National Renewable Energy Laboratory
Innovation for Our Energy Future

Western Renewable Energy Zones

Composite photo created by NREL

Meeting Transmission Challenges in the Rocky Mountain Region

Jeff Hein

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Presentation Outline

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

WREZ Vision

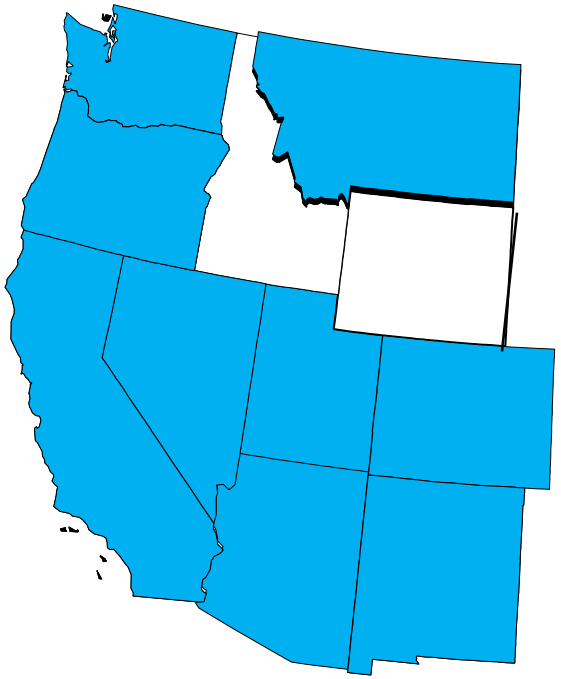
- Western Governor's Association and U.S. Department of Energy initiated effort to develop renewable energy resources and reduce GHG emissions
- Develop a high level "screening tool" to identify potential projects that allows industry stakeholders to analyze and compare economics of multiple projects
- 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

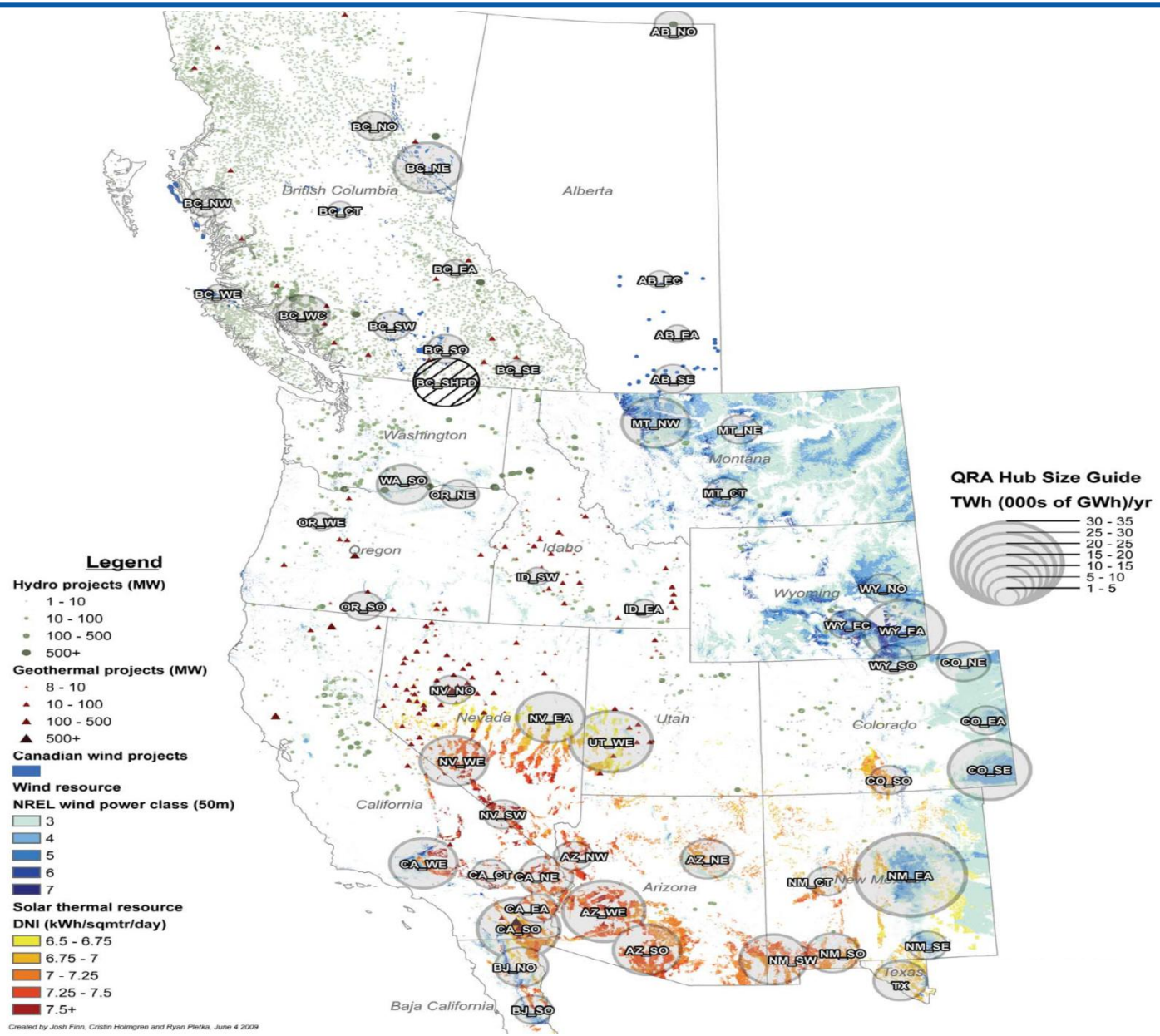
- **Phase 3**: Identify zones of common interest to multiple LSEs (foster regional renewable generation and transmission projects)

