



POWERING THE FUTURE:

Harnessing Industrial Demand Flexibility to
Reduce Emissions and Integrate Renewables

IN PARTNERSHIP WITH



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EXECUTIVE SUMMARY

Power grids are undergoing a paradigm shift—spelling fresh opportunity for industrial leaders to partner with grid operators to manage energy costs, support grid reliability, reduce carbon emissions, and help integrate more renewable energy.

With this in mind, industrial customer Hemlock Semiconductor (HSC), utility Consumers Energy, and environmental tech nonprofit WattTime teamed up to explore how much industrial demand could shift on various time scales. Together, we investigated implications for factors such as emissions reductions and renewables integration—both now and as grids across the country and around the world further decentralize and decarbonize.

Based on our analysis for HSC in MISO's grid today, we found that emissions reductions through demand flexibility were negligible (0.74%) via a cost-based approach similar to real-time pricing (RTP). An emissions-based approach to demand flexibility, such as via WattTime's Automated Emissions Reduction (AER) technology, was better. Using AER, load shifting could reduce associated emissions 1.7–3.4% relative to the baseline for the flexible load, translating to annual emissions reductions up to ~2,500 metric tons of CO₂.

These results are largely due to two interrelated factors: 1) fossil-fueled power plants currently make up roughly two-thirds of electricity generation in Michigan and MISO more broadly, and 2) natural gas power plants also tend to be the marginal generating unit, resulting in the marginal emissions rate having relatively little variability on a daily basis and thus offering limited opportunity for time-based arbitrage of marginal emissions rates.

Although today's grid in MISO yielded only small opportunities for incremental emissions reductions through industrial demand flexibility, times are changing. By 2030, variable renewable generation (i.e., solar, wind) is expected to grow

5x, from 8% in 2019 to nearly 40% by 2030. In parallel, fossil-fueled generation is expected to decline substantially, from nearly 70% in 2019 to 40% by 2030.

With this context in mind, we also analyzed the emissions-reduction potential of AER applied to HSC's demand flexibility in other markets—CAISO and SPP—that reflect current grids in different parts of the country, as well as which represent a 'postcard from the future' for what Michigan and MISO might expect in the years ahead.

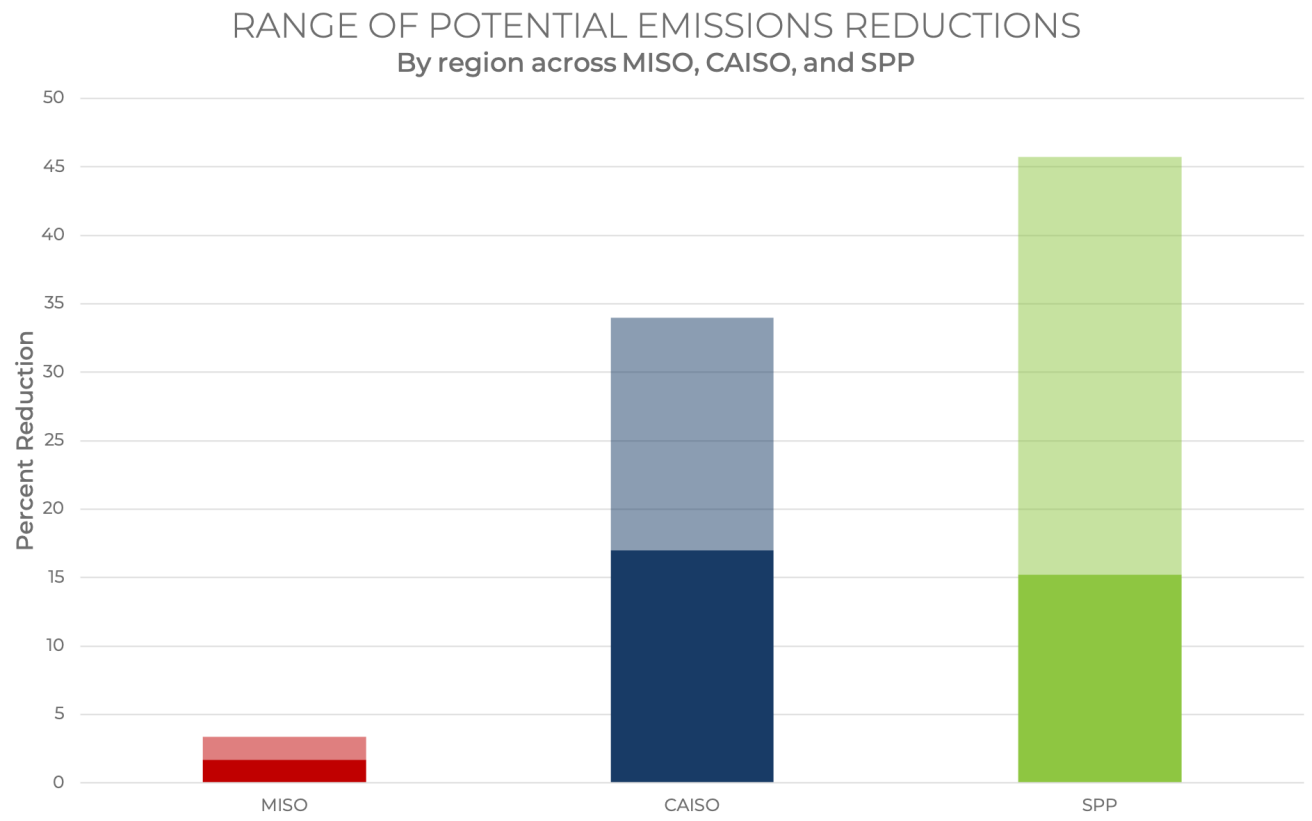
We found substantial emissions-reduction potential on the order of 15–34% vs. baseline emissions associated with the shifted load, approximately 10x greater emissions savings on a percentage basis and 8x on an absolute basis than what is achievable in MISO today. This suggests an enormous opportunity if adopted for industrial customers' flexible loads across a range of power grids that are increasingly becoming the norm as the U.S. continues its energy transition.

