381,000 GWh, or
 - 43,000 aMW, or
 - 128,000 MW of wind

Region	GHG Case Target	Preferred Resource Gap (GWh)
Alberta	48%	35,304
Arizona-Southern Nevada	50%	68,299
British Columbia	19%	15,017
California	35%	99,135
Colorado	43%	36,123
Montana	81%	9,403
New Mexico	54%	13,953
Northern Nevada	55%	7,689
Northwest	28%	51,325
Utah-Southern Idaho	49%	35,925
Wyoming	51%	9,131
WECC Total	38%	381,303

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Notes

- This case is roughly comparable to what a 1990 emissions case might look like.
- For this case, we calculated RPS-like targets for each region. The targets represent the amount of carbon-free energy that must be added in order to reduce emissions by 30% from our 2008 baseline.
- In order to calculate the targets, we assumed that new, carbon-free resources would displace existing resources in each region. We calculated a CO2 reduction factor for each region based on the average of the fossil fuel resources in the region.
- When selecting resources, we assume that either nuclear or IGCC with carbon capture is a preferred resource and did not distinguish between those resources and renewables. Thus, this case is interesting because it has less reliance on renewables than the RPS cases.
- This case does not consider potential assignment of responsibility for CO2 emissions across regions, e.g., Colstrip emissions are allocated 100% to Montana rather than to loads in the Northwest. Thus, this case may understate the benefits of interregional transmission by placing higher demand for carbon-free resources in the Mountain states rather than the coastal states.

Overview of Resource Supply Curves



Renewable Energy Data Overview

- Five renewable technologies evaluated

- Wind
- Solar Thermal
- Geothermal
- Hydro
- Biomass



- General approach: use uniform cost assumptions and let resource availability drive regional supply curves

- Mainstream estimates for 2007 technology
- Regional capital cost multipliers (CA=1.20, WY=0.92)

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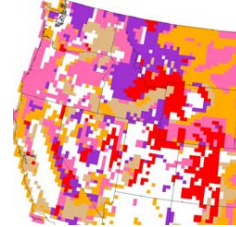
Notes

- We relied principally on data from NREL and EIA for our renewables supply curves.
- For wind and solar thermal, we obtained data from NREL's GIS mapping tools. We used NREL's estimates of resource availability by resource class and transmission availability category within each region to develop regional supply curves.
- NREL excludes many resources because they are located in restricted areas, e.g., national parks, wilderness areas, military reserves. NREL also excludes resources based on transmission availability.
- NREL's transmission availability methodology assigns transmission lines to resources by location starting with the best resources first. As transmission lines are used up, lower class resources are forced to look farther for transmission of a suitable size. The resulting dataset contains a distance to transmission for each resource class within each zone. We then added transmission costs to the resources using a rule of thumb of \$1600/MW-mile.
- Capital cost estimates come primarily from EIA's Annual Energy Outlook 2007, with adjustments to reflect recent capital cost escalation.
- For hydro, geothermal and biomass, we used site-specific data from EIA, INL, and other sources to develop capital cost estimates and transmission integration estimates.

Wind Resource & Cost Data

■ Resource Potential from NREL

- GIS input for WinDS model
- 98 resource regions in WECC
- Exclude cities, lakes, federal lands, >20% slopes
- Use resource class (1-7) to calculate capacity factor



■ Generation costs (in 2008 \$):

- Installed capital cost: \$1634/kW for base plant (AWEA Wind Vision study)
- Production tax credit: 1.9¢/kWh for 10 years
- Levelized busbar cost range for all sites in supply curve: \$65/MWh - \$125/MWh

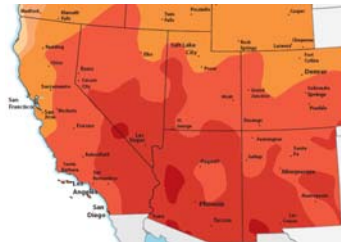
■ Other costs:

- Interconnection (used NREL "assignment" method): \$1/MWh - 18/MWh
- Firming (assume 10% capacity on peak): \$19/MWh - \$36/MWh
- Integration (depends on region size and wind penetration): \$2/MWh - \$12/MWh

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Solar Thermal Resource & Cost Data



■ Resource Potential from NREL

- GIS data used for WGA CDEAC analysis
- 31 resource regions in WECC
- Exclude cities, lakes, federal lands, >1% slopes
- Capacity factor based on irradiation and latitude

■ Generation costs (in 2008 \$)

- Wide range of estimates in literature: \$71 to \$219/MWh
- Parabolic trough technology, Black & Veatch (2006) costs
- Installed capital cost: **\$2,928/kW for base plant**
- Investment tax credit: **10% in base case, 30% in high case**
- Levelized busbar cost range for all sites in supply curve: **\$123-160/MWh**

■ Other costs

- Interconnection (distance from center of region to 230kV+ line): **\$0.15- \$8/MWh**
- Firming (assume 85% capacity on peak): **\$6-8/MWh**

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Geothermal Resource & Cost Data

■ Resource Potential

- Project-specific MW and cost estimates
 - Used CEC/Geothermex (2004) for CA & NV sites
 - Used WGA CDEAC (2006) for rest of WECC
- Results after applying EIA filters:
 - CA: 3000 MW at 21 sites
 - NV: 1300 MW at 43 sites
 - BC: 185 MW at 2 sites
 - Rest of WECC: 1500 MW at 24 sites



■ Generation Costs

- Site-specific; varies with depth, temperature, & proven resource
- Installed capital costs for most sites: \$2800/kW to \$6700/kW
- Investment tax credit: 10%
- Levelized busbar costs for most sites: \$90/MWh - \$200/MWh
- Interconnection Cost (distance from location to nearest 115kV line): up to \$2/MWh

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Hydro and Biomass Resource & Cost Data

■ Hydro

- Site-specific MW & cost estimates
- Site list compiled by INL based on FERC applications, filtered by EIA based on cost and other parameters
- E3 selected only sites with existing dam and no documented barriers
- Levelized cost range: \$76-300/MWh

■ “Biomass” includes many different resource types

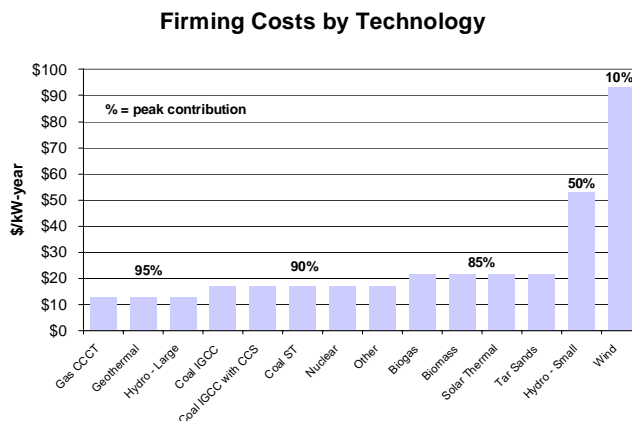
- Solid Biomass (Wood, Mill Waste, Municipal Solid Waste, Ag Residues)
- Biogas (Landfill Gas, Wastewater Treatment, Dairy/Manure)
- High gross potential, but hard to tell how much is developable
- Used scaled NREL state-level biomass availability by type
- Levelized cost range for Biogas: \$95-117/MWh
- Levelized cost range for Biomass: \$125-153/MWh

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Firming Costs and Capacity Balance

- Firm all resources with CT costs to 115% of nameplate
- On-peak contribution varies by resource
- Costs represent capacity charge, not actual CT
- This approach ensures model is adding enough capacity in each region



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Notes

- There is no consensus in the literature on how much credit to give wind in meeting peak demand.
- WECC-wide data for heat wave of July 24, 2006 showed 13% average capacity factor during peak hour.
- E3 assumed 10% for this study.
- E3 assumed that each new resource is firming to 115% of nameplate capacity.
- This ensures that the model builds enough capacity to meet growing peak demands, plus a 15% reserve margin.
- Firming resource cost is based on net annual carrying cost of CT.
- Firming resource is not a physical resource, but simply an additional fixed cost added to the resource cost to ensure apples-to-apples comparison across resource types.