- **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)



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.

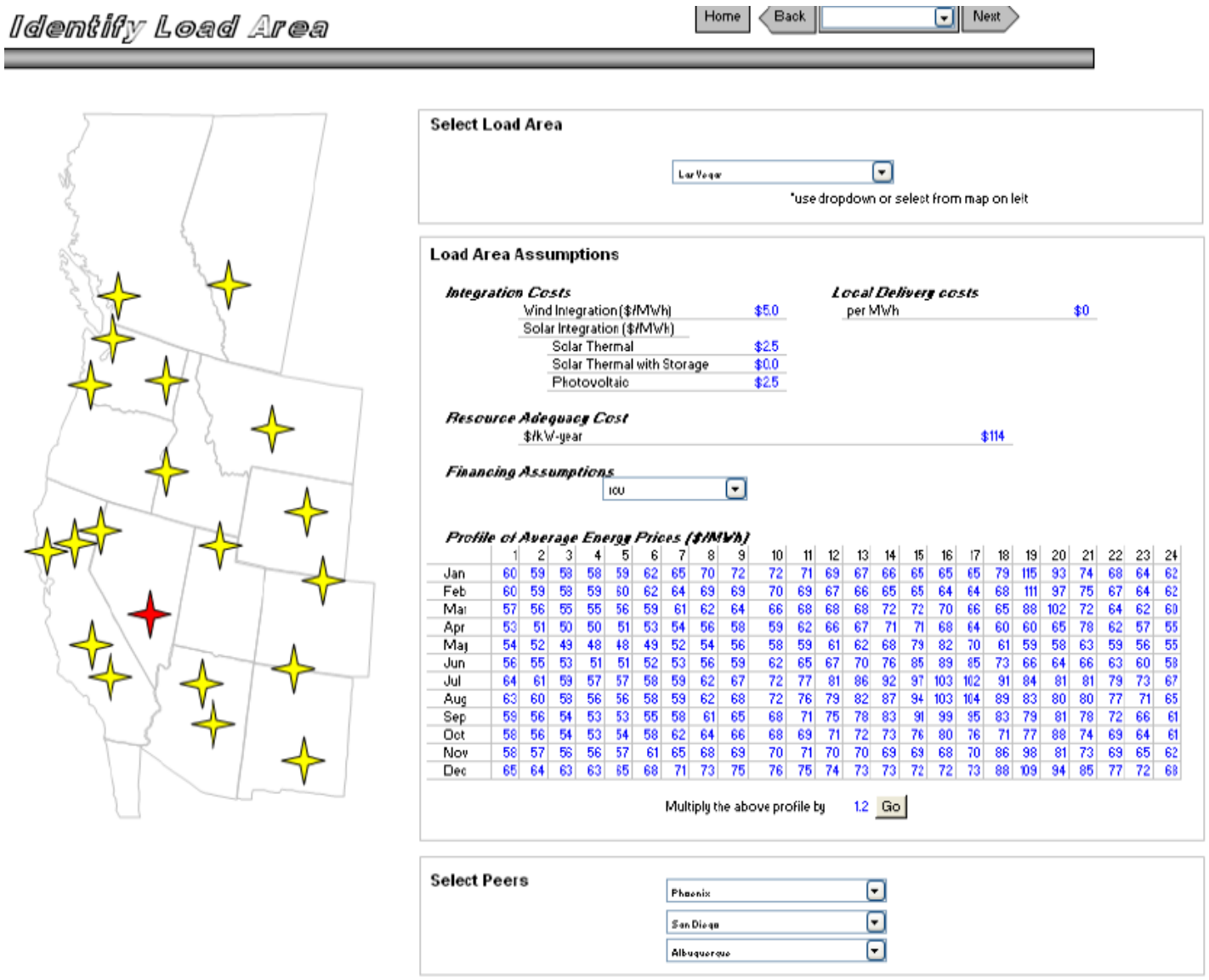
- A **hub** is the center of a zone. It represents a transmission substation where the zone's resources are collected and get onto the grid.

