

Western Renewable Energy Zones



Composite photo created by NREL

**Meeting Transmission
Challenges in the Rocky
Mountain Region**

Jeff Hein

June 21, 2011

NREL/PR-5500-52000

Presentation Outline

- WREZ Vision;
- Chronology;
- WREZ Initiative Overview;
- Generation and Transmission Model;
- Lessons Learned;
- Future Activities.

WREZ Vision

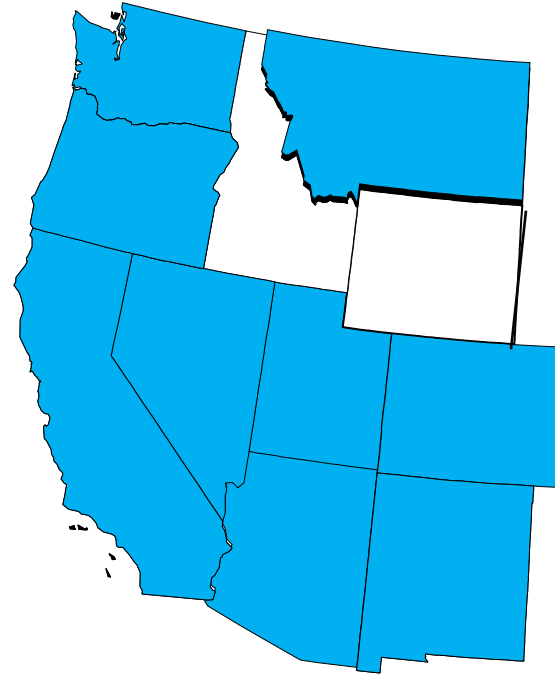
- Western Governors' Association and U.S. Department of Energy initiated effort to develop renewable energy resources and reduce GHG emissions.
- Develop a high level “screening tool” to identify potential projects that allows industry stakeholders to analyze and compare economics of multiple projects.
- Find the high quality, **developable** renewable resource zones (based on NREL data).
- Assume incremental transmission expansion to bring generation to load.
- Identify the areas where there are impediments.

WREZ: Why was it developed?

- **U. S. Utilities Must Install More Renewable Energy Generation**

Nine western states have adopted targets for the percent of all electricity generation that must come from renewable energy:

- | | | |
|----|------------|-------------|
| 1. | Arizona | 15% by 2025 |
| 2. | California | 33% by 2020 |
| 3. | Colorado | 30% by 2020 |
| 4. | Montana | 15% by 2015 |
| 5. | Nevada | 20% by 2015 |
| 6. | New Mexico | 20% by 2020 |
| 7. | Oregon | 25% by 2025 |
| 8. | Utah | 20% by 2025 |
| 9. | Washington | 15% by 2020 |



- **Western states work together to develop most economical resources**

**Note: British Columbia is seeking renewables for all new generation.*

WREZ Chronology of Events

- 2005-2006 Western Governors' Association Clean and Diversified Energy Initiative;
- 2007 - WREZ Concept Emerges (based largely on TX Competitive Renewable Energy Zones effort);
- 2008 – DOE WREZ Grant to WGA;
- 2009 – Transmission Planning FOA funds;
- 2010 – WREZ findings incorporated into interconnection-wide transmission planning (WECC).