Total Renewable Resource Availability by Region (MW)

	Biogas	Biomass	Geo-thermal	Small Hydro	Solar Thermal	Wind	Total
Alberta	-	-	-	100	-	11,999	12,099
Arizona-Southern Nevada	33	43	-	-	141,243	1,809	143,129
British Columbia	50	208	185	1,521	-	4,601	6,565
California	300	600	3,063	221	310,133	23,762	338,080
Colorado	59	44	20	-	18,050	5,138	23,310
Montana	5	162	-	37	-	54,542	54,745
New Mexico	18	26	80	-	66,897	11,066	78,087
Northern Nevada	15	15	1,281	10	150,062	5,523	156,906
Northwest	88	1,060	335	230	-	17,039	18,753
Utah-Southern Idaho	21	181	1,040	221	43,153	2,805	47,421
Wyoming	2	22	-	17	-	138,721	138,762
WECC Total	592	2,361	6,004	2,356	729,538	277,005	1,017,856

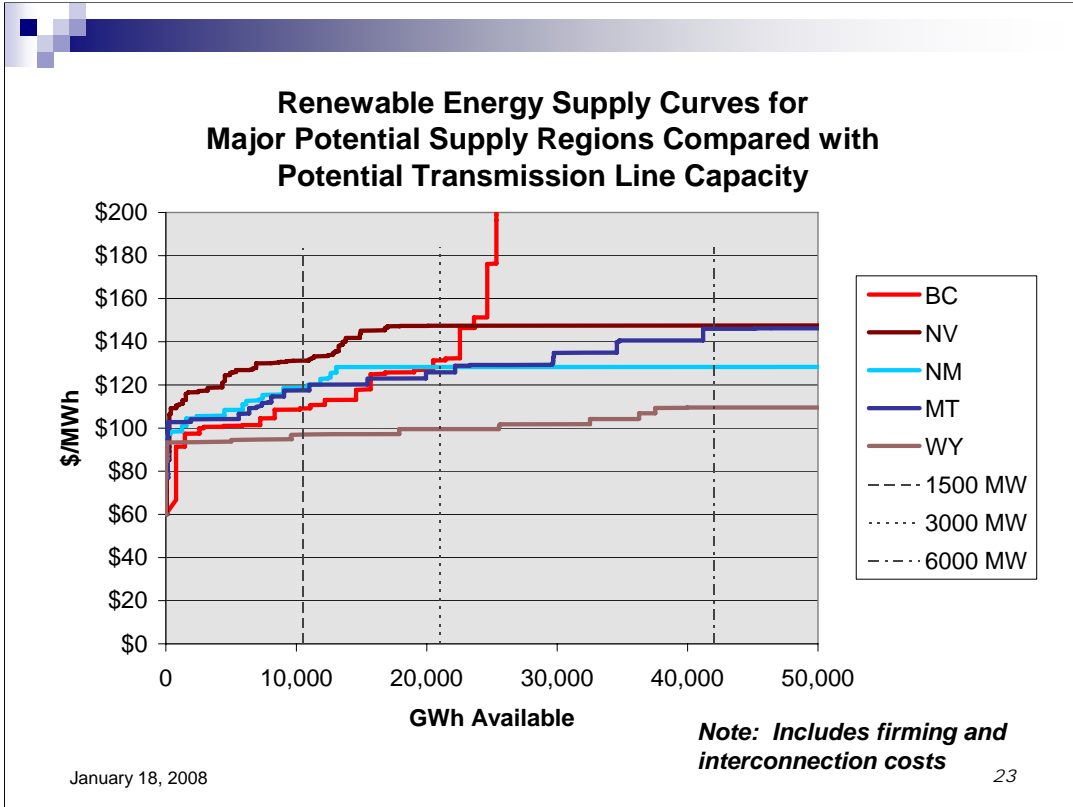
- Biomass & hydro limited and not very interesting
- Some geothermal potential in most areas
- Good wind resources scarce in the Southwest, plentiful in Rockies
- Lots of solar thermal theoretically available, but at high cost

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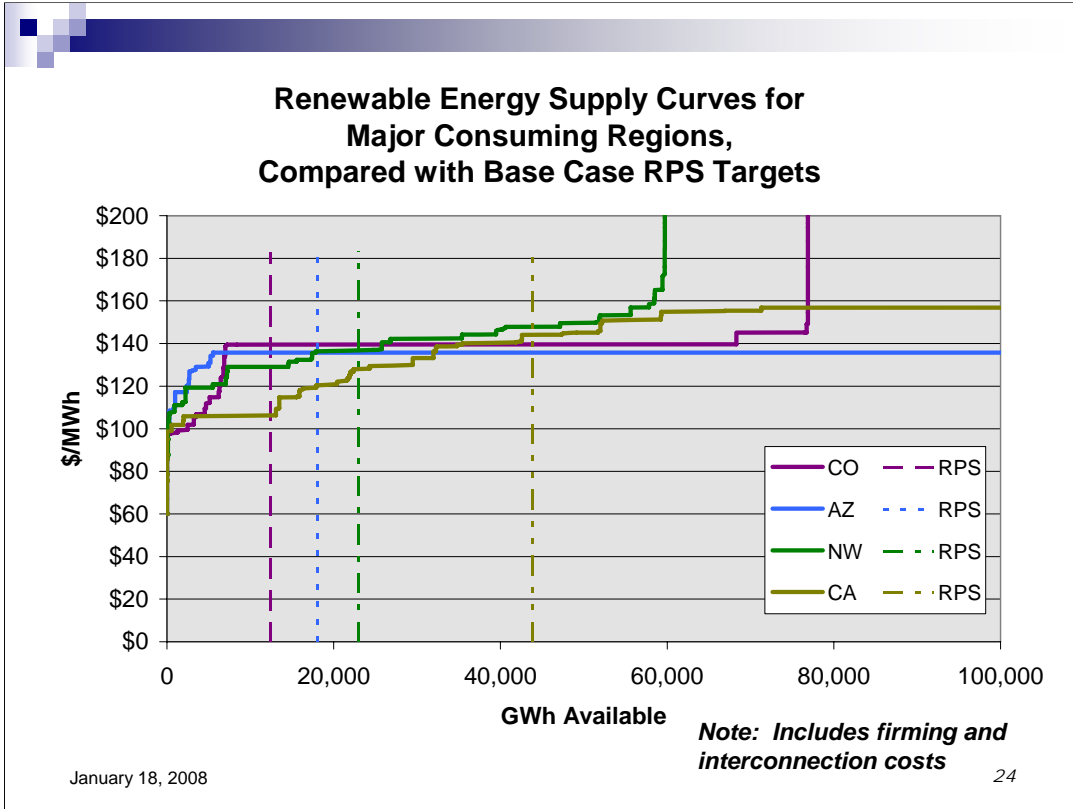
Notes

- Our data indicates very limited availability of small hydro and biomass resources.
- “Small” hydro means less than 30 MW. Our model also includes supply curves for large hydro (> 30 MW), but does not treat large hydro as a “preferred resource”.
- We show 6,000 MW of geothermal resources, mostly in California, Northern Nevada and Utah-Southern Idaho. However, many of these resources are very costly.
- The data we received from NREL indicates a high availability of wind and solar thermal resources.
- However, many of these resources are of lower resource class or are remote from the transmission grid. These resources are assigned lower capacity factors and/or higher integration costs, making them less economic to develop.
- The real question is how much high-quality wind can be developed and integrated into the regional grid. Wind is the only resource of which large quantities are available for less than \$100/MWh.
- Data for Canadian provinces is of a different nature, since NREL does not maintain a database of non-US areas. Data for BC was taken from BC Hydro's 2006 Integrated Energy Plan, but required substantial conditioning to make it comparable to data for the U.S. Data for Alberta was derived from multiple sources, but is even more speculative than data for BC.