- 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

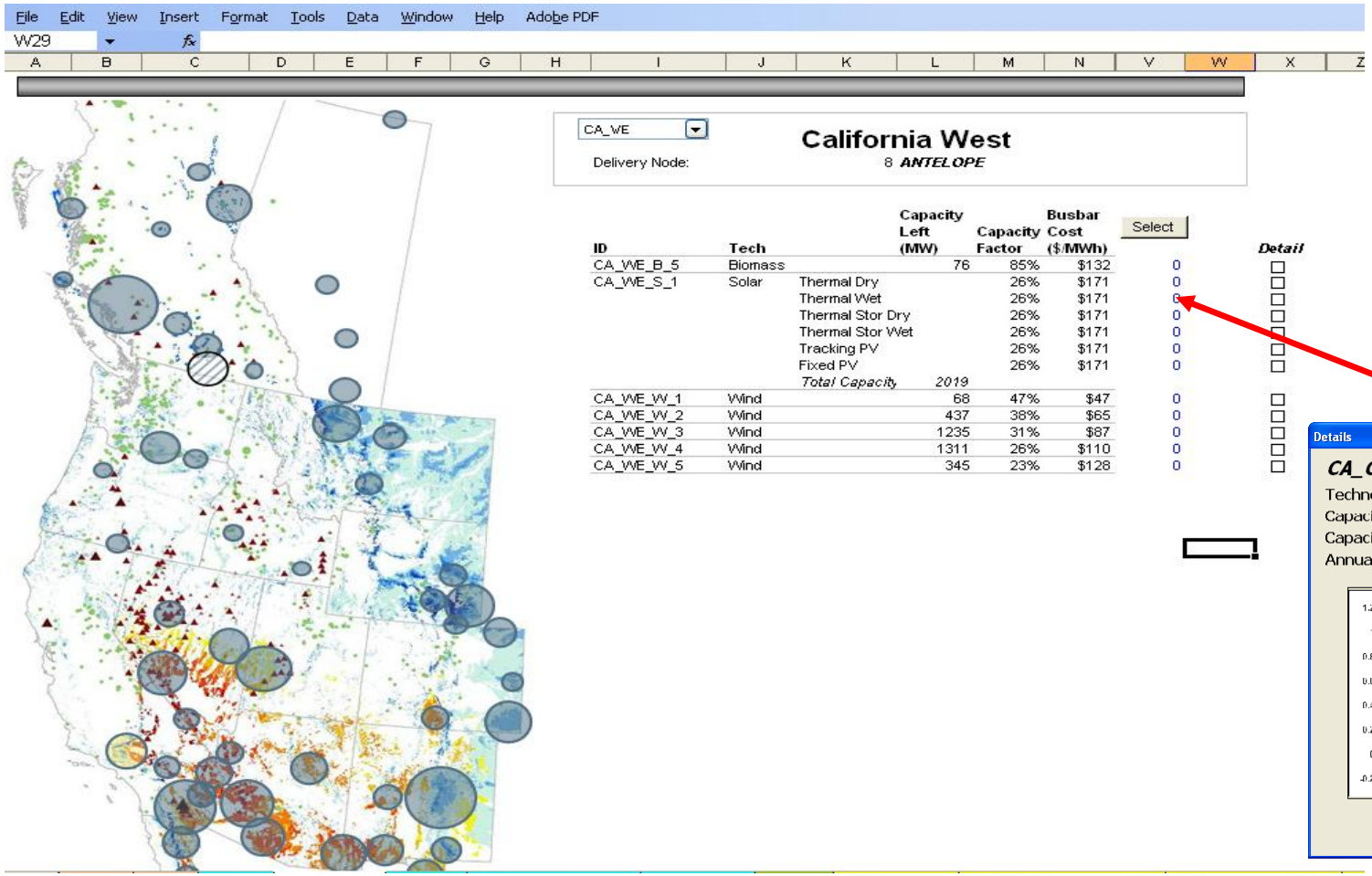
- Create Generation and Transmission Model (GTM)
- Calculates cost of delivered energy from 54 zones to 20 load centers in WECC.
- High level “screening tool” that performs a simplified economic analysis for quick project comparison.
- Easy-to-use spreadsheet downloadable from web.
- Anybody can download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

