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Integrating Wind into Transmission Planning: The Rocky Mountain Area Transmission Study (RMATS)

Preprint

Roger Hamilton
West Wind Wires

Ron Lehr
American Wind Energy Association

Dave Olsen
Center for Energy Efficiency and Renewable Technologies

John Nielsen
Western Resource Advocates

Tom Acker and Michael Milligan (Consultant)
National Renewable Energy Laboratory

Howard Geller
Southwest Energy Efficiency Project

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National Renewable Energy Laboratory
1617 Cole Boulevard, Golden, Colorado 80401-3393
303-275-3000 • www.nrel.gov

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Abstract

Plans to expand the western grid are now underway. Bringing power from low-cost remote resources—including wind—to load centers could reduce costs for all consumers. But many paths appear to be already congested. Locational marginal price-based modeling is designed to identify the most cost-effective paths to be upgraded. The ranking of such paths is intended as the start of a process of political and regulatory approvals that are expected to result in the eventual construction of new and upgraded lines. This paper reviews the necessary data and analytical tasks to accurately represent wind in such modeling, and addresses some policy and regulatory issues that can help with wind integration into the grid. Providing wind fair access to the grid also (and more immediately) depends on tariff and regulatory changes. Expansion of the Rocky Mountain Area Transmission Study (RMATS) study scope to address operational issues supports the development of transmission solutions that enable wind to connect and deliver power in the next few years—much sooner than upgrades can be completed.

Taken together, the economic modeling and tariff investigation of the RMATS study provide an unprecedented opportunity for utility planners, regulators, and state officials to consider the integration of gigawatt-scale additions of wind power into the Western Interconnection. In doing so, it sets important precedents for treating wind in transmission studies in other regions.

1.0 Policy Issues in the Rocky Mountain region

The RMATS study provides an opportunity for wind developers to engage with system planners and planning institutions in the region. Wyoming Governor Freudenthal and Utah Governor Leavitt (now director of the U.S. Environmental Protection Agency) in September 2003 announced an initiative to develop proposals for transmission additions. This subregion of the Western Interconnection includes Colorado, Idaho, and Montana, and is part of a greater West-wide region that includes the Southwest, California, the Pacific Northwest, British Columbia, Alberta, and Baja California Norte. The announcement cited the need to "break the log jam of inactivity" around transmission planning and investment and identify "specific, incremental transmission and generation projects to meet the growing consumer demands" in the region. It also cited transmission constraints that have caused "the region's vast wind, natural gas, and coal resources" to be "underutilized." The governors' urgency and its relevance to short-term wind industry needs are underscored by their calling for a six-month timeline for completing the study charter.

The governors' announcement cited a need for follow-through on the findings of a 2001 Western Governors Association (WGA) conceptual transmission study that recognized that "new transmission and generation infrastructure located remotely from population centers can provide benefits for consumers throughout the west." It also referred to "fundamental policy concerns regarding over reliance on natural gas to fuel electricity generation." The opportunity for wind is to take advantage of high-level political and economic interest in developing and delivering to western markets remote wind resources to hedge against natural gas price volatility. A further opportunity for wind and a policy challenge for natural gas turbine developers is that most of the region's natural gas must be imported from Canada, as liquefied natural gas from overseas, or extracted from within the region through methods (as with coal-bed methane) that have serious environmental impacts.

A second and more complex policy issue is that remote wind is geographically proximate, particularly in Wyoming, to remote, low-cost mine-mouth coal. The opportunity for joint transmission projects may merit detailed investigation, but a partnership between wind and coal that led to an increase in coal-burning emissions would eliminate the benefit of adding zero-emission wind power, and could further concentrate the region's already-heavy reliance on coal. The RMATS study provides an opportunity to evaluate the emissions benefits that may result from developing different amounts of wind power, while considering a range of costs for compliance with future CO2 controls. Policy-makers will then have a menu of choices and trade-offs among coal, wind, and gas resource scenarios, which depend on a range of forecasts for gas prices, demand growth, and export opportunities.

The study will also assess the consequences of different levels of demand-side efficiency on the transmission system. Of particular interest is the extent to which transmission congestion may be relieved through more aggressive energy efficiency and demand-side management (EE/DSM) programs, especially during on-peak periods. This would improve the utilization of the transmission system, and may also provide more opportunities for wind to gain greater access to the transmission system.

Finally, the study specifically addresses regulatory barriers to wind. An inherent weakness of the LMP-based production cost modeling is that it assumes perfect competition with full access to the grid for wind projects whenever it is economically justified. This is not reality, so wind advocates formed a study team to address current operational and regulatory barriers to wind in cooperation with the Federal Energy Resource Commission (FERC). The team has identified where regulatory reform might provide a non-wires alternative to transmission infrastructure additions, particularly in the short term, by selecting specific congested transmission paths for analysis.

2.0 Context and Goals of the RMATS Study

In response to the western power crisis of 2000-2001, the WGA developed a conceptual plan to focus thinking about generation and transmission development in the Western Interconnection. According to the governors, the changing electrical industry regulatory structure, "has uncoupled the historical linkages between new generation development and transmission construction."[1] And in fact, no major transmission project has been permitted or built in the region for 20 years. The WGA plan considered two scenarios: gas-fired generation at load centers, to minimize transmission construction; and an "Other Than Gas" alternative that added coal, gas, and a small amount of wind.

In 2002-2003, the Seams Steering Group-Western Interconnection (SSG-WI) followed up the WGA study in more detail. It modeled three scenarios: High Gas; High Coal; and Renewables, which looked at the effect of adding 13,000 MW of wind, and 5,000 MW of geothermal, biomass, and solar to the western grid. The group found that the High Coal and the Renewables scenarios could reduce costs to all consumers across the region (adding remote wind and coal reduced the total spent on power across the region, after

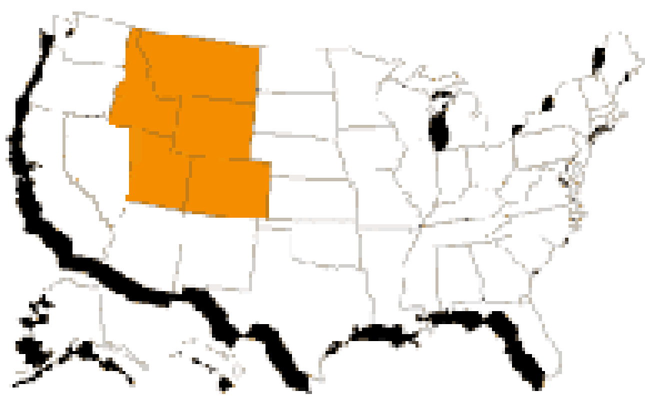

FIGURE 1. STATES INCLUDED WITHIN THE ROCKY MOUNTAIN AREA TRANSMISSION STUDY.

required new transmission is accounted for). The SSG-WI study was conceptual and illustrative only. Detailed studies are necessary to identify and rank transmission solutions for specific major paths. In late 2003 this work was delegated to three subregional planning groups: RMATS for the Mountain states; STEP for the Southwest; and NTAC for the Northwest. Figure 1 shows the region that is covered by RMATS. The Central Arizona Transmission Study (CATS) was a precursor to SSG-WI, and was the first of these new sub-regional transmission planning groups.

2.1 The RMATS Charter and Process

Elements of the RMATS charter invite productive wind industry involvement in the study process and license to affect its outcomes.

One goal states: *Identify technically, financially and environmentally viable generation projects with potential for development in the Rocky Mountain sub-region in the near future.* Wind projects, like the Lamar wind farm in eastern Colorado, have a much shorter lead time than transmission projects or competing coal or gas plants. This creates a mismatch between the transmission planning process horizon and wind development, but also provides an opportunity to advance to the front of the line in response to the governors' stated goals.

Another goal states: *Evaluate needs, alternatives, costs and benefits of generation and transmission…* Another goal calls for *developing necessary information to facilitate regulatory approvals of new transmission*. This presents an opportunity to make a case for environmental benefits across the entire region, and the argument for socialized funding through rolled-in rate treatment across a broad-base of regional consumers to meet public purpose goals.

These wind-related goals are reiterated in the form of additional principles. Most notably:

Conduct analysis of generation and transmission alternatives based on data, assumptions, and scenarios developed by participating stakeholders.