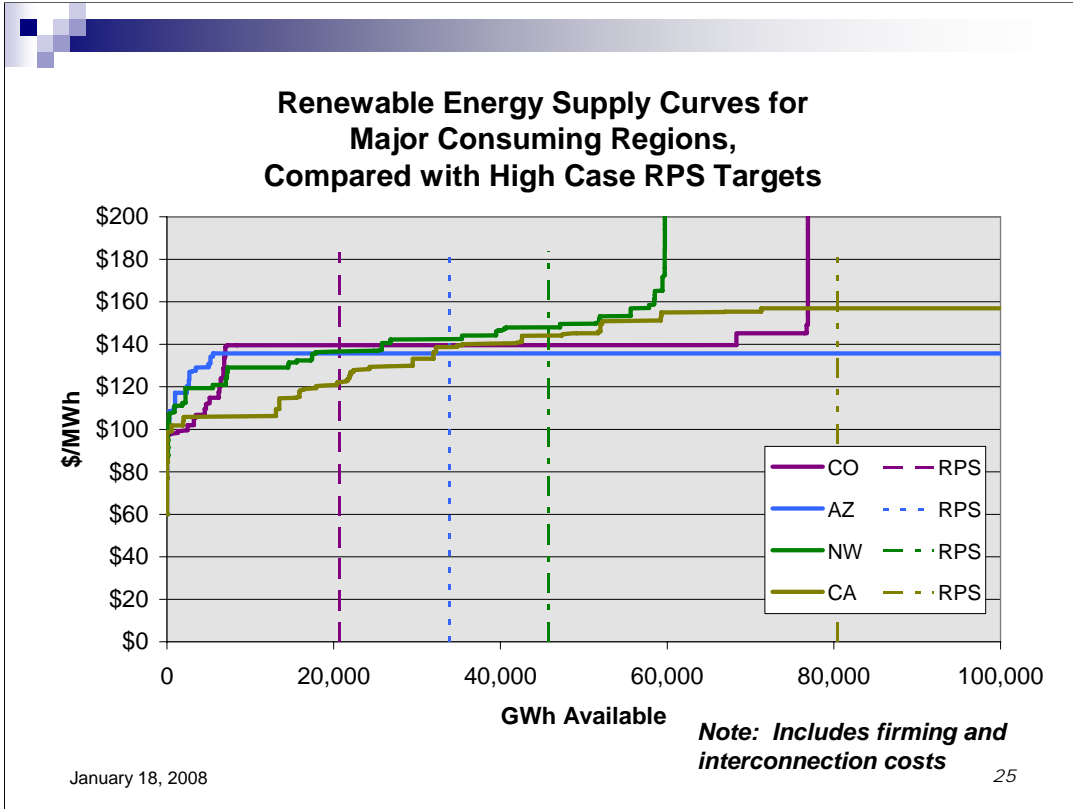
Notes

- Chart shows renewable energy supply curves for each potential supply region.
- Dashed, vertical lines represent approximate quantities of energy that can be shipped over a 1500 MW, 3000 MW and 6000 MW line.
- The supply curve for BC is based on the quantity of resources analyzed for BC Hydro’s IEP.
- This data set does not represent all of the theoretical potential in the province in the way that the NREL data does for the U.S. Therefore, we believe that the BC supply curve is too short and does not represent the total economic potential under the aggressive policy scenarios considered in this model.



Notes

- Chart shows renewable energy supply curves for each major consuming region.
- Dashed, vertical lines represent approximate quantities of renewable energy that are needed to meet Base Case RPS targets.
- Chart shows that some demand areas such as California have a rich endowment of renewables, but very high demand causes a high marginal cost even at the Base Case RPS.



Notes

- Chart shows renewable energy supply curves for each major consuming region.
- Dashed, vertical lines represent approximate quantities of renewable energy that are needed to meet High Case RPS targets.
- Chart shows that the marginal renewable resource cost is high for all consuming regions.

Conventional Resources

- Add conventional resources after RPS requirements have been fulfilled
- Five technologies considered:
 - Gas combined-cycle combustion turbine (CCCT)
 - Pulverized coal steam
 - Coal integrated gasification combined cycle (IGCC)
 - Coal IGCC with carbon capture and sequestration (CCS)
 - Nuclear



Cost in Levelized 2008 \$/MWh

	Wyoming	Arizona	California
Coal ST	\$ 70.04	\$ 84.28	N/A
Gas CCCT	\$ 75.61	\$ 85.79	\$ 91.87
Coal IGCC	\$ 77.14	\$ 91.63	\$ 109.13
Nuclear	\$ 112.21	\$ 121.02	\$ 143.02
Coal IGCC with CCS	\$ 115.15	\$ 134.17	\$ 159.84

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Notes

- Given the low spreads between conventional resource costs across regions, conventional resources are not the main driver for our results.
- Our model adds preferred resources first until the policy requirements are met, then fills in with the lowest-cost conventional resources in each region.
- We consider five baseload resources, and make no attempt to ensure an appropriate mix of peakers and baseload plants (since wind is firmed with CTs, our model adds enough capacity to meet peak load growth in all cases).
- We assume no limit on the amount of conventional resources that can be developed in each region, but the quantity added is capped by the load growth less the preferred resources added.
- IGCC with CCS and nuclear are designated as preferred resources under the CO2 Reduction case, and are assumed for simplicity to have zero carbon emissions.

Energy Costs Under Local Resources Only



New Resources Selected by Region, Base Case (MW)

	Conventional	Wind	Geothermal	Hydro	Biomass	Solar Thermal	Total
AB	1,736	793	-	-	-	-	2,529
AZ	2,694	1,736	-	-	76	3,770	8,276
BC	-	1,582	185	1,256	50	-	3,073
CA	984	7,802	2,183	105	300	-	11,373
CO	777	2,303	-	-	103	1,238	4,421
MT	255	190	-	25	5	-	475
NM	480	1,168	-	-	18	-	1,667
NV	215	220	219	-	15	-	669
NW	1,380	5,023	140	118	845	-	7,506
UT	1,982	795	-	161	21	-	2,959
WY	531	102	-	12	-	-	645
WECC	11,033	21,714	2,727	1,676	1,434	5,008	43,591

- Model mostly picks wind to meet RPS goals
- Some geothermal and others
- Solar thermal in Arizona and Colorado

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Notes

- This chart shows the resources selected by the model for the Base Case RPS targets.
- For “conventional”, the model selects pulverized coal in Arizona, Montana and Wyoming and gas combined cycle combustion turbines in all other regions.
- The model selects large hydro instead of fossil in BC.

New Resources Selected by Region, High RPS Case (MW)

	Conventional	Wind	Geothermal	Hydro	Biomass	Solar Thermal	Total
AB	-	6,883	-	-	-	-	6,883
AZ	554	1,736	-	-	76	8,533	10,898
BC	-	3,394	185	1,267	173	-	5,019
CA	-	14,377	2,758	72	900	2,820	20,927
CO	-	2,303	-	-	103	3,764	6,170
MT	79	564	-	25	5	-	673
NM	221	1,800	-	-	18	-	2,039
NV	122	447	219	-	15	-	803
NW	-	12,247	285	125	1,148	-	13,805
UT	76	1,373	300	201	202	2,989	5,141
WY	19	1,189	-	12	-	-	1,220
WECC	1,070	46,313	3,747	1,703	2,641	18,106	73,579

- Model digs much deeper into wind and solar thermal supply curves
- Very few conventional resources added

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Notes

- This chart shows the resources selected by the model for the High Case RPS targets.
- The model selects no conventional resources in AB, BC, CA, CO and NW because preferred resources exceed load growth for 2008-2020.
- Our model selects baseload resources added for energy. In reality, CTs would still need to be added in addition to the renewables in order to meet peak demands.

New Resources Selected by Region, CO2 Reduction Case (MW)

	Gas CCCT	Other Conventional	Wind	Geothermal	Hydro	Biomass	Solar Thermal	Total
AB	-	3,813	2,000	-	100	-	-	5,913
AZ	-	8,507	1,621	-	-	76	-	10,204
BC	-	-	-	185	3,115	-	-	3,300
CA	-	-	14,377	2,758	205	900	7,916	26,157
CO	-	3,958	1,804	-	-	103	-	5,865
MT	-	-	2,687	-	25	5	-	2,717
NM	-	-	4,079	-	-	44	277	4,400
NV	-	-	1,437	389	-	15	-	1,842
NW	-	-	13,533	285	1,112	1,148	-	16,078
UT	-	3,786	1,260	200	168	202	-	5,616
WY	-	-	2,592	-	12	2	-	2,606
WECC	-	20,064	45,390	3,817	4,737	2,496	8,194	84,698

- More aggressive goal results in more GWh of new resources
- Model picks coal IGCC with carbon capture and sequestration in areas where renewables are high-cost

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Notes

- This chart shows the resources selected by the model for the CO2 Reduction case.
- Aggressive reduction goals require all new conventional resources to be low-carbon. Model builds no new gas CCCTs.
- “Other conventional” resources are coal IGCC with carbon capture and sequestration (“IGCC with CCS”).
- Our model selects IGCC with CCS, but nuclear could be substituted. Both technologies are baseload technologies with potential to provide substantial quantities of low-carbon energy.
- Cost of both nuclear and IGCC with CCS is unknown, but is likely to be very high compared to current conventional technologies and compared to better renewables.
- The model selects large hydro instead of fossil in BC.