WECC Load Centers – GTM Screenshot



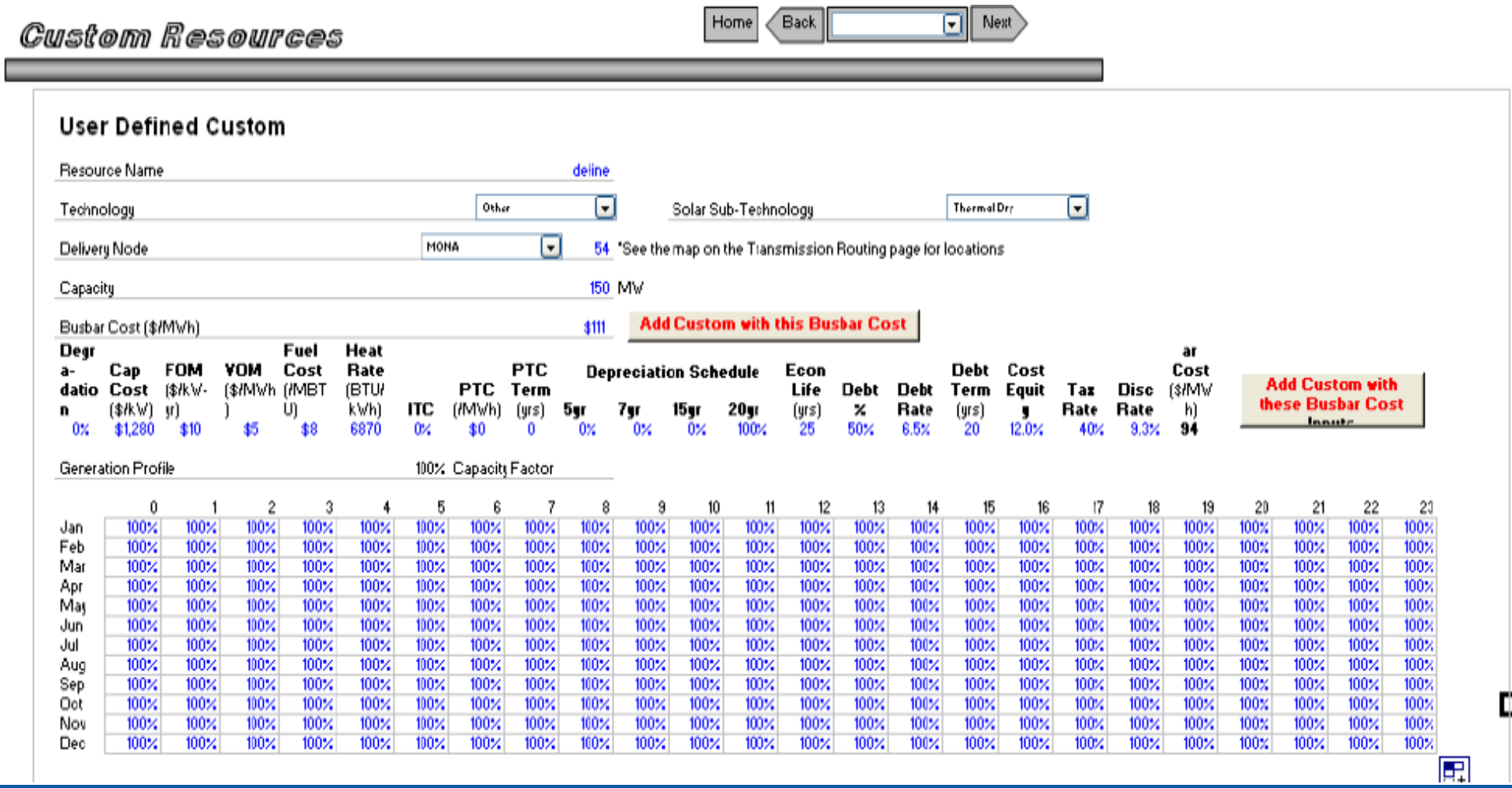
Resource Selection

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



Custom Resource Design – User Defined

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



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	RIC PUERCO 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 5yr	7yr	15yr	20yr	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	0%	0%	0%	100%	25	50%	6.5%	20	12.0%	40%	9.3%

Generation Profile 85% Capacity Factor

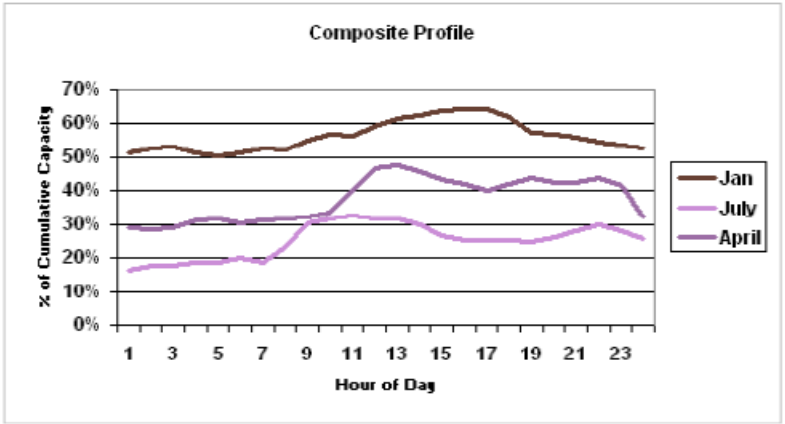