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FIGURE ES-1

The range of emissions-reduction potential for AER with industrial customers in SPP and CAISO today suggest exciting opportunities for what will be possible in MISO in the near future tomorrow.



BASED ON THESE RESULTS, WE DRAW SEVERAL CONCLUSIONS:

1. **For remaining fossil-heavy grids** (and/or grids where fossil generation is often marginal), industrial demand flexibility primarily supports cost and grid reliability, plus some future proofing for the coming energy transition.
2. **For grids in transition** (mix of fossil and clean generation), industrial demand flexibility spells new opportunity for emissions arbitrage. Thanks to AER, industrial facilities can prioritize clean energy use and avoid fossil-fueled energy, resulting in deeper and faster emissions reductions. Industrial demand shifting today also lays the groundwork increasing impact as grids evolve with a greater mix of renewables.
3. **For grids rich in renewables**, industrial demand flexibility has become a crucial tool for supporting the paradigm shift from load-following generation to generation-following load. Industrial leaders can now sync up with renewable generation profiles and help their respective grids move to a higher percentage of renewables and reduce renewable curtailment.

INTRODUCTION

Power grids are undergoing a paradigm shift—spelling fresh opportunity for industrial leaders to manage energy costs, support grid reliability, reduce carbon emissions, and help integrate more renewable energy. Several interrelated themes define this shift:

1. **From centralized, one-way generation** and transmission to two-way flows of value via grid-edge distributed energy resources (DERs)
2. **From fossil-heavy thermal generation** to renewables-rich clean generation
3. **From ‘always on’ baseload generation** to an orchestrated mix of variable generation
4. **From static demand forecasts** to demand as a dynamic variable, including flexible loads that can be responsive to grid needs
5. **From analog ‘dumb’ demand** to digitalized ‘smart’ demand flexibility

“While energy efficiency (EE) programs of the past were primarily used to reduce baseload in a central-station paradigm, the demand-side management (DSM) programs of the future will also need to align with distributed energy management and resource flexibility goals. At the same time, the growing number of connected devices, self-generation and energy management options means that customers have a central role to play in the future of the grid — they will no longer be viewed as passive load, but instead as flexible grid resources,” [noted Utility Dive in 2018](#).

In the increasingly prevalent new paradigm, demand flexibility solutions are paramount. Consequently, demand-side management (DSM) programs have grown rapidly over the past few years, now encompassing energy efficiency (EE) programs, demand response (DR) programs, Automated Emissions Reduction (AER), rate designs that influence load shape such as time-of-use (TOU) and real-time pricing (RTP), smart meters, and energy management systems.

Powered by a simultaneous acceleration in Internet of Things (IoT), artificial intelligence (AI), and connective technology adoption, today's demand-side management (DSM) programs directly support dynamic energy generation and management as well as resource flexibility. For example, WattTime’s Automated Emissions Reduction (AER) software has enabled battery energy storage systems in California to [slash their emissions footprint](#). Applying that same technology to [electric vehicle charging](#) could reduce their emissions by up to 20% annually and up to 90% on individual days.

Beyond the common focus on residential and commercial sectors, industrial customers and their large demand represent an increasingly important tool as power grids transition. Industrial energy use comprises roughly [25%](#) of U.S. electricity demand yet represents around [50%](#) of potential peak demand savings from retail demand response (DR) programs. Industrial demand flexibility could represent a huge untapped opportunity for managing ‘grids of the future.’ Although industrial electricity loads are often stereotyped either as a small fraction of overall industrial energy demand or as an inflexible portion of industrial load, many industrial customers in fact have both meaningful electricity demand and opportunities for flexible demand shifting.

With this in mind, industrial customer Hemlock Semiconductor (HSC), utility Consumers Energy, and environmental tech nonprofit WattTime teamed up to explore how much industrial demand could shift on various time scales. Together, we investigated implications for factors such as emissions reductions and renewables integration—both now and as grids across the country and around the world further decentralize and decarbonize.

DEEP DIVE

THE POTENTIAL FOR AER AT HEMLOCK

Based in Michigan, Hemlock Semiconductor (HSC) manufactures hyper-pure polysilicon for the electronic and solar power industries. The production of polysilicon is generally energy intensive. At full production, HSC is the largest single-site user of electricity in the state of Michigan and the largest customer of utility Consumers Energy.

HSC represents a manufacturing plant with a high-intensity energy load but also a degree of load flexibility, making it an example of a useful and relevant case study for other industrial leaders to consider. Consumers Energy developed a rate—