New Resources Selected by Region, Low Solar Cost Case (MW)

	Conventional	Wind	Geothermal	Hydro	Biomass	Solar Thermal	Total
AB	1,736	793	-	-	-	-	2,529
AZ	2,694	20	-	-	33	5,331	8,078
BC	-	1,582	185	1,256	50	-	3,073
CA	984	1,230	1,938	86	300	6,395	10,932
CO	777	1,253	-	-	59	2,349	4,438
MT	255	190	-	25	5	-	475
NM	480	410	-	-	18	727	1,635
NV	215	183	219	-	15	35	667
NW	1,380	5,023	140	118	845	-	7,506
UT	1,982	640	-	156	21	153	2,952
WY	531	102	-	12	-	-	645
WECC	11,033	11,424	2,482	1,653	1,347	14,990	42,930

- Solar displaces wind as predominant renewable resources throughout the Southwest

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Notes

- This chart shows the resources selected by the model for the Low Solar Thermal Case.
- “Conventional” resources are the same as in the Base Case.
- The model selects mostly solar thermal to meet RPS targets in the Southwest.
- New wind is reduced from 21,000 MW in the Base Case to 11,000 MW.

Average Cost of New Resources Selected by Region, All Cases

- AZ-SNV cost driven by high reliance on solar thermal
- Low solar costs reduce compliance costs in AZ-SNV, CO
- Similar cost scale for High RPS and CO2 reduction for most regions

	Base Case	High RPS Case	CO2 Reduction Case	Low Solar Cost Case
AB	\$ 80.43	\$ 124.56	\$ 130.37	\$ 80.43
AZ	\$ 105.46	\$ 126.94	\$ 132.52	\$ 95.27
BC	\$ 87.24	\$ 103.07	\$ 81.13	\$ 87.24
CA	\$ 114.16	\$ 131.80	\$ 136.21	\$ 113.01
CO	\$ 102.92	\$ 125.24	\$ 121.42	\$ 95.82
MT	\$ 80.36	\$ 88.98	\$ 97.25	\$ 80.36
NM	\$ 88.30	\$ 92.53	\$ 104.33	\$ 90.10
NV	\$ 100.09	\$ 103.31	\$ 113.76	\$ 100.35
NW	\$ 108.28	\$ 128.29	\$ 128.48	\$ 108.28
UT	\$ 81.68	\$ 127.62	\$ 126.85	\$ 81.81
WY	\$ 71.41	\$ 83.83	\$ 84.83	\$ 71.41

Note: Average cost includes firming and interconnection costs, but not wind integration

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Notes

- This slide shows the average cost of all the new resources selected for each region, under each of the four cases.
- Resource costs include interconnection, integration and firming costs in addition to fixed and variable costs of the resource.
- Red shaded areas indicate average new resource costs higher than \$120/MWh



Summary of Lessons Learned

- Southwest region faces high marginal costs for renewables
 - Arizona-Southern Nevada and Colorado have a limited supply of wind and geothermal
- Coastal states may also benefit from looking outside their region
 - California and the Northwest have lots of renewables, but also high demand
- All the major consuming regions might benefit by investigating lower-cost resources in other regions

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Notes

- Some regions will have a difficult time meeting policy targets without a large rate impact.
- Arizona-Southern Nevada and Colorado have a limited supply of low-cost wind and other renewable resources.
- California and the Northwest have rich endowments, but also high demand for renewables due to large loads and aggressive RPS targets.
- All of the major consuming regions would benefit by looking outside of their immediate areas toward low-cost resources that are available in other regions.

Energy Value of New Transmission



What Drives the Value of New Transmission?

- Differences in supply curves by region
 - Lower land and labor costs in interior West
 - Superior resource endowments in supply regions
- Differences in demand by region
 - California and the Northwest use up their endowments to meet RPS targets
 - Wyoming and Montana do not require much energy to meet local load growth or RPS targets
- Conventional resources do *not* drive expansion
 - Biggest spread is WY coal (\$70/MWh) to CA gas (\$92/MWh)

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Notes

- The value of the transmission is driven both by supply and demand considerations.
- Some regions like Montana and Wyoming have superior resource endowments, low cost of doing business, and little competition from local loads.
- California and the Northwest have good resource endowments but very high local demand and higher cost of doing business.
- Arizona-Southern Nevada and Colorado have both poor resource endowments and relatively high demand.
- Conventional cost spreads are not high enough to drive new transmission, even without considering the cost of CO2 emissions abatement.

New Transmission Assumptions

- New line allows unidirectional energy transfers from one region to another
- Line is operated at 60% annual capacity factor
- Intermittent renewables (wind and solar) limited to 67% of energy flows
- Line is utilized only if the all-in cost of resources in the producing region is less than in the consuming region



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Notes

- This slide lists some of the assumptions that we used in modeling new transmission capacity.
- When modeling transmission, we allow unidirectional energy transfers from the producing region to the consuming region.
- This allows resources not selected in the producing region to meet demand in the consuming region.
- We set a line size in MW, and allow energy transfers at 60% usage factor. For example, a 1500 MW line would allow $1500 * 8760 * 60\% \div 1000 = 7,884$ GWh of energy transfers.
- Intermittent renewables are limited to 67% of energy flows. E.g., for a 1500 MW line, $7,884 \text{ GWh} * 67\% = 5,256$ GWh of wind can flow. At 40% capacity factor, only 1500 MW of wind could be added under a 1500 MW line. This prevents the model from forcing too much wind to be shaped in the producing region.
- The remaining 50% of the potential energy transfers can be non-intermittent resources (hydro, biomass, geothermal, or conventional), if available. Any benefits associated with these transfers are small in our model due to low conventional cost spreads.
- No benefits accrue if the all-in cost of new resources in the producing region is higher than in the consuming region.
- The model assumes no benefits from more efficient dispatch of existing resources.

Transmission Cost Estimates

- Estimated line costs based on simple DC configuration, including adder for recent escalation in materials cost
- Financed over 40 years at 9.37% WACC

Construction Cost Estimates for DC Lines (\$ billions)

1500 MW

		Consuming region			
		AZ	CA	CO	NW
Producing region	MT	\$2.00	\$1.88	\$1.40	\$1.07
	NM	\$0.96	\$1.48	\$0.97	\$2.04
	NV	\$1.35	\$1.11	\$1.37	\$1.07
	WY	\$1.49	\$1.79	\$0.53	\$1.66

3000 MW

		Consuming region			
		AZ	CA	CO	NW
Producing region	MT	\$2.85	\$2.68	\$2.10	\$1.68
	NM	\$1.54	\$2.18	\$1.55	\$2.90
	NV	\$2.02	\$1.71	\$2.05	\$1.67
	WY	\$2.21	\$2.56	\$0.76	\$2.42

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Annual Cost Estimates for DC Lines (\$ millions)

1500 MW

		Consuming region			
		AZ	CA	CO	NW
Producing region	MT	\$274	\$257	\$192	\$147
	NM	\$132	\$203	\$133	\$280
	NV	\$184	\$152	\$188	\$147
	WY	\$204	\$245	\$72	\$227

3000 MW

		Consuming region			
		AZ	CA	CO	NW
Producing region	MT	\$391	\$367	\$288	\$230
	NM	\$212	\$298	\$212	\$398
	NV	\$277	\$234	\$281	\$229
	WY	\$302	\$351	\$105	\$331

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- There is a substantial degree of uncertainty in an analysis of this nature about how the transmission would be configured, and hence, how much it would cost. We assumed DC lines except in the case of WY-CO, because DC lines are less costly on a \$/MW-mile basis.
- AC lines are more realistic for shorter segments, and provide additional benefits such as congestion relief, better reliability, the possibility of including multiple pickup and dropoff points, etc. Our analysis has considered neither the additional costs nor the additional benefits of AC lines relative to DC lines.
- Our analysis should not be interpreted as favoring DC over AC lines. Rather, the DC line configuration matches up better with our generation analysis, which compares resource costs in the upstream region with resource costs in the downstream region and does not consider the effect on any region in between.
- That is, we believe that the selection of DC lines results in a better indicator of the overall economic value of new transmission between the regions based on differences in energy costs. The ultimate choice of AC or DC configuration depends on a multitude of factors, of which the economics of new renewable resources is only one.
- Transmission line costs are loaded with taxes and investor returns and translated into annualized revenue requirements using a capital cost recovery factor of 13.7% (that is, the transmission provider recovers 13.7% of the initial capital costs each year).