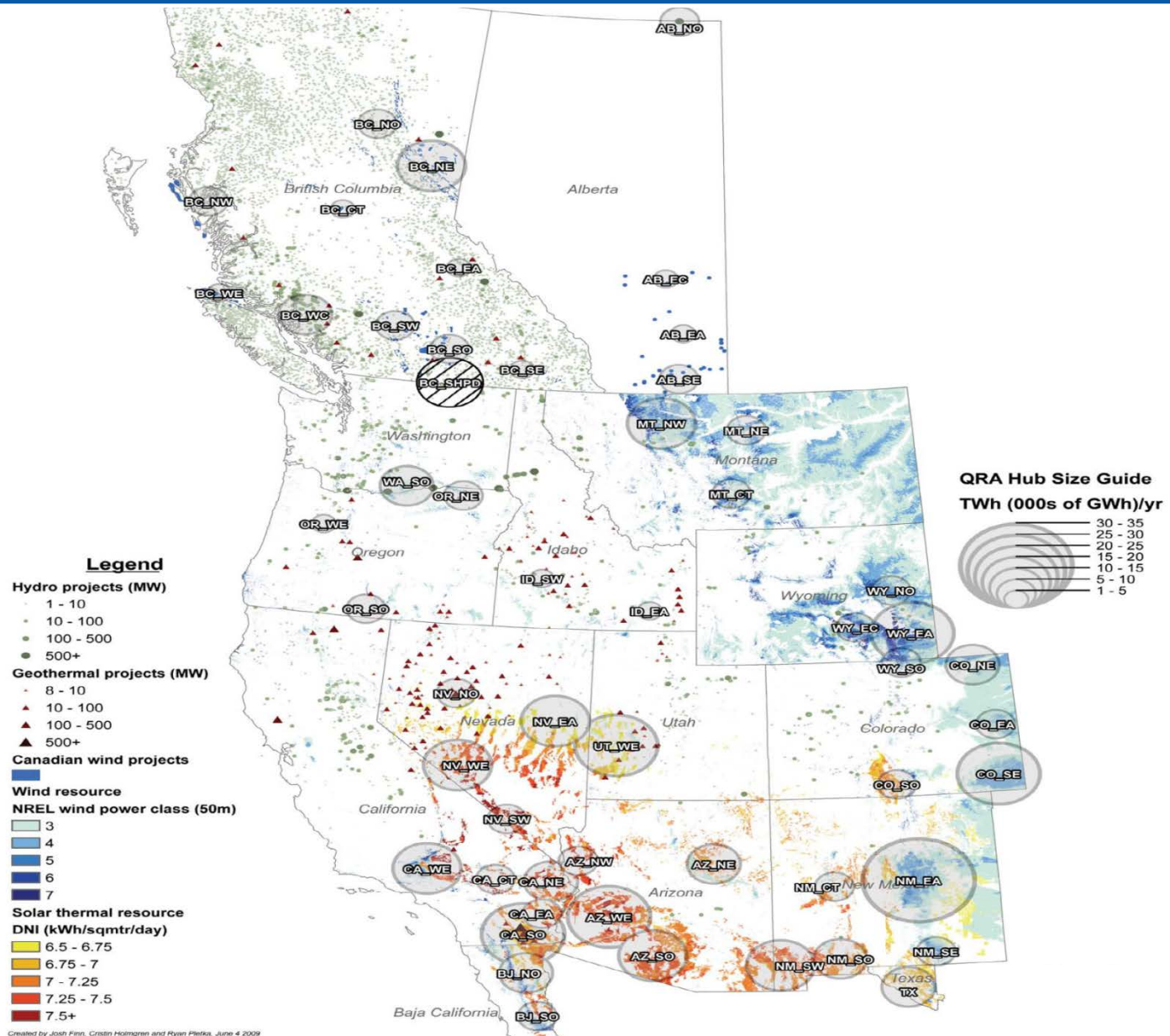
WREZ Four Phases

- **Phase 1**: Identify renewable energy zones (REZs), estimate quantity of REZ resources, estimate busbar cost of REZ resources;
- **Phase 2**: Develop modeling tool to estimate delivered cost of energy from any REZ to any major load center in the West; submit scenarios to WECC for detailed study;
- **Phase 3**: Identify zones of common interest to multiple LSEs (foster regional renewable generation and transmission projects);
- **Phase 4**: Institution-building, address transmission siting and cost allocation issues.

WREZ Phase 1

- Include all states and provinces in the Western Interconnection
- “Filters” applied to eliminate certain land types (national parks, urban areas, etc.)
- Areas identified represented large resources, smaller areas still show potential for smaller local loads.
 - Wind Class Threshold
 - Solar DNI Threshold
- Standard economic assumptions
 - Capital cost of each technology
 - Capacity factor
 - Operation and maintenance costs
- Estimate typical annual production (MWh) - each technology at each quality level.

Western Renewable Energy Zones Initiative (WREZ)



Created by Josh Finn, Cristin Holmgren and Ryan Pletka, June 4 2009

Renewable Energy Zones

- A zone has no real boundary. Grid lines do not limit development. They are for the analytical purpose of estimating resources and deciding how large to build the transmission system.
- A **hub** is the center of a zone. It represents a transmission substation where the zone's resources are collected and get onto the grid.
- All of the resources in the vicinity of the hub that passed screening are used to estimate the capacity available at the hub.

