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

Energy and Environmental Economics, Inc.

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

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.

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

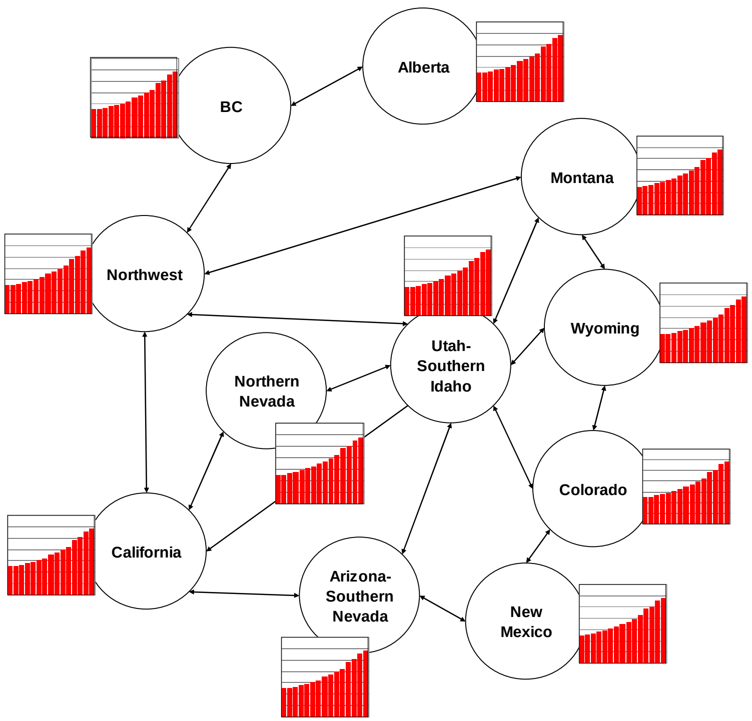
Summary of Results

- 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

Description of Analysis and Scenarios

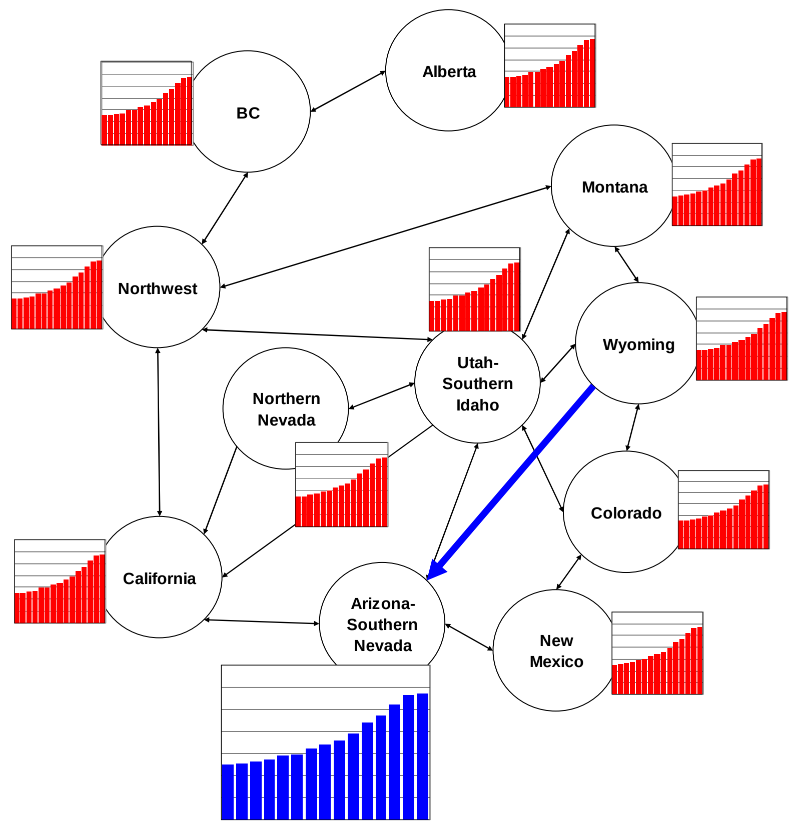
Step 1: Cost of Procuring Energy from Local Resources

- 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



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



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

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

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

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

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

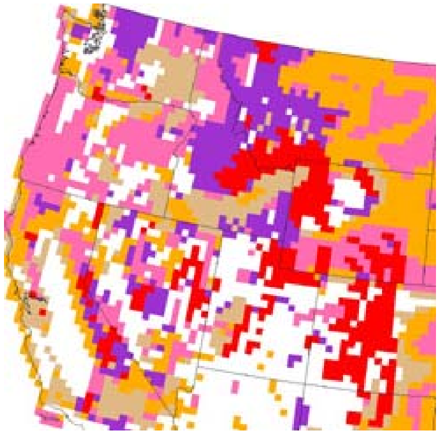
Overview of Resource Supply Curves

Renewable Energy Data Overview

- Five renewable technologies evaluated
  - Wind
  - Solar Thermal
  - Geothermal
  - Hydro
  - Biomass