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Jan	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%
Feb	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%
Mar	70%	70%	70%	70%	70%	70%	70%	70%	70%	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%

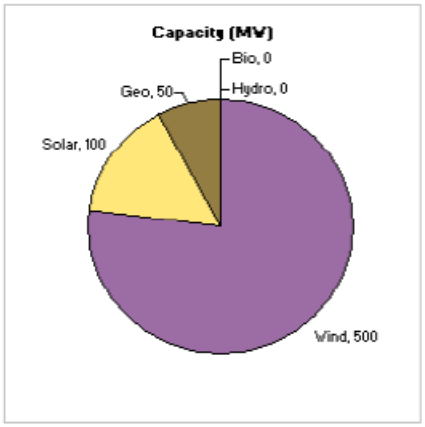
Resource Portfolio

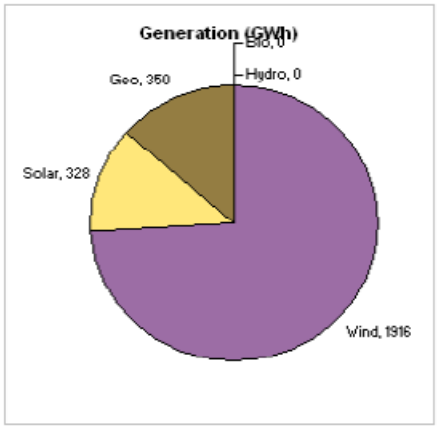
- Shows specifics of resource portfolio.
- Graphic representation of energy profile, capacity, and annual energy.
- Specific resources can be removed from portfolio (enter 0 for Cap (MW))