WREZ Phase 2

- Create Generation and Transmission Model (GTM)
- Calculates cost of delivered energy from 54 zones to 20 load centers in WECC.
- High level “screening tool” that performs a simplified economic analysis for quick project comparison.
- Easy-to-use spreadsheet downloadable from web.
- Anybody can download and use – LSEs, PUCs, Industry Stakeholders – and yes your dog.

WECC Load Centers – GTM Screenshot

Identify Load Area

[Home](#)
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[Next](#)


Select Load Area

*use dropdown or select from map on left

Load Area Assumptions

Integration Costs

Wind Integration (\$/MWh)	\$5.0
Solar Integration (\$/MWh)	
Solar Thermal	\$2.5
Solar Thermal with Storage	\$0.0
Photovoltaic	\$2.5

Local Delivery costs

per MWh \$0

Resource Adequacy Cost

\$/kW-year \$114

Financing Assumptions

Profile of Average Energy Prices (\$/MWh)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Jan	60	59	58	58	59	62	65	70	72	72	71	69	67	66	65	65	65	79	115	93	74	68	64	62
Feb	60	59	58	59	60	62	64	69	69	70	69	67	66	65	65	64	64	68	111	97	75	67	64	62
Mar	57	56	55	55	56	59	61	62	64	66	68	68	68	72	72	70	66	65	88	102	72	64	62	60
Apr	53	51	50	50	51	53	54	56	58	59	62	66	67	71	71	68	64	60	60	65	78	62	57	55
May	54	52	49	48	48	49	52	54	56	58	59	61	62	68	73	82	70	61	59	58	63	59	56	55
Jun	56	55	53	51	51	52	53	56	59	62	65	67	70	76	85	89	85	73	66	64	66	63	60	58
Jul	64	61	59	57	57	58	59	62	67	72	77	81	86	92	97	103	102	91	84	81	81	79	73	67
Aug	63	60	58	56	56	58	59	62	68	72	76	79	82	87	94	103	104	89	83	80	80	77	71	65
Sep	58	56	54	53	53	55	58	61	65	68	71	75	78	83	91	99	95	83	79	81	78	72	66	61
Oct	58	56	54	53	54	58	62	64	66	68	69	71	72	73	76	80	76	71	77	88	74	69	64	61
Nov	58	57	56	56	57	61	65	68	69	70	71	70	70	69	69	68	70	86	98	81	73	69	65	62
Dec	65	64	63	63	65	68	71	73	75	76	75	74	73	73	72	72	73	88	109	94	85	77	72	68

Multiply the above profile by [Go](#)

Select Peers

Resource Selection

- Build resource portfolio
 - Unlimited resources from 5 Zones or less
 - Resource energy profile exists and can be viewed (as shown)
 - Select zone, then resource

The screenshot displays a software interface for resource selection. On the left is a map of California with various resource locations marked by colored circles and triangles. The main panel shows a dropdown menu set to 'CA_WE' and a title 'California West' with a delivery node of '8 ANTELOPE'. Below this is a table of resources with columns for ID, Tech, Capacity Left (MW), Capacity Factor, and Busbar Cost (\$/MWh). A 'Select' column with checkboxes is on the right. A red arrow points from the 'Select' column to a details window titled 'CA_CT_5_6'. The details window shows the technology as 'SolarThermal', the zone as 'CA', capacity as '1,628 MW', price as '\$160.71', capacity factor as '27%', and annual generation as '3,888 GWh'. It also includes a line graph showing the energy profile for January, July, and April.

ID	Tech	Capacity Left (MW)	Capacity Factor	Busbar Cost (\$/MWh)	Select
CA_WE_B_5	Biomass	76	85%	\$132	☐
CA_WE_S_1	Solar				☐
	Thermal Dry		26%	\$171	☐
	Thermal Wet		26%	\$171	☐
	Thermal Stor Dry		26%	\$171	☐
	Thermal Stor Wet		26%	\$171	☐
	Tracking PV		26%	\$171	☐
	Fixed PV		26%	\$171	☐
	Total Capacity	2019			
CA_WE_WV_1	Wind	68	47%	\$47	☐
CA_WE_WV_2	Wind	437	38%	\$65	☐
CA_WE_WV_3	Wind	1235	31%	\$87	☐
CA_WE_WV_4	Wind	1311	26%	\$110	☐
CA_WE_WV_5	Wind	345	23%	\$128	☐

Details
CA_CT_5_6
Technology: SolarThermal Zone: CA
Capacity: 1,628 MW Price: \$160.71
Capacity Factor: 27%
Annual Generation: 3,888 GWh

Graph showing energy profile (Y-axis: 0.0 to 1.2, X-axis: 1 to 23) for Jan, July, and April.