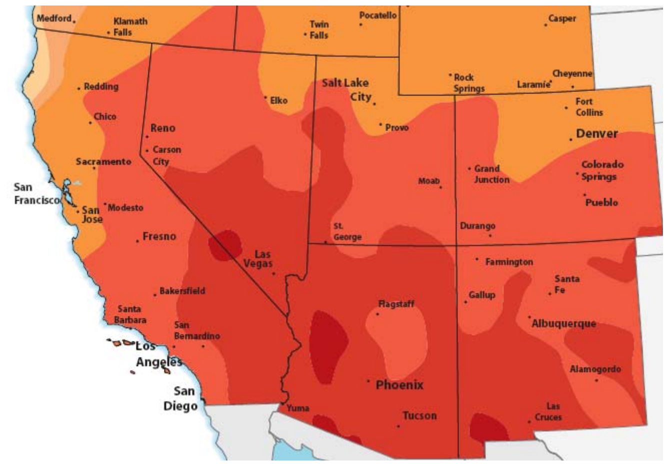
- General approach: use uniform cost assumptions and let resource availability drive regional supply curves
  - Mainstream estimates for 2007 technology
  - Regional capital cost multipliers (CA=1.20, WY=0.92)

Wind Resource & Cost Data



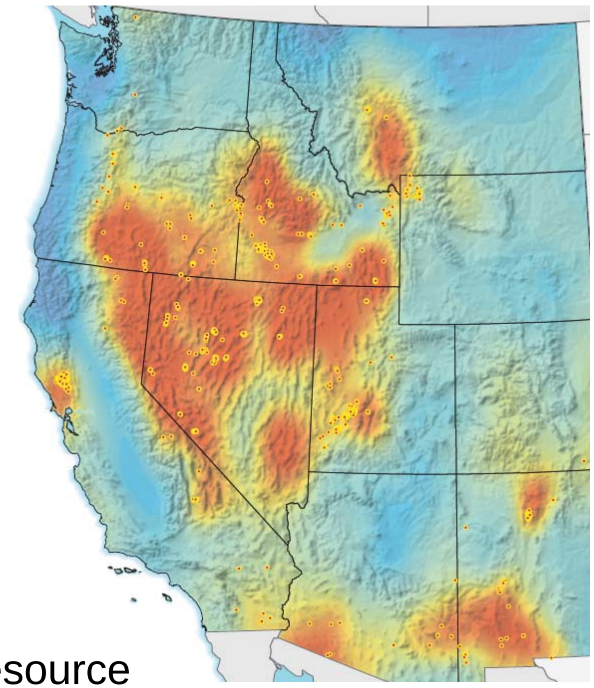
- **Resource Potential from NREL**
  - GIS input for WinDS model
  - 98 resource regions in WECC
  - Exclude cities, lakes, federal lands, >20% slopes
  - Use resource class (1-7) to calculate capacity factor
- **Generation costs (in 2008 $):**
  - Installed capital cost: $1634/kW for base plant (AWEA 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

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

Geothermal Resource & Cost Data



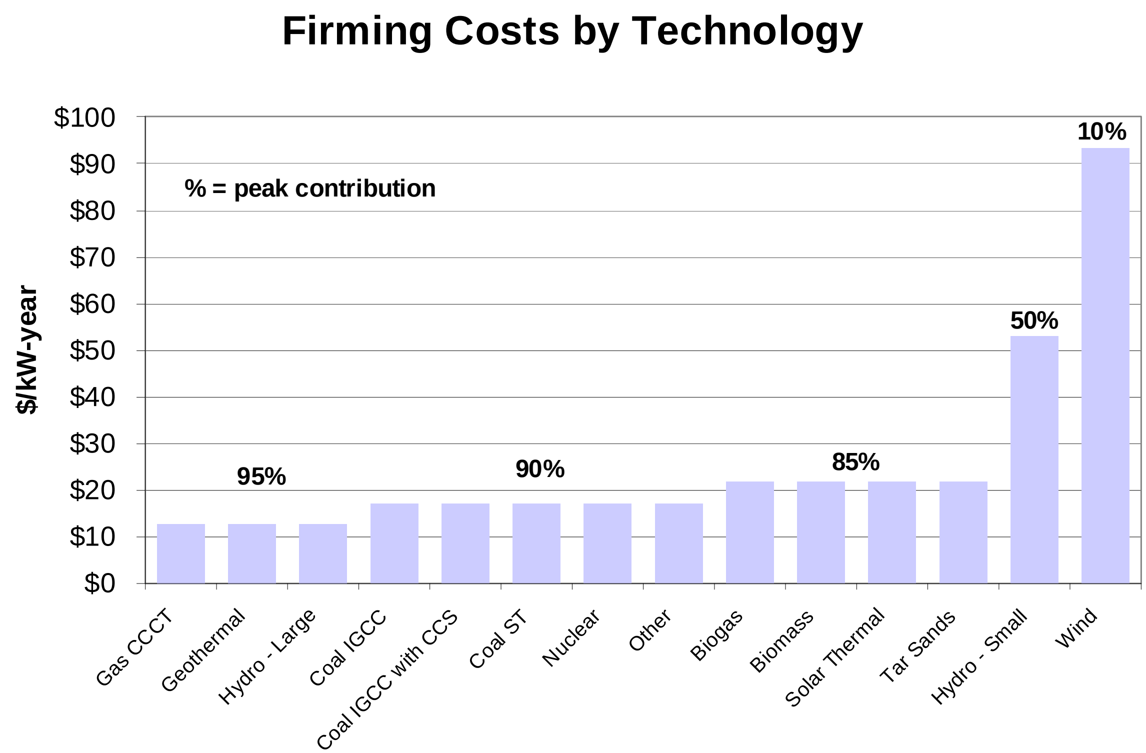
- **Resource Potential**
  - Project-specific MW and cost estimates
    - Used CEC/Geothermex (2004) for CA & NV sites
    - Used WGA CDEAC (2006) for rest of WECC
  - Results after applying EIA filters:
    - CA: 3000 MW at 21 sites
    - NV: 1300 MW at 43 sites
    - BC: 185 MW at 2 sites
    - Rest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

