Executive Summary

Joint Coordinated System Plan 2008 Overview

The Joint Coordinated System Plan 2008 (JCSP'08) analysis offers a conceptual regional transmission and generation system plan for a large portion of the Eastern Interconnection in the United States, developed with the participation of most of the major transmission operators in the Eastern Interconnection. This initial effort looks at two scenarios that expand transmission and generation opportunities between 2008 and 2024 – a Reference Scenario and a 20% Wind Energy Scenario in support of the U.S. Department of Energy's Eastern Wind Integration and Transmission Study. Future JCSP analyses will examine additional scenarios.

Several features distinguish the JCSP'08 study from prior transmission expansion studies:

- The JCSP'08 is the first inter-regional planning effort to involve most of the major transmission operators in the Eastern Interconnection. The study represents the collaborative efforts of Midwest ISO, SPP, PJM, TVA, MAPP and several key members of SERC. The New England and New York areas are also included in the study analysis. Most other transmission studies address smaller regional footprints.
- The JCSP'08 used a collaborative, transparent, stakeholder process to develop and screen key analytical assumptions and design the transmission expansion options for the two scenarios studied; many other transmission studies have less direct stakeholder involvement.
- The JCSP'08 uses common economic and system condition assumptions to characterize most of the Eastern Interconnection in a single multi-regional analysis, rather than through parallel, region-specific analyses.

This JCSP'08 study is valuable as a demonstration of the value of an inter-regional planning process, as well as for its analytical planning results. From the process standpoint, the JCSP'08 put together a wide-reaching stakeholder involvement process over a near-Interconnection-wide area; this will enhance the Eastern Interconnection's ability to conduct future planning activities pursuant to FERC Order 890. The JCSP'08 also developed a process to identify, evaluate and screen alternative high-voltage transmission overlays, which has rarely been done in planning to serve smaller regions. From an analytical standpoint, the JCSP'08 establishes that transmission overlays may provide significant economic value by reducing grid congestion and facilitating new renewable resource development (within the context of the scenarios evaluated).

The JCSP'08 offers a valuable foundation for future planning work within the Eastern Interconnection. Future interconnection-wide planning analyses should test additional scenarios to examine the reliability and economic impacts of alternative combinations of supply-and-demand-side resource technologies, densities and locations and transmission infrastructure options, and also conduct sensitivity analysis to determine the implications of varying assumptions such as fuel and technology costs, load projections, plant retirements, and carbon regulation options and costs.

Section 2 of this study describes the process of developing the JCSP'08.

JCSP'08 Scenario and Transmission Overlay Development

The traditional approach to transmission planning is to evaluate targeted transmission additions to meet specific reliability or economic needs, building individual high voltage transmission lines (mostly 345 kV and below) and adding substation and voltage management equipment to meet identified system needs such as load growth or new generation interconnection. These targeted additions are evaluated using both reliability and economic modeling, often under alternative scenarios stretching out to a specified future horizon year. An alternative to this approach entails using production cost simulation information to identify a portfolio of transmission system expansion options involving multiple, major, simultaneous high voltage additions (that can include HVDC as well as 765kV, 500kV and 345 kV technologies) that together serve and link entire regions and markets across an entire interconnection. Such a transmission expansion is called a "transmission overlay." The targeted method has been the dominant means of transmission expansion in the Eastern Interconnection. But with the possibility of national Renewable Portfolio Standards and the development of large amounts of new generation resources in certain regions of the nation to meet such standards, this JCSP'08 analysis was designed to look at the costs and benefits of transmission overlays that can serve a range of policy goals. As with any transmission expansion plan, evaluation of an overlay requires considering a broad range of reliability, economic, and environmental drivers.

