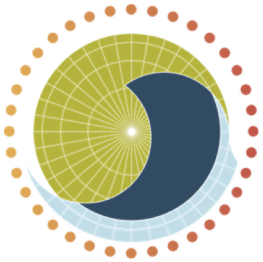

RDCEP POLICY ANALYSIS PAPER

Center for Robust Decision-making on Climate and Energy Policy

October 2012

Feasibility and Implications of the Michigan 2012 Proposal 3 for a 25% State Renewable Portfolio Standard

Elisabeth Moyer, Sean Johnson, Lexie Goldberger, Joe Zhu

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Feasibility and Implications of the Michigan 2012 Proposal 3 for a 25% State Renewable Portfolio Standard

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Summary

Analysis of the wind resources of Michigan suggests that the 2012 ballot Proposal 3, which would amend the state's constitution to mandate that 25% of the state's electricity sales derive from renewable sources, can be met by its 2025 target date with a moderate direct financial impact on the consumer. The amendment as written does pose some conflict between the stated intent of in-state business support and consumer cost-protection, with the responsibility for balancing these objectives likely placed on the Michigan Public Service Commission (MPSC).

The language in Proposal 3 implies intent to favor in-state generation for the purpose of economic stimulus, but through a technicality allows the use of out-of-state windpower in large parts of Wisconsin, Illinois, Indiana, and Ohio, and, depending on the interpretation of the MPSC, possibly also portions of Minnesota, North Dakota, and South Dakota. (This same exception, that covers all service territories of utilities that serve Michigan customers, also applies to the smaller existing state renewable portfolio standard enacted in Public Act 295.) Over much of the out-of-state eligible area, wind speeds are substantially higher and so the cost of windpower generation is lower than in Michigan. While Michigan has some high-quality onshore wind resources, particularly in the "Thumb" of the state, wind farm site quality would drop off as more in-state wind capacity is built.

We estimate that meeting the Proposal 3 requirements with onshore Michigan wind would raise average Michigan retail electricity rates by 6.5% over 2010 rates if federal subsidies for renewables are continued and 11% if they are permitted to expire (as may happen at the end of 2012). Using the lowest-cost eligible wind instead would result in significant cost savings but would drive almost all renewables development out of state. Meeting Proposal 3 with out-of-state wind, if the eligible territories are restricted to the Great Lakes states (as is most likely), would cause Michigan retail electricity price increases of 5% with federal subsidies and 9% without them. If the wind-rich Great Plains territories were used, fulfilling Proposal 3 would cause rate increases of only 3.5% with federal support and 6.5% without it. A scenario where the best Michigan sites are supplemented by out-of-state wind would obviously result in intermediate costs. Because the language in Proposal 3 does not explicitly resolve the conflicting objectives of local economic stimulus and consumer cost protection, the choice of how to implement the renewables mandate would likely be left to the MPSC.

The smaller existing Michigan mandate of 10% renewables by 2015, enacted in PA 295, carries a fixed cost cap that may affect its implementation. The PA 295 cost cap would freeze requirements if renewables caused average Michigan retail prices to rise by a fixed amount roughly equivalent to a 3% rise in rates. The PA 295 renewables target is small enough to meet with commercial-quality Michigan wind sites and is feasible within its cost cap with in-state wind if federal subsidies continue. If federal subsidies expire, meeting the PA 295 target with in-state wind is likely impossible. Even with federal support, care in cost control is required to ensure feasibility of the statute as written. Meeting the terms of PA 295 within its cap requires holding average payments to post-2008 renewables generators to $\approx$ \$80/MWh, but power purchasing agreements with renewables generators approved by the MPSC to date generally exceed this value. Michigan wind quality should however be sufficient to allow profitable generation within this constraint.

1 Background: Renewables in the Michigan Electric Sector

Like 29 other U.S. states, Michigan law contains a renewable portfolio standard (RPS) mandating that utilities serving MI customers source a certain fraction of their electricity from renewables by 2015. The current Michigan requirement, enacted in 2008 Public Act 295, requires that renewables make up 10% of Michigan-serving generation by 2015 [2]. The constitutional amendment in Proposal 3 would raise that renewables requirement further to 25%, with a target achievement date of 2025 [1]. This scale and implementation timetable are common to many existing U.S. state RPSs (Figure 1). In this report we analyze the likely costs of implementation of the Proposal 3 requirements and consider pathways for implementation. Although part of the intent of Proposal 3 is to benefit the Michigan economy by economic stimulus, we restrict this analysis to only the "direct costs" that would be incurred by the consumer. The reader should keep in mind that those costs may be offset by other economic benefits.

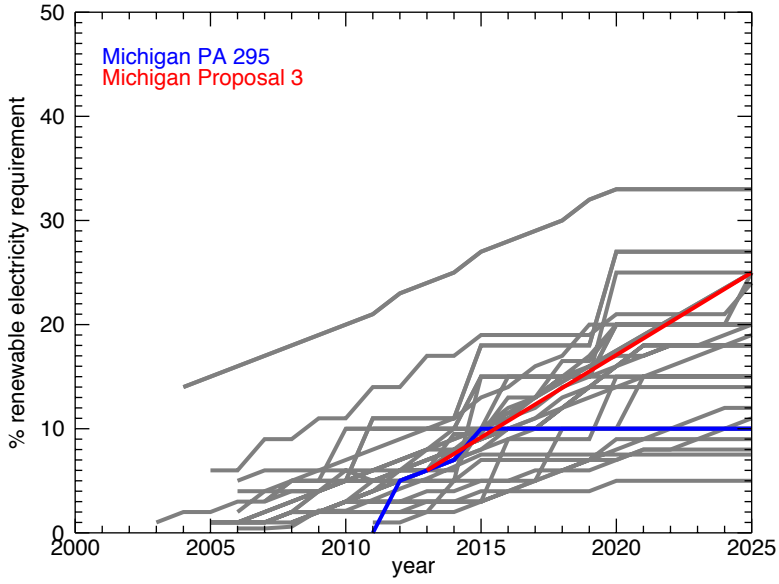


Figure 1. Mandated renewables levels in the 29 U.S. states with renewable portfolio standards. Michigan's PA 295 is highlighted in blue. Proposal 3 specifications are shown in red.

1.1 Michigan Electric Sector

Michigan is quite typical among U.S. states in its electricity use and generation. Per capita electricity use in Michigan is slightly below the U.S. national average (1200 W vs. 1400 W, 15% lower), likely because Michigan's climate permits a lower than average air conditioning use. (Numbers throughout this section are 2010 values from [13] unless otherwise cited). At present Michigan's electricity is derived largely from imported coal: in 2010, 59% the state's generation was from coal, 27% from nuclear power and the remainder from natural gas (11%) and renewable sources

(3.6%) [6]. Renewables include wood waste (1.5%), hydropower (1.1%), landfill gas (0.7%), and wind ($< 1\%$ in 2010 but projected to grow to nearly 5% by 2013 [4]). The recent rapid growth of windpower in Michigan has largely been in response to the renewables requirements enacted in 2008 through PA 295. Michigan's heavy coal use means that the state's electric sector has been slightly more CO_2-intensive than the national average, balancing out the state's lower per capita electricity use so that electricity-derived CO_2 emissions per Michigan resident are essentially at the national average. Finally, retail electricity prices in Michigan are also almost exactly the national average (9.88 cents/kWh vs. the U.S. average 9.83 cents/kWh) [1].

1.2 Michigan RPS Specifications

Although renewables generation in Michigan is growing, the proportion of Michigan electricity generated by renewables is still only 4.5% in 2012 [6], meaning that both PA 295 and Proposal 3 would require substantial additional new builds. Since Michigan's total electricity sales are $\approx$ 12 GW, fulfilling PA 295 would require a total of $\approx$ 1.2 GW generation from renewables, or an additional $\approx$ 800 MW over 2008 renewable generation. Fulfilling Proposal 3 would require $\approx$ 3 GW, or an extra $\approx$ 2.5 GW over 2012 renewable generation[2].

In both the existing PA 295 and Proposal 3, new renewables generation can be derived from a broad range of sources. PA 295 sources include windpower, solar power (both thermal electric and photovoltaics), hydroelectric power, geothermal electricity, and combustion of landfill gas, biomass, or municipal solid waste [2]. Proposal 3 includes all these other than the minor potential sources of landfill gas, municipal waste, and geothermal [1]. Michigan's substantial forestry sector and existing dams make biofuel (wood waste) and hydropower a significant contributor to the state's electricity generation (2.6% of total electricity) [13], but we assume that the potential for those energy sources is largely utilized and the remainder of the state RPS is likely to be met with windpower, generally the lowest-cost non-hydro renewable. (Wind did in fact constitute 94% of all renewable energy contracts approved by the MPSC from 2009-2011 [6]). Both PA 295 and Proposal 3 therefore represent mandates to move the state's electricity generation away from imported coal to presumably in-state wind. (Both statutes contain language that explicitly refers to the objective of in-state economic stimulus) [2, 1].

Both PA 295 and Proposal 3 contain "cost caps", provisions that alter requirements if they cause electricity prices to rise above a certain threshold. The cost caps are structured quite differently. In the existing PA 295, the cap is a fixed maximum price rise, specified separately for residential, commercial, and industrial customers, that for the current distribution of customers is equivalent to $\approx$ 3% of 2010 average Michigan retail price (derived from [22]). A 3% cap on a 10% RPS means that each unit of windpower applied to meeting the state standard must contribute an addition of no more than 30% to the average retail rate. In other words, the "wind premium", the additional

[1] Although Michigan customers see an electricity price essentially equal to the national average, the many low-population states with low electricity prices means that Michigan ranks as high as 17th among the 50 states plus D.C. in electricity price.