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

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

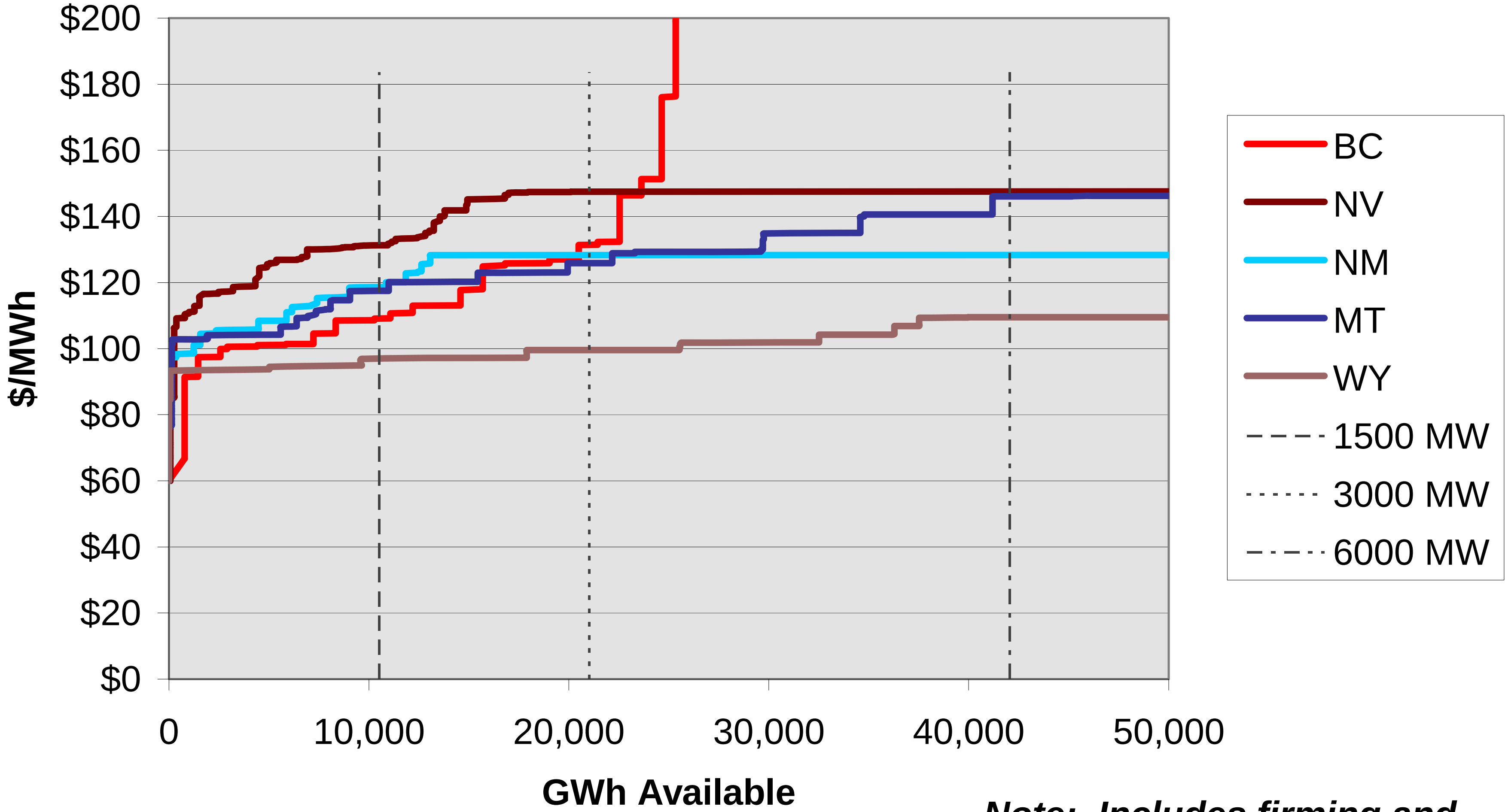


Total Renewable Resource Availability by Region (MW)