Identify the costs and benefits of generation and transmission options …that make operational, economic, and environmental sense for the sub-region.

Consistent with these goals and principles, wind advocates have successfully pressed for a number of modeling runs, including DSM and carbon sensitivities, near-term wind additions in a 2008 base case, and four 2013 alternatives. These modeling runs simulate the results of developing substantial additions of wind generation to serve Integrated Resource Plans (IRPs) with a minimum of transmission additions, wind development in the high plains areas of Wyoming and Colorado, and wind additions to serve export markets in California and the Northwest. Collecting information from regional wind developers, and with the assistance of personnel from the National Renewable Energy Laboratory (NREL), an RMATS team worked with AWEA and West Wind Wires to identify specific levels of potential wind development in the base case and the 2013 alternatives for specific resource "bubbles" in the five-state RMATS subregion. This information required technical analysis of wind capacity factors and likely turbine types.

3.0 Structure and Process

The RMATS study is led by an 18-person steering committee co-chaired by the Wyoming Governor's energy advisor and the Utah State Energy Coordinator. Members of the steering committee represent mainly state or other public agencies. Study tasks are carried out by seven work groups. Participation is open to all stakeholders. More than 165 people participate in the study, in one or more work groups, about 40 of them actively. They represent all the transmission owners in the region, and investor-owned utilities, generation and transmission co-ops, public power agencies, generation developers, environmental groups, and state regulatory commissions. The modeling team is provided by PacifiCorp, which has the largest utility service territory in the region. An experienced facilitator respected by all parties has been instrumental in keeping the weekly meetings and the overall process on schedule and focused on study goals.

3.1 Study Process

The study process is in practice considerably narrower than the RMATS charter. The SSG-WI study identified 18 major congested transmission paths or "cutplanes" in the RMATS subregion (Figure 2). In this figure, the light blue lines indicate the approximate borders of "load regions" in the RMATS states. These boundaries are generally quite accurate, but one known error is that the northeast corner of Montana should be included in the MPC load region and not the Bdvw region as shown). These load regions are defined by similar load and generation characteristics, and there is limited transmission between adjacent load regions. For eastern Colorado, Figure 2 shows a black circle with a "Colo E" label, which was assigned by the PacifiCorp modelers to the eastern Colorado load region (essentially east of the continental divide in Colorado). A similar label is located in each load region. Also shown are power plants (indicated by colored dots), where the color of the dot identifies the fuel source (coal, gas, etc.) Wind facilities are included in the "other" category, and identified with an orange dot. The light gray lines show transmission lines in the RMATS region. Red lines overlap parts of the light-blue load region boundaries. These lines are the "cutplanes," and represent transmission paths between adjacent load regions that may be constrained. Labels are also provided for each cutplane. For example, the cutplane between the LRS (Laramie River Station) load region in southwest Wyoming and Colo E is labeled "Tot 3." Figure 3 shows the load regions and cutplanes in a simple bubble diagram, and puts the RMATS region in context of the broader Western Electricity Coordinating Council (WECC). When the model is run, the entire WECC region is considered, so the effects of load regions outside the RMATS area are captured. The RMATS study focuses on identifying solutions to the congestion on these paths that reduce total cost. Solutions will emphasize construction of upgrades.

The study uses 2008 as its base case. Generating projects under construction in 2003 are assumed to be the only new resources added to the regional grid by 2008. As a result, the base case represents current congestion on the transmission system. The study then compares dispatch of the current system with four alternative scenarios for 2013. Wind plants, however, can be sited and built in a much shorter time frame than conventional power plants. which leads to a fundamental inconsistency in the time frame of this process. To account for the likelihood that considerable wind capacity will be installed in the region before 2013, a 2008 high wind sensitivity run was included in the study. The 2008 base case includes 508 MW (nameplate) of wind generation in the RMATS region. The 2008 high wind sensitivity case considers 2250 MW (nameplate) of wind capacity throughout the RMATS region.

To construct these scenarios, the Load Forecast Work Group first developed projections of demand growth for each load center. These projections were aggregated into forecasts for each load region, and then into an overall load growth projection for the entire RMATS region. Regional demand is estimated to grow from 136,828 GWh in 2008 to 153,285 GWh in 2013, an increase of 16,457 GWh. See Table 1 for further details about projected load growth by RMATS load region.

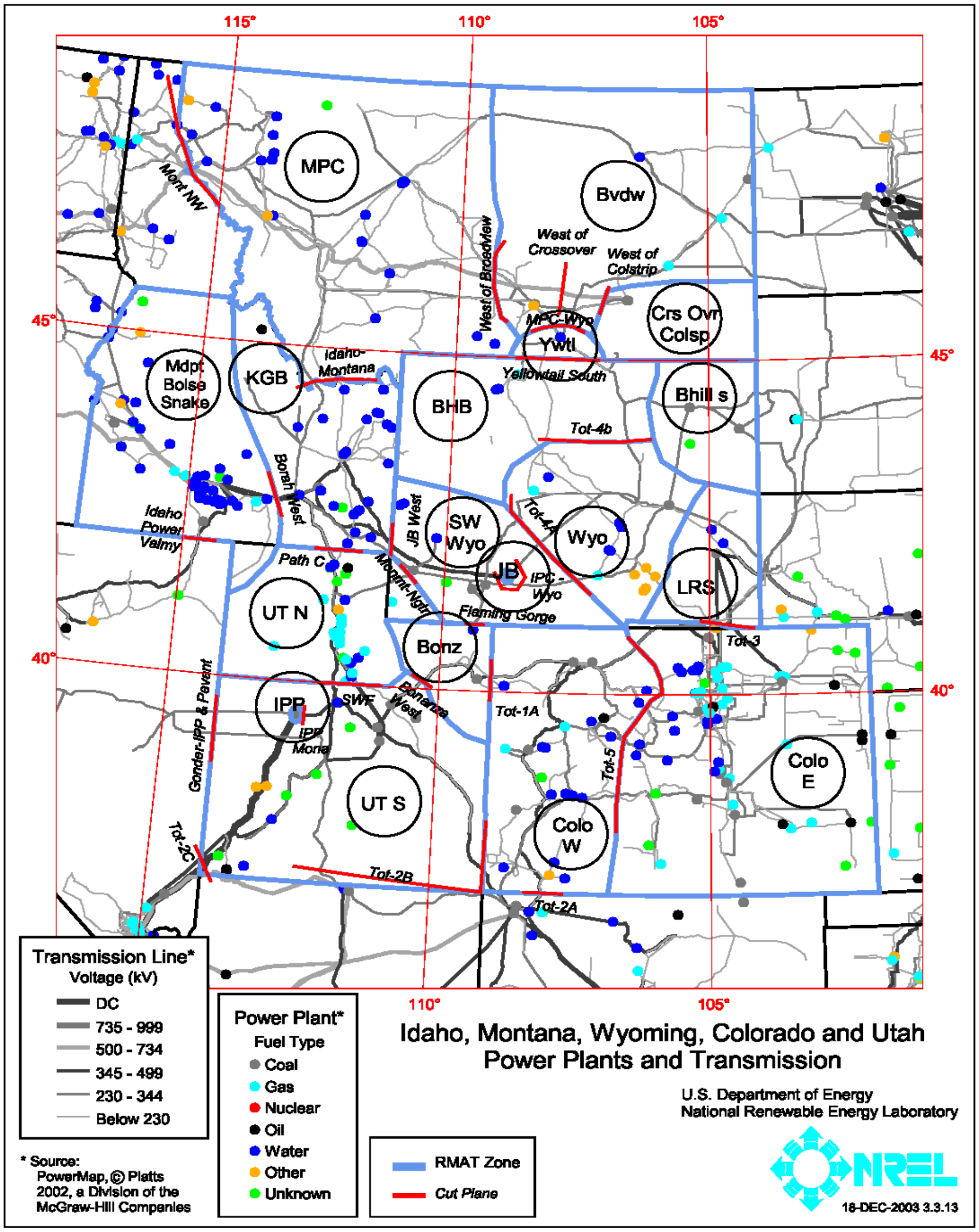

FIGURE 2. LOAD REGIONS AND CUTPLANES WITHIN THE RMATS STATES.