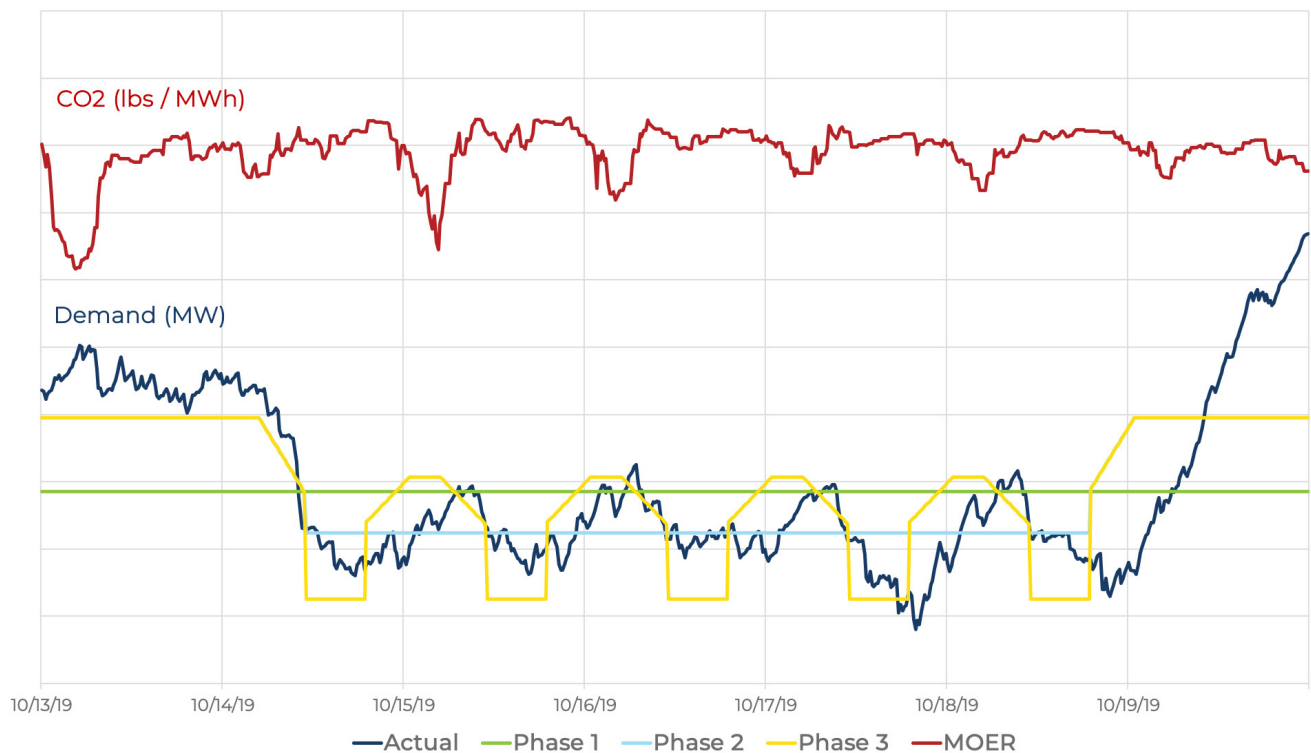
known as the Long-term Industrial Load Retention Rate (LTILRR)—with both real-time pricing (RTP) and demand-based attributes for Hemlock, to further encourage load flexibility. Prior to the rollout of LTILRR, Hemlock experimented with time-based load shaping (see Figure 1).

To advance its corporate commitment to moving the world toward a greener future, HSC leaders also teamed up with WattTime to assess the current emissions impact of its operations and the potential benefits of incorporating an Automated Emissions Reduction (AER) program.

FIGURE 1

In advance of Consumers Energy rolling out a real-time pricing tariff, HSC explored several hypothetical versions of time-based load shifting. Associated emissions reductions were negligible in MISO's grid today.

SCENARIOS OVERVIEW
Demand and emissions during the week of 10/13/2019



ASSUMPTIONS & METHODOLOGY

We evaluated HSC's emissions-reduction potential from demand flexibility, using retrospective data from 2018–2019, with the following considerations:

1. **Grid Region:** MISO_Detroit¹
2. **AER:** Minimizing the marginal emissions impact, using WattTime's v3.0 MOERs
3. **Flexible Load:** 10% of the baseline load in each interval
4. **Max Load:** 100% of annual peak (load-shifting cannot exceed the annual peak load)
5. **Constraints:** shift load within 24-hour window, shift load from dirtiest to cleanest 12 hours, shift by rank order

RESULTS

Based on our analysis for HSC in MISO's grid today, we found that emissions reductions through a cost-based RTP approach to demand flexibility were negligible (0.74%). An emissions-based approach to demand flexibility, such as via AER, was far better but still limited on a percentage basis. Using AER, load shifting would be able to reduce associated emissions 1.7–3.4% relative to the baseline for the flexible load and 0.1–0.2% relative to HSC's total load.

These modest results are largely due to two interrelated factors: 1) fossil-fueled power plants currently make up roughly two-thirds of electricity generation in Michigan and MISO more broadly, and 2) natural gas power plants also tend to be the marginal generating unit, resulting in the marginal emissions rate having relatively little variability on a daily basis and thus offer somewhat limited opportunity for time-based arbitrage of marginal emissions rates.

These results still translate to significant annual emissions reductions: up to ~2,500 metric tons of CO₂ emissions savings, **equivalent to** eliminating more than 6 million miles driven by a passenger car or not burning more than 2.7 million pounds of coal.



¹WattTime's balancing areas (BAs) are defined differently than traditional MISO zones. WattTime BAs are defined by grouping areas of similar grid behavior. Hence WattTime's MISO_Detroit zone includes only the eastern half of the Michigan peninsula, while MISO Zone 7 is essentially the entire peninsula.



Spotlight: Inventory spheres as MW-size virtual battery

As a manufacturing producer with a significant electrical demand and production volume, Hemlock Semiconductor possesses a number of large storage vessels to store process chemicals between manufacturing steps. By controlling and planning the inventory levels of precursors and products at different steps in the polysilicon manufacturing process, Hemlock can facilitate controlled variation in its electrical consumption without disrupting upstream supply chains. For example, at times of high electricity market prices, Hemlock may reduce its electrical consumption and elect to increase its working inventory of precursor chemicals. Any short term reduction in energy use is later offset by an increase in production at a time of lower grid demand in order to bring inventory levels back to their initial level.