	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*

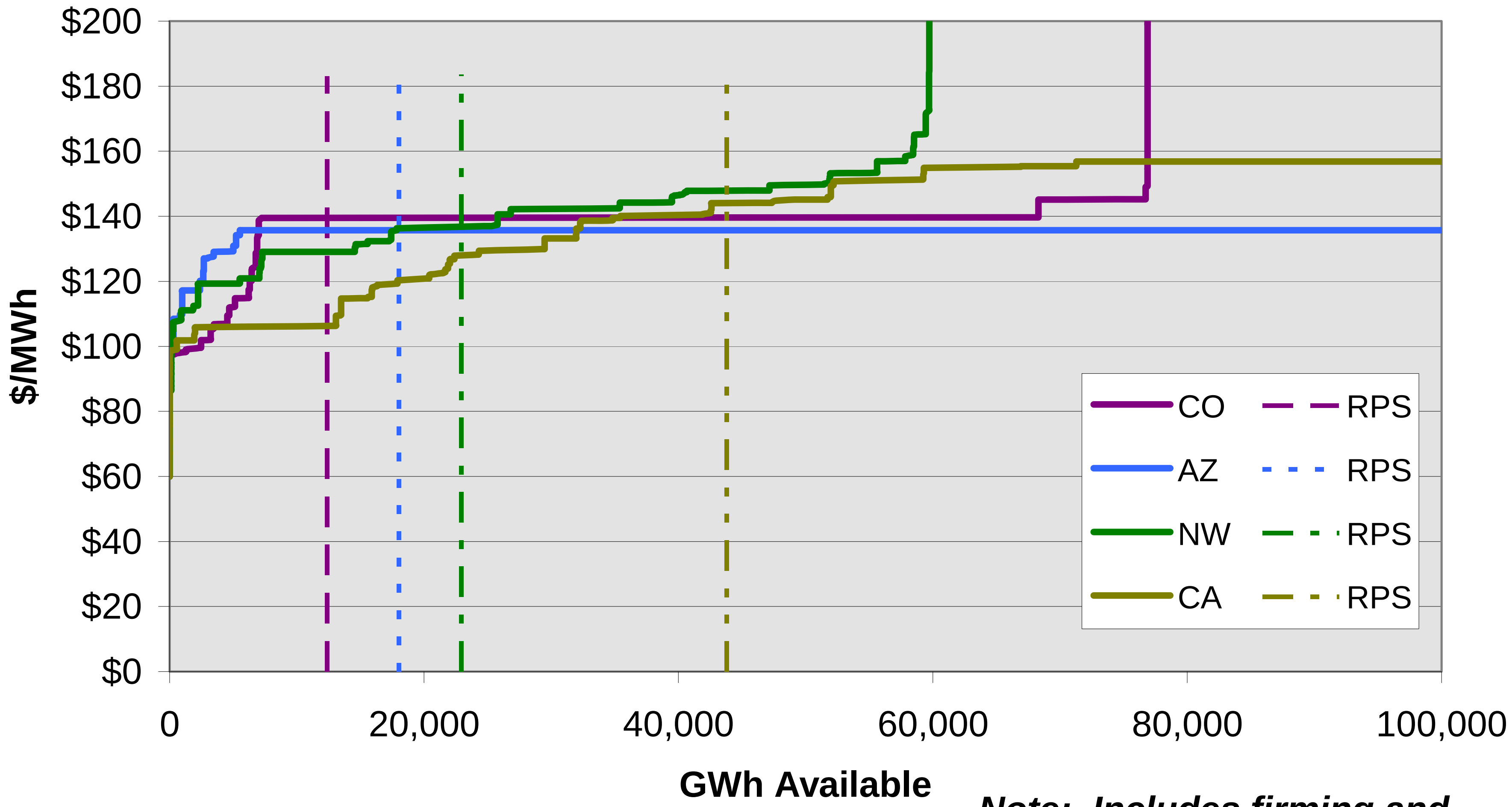
- Biomass & hydro limited and not very interesting
- Some geothermal potential in most areas
- Good wind resources scarce in the Southwest, plentiful in Rockies
- Lots of solar thermal theoretically available, but at high cost

Renewable Energy Supply Curves for Major Potential Supply Regions Compared with Potential Transmission Line Capacity