Custom Resource Design – User Defined

- Users can enter custom resources at either generation point or load point.
- Multiple renewable technologies available.

Custom Resources

Home Back Next

User Defined Custom

Resource Name

[delete](#)

Technology

Other

Solar Sub-Technology

Thermal Drr

Delivery Node

HONA

54 *See the map on the Transmission Routing page for locations

Capacity

150 MW

Busbar Cost (\$/MWh)

\$111

Add Custom with this Busbar Cost

Degr	Cap	FOM	YOM	Fuel	Heat	PTC	PTC	Depreciation Schedule	Econ	Debt	Debt	Debt	Cost	Tax	Disc	ar
atio	Cost	(\$/kWh-	(\$/MWh	Cost	Rate	ITC	Term	5gr	7gr	15gr	20gr	Life	Equit	Rate	Rate	Cost
n	(\$/kWh)	yr)	)	(\$/MWh)	(BTU/kWh)	0%	(grs)	0%	0%	0%	100%	(grs)	g	40%	9.3%	(\$/MWh)
0%	\$1,280	\$10	\$5	\$8	6870	0%	0	0%	0%	0%	100%	25	12.0%	40%	9.3%	94

Add Custom with these Busbar Cost

Generation Profile

100% Capacity Factor

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Jan	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Feb	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Mar	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Apr	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
May	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Jun	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Jul	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Aug	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Sep	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Oct	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Nov	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Dec	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Custom Resource Design – Conventional Generation

- Users can enter custom conventional resources at either generation point or load point.
- Multiple technologies available.

Conventional Generation

Resource Name [Define](#)

Technology [Other](#)

Delivery Node [56](#) *See the map on the Transmission Routing page for locations

Capacity [150](#) MW

Cost of Carbon

Carbon Price (\$/tonCO2)	\$35
Carbon Intensity (tonCO2/MMBTU)	0.06
Additional cost	\$14

Pre-Loaded Conventional Inputs

[Load CC Profile](#) [Load GT Profile](#)

Busbar Cost

User Defined Busbar Cost (\$/MWh)	\$111	Add Conventional with this
User Defined Busbar Cost with Carbon Cost (\$/MWh)	\$125	Add Conventional with this
Model-Derived Busbar Cost (\$/MWh)	\$98	Add Conventional with this Cost and
Model-Derived Busbar Cost with Carbon Cost (\$/MWh)	\$112	Add Conventional with this

Degradation	Cap Cost (\$/kW)	FOM (\$/kW-yr)	VOM (\$/MWh)	Fuel Cost (\$/MBTU)	Heat Rate (BTU/kWh)	ITC	PTC (\$/MWh)	PTC Term (yrs)	Depreciation Schedule				Econ Life (yrs)	Debt %	Debt Rate	Debt Term (yrs)	Cost Equity	Tax Rate	Disc Rate
0%	\$1,280	\$10	\$5	\$8	6870	0%	\$0	0	5yr	7yr	15yr	20yr	25	50%	6.5%	20	12.0%	40%	9.3%