In practice, the strategy of maintaining upstream supply chains and taking short-term load deviations in chemical inventory levels acts as a virtual battery. The battery is depleted when inventory levels of precursor are allowed to rise, and the battery is “charged” when Hemlock catches up on the deferred production and consumes the inventory levels built. This operating strategy has been demonstrated at Hemlock to offset more than 500 MWh of electricity for a single “charge cycle” of this virtual battery.

THE POTENTIAL FOR AER-BASED INDUSTRIAL LOAD SHIFTING IN OTHER GRID REGIONS TODAY AND MICHIGAN IN THE FUTURE.

Although today's grid in MISO yielded only small opportunities for incremental emissions reductions through industrial demand flexibility, times are changing. By 2030, variable renewable generation (i.e., solar, wind) is expected to grow 5x, from 8% in 2019 to nearly 40% by 2030. In parallel, fossil-fueled generation is expected to decline substantially, from nearly 70% in 2019 to 40% by 2030.

Most recently, in June 2021 Michigan utility Consumers Energy **announced an updated plan** to retire all coal-fired generation by 2025, 15 years ahead of its original schedule. This comes as part of Consumers Energy's updated Clean Energy Plan, which calls for **1,100 MW of new solar capacity by 2024** and nearly **8,000 MW of new solar by 2040**.

Industrial customers could further help the grid integrate ever-higher percentages of renewables while mitigating challenges with curtailment. That's because flexible industrial loads can be shifted to soak up excess renewable generation during sunny or windy hours on a day-to-day basis. For example, a February 2020 MISO study suggests that as wind and solar reach a combined 40% of MISO's generation mix, curtailment could reach as high as 25% without corrective action.

Flexible industrial loads also have the potential for **macro-scale demand shifting on a seasonal basis**. Consider Consumers Energy's plan for adding 8 GW of solar PV capacity by 2040. During summer when temperatures are hotter and air conditioning demand and overall grid demand are up, solar can contribute to meeting that peak. But during the spring and fall shoulder seasons, residential and commercial electricity demand is far lower, putting solar at risk of curtailment because of insufficient demand. Industrial loads like that of HSC could essentially back fill the "missing" demand, helping absorb more solar generation on Michigan's grid.

In other words, on a variety of time scales, every MW of industrial load made flexible potentially allows another MW of renewable energy to be built without the risk of that curtailment—important benefits as grid operators across the United States and around the world continue renewables generating capacity buildout.

Meanwhile, these same factors impacting MISO's near-future grid are already the reality in a number of grid regions across the U.S. today. For example, in **2019 solar-rich CAISO** saw non-hydro renewables contribute 27% to the annual generation mix, while natural gas contributed 30%. Similarly, in **2019 traditionally coal-heavy SPP** saw wind generation contribute 27% to the mix, while coal-fired generation had declined from 60+% pre-2014 to 35% (see Figure 2).

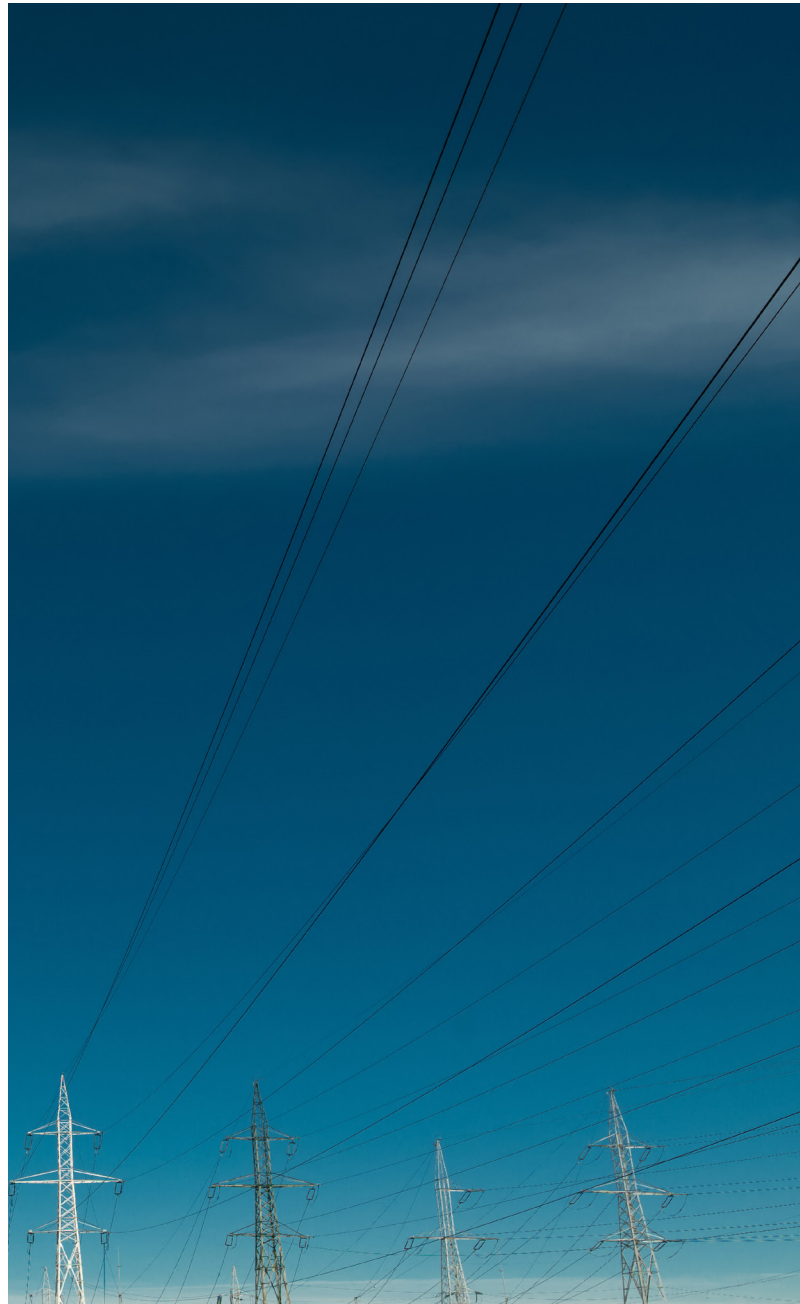


FIGURE 2

Although fossil fuels, especially natural gas, dominate MISO's generation mix today, within a few years variable renewables will contribute a proportion similar to that of CAISO and SPP today. By the turn of the decade, total emissions-free generation in MISO will rival that of CAISO and SPP today.