Simultaneously, the Resources Additions Work Group (RAWG) identified all planned and potential generating projects in the region and their points of interconnection to major lines. To estimate the wind projects likely to be added to the regional generation stack, the RMATS Wind Group[2] surveyed the development plans (project size and location) of 15 wind power companies active in the region. It also considered the quantities and locations of renewable resources likely to be required by IOU Integrated Resource Plans and state Renewable Portfolio Standard requirements, projected load growth, and evaluation of regional wind resources provided by NREL staff at the National Wind Technology Center.

The steering committee selected four scenarios ("buckets" in RMATS terminology) to be modeled: Buckets 1 and 2 add new generation sufficient only to meet in-region load growth. Bucket 1 meets load growth and minimizes transmission investment; Bucket 2 uses some remote wind and coal to meet that same load. Buckets 3 and 4 are export scenarios. Bucket 3 adds resources sufficient to meet twice the in-region load growth, and Bucket 4, three times the in-region load growth. The resource mix of these scenarios (in MW of new generation) looks like this:

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Coal (MW)	2,600	2,959	6,149	8,559
Gas (MW)	785	350	660	1,053
Wind (MW nameplate)[3]	2,575	2,955	4,955	10,440
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Total MW (Firm Energy equivalent)	3,900	3,900	7,800	11,700

TABLE 1. 2008 AND 2013 LOADS BY REGION, IN CAPACITY (MW) AND ENERGY (GWH).

		RMATS Loads by Region 2008			RMATS Loads by Region 2013			2008 to 2013 Percent Change		
State	RMATS Load Region	Summer Peak (MW)	Winter Peak (MW)	Energy (GWh)	Summer Peak (MW)	Winter Peak (MW)	Energy (GWh)	Summer Peak	Winter Peak	Energy
Colorado	Colo E	8878	7920	52311	10205	8559	59158	15%	8%	13%
Colorado	Colo W	871	913	5834	941	969	6265	8%	6%	7%
Idaho	KGB	1275	1144	6123	1436	1206	6621	13%	5%	8%
Idaho	Mdpt Boise Snake	3025	2401	15015	3388	2656	16552	12%	11%	10%
Montana	Bvdw	295	299	1875	303	305	1932	3%	2%	3%
Montana	MPC	1107	1120	7033	1136	1145	7244	3%	2%	3%
Montana	Crs Ovr Colsp	74	74	469	76	76	483	3%	3%	3%
Utah	Bonz	49	46	289	57	52	327	16%	13%	13%
Utah	IPP	1	1	8	1	1	8	0%	0%	0%
Utah	UT N	4818	3705	26801	5886	4363	31365	22%	18%	17%
Utah	UT S	537	424	2922	634	490	3354	18%	16%	15%
Wyoming	Bhill s	851	835	5674	936	939	6316	10%	12%	11%
Wyoming	JB	1	1	8	1	1	8	0%	0%	0%
Wyoming	LRS	531	520	3761	566	532	3931	7%	2%	5%
Wyoming	Wyo	304	298	2111	316	312	2223	4%	5%	5%
Wyoming	BHB	425	474	3446	451	496	3625	6%	5%	5%
Wyoming	SW Wyo	423	409	3140	514	504	3868	22%	23%	23%
Wyoming	Ywtl	1	1	8	1	1	8	0%	0%	0%
	TOTAL	23466	20585	136828	26848	22607	153288	14%	10%	12%

The Transmission Additions Work Group (TAWG) then proposed technical solutions for moving the power required by each scenario. It refined these solutions through iterations with the modeling team. It also determined the capital cost of transmission additions to estimate the cost/benefit ratio of each scenario. As in the SSG-WI study, RMATS used the ABB MarketSimulator (COUGER) production cost model as the main modeling tool. In fact, the SSG-WI model was used as the starting point for the RMATS model. More resolution was added in the RMATS region (see Figure 3) and improvements were made to modeling of the wind-generated electricity. A schematic that depicts an overview of the MarketSimulator model is provided in Figure 4. In essence, the model uses a complete data set of generators (capacity, operating costs, availability) and hourly loads by load region, and for each of the four identified scenarios, generation resources are dispatched to meet the load such that the total West-wide production costs are minimized.[4] The model calculates locational marginal prices (LMPs) for both generation and load. Differential LMPs between load regions indicate congestion. For each scenario, the modeling team determined LMPs with the new resources added, without any new transmission added (and with current constraints removed). An increase in LMP relative to the base case indicates additional congestion, whereas a decrease indicates mitigation of the congestion. Iterations were then run to define transmission needs and estimates of the economic benefits (savings in variable operating costs) produced by adding such transmission to reduce congestion and deliver power from lower cost generation.

When the MarketSimulator model is run, hydropower and wind power resources are dispatched *first* because they have the lowest variable operating costs. A realistic hourly wind power production profile for the study years is required by the model. No ancillary service costs associated with wind energy were considered, as they were below the level of detail of the model. Because wind and hydro resources were dispatched first, and because no ancillary service costs were modeled, there was no attempt to model a wind/hydro scenario. In such a scenario, wind and hydro resources are combined to reduce ancillary service costs and take advantage of the built-in energy storage of the hydro facilities. As analysis capabilities of wind and hydropower integration improve, there may be a sensible way to incorporate a wind/hydro scenario into future transmission planning studies.

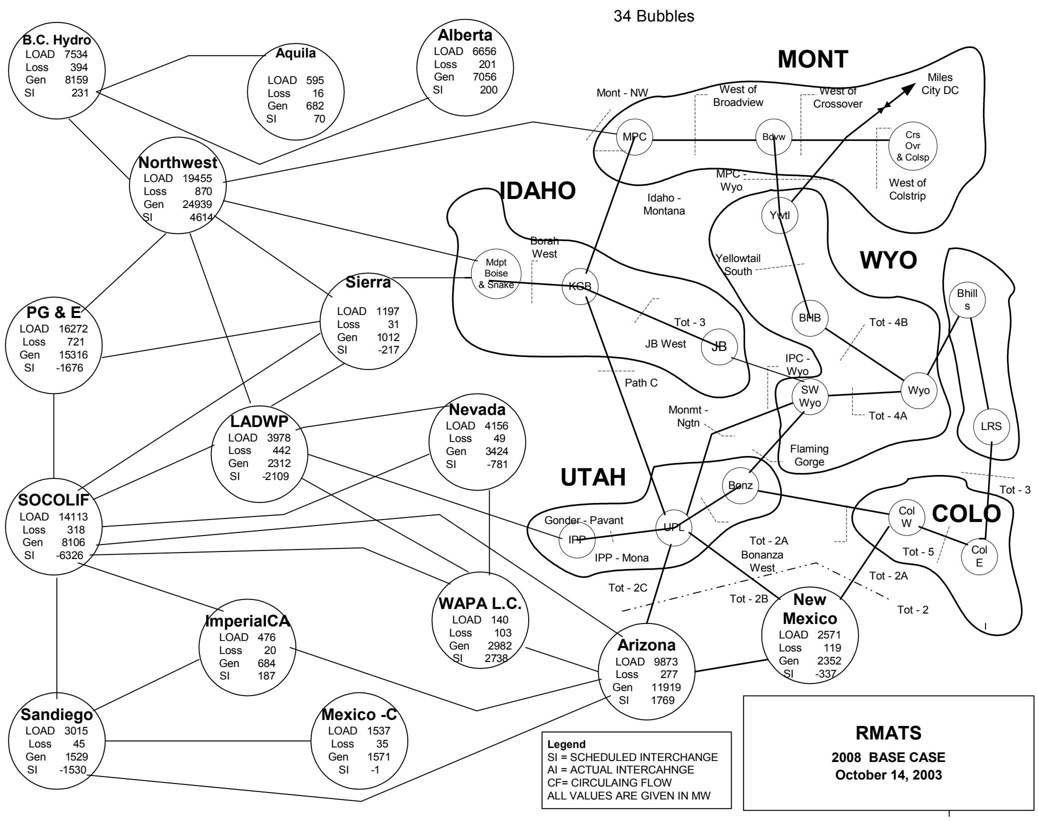

FIGURE 3. RMATS LOAD REGIONS WITHIN THE WESTERN TRANSMISSION SYSTEM.