[2] These values are actual realized power produced, not "capacities". Because the wind capacity factor is $\approx$ 30%, necessary installed wind capacity to fulfill Proposal 3 would be three times higher, i.e. $\approx$ 7 GW.

subsidy wind generators must receive to be profitable, must be no larger than 30% of the retail rate. Using \$100/MWh and \$35/MWh for Michigan retail and wholesale rate, this implies that the total revenue per unit of electricity R (in \$/MWh) paid by Michigan ratepayers to wind generators under PA 295 can be no more than $(R-35)/100 = 30\%$, or $R = 30+35 =$ \$65/MWh. That is, the PA 295 cap allows renewables generators an average subsidy of \$30/MWh.

The subsidy permitted to *new* renewables generators built specifically in response to PA 295 is still larger than this value. At the time of enactment of PA 295, 3.4% of Michigan's electricity was already derived from renewables [11], and any additional costs for those existing facilities were already folded into 2008 rates. The entirety of the PA 295 permitted subsidy would then go to new renewables generators, which can receive $(10/6.6) \times 30$ = \$45/MWh subsidy, for a total revenue of \$80/MWh from Michigan ratepayers, over twice what they would receive from selling electricity on the wholesale market. PA 295 is therefore more pragmatic and realistic about the cost of renewables than are some other state statutes with unrealistically tight cost caps. (See [19]).

Furthermore, wind farms with higher operating costs than \$80/MWh may still be viable in Michigan because renewables are also supported by federal subsidies. The federal Production Tax Credit and Investment Tax Credit (henceforth "PTC") effectively reimburse developers of commercial wind farms by 30% of construction costs. (See [19] and references therein for details and discussion). These subsidies top up the contribution of state RPSs. However, subsidies for commercial wind farms are due to expire in 2012 unless new federal legislation is passed.

Proposal 3, in contrast to PA 295, does not limit the total price increase due to implementation but instead caps the *rate* of increase, permitting no more than a 1% average price rise per year. (The relative burden on different classes of customers is not specified). Proposal 3 also explicitly allows a delayed implementation of the RPS past 2025 as necessary until the mandate is met. Those provisions mean that the target renewables level under Proposal 3 would always eventually be met: the cap can alter the timescale of full implementation but not the mandate itself. This design removes any feasibility constraints, but at the expense of some uncertainty about total potential cost. In the remainder of this analysis, we estimate the cost of full implementation of both PA 295 and Proposal 3 in order to assist Michigan voters in making informed choices. Because continuation of federal wind subsidies is uncertain, we consider cases both with and without the PTC.

2 Windpower Resources and Costs

2.1 Eligible Wind Resources

The cost of fulfilling a renewables mandate with wind depends on where wind farms are built, because the power derived from wind turbine (and therefore the necessary subsidy per unit of electricity generated) is highly dependent on wind speed. Michigan is a moderately-endowed state for wind resources, ranked by the American Wind Energy Association (AWEA) as 14th in potential production from commercial-quality wind sites [3]. Michigan statewide average wind speeds are considerably below those of the central "wind belt" that runs through the Great Plains, but that

average incorporates a wide range of site quality. Michigan has some very high-quality wind areas in the state's "Thumb" and along Lake Michigan's eastern shore. In the remainder of the states, wind speeds drop off considerably (Figure 2).

Both PA 295 and Proposal 3 contain an opt-out from Michigan wind: they allow renewables mandates to be met not only by in-state generation but by out-of-state generation in the service territories of entities that also serve Michigan electricity customers [3]. Michigan has five of these utilities and cooperatives (Table 1), three serving small numbers of customers in the Upper Peninsula. The out-of-state territories of these utilities include substantial portions of Wisconsin, Illinois, Indiana, and Ohio, and, depending on interpretation, possibly also territories in Minnesota, North Dakota, and South Dakota that rank among the best wind resources in the United States (Figure 2). The ambiguity over the eligibility of wind belt territories stems from the interpretation of a case of multiple nested ownership. Northern States Power - Wisconsin, which serves customers in Michigan's Upper Peninsula, has an interchange agreement with Northern States Power Company - Minnesota (NSP-MN); these are jointly known as "NSP Companies" and are owned in turn by Xcel. In the body of this analysis, we show the case in which the territories of NSP-MN are ruled ineligible, but we show the case including them in Appendix F.

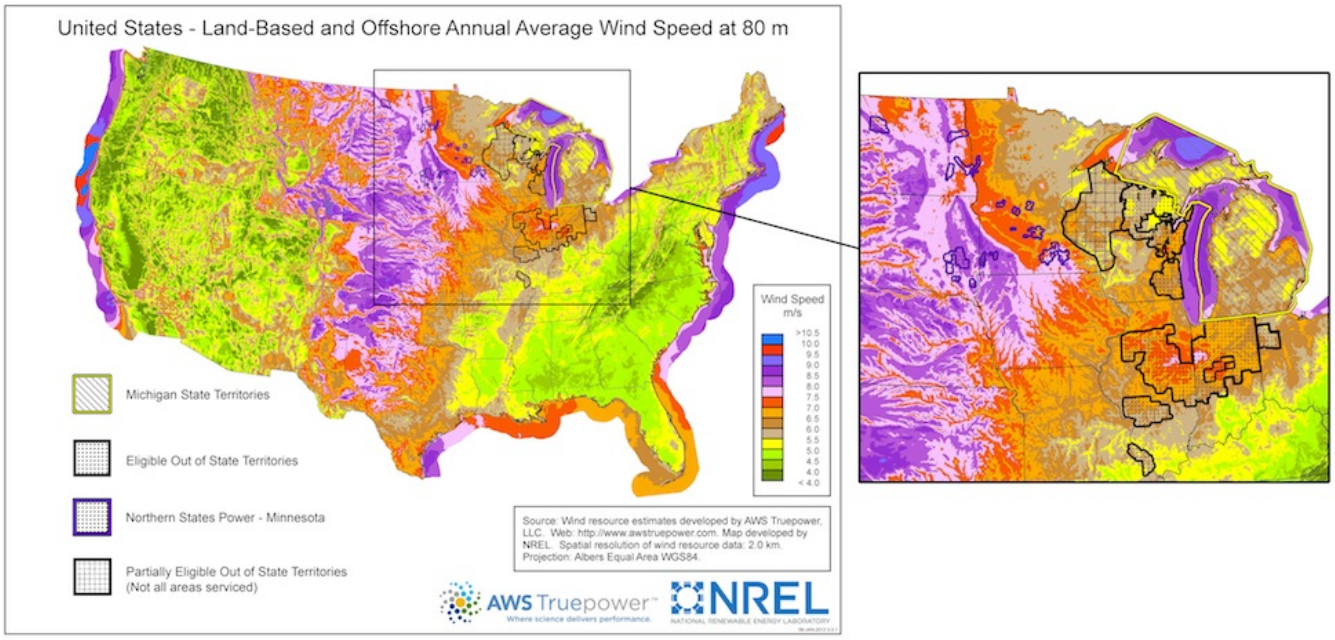


Figure 2. Windspeeds in the U.S. (NREL), with eligible and potentially eligible areas under the current and proposed Michigan RPSs marked. While Michigan is moderately-endowed state for onshore wind resources, the service territories of utilities serving Michigan customers extend into higher-wind locations. The territories of NSP-MN, which may be ruled eligible, lie in the U.S. "wind belt."

[3] PA 295 also has additional provisions for existing out-of-state wind contracts and permits exceptions at the discretion of the MPSC.

Utility	Other states served	% of MI customers
	Upper Peninsula customers	
Wisconsin Electric Power Company	WI	0.6%
Wisconsin Public Service Corporation	WI	0.2%
Northern States Power - Wisconsin	WI	0.2%
(part of NSP Companies)	*+ MN, ND, SD*	
	Remainder of state	
Indiana Michigan Power Company	IN	3%
Midwest Energy Cooperative	IN, OH	0.8%
(part of Wabash Valley Power Assoc.)	+ IL, MO	

Table 1. Michigan utilities with out-of-state territories. It remains unclear whether eligibility under a Michigan RPS would extend to all of NSP Companies. Indiana Michigan is a unit of American Electric Power and is sometimes known as AEP. Utility information is from the EIA [12] and stems originally from the Federal Energy Regulatory Commission (FERC) and the Rural Utilities Service (RUS).

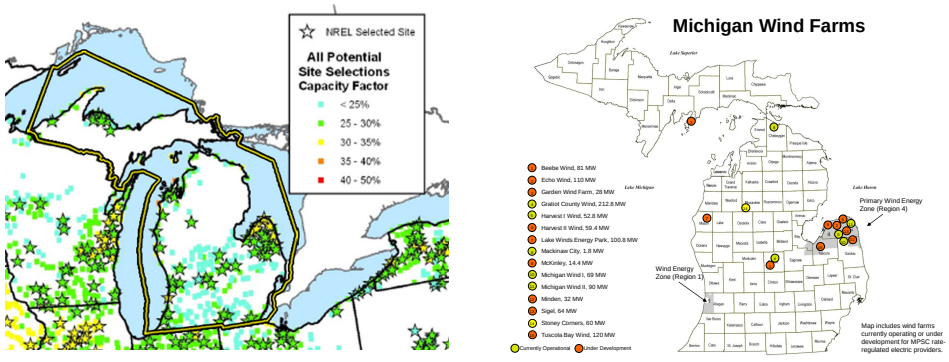
Because the utilities of Table 1 serve only a small fraction of Michigan's residential customers (less than 5%), and their Michigan RPS requirements scale with their Michigan customer base, they have little direct impact on the implementation of Michigan's RPS statute. Total Michigan renewables generation would be only slightly affected if the six utilities of Table 1 satisfied their RPS requirements with generation from out-of-state facilities. (Indiana-Michigan already does so, meeting their obligations to PA 295 with windpower from two wind farms in Indiana)[6]. The overwhelming majority of Michigan's electricity customers are served by only two in-state utilities, Detroit Edison (2.1 M customers) and Consumers Energy (1.8 M), which combined sell 86% of all of Michigan's marketed electric power [22].