Resource Portfolio

Home | Back | Next







My Resources

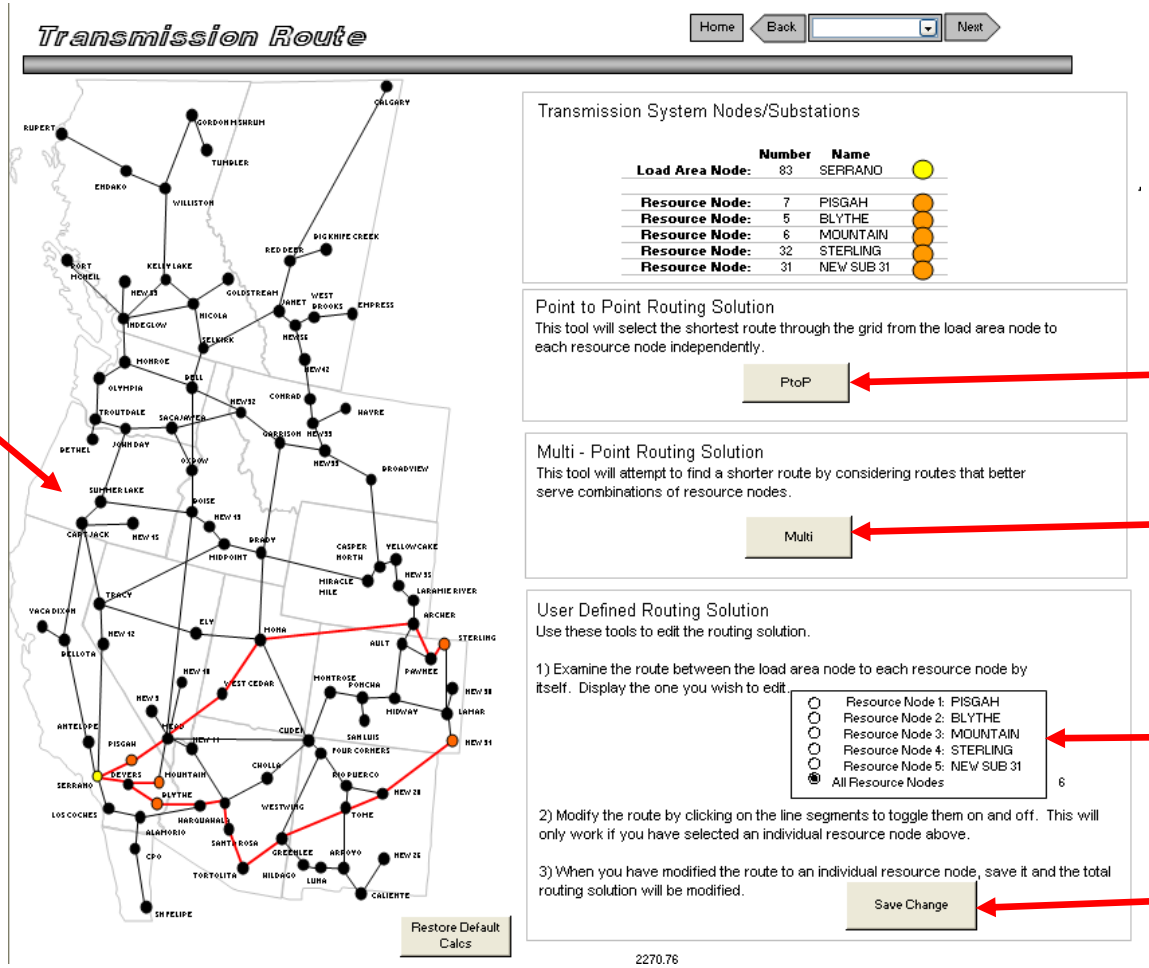
Clear

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 (/MWh)	PTC Term (yrs)	ITC	Fuel (/MMBTU)	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_S	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



Point-to-Point

Multiple-Area

Select Resource(s)