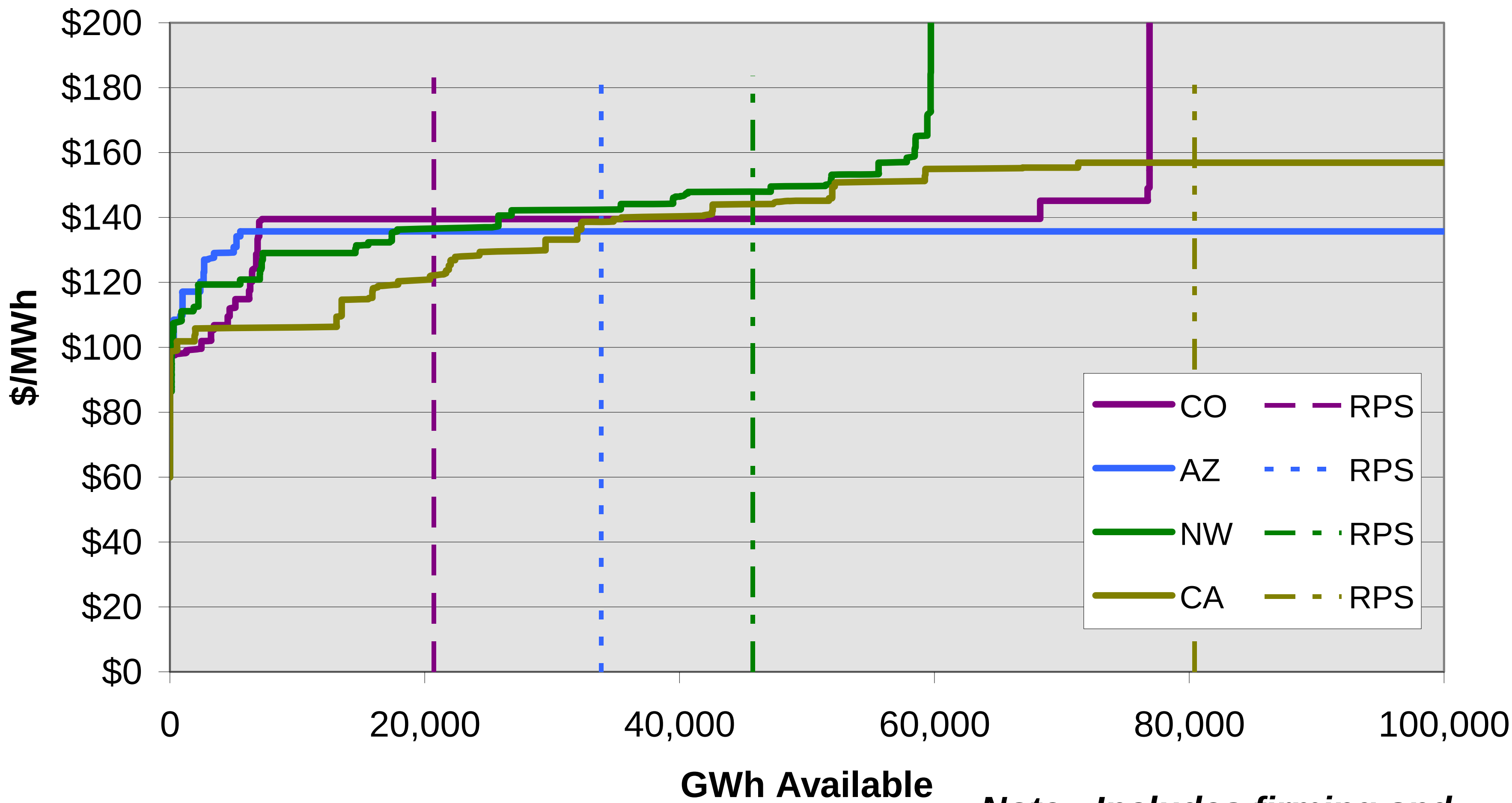
Note: Includes firming and interconnection costs

Renewable Energy Supply Curves for Major Consuming Regions, Compared with Base Case RPS Targets



Note: Includes firming and interconnection costs

Renewable Energy Supply Curves for Major Consuming Regions, Compared with High Case RPS Targets



Note: Includes firming and interconnection costs

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

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

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

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

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

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

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

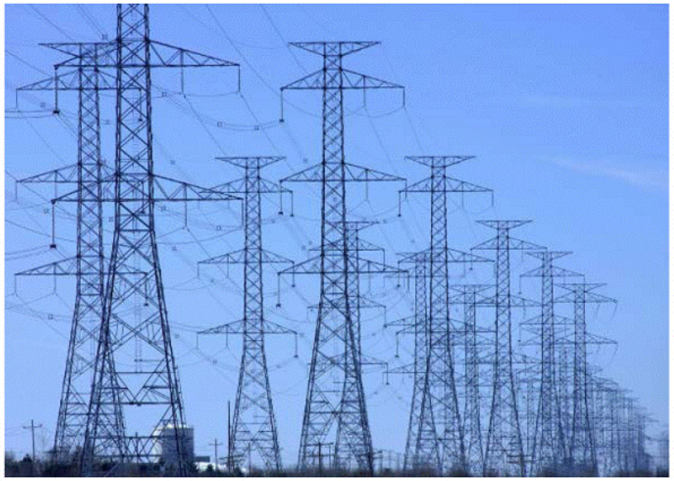
Energy Value of New Transmission

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)