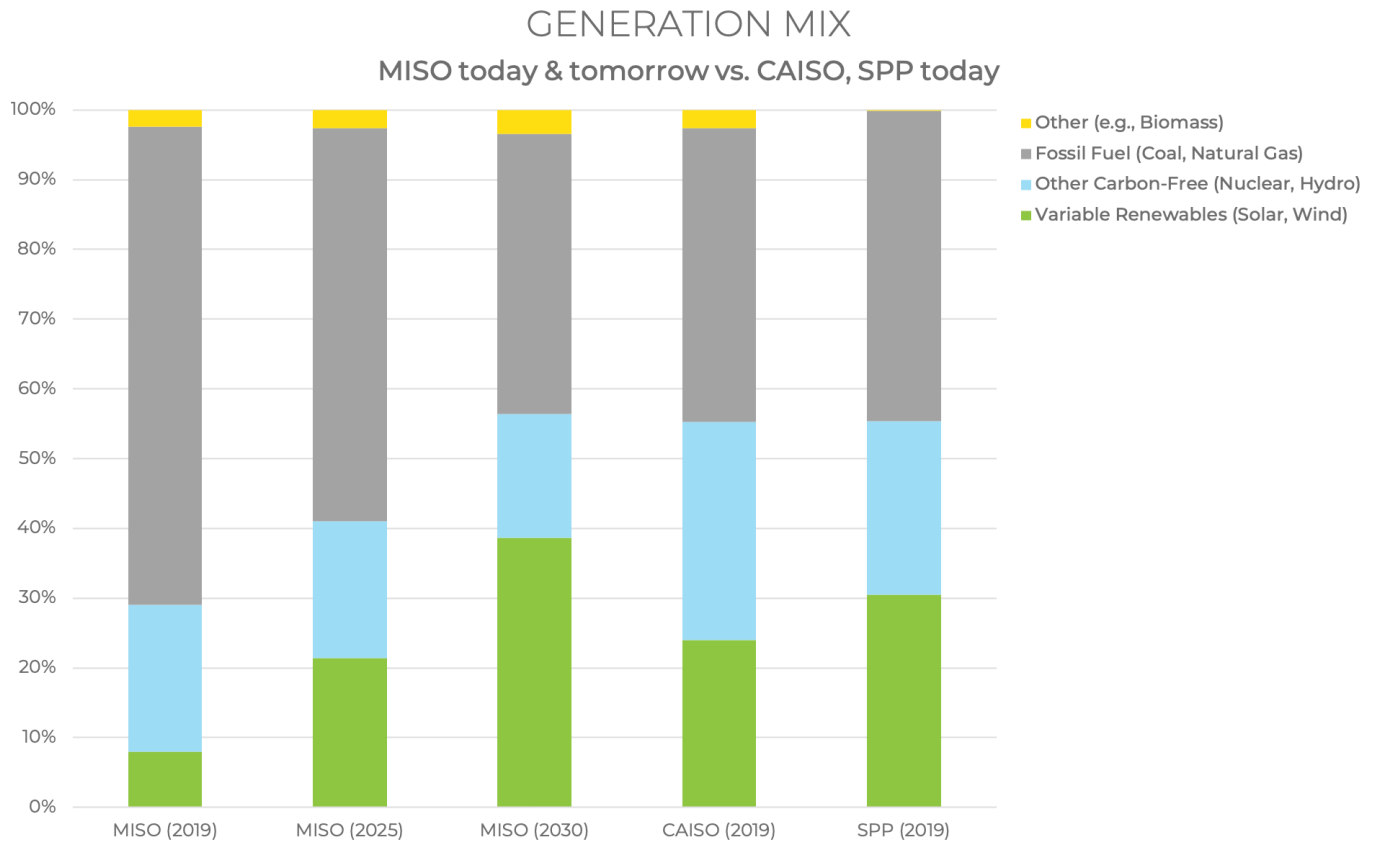
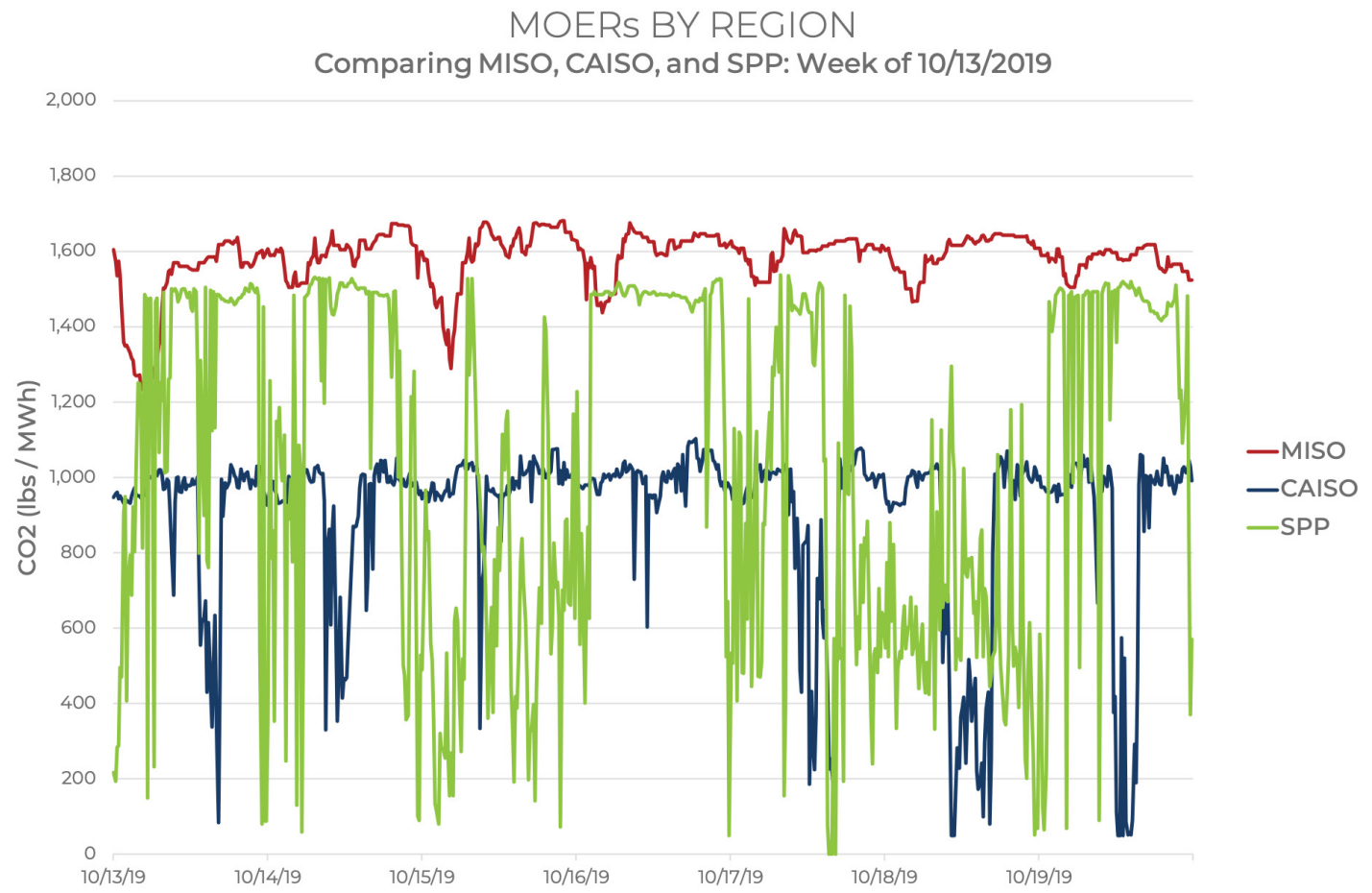