Save Route

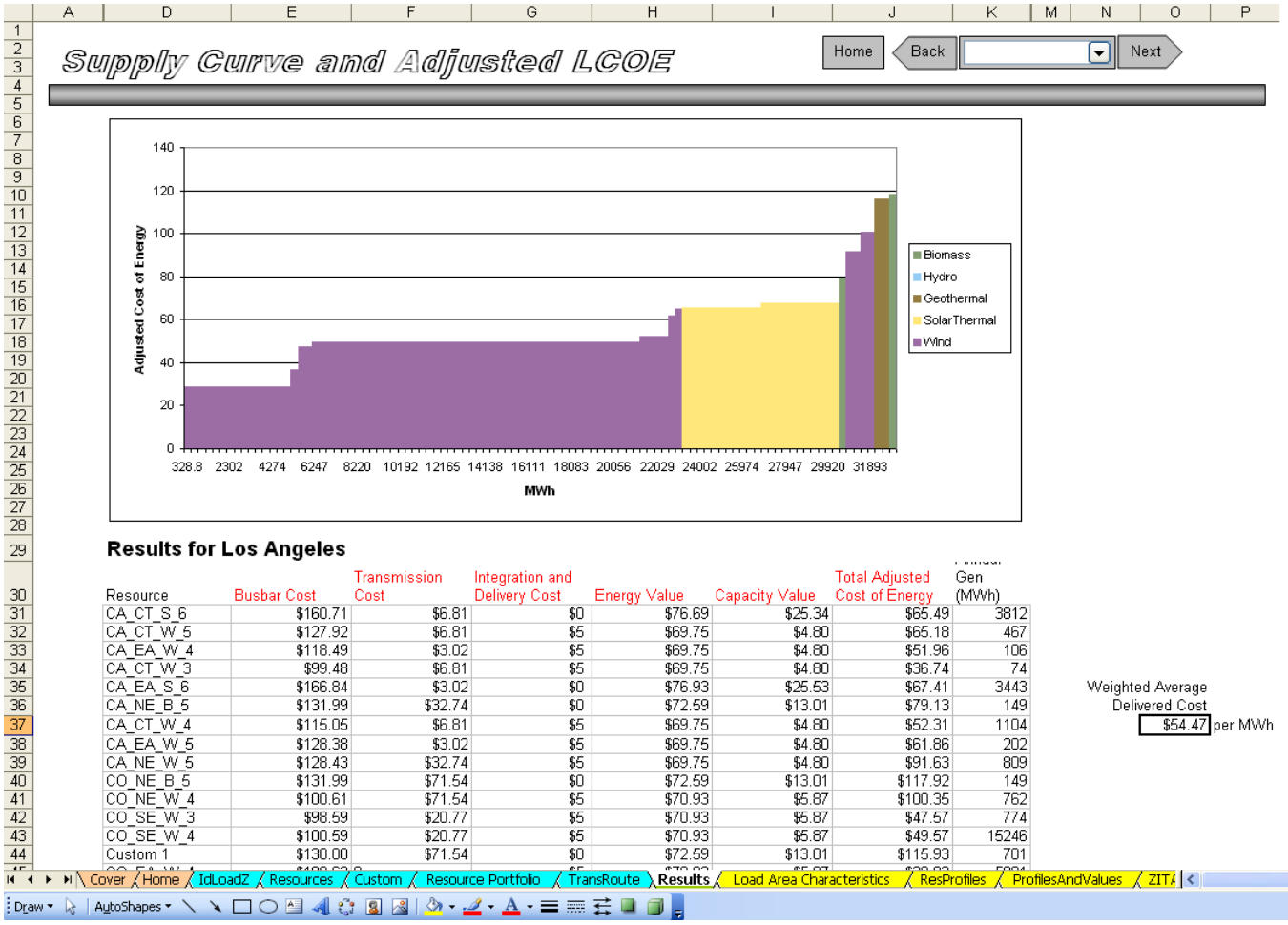
Selected Transmission Route(s) Design

- 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	12.5%	70	$1,800	$126,324	$15,929	$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