The JCSP'08 Study developed and analyzed the costs and benefits of conceptual transmission overlays for two scenarios. The Reference Scenario assumes that the existing laws and policies governing generation resource choices remain in place and was premised on the assumption that incremental wind development would address existing RPS requirements, which translates to an average 5% wind energy development across the U.S. portion of the Eastern Interconnection. The scenario assumes each state will build as much new on-shore wind generation as its total RPS requires, and on-shore wind generation will be built as closely as possible to the regional load. For example, the JCSP'08 reference scenario assumes that wind needs within New England are met with on-shore wind projects within New England,[1] as opposed to wind imports from the Midwest or Canada. Under the Reference Scenario there will be about 60,000 MW of new wind developed by 2024, along with 75,600 MW of additional base load steam generation. Many possible transmission overlays were developed and one was selected to represent the Reference Scenario.

The second scenario, the 20% Wind Energy Scenario, assumes that the entire Eastern Interconnection will meet 20% of its energy needs using wind generation by 2024. In this scenario, the bulk of the wind production capacity is assumed to be located in those areas with the highest quality (best capacity factor) on-shore wind resources, which are located in the western part of the Eastern Interconnection.[2] The 20% Wind Energy Scenario assumes that 229,000 MW of new wind capacity will be built by the year 2024, with 36,000 MW of new base load steam generation. Here too, a number of possible transmission overlays were examined and one was selected because it provided the best optimal performance based on the assumptions in the study.

[1] It was beyond the scope of this study to examine and model the potential for off-shore wind development along the East Coast due to lack of data availability, but those options should be examined in future transmission development scenarios.

[2] The study authors recognize that beyond the specific 20% Wind Energy Scenario outlined here, there are other options for meeting a 20% wind energy target, as well as more broadly formulated targets for renewable energy, that would involve different renewable resource development patterns and different transmission overlay patterns. This study makes no judgment on the superiority or desirability of this scenario relative to others, which could and should be developed in future analyses of the Eastern Interconnection.

The JCSP'08 used an iterative process to assure that each conceptual overlay delivers economic value as well as system reliability. The planning process starts by performing a capacity expansion analysis for each of the regions under study. These capacity expansion assumptions are then incorporated into transmission and production cost models. These models then allow for the development of conceptual transmission overlays to economically deliver energy to the Eastern Interconnection. Established transmission planning processes evaluate the reliability requirements (under NERC standards) and economic benefits of the expansion options for the planning period; the JCSP'08 did so as well, although the JCSP'08 conducted the production cost analysis for 2024 before conducting the reliability analyses. As the production cost models perform security constrained economic dispatch of the entire Eastern Interconnection for each hour of the year being analyzed (here 2024), the conceptual transmission overlays that result from this process consider reliability only to the extent that they ensure that pre-overlay security constraints are enforced. However, a production cost-based analysis does not contain the level of detail required to satisfy all reliability analysis requirements.[3] More detailed reliability analysis of the conceptual transmission overlays must be conducted for each of the overlays, to make the final conceptual overly both economic and reliable.

The two scenarios are described in detail in Section 3. The Reference and 20% Wind Energy Scenarios share common load growth and economic assumptions; they differ in terms of how much wind is developed and how the wind penetration levels affect the need for transmission and other types of generation. Although the modeling results indicate that the bulk of new fossil generation under these scenarios could be coal-fired, that result appears to be an artifact of the modeling assumptions and process rather than a prediction regarding the implications of transmission overlay development. Future analyses that incorporate more detail on technology and fuel costs (e.g., carbon sequestration), carbon regulation options, and operational needs relating to intermittency (as it relates to assuring reliable grid operations with high levels of wind resources) will lead to more firmly grounded conclusions regarding future generation technology mixes.

Both transmission overlays incorporate specific transmission projects that will contribute to the system's reliability needs for the ten-year period through the year 2018, and provide economic benefits in the 2024 time frame. The conceptual overlays were developed consistent with assumptions about fuel costs, load levels and resource expansion through 2024 for most of the Eastern Interconnection, with the important assumption that the Eastern Interconnection would be operated as a fully coordinated market. The process of creating the overlay options entailed extensive discussions in workshops with Eastern Interconnection stakeholders. The overlay options were systematically refined, adding and dropping various combinations of transmission facilities to develop the final sets of options that are economic within the context of the study's assumptions.[4] The final overlays for these scenarios have been reviewed using basic reliability screens, but have not been subjected to detailed design and reliability analyses; these transmission overlays should be viewed as conceptual rather than project-specific.