In the 2013 simulations, the base case for each scenario uses a gas price of \$5/MMBtu, average hydro conditions, and no cost for carbon emissions. The initial runs calculate LMPs of meeting the 2013 loads with the current constraints—i.e., no new transmission added. Iterations then consider removing constraints by adding or upgrading transmission on successive regional (Rocky Mountain) paths and then interregional paths that export power to the Pacific Northwest and Southwest.

Sensitivity model runs examine modifications to these general scenarios. These include low hydro conditions; gas at \$4/MMBtu; CO_2 emissions at \$5/ton, \$10/ton, and \$20/ton; and wider and more consistent use of energy efficiency and DSM programs to reduce load growth. Rather than assume that DSM reduces average load growth across the entire region, RMATS models the effect of load reductions in major regional load centers, to more accurately represent the likely effect of such policies on the regional transmission system. This is significant for wind power because reducing demand in load centers may free up transmission capacity for potential use by wind projects.

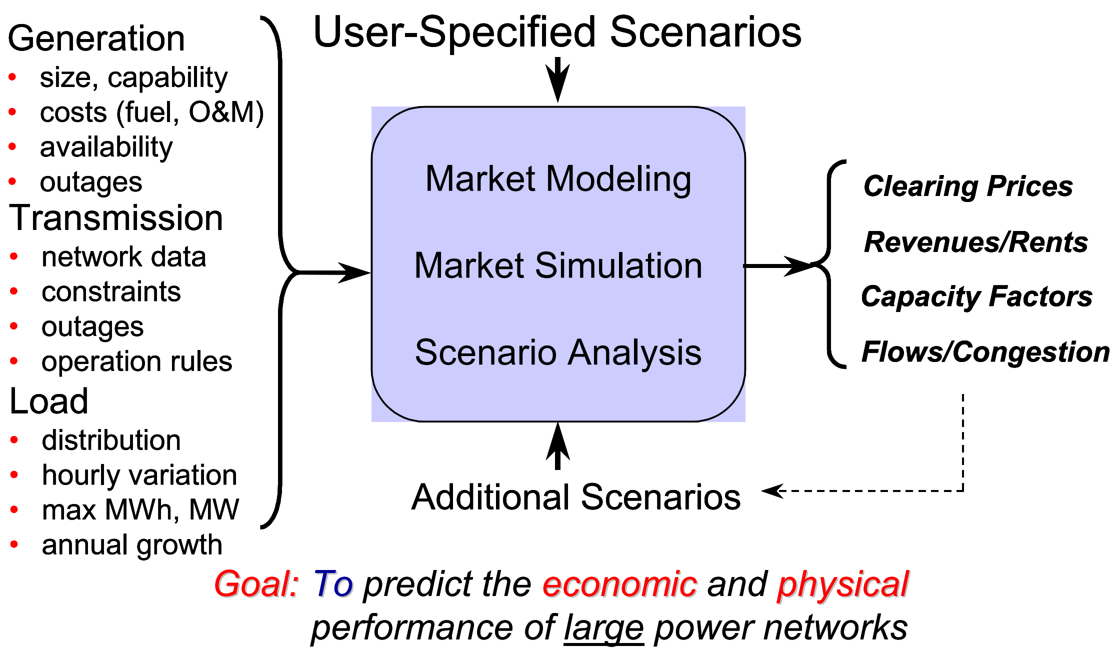

FIGURE 4. OVERVIEW OF THE ABB MARKET SIMULATOR MODEL USED IN THE RMATS STUDY.

The study will ultimately recommend upgrades to specific lines and paths. The modeling process will quantify expected savings in variable costs from reducing congestion on specific paths, after new generation is added. The RAWG estimates the capital cost of the new generation in each scenario, and the TAWG estimates the capital cost of the transmission additions as modeled. Together with the variable cost savings, these produce a cost/benefit ranking for each transmission solution. Study findings will be presented to the SSG-WI for integration into WECC-wide planning and to determine the impact on transfer capability. The study will also present these economically ranked alternatives to the governors.

The RMATS Cost Allocation-Cost Recovery Team addresses the political, legal, and regulatory issues that determine who will pay for any new transmission. It develops a methodology for determining cost responsibility and beneficiary identification. The benefits of relieving congestion on specific paths (which may also mitigate loop flow problems) are often widespread and greatly diffused. This complicates this problem but provides an opportunity to spread the costs of improving the transmission system across the widest class of beneficiaries.

4.0 Tariff and Regulatory Issues

RMATS established a Tariff/Regulatory Work Group (TRWG) to address the potential of using transmission assets more efficiently without constructing new transmission. This broadens the scope of the RMATS study beyond economic modeling and is of great importance to wind power development.

Regulatory and operational practices and policies directly affect the amount and timing of wind development in the RMATS area. Changes in regulation and operations in the 2004-2008 time frame will define the amount of transmission that must be added to the regional system during the study period 2008-2013.

FERC Order 888 and the resulting Open Access Transmission Tariff (OATT) make it nearly impossible for wind to be developed on a merchant or exempt wholesale generator basis. Pancaked tariffs raise the cost of bringing remote, high-quality wind to market. Capacity-based transmission access fees require wind to pay for 100% of line capacity, even though it uses that capacity only about 35% of the time. Making best use of our wind resources requires tariffs in which access fees are paid on load ratio shares and transmission is reserved on an energy-use basis.

Scheduling and imbalance penalties unduly discriminate against wind. No wind project in the country takes firm point-to-point transmission service under a pure Order 888 tariff because imbalance penalties and other ancillary service charges would make wind noncompetitive. Instead, every wind project in the United States takes some form of network service from the transmission provider in the control area where the project is located, has some sort of de jure "exemption" from Order 888, or enjoys a competitive market-like tariff regime. This restricts wind projects' output to one buyer. Meanwhile, there are fair and proven ways of eliminating scheduling penalties The FERC-approved California Independent System Operator (CAISO) protocols allow wind projects to net their over- and under-deliveries on a monthly basis, which effectively eliminates imbalance penalties. Most transmission providers in the RMATS region have yet to consider these reforms.

4.1 Curtailable or Contingent Firm Transmission Product Service

In the RMATS region, as in many others, no firm Available Transfer Capability (ATC) is available over most transmission paths to which wind needs access, even though many are congested for fewer than 20-50 hours per year. Further, this minimal congestion often is at times of low wind output. There appears to be physical capacity on the current system to move significant amounts of wind energy, but no access to that capacity under Order 888 tariffs. The only other product available is short-term, nonfirm point-to-point service, under which wind projects cannot be financed because nonfirm transmission service has no curtailment priority. Using the available physical transfer capacity will require a "contingent or curtailable firm" long-term transmission service product with these fundamental characteristics:

- Quantified curtailment risk and up-front assignment for risk assumption.
- Curtailment priority ahead of short-term firm and any nonfirm transactions.
- Option to upgrade to firm service if ATC becomes available.

4.2 Expansion of Network Service and Related Innovations

Network service, dynamic scheduling, and "virtual wheeling" are alternatives to transmission investment that enable wind to be economically delivered to loads, despite physical constraints and regulatory and operational barriers. Under network service, the interconnecting transmission provider accepts wind-generated electricity as a system resource, by sinking it to its own loads or dynamically scheduling it to buyers in another transmission provider's system. In a few instances, wind generation is accepted in one time frame and other resources are dispatched in another to allow equivalent amounts of energy to flow on unconstrained paths, or at unconstrained times. Circumstances and motivations that allow wind to use network service will be analyzed in RMATS to encourage the broadest possible use of these techniques.

4.3 Dynamic Scheduling/Virtual Wheeling

Two Colorado wind projects connected to the Western Area Power Administration (Western) system north of the constrained Tot 3 cutplane along the Colorado-Wyoming border (see Figure 2) are dynamically scheduled out of Western's territory to Xcel's control area south of the constraint. Essentially, the projects' output data and control responsibilities are handled in Xcel's control operation in Golden, Colorado, rather than in Western's control room in Loveland, Colorado. This mechanism avoids physical flows of power across constrained interfaces. In principle, this appears to be broadly applicable across the RMATS region. A detailed description of these arrangements in RMATS will help to determine whether the extent to which the expansion of dynamic scheduling offers an alternative to transmission investment.