The language in both PA 295 and Proposal 3 does however open one significant possible alternative for RPS implementation: that Detroit Edison and Consumers Energy could legally meet their own renewable obligations from facilities in the eligible out-of-state territories of other Michigan-serving utilities. Those territories include substantial areas where wind speeds are considerably higher in and therefore costs lower than in Michigan. In the current system for demonstrating compliance with the RPS, individual utilities have no direct incentive to go out of state, since nearly all their RPS obligations are satisfied via power purchase agreements with individual wind farms approved by the Michigan Public Service Commission, with costs passed on to consumers. If the MPSC chose to deny approval to more expensive local projects, however, Michigan utilities could be effectively forced to use lower-cost out-of-state wind. The MPSC therefore has great discretion in determining the location of facilities satisfying the Michigan RPS.

2.2 Site Quality

Since windpower production costs are a function of wind speed, we assume that investors would build on the best wind sites first, and as builds progress would turn to sites of increasingly lower quality and higher production costs. The first step in estimating RPS cost is therefore modeling this "site depletion" progression. We evaluate site depletion here using the methods of Johnson and Moyer 2012 ([19]) developed for a study of the Illinois RPS, using the standard national inventory of wind potential in the Eastern U.S., the 2010 Eastern Wind Integration and Transmission Study (EWITS), released by the Department of Energy's National Renewable Energy Laboratory [9]. EWITS estimates site quality by first identifying areas favorable for constructing wind farms (excluding for example protected lands, populated areas, and critical infrastructure) and then determining site quality by modeling the distribution of wind speeds at each site and and resulting power generation from suitable wind turbines for each site.

Wind site quality is given as a "capacity factor": the ratio of *actual* power generation of a wind farm to the *maximum* power generation if the wind blew optimally at all times. Commercial U.S. wind farm sites developed in the last decade have capacity factors ranging from 15-55% [25], highest in the wind belt states and lowest for a few sites in New England. In other words, generation costs for existing U.S. wind farms differ by over a factor of three depending on location. In this study, we rank EWITS sites by capacity factor and assume that builds will occur in that order. Comparison of existing Michigan wind farms to EWITS sites suggests that wind developers do largely follow this practice (Figure 3). We then use the capacity factor and an assumed spacing of wind turbines of 5 W/m^2 to estimate the total power output of each wind farm as builds progress until the RPS is fulfilled.



(a) EWITS site choice **(b)** 2012 Michigan wind farms

Figure 3. EWITS suggested wind farm sites in Michigan (L) and actual location of wind farms in Michigan (R). With a few exceptions (e.g. a tiny 1.8 MW facility in Mackinaw City), wind developers appear to be choosing optimal wind sites. L. figure from NREL and R. from MPSC.

The resulting site depletion curves imply that both PA 295 and Proposal 3 can be met with in-state Michigan wind, but that the higher requirement of Proposal 3 would require use of sites with

capacity factors lower than those typically used for commercial wind (lower curve in Figure 4). Because EWITS only models wind farms on sites of assumed good commercial quality, we must otherwise estimate the characteristics for the last Michigan sites used to fulfill the requirements of Proposal 3. We assume that they would lie somewhere between characteristics of the lowest EWITS sites (25% capacity factor) and those of the large areas of Michigan with moderate wind (windspeeds $\approx$ 5.5 m/s, Figure 2, with a capacity factor of $\approx$ 20%). (See Appendix B Figure B.1 for estimation of capacity factors in low winds). Technology for commercial wind turbines optimized for these low wind speeds continues to develop [23, 15].

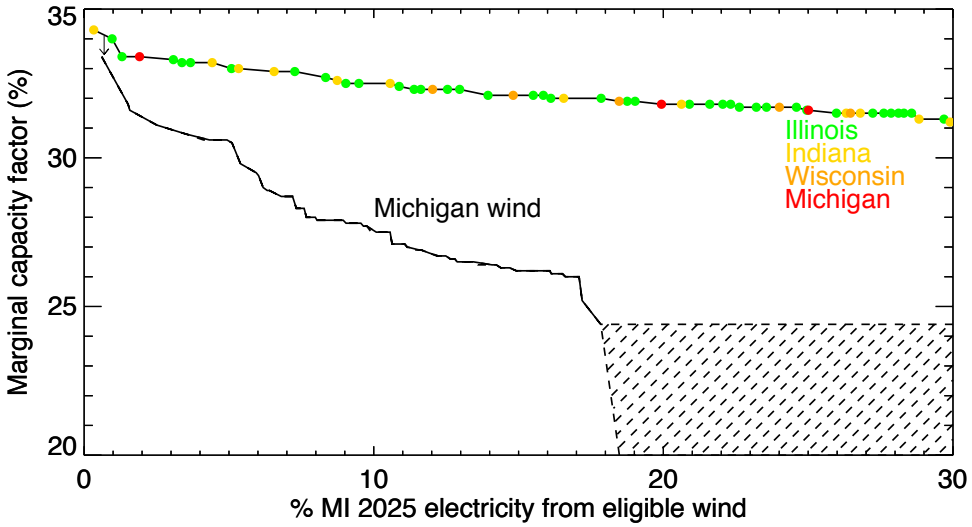


Figure 4. Reduction in site quality as wind sites are progressively occupied during buildup of renewables generation. The lower curve includes only Michigan sites, the top curve those definitely eligible under PA 195 and Proposal 3 (Great Lakes only). Shaded area represents the uncertainty in the quality of the last Michigan sites that must be used. Out-of-state territories largely outcompete Michigan wind.

The falloff in in-state site quality opens the possibility that the MPSC may choose to fill part of Proposal 3, if passed, with eligible out-of-state wind. If sites in the eligible area (exclusive of NSP-MN) were chosen in order of site quality, Proposal 3 renewable requirements would be met almost completely by wind farms in Illinois, Indiana, and Wisconsin (upper curve in Figure 4). These states have peak capacity factors no higher than the best sites in Michigan, but they have far more area of this quality than does Michigan. Note that the model of Figure 4 does not account for the fact that some sites are already occupied by wind farms with long-term contracts to other customers. We also do not consider transmission limitations. Nevertheless, the flatness of the site depletion curve for the non-Michigan areas suggests that these factors would not change the conclusions here, that out-of-state wind facilities would dominate were the Michigan renewables standard to be filled on the basis of generation cost alone.

That domination would be even stronger were the territories of Northern States Power - Minnesota ruled eligible to serve the Michigan RPS, allowing access to the intense winds of the wind belt. Peak capacity factors in potentially eligible areas of Minnesota, North Dakota, and South

Dakota are almost a third higher than those of the best Michigan sites (Figure 6).

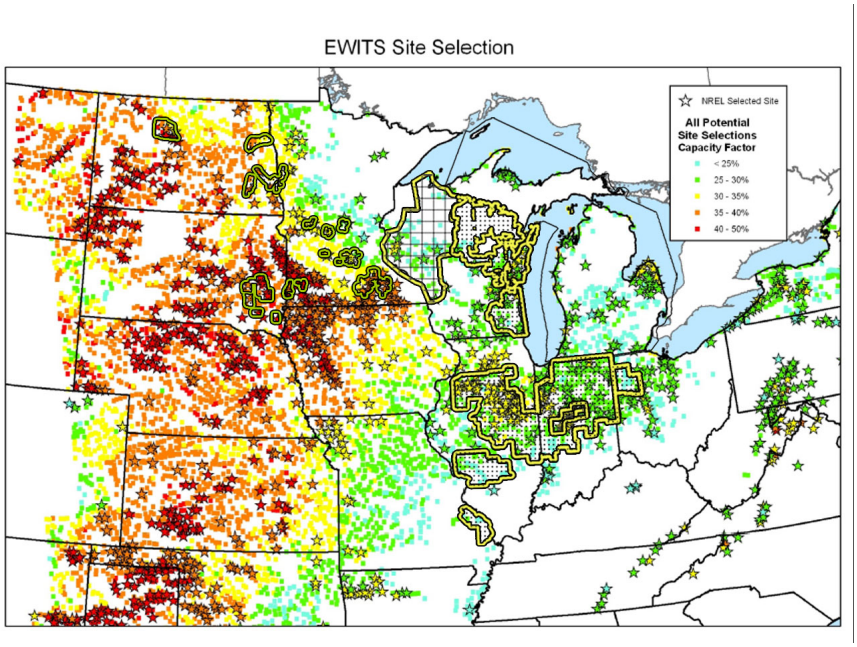


Figure 5. Designated EWITS wind sites, colored by capacity factor. Capacity factors are generally higher in the MI-eligible areas outside of Michigan, and highest in the potentially eligible areas of MN, ND, and SD. Hatching of eligible, partially eligible, and potentially eligible areas is as in Figure 2.