[3] Additional reliability analyses needed include stability analysis, voltage and reactive power requirements, and analysis of the lower voltage systems that are necessary to successfully integrate the EHV transmission overlay's elements. Such analyses could be included in future transmission overlay analyses.

[4] Electric system cost-effectiveness analysis requires comparison of a project's economic savings relative to new generation and transmission capital and energy production costs. The JCSP study could not conduct rigorous cost-effectiveness analysis because it examined energy production costs and savings only for the years 2018 and 2024, and assumed that new transmission and generation investment occurred instantly (overnight) at the start of each horizon year. A more thorough cost-effectiveness analysis would incorporate the full stream of costs and benefits (i.e., energy and environmental savings) in every year of the forecast period; such a task was beyond the scope of this initial JCSP study.

The process of locating new generation and developing and refining the transmission overlays is described in Sections 4 and 5.

To determine the net costs and impacts of each scenario, the JCSP'08 compared each scenario to a common base case, which contains the transmission constraints inherent in the existing system. Each scenario is evaluated by comparing the costs and benefits (production cost savings) of the base or constrained case to those of the scenario to determine the net impact of the transmission and generation assumed in each scenario. However, due to time constraints, the economic impacts have been calculated as point estimates for the year 2024 alone, rather than as a full year-after-year stream of benefits and costs. Although these estimates are offered in future value terms (2024 $), the reader should not assume that the costs and benefits represent cumulative benefits over a number of years; estimated capital costs are represented as if all of the new wind and fossil generation and transmission were built overnight at the start of the examined year. For that reason, this study does not attempt to estimate cost-effectiveness results for the two scenarios studied. Future studies should put more effort into refining the cost and economic assumptions and developing more rigorous cost and benefits calculations that span the full analysis period

Study Results

The JCSP'08 study examined two different resource and transmission paths to serve a total of 745,000 MW of coincident peak load in the Eastern Interconnection, except Florida in 2024. The Reference Scenario, which assumes that present RPS requirements are met with local on-shore wind resources, would add 10,000 miles of new extra high voltage transmission at an assumed cost of approximately $50 billion. With 5% of the Interconnection's energy coming from wind and 54% from base load steam generation, total energy production costs in 2024 would equal $104 billion and total generation capital costs would equal $674 billion. In contrast, the 20% Wind Energy Scenario, which assumes a 20% national RPS requirement met by U.S. on-shore wind development, would add 15,000 miles of new EHV transmission at an assumed cost of approximately $80 billion. Under this scenario, energy production costs in 2024 would equal $85 billion and the capital cost of new generation would equal $1,050 billion. These results should be viewed as illustrative or "ballpark" costs rather than definitive findings about the costs of new transmission and generation related to either the status quo expansion path or a high-renewables scenario. Even with that caveat, however, the findings suggest that transmission overlays should be strongly considered as a way to improve the future reliability and economics of the nation's bulk power electric system under either policy path.

The transmission and generation additions assumed under each scenario are summarized below and discussed in detail in Section 5.

Incremental Capacity Needs By 2024

To maintain electric reliability in 2024, new resources must be added to keep up with assumed future increases in demand. A new resource can be generation and transmission, or demand-side measures such as efficiency and demand response. In this study, a capacity expansion path was developed for each of the nine areas in the study to maintain an approximate 15% reserve margin across the Eastern Interconnection.

The JCSP'08 process handled resource additions for wind, demand response, and remaining supply-side resources as follows. The amount of new wind resource is based on the requirements of meeting either the Reference (5% wind) or 20% Wind Energy Scenario needs. The amount of demand response for this study is assumed to maintain the same percentage level of demand response as exists in 2008 (e.g., if a region had DR serving approximately 2.5% of peak demand in 2008, then new demand response additions were added out through 2024 to maintain that 2.5% share); energy efficiency was assumed to be embedded within the demand forecast. The type and timing of all of the other new supply-side resource additions is based on the relative life cycle costs of those resources, given stakeholder-accepted forecast assumptions for different technologies' capital costs, fuel and production costs, and environmental costs.