4.4 Virtual Wheeling

In 2001, the National Wind Coordinating Committee reported three Wind Power Transmission Case Studies. Two reported innovative methods for moving wind to markets, in the PacifiCorp, Xcel, and AEP WTU service territories, substitute wind power in time and place with conventional system power. In the case of PacifiCorp and Xcel, high transmission costs across Tot 3 were avoided by substituting energy from 25 MW of PacifiCorp-owned coal power in northwest Colorado for 25 MW of Xcel-owned wind at the Wyoming Foote Creek Rim wind site. In the case of WTU, wind production that would otherwise have been curtailed behind a transmission constraint in West Texas was taken in by WTU and delivered later, when transmission was available.

4.5 Tot 3 Case Study

With active support from FERC, the TRWG will use the constrained Tot 3 (SE Wyoming to Denver) interface to explore several of these approaches. It will determine the amount of physical transfer capacity available during every hour, and if warranted, propose contractual and tariff measures to use this capacity. It will also investigate more extensive use of dynamic scheduling as a means of moving wind across the constraint.

These operational and tariff changes can deliver low-cost wind resources to markets in the short term. By improving collective understanding of these issues, the RMATS can make a contribution to determining whether and to what extent they are alternatives to transmission investments. RMATS can help define the issues for presentation and resolution at FERC, at state utility commissions, and in the business decisions of affected firms.

5.0 Demand-Side Management and Carbon Sensitivities

The RMATS steering committee, at the urging of wind advocates who participated in the study, charged a working group to develop a demand-side efficiency sensitivity to be modeled in the study. Its purpose is to provide information to regulators and decision-makers on how the transmission system may be affected by different levels of DSM. As a supply resource, efficiency might relieve congestion on the existing or planned transmission system, and is a potentially least-cost and environmentally friendly alternative to building new wires. The DSM level is based on the accelerated adoption of cost-effective energy efficiency measures, including:

- More efficient appliances and air conditioning systems
- More efficient lamps and other lighting devices
- More efficient design and construction of new homes and commercial buildings
- Efficiency improvements in motor systems
- Greater efficiency in other devices and processes used by industry.

These measures are all commercially available but underused. Efficiency at the proposed levels can offset the need to build new generation plants (as many as 17, 500-MW power plants in the RMATS region by 2020) with their associated transmission requirements.

The sensitivity runs evaluate higher levels of energy efficiency and DSM in Scenario 2 (meeting load with only regional resources) and Scenario 4 (the high export case). These high efficiency sensitivities assume that utility (or state-based) energy efficiency programs ramp up during 2004 and 2005, and that these programs reduce electricity use by 1% per year and summer peak demand by 1.5% per year during 2006-2013. These programs occur in all states under consideration: Colorado, Idaho, Montana, Utah, and Wyoming. Several considerations underpin these assumptions:

- There are few or no electricity savings from utility or state-based energy efficiency programs in the baseline scenario.

- After the phase-in period, the electricity savings are equivalent to those achieved by the best efficiency programs in the country, but are only about half the savings identified in the Southwest Energy Efficiency Project's (SWEEP's) *New Mother Lode* study.

- The peak demand reduction is greater than the electricity savings in percentage terms because DSM programs tend to emphasize measures that reduce peak electricity demand, such as reducing cooling load and improving the efficiency of cooling systems.

These measures emphasize summer peak load reduction. Winter peak load reduction is assumed to be the same as the overall electricity savings in percentage terms.

Assuming a 0.33% energy saving in 2004, 0.67% in 2005, and 1% each year during 2006-2013, cumulative total savings would be 9% in 2013 (assuming no degradation in savings from measures installed in the early years). Since in reality there will be some loss of savings over time, it is more conservative to assume 8% energy savings in 2013 as a result of this effort. The winter peak demand reduction is assumed to be 8% as well. But since the rate of peak demand reduction is assumed to be 1.5 times the rate of electricity savings in percentage terms, there would be a 12% summer peak demand reduction by 2013.

Several utilities in the Southwest region have already established electricity savings and peak demand reduction goals along these lines. For example, the Fort Collins, Colorado, municipal utility has adopted a goal to reduce per capita electricity consumption 10% and per capita peak demand 15% by 2012. And Austin Energy, the municipal utility in Austin, Texas, plans to cut electricity use and peak demand 15% by 2020 through its energy efficiency and load management efforts.

Table 2 presents the electricity savings and peak load reductions in the high efficiency scenario in 2013 by load area, for the primary load areas in the RMATS project. The electricity savings and summer peak load reductions eliminate a significant fraction of the load growth projected during 2003-2013 in the baseline scenario, especially in key areas such as the Colorado East (Colo E) and Utah North (UT N). For the region as a whole, the high efficiency scenario eliminates about 50% of the summer peak demand growth and 40% of the total electricity load growth during 2003-2013 in the baseline scenario.

Table 3 presents the estimated investment in energy efficiency measures necessary to realize this level of electricity savings and peak load reduction by 2013. These estimates assume that electricity in the region costs on average \$0.06/kWh (2004 dollars) and that efficiency measures have an average three-year simple payback period. This is a fairly conservative assumption; many efficiency measures have shorter paybacks. To achieve the projected energy savings in the high efficiency scenario, the estimated total investment in energy efficiency in the RMATS region during 2004-2013 is about \$2.3 billion (2004 dollars). This table includes utility and participant costs, and includes a 5%

surcharge on top of the cost of efficiency measures to account for efficiency program marketing, administration, etc.

TABLE 2. ELECTRICITY SAVINGS AND PEAK LOAD REDUCTIONS
IN THE 2013 HIGH EFFICIENCY SCENARIO BY RMATS LOAD REGION

				Baseline Scenario			High Efficiency Scenario			High Eff. Scenario Savings			Savings in 2013 as a fraction of baseline growth 2003-2013		
RMATS Load Region	2003 Summer Peak (MW)	2003 Winter Peak (MW)	2003 Energy (GWh)	2013 Summer Peak (MW)	2013 Winter Peak (MW)	2013 Energy (GWh)	2013 Summer Peak (MW)	2013 Winter Peak (MW)	2013 Energy (GWh)	2013 Summer Peak (MW)	2013 Winter Peak (MW)	2013 Energy (GWh)	Summer Peak (MW)	Winter Peak (MW)	Energy (GWh)
Colo E	7,724	7,329	46,256	10,205	8,559	59,158	8,980	7,874	54,425	1224.6	684.72	4732.64	0.49	0.56	0.37
Colo W	806	860	5,433	941	969	6,265	828	891	5,764	112.92	77.52	501.2	0.84	0.71	0.60
KGB	1,132	1,085	5,662	1,436	1,206	6,621	1,264	1,110	6,091	172.32	96.48	529.68	0.57	0.80	0.55
Mdpt Boise Snake	2,701	2,170	13,621	3,388	2,656	16,552	2,981	2,444	15,228	406.56	212.48	1324.16	0.59	0.44	0.45
Bvdw	287	293	1,820	303	305	1,932	267	281	1,777	36.36	24.4	154.56	2.27	2.03	1.38
MPC	1,079	1,096	6,828	1,136	1,145	7,244	1,000	1,053	6,664	136.32	91.6	579.52	2.39	1.87	1.39
Crs Ovr Colsp	72	72	455	76	76	483	67	70	444	9.12	6.08	38.64	2.28	1.52	1.38
Bonz	42	41	255	57	52	327	50	48	301	6.84	4.16	26.16	0.46	0.38	0.36
UT N	3,944	3,146	22,901	5,886	4,363	31,365	5,180	4,014	28,856	706.32	349.04	2509.2	0.36	0.29	0.30
UT S	455	367	2,546	634	490	3,354	558	451	3,086	76.08	39.2	268.32	0.43	0.32	0.33
Bhill s	774	743	5,097	936	939	6,316	824	864	5,811	112.32	75.12	505.28	0.69	0.38	0.41
LRS	498	508	3,598	566	532	3,931	498	489	3,617	67.92	42.56	314.48	1.00	1.77	0.94
Wyo	292	285	2,005	316	312	2,223	278	287	2,045	37.92	24.96	177.84	1.58	0.92	0.82
BHB	400	453	3,276	451	496	3,625	397	456	3,335	54.12	39.68	290	1.06	0.92	0.83
SW Wyo	348	332	2,549	514	504	3,868	452	464	3,559	61.68	40.32	309.44	0.37	0.23	0.23
Other	3	3	24	3	3	24	3	3	22	0.36	0.24	1.92	NA	NA	NA
Total	20,557	18,783	122,326	26,848	22,607	153,288	23,626	20,798	141,025	3221.76	1808.56	12263.04	0.51	0.47	0.40

To effectively model the impact of efficiency in the high export case, it was important to look at efficiency programs in western states outside the RMATS region. For Arizona and New Mexico, the same electricity savings potential (8% electricity savings, 12% summer peak demand reduction by 2013) is assumed, since these states have very weak energy efficiency programs. However, half as much incremental savings potential is assumed in in California, Oregon, and Washington (an incremental 4% electricity savings and 6% peak demand by 2013), since relatively well-funded, substantial energy efficiency programs are underway in these states and savings from these programs is already factored into load forecasts. Efficiency programs can still be scaled up to achieve greater energy savings in the coastal states, and in fact California is in the midst of establishing new, more aggressive energy savings and peak load reduction goals and scaling up DSM programs to meet these goals.