Results for Los Angeles

Resource	Busbar Cost	Transmission Cost	Integration and Delivery Cost	Energy Value	Capacity Value	Total Adjusted Cost of Energy	Gen (MWh)
CA_CT_S_6	$160.71	$6.81	$0	$76.69	$25.34	$65.49	3812
CA_CT_W_5	$127.92	$6.81	$5	$69.75	$4.80	$65.18	467
CA_EA_W_4	$118.49	$3.02	$5	$69.75	$4.80	$51.96	106
CA_CT_W_3	$99.48	$6.81	$5	$69.75	$4.80	$36.74	74
CA_EA_S_6	$166.84	$3.02	$0	$76.93	$25.53	$67.41	3443
CA_NE_B_5	$131.99	$32.74	$0	$72.59	$13.01	$79.13	149
CA_CT_W_4	$115.05	$6.81	$5	$69.75	$4.80	$52.31	1104
CA_EA_W_5	$128.38	$3.02	$5	$69.75	$4.80	$61.86	202
CA_NE_W_5	$128.43	$32.74	$5	$69.75	$4.80	$91.63	809
CO_NE_B_5	$131.99	$71.54	$0	$72.59	$13.01	$117.92	149
CO_NE_W_4	$100.61	$71.54	$5	$70.93	$5.87	$100.35	762
CO_SE_W_3	$98.59	$20.77	$5	$70.93	$5.87	$47.57	774
CO_SE_W_4	$100.59	$20.77	$5	$70.93	$5.87	$49.57	15246
Custom 1	$130.00	$71.54	$0	$72.59	$13.01	$115.93	701

Weighted Average Delivered Cost
$54.47 per MWh

Regional transmission scenarios

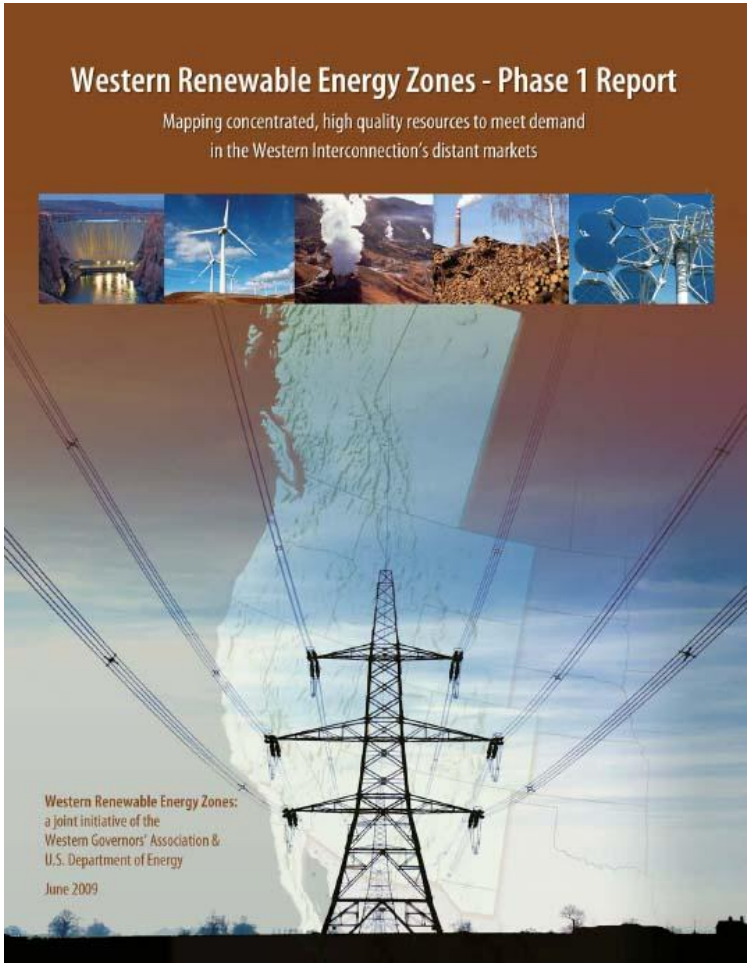
- Zone hubs and their supply curves went into a conceptual delivered cost model
  - Excel-based
  - Populated with busbar costs from Phase 1, but may be customized to capture user-defined projects or scenarios
  - Delivered costs estimated on the basis of user-selected load hub and user-selected REZ 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/index.php?option=com_content&view=article&id=219&Itemid=81

- 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 50m wind data w/ 80m)
- Improved DG integration
- Outreach to LSEs and states

WREZ Additional Information:

- Data, Presentations, and Reports
  - Website at: http://www.westgov.org/index.php?option=com_content&view=article&id=219&Itemid=81

- Questions?
  - Email: jeff.hein@nrel.gov
  - 303-384-7090

Questions / Comments