Benefit-Cost Ratios for 1500 MW Line Under Base Case RPS

- Add up state-by-state RPS requirements:
 - 15% of energy in the WECC renewable by 2020
 - 14,000 aMW of new resources WECC-wide
- WY-CO most cost-effective path
- Several other interesting possibilities

Benefit-Cost Ratio for 1500 MW Line, Base Case RPS

		Consuming Region			
		AZ	CA	CO	NW
Producing Region	MT	0.7	0.9	0.7	1.2
	NM	1.1	0.9	0.7	0.4
	NV	0.3	0.6	0.2	0.3
	WY	1.3	1.3	3.2	1.1

Key: >1.0 0.7-1.0 <0.7

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Table entries represent benefit-cost ratios: the annual energy benefit, net of losses and adjusted for changes in wind integration costs, divided by the net annualized cost of the transmission line.

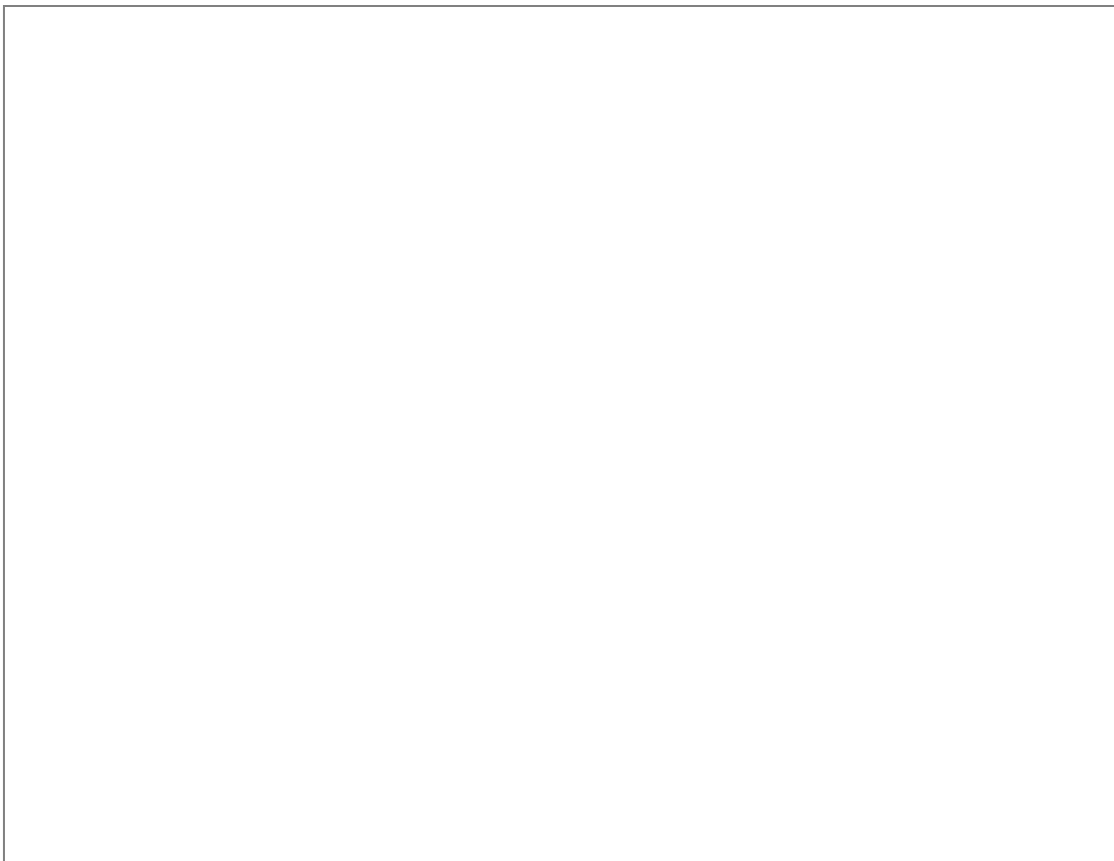
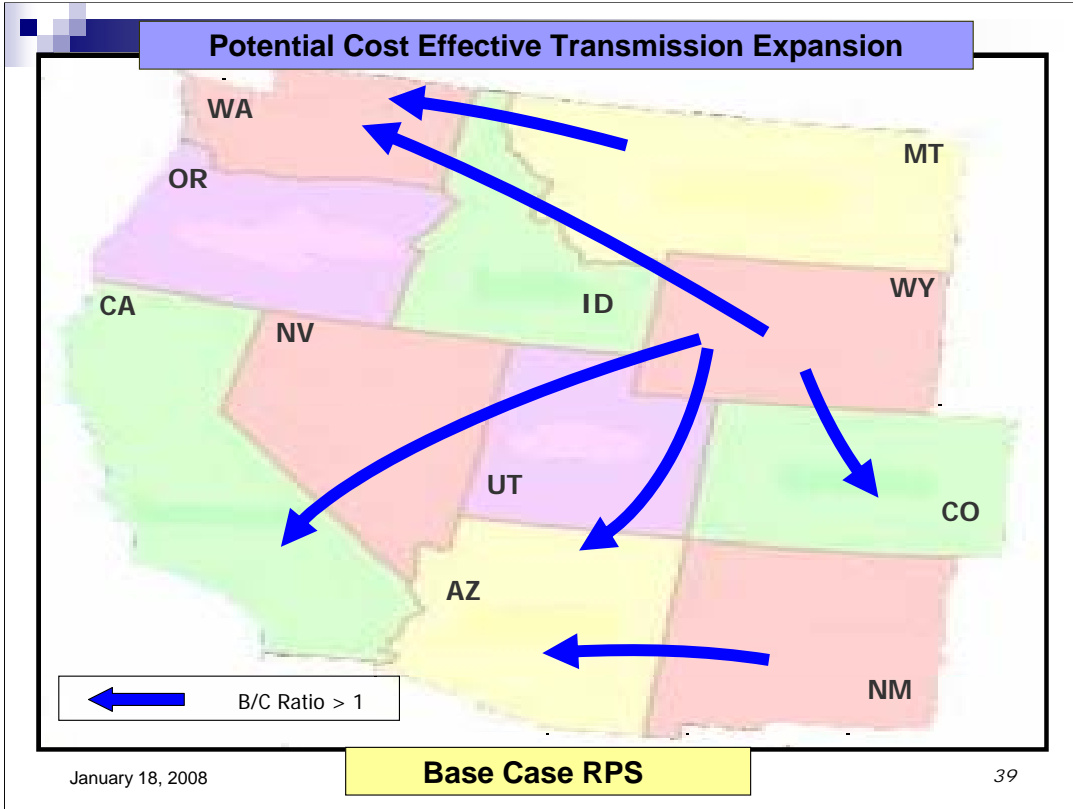
Color code

Dark Blue: B-C ratio > 1.0

Light Blue: 0.7 < B-C ratio < 1.0

White: B-C ratio < 0.7

- WY is a promising seller due to tremendous wind resource. MT and NM also have good wind resources, but WY's is superior. Solar thermal is the marginal resource in AZ and CO, while high-cost wind is marginal in CA and the NW. All regions might benefit from looking at transmission to remote renewables.
- The WY-CO line is the most cost-effective because it is short and because CO does not have a large endowment of low-cost renewables. Solar thermal is the marginal resource in CO under the Base Case RPS.
- Benefit-cost ratio of lines originating in BC not displayed due to concerns about the lack of comparable data on renewable energy supply.



Benefit-Cost Ratios for 1500 MW Line Under High RPS

- High RPS Case, 30% RPS in CA, 25% elsewhere
 - 27% of energy in the WECC renewable by 2020
 - 28,000 aMW of new resources WECC-wide
- Lines into CA and NW gain value
- Lines into CO lose value due to wind integration

Benefit-Cost Ratio for 1500 MW Line, High RPS

		Consuming Region			
		AZ	CA	CO	NW
Producing Region	MT	0.6	1.0	0.6	1.6
	NM	0.9	1.0	0.5	0.6
	NV	0.3	1.3	0.2	1.0
	WY	1.3	1.3	2.9	1.3

Key: >1.0 0.7-1.0 <0.7

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Table entries represent benefit-cost ratios: the annual energy benefit, net of losses and adjusted for changes in wind integration costs, divided by the net annualized cost of the transmission line.