Figure 1-1 shows the capacity additions projected for the Reference and 20% Wind Energy Scenarios. Because the wind capacity figures are essentially fixed in each scenario, the remaining resources were selected by a least cost regional resource forecast model to fill in around the wind capacity. Future analyses should look further at alternative scenarios that rely more heavily on energy efficiency and demand response as resources that modify both supply and demand patterns and capabilities, as well as at alternate supply-side resource fuel and technology mixes.

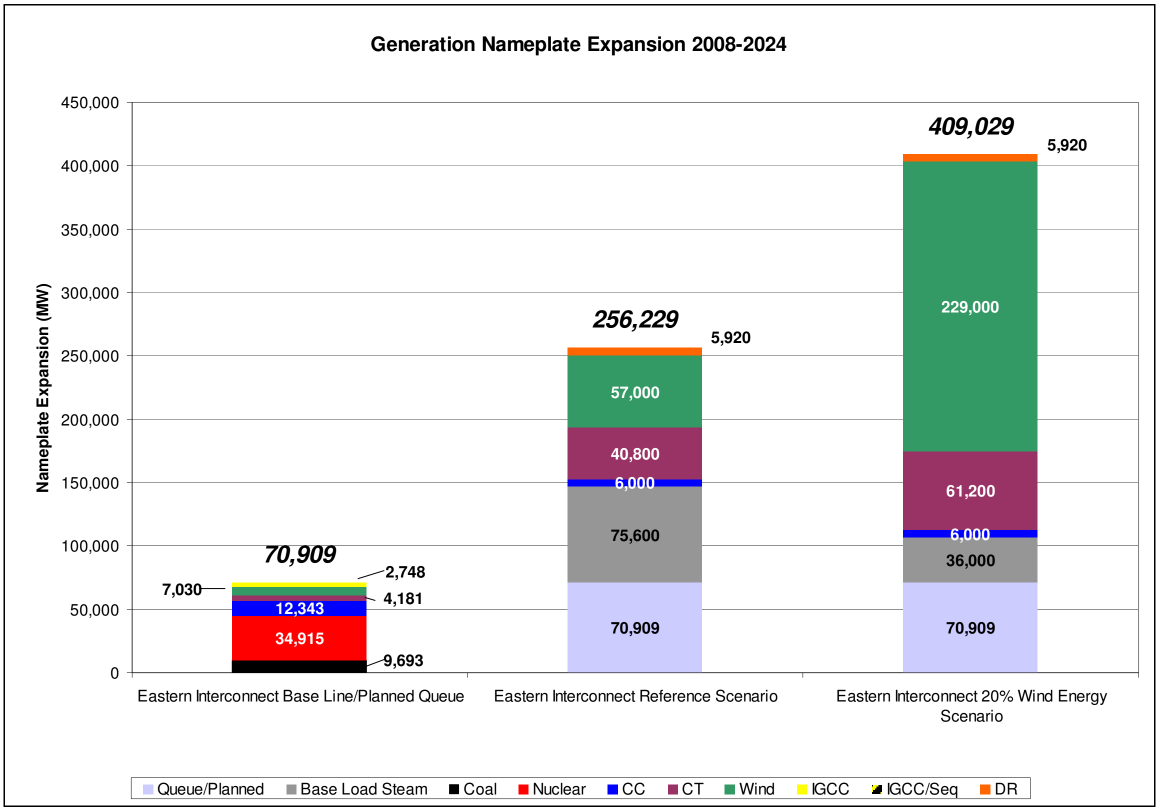

Figure 1-1: Capacity Additions by Resource Type

Table 1-1 provides more details on the transmission and generation investments made under the Reference and 20% Wind Energy Scenarios. While Figure 1-1 highlights the differences in generation types projected for each scenario, Table 1-1 shows that the Wind Scenario assumes significantly more high voltage direct current transmission construction (at a notably higher cost), reflecting the long distances over which wind energy is assumed to be shipped from the western Midwest to the northeast and southeast. There are high levels of base load steam generation assumed in both scenarios (54% under the Reference Scenario and 42% in the Wind Scenario), with the increased wind generation offsetting primarily base load steam production while requiring more production from fast-response, gas-fired combustion turbines. As might be expected, generation investment costs would be significantly higher under the 20% Wind Energy Scenario than under the Reference Scenario, but energy production costs would be lower with greater wind-power use, and those savings would increase over time.

		Reference Scenario		Wind Scenario	
			Percentage		Percentage
Transmission Overlay (Miles)	EHV AC (>=345kV)	7,109	71%	6,898	48%
	HV AC (<345kV)				
	HV DC	2,870	29%	7,582	52%
	Total	**9,979**	**100%**	**14,480**	**100%**
New Generation Expansion Capacity (MW)	Wind	58,000	31%	229,000	67%
	Base Load Steam	76,800	40%	37,200	11%
	Gas CT	49,200	26%	69,600	20%
	Gas CC	4,800	3%	4,800	1%
	Other Fossil	1,200	1%	1,200	0%
	Total	**190,000**	**100%**	**341,800**	**100%**
Energy Production (TWH)	Wind	242	6%	764	18%
	Base Load Steam	2,160	54%	1,741	42%
	Gas	210	5%	301	7%
	Other	1,356	34%	1,371	33%
	Total	**3,968**	**100%**	**4,177**	**100%**
Transmission Capital Cost (2024 million $)	Transmission - overlay	42,159		72,825	
	Transmission – substations	6,401		7,074	
Overnight Construction Costs for Capacity Added through 2024 (2024 million $)	Generation – Wind	176,009	26%	648,813	62%