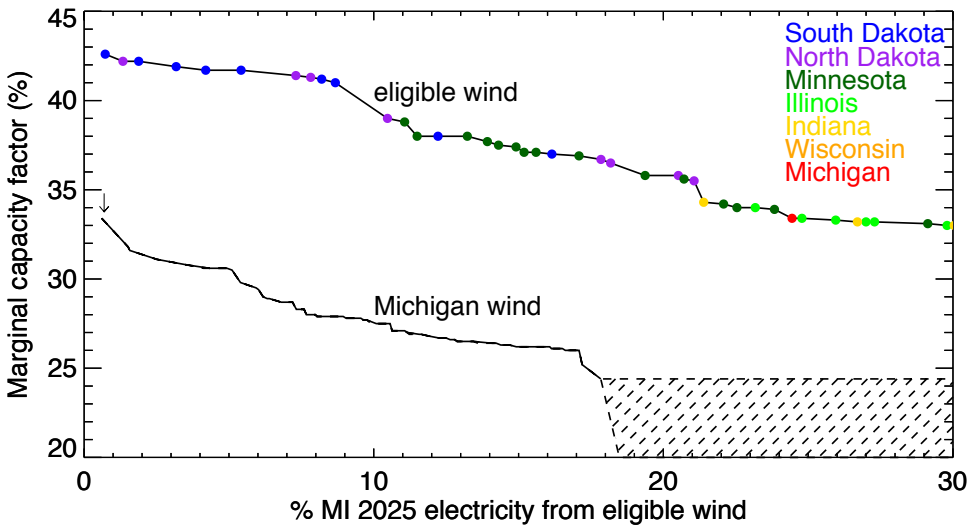


Figure 6. Site depletion if NSP-MN territories are ruled eligible. Even small areas of wind belt states would fill nearly the entire Proposal 3 requirement. Shading again represents uncertainty in quality of last Michigan sites. Compare to Figure 4.

The siting analysis above depends significantly on the assumption of turbine spacing. The tighter that turbines can be packed together without interfering with each other, the more power can be produced from each wind farm. If wind farm designers find they must space turbines more widely than we have assumed to achieve optimal power, the highest-quality Michigan sites would contribute less to filling the Michigan RPS, increasing the incentive to turn to out-of-state wind. If turbine spacing is tighter than we have assumed, site depletion would be reduced and Michigan wind more favored. We have assumed here a capacity density of 5 W/m^2, a slightly optimistic number, as the American Wind Energy Association recommends that wind farms not space turbines closer together than 60 acres per megawatt, or 4 W/m^2 [21]. (If turbines are packed too tightly, wake interference reduces the power they generate, i.e. effectively drops the capacity factor.) For one of the wind turbines in common use in the U.S. and modeled by EWITS, the GE 1.5xle [9], our 5 W/m^2 value is equivalent to spacing individual wind turbines a bit under ≈ 7 rotor diameters apart, or 5×10 along the prevailing wind direction. (Turbine specifications are 1.5 MW max power and 82.5 m rotor diameter.) We do not use total power output directly from EWITS as the EWITS assumed turbine spacings are are unrealistically tight, with average capacity densities of 14.2 W/m^2 [9], over three times the AWEA's recommended maximum. We assume instead that there is some error in this aspect of EWITS. Our spacing of 5 W/m^2 represents the tightest plausible spacing for new wind farms built in response to a Michigan RPS, and therefore a lower bound on site depletion effects. Existing wind farms in the U.S. in fact typically use wider spacings, averaging 2.9 W/m^2 in 2009 [10]. (For existing Michigan wind farms, see Appendix C).

2.3 Wind Costs

The cost of windpower in the U.S. is highly dependent on location. In 2011, new wind projects in the U.S. received revenues that differed by a factor of nearly three, from $\approx$ \$35/MWh - \$115/MWh [25][4]. Those revenues presumably represent the amounts that wind generators must receive per unit of electrical energy generated to cover their expenses, and the difference in expenses per energy generated is principally due to site quality. The higher the capacity factor for a wind farm site, the greater the electrical energy produced by each turbine and the lower the windpower cost, and in turn the lower the subsidy required to allow wind generators to be profitable. At the best U.S. wind sites, with capacity factors over 45%, windpower is competitive with natural gas or coal generation, especially given the subsidy in the form of the PTC.

We show estimated windpower cost as a function of site quality both with and without the PTC in Figure 7. Since most of the cost of wind generation is the upfront expense of buying and installing a turbine, the PTC rebate of 30% of installation cost approximately lowers the cost of generation by 30%. Wind costs are estimated here as in [19], combining installation, fixed operating, and variable operating costs from the literature and applying standard financing assumptions. (See Appendix D). The resulting cost estimates are consistent with the costs of U.S. wind generators compiled in NREL's 2011 Wind Technologies Report [25].

[4]Costs are given as "levelized costs", i.e. the amount in current dollars that an operator would need to receive each year to recover his investment.

The analysis here implies that if in-state Michigan wind is used to meet Proposal 3 requirements, site depletion during buildup of wind farms would raise marginal generation costs by ≈ 30%. If federal subsidies remain in effect, Michigan wind costs would rise from ≈ $55 to $70-80/MWh (Figure 7). Without federal support, costs would rise from ≈ $75 to over $100/MWh.

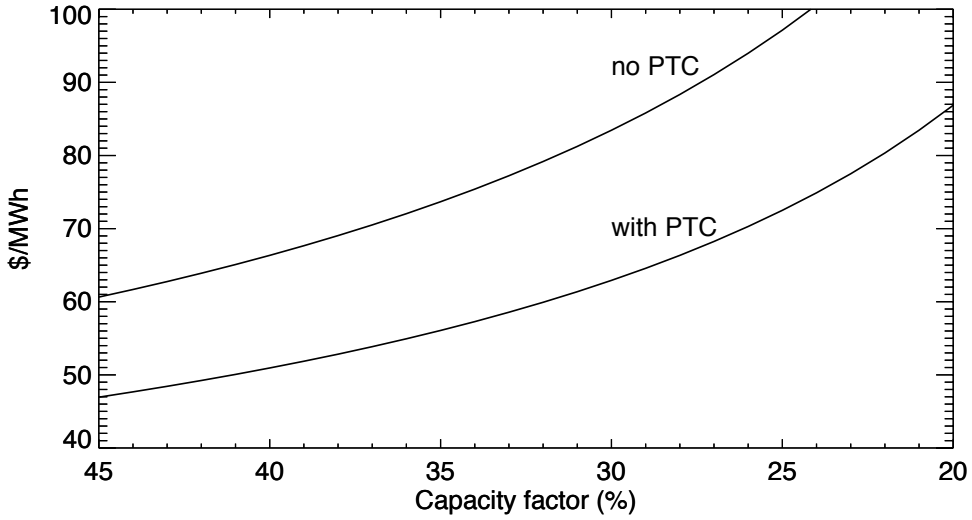


Figure 7. Estimated cost of generation of windpower as a function of capacity factor. Capacity factors shown here span the range of those in Michigan and out-of-state potentially eligible territories under PA 295 and Proposal 3.

3 Forecast Evolution of Proposal 3 and PA 295

3.1 Proposal 3

Predicting the direct impact of Proposal 3's impact on Michigan ratepayers is relatively straightforward once wind costs and site quality distributions are known. Because Michigan renewables generally pre-sell their electricity to specific utilities via power purchase agreements (PPAs) rather than selling electricity and renewable energy credits on the market, their revenues can be tied directly to their generating costs. We assume that wind generators receive contracts to sell electricity at rates just sufficient to allow them to cover their costs. The estimates therefore represent a lower bound on impact to the Michigan consumer. As more wind farms are built and a larger and larger fraction of Michigan electricity derives from wind, total subsidies to wind generators and impact on Michigan ratepayers necessarily grow. The resulting pathway of price increases suggest that the Proposal 3 target should be achievable in the desired timetable, by 2025, even within the cap of 1%/year price increases.

If federal subsidies continue, we estimate that the meeting the requirements of Proposal 3 wind would cause an increase in retail electricity rates over 2012 values of ≈ 6.5% if only Michigan

wind were used and $\approx 5\%$ if facilities could be sited in the best eligible territories in the Great Lake states (Figure 8). If eligibility was opened to NSP-MN territories in Minnesota and the Dakotas, fulfilling the Proposal 3 mandate could be achieved with impact on Michigan retail prices as low as 3.5%; see Appendix F Figure F.6.

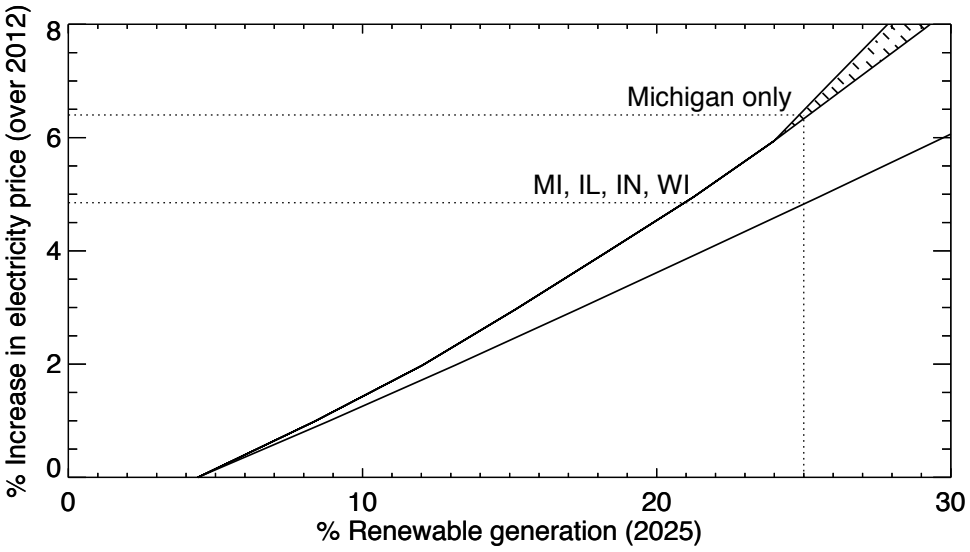


Figure 8. Estimated average Michigan retail price over 2012 values increases as renewables penetration increases, assuming the PTC continues. Existing renewables (4.5% of Michigan's electricity) are included in the reference 2012 rates.