5.1 Carbon Sensitivity

The RMATS steering committee also asked the DSM work group to develop a carbon sensitivity, to measure impacts on the model results of some level of carbon regulation. For this study, \$5, \$10, and \$20 per ton adders for CO_2 were introduced into the modeling runs for the same 2013 cases as in the DSM sensitivity: the regional transmission case that assumes development of high plains coal and wind, and the high export case. These adders were assumed to be reasonable since the current PacifiCorp IRP considers CO_2 at \$8 per ton and the company is required to model as much as \$40 per ton for the Oregon Public Utility Commission. The tipping point between the net present value of costs for coal and wind is also currently about \$8 per ton, according to the Oregon Department of Energy. In other words, when CO_2 costs \$8/ton or more, wind will begin to be dispatched ahead of coal. The reasonableness of the value used in the study is supported by the fact that the average of a number of studies of the cost of saving one ton of CO_2 places this cost at about $27 per ton.

TABLE 3. ESTIMATED INVESTMENT IN ENERGY EFFICIENCTY MEASURES NECESSARY TO REALIZE ELECTRICITY SAVINGS AND PEAK LOAD REDUCTION BY 2013

Area	2013 Baseline Energy (GWh)	2013 Energy Savings (GWh)	Value of Savings in 2013 (Million $)	Energy Efficiency Investment (Million $)
Colo E	59,158	4,732.6	313.3	986.9
Colo W	6,265	501.2	33.2	104.5
KGB	6,621	529.7	28.7	90.3
Mdpt Boise Sna	16,552	1,324.2	71.6	225.7
Bvdw	1,932	154.6	11.1	35.0
MPC	7,244	579.5	41.7	131.3
Crs Ovr Colsp	483	38.6	2.8	8.8
Bonz	327	26.2	1.5	4.7
UT N	31,365	2,509.2	143.8	452.9
UT S	3,354	268.3	15.4	48.4
Bhill s	6,316	505.3	24.8	78.1
LRS	3,931	314.5	15.4	48.6
Wyo	2,223	177.8	8.7	27.5
BHB	3,625	290.0	14.2	44.9
SW Wyo	3,868	309.4	15.2	47.9
Other	24	1.9	0.1	0.4
Total	153,288	12,263	742	2,336

The 2003 initiative by the governors of California, Oregon, and Washington to substantially reduce their greenhouse gas emissions is relevant to the high export case. The agreement includes emissions from resources imported from other states, which makes it important to analyze the results of a carbon-sensitivity study in the export scenario to determine the attractiveness of RMATS resources in coastal state markets.

6.0 Wind Data Collection Issues

To accurately model the transmission system, the ABB model requires hourly wind power production estimates from each RMATS load region for 2008 and 2013. Although NREL has a significant archive of hourly wind speed data from several sources, the data had to be adapted for this study. The primary data sources are from Kenetech's data collection program and the Utility Wind Resource Assessment Program. Figure 5 shows the location of these sites. Unfortunately, the data from these sources are generally not time-coincident, and the quality of the data is variable. During the data gathering process, AWEA polled its industry members for wind speed data; however, this information was proprietary and could not be provided.

The resource assessment group at NREL did a detailed quality assessment of the data that most closely matched the study region. Sites with very poor data recovery rates were eliminated, as were sites that did not have data to adequately represent the load areas. Missing hourly data were replaced based on either correlation with other nearby sites or by a combination of statistical techniques and the professional judgment of the analyst. In some cases, the hourly data are from anemometers placed too low to the ground to represent the wind that would be encountered by a modern wind turbine. These data were adjusted to accurately represent a potential wind site, and were correlated with other known data from wind mapping efforts.

Once hourly wind speeds were calculated for each load region, they were applied to a power curve for a modern (2004), currently available wind turbine with an 80-meter hub height. In the context of the RMATS study, which examines 2008 and 2013, the hourly wind energy estimates seem quite conservative compared to the technology that will be in the ground nearly ten years in the future. Figure 6 shows the annual capacity factors from each representative wind site, which are significantly higher than those computed with the power curve for wind turbine technology only a couple years old. Also, the effects of elevation (i.e., decrease in air density) were factored into these calculations.

Several members of the RAWG proposed using an approximation method to calculate the capacity contribution of the wind plants. The proposal was to calculate the wind capacity factor during the summer peak hours (June 15 – September 15, hours ending between 1:00 p.m. and 7:00 p.m.). Figure 7 illustrates this capacity value proxy. Although this approach is similar to the one adopted in the PJM interconnection (Pennsylvania, New Jersey, and Maryland regional transmission organization), a better approach is to base the capacity credit proxy calculation on the top 10% of load hours, unless a reliability model can be used to calculate capacity value directly. Using a summer period exclusively for regions that experience both summer and winter peaks misses some of the high-risk hours that should be captured by the capacity value calculation. Using this approach, we calculated the capacity value of wind projects in each of the RMATS load areas. These capacity values averaged 31% across the region. This notwithstanding, the RMATS steering committee assigned a 20% capacity value to all the wind projects modeled in each load region. In future studies we hope that a more empirical approach can be taken.