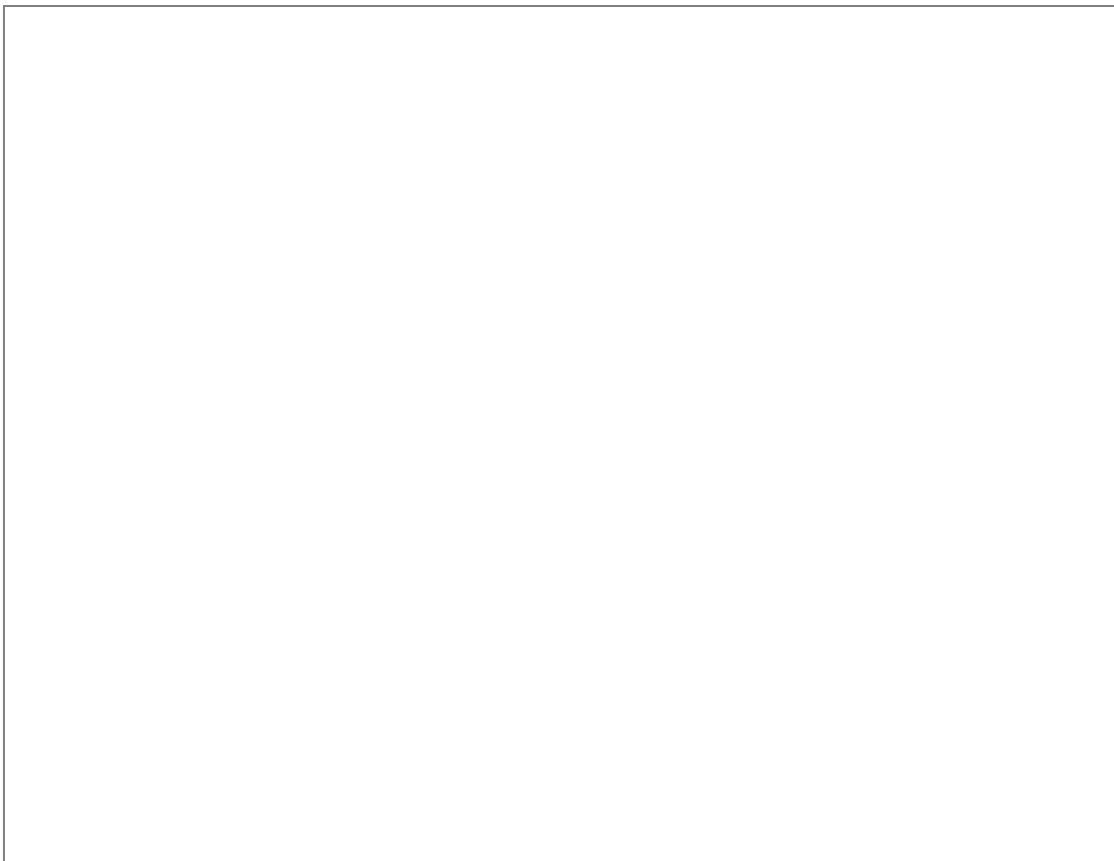
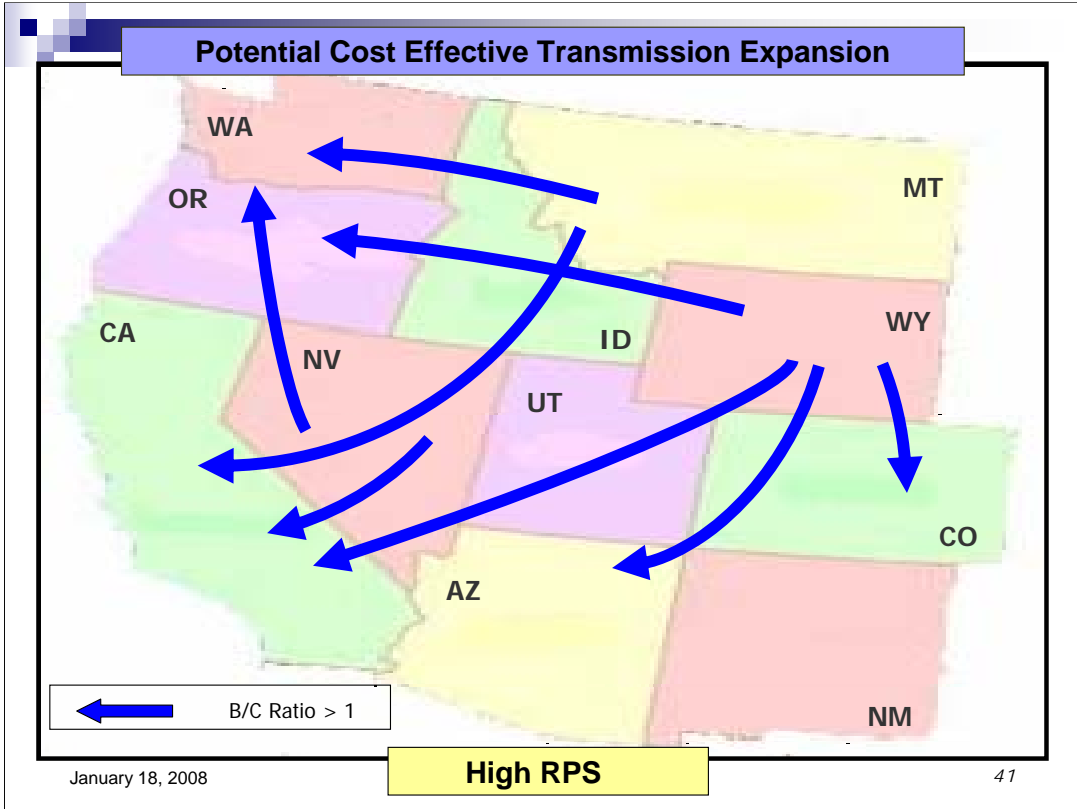
Color code

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White: B-C ratio < 0.7

- High RPS case assumes aggressive RPS targets everywhere in the WECC.
- Values are generally higher under the High RPS case, although increased wind integration costs mitigate the increased value of lines from WY and N M.
- NV becomes an interesting supplier due to a higher concentration of flat-profile geothermal power.



Benefit-Cost Ratios for 1500 MW Line Under CO2 Reduction Case

- Reduce CO2 by 30% from 2008 levels
 - 43,000 aMW of new low-carbon resources in WECC by 2020
 - Allow nuclear and IGCC with carbon capture as low-carbon resources
- WY still big supplier if IGCC pans out
- NW and CA still big buyers

Benefit-Cost Ratio for 3000 MW Line, CO2 Reduction Case

		Consuming Region			
		AZ	CA	CO	NW
Producing Region	MT	0.3	0.9	(0.1)	1.5
	NM	0.5	1.2	0.0	0.8
	NV	0.0	0.9	-	0.8
	WY	1.3	1.7	2.5	1.7

Key: >1.0 0.7-1.0 <0.7

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Table entries represent benefit-cost ratios: the annual energy benefit, net of losses and adjusted for changes in wind integration costs, divided by the net annualized cost of the transmission line.

