Michigan and the Clean Power Plan:

Clarifying the Compliance Options

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17 February 2015

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The 5 Lakes Energy team provides the expertise and experience to move clean energy and sustainability aspirations into concrete action. The principals and consultants of 5 Lakes Energy catalyze collaborations and aggregate resources, building consensus and support to operationalize clean energy ideas and ambitions. Working with the private sector, foundations and non-profits, government and academia, 5 Lakes Energy offers a portfolio of services that enable and accelerate innovation. More information about 5 Lakes Energy can be found at www.5lakesenergy.com.

Acknowledgments

Development of the SCRAPS model used in preparation of this report was funded by The Energy Foundation.

Funding of the STEER model that enhances the SCRAPS model as described in this report was funded by Advanced Energy Economy.

Primary development of the SCRAPS and STEER tools referenced in this report was done by The University of Michigan, Jeremiah Johnson, Principal Investigator under contract to 5 Lakes Energy. University of Michigan graduate student Rachel Chalat did much of the model development under Dr. Johnson's direction. 5 Lakes Energy is grateful for their excellent work.

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Executive Summary

The United States Environmental Protection Agency, pursuant to the Clean Power Plan, is currently developing a rule that would require each state to reduce carbon emissions from existing fossil-fueled power plants to a state-specific rate that will be established in the final rule. EPA's stated intent is to give states great flexibility in how they achieve these carbon emissions reduction.

This paper explores some key issues that the State of Michigan will need to address in developing its compliance with the Clean Power Plan. Using a tool designed at The University of Michigan to find the least-cost power system that complies with a carbon emissions target, this report summarizes the nature of the least-cost plan under two scenarios about future fuel prices.

In 2013, Michigan generated 56.2 TWh electricity from coal. Assuming that natural gas remains as inexpensive as it was in 2014, the least-cost plan is to reduce electricity generated from coal to 32.3 TWh by implementing all cost-effective energy efficiency and building new natural gas combined cycle plants. Assuming that natural gas prices follow the Energy Information Administration long-term reference case, the least-cost plan is to reduce electricity generated from coal to 44.4 TWh by implementing all cost-effective energy efficiency and building new renewable generation resources.

Implementing all cost-effective energy efficiency corresponds to a utility energy efficiency resource standard (called the Energy Optimization Standard under Michigan law) of about 1.5% per year. Implementing sufficient renewable generation to comply with EPA's draft rule for the Clean Power Plan corresponds to a Renewable Portfolio Standard of approximately 28% by 2030 as well as aggressive improvements in the heat rates of the remaining coal plants.

Choosing between these compliance strategies requires careful consideration of risk. The natural gas price above, which the least-cost plan is to focus on replacing coal generation with renewables is about $4.90 per MMBtu. According to the Energy Information Administration's 2014 reference case, this price is reached by about 2019. If we choose the renewables path and natural gas prices remain low, we may regret that we are not using cheap natural gas. If we choose the natural gas path and natural gas prices rise, we may regret that we are stuck using expensive natural gas when we could have had free wind or solar "fuel".

Complying with the Clean Power Plan by replacing coal generation with natural gas leads to the retirement of far more coal generation than does replacing coal generation with renewable generation. This also means that in the near term, choosing the natural gas path reduces criteria pollutants and airborne toxics more than the renewables path. We can no longer just compare direct cost of energy from renewables to direct cost of energy from natural gas, nor are the pollution implications of these choices straightforward. We need to approach this choice with a more sophisticated approach to uncertainty and risk than has been past practice.

Background on the Clean Power Plan

The Clean Power Plan is a U.S. EPA initiative pursuant to its authority under the Clean Air Act to reduce carbon and other forms of pollution from the nation's electric power system. The biggest step in the Clean Power Plan is the reduction of emissions from existing power plants based on EPA's authority under section 111(d) of the Clean Air Act.

Under section 111(d) of the Clean Air Act, EPA's responsibility is to promulgate a Best System of Emissions Reduction (BSER). EPA published a draft rule establishing carbon pollution standards for existing power plants in June 2014 and is on course to issue a final rule in summer 2015. The draft rule proposed to set a carbon emissions target for each state, expressed as a rate of carbon emissions per unit of electricity generated from certain types of power plants. EPA would then allow each state to develop its own plan for compliance, incorporating a variety of different approaches to reduce carbon emissions. In the draft rule, EPA proposed to set each state's carbon emissions rate target by considering that state's potential to reduce carbon emissions through improvements in the fuel-efficiency (or heat rate) of existing power plants, shifting the balance of generation from existing coal plants to existing natural gas plants, reducing fossil fuel combustion by deploying additional renewable generation, and by reducing electricity use through energy efficiency. There has been and will continue to be much debate about the appropriateness of each of these "blocks" and the particulars of how each state's obligations will be determined. However, EPA has been clear that it does not expect states to necessarily follow the recipe EPA uses to establish the carbon emissions reduction requirements when it comes to actual implementation. Rather, each state is encouraged to develop a plan that best meets its needs while achieving the required emissions reductions.