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



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

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

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

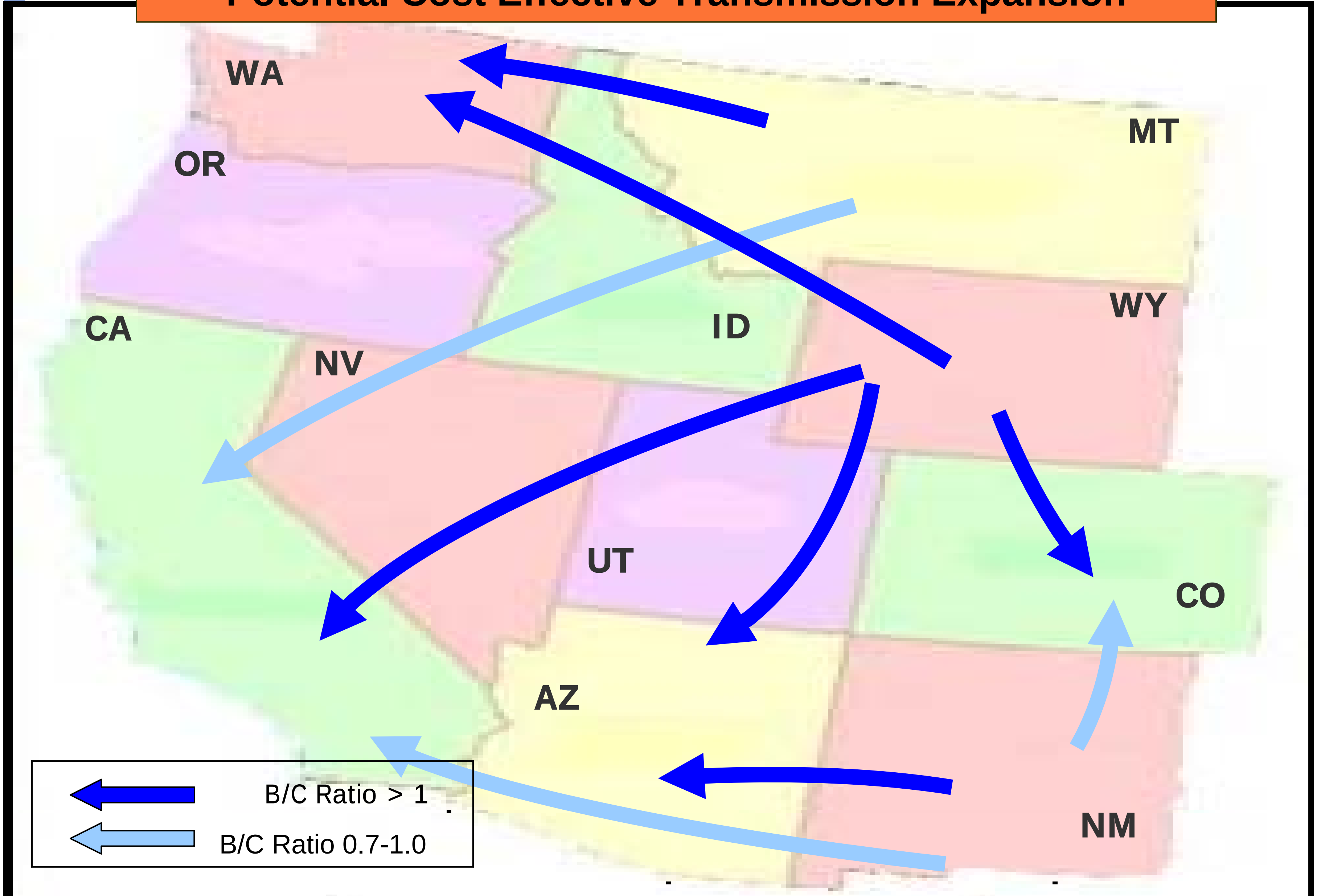
- Add up state-by-state RPS requirements:
  - 15% of energy in the WECC renewable by 2020
  - 14,000 aMW of new resources WECC-wide
- WY-CO most cost-effective path
- Several other interesting possibilities

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

Potential Cost Effective Transmission Expansion



Base Case RPS

Benefit-Cost Ratios for 1500 MW Line Under High RPS

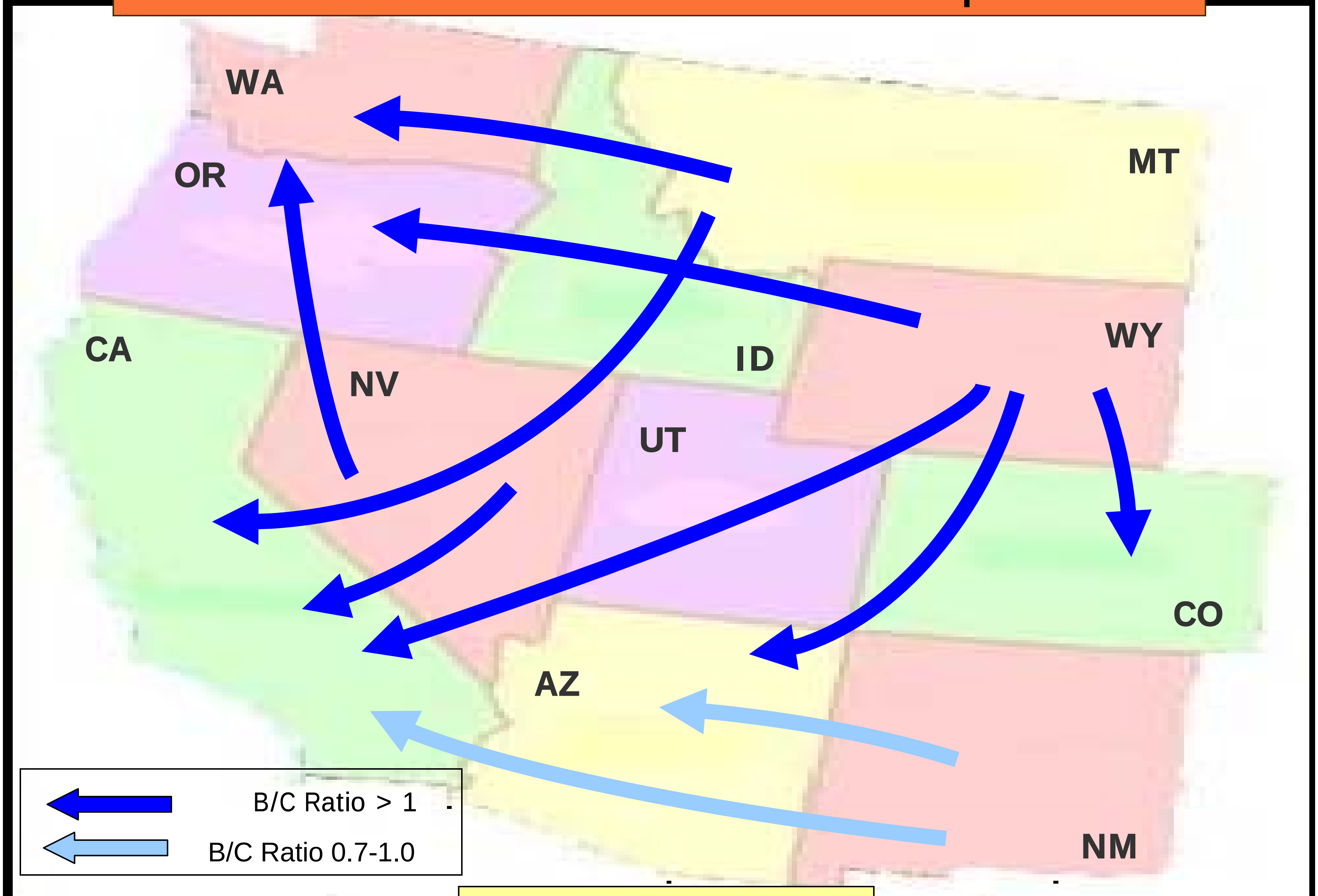
- High RPS Case, 30% RPS in CA, 25% elsewhere
  - 27% of energy in the WECC renewable by 2020
  - 28,000 aMW of new resources WECC-wide
- Lines into CA and NW gain value
- Lines into CO lose value due to wind integration