Generation Profile

85% Capacity Factor

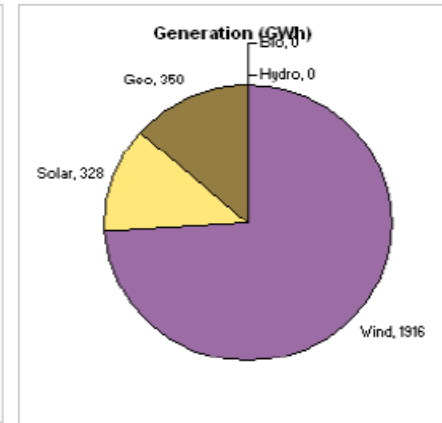
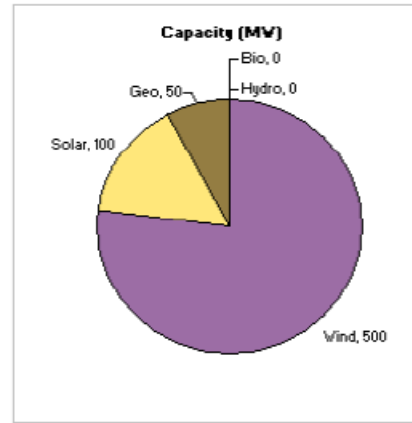
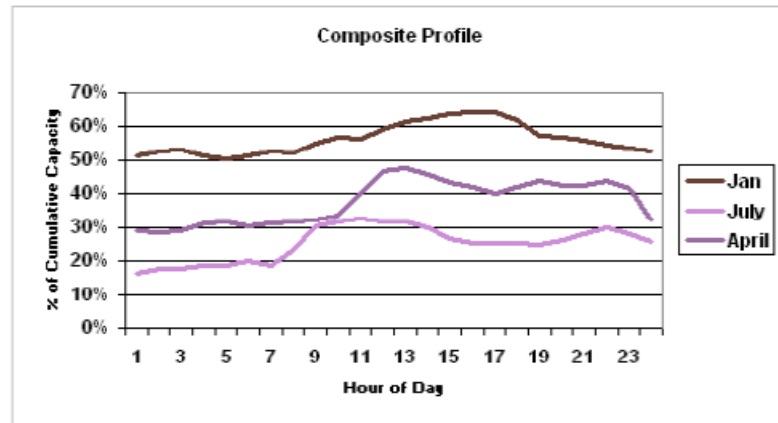
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Jan	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%
Feb	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%
Mar	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%
Apr	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%
May	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%
Jun	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%
Jul	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%
Aug	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%
Sep	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%
Oct	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%
Nov	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%
Dec	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%

Resource Portfolio

- Shows specifics of resource portfolio.
- Graphic representation of energy profile, capacity, and annual energy.
- Specific resources can be removed from portfolio (enter 0 for Cap (MW)).

Resource Portfolio

Home Back Next



My Resources

Clear

Project ID	State	Node	Technology	Cap (MW)	Cap Factor	Cost (\$/kW)	Debt Term (yrs)	Econ Life (yrs)	Tax life (yrs)	% Depr	FOM (\$/kW-yr)	VOM (\$/Mwh)	PTC (\$/MW h)	PTC Term (yrs)	ITC	Fuel (\$/MMB TU)	Rate (BTU/kWh)	Disc Rate	Debt %	Debt Rate	Tax Rate	Cost Equity	Busbar Cost (\$/MWh)	GWh
WY_EA_W_2	WY	70	Wind	500	44%	\$2,400	15	20	5	100%	\$60	\$0	\$21	10	0%	\$0	0	11%	60%	8%	40%	15%	\$62	1916
NV_NO_G_3	NV	13	Geothermal	50	80%	\$4,648	15	20	5	100%	\$0	\$35	\$21	10	0%	\$0	0	11%	60%	8%	40%	15%	\$90	350
NV_WE_S_6	NV	12	SolarThermal	100	37%	\$7,575	15	20	5	85%	\$66	\$0	\$0	0	30%	\$0	0	11%	60%	8%	40%	15%	\$163	328
																							0	0

Identify Incremental Transmission Path(s): REZ(s) to Load

- Select Point-to-Point or Multi-Area Transmission Path(s).
- User may define the route for each resource(s)

User defined
Route: Select
"Click" on
Segments

Transmission Route

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Transmission System Nodes/Substations

	Number	Name	
Load Area Node:	83	SERRANO	
Resource Node:	7	PISGAH	
Resource Node:	5	BLYTHE	
Resource Node:	6	MOUNTAIN	
Resource Node:	32	STERLING	
Resource Node:	31	NEW SUB 31	

Point to Point Routing Solution
This tool will select the shortest route through the grid from the load area node to each resource node independently.

PtoP

Multi - Point Routing Solution
This tool will attempt to find a shorter route by considering routes that better serve combinations of resource nodes.

Multi

User Defined Routing Solution
Use these tools to edit the routing solution.

1) Examine the route between the load area node to each resource node by itself. Display the one you wish to edit.