This paper begins to address the best path forward, assuming EPA adopts a rule that sets a carbon emissions target for Michigan and allows broad flexibility in the means to achieve that target. We will have to wait for the final rule to know Michigan's carbon emissions target and all of the details of the score- keeping and available options. However, we can begin to identify the questions that state environmental and utility regulators, utilities, and other stakeholders will need to answer as we implement the Clean Power Plan in Michigan.

Overview of the SCRAPS/STEER Model

Anticipating the need for a tool to analyze options to comply with the Clean Power Plan, 5 Lakes Energy contracted with the University of Michigan, with Jeremiah Johnson as the principal investigator, to develop a power system model for this purpose. We refer to the initial version used in developing this paper as SCRAPS (State-based Carbon Rule Analysis for Power Systems). SCRAPS provides means to find the least-cost plan of compliance using the major options available to utilities under the draft rule:

- heat rate improvements at existing power plants;
- changes in dispatch order to increase use of natural gas combined cycle plants and reduce use of coal plants;
- development of additional wind, solar, and biomass generation; and
- electric-utility customer energy efficiency programming,
- as well as allowing for potential development and use of new combustion turbine natural gas plants, new combined cycle natural gas plants, and new conventional combined heat and power plants.

We are currently working on a new version of the model that will incorporate additional technologies and reflect the final rule. This new version will be called the STEER (State Tool for Electricity Emissions Reduction) model and should be available soon after the final rule is published by EPA.

Every technological option in the SCRAPS/STEER model can be turned on or off by the user and all major assumptions are modifiable through the user interface. All data and assumptions are from official public sources.

One of the fundamental premises of our SCRAPS project is that the model should be accessible and usable by all stakeholders so that they can have an informed consideration of the most cost-effective implementation in Michigan of the Clean Power Plan. It was developed as a rather large, highly functional Excel spreadsheet and every data element, formula, and assumption is visible to and modifiable by the user. 5 Lakes Energy will make the Michigan SCRAPS/STEER models available to anyone who asks. A user manual that explains the logic and operation of the SCRAPS model is available now. Once the STEER model is complete, we will prepare an academic paper providing details of the model.

The initial SCRAPS model uses data for Michigan's power system. Versions of the STEER model will also be delivered for several other states. It would also be possible to remove and modify data so that the model will work for a single utility, a sub-state region, or a multi-state region.

The SCRAPS/STEER model uses the standard logic of utility integrated resource planning to find the least-cost changes to the power system that will achieve a user-specified level of carbon emissions reduction.

Starting from 2012 hourly load data for 24 representative days of the year, it forecasts future loads out to 2030 considering both load growth and any changes in load profile that result from the selected energy efficiency programs. The STEER model will further adjust the load profile based on forecasted adoption of electric vehicles and selected demand response, storage, and smart grid programs.

The SCRAPS model contains performance data for every electricity generating unit in Michigan, including separate consideration of the multiple units within each power plant. It calculates the least-cost dispatch of these generating units to satisfy load for each hour, then calculates coal usage, natural gas usage, variable costs, carbon emissions, sulfur oxide emissions, nitrous oxide emissions, and mercury emissions based on that plan of operations. The dispatch model also derives projected locational marginal price for use in the selection of least-cost carbon mitigation measures; we have verified that the locational marginal prices it projects using historical data closely approximate the actual historical locational marginal prices. If a carbon price policy is applied to dispatch, the model calculates dispatch, locational marginal price, and incremental cost of operating the power system accordingly.

If the model finds that existing capacity is insufficient to satisfy the forecasted load, plus reserve margin, it adds natural gas combustion capacity to the generation fleet. Capacity value of combined cycle natural gas plants or renewable resources is considered when those are chosen for carbon mitigation and these may forestall the use of natural gas combustion turbines for capacity.

Costs and effects of heat rate improvements at existing plants default to the assumptions EPA made in their development of the draft rule for existing power plants under the Clean Power Plan. However, a user may specify plant-specific assumptions if engineering data are available or make different default assumptions.

Renewable resource options are based on inventories of renewable resources developed by the National Renewable Energy Laboratory. Wind resources include 57 sites throughout Michigan and are modeled with hourly generation based on site-specific 10-minute-interval wind data. Solar resources include six cities around Michigan and are modeled for both fixed-mount distributed generation and single-axis-tracking utility-scale generation based on actual hourly insolation. Capacity factors, capacity credits, and hence power system value of wind and solar generation are the result of calculations using site-specific data rather than general assumptions. Biomass resource flows are in eight categories running from municipal waste and landfill gas through timber residuals.

Energy efficiency measures included in the SCRAPS model, their costs, and their achievable potential are taken from the Michigan energy efficiency potential study performed by GDS Associates in 2013[1] and released as part of Governor Snyder's "Ensuring Michigan's Future" report series in November 2013. These measures include residential, commercial and industrial customers and number 190. For purposes of modeling effects on load profiles, we classified each measure as affecting all load or peak load. As defined in the GDS report, we allow the user to specify whether the model should consider all achievable cost-effective energy efficiency or to constrain these programs to a spending cap of 2% of utility revenues, as provided in current law.