	Generation – Base Load Steam	250,882	37%	134,401	13%
	Generation – Gas	68,317	10%	87,861	8%
	Generation – Other	179,138	27%	179,138	17%
	Total	**674,346**	**100%**	**1,050,213**	**100%**
2024 Production Cost and Savings (2024 million $)	**Total Energy Production Cost**	**104,294**		**85,167**	
	Total Production Cost Savings from Constrained Case	**10,624**		**20,362**	

Table 1-1: Summary Statistics for the Two Scenarios

Capacity expansion in these scenarios is driven by the underlying need to maintain appropriate reserve margins within each region and across the Eastern Interconnection as a whole. In these scenarios, only 15% of the wind generation is counted as a capacity resource for reserve calculation purposes. This is because wind generation is only available when the wind blows, and is not available and dispatchable by system operators during all time periods. Since system operators can only count on fully dispatchable and predictable resources (such as fossil and nuclear resources and hydro storage units) for reliability purposes, less of the wind resource can be counted toward regional and Interconnection-wide reserve margins. Changes in loads, technologies and costs (including environmental or carbon costs and the capability of dynamic response and smart grid technologies to firm intermittent wind generation) could significantly change the pattern of generation capacity expansion and should be studied through further scenario and sensitivity analyses.

Carbon Emissions

The capacity expansion analysis allows the calculation of the amount of carbon and other emissions produced under each scenario studied. The JCSP'08 analysis found that under the Reference Scenario, the generation mix in the Eastern Interconnection produced a total of 35 billion tons of carbon between 2008 and 2024, with 5% wind energy; under the 20% Wind Energy Scenario, comparable carbon emissions reached 32.1 billion tons, an 8% reduction.

These carbon output findings are highly dependent upon the generation mix developed under each scenario. Any combination of changes to the scenarios and their underlying assumptions could materially change the carbon emissions results, including assumptions about more energy efficiency, more renewable energy generated in Canada and East Coast off-shore wind, a carbon tax or tight carbon emissions regulation, the relative economics between base load steam and gas generation, or transmission capital costs and congestion as they affect the ability to move renewable or base load steam power across the Interconnection.