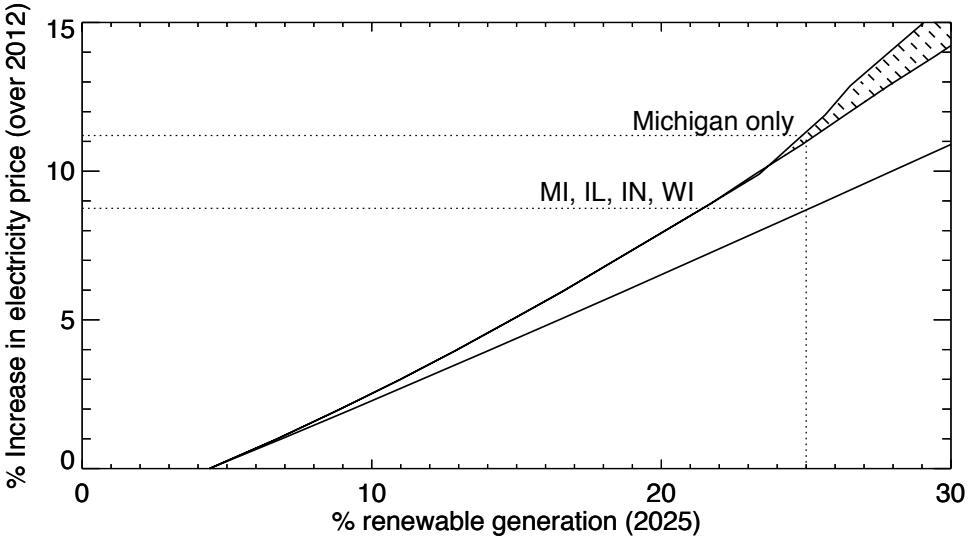


Figure 9. Estimated average Michigan retail price increases over 2012 values as renewables penetration increases, assuming the PTC expires. Compare to Figure 8.

If the federal PTC were not renewed, wind generators would need more support from Michigan to operate. We estimate the direct impact on the Michigan ratepayer of filling Proposal 3 without federal support as 11% with in-state wind, 9% with eligible Great Lakes wind, and 6.5% if the wind belt territories of NSP-MN were used (Figures 9 and Appendix F Figure F.7). In both cases, the uncertainty over the exact capacity factor in the last Michigan sites used to fill the renewables requirement does not meaningfully affect the estimates. We note however that these estimates are essentially minimum ratepayer impacts. We have assumed that the best identified wind sites are both available and actually used, and that wind generators barely cover their costs. Use of sub-optimal sites or granting of windfall profits would raise impacts on Michigan ratepayers.

Although the estimated rate impacts of Proposal 3 are not trivial, they would not significantly affect Michigan's competitiveness as a business environment among U.S. states (Figure 10). This conclusion holds whether or not in-state wind is used and indeed whether or not the PTC is continued. Michigan is currently the 17th-highest U.S. state in retail electricity rates, and the added costs of meeting Proposal 3 would move it at most only two places further up, passing only Pennsylvania and Florida. The next highest state, Delaware, has retail rates nearly 12 cents/kWh. (Price data from [12]).

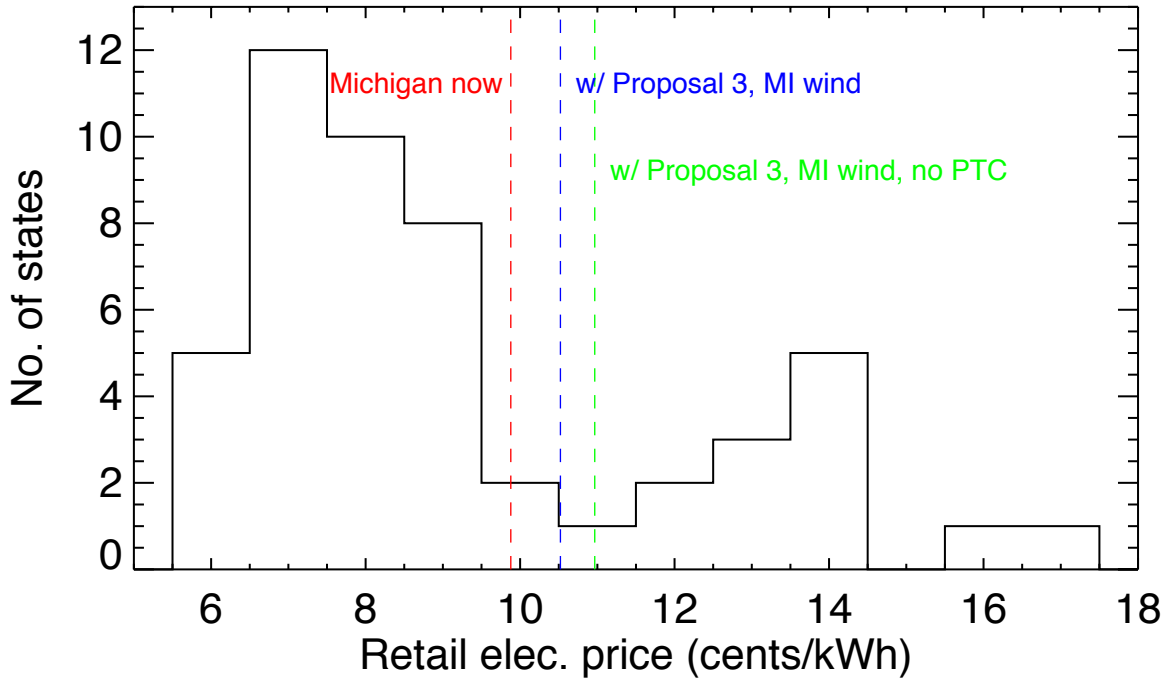


Figure 10. Histogram of retail electricity price in U.S. states + Washington DC, excluding only Hawaii that is off-scale at 25 cents/kWh. Michigan is 17th in retail electricity prices at present. Fulfilling the targets of Proposal 3 with in-state wind would not significantly alter Michigan's competitive position, even if federal PTC support for windpower is not renewed.

3.2 PA 295

The analysis here can be also used to estimate the expected costs of implementation of the existing Michigan renewables mandate, PA 295. It is not valid however to estimate PA 295's feasibility directly from Figures 8 and 9 above, because those figures show increases on 2012 rates and the PA 295 cost cap is benchmarked to rates in 2008, the year of enactment. Figures 8 and 9 above treat the renewables growth since enactment of PA 295, over 1% of Michigan's electricity supply, as essentially free.

Because we do not have a simple means of retroactively determining the impact on the ratepayer of renewables builds between 2008-2012, the most instructive feasibility test is to consider whether PA 295 requirements can be met by renewables generators receiving the maximum average payments permitted under the statute's cost cap. As discussed in Section 1 of this report, PA 295 can be fulfilled within its cost cap if new renewables built in response to the mandate are granted average revenues of no more than $80/MWh. Figure 11 implies that wind generation in Michigan filling the requirements of PA 295 should be profitable at $80/MWh given the additional support provided by the federal PTC.

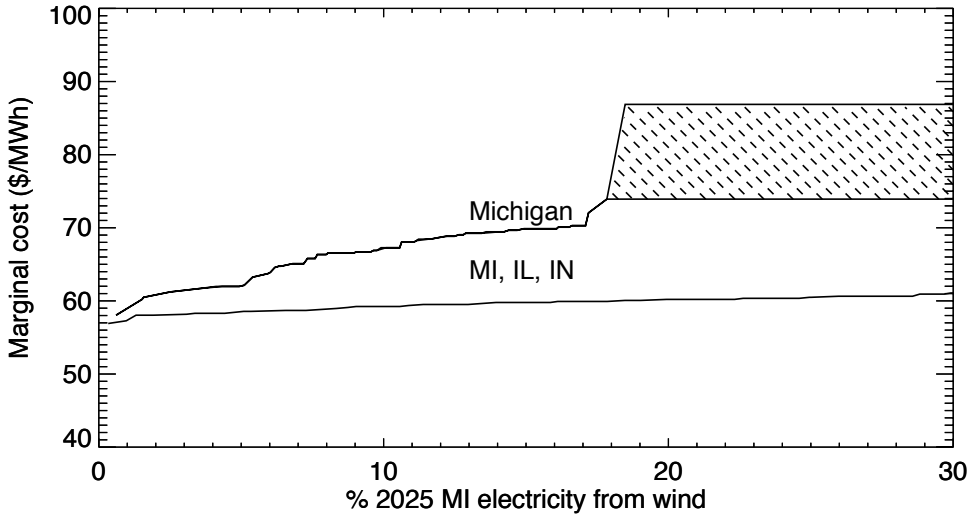


Figure 11. Marginal cost of windpower production with increasing penetration, assuming the PTC is continued. Upper curve shows the case of in-state wind only, with marginal costs rising as the best wind sites are used up. Shading again denotes uncertainty in site characteristics after all EWITS sites in Michigan are consumed. The lower curve includes territories in Great Lakes states eligible under PA 295 and Proposal 3. PA 295 appears fulfillable with the constraint of average new renewables cost of $80/MWh, even with in-state wind

Without the federal PTC, complete fulfillment of PA 295 appears impossible with in-state wind and uncomfortably tight even with use of eligible sites in other Great Lakes states (Figure 12). (Fulfilling PA 295 would however be very feasible if eligibility were extended to the wind belt territories of NSP-MN; see Appendix F Figure 12). In the absence of federal support, wind-

generated electricity from even the best sites in the Great Lakes eligible territories would cost $75/MWh, close to the PA 295 limit. If renewables were restricted to Michigan alone, marginal cost would rise to nearly $90/MWh before the PA 295 requirements were met. The subsidy granted to renewables generators by Michigan voters through PA 295 is simply not enough alone to support continued renewables development in the state under current cost conditions. Given that the final timeline for implementation of PA 295 is only three years away, it is also unreasonable to expect any radical technological improvement than can dramatically lower the cost of wind generation. The feasibility of PA 295 therefore depends on continuation of federal support for renewables, or on the willingness of Michigan ratepayers and agencies to use primarily out-of-state wind sites.