In addition to these features of Michigan's power system, the SCRAPS model also incorporates the operation of the Ludington Pumped Storage Plant and the possibility of power imports and exports subject to current transmission limitations established by the regional transmission organizations. A user can make changes to the import and export capacity limits.

A SCRAPS user can examine details of the model's calculations if they wish, but to facilitate use we summarize the modeled performance of the power system by presenting the contributions of various options to carbon mitigation, the effects of carbon mitigation on total power system costs and rates, the marginal cost of carbon mitigation, the projected composition of generation, and changes in fuel consumption and emissions of conventional pollutants.

SCRAPS also provides users the ability to retire existing generating units and provides the capacity factors, dispatch order, air pollutant emissions, and other information that a user might consider in making retirement decisions. Cost projections based on retirements include the need to pay for remaining book value of the retired plants, assumed to be done through securitization. Retirement decisions are not automated in the least-cost planning algorithm because those decisions are based on a variety of considerations that are not included in our modeling.

The STEER model on which we are currently working will incorporate additional technologies such as geothermal and nuclear electricity generation, biomass co-firing in existing coal plants, new hydropower, fuel cell cogeneration, demand response, smart grid technologies, electric vehicle integration, and battery storage.

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[1] GDS Associates. (2013a). Michigan Electric and Natural Gas Energy Efficiency Potential Study. Prepared for Michigan Public Service Commission, Consumers Energy, DTE Energy. Oct 2013.

As with any model, simplifications have been made that can affect modeling results. Two are important to the interpretation of SCRAPS modeling results. The first is that the model assumes there are no binding transmission constraints within Michigan. Standard transmission costs are included in the model, but it is possible that the model would partly replace generation from a fossil fuel plant with renewables in a remote location. New natural gas and biomass plants are not assigned to specific locations, so their locations can reflect transmission availability and support requirements. Actual model results do not appear to be distorted as a result of this simplification.

The second simplification is that the model calculates the best plan for a single year, chosen by the user, and does not aggregate year-by-year results into the optimum plan over a period of time. For example, the model might calculate that the least-cost plan uses a new natural gas combined cycle plant based on projected conditions in 2020. However, based on projected conditions in 2030, the model may calculate that a combination of wind generation and a combustion turbine plant is best. The model does not attempt to resolve these different conclusions by solving the dynamic programming problem of how best to act over the full life-cycle of each generator although that analysis can be performed by using the model to analyze results year-by-year and evaluating the life-cycle results.

With these simplifications in mind, SCRAPS should be considered a useful strategic planning tool, enabling rapid consideration of a wide range of alternatives and providing transparency as to why the model calculates its recommendations in a particular scenario. It can serve as an all-stakeholder screening tool to identify compliance plans for further analysis and refinement using more cumbersome and proprietary software such as utility companies utilize for long-term planning tools.

Key Assumptions and Scenarios

The SCRAPS model uses a significant number of parameters, all of which are visible in the model and the sources of which are documented in the user manual. For the analysis presented below, certain key assumptions were made about policies, and scenarios were constructed around future cost projections. These analyses were done using version 101414 of the SCRAPS model.

The scenarios presented below assumed that both the production tax credit and investment tax credits for renewable generation will expire. These scenarios also assumed continuation of existing tax advantages and relaxed regulation of natural gas production, continuation of the nuclear production tax credit, and continuation of implicit subsidies for coal from federal lands.

These scenarios also conservatively assume that wind turbine capital costs and power curves will remain at current levels through 2030 rather than follow current improvement trends. Solar costs are assumed to begin at 2014 levels and continue to decline along the well-defined solar experience curve to the DOE Sunshot goal of $1.00/watt installed cost for utility scale systems. This assumption is less conservative than the assumption for wind, but is consistent with current evidence and authoritative forecasts.

The final 111d Clean Power Plan rule's specific carbon emissions reductions targets for each state will likely differ from the draft rule. Nonetheless, for the analysis presented below, the emissions rate target proposed by EPA for Michigan as of 2030 in the draft rule was assumed, which was 1,161 lbs per MWh of eligible generation or efficiency credits.

In each scenario, the coal plant retirements already announced were used as a starting point and further retirements were analyzed based on total power system cost reductions, assuming compliance with the Clean Power Plan. Plants that are supported by System Support Resource payments from the Midcontinent Independent System Operator are not considered as announced retirements but are retired as warranted based on projected use and costs in each scenario.

Below are results from using the SCRAPS model to find the least-cost plan for compliance with the Clean Power Plan in 2030 under two fuel-price scenarios. Both scenarios discussed below allow the possibility that new natural gas generating units will be counted as mitigation under the Clean Power Plan, although this is not a definite option under the draft rule. In both scenarios, energy efficiency is not constrained by a spending cap. However, the cost of applying Michigan's existing spending cap under Public Act 295 of 2008 is reported for comparison.