FIGURE 3

Compared to MISO today, both CAISO and SPP show substantially more variability in the grid's marginal emissions rate, offering greater opportunities for emissions reductions via time-based shifting of flexible loads.



With this context in mind, we also analyzed the emissions-reduction potential of AER applied to HSC's demand flexibility in other markets—CAISO and SPP—that reflect current grids in different parts of the country, as well as which represent a 'postcard from the future' for what Michigan and MISO might expect in the years just ahead (see Figure 3).

In short, **we found substantial emissions-reduction potential on the order of 15–34% vs. baseline emissions associated with the shifted load**, approximately 10x greater emissions savings on a percentage basis and 8x greater on an absolute emissions basis than what is achievable in MISO today (see Figures 4 and 5). This suggests an enormous

opportunity if adopted for industrial customers' flexible loads across a range of power grids that are increasingly becoming the norm as the U.S. continues its energy transition.

As 24x7 clean energy strategies gain popularity, we find that emissions-based industrial load shifting offers a compelling alternative for achieving cost-effective, system-wide emissions reductions. In addition to the aforementioned emissions-reduction potential, industrial demand flexibility can help alleviate grid capacity constraints—avoiding capacity expansion and costs that would otherwise be passed along to utility customers.

FIGURE 4

In grid regions such as SPP and CAISO—where there’s much variability in the marginal emissions rate due to the generation mix of those grids—we found substantial emissions-reduction potential on the order of 15–34% vs. baseline emissions associated with the shifted load, approximately 10x greater on a percentage basis and 8x greater on an absolute basis than what is achievable in MISO today.