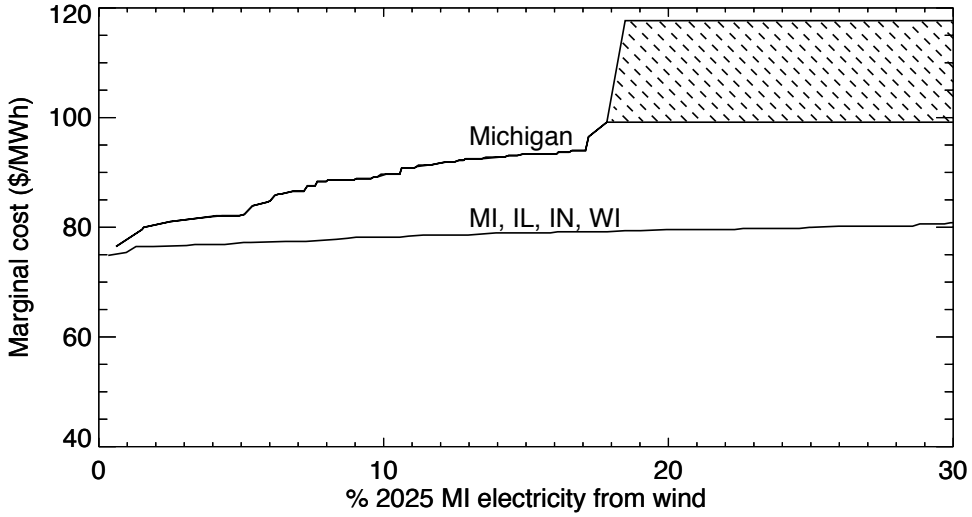


Figure 12. Marginal cost of windpower production with increasing penetration, assuming the PTC expires. Same as Figure 11 otherwise. Fulfillment of PA 295 appears impossible in Michigan without federal support for renewables generators, and tight even using out-of-state Great Lakes eligible territories.

4 Conclusion

The analysis here suggests that the 2012 ballot Proposal 3, which would amend the state's constitution to mandate that 25% of the state's electricity sales derive from renewable sources, can be met by its 2025 target date with a moderate direct financial impact on the consumer. The amendment as written does pose some conflict, however, between the stated intent of in-state business support and consumer cost-protection. Windpower in territories explicitly permitted by Proposal 3 is lower in cost than is in-state Michigan wind, and in the absence of guidance in the terms of Proposal 3, the responsibility for balancing these objectives would likely be placed on the Michigan Public Service Commission (MPSC).

The smaller existing Michigan mandate of 10% renewables by 2015, enacted in PA 295, should be possible to meet with commercial-quality Michigan wind sites and is feasible with in-state wind

within its cost cap if federal subsidies continue. If federal subsidies expire, however, meeting the PA 295 target is impossible with in-state wind and may be impossible even with out-of-state eligible wind. We also note that average of power purchase agreements with renewables generators approved by the MPSC to date exceeds the limiting average payments permitted by the PA 295 cost cap of $\approx$ \$80/MWh (Appendix E). Care in cost control is necessary to ensure feasibility of the statute as written. However, given the continuation of federal subsidies, it should be possible for Michigan generators to fulfill the PA 295 renewables mandate within its cost constraints.

Acknowledgments

The methodology used throughout this analysis was developed with the help of many other people; for a complete list see acknowledgments in [19]. Alison Brizius provide invaluable logistical assistance that made this report possible. The Center for Robust Decision-making on Climate and Energy Policy (RDCEP) is supported by the National Science Foundation through the Decision Making Under Uncertainty program (Award No. SES-0951576).

Nomenclature

AWEA American Wind Energy Association.

Capacity factor The actual power output of a generator over a period of time divided by the maximum possible power output of that generator. As used here, effectively a measure of wind speed and site quality. Capacity factors of wind facilities in the United States built in the last decade range from 15% to nearly 55%.

Capacity density The power produced by a wind farm per area if all turbines were operating at maximum power. Capacity density is therefore a measure of the spacing of wind turbines. (Higher capacity density means more wind turbines per area).

EIA Energy Information Agency: a federal agency charged with compiling energy-related data.

EWITS Eastern Wind Integration and Transmission Study: an NREL-released study of wind power potential in the Eastern U.S. that provided capacity factors for this analysis.

MPSC Michigan Public Service Commission: the state agency responsible for administering Michigan's renewable portfolio standards.

MW Megawatts: a unit of power, i.e. energy per time. One MW is 1 million Watts.

MWh Megawatt-hour: a unit of electrical energy, equivalent one million watts power consumed/generated for one hour. Also equivalent to 1000 kilowatt-hours. Residential electricity rates are usually given in units of kWh/month. Renewable energy credits are typically denoted in MWh.

NREL National Renewable Energy Laboratory.

NSP-MN Northern States Power - Minnesota, a utility which does not directly serve Michigan customers but which has an interchange agreement with the Michigan-serving Northern States Power - Wisconsin. NSP-MN's territories may therefore be eligible to provide renewable electricity under Michigan's RPS; if so, costs of fulfillment could be significantly reduced.

PA 295 Michigan Public Act 295, enacted in 2008, which established the state's renewable portfolio standard.

PPA Power Purchase Agreement: a contract by which a utility agrees purchase electricity from a generator for a set price and duration. Usually signed before construction of the facility.

Proposal 3 A 2012 ballot item that would approve a Michigan constitutional amendment that increased the state's renewable portfolio standard over the requirements of PA 295.

PTC The federal Production Tax Credit and Investment Tax Credit. In their current forms, these credits collectively effectively reimburse renewables generators for 30% of their construction costs.

RPS Renewable Portfolio Standard: a requirement that a certain fraction of electricity be derived from renewable sources. Often administered at state level.

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A PA 295 Cost Cap and Michigan Renewables Fraction

	price cents/kWh	sales MMWh/yr	revenue $B/yr	customers 1000s	monthly bill $/month/cust.	PA 295 cap $/month/cust.	cap % %
residential	12.6	32.9	4.13	3,990	86	3.00	3.5
commercial	9.9	29.8	2.96	465	530	16.58	3.1
industrial	7.0	24.1	1.69	11	12,850	187.50	1.5
total	*10.1*	*86.7*	*8.77*	*4,470*	*164*	*4.87*	*3*

Table A.1. Michigan electric sector breakdown for 2010, from sales data collected by the Michigan Public Service Commission [6], as needed to calculate the size of the PA 295 cost cap relative to statewide revenue. The cap is specified in [2]. "Total" numbers here include only direct sales to residential, commercial, and industrial, the categories explicitly referred to in the PA 295 cost cap. We disregard customers labeled "other" and disregard electricity resale. Note that exact values of electric sector data depend on accounting practices. The 2010 average Michigan retail rate inclusive of those factors (9.57 cents/kWh) was slightly lower than the average for the three customer classes (10.1 cents/kWh), and the EIA's estimate of 9.88 cents/kWh lies midway [13]. In this study we use either the EIA value or a rough 10 cents/kWh; our conclusions are robust to this level of imprecision.

Similarly detailed data on the Michigan electric sector were not readily available from the MPSC for 2008, the year of enactment of PA 295. We have assumed that both prices and the breakdown of Michigan industrial, commercial, and residential customers remain roughly the same from 2008-2010.

	2008 MI electricity	hydropower	other renew.	total renew.
GW	13.1	0.16	0.30	0.45
%	(100)	1.2	2.3	3.4

Table A.2. Michigan net generation from renewables in 2008 [13]. A third of PA 295's renewables mandate was already met at the time of enactment, and the entire allowable subsidy under PA 295's cost cap can support the remaining new builds.

B Wind Speed and Capacity Factor

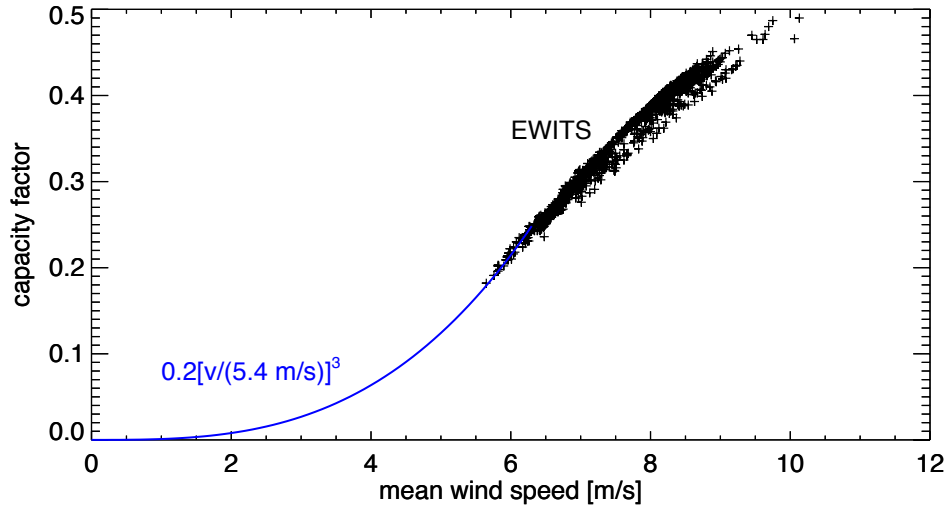

Figure B.1. Capacity factor as a function of wind speed in the EWITS database. Capacity factors in low winds here are estimated by projecting this relationship. The power carried by wind, and in turn power generated and capacity factor, goes approximately as the cube of the wind speed.