In the "Low Natural Gas Prices" scenario, it is assumed that natural gas, coal, nuclear, and other fuel prices in 2030 will be the same in 2014 money as in 2014. In the "EIA Projected Natural Gas Prices" scenario, 2030 fuel prices in 2014 money are taken from EIA's reference case in the 2014 Annual Energy Outlook. The "Low Natural Gas Prices" assumption is well below EIA's forecast of 2030 fuel prices.

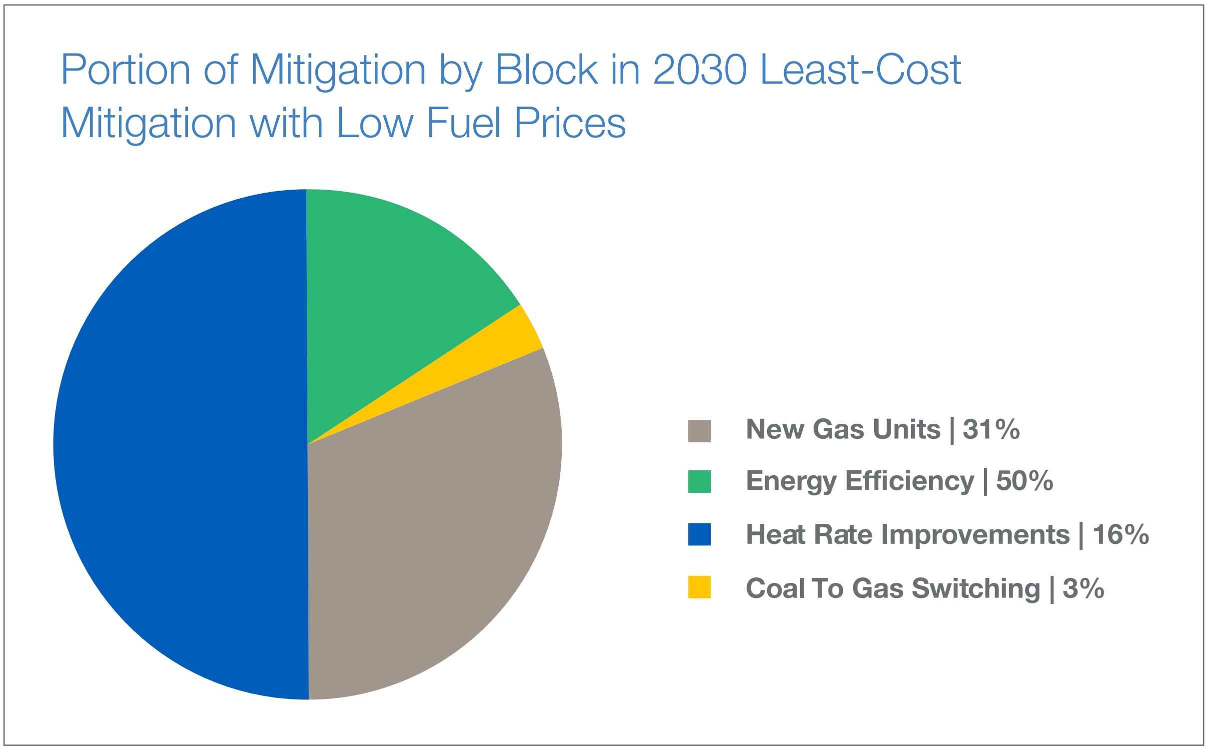
Fuel price forecasts in 2030, in 2014 money, under these two scenarios are shown below. Although these prices are published by EIA as reference prices, they enter model calculations as the price as delivered to the power plant.