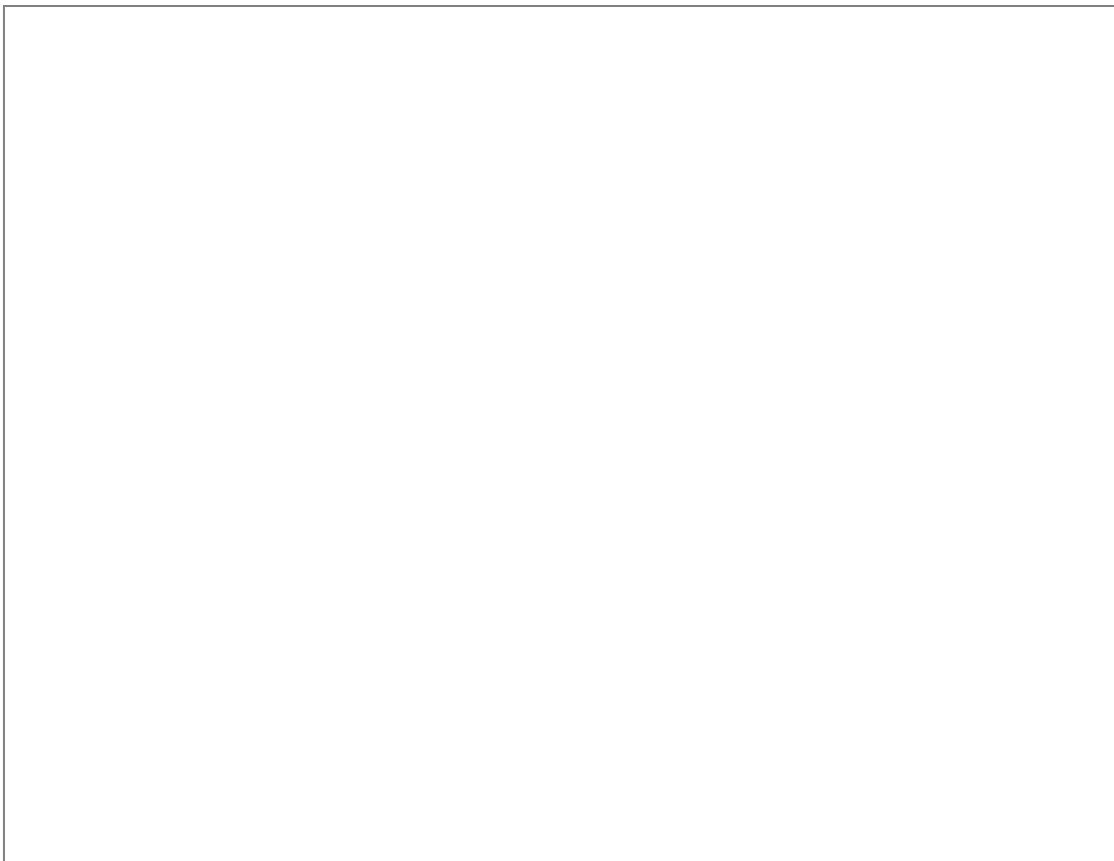
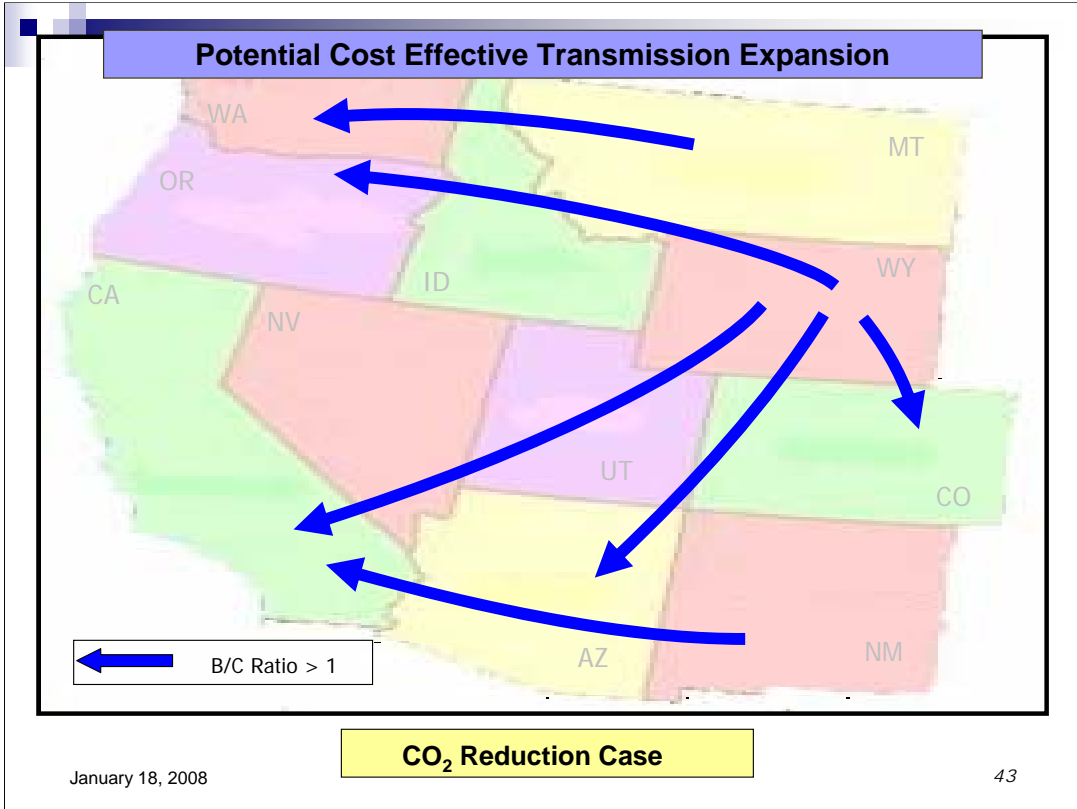
Color code

Dark Blue: B-C ratio > 1.0

Light Blue: 0.7 < B-C ratio < 1.0

White: B-C ratio < 0.7

- CO2 reduction case calculates an RPS-like target that reduces emissions by 30% from 2008 levels in each region.
- Increased resource target generally results in higher values, although downstream regions have more tools (e.g., nuclear) with which to meet targets. WY is still a big supplier due to low capital costs and low-cost coal supplies.
- A more accurate assignment of responsibility for CO2 emissions reductions may result in somewhat higher transmission values by increasing demand for low-CO2 resources in the Coastal states and reducing it in the Mountain states relative to our model.



Benefit-Cost Ratios for 1500 MW Line Under Low Solar Cost Case

- Reduce cost of solar thermal by 20%
- Base case RPS
- Model selects 10,500 MW of solar thermal in AZ, CA and CO
- Lines into CA, CO and AZ lose value
- NW values unaffected

Benefit-Cost Ratio for 3000 MW Line, Low Solar Cost Case

		Consuming Region			
		AZ	CA	CO	NW
Producing Region	MT	0.3	0.7	0.1	1.2
	NM	0.4	0.8	0.3	0.5
	NV	-	0.4	(0.1)	0.4
	WY	0.9	1.1	1.7	1.1

Key:	>1.0	0.7-1.0	<0.7
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Table entries represent benefit-cost ratios: the annual energy benefit, net of losses and adjusted for changes in wind integration costs, divided by the net annualized cost of the transmission line.