C Michigan Capacity Densities

Wind Farm	Capacity (MW)	Capacity Density (Wm^{-2})
Lake Winds Energy Park	100	1.5
Michigan Wind 2 (Minden City)	90	1.7
Gratiot County	212	1.8
Stoney Corners III	18	2.2
Harvest Wind Farm	53	4

Table C.3. Estimated capacity densities of existing MI wind farms, in units of Watts per square meter. Information about wind farm capacity and physical size was derived from a variety of industry and media sources including [18, 7, 17, 8, 14, 4, 20, 16, 24]. We include here only farms for which area estimates were readily available.

D Cost Assumptions

Description	Input	Levelized Cost (if applicable)
Installed Cost	\$2/W	
O&M	\$10/MWh	\$10/MWh
Integration Cost	\$5/MWh	\$5/MWh
Financing	6%, 20 years	(9% amortization)
Capacity Factor	(from EWITS)	
Capacity Density	5 W/m^2	
Wholesale value	\$35/MWh	

Table D.4. Assumptions used to calculate wind costs. Methods follow those of Johnson and Moyer 2012 [19]. The wholesale electricity price here is intended to represent average Michigan wholesale rates. Capacity density assumptions are slightly optimistic compared to realized capacity densities in Michigan wind farms listed in Appendix C.

E Michigan Approved PPAs for Renewables Under PA 295

Consumers Energy Company's Renewable Energy Contracts Submitted to the MPSC for Approval.

	Consumers Energy : Contracts							
	Seller	Quantity	Cost*	Term	Renewable Energy Type	Request for Proposal	Commission Approval	Commercial Operation Date
	Experimental Advanced Renewable Energy Program	987.7 KW	Commercial $0.375/KWh Residential $0.525/KWh	12 Years	Solar	Unsolicited	5/10/2011	5/1/2011
	Vestas-American Wind Technology	56 V100 1.8 MW Turbines	$95.00/MWh	Company Owned	Wind	1/15/2010	12/2/2010	12/31/2012
	White Construction, Inc. U-15805 edocket files # 251-256	Installation and Construction				7/23/2010		
	GE Prolec Transformers, Inc.	2-125 KV transformers				7/27/2009		
	Heritage Garden Wind Farm I	28.6 MW	$106.20 MWh	20 Years	Wind	Unsolicited	11/19/2010	1/1/2012
	Heritage Stoney Corners Wind Farm II	12.3 MW	$98.50 MWh	20 Years	Wind	Unsolicited	11/19/2010	1/1/2012
	Experimental Advanced Renewable Program	Commercial 836.6 KW Residential 200.1 KW	Commercial $0.45/KWh Residential $0.65/KWh	12 Years	Solar	Unsolicited	12/21/2010	5/1/2010
	Scenic View Dairy**	0.35 MW	$83.07/MWh	63 Months	Anaerobic	Unsolicited	10/26/2010	7/29/2010
	Blissfield Wind	81 MW	$100.88/MWh	20 Years	Wind	5/7/2009	7/27/2010	12/31/2012
	Harvest II Wind	59.4 MW	$98.38/MWh	20 Years	Wind	5/7/2009	7/27/2010	12/31/2012
	Michigan Wind 2	90 MW	$94.00/MWh	20 Years	Wind	5/7/2009	7/27/2010	6/30/2012
	WM Renewable Energy - Pine Tree Acres	12.8 MW	$98.75/MWh	20 Years	Landfill Gas	5/7/2009	7/27/2010	6/30/2012
	WM Renewable Energy - Northern Oaks Landfill 1	1.6 MW	$122.39/MWh	20 Years	Landfill Gas	1/29/2009	10/13/2009	11/11/2010
	WM Renewable Energy - Northern Oaks Landfill 2							
	NANR – Lennon 1	1.6 MW	$137.27/MWh	20 Years	Landfill Gas	1/29/2009	10/13/2009	12/31/2010
	NANR – Lennon 2							
	Elk Rapids Hydro Electric** 1	0.7 MW	$121.31/MWh	10 Years	Hydro	1/29/2009	10/13/2009	7/11/2009
	Elk Rapids Hydro Electric** 2							
	Zeeland** 1	1.6 MW	$122.20/MWh	7 Years	Landfill Gas	1/29/2009	10/13/2009	7/11/2009
	Zeeland** 2							
	Freemont Community Digester 1	3.1 MW	$139.35/MWh	20 Years	Anaerobic	1/29/2009	10/13/2009	11/11/2012
	Freemont Community Digester 2							
	Scenic View Dairy** 1	0.82 MW	$138.17/MWh	7 Years	Anaerobic	1/29/2009	10/13/2009	7/11/2009
	Scenic View Dairy** 2							
	Total	396 MW						

* Per MWh prices represent levelized costs.

** Pre-existing projects prior to 2008 PA 295 - The commercial operation date would refer to the effective date of the contract.

Figure E.2. Consumers Energy Company's renewable energy contracts submitted to the MPSC for approval to date. [5]

Detroit Edison Company's Renewable Energy Contracts Submitted to the MPSC for Approval.

Detroit Edison Company : Contracts							
Seller	Quantity	Cost*	Term	Renewable Energy Type	Request for Proposal	Commission Approval	Commercial Operation Date
Michigan Waste Energy, Inc.	Up to 65,000 RECs/Year	$7.00/REC	13 Years	Incinerator	Unsolicited	12/6/2012	1991
Nova Consultants, Inc.	Solar EPC	Up to $48 Million	Company Owned	Solar	2/28/2011	11/10/2011	12/31/2015
McNaughton-McKay Electric Company	Supply up to 15 MW of Modules	Up to $24 Million					
Inovatus Solar, LLC	Supply up to 15 MW				3/24/2011		
General Electric Company	Up to 69 1.6MW-100 Turbines	$61-$64/MWh	Company Owned	Wind	3/9/2011		
Barton Malow Company	Installation and construction				5/6/2011	9/13/2011	12/31/2012
Tuscola Bay Wind, LLC	120 MW	Up to $60.90/MWh	20 Years	Wind	11/18/2010	8/25/2011	10/31/2012
L'Anse Warden Electric Company	110,374 RECs	$11.98 (Average of 4 REC/ACEC Contracts)	Amendment Acquiring Vintage RECs	Biomass	8/18/2009	8/25/2011	7/1/2010
Nova Consultants	Unchanged from original contract	Unchanged from original contract	Company Owned	Solar	Extension	12/21/2010	12/31/2011
Blue Water Renewables - Smiths Creek Landfill	3.2 MW	$99.00/MWh	20 Years	Landfill	Unsolicited	1/20/2011	12/31/2011
Gratiot County Wind	110.4 MW 89.6 MW Company Owned	Up to $94.43/MWh Price not available	20 Years Company Owned	Wind	8/18/2009	9/14/2010	12/1/2011
WM Renewable Energy - Eagle Valley Landfill	3.2 MW	Combined average price of	20 years	Landfill	8/18/2009	8/10/2010	6/1/2011
L'Anse Warden Electric Company	17 MW	$98.94/MWh	20 years	Biomass	8/18/2009	8/10/2010	7/1/2010
Boyce Hydro**	Firm 210,000 RECs w/additional 112,000 RECs dependent on generation	$7.75/ REC	7 Years	Hydro	12/23/2009	4/27/2010	3/16/2010
Nova Consultants	Up to 3 MW	Up to $18 Million	Company Owned	Solar	11/23/2009	3/2/2010	12/31/2010
Heritage Sustainable Energy Stoney Corners Wind Farm	12.2 MW	Unchanged from original contract	20 Years	Wind	Unsolicited	12/1/2009	1/1/2011
UPPCO**	Firm 500,000 RECs	Combined average price of	7 Years	Hydro	12/23/2009	12/1/2009	10/1/2009
Sterling Planet**	Firm 2,500,000 RECs	$12.46/REC	10 Years	MISC	12/23/2009	12/1/2009	10/1/2009
Heritage Sustainable Energy Stoney Corners Wind Farm	14 MW	$115.00/MWh	20 Years	Wind	Unsolicited	4/30/2009	12/21/2009
Total	**482 MW**						

* Per MWh prices represent levelized costs.

** Pre-existing projects prior to 2008 PA 295 - The commercial operation date would refer to the effective date of the contract.

Figure E.3. Detroit Edison Company's renewable energy contracts submitted to the MPSC for approval to date. [5]

Contracts Submitted to the Commission Exclusive from Detroit Edison and Consumer Energy Contracts

Alpena Power Company : Contracts							
Seller	Quantity	Cost	Term	Renewable Energy Type	Request for Proposal	Commission Approval	Commercial Operation Date
Consumers Energy	"Bulk of RECs needed to meet the RPS"	$30.37/REC (estimated)	20 Years	MISC	Unsolicited	9/15/2009	8/4/2009
AEP/Indiana Michigan : Contracts							
Seller	Quantity	Cost	Term	Renewable Energy Type	Request for Proposal	Commission Approval	Commercial Operation Date
Fowler Ridge Wind Farm II	50 MW	Redacted	20 Years	Wind	Unsolicited	9/15/2009	2/15/2010
Wildcat I Wind Farm, LLC	100 MW	Redacted	20 years	Wind	Competitive Solicitation	8/25/2011	12/31/2012

Figure E.4. Renewable energy contracts submitted to the MPSC for approval by utilities other than Detroit Edison and Consumers Energy. [5]

F Case Study: Northern States Power - Minnesota Included

We repeat below the primary figures of this report for the case where the territories of Northern States Power - Minnesota are ruled eligible to meet the Michigan renewables requirements of PA 295 and Proposal 3.