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

Potential Cost Effective Transmission Expansion



High RPS

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

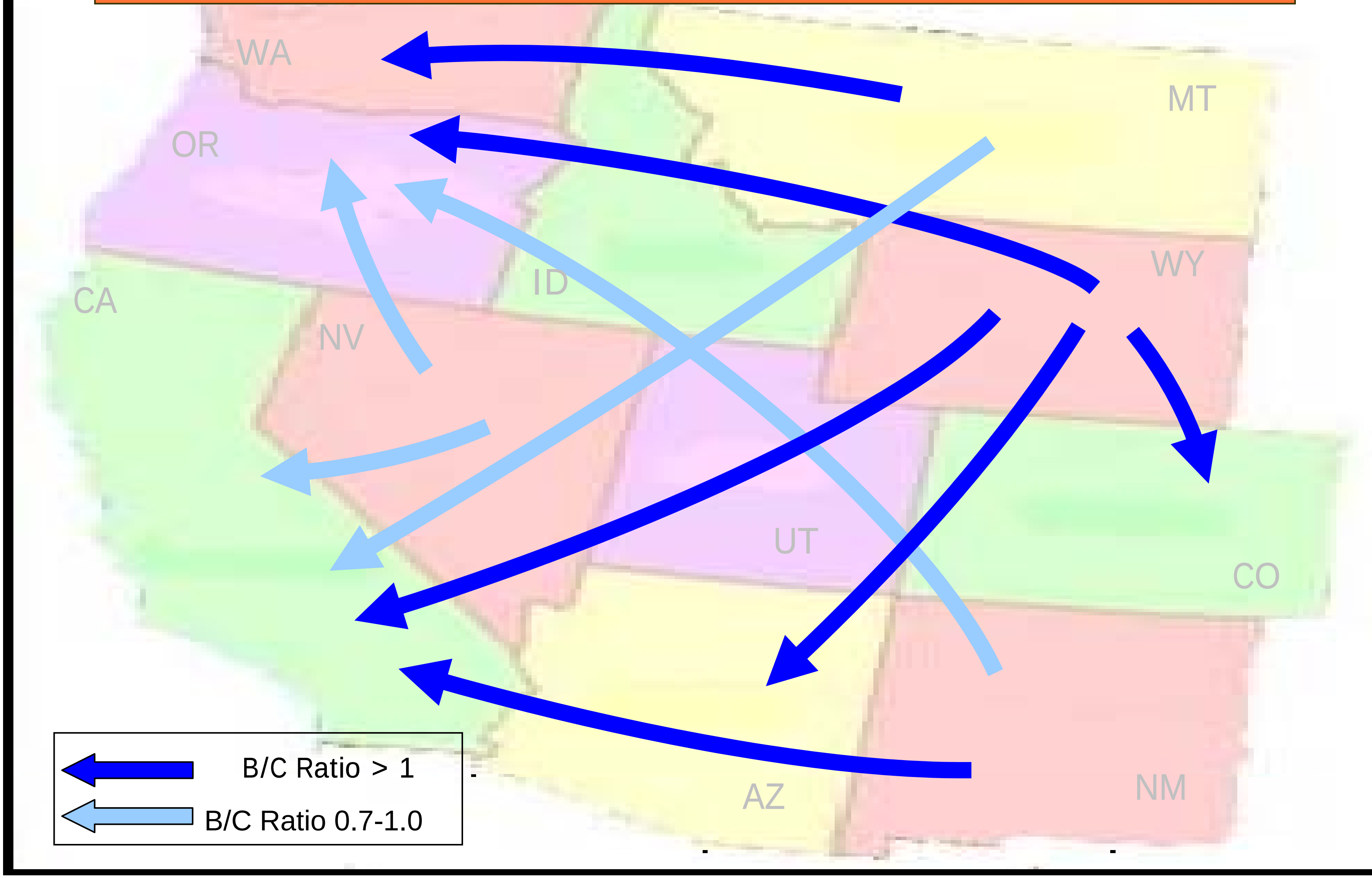
- Reduce CO_2 by 30% from 2008 levels
  - 43,000 aMW of new low-carbon resources in WECC by 2020
  - Allow nuclear and IGCC with carbon capture as low-carbon resources
- WY still big supplier if IGCC pans out
- NW and CA still big buyers