☐ Resource Node 1: PISGAH
☐ Resource Node 2: BLYTHE
☐ Resource Node 3: MOUNTAIN
☐ Resource Node 4: STERLING
☐ Resource Node 5: NEW SUB 31
☒ All Resource Nodes

2) Modify the route by clicking on the line segments to toggle them on and off. This will only work if you have selected an individual resource node above.

3) When you have modified the route to an individual resource node, save it and the total routing solution will be modified.

Save Change

Restore Default Colors

2270.76

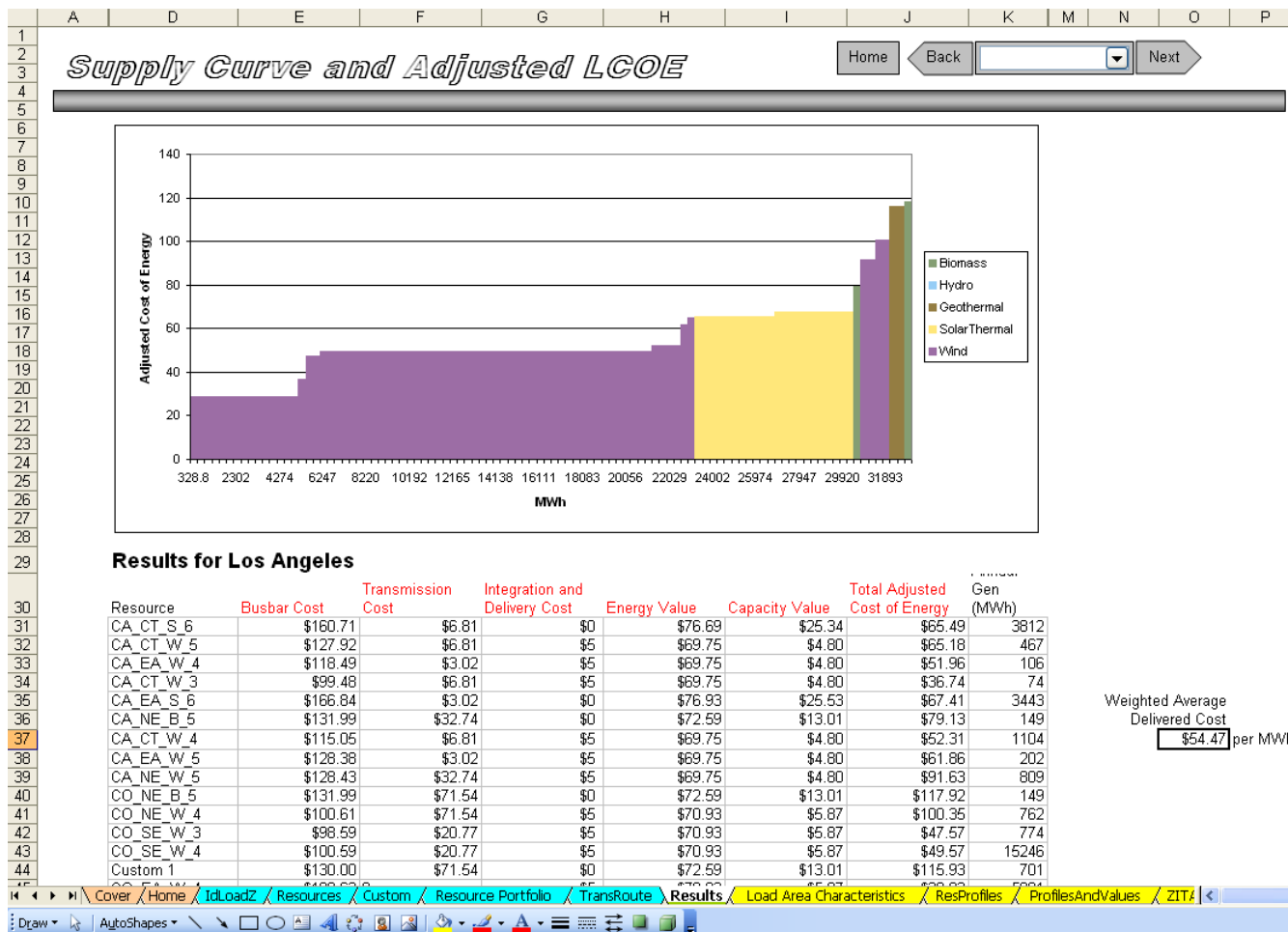
Selected Transmission Route(s) Design

- Highlighted line segments shown.
- Line segment characteristics can be changed – all blue fields.
- Transmission costs combined with resource portfolio costs to estimate project cost.