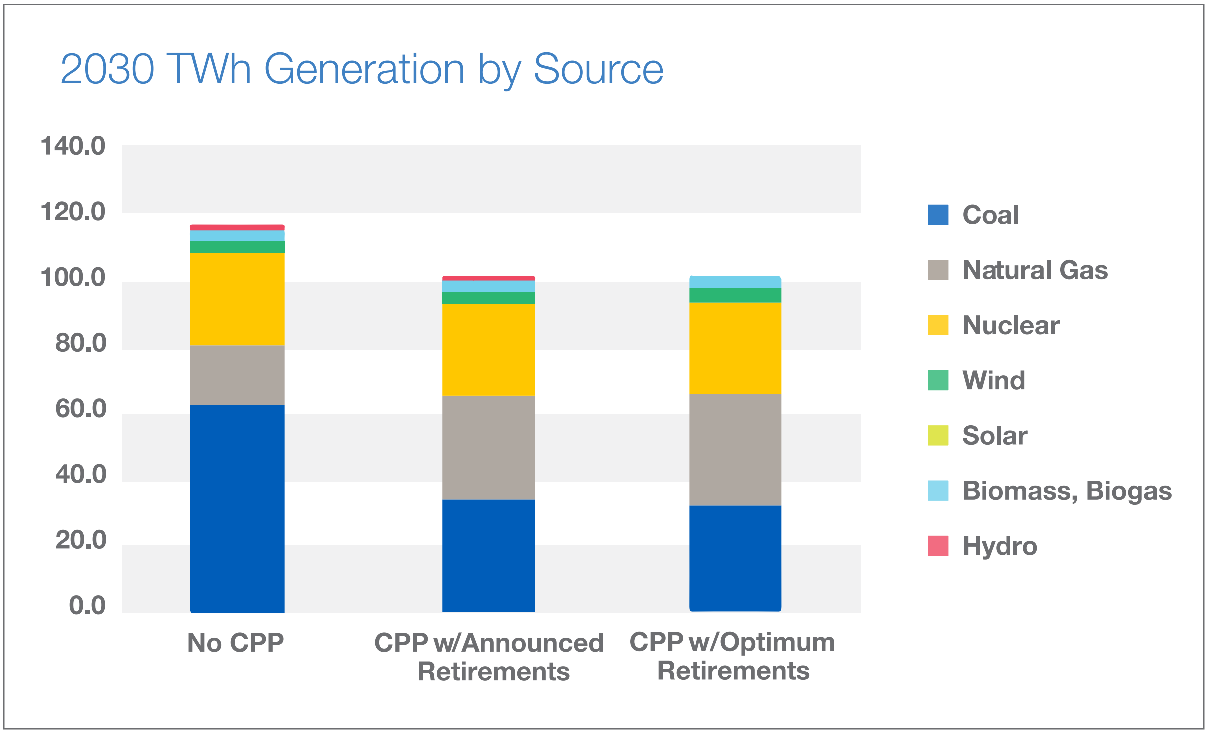
Fuel	Low Natural Gas Price Scenario	EIA Projected Natural Gas Price Scenario
Steam Coal	$2.49/MMBtu	$3.03/MMBtu
Natural Gas	$3.83/MMBtu	$6.73/MMBtu
Nuclear	$0.25/MMBtu	$0.25/MMBtu

Least-cost Plan of Compliance Assuming Low Natural Gas Prices

As described above, the low natural gas price scenario assumes that natural gas at the power plant costs $3.83 per MMBtu.

If we assume that 2015 fuel prices will still persist in real terms in 2030, then the least cost plan for compliance with the 2030 carbon emissions goal in EPA's draft rule for existing plants is composed of heat rate improvements at existing plants, all cost-effective energy efficiency, and substitution of natural gas generation for coal.





	No CPP	CPP with Announced Coal Retirements	CPP with Least-cost Coal Retirements
Coal (TWh)	62.9	34.7	32.3
Natural Gas (TWh)	17.5	31.5	34.0
Nuclear (TWh)	28.0	28.0	28.0
Wind (TWh)	4.2	4.2	4.2
Solar (TWh)	–	–	–
Biomass, Biogas (TWh)	3.1	3.3	3.2
Hydro (TWh)	1.4	1.4	1.4
Total (TWh)	**117.2**	**103.0**	**103.2**

This plan calls for retirement of 5,825 MW nameplate coal generation capacity, of which 1,205 MW has already been announced. As can be seen from the preceding graph and table, these additional retirements largely reflect that this capacity will not be used due to the carbon emissions limit and do not significantly reduce coal generation. For purposes of modeling the effect of retirements, the coal plants with near-zero capacity factors in the projected future were retired until total system cost began to increase due to the addition of new replacement capacity. Other factors, particularly anticipated required maintenance investments and environmental control investments might change the plants selected for retirement, but would not materially affect the optimum capacity to be retired.

Energy efficiency measures correspond to approximately 1.6% annual electric utility energy optimization goals. Renewable generation is just the 10% by 2015 renewable credit portfolio standard required by current Michigan law.