The Reference Scenario - New Transmission Projects Totaling $50 Billion of Investment by 2024

The Reference Scenario assumes that wind generation from relatively local, on-shore sources produces 5% of the U.S. Eastern Interconnection's energy use. These assumptions and the resulting generation and transmission needs drive design of a transmission overlay and underlying expansion that includes 10,000 miles of new extra high voltage (EHV) transmission at an estimated cost of $50 billion. The new transmission is comprised of a mix of transmission line sizes ranging from 345 kV to 765 kV for AC lines and up to 800 kV for DC lines. The transmission required under this scenario enables renewable and base load steam energy generated in the western side of the Eastern Interconnection to reach a wider area, and has the potential to reduce energy costs to eastern consumers. For these assumptions, work performed to date indicates the transmission overlay for the Reference Scenario, with 5% wind energy, may have benefits that exceed costs on an aggregate interregional basis.

The types and approximate locations for the new transmission are shown in Figure 1-2.

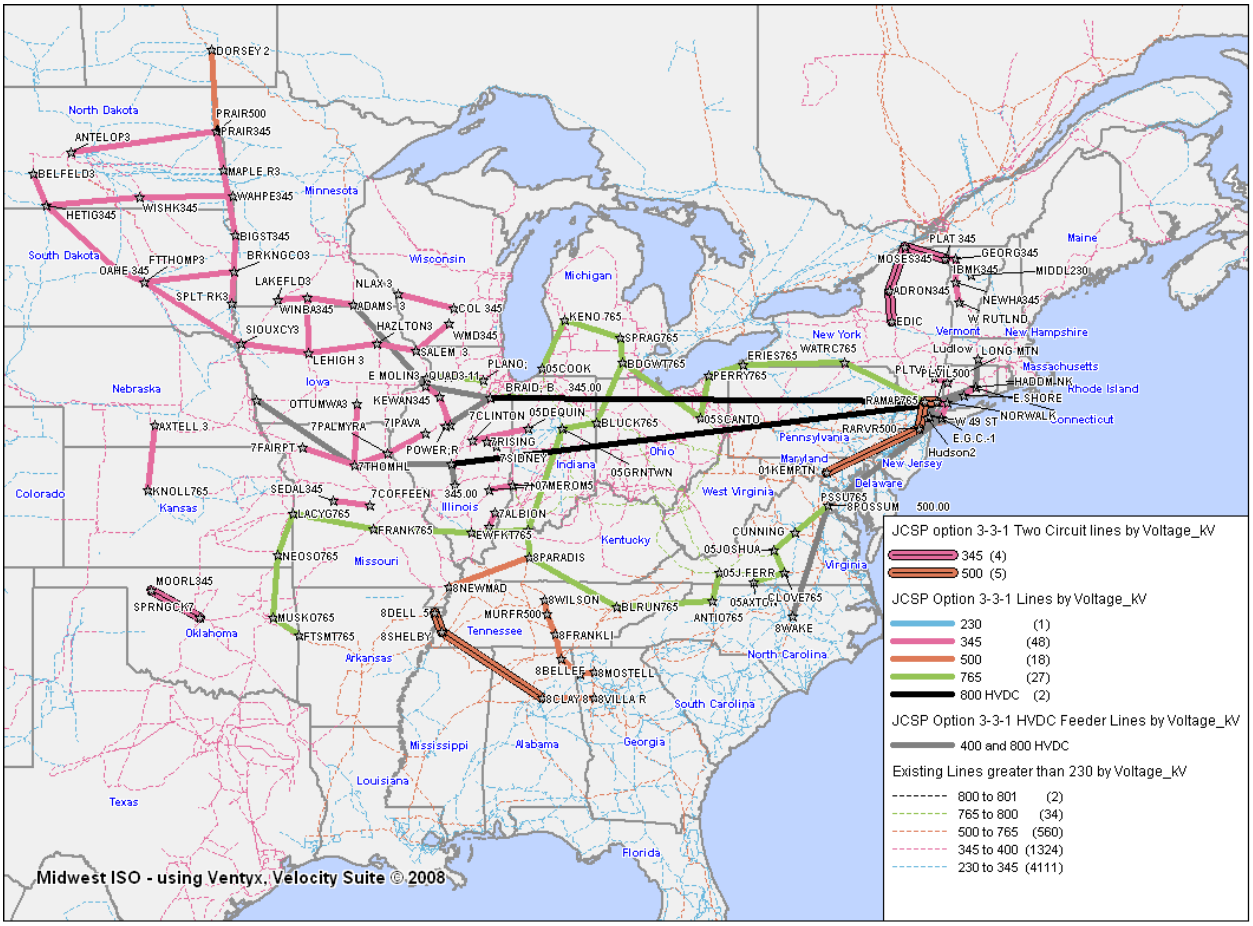

Figure 1-2: Reference Scenario Conceptual Transmission Overlay

The 20% Wind Energy Scenario – New Transmission Projects Totaling $80 Billion of Investment by 2024

The 20% Wind Energy Scenario presumes construction of a transmission overlay with 15,000 miles of new EHV transmission at an estimated cost of $80 billion. The new transmission would be a mix of transmission line sizes ranging from 345 kV to 765 kV for AC lines and up to 800 kV for DC lines. The majority of the conceptual overlay (approximately 75%) would be 765kV AC or 800kV DC. As in the Reference Scenario, the transmission overlay enables renewable and base load steam energy from the Midwest to reach a wider area and also has the potential to reduce energy costs to consumers along the Eastern Seaboard. Again, under the assumptions made in the JCSP'08, preliminary analysis indicates that this illustrative transmission overlay's benefits may exceed its costs.

The types and approximate locations for the new transmission are shown in Figure 1-3.