Line	Type	Capacity	No. lines	Project Cap	Utilization (%)	Distance	Cost per mile	Cap Cost	ROW Cost	Cost (\$000)	per kW	Lev Cost	Losses
BLYTHE to DEVERS	500 kV AC Single	1500	4	6000	40.7%	114	\$1,800	\$205,400	\$25,900	\$231,300	\$39	\$2	1%
HARQUAHALA to WESTWING	500 kV AC Single	1500	4	6000	33.5%	54	\$1,800	\$97,414	\$12,283	\$109,698	\$18	\$1	0%
NEW SUB 31 to LAMAR	500 kV AC Single	1500	1	1500	12.3%	57	\$1,800	\$102,308	\$12,900	\$115,208	\$77	\$13	0%
TORTOLITA to GREENLEE	500 kV AC Single	1500	4	6000	33.5%	126	\$1,800	\$227,534	\$28,691	\$256,225	\$43	\$3	1%
SANTA ROSA to WESTWING	500 kV AC Single	1500	4	6000	33.5%	62	\$1,800	\$111,284	\$14,032	\$125,316	\$21	\$1	0%
DEVERS to SERRANO	500 kV AC Single	1500	4	6000	42.6%	70	\$1,800	\$126,324	\$16,929	\$142,253	\$24	\$1	0%
MOUNTAIN to DEVERS	500 kV AC Single	1500	1	1500	7.3%	85	\$1,800	\$153,176	\$19,315	\$172,490	\$115	\$32	1%
PISGAH to SERRANO	500 kV AC Single	1500	2	3000	20.8%	104	\$1,800	\$187,557	\$23,650	\$211,207	\$70	\$7	1%
HARQUAHALA to BLYTHE	500 kV AC Single	1500	4	6000	33.5%	92	\$1,800	\$164,848	\$20,786	\$185,634	\$31	\$2	1%
STERLING to LAMAR	500 kV AC Single	1500	1	1500	12.3%	172	\$1,800	\$309,502	\$39,026	\$348,529	\$232	\$38	1%
NEW SUB 31 to NEW SUB 28	500 kV AC Single	1500	4	6000	33.5%	214	\$1,800	\$384,712	\$48,510	\$433,221	\$72	\$4	2%
GREENLEE to NEW SUB 28	500 kV AC Single	1500	4	6000	33.5%	275	\$1,800	\$494,868	\$62,400	\$557,268	\$93	\$6	2%
SANTA ROSA to TORTOLITA	500 kV AC Single	1500	4	6000	33.5%	50	\$1,800	\$90,736	\$11,441	\$102,178	\$17	\$1	0%
	500 kV AC Single	1500	0	0	#DIV/0!		\$1,800	\$0	\$0	\$0	#DIV/0!	#VALUE!	0%

Project Results – Generation Resource & Transmission

- Supply curve shows levelized cost of electricity to load from portfolio (\$/MWh):
 - Detailed resource cost;
 - Detailed transmission cost.



Regional Transmission Scenarios

- Zone hubs and their supply curves went into a conceptual delivered cost model:
 - Excel-based;
 - Populated with busbar costs from Phase 1, but may be customized to capture user-defined projects or scenarios;
 - Delivered costs estimated on the basis of user-selected load hub and user-selected REZ hub;
 - Available to load-serving entities and regulators to test scenarios.