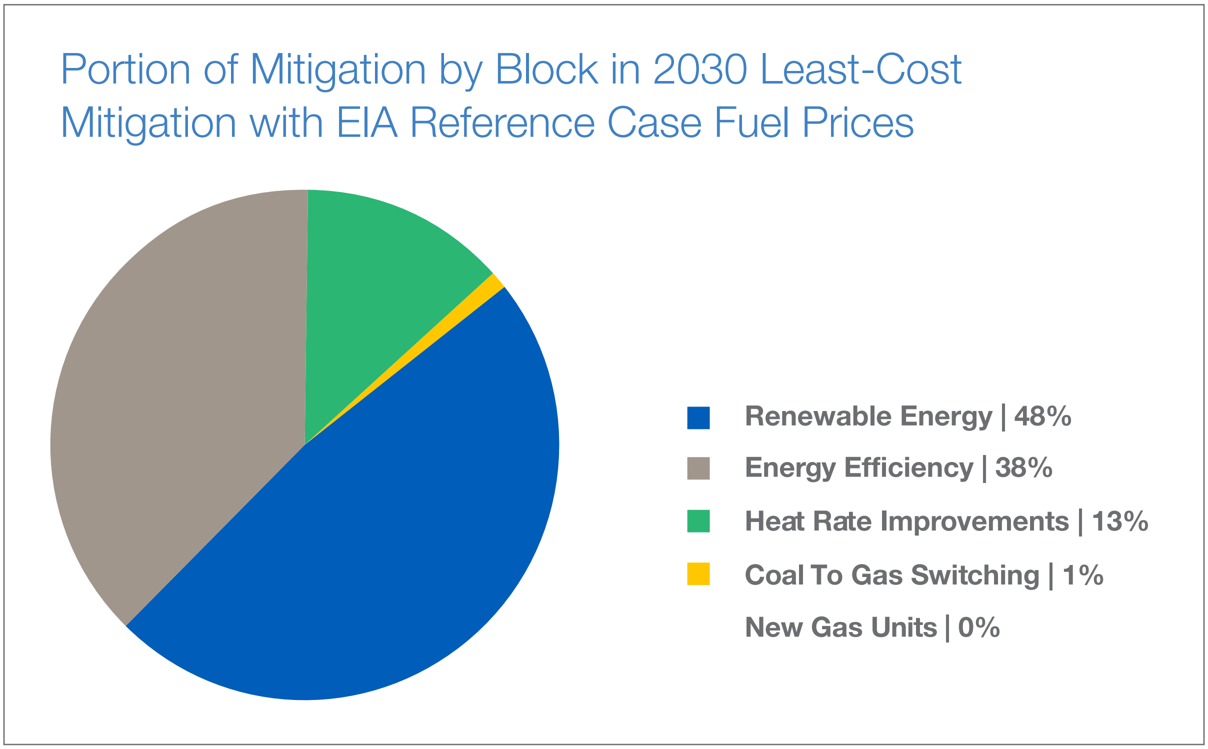
Implementation of this plan for Michigan to comply with the Clean Power Plan will reduce Michigan's total electricity bill by $609 million per year compared to the $12.351 billion we would otherwise pay for electricity in 2030. This corresponds to an average of six-tenths of a cent per kilowatt-hour lower electricity rates. This savings compared to business as usual is largely due to the retirement of Michigan's current excess baseload generation capacity, replaced by new natural gas plants and energy efficiency. In this scenario, if we were to limit energy efficiency programs to 2% of revenue as in current law, then compliance with the Clean Power Plan would cost an additional $145 million or $464 million less than electricity would cost in 2030.

Compliance with the Clean Power Plan in 2030, based significantly on the use of natural gas as a replacement for coal, reduces Michigan's annual coal consumption for electricity generation by 55% and increases its level of natural gas consumption for electricity generation to more than 200% above 2014 natural gas consumption for electricity production. This reduced coal use also reduces air pollution from power plants, reducing nitrous oxide emissions by 43.2%, sulfur oxide emissions by 53.4%, and mercury emissions by 53.6%.

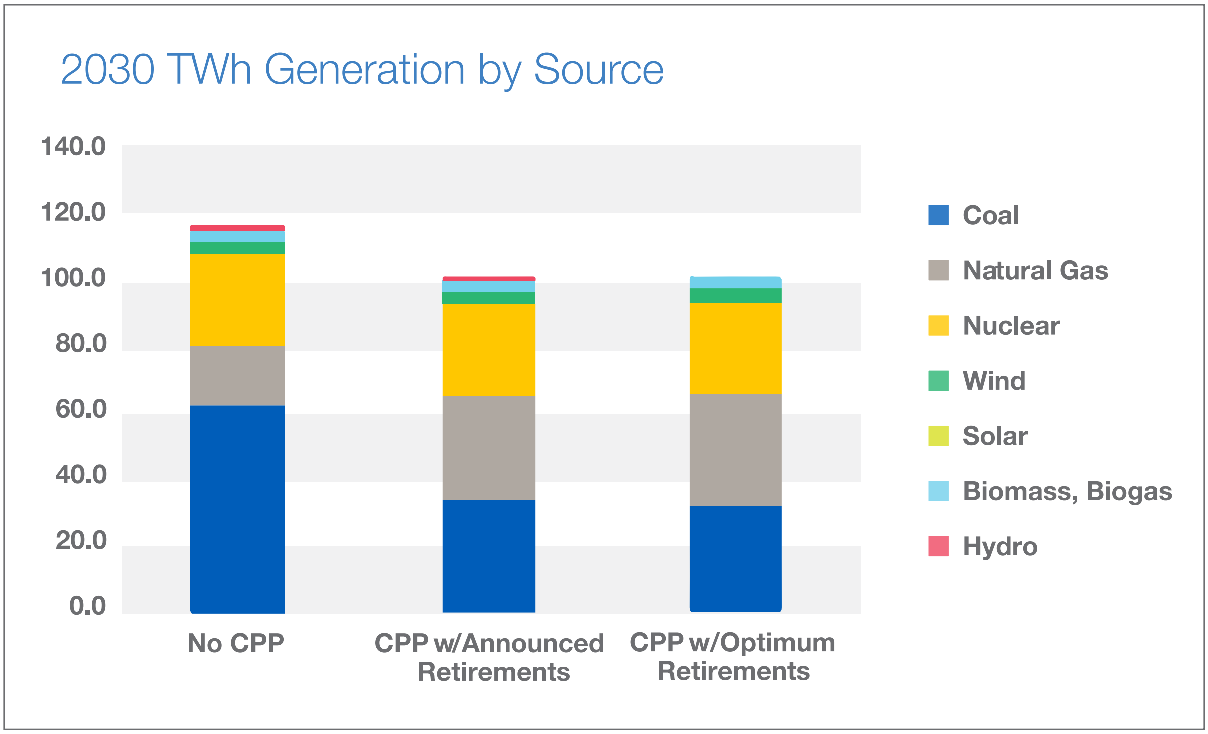
Least-cost Plan of Compliance Assuming EIA Projected Natural Gas Prices

As described above, the low natural gas price scenario assumes that natural gas at the Henry Hub costs $6.73 per MMBtu.