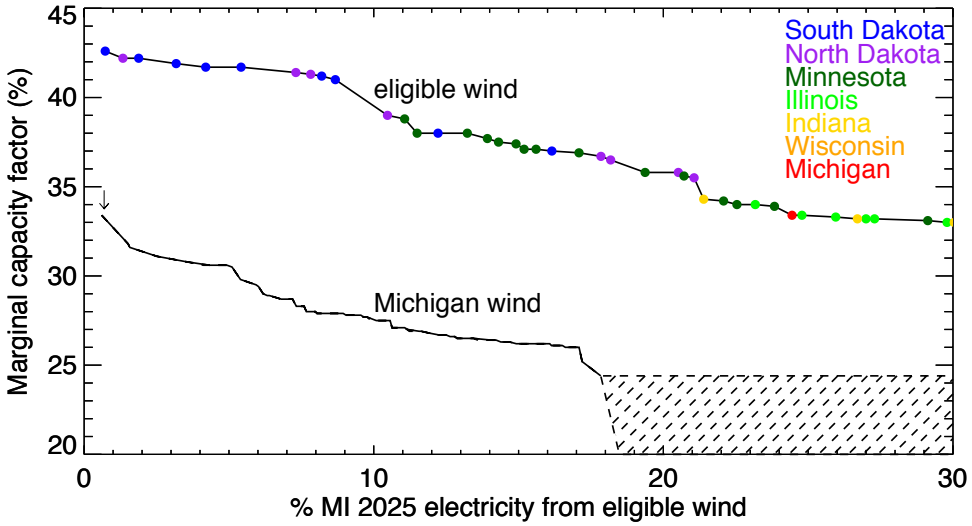

Figure F.5. Site depletion if NSP-MN territories are ruled eligible. Even small areas of wind belt states would fill nearly the entire Proposal 3 requirement. Shading again represents uncertainty in Michigan sites. This figure is repeat ofFigure 6. Compare to Figure 4.

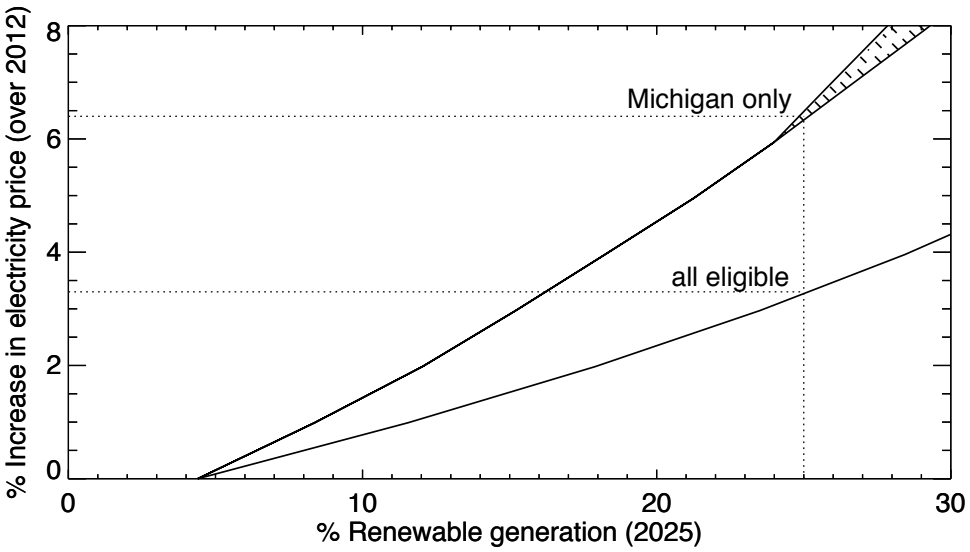

Figure F.6. Estimated average Michigan retail price over 2012 values increases as renewables penetration increases, assuming the PTC continues. Existing renewables (4.5% of Michigan's electricity) are included in the reference 2012 rates. Eligible territories include those of NSP-Minnesota.

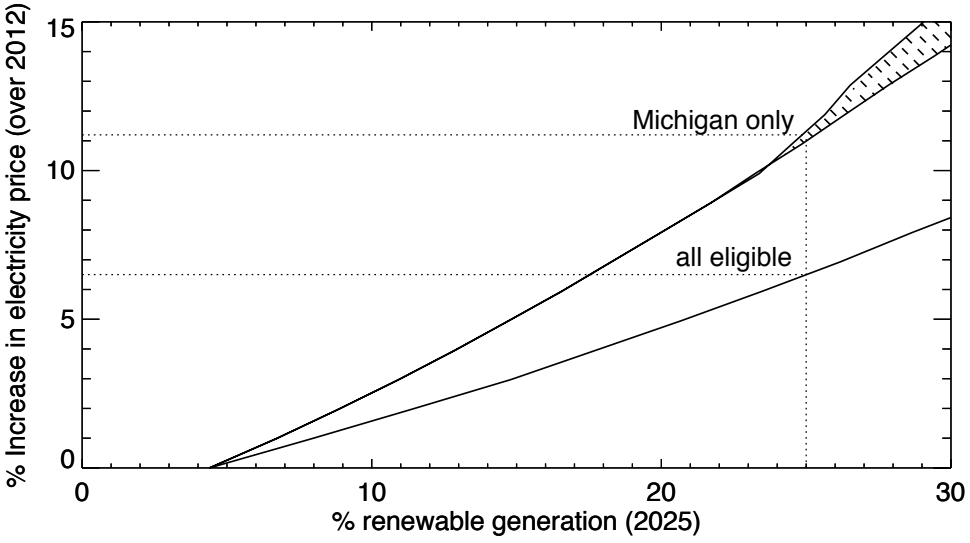

Figure F.7. Estimated average Michigan retail price increases over 2012 values as renewables penetration increases, if the PTC expires. Eligible territories include those of NSP-Minnesota.

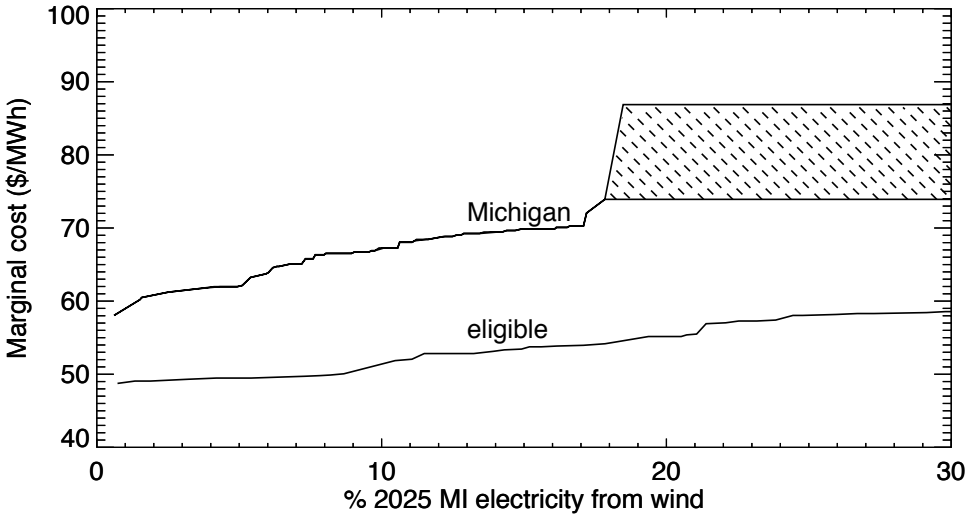

Figure F.8. Marginal cost of windpower production with increasing penetration, assuming the PTC is continued. Upper curve shows the case of in-state wind only, with marginal costs rising as the best wind sites are used up. Shading again denotes uncertainty in site characteristics after all EWITS sites in Michigan are consumed. The lower curve includes all territories not eligible under PA 295 and Proposal 3, including those of NSP-Minnesota. PA 295 appears fulfillable with the constraint of average new renewables cost of $80/MWh, even with in-state wind

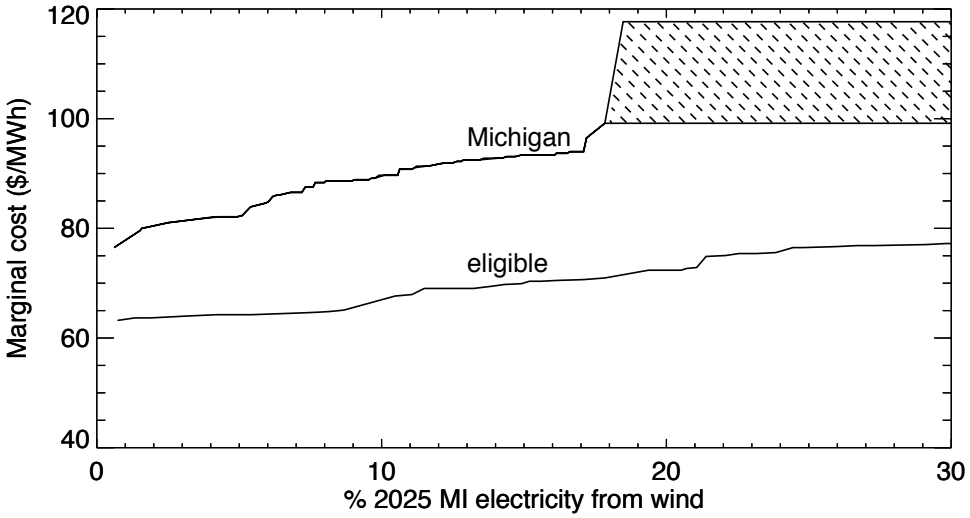

Figure F.9. Marginal cost of windpower production with increasing penetration, assuming the PTC expires. Same as Figure F.8 otherwise. Fulfillment of PA 295 without federal support for renewables generators was not possible if eligible territories were restricted to the Great Lakes states (see Figure 11), but is if the the territories of NSP-Minnesota are included, as shown here. Wind belt sites can generate windpower with costs below the PA 295 new-renewables cap of $80/MWh.