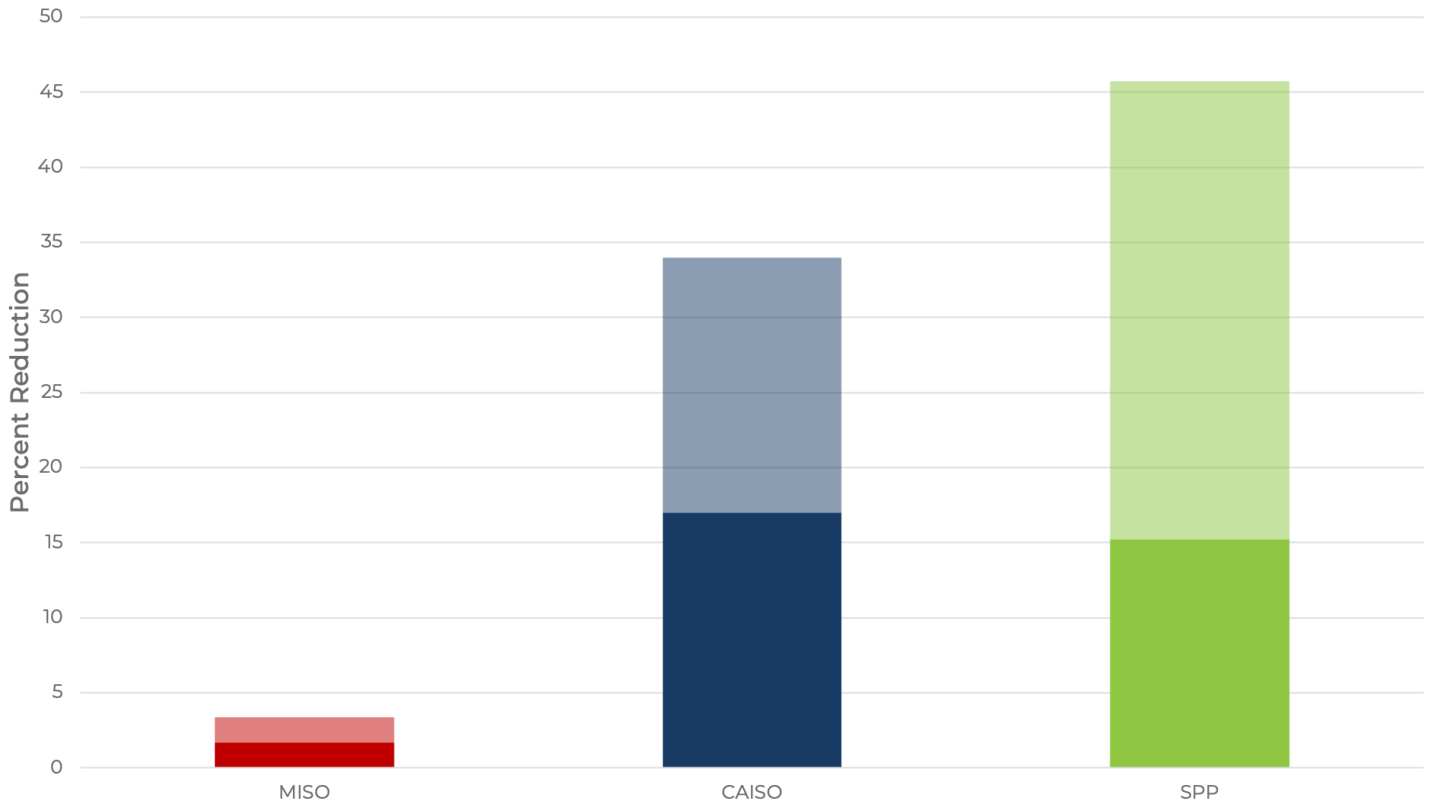
Potential Future AER Performance for HSC

Carbon Impact of the Flexible Load	Max Demand (MW)	Annual Energy (MWh)	Marginal CO2 Emissions (Tons)	Ideal CO2 Savings (Tons)	Ideal CO2 Savings (%)	Expected CO2 Savings (Tons)	Expected CO2 Savings (%)	Expense savings from AER or (Cost)	% Cost Savings	\$ / ton Savings or (Cost)
MISO_DETROIT	31	91,000	74,718	2,529	3.4%	1,265	1.7%	(\$52,498)	-2.2%	(\$21)
SPP_WESTNE	31	91,000	64,620	19,695	30.5%	9,847	15.2%	\$155,269	9.6%	\$8
CAISO_NORTH	31	91,000	45,748	15,541	34.0%	7,771	17.0%	\$937,093	24.9%	\$60

FIGURE 5

The range of emissions-reduction potential for AER with industrial customers in SPP and CAISO today suggest exciting opportunities for what will be possible in MISO in the near future tomorrow.

RANGE OF POTENTIAL EMISSIONS REDUCTIONS By region across MISO, CAISO, and SPP



Driving Solar Supply Chain Decarbonization

HSC is a member of the [Ultra Low-Carbon Solar Alliance \(ULCSA\)](#), which consists of companies across the solar PV value chain and other stakeholders committed to expanded market awareness and deployment of ultra low-carbon PV to accelerate reductions in solar supply chain GHG emissions. ULCSA notes:

“Globally, solar PV deployment is expanding rapidly because of its superior greenhouse gas performance vs. fossil fuel-based electricity. However, not all solar panels are created equal. Differences in PV supply chain emissions (‘embodied’ carbon) can have a substantial impact on the greenhouse gas emissions avoided by solar projects. The use of materials with lower embodied carbon in PV panels can reduce the carbon footprint of solar systems by 50 percent, regardless of where the panels are produced.”

[A joint 2020 analysis from WattTime and First Solar](#)—also an ULCSA member—found that a solar project’s net emissions reductions were a function of the embodied emissions of the solar PV system itself vs. the avoided fossil-fueled emissions the solar project would displace (also known as its emissionality) over its operating lifetime.

Location—where a solar PV project gets built—proved the greatest influence on lifetime avoided emissions. But for the embodied emissions side of the equation, industrial demand flexibility could be a powerful lever for further reducing emissions throughout the solar PV supply chain for companies such as HSC. Moreover, as power grids around the world get cleaner and cleaner, solar PV systems’ embodied emissions will become a more significant portion of their net emissions reduction profile, underscoring the ongoing importance of reducing supply chain emissions through industrial demand flexibility and other levers.