If we assume the 2030 fuel prices in EIA's 2014 Annual Energy Outlook reference case, then the least cost plan for compliance with the 2030 carbon emissions goal in EPA's draft rule for existing plants looks considerably different.



The model still recommends some heat rate improvements and all cost-effective energy efficiency. However, with the higher price for fuels, the least-cost plan now substitutes renewable generation instead of natural gas for coal. The following graph illustrates the projected 2030 composition of power services.



	No CPP	CPP with Announced Coal Retirements	CPP with Least-cost Coal Retirements
Coal (TWh)	62.9	34.7	32.3
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Biomass, Biogas (TWh)	3.1	3.3	3.2
Hydro (TWh)	1.4	1.4	1.4
Total (TWh)	**117.2**	**103.0**	**103.2**

This plan calls for retirement of 3,650 MW nameplate coal generation capacity, of which 1,205 MW has already been announced.

It is noteworthy that the amount of coal plant retirement in the least-cost plan that replaces coal with renewable generation to meet the Clean Power Plan carbon emissions reduction is much less than the 5,825 MW coal capacity that should be retired in the least-cost plan that replaces coal with natural gas generation. This occurs because replacing a megawatt-hour of coal generation with renewable generation eliminates all of the carbon emissions associated with coal generation, while replacing a megawatt-hour of coal generation with natural gas generation only eliminates a fraction of the carbon emissions associated with coal generation. The ongoing debate about comparative costs of electricity from renewables and natural gas will be necessarily expanded to include discussion about the relative cost of carbon pollution mitigation using these generation resources.

Energy efficiency measures optimally chosen in this scenario correspond to approximately 1.5% annual electric utility energy optimization goals. Renewable generation is equivalent to a 27% renewable energy credit portfolio.

Implementation of this plan for Michigan to comply with the Clean Power Plan will reduce Michigan's total electricity bill by $378 million per year compared to the $12.861 billion we would otherwise pay for electricity in 2030. This corresponds to an average of four-tenths of a cent per kilowatt-hour lower electricity rates. This savings compared to business as usual is largely due to avoided capacity costs due to energy efficiency programs. In this scenario, if we limit energy efficiency programs to 2% of revenue as in current law, then compliance with the Clean Power Plan costs an additional $699 million or $321 million more than we would otherwise pay for electricity in 2030.

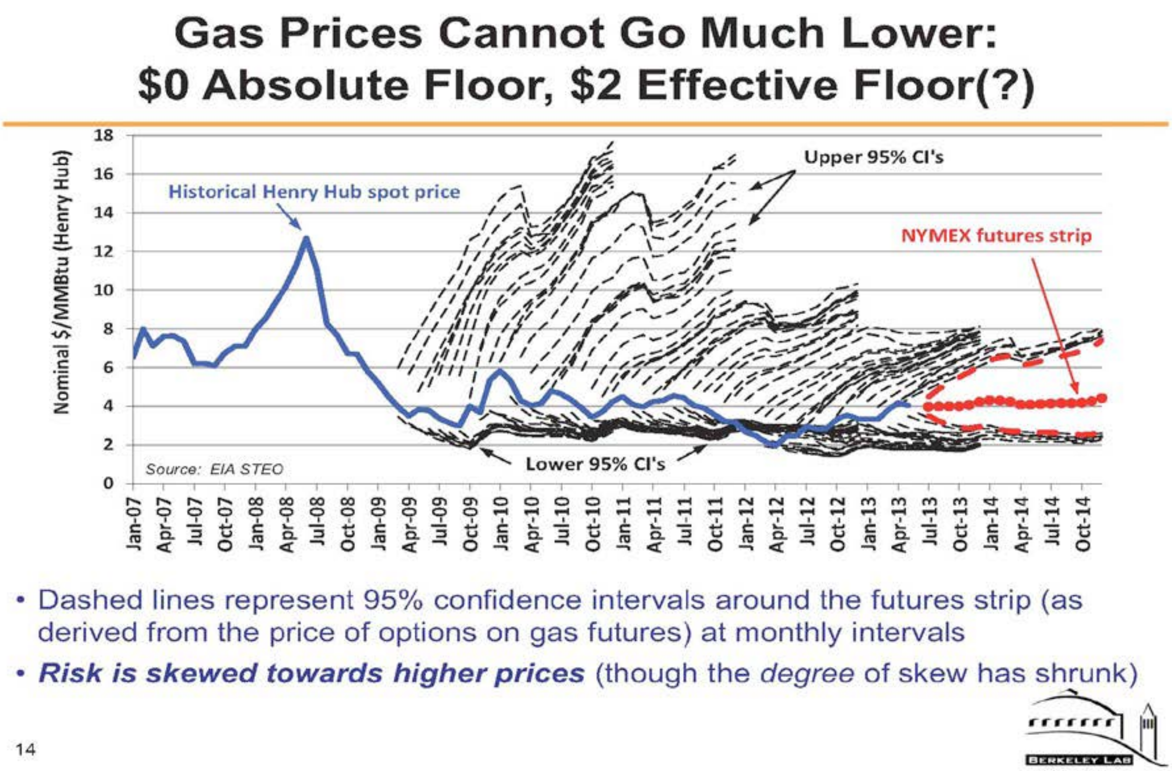
Compliance with the Clean Power Plan in 2030, based on the use of renewables as a replacement for coal will reduce Michigan's annual coal consumption for electricity generation by 30% and reduce our annual natural gas consumption for electricity generation by almost 50% below Michigan's 2014 natural gas consumption for electricity production. This reduced fuel use also reduces air pollution from power plants, reducing nitrous oxide emissions by 38.8%, sulfur oxide emissions by 37.6%, and mercury emissions by 31.3%.