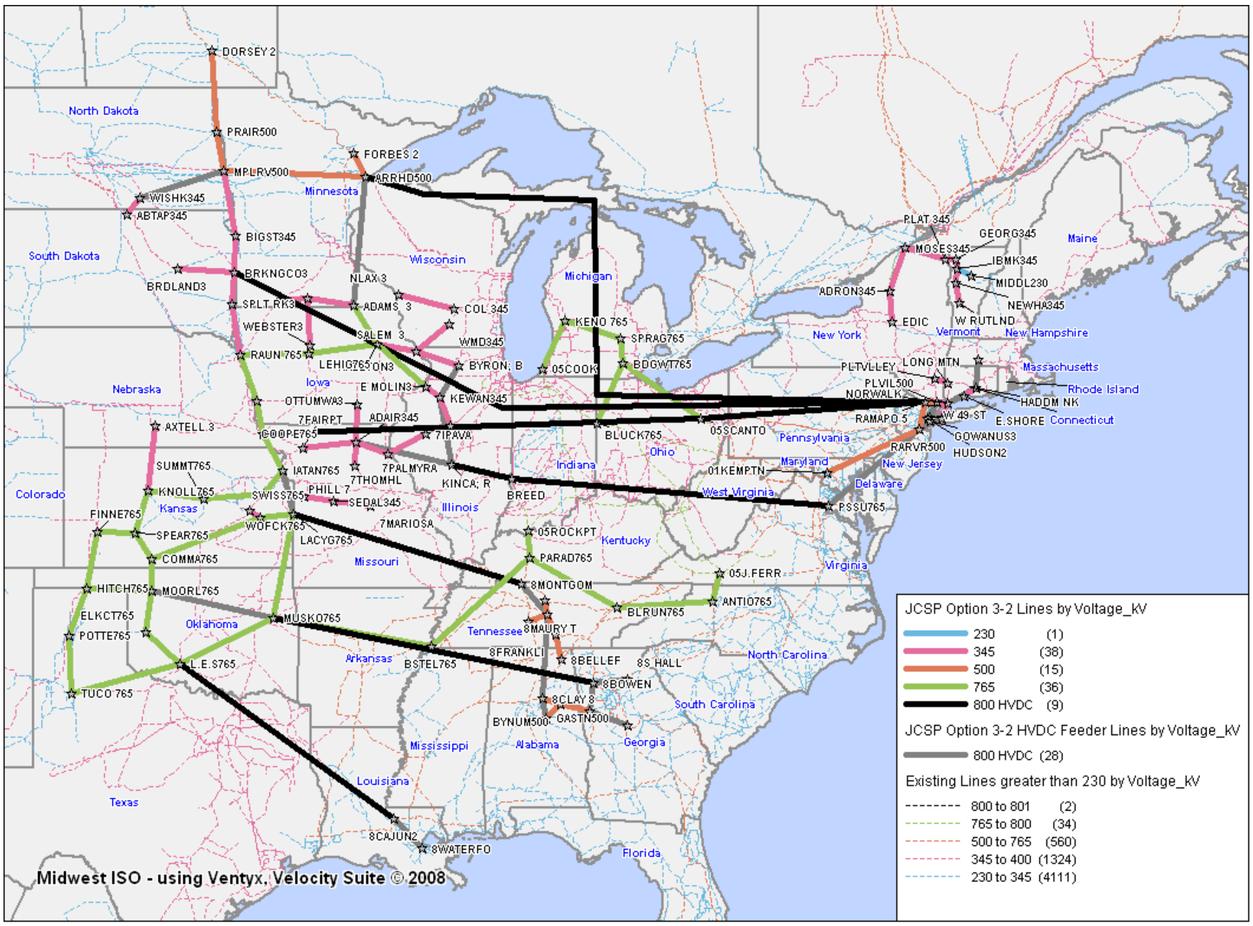

Figure 1-3: 20% Wind Energy Scenario Conceptual Transmission Overlay

Future analyses of high renewable generation scenarios should examine alternate assumptions about the location and density of future renewables development, with more attention to renewable resource development sited off-shore and in Canada and more local rather than long-distance production and transmission. Each of these resource options would affect the type, location and cost of new transmission infrastructure needed.

Looking Forward: JCSP'09 and Beyond

The JCSP'08 process offers an integrated approach to planning transmission and resource expansion for a very large area, considering both economic value and reliability needs. This approach has particular relevance if the nation is considering policies that would develop large amounts of remotely-located renewable and other generation distant from load centers. Although further analysis of reliability requirements is needed, the JCSP'08 study offers planners and policy-makers valuable insights for long-term transmission development.

Building upon the relationships and insights gained from this initial JCSP'08 effort, the stakeholders are looking forward. Possible changes include developing a new name -- the Eastern Interconnection Transmission Assessment Group (EITAG) -- to reflect the broader concept of the organization, and adoption of a formal charter. The EITAG will follow up on the JCSP'08 work and develop new scenarios to address analysis gaps. One question the EITAG can address is whether EHV transmission overlays offer superior reliability and economic results to incremental transmission development under alternative policy- and cost-driven scenarios. After examining a wide range of future generation, load and policy scenarios, planners should be able to identify the common transmission elements and principles that surface in all of these futures, and use those common elements as the foundation for a robust final transmission plan that serves the Eastern Interconnection economically and reliably as electricity policies and economics evolve. Insights developed by the EITAG can inform a broad spectrum of groups including policy makers, transmission owners and developers, generation owners and developers and regulators, and help to improve the nation's transmission over the long term.

Although the JCSP'08 and successor efforts can help improve bulk power system planning in the Eastern Interconnection, parallel efforts will be needed to turn those plans into realities. Although many new generation and transmission investments are moving forward, continuing uncertainties about the nation's policies with respect to carbon regulation, renewable development policies, and super-regional cost and benefit allocation for projects that span multiple regions constrain other investments. More clarity about these policy issues will facilitate new bulk power system investments needed to turn infrastructure plans into reality and make inter-regional and interconnection-wide transmission expansion planning effective.