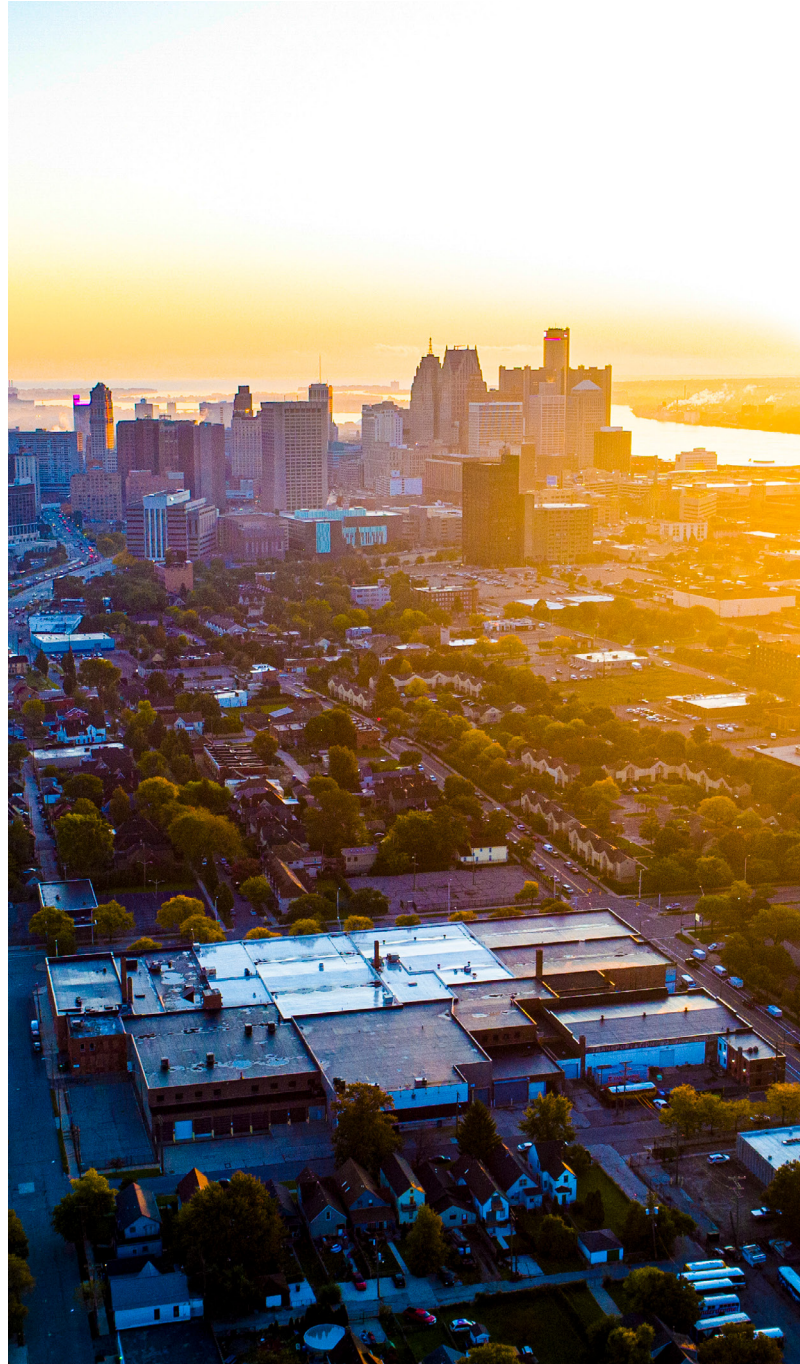
CONCLUSION

For remaining fossil-heavy grids (and/or grids where fossil generation is often marginal), industrial demand flexibility primarily supports cost and grid reliability, plus some future proofing for the coming energy transition.

For grids in transition (mix of fossil and clean generation), industrial demand flexibility spells new opportunity for emissions arbitrage. Thanks to AER, industrial facilities can prioritize clean energy use and avoid fossil-fueled energy, resulting in deeper and faster emissions reductions. Industrial demand shifting today lays the groundwork to prepare for increasing impact as grids evolve into a greater mix of renewables.

Moreover for grids in transition where solar manufacturing exists or could be located, there is a secondary benefit of solar supply chain decarbonization that lowers the embodied carbon in the production of solar modules and components instead of producing these modules and components in high-carbon, fossil-heavy grids.

For grids rich in renewables, industrial demand flexibility has become a crucial tool for supporting the paradigm shift from load-following generation (in which generation is dispatched in response to forecasted and real-time demand) to generation-following load (in which flexible demand is modulated to accommodate variable generation sources such as renewables). Industrial leaders can now sync up with renewable generation profiles and help their respective grids move to a higher percentage of renewables and otherwise reduce renewable curtailment. Already, grids like this in some regions of the world are powering sustainable solar manufacturing, demonstrating how solar supply chain decarbonization and industrial demand flexibility can be both synergistic and contribute to significant decarbonization.



ABOUT THE PARTNERS



Hemlock Semiconductor is a producer of hyper pure polycrystalline silicon, providing the key feedstock for the semiconductor and photovoltaic industries. As the single largest consumer of electricity in the state of Michigan, HSC is dedicated to reducing its carbon emissions. HSC participates in existing market programs concerning MISO Demand Response and engages in load shifting in accordance with market programs and time of use pricing. Recently HSC's efforts were recognized as Project of the Year by the Michigan EIBC (Energy Innovation Business Council) for work in shifting electrical consumption from on-peak to off-peak periods, and the Michigan Department of Environmental Quality (DEQ) has also designated HSC as a Clean Corporate Citizen (C3).

Learn more about HSC at <https://www.hscpoly.com/>.



WattTime is an environmental tech nonprofit that empowers all people, companies, policymakers, and countries to slash emissions and choose cleaner energy. Founded by UC Berkeley researchers, we develop data-driven tools and policies that increase environmental and social good, including Automated Emissions Reduction and emissionality. WattTime is also the convening member and cofounder of the global Climate TRACE coalition. During the energy transition from a fossil-fueled past to a zero-carbon future, WattTime 'bends the curve' of emissions reductions to realize deeper, faster benefits for people and planet.

Learn more at <https://www.watttime.org/>



Consumers Energy, Michigan's largest energy provider, is the principal subsidiary of CMS Energy (NYSE: CMS), providing natural gas and/or electricity to 6.8 million of the state's 10 million residents in all 68 Lower Peninsula counties.

Learn more at <https://www.consumersenergy.com/>.