Risks and Regrets

It is not valid to compare the projected costs of electricity in Michigan under the two scenarios above and select the cheapest. These are scenarios based on different fuel price forecasts and fuel prices will be determined by events and policies outside of Michigan's electricity planning. We, therefore, need to consider our risks.

By experimenting with the SCRAPS model using a range of price projections, it appears that the price forecast that tips the balance between coal-to-gas and coal-to-renewables as the least-cost plan is for natural gas price delivered to the plant at about $4.90/MMBtu. EIA's reference forecast from the 2014 Annual Energy Outlook is that we reach this price level in 2018 or 2019. It is certainly possible that EIA is wrong and that betting on low natural gas prices will pay off. However, it is also plausible that EIA is wrongly forecasting lower natural gas prices than will actually develop.

The following graph[2] illustrates the essential issues. The dashed lines on either side of the historical and projected prices represent the upper and lower limits of the range of uncertainty about future gas prices as reflected in future options prices at the time the lines depart from the price history. The cone of uncertainty around future prices reflects the price-risk assessments of sophisticated market participants over time. There is the probability of continued low natural gas prices, balanced by a nearly equal probability of higher future natural gas prices, but the probabilities are asymmetrical, with higher prices being much higher and lower prices being only modestly lower.



The scenarios presented above suggest that if we choose the renewables path and natural gas prices remain low, we may regret that we are not using cheap natural gas. However, in that scenario, we will have significant remaining coal capacity that can be replaced with natural gas generation to take advantage of the continuing low natural gas prices.

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6 From "Valuing Renewables as a Long-Term Price Hedge, Even in an Era of Low Natural Gas Prices", presentation by Mark Bolinger, Lawrence Berkeley National Laboratory to 2013 EIA Energy Conference.

If we choose the natural gas path and natural gas prices rise, we may regret that we are stuck using expensive natural gas when we could have had free wind or solar "fuel". Of course, we can then start building renewable generation to reduce our use of natural gas, but will still need to pay for the natural gas generation capacity.

It is also important to note that in modeling these scenarios, natural gas prices were fixed at the assumed price. EIA's 2014 Annual Energy Outlook reference case did not assume the Clean Power Plan. Thus, it is very likely that if many states pursue the natural gas path for compliance, natural gas prices will rise even faster than in EIA's reference case. On the other hand, if most states pursue the renewables path, natural gas consumption may be less than EIA forecast in its reference case and natural gas prices will not rise as fast as forecast.

Choosing A Path

Michigan's Governor Snyder has been calling for a "no regrets" approach to energy policy. It is clear from analysis using the SCRAPS model that the best plan for compliance with the Clean Power Plan includes all cost-effective energy efficiency, which appears to be above 1.5% annual energy savings.

It is also clear that choosing to comply with the Clean Power Plan by replacing coal generation with natural gas leads to the retirement of far more coal generation than does replacing coal generation with renewable generation. This also means that in the near term, choosing the natural gas path reduces criteria pollutants and airborne toxics more than the renewables path. Thus, it appears that a key question to finding the best path forward is the status of our coal fleet. Is there enough coal capacity that is ripe for retirement that it is easy to make the shift to natural gas or will we struggle with accelerated retirements and stranded costs?

Given the status of our coal fleet, we will still face some irreducible uncertainty about which path is least costly. The choice before Michigan when implementing the Clean Power Plan is different than the typical debate we've been having about the role of renewables. We can no longer just compare direct cost of energy from renewables to direct cost of energy from natural gas, nor are the pollution implications of these choices straightforward. We need to approach this choice with a more sophisticated approach to uncertainty and risk than has been past practice.

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