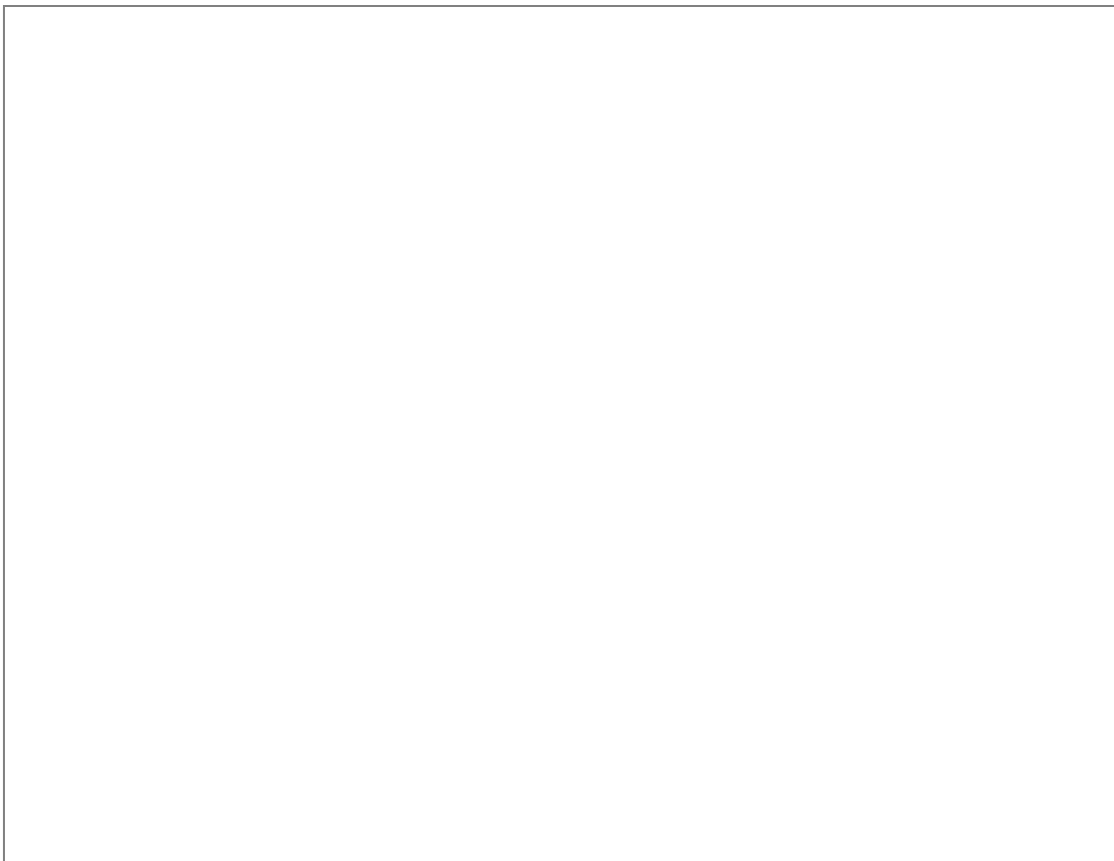
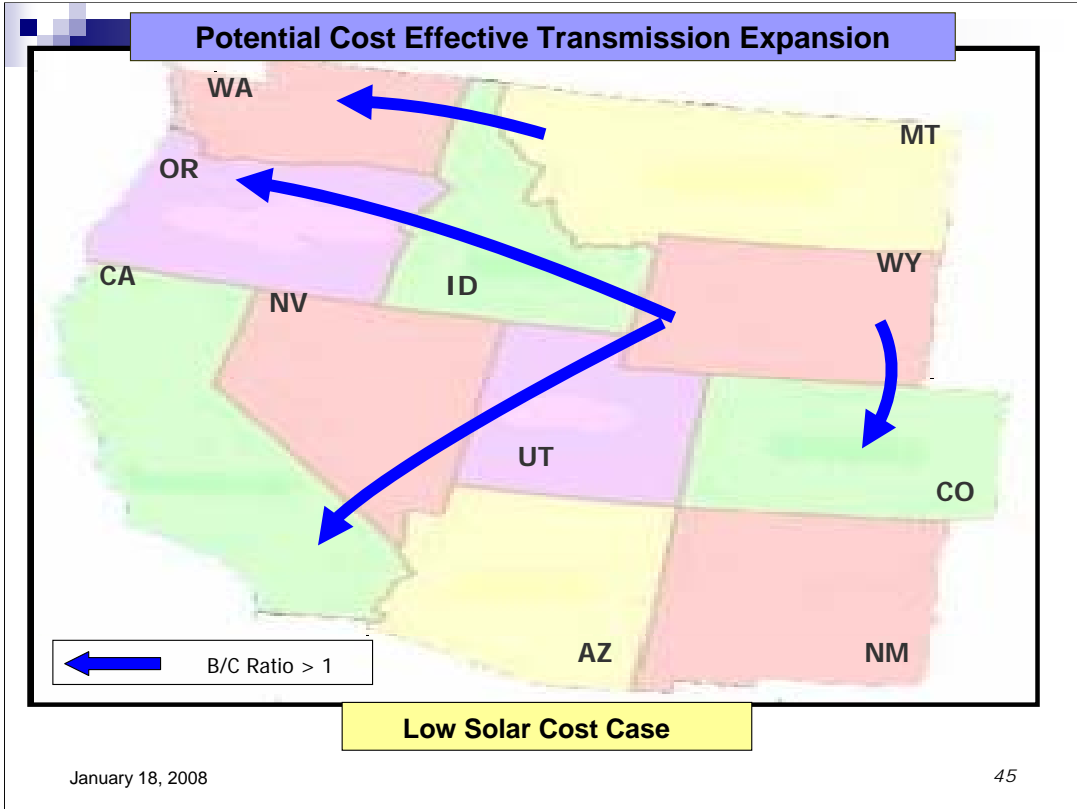
Color code

Dark Blue: B-C ratio > 1.0

Light Blue: 0.7 < B-C ratio < 1.0

White: B-C ratio < 0.7

- Solar thermal costs are a big unknown with a high potential to change which transmission investments are economic.
- Solar thermal is the marginal resource under the Base Case RPS for AZ, CA and CO.
- This case reduces the value of transmission segments into the Southwest.
- However, resource is still relatively high-cost, so transmission into CA still appears cost-effective.
- Cases with even lower solar thermal costs or higher federal tax credits result in lower transmission values in the Southwest. In some cases the Southwest could become an exporter of renewable resources.





Value of Tradable Renewable Energy Credits

Modeling Technique

- “Before” case: Base Case RPS requirements
 - Add *local resources* on a MWh-for-MWh basis to meet load growth and RPS targets within each WECC region
- “After” case: Select resources from a WECC-wide supply curve subject to two restrictions:
 - Maximum wind penetration: 30% of nameplate in each region
 - Total resources added in each region equal to load growth
- Value of REC trading is difference in WECC-wide energy procurement cost between the two cases

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- The group asked E3 to assess the value of tradable RECs.
- The analysis uses the Base Case RPS requirement using local resources only as the Base Case
- Resources are selected from a WECC-wide supply curve for the change case.
- When a given region’s resources are tapped out by the two restrictions, the model selects from the next-highest cost region.
- The value of RECs is predicated on differences in regional resource costs. It doesn’t matter which resource type is lower cost.

Results of Tradable REC Analysis

Renewables subtracted:

- California wind: 3,581 MW
- Colorado solar: 1,238 MW
- Northwest biomass: 757 MW
- California other: 214 MW

Renewables added:

- Wind (all regions): 4,291 MW
- Solar (NM, AZ): 1,364 MW
- Hydro (BC, UT, WY): 278 MW
- Biomass (all regions): 231 MW
- Geothermal (UT): 200 MW

Conventional:

- Subtract 3,307 MW in AB, AZ, BC, MT, NM, NV, UT, WY
- Add 2,931 MW in CA, CO and NW

Total annual value of REC trading in 2020: \$351 million

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- The slide lists the changes in resources added from the Base Case to the Tradable REC case.
- The Tradable REC case results in the same GWh of renewables and conventional resources constructed in the WECC as the Base Case, but the locations are different.
- For example, the Tradable REC case transfers 3800 MW of renewable construction from California to the rest of the WECC. This requires conventional resources to be constructed to meet load growth in California.
- Nameplate MW additions may be different due to selection of different resource types, but total GWh additions are the same in both cases.
- Changing the locations of renewable and conventional resources results in cost savings that accrue to the entire WECC region. No assumption was made about how these savings would be allocated.
- The annual value of RECs is the net of the change in renewable and conventional resources.

Discussion of Tradable REC Analysis

- The REC analysis is not a “conservative” analysis
 - Assumes least-cost resource procurement across the WECC
 - Assumes no new inter-regional transmission to reduce the cost of compliance in the Base Case
- Results are not dependent on high solar thermal costs
 - Value *increases* to \$393 million under Low Solar Cost Case
- Small amount of additional value under High RPS from displacing higher-cost renewables

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- The Tradable REC analysis assumes least-cost procurement of renewable and conventional resources across the WECC.
- The value of RECs increases under both lower and higher solar thermal costs. Under lower solar thermal costs, new solar thermal in the Southwest displaces higher-cost wind elsewhere in the WECC. Under high solar thermal costs, lower-cost wind elsewhere in the WECC displaces higher-cost solar thermal in the Southwest.
- We anticipate higher value under a High RPS case because the consuming regions are relying on more and more expensive renewables.

Important Contributors

Initial Technical Review Group

- Brad Albert, APS
- Rich Bayless, CPS
- Wally Gibson, NWPCC
- Don Kondoleon, CEC
- Rich Lauckhart, Global Energy Decisions
- Jay Loock, WECC
- Mark Maher, WECC
- Yakout Mansour, CAISO
- Henry Martinez, LADWP
- Jim Shetler, SMUD
- Paul Smith, APS
- Eric Toolson, PLEXOS Solutions LLC
- Vicki Van Zandt, BPA

Follow-up Review Group

- Stephen Drake, SRP
- Karen Edson, CAISO
- Bill Esposito, SPR
- Curt Hatton, PG&E
- Vicken Kasarjian, SMUD
- Mike McClenahan, SDG&E
- Greg Miller, PNM
- Mark Minick, SCE
- Mike Niggli, SDG&E
- Lorraine Paskett, LADWP
- Jim Peterson, SRP
- Pedro Pizarro, SCE
- Pat Reiten, PacifiCorp
- Marco Rios, PG&E
- Mario Villar, SPR
- Steve Wright, BPA

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We would like to recognize these individuals for their participation in the review groups and for their invaluable contributions to this analysis. Contributions were also made by many others at these and other companies.



Contact Information

Energy and Environmental Economics, Inc. (E3)
101 Montgomery Street, Suite 1600
San Francisco, CA 94104
Phone: 415-391-5100
Fax: 415-391-6500

Ren Orans, Managing Partner (ren@ethree.com)

Arne Olson, Senior Consultant (arne@ethree.com)

Jack Moore, Senior Associate (jack@ethree.com)

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