Western Renewable Energy Zones

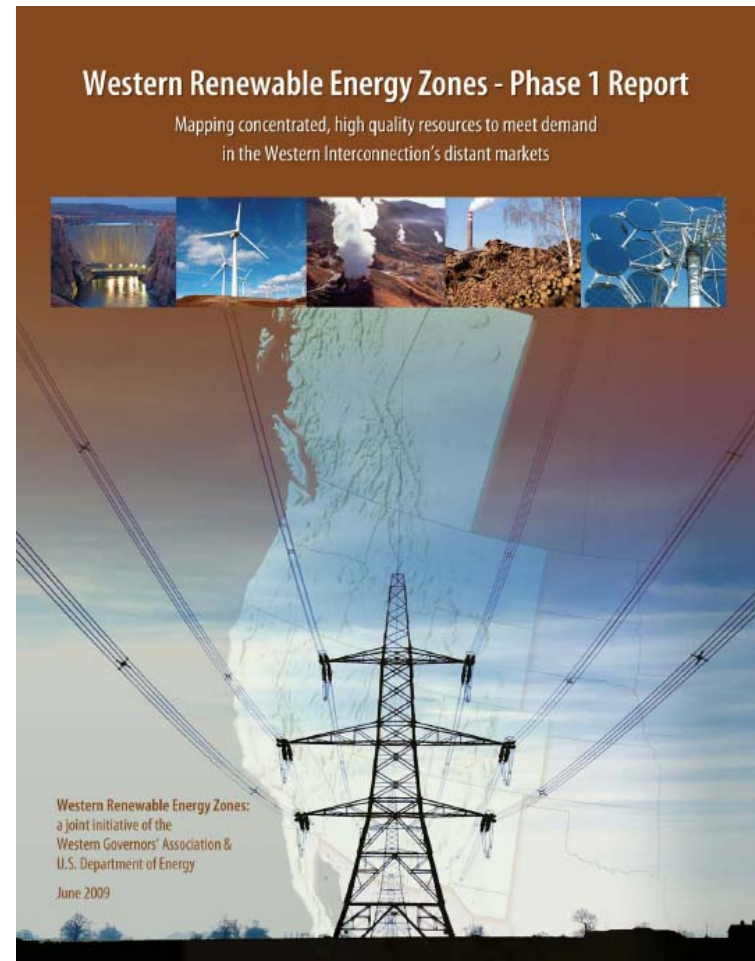
- WREZ on the Western Governors' web site:

<http://www.westgov.org/wga/initiatives/wrez/>

- GIS portal for WREZ maintained by NREL:

•<http://mercator.nrel.gov/wrez/>

- Login “wrez”
- Password “guest”



WREZ Phases 1 & 2 Lessons Learned / Impediments

- Transmission is the biggest obstacle to installing large amounts of new renewable energy generation.
- Wildlife sensitivity analysis did not get developed adequately, and is an impediment. Accordingly, this issue is not in the Phase 1 report.
- Wildlife issues can overwhelm renewable energy potential.
- The WREZ took on significant importance to developers and others.
- In the end, the policies of the individual states can drive project outcomes.

WREZ Phase 3 – Identify Zones of Common Interest

- Multiple LSEs may benefit from the same regional transmission and REZ(s) project.
- LSE and PUC interviews are completed:
 - Regulatory Assistance Project;
 - NREL/LBNL.
- Initial finding – local resources sufficient to meet RPS requirements.
- Funding under FOA 68, Area of Interest 2, 2010.

WREZ Phase 4 – Fostering Interstate Cooperation

- Develop environment for regional interstate transmission and REZ(s) projects.
- Address policy and regulatory obstacles to interstate transmission projects, such as:
 - Siting
 - Federal lands, protected lands, sensitive lands, etc.
 - Cost allocation
 - Energy recipient(s)
 - Reliability beneficiary(s)

WREZ General Lessons Learned:

- Most LSEs and states prefer to use in-state/local renewable resources due to transmission timing and state economic benefits.
- States with energy export potential want to see G&T projects developed in order to bring the resource to market.
- Disturbed lands with valuable renewable resources should be a priority.
- Renewable resources will increase if:
 - They are economical or required:
 - Greenhouse gas emissions;
 - Renewable portfolio standards;
 - Price signals;
 - Technology breakthrough.

WREZ Continuing Efforts:

- Update wildlife and water issues into the generation data.
- Improve the WREZ model:
 - Improved GTM functionality;
 - Improved annotation;
 - Updated/Improved data (e.g., replacing 50-m wind data w/ 80 m).
- Improved DG integration.
- Outreach to LSEs and states.

WREZ Additional Information:

- Data, Presentations, and Reports
 - Website at:
<http://www.westgov.org/wga/initiatives/wrez/index.htm>
- Questions?
 - Email: jeff.hein@nrel.gov
 - 303-384-7090

Questions / Comments