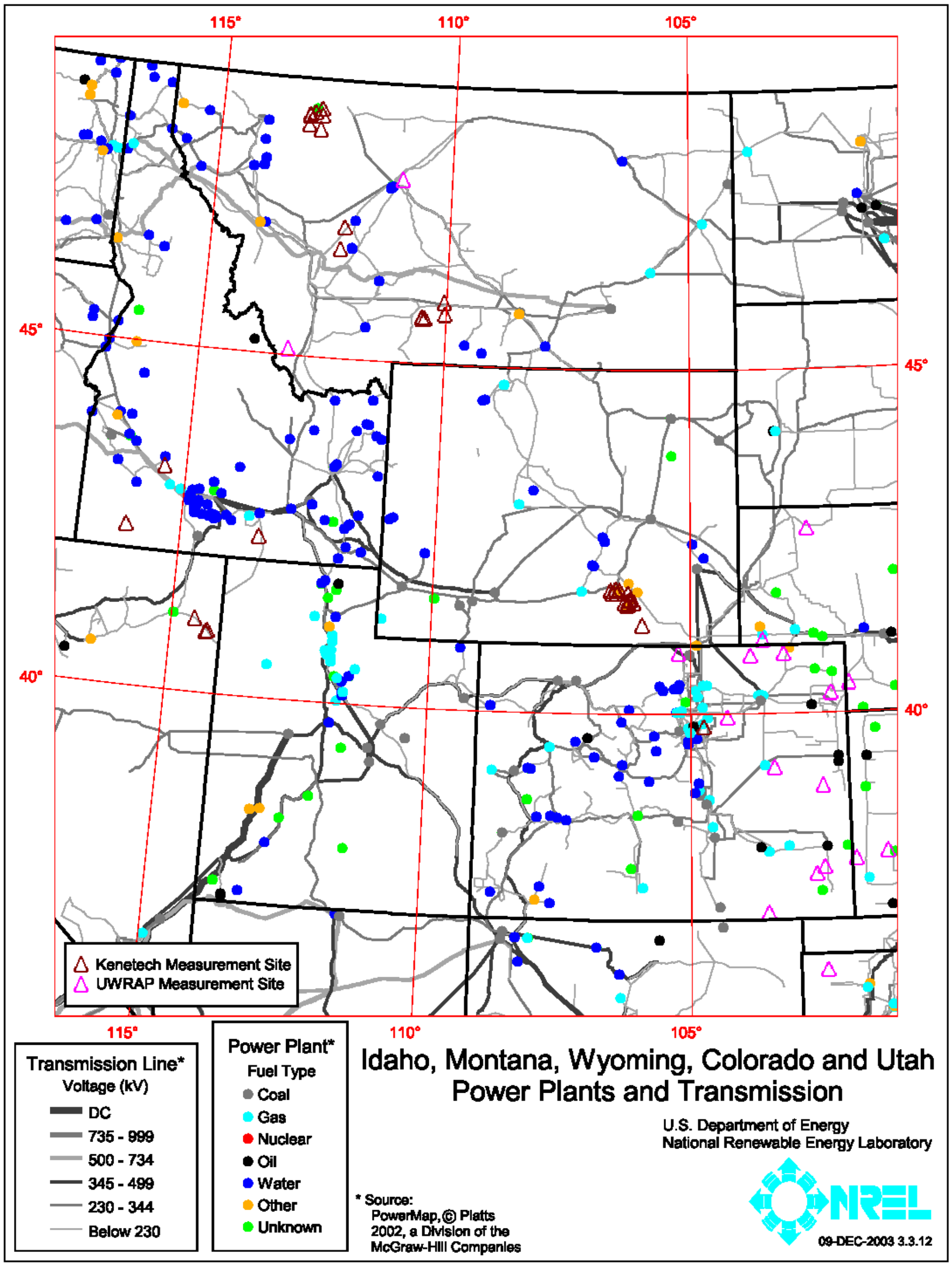

FIGURE 5. RMATS REGION WIND DATA RESOURCES.

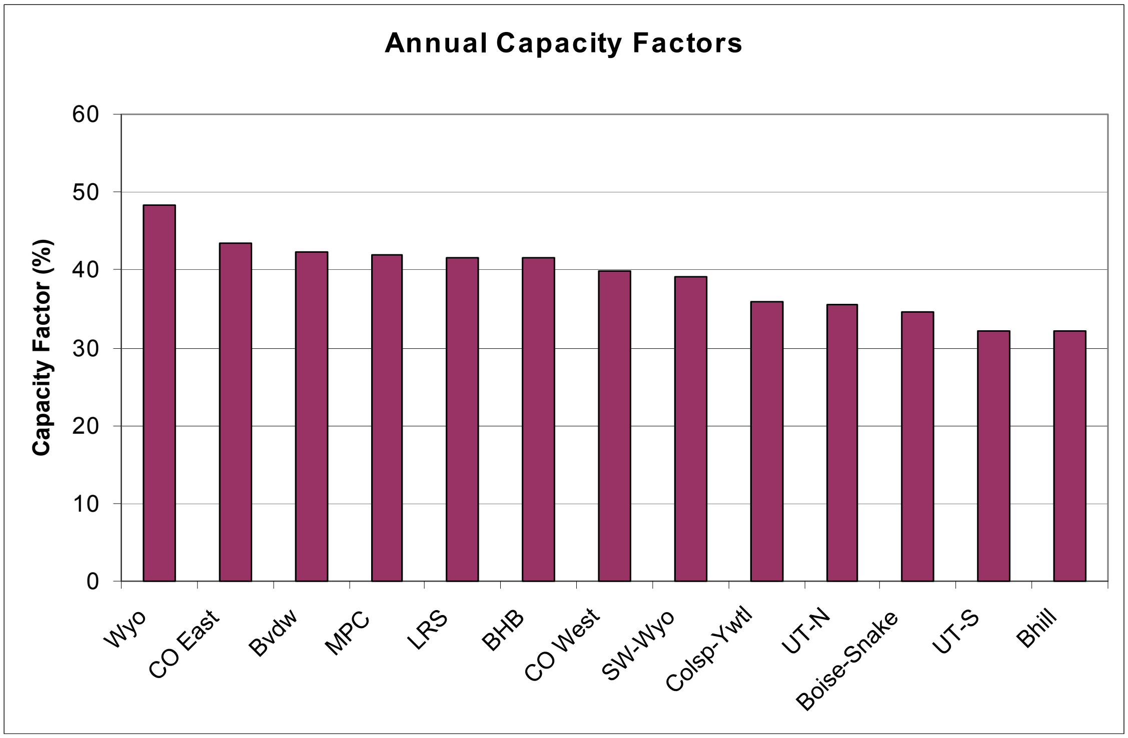

FIGURE 6. WIND CAPACITY FACTORS IN THE RMATS LOAD REGIONS.

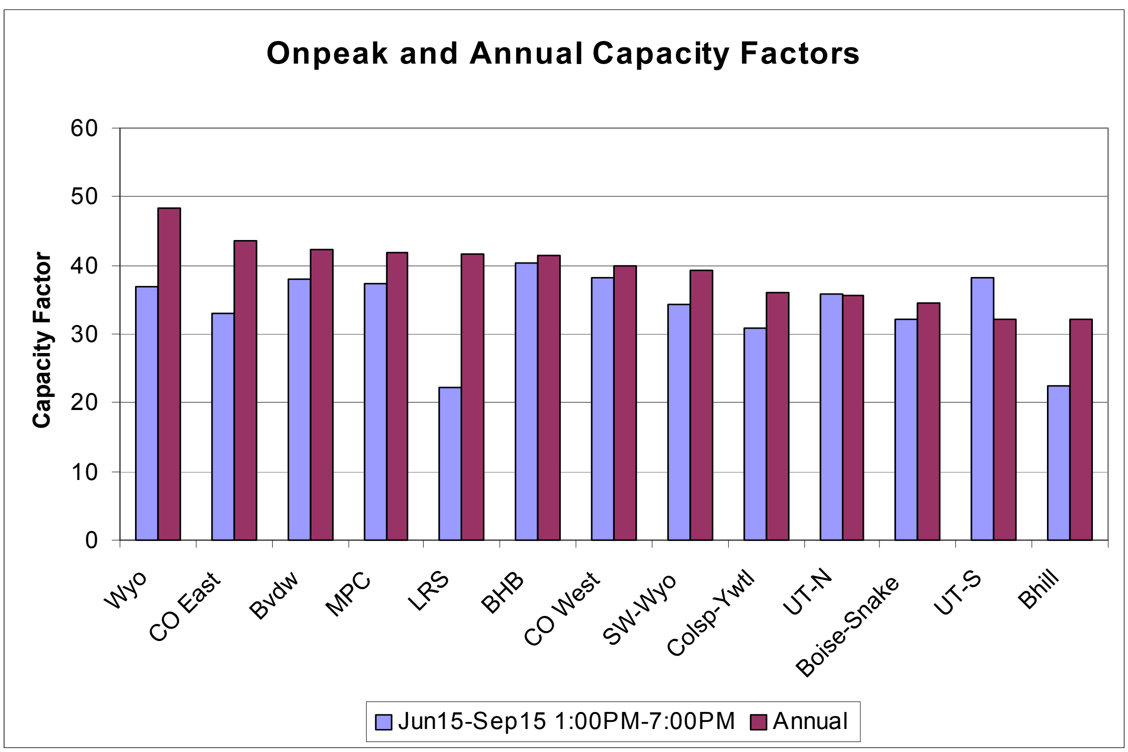

FIGURE 7. CAPACITY CREDIT PROXY BASED ON SUMMER PEAK PERIOD IN THE RMATS LOAD REGIONS.

Determining the magnitude and temporal characteristics of wind power production for the RMATS modeling process required us to determine where wind development would most likely take place over the next several years, and to develop hourly wind speed data in those areas. Some important conclusions were reached during the data collection process, and its transformation into hourly power production estimates:

- Little wind speed data are available for public use from towers 40 meters or taller throughout the West. A focused effort to obtain a minimally sufficient set of time-coincident tall tower data in many of the wind regimes throughout the West is needed.

- Using the most recent wind turbine technology and power curves (adjusted for elevation) to compute power output and capacity factors is crucial and can have a significant impact on capacity factors.

- Transmission planning expansion is likely to drive where and how much wind is developed in the next several years. A wind industry advisory group could be instrumental in leading these planning processes to consider how much wind development could occur in different regions.

7.0 Critique of the RMATS Process

Structural and analytical limitations directly affect reported results. These include:

- **Assumption that new construction is necessary**. This bias is understandable, given that no new transmission has been built in the region for 20 years even as loads have grown. However, the western power crisis of 2000-2001 created an urgency to re-examine transmission needs. Further, ample data indicate that investments to relieve congestion will reduce the overall regional cost of power. But structuring the study around this assumption discourages consideration of nonconstruction alternatives for reducing congestion—even though such alternatives may be less expensive and could be implemented much more quickly than upgrades.

  This study bias affects wind and energy efficiency much more than other supply resources. Many paths in the region are constrained only a few hours per year. Because intermittent wind projects can accept some level of curtailment, they can use the physical transfer capacity available on such lines in the hours they are not constrained. For wind, more efficient use of the existing transmission system is the most important issue.

- **Little focus on better use of existing transmission assets**. Although no ATC is available on the main paths in the region, many interfaces are constrained only a small number of hours per year. Identifying the amount of physical transfer capacity available on major paths hour by hour could identify opportunities for moving significant amounts of power across the existing system. This is potentially a cost-effective alternative or complement to upgrades and new transmission construction.

- **Lack of integrated resource planning**. Many utilities that contribute load growth forecasts to the study do not have DSM programs and do not consider efficiency improvements as a supply resource. Widespread unfamiliarity with DSM (and corresponding skepticism about its effectiveness) led the RAWG to model efficiency only as a lower rate of regional average demand growth, and then only as a sensitivity to the base cases that assume business as usual demand growth.

  To the extent that DSM programs constitute the least-cost way to meet demand growth, and given that efficiency increases will relieve congestion without new construction, the study may thus overestimate the cost-effectiveness of new transmission. This issue affects wind power directly, because as an intermittent resource it may be able to make full use of transmission capacity created by demand reduction—especially during peak periods. A least-cost transmission plan would likely need to explore how much efficiency and wind could be added.

  Further, no explicit criteria or systematic approach was used to select the mix of coal, gas, and wind modeled for each scenario. Instead, these were chosen on an ad hoc basis and influenced heavily by past utility practice and comfort with fossil resources.

- **LMP-based modeling**. LMP models assume the market is perfectly competitive and (unless manually jiggered by adjusting path ratings) that there are no tariff and contractual restrictions on power transfer. They therefore significantly overstate transfer capability, compared to actual amounts. Upgrades found cost-effective in the modeling may be less so when applied to contractually constrained (versus physically constrained) interfaces. The overstatement, however, may indicate the value of solving the congestion problem on subject paths.

- **Unclear authority over study process and results**. There is no formal linkage between the RMATS process and transmission planning work at SSG-WI or WECC, although many of the parties active in RMATS are also active in SSG-WI and WECC. All processes are voluntary. The RMATS steering committee has responsibility for the study process and results, and is answerable to the governors who requested the study. But study results remain vulnerable to special influence by those utilities (including ones outside the region) that have large financial stakes in which transmission routings and which generation mixes are modeled.

- **Uncertain standing of study recommendations**. RMATS, like SSG-WI, is not sanctioned by any state or federal authority. Implementation of any study recommendations will depend on regulatory and legislative approvals, and the large investment in planning made by participants will remain at risk for some time.

- **Initiative is dependent on commitment of governors**. RMATS was launched by two governors. The willingness of stakeholders to participate in the project is significantly driven by the interest of Western governors in transmission planning.

- **Major commitment required by at least one utility**. PacifiCorp has been the lynchpin in the RMATS transmission modeling effort. It would not be possible to conduct the RMATS project without the commitment of PacifiCorp's modeling team.

- **Role of new transmission technologies is unclear**. A number of promising new transmission technologies are being commercialized. However, it is not clear whether these technologies will be adequately evaluated in the RMATS process because of the conservatism of transmission planners and the lack of active participation by knowledgeable advocates of new transmission technologies in the RMATS process.

8.0 Results to Date: Lessons for Wind Transmission Planning

At this writing, the RMATS study is still in process. Phase 1 is intended to quantify the costs of regional transmission congestion in 2008 and 2013 and the most cost-effective ways of reducing that congestion, through upgrades and new transmission construction and through changes to regulatory and operational policies. Phase 1 is scheduled for completion in June 2004. Phases 2 and 3 will then focus on regulatory approvals, siting, engineering, financing and construction of the priority solutions.

The 2008 base case found that removing all transmission constraints in the WECC would produce savings in variable operating and maintenance (VOM) costs of $129 million/year. Removing just the constraints in the RMATS region would produce VOM savings of $7.5 million/year. It found the six most congested Rocky Mountain paths, ranked in order of cost-effectiveness to solve, to be: Idaho to Montana (E. Idaho to W. Montana); Tot 2C (SW Utah to SE Nevada): Bridger West (SW Wyoming to SE Idaho/Pacific Northwest); the IPP DC line (central Utah to So. California); Tot 3 (SE Wyoming to NE Colorado); and SW Wyoming to E. Utah.

For 2013, the study investigates the four scenarios outlined in Section 3.1 above. Scenarios 1 and 2 add 3,900 MW of generation, to meet RMATS regional load growth to 2013; Scenario 3 (7,800 MW new generation) and 4 (11,700 MW new generation) consider export of power from the region. Draft Scenario 2 results show that removing Rocky Mountain constraints would produce VOM savings of $228 million/year. No other economic results are yet available.

The study will next add in the capital costs of both the new generation and the transmission upgrades to the VOM-based results of the production cost modeling in order to estimate the total costs and benefits of physical upgrades. It will also conduct sensitivity runs to evaluate the effects of different fuel prices, hydro conditions, energy efficiency-driven load reductions, and carbon costs.

Both the SSG-WI and RMATS studies provide a major opportunity for transmission owners, operators, planners and regulators to evaluate renewable resources and energy efficiency as potentially significant and cost-effective supply options alongside coal and gas. They also provide an important opportunity for clean power advocates to learn more about the operation of the grid. Active participation in these—and the similar studies underway or planned for other regions—is critical to the near-term and intermediate-term prospects for wind power. Without the sustained participation of representatives of the wind power and energy efficiency industries and of environmental organizations, it is likely that the current electricity planning for the region would have taken a much more limited approach to diversifying regional power supply.

9.0 Acknowledgments

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[1] *Conceptual Plans for Electricity Transmission in the West*, Report to the Western Governors' Association, August 2001.

[2] Roger Hamilton, Wind Wires West; Ron Lehr, AWEA; Dave Olsen, Center for Energy Efficiency and Renewable Technologies; John Nielsen, Western Resource Advocates; Wayne Shirley, Regulatory Assistance Project; and Brian Parsons, Michael Milligan (consultant) and Tom Acker of NREL.

[3] The RAWG multiplied nameplate wind MW by a 20% capacity credit to represent firm capacity. NREL wind resource assessment staff subsequently calculated the wind capacity credit for each of the 18 RMATS load regions; these averaged 30.1% across the region. NREL also calculated capacity factors for wind in each of the 18 RMATS load regions; these ranged from a low of 30% in southern Idaho to a high of 48.5% in south-central Wyoming.

[4] Framework for Expansion of the Western Interconnection Transmission System, October 2003, Report of the Seams Steering Group-Western Interconnection (SSG-WI), Appendix A, http://www.ssg-wi.org/GeneralWorkGroupDetails.asp?wg_id=3&wg_name=Planning.

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14. ABSTRACT *(Maximum 200 Words)*
Plans to expand the western grid are now underway. Bringing power from low-cost remote resources—including wind—to load centers could reduce costs for all consumers. But many paths appear to be already congested. Locational marginal price-based modeling is designed to identify the most cost-effective paths to be upgraded. The ranking of such paths is intended as the start of a process of political and regulatory approvals that are expected to result in the eventual construction of new and upgraded lines. This paper reviews the necessary data and analytical tasks to accurately represent wind in such modeling, and addresses some policy and regulatory issues that can help with wind integration into the grid. Providing wind fair access to the grid also (and more immediately) depends on tariff and regulatory changes. Expansion of the Rocky Mountain Area Transmission Study (RMATS) study scope to address operational issues supports the development of transmission solutions that enable wind to connect and deliver power in the next few years—much sooner than upgrades can be completed.

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