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

Potential Cost Effective Transmission Expansion



CO_2 Reduction Case

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

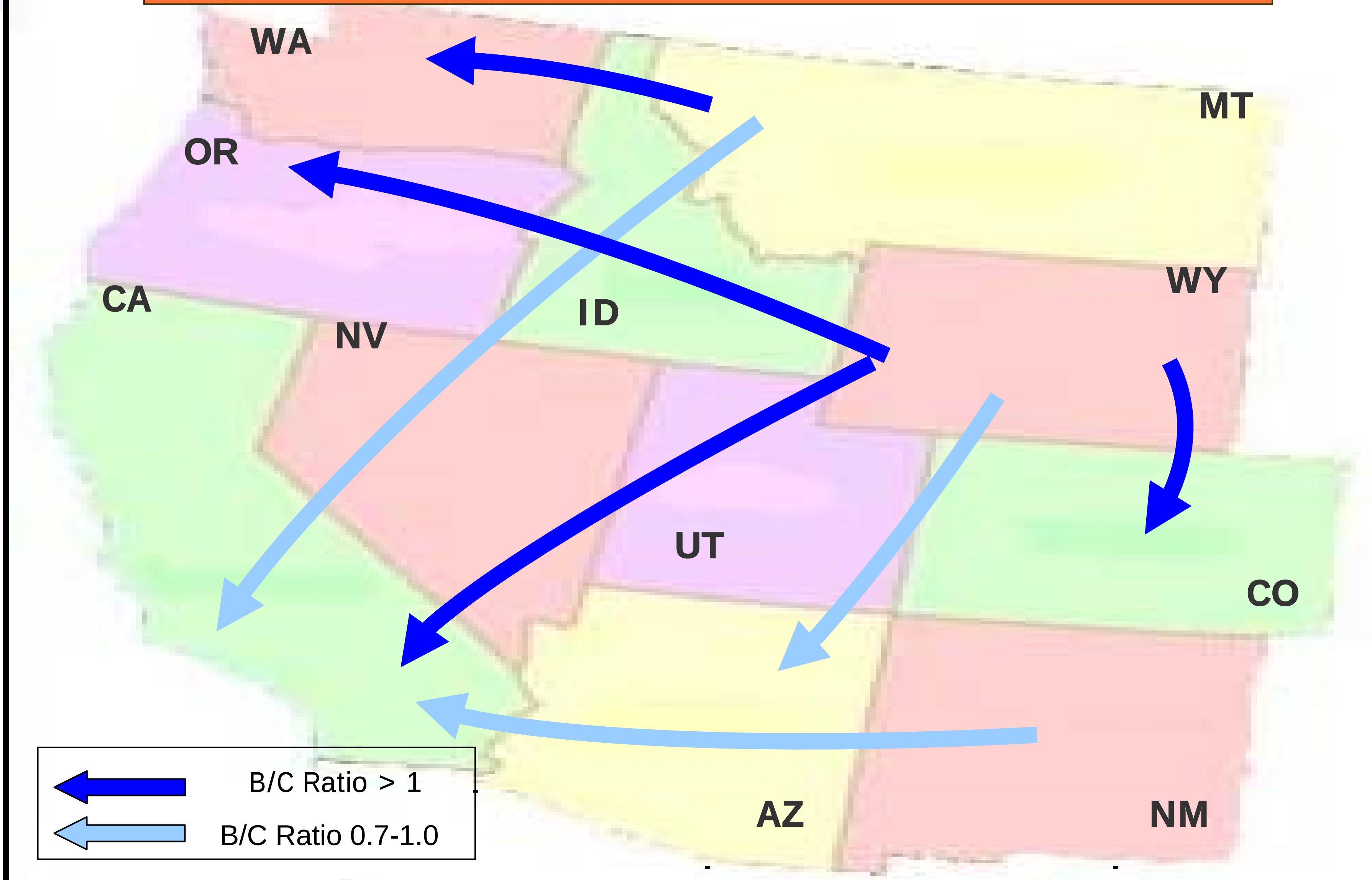
- Reduce cost of solar thermal by 20%
- Base case RPS
- Model selects 10,500 MW of solar thermal in AZ, CA and CO
- Lines into CA, CO and AZ lose value
- NW values unaffected

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

Potential Cost Effective Transmission Expansion



Low Solar Cost Case

Value of Tradable Renewable Energy Credits

Energy and Environmental Economics, Inc.

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

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

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

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

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)