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June 24, 2024

Via E-Filing

Ms. Lisa Felice
Executive Secretary
Michigan Public Service Commission
7109 West Saginaw Highway
Lansing, MI 48917

RE: MPSC Case No. U-21291

Dear Ms. Felice:

Please find enclosed the Official Exhibits FLO-7 to FLO-23 sponsored by Jackson Koeppel (Part 2 of 13) on Behalf of Frontline Organizations, along with proof of service for electronic filing in the above-referenced matter. Please do not hesitate to contact me with any questions or comments.

Sincerely,

Mark N. Templeton, *pro hac vice*
6020 S. University Avenue
Chicago, IL 60637
Phone: (773) 702-9611
Email: templeton@uchicago.edu

xc: Parties to Case No. U-21291

The University of Chicago Law School
1111 East 60th Street, Chicago IL 60637 www.law.uchicago.edu/clinics

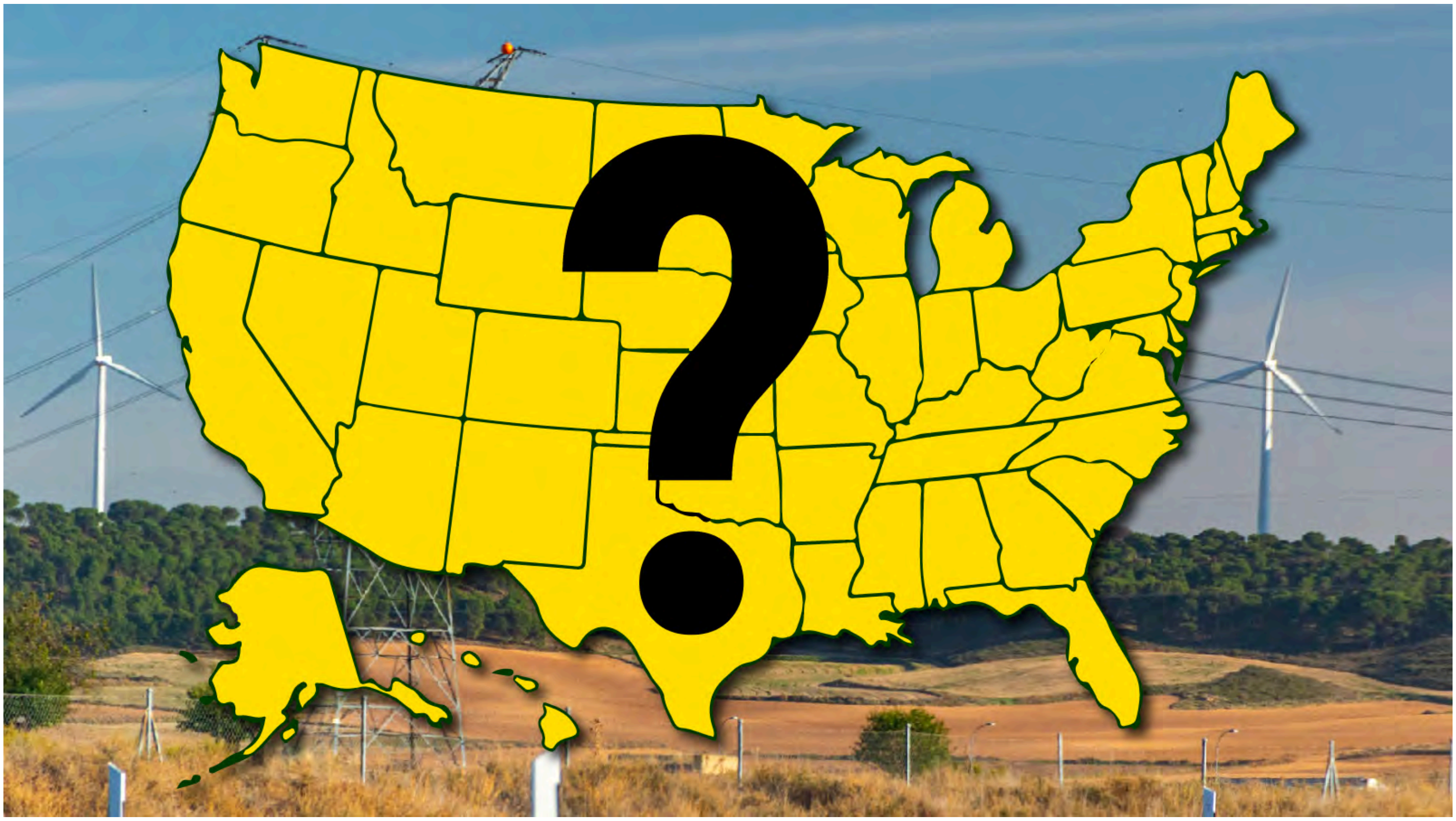
YALE
Climate
Connections

NUGGET OF THE DAY

Which state is winning at renewable energy production?

If you guess correctly, you win 1,000 points.

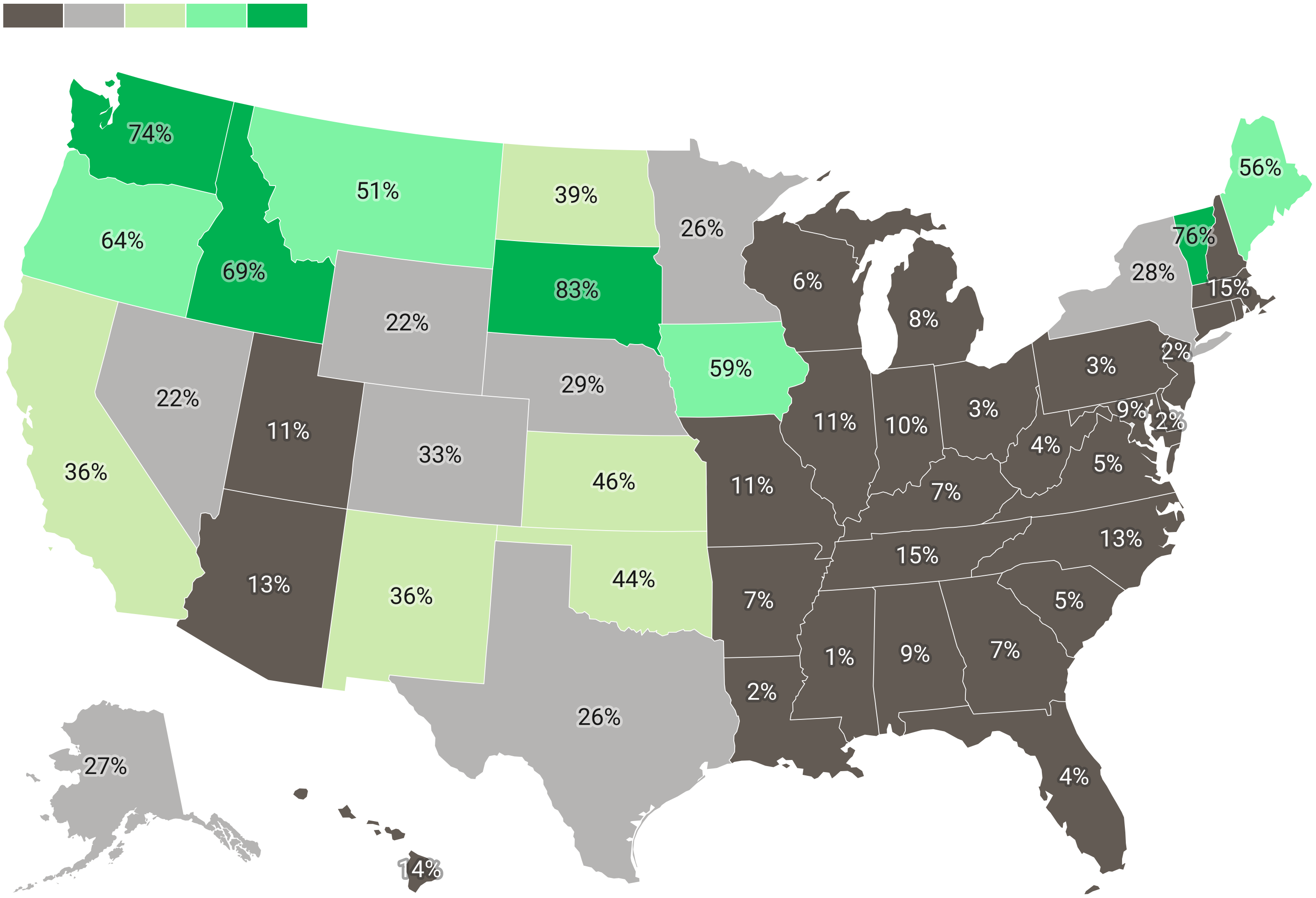
by **KARIN KIRK**
FEBRUARY 23, 2023



Electricity is changing. As states like **Minnesota** commit to 100% carbon-free electric power, **Montana** is opting to double down on coal. Some of these developments make headlines, while others go unnoticed – though they're no less important. Case in point: Can you guess which state generates the largest fraction of its electricity from renewable sources?

Of the electricity generated in each state, how much is from renewable sources?

Hover over each state to show the energy sources used for electricity generation.



Annual data from 2021.
Renewable sources are hydro, wind, and solar.
Map does not account for electricity imported or exported between states.
Subtotals of electricity sources for each state may not add up to 100% because minor sources of electricity such as oil or biomass are not included.

Map: Karin Kirk for Yale Climate Connections • Source: Energy Information Administration • Get the data • Embed • Download image • Created with Datawrapper

The answer: South Dakota. That state produced 83% of its in-state electricity from renewable sources in 2021, the result of its impressive implementation of wind energy. Between 2019 and 2021, South Dakota more than tripled wind energy production.

Bonus data points

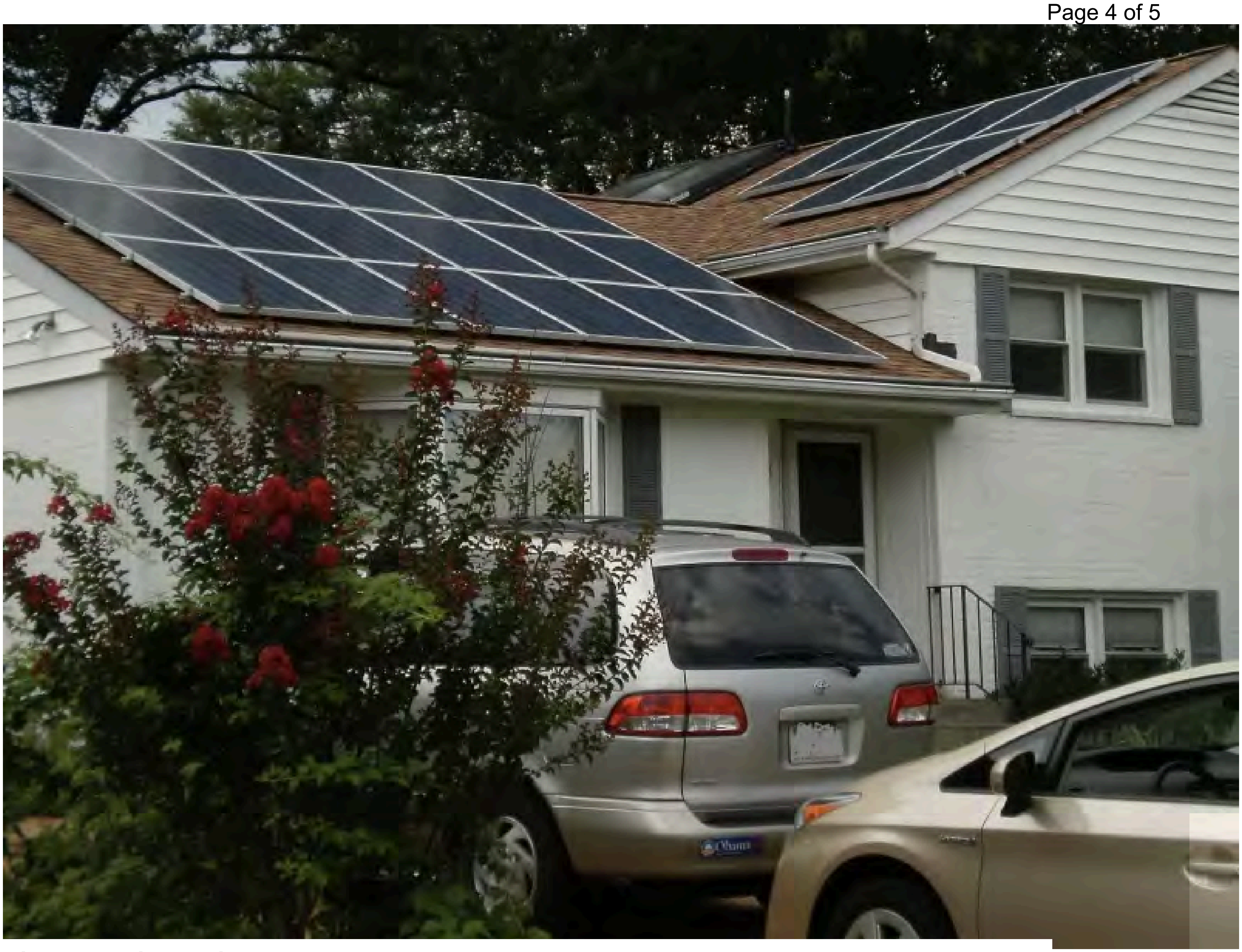
- The other leading states on this measure — Vermont, Washington, and Idaho — all derive the majority of their renewable energy from hydropower.

- Texas produces the most renewable energy of any state, but it also generates an outsized amount of electricity from fossil fuels. So renewables only account for 26% of the state’s total electricity production. In 2021, 44% of Texas’s electricity came from fossil gas, also known as natural gas.
- Important note: The map shows electricity production within each state’s borders. Many states and utility companies exchange electricity with other states. So this data may not reflect the energy that is actually *consumed* — as opposed to *generated* — within each state.

Data for electricity generation in all 50 states over the past 20 years is available from the U.S. Energy Information Administration’s **Electricity Data Browser**.

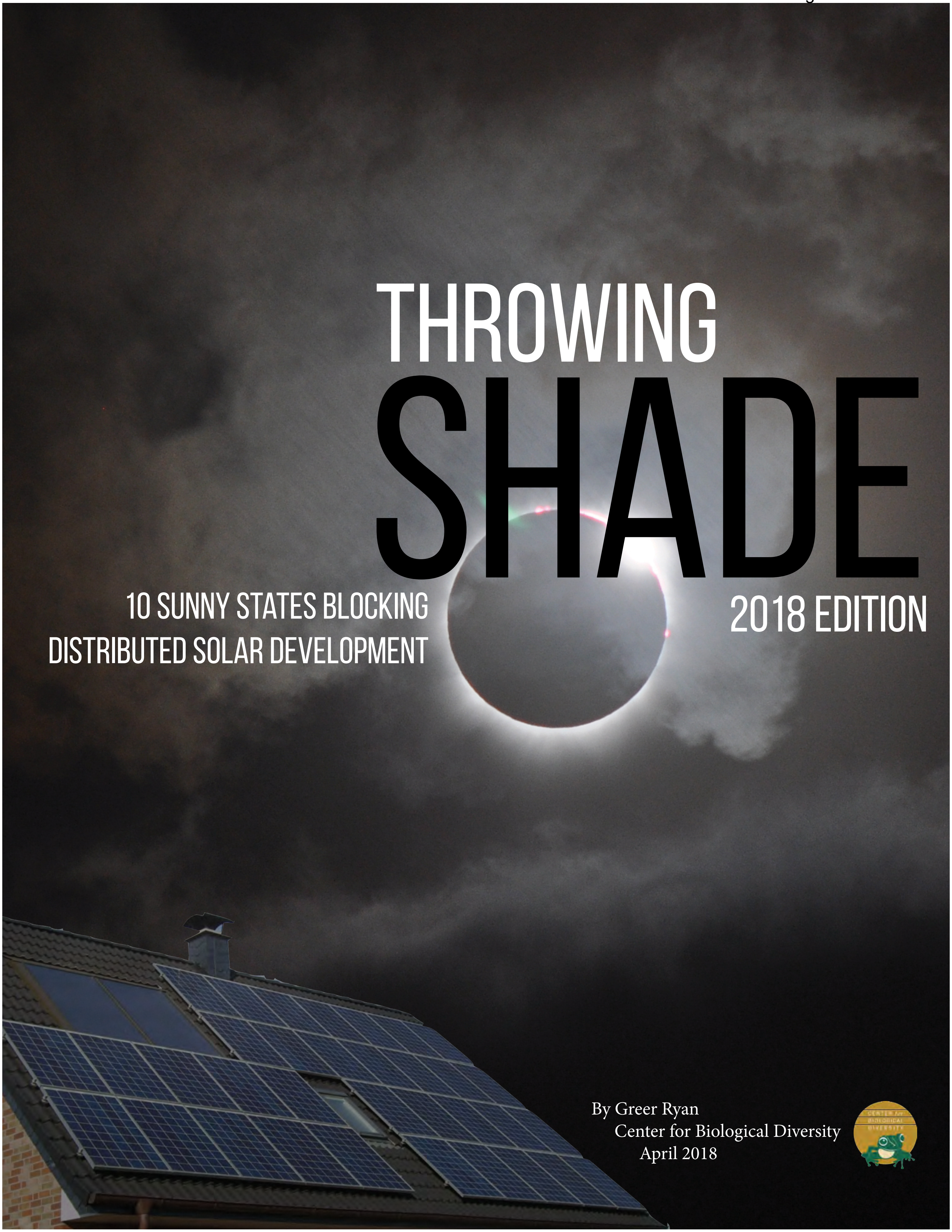
MORE LIKE THIS

‘Just do it!’ Wisconsin couple built a net-zero home



What are virtual power plants?

What is a passive house?



THROWING SHADE

10 SUNNY STATES BLOCKING DISTRIBUTED SOLAR DEVELOPMENT

2018 EDITION

By Greer Ryan
Center for Biological Diversity
April 2018

CONTENTS

EXECUTIVE SUMMARY

As the Trump administration turns back the dial on climate progress at the federal level, states play an increasingly critical role in creating and stimulating clean-energy progress in the United States. In particular, state-level policies have an enormous influence on distributed solar, such as those on existing rooftops, parking lots and along roadways. If fully developed, distributed solar could provide most of the United States' electricity with minimal negative social and environmental impacts, paving the way for important reductions on fossil fuels that are driving the climate crisis.[1]

For this report, we highlight 10 states with high potential for distributed solar but poor policies to realize that potential.

Our key findings:

- Although the 10 states in this report account for more than a third of the total rooftop-solar potential in the contiguous United States, they account for just 7.5 percent of net generation for 2017.[2]
- Texas and Florida stand out as two of the states with the most potential but the worst distributed-solar policies.
- Among the most common barriers to the expansion of distributed solar in the 10 states are lack of community solar policies, poor compensation policies, and prohibited or unclear third-party ownership legality.

All 10 states highlighted in this report — Alabama, Florida, Georgia, Indiana, Louisiana, Oklahoma, Tennessee, Texas, Virginia and Wisconsin — are barely skimming the surface of their technical potential for rooftop solar. Only 0.01 percent to 0.99 percent of their technical potential is being met, far below that of leading states such as California and Arizona, which are at least at 3.81 and 4.51 percent, respectively.[3] In many of these states, fossil fuel companies and utilities are also waging campaigns to create policy barriers and restrictions, making it harder for people to go solar.[4]

Recommendation:

State policies that prevent the expansion of the distributed-solar market threaten the swift transition from fossil fuels to a fully renewable energy system. This system is needed to stave off the worst impacts of climate change and protect the health of communities and the planet. All 50 states should make improvements to their renewable energy policies in one way or another. But the 10 states identified as the top offenders when it comes to blocking distributed solar can have a significant impact on distributed-solar progress — and therefore on environmental health, energy democracy and the climate crisis — by following the recommendations outlined in this report.

Table 1. 10 States Blocking Distributed Solar: Overall Policy Grade, Small-scale Rooftop-solar Photovoltaic Generation Potential Rank, and Net Generation from Small-scale Rooftop PV

State	Overall Policy Grade	Small Scale Rooftop PV Technical Potential: Rank of Contiguous U.S.	Net Generation from Small Scale Rooftop PV: Rank of Contiguous U.S.
Alabama	F	19	46
Florida	F	3	13
Georgia	F	10	34
Indiana	F	14	35
Louisiana	F	22	12
Oklahoma	F	20	42
Tennessee	F	15	32
Texas	F	2	6
Virginia	F	13	24
Wisconsin	F	16	31

ADDITIONAL REPORT HIGHLIGHTS

All 10 states have significant barriers in place to distributed-solar development and have earned an overall policy grade of “F” in our analysis. By contrast, the 10 states that obtained an “A” grade in our analysis account for 27 percent of the total rooftop-solar photovoltaic annual generation potential in the contiguous United States, but were responsible for about 68 percent of total generation.[5]

We based state grades on a thorough review of the presence, or absence, and strength of key distributed-solar policies, and, combined with the overall rooftop-solar photovoltaic technical potential rankings by National Renewable Energy Laboratory (NREL), identified the states that would benefit most from improvements to their distributed-solar policy landscapes.[6]

Of the 10 states highlighted in this report:

- Nine remain from the 2016 list. These states have made few notable improvements in the past two years to their distributed-solar policy landscapes. Michigan updated its Renewable Energy Standard in December 2016, so it was replaced on the list by Louisiana, which has made no notable improvements to its solar policy landscape in the past two years.
- Eight lack renewable portfolio standards (RPS), policies that are key to creating a safe market for investing in rooftop solar. The two states with mandatory RPSs in place — Texas and Wisconsin — have already met their low targets and have not taken steps to update their policies, so these RPSs are doing nothing to bolster the solar industry at this point. In fact Texas met its incredibly unambitious goal of 10,000 MW *15 years ahead of schedule*.[7]
- Five lack mandatory statewide net-metering policies, possibly the most important policy model in place in the United States that allows for solar customers to connect with the grid. Only 12 states in the country are without these standards.
- Only three allow for third-party power purchase agreements (PPAs) — a financing model that has fostered a distributed-solar boom across the United States by allowing for those who wouldn’t otherwise be able to afford solar panels outright to be able to install them on their property. One allows for leasing but not PPAs.
- None have state-wide community solar programs in place, which are key to encouraging broad access to distributed-solar resources and promoting community resiliency. Virginia has a pilot program.
- Eight lack strong interconnection laws, making the process of installing solar panels harder for homeowners, business owners and third-party companies alike.
- Four don’t have any solar-rights laws that protect home and business owners from local restrictions on solar-panel installations due to issues like neighborhood aesthetics.

All 10 of these states are bad actors in the distributed-solar policy game, but two in particular stand out as the worst: Florida and Texas. These two states fall in the top three for rooftop-solar photovoltaic technical potential, just after California. Both Florida and Texas could feasibly have some of the best markets in the country for distributed-solar growth; they make up more than 16 percent of the total generation potential for small building solar in the contiguous United States. Because of bad policies, however, Florida and Texas only account for about 5 percent of the total net generation. By contrast California makes up about 13 percent of total generation potential for small building solar, but generated about 49 percent of the net generation.

INTRODUCTION

In order to stave off the worst impacts of climate change, the United States needs a rapid transition to a 100 percent clean-energy system — a move supported by leading climate scientists, industry experts, religious groups, justice organizations and environmentalists alike. The technology exists to make this happen in a way that takes into account vulnerable species, habitats and communities.

Obtaining a significant portion of our energy from clean sources within the already-built environment — such as on existing rooftops, parking lots and along roadways — would allow us to address climate change and meet our energy needs. It would enable a transition without paving over the planet and could help to alleviate some of the strain our energy system has on low-income communities and communities of color. Distributed sources such as photovoltaic (PV) solar built on existing structures have the potential to meet significant electricity and heating/cooling needs with much fewer social and environmental impacts than traditional energy sources, particularly fossil fuels.*

Current federal and state policies are not sufficient to meet the high levels of diffusion of distributed PV generation we need to reach a just and wildlife-friendly energy future. At the federal level, a 30 percent investment tax credit (ITC) that has helped to spur renewable energy market growth is set to expire at the end of 2019. With new 30 percent tariffs on imported solar panels from China and Taiwan instituted by the Trump administration, solar prices will increase. This will set us further back on the path to a clean-energy future.[8]

State-level policies, which in many ways determine the success of energy markets and the affordability of solar, largely fail to support distributed-solar growth potential. State legislation determines how utilities work with home and business owners to connect their distributed-solar energy systems to the electric grid, whether solar system owners get paid for excess generation supplied to the grid, and whether there is any support for low-income homeowners or individuals who would otherwise have a hard time installing solar panels on their own.

What Is Distributed Solar?

Generally, when people talk about distributed solar, they are referring to solar panels on rooftops of homes and businesses — but the term can refer to any kind of solar electric system that is placed on or near where electricity is used. Solar arrays are often found on building rooftops, but some emerging technologies allow for solar cells to be incorporated onto other building surfaces. One example of this is thin-film cells on windows. Solar panels as shades on parking lots, community solar farms and even individual solar panels on street lamps are all forms of distributed generation.

Distributed-solar generation is an important part of a sustainable energy future for many reasons. Reducing the distance between where electricity is generated and where it is used prevents energy loss in transmission, creates ownership opportunities in the energy system for individuals and communities, and decreases the amount of land destroyed by large-scale energy operations.

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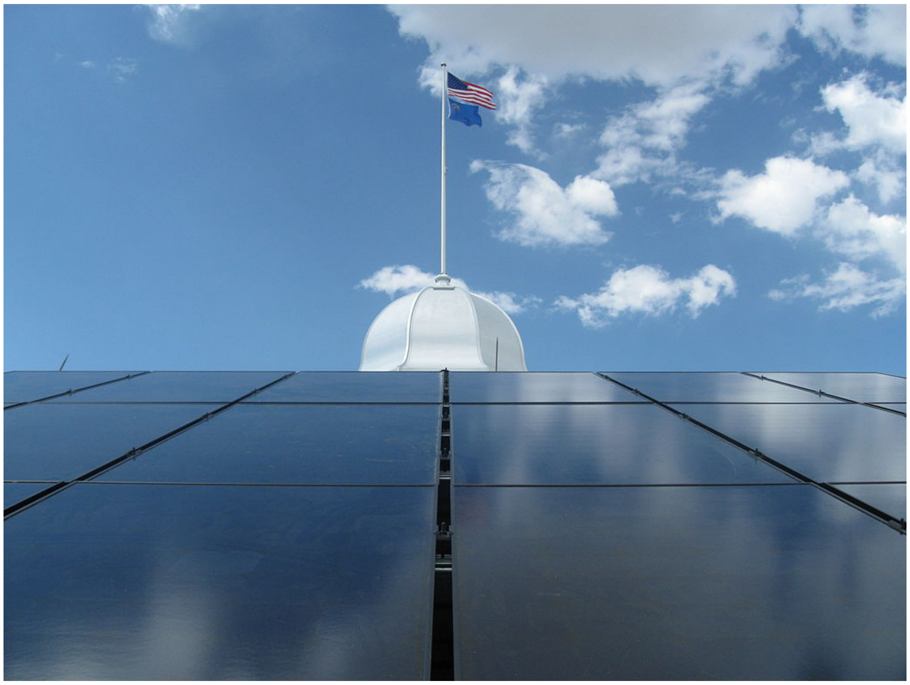
*Distributed generation refers to energy that is generated at or near the point of consumption. It generally includes small-scale electricity generation, considered less than 10 megawatts (MW) in size, which is connected directly to the distribution network (grid). It can refer PV solar or any type of energy generation of this connection type and size, including wind, coal, natural gas, geothermal, etc.

Distributed generation, which plays an important role in decentralizing electricity distribution, allows for customers to buy less power from their monopoly utility provider. Because this threatens their business model, investor-owned utilities, which distribute power to about 75 percent of U.S. homes, along with fossil fuel companies and even public utilities, are blocking distributed-solar progress by pressuring state utility regulators to enact anti-solar policies.[9,10] These actions, by slowing the clean and wildlife-friendly energy transition, pose serious threats to endangered species, sensitive habitats and communities that are often left to bear the consequences of our energy system's public health and economic losses without aid.

In many states there are few policies in place that require utilities to treat solar customers fairly. Instead there are active barriers in place to prevent utility customers from "going solar." Furthermore, in states where policies have been successful in encouraging distributed-solar market growth, utilities and corporate interests have been fighting to remove or weaken these policies — waging a "war on rooftop solar."[11,12] Without strong distributed-solar policies, individuals and businesses are often left without options to fund or install solar-energy systems on their property. And in some states, enough barriers exist that property owners are essentially prohibited from installing solar panels even if they have the funds.

This report highlights 10 states that have some of the highest potential for distributed-solar market growth, and therefore the ability to mitigate the negative effects of fossil fuel use, but the worst policies in place. All states are identified by National Renewable Energy Laboratory (NREL) as being in the top 25 states for rooftop-solar photovoltaic technical potential, and all have obtained poor distributed-solar policy grades in our analysis.[13]

This report specifically considers *distributed-solar* growth and evaluates the states that are blocking progress. That serves to identify improvements that need to be made in order to prioritize distributed-solar technology diffusion in these states and demonstrate policy changes that can increase distributed solar across the country.



PV Installation, photo courtesy Ballonboy101, Wikimedia Commons.

KEY STATE-LEVEL DISTRIBUTED-SOLAR POLICIES AND BARRIERS

There is no silver bullet to overcome distributed-solar barriers at the local, state or national level. There are many expert opinions regarding individual model policies. States that have emerged as leaders in distributed-solar generation, such as California, New York and Massachusetts, have done so by creating solar-friendly policy landscapes. These leading states tend to have three categories of key solar policies, as broken down by the National Renewable Energy Laboratory:[14]

- Market preparation policies allow for home and business owners to install solar panels on their property by creating the regulatory structure needed to connect small solar installations to the grid. Without these policies in place, the barriers are often too great for installation, regardless of the property owner's interest level. These policies include interconnection standards, net-metering programs and solar-rights policies.
- Market-creation policies set up the conditions needed for solar businesses to sell energy or technology to home and business owners. The main market creation policy model in the United States that influences distributed generation diffusion is a renewable-portfolio standard (RPS), also known as a renewable-electricity standard. These standards set minimum requirements for renewable-energy generation for utilities. RPSs that include specific minimum requirements for solar-energy generation, or distributed generation, are said to have a solar "carveout."
- Market-expansion policies are those that help expand access to solar energy and technology to those who wouldn't otherwise have access, such as renters or low-income homeowners. These include financial incentives such as grants, rebates and tax incentives; community solar laws (including virtual net metering); and third-party ownership laws.

Most states are lacking in one or more of these key policies. Even some of the leading states have barriers within their distributed-solar policies in the form of access restrictions and prohibitive fees. By putting barriers in place or lacking key policies altogether, states and utilities are preventing home and business owners from choosing to go solar, ultimately blocking climate action. Some of the more common avenues that states take to do so include: prohibiting third-party ownership financing models of solar, such as PPAs; setting unambitious renewable portfolio standards (RPS) or failing to update them as needed; including restrictions in net-metering rules, such as fees, system size limits and program caps; setting rates that don't take into account the true value of solar and prioritize utility profit-making; and excluding certain sized solar systems from tax exemptions and other financial incentive programs.

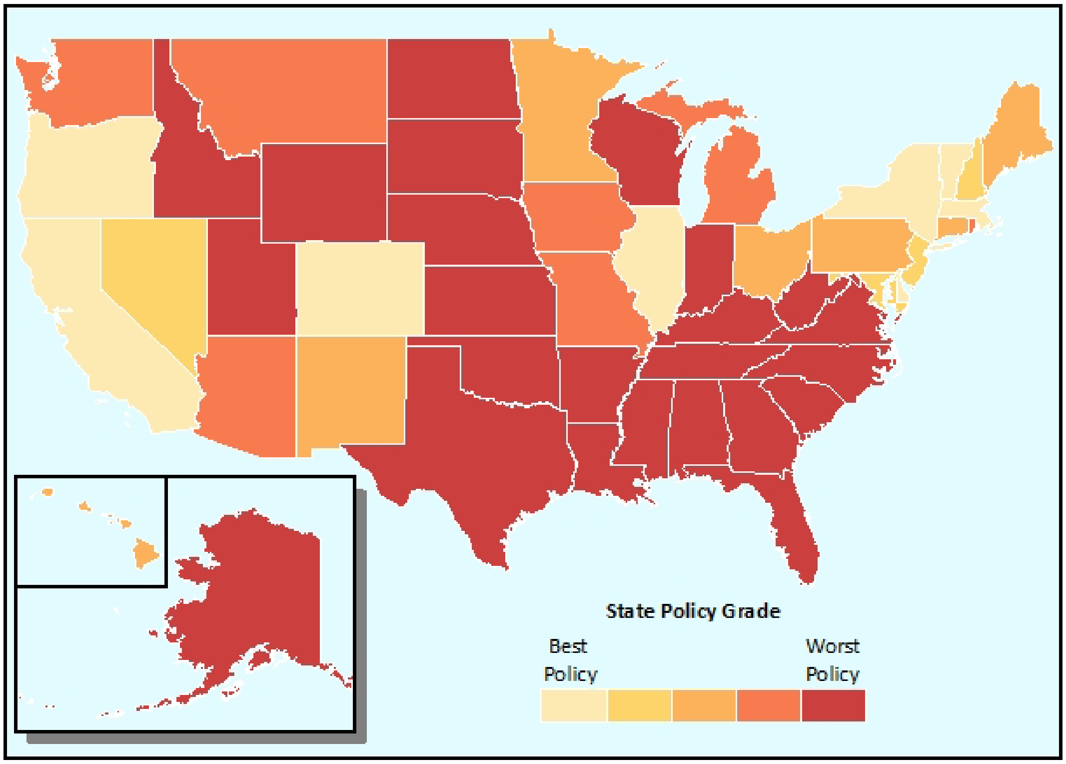


Image 1. Map of state overall distributed-solar policy grades

For the purpose of identifying states blocking access to distributed solar, and thus failing to meet their solar potential, we examined key policies within each of these categories that specifically affect the diffusion of distributed-solar generation and access: renewable-portfolio standards (RPSs), net-metering policies, community solar laws, interconnection standards, third-party ownership laws and solar-rights laws. We did not go into great detail on tax credits, rebates or other financial incentives, as many of these are contingent on federal and local policy and are not determined at the state level. Our methodology for assigning policy grades can be found in Appendix B.

Renewable Portfolio Standards and Solar Carveouts

Mandatory renewable-portfolio standards (RPS) or renewable-electricity standards exist in 29 states and Washington, D.C. In general these standards require utilities to generate electricity from renewable sources — or acquire renewable energy certificates from other generators — equal to a target percentage of their sales. Over half of the 120 GW of renewable energy capacity built since 2000 has been driven at least in part by RPS policies.[15] Across the United States, new renewable-energy sources for RPS compliance resulted in a 3.6 percent reduction in total fossil fuel generation.[16] Lifecycle greenhouse gas emissions were reduced by 59 million metric tons of carbon dioxide equivalent due to these new sources.[17]

RPS requirements differ across states, not only in the percent renewable-energy contribution required but also in the way they treat different renewable technologies. Of the 29 states with RPSs, 18 have provisions in their RPS policies that favor either solar-energy sources generally or distributed-electricity generation (which is de facto PV solar, given current technologies). Colorado and New Jersey, for example, each require that 3 percent of their electricity comes from distributed generation by 2020.[18,19] Since the last iteration of this report, Michigan has extended its RPS with a credit multiplier for distributed energy sources, which we hope will help distributed-solar growth.

Of the 10 states highlighted in this report, eight do not have any state-wide mandatory RPS, and the two states that do — Texas and Wisconsin — passed their unambitious goal deadlines by 2015. Even so, simply the presence of an RPS does not mean that it will drive distributed-solar growth specifically. Many states have RPSs in place that do not have solar or distributed generation carveouts. A carveout specifies that a certain portion of the RPS goal be met through specific sources and ideally would include a generous distributed PV carveout. Without a specific carveout for distributed solar, a solar carveout may be met with utility-scale solar, which is often sited in remote areas that may contain sensitive habitats or imperiled species habitat. Nonetheless, it is still better for the distributed-solar market than no carveout at all.

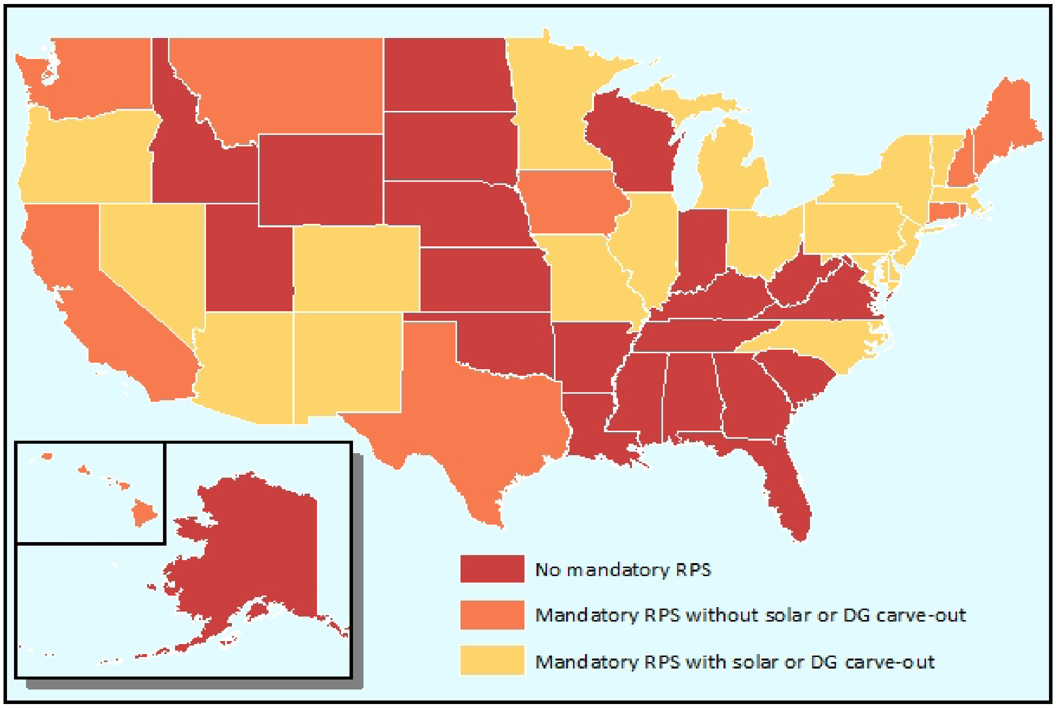


Image 2. Map of mandatory state renewable portfolio standards (RPS)

Net Metering

Net-metering policies have proven critical to the deployment of distributed solar.[20] Net-metering policies allow utility customers to sell excess electricity generated from their rooftop-solar panels back to the utility and receive credit on their bill. This credit helps to offset the customers' electricity consumption from the grid during other times of the day or year, reducing their total electricity purchases from the utility.[21,22] As of the end of 2017, 38 states and Washington, D.C., had net-metering policies in place.[23] Seven states offer distributed generation compensation rules other than net metering.

As distributed PV has reached higher levels of market penetration, debates across the country have waged about whether to maintain full-retail net metering — i.e., net metering that allows for solar customers to be paid full retail rate for the excess electrical generation they send to the grid, as a pricing mechanism.[24,25] Some argue that higher levels of rooftop-solar diffusion will challenge the traditional utility business model by altering the relationship between the customer and utility.[26]

In response to increased levels of solar, electric utilities and pro-fossil fuel special-interest groups who do not support solar energy expansion, such as Edison Electric Institute, Americans for Prosperity and Consumer Energy Alliance, have raised concerns about "cost shifting." They claim that the net-metering fees paid to solar customers for excess generation unfairly transfer costs both to non-solar customers and the electric utilities by reducing the number of customers contributing to grid maintenance.[27,28,29] These groups have attacked distributed solar policies across the country by developing model legislation, funding and political cover for anti-solar campaigns.[30]

To address "cost shift" and other solar-pricing-model concerns so that solar customers can be paid for their excess generation without impacting non-solar customers unfairly, many states and utilities have conducted cost-benefit studies of net metering. Two meta-analyses of such studies revealed that the marginal value of solar connected via net-metering programs exceeds the retail rate of electricity, and that net metering therefore provides a net benefit to all customers, not just those with solar panels.[31,32] The savings are possible because rooftop solar provides electricity exactly when it's needed, taking pressure off the grid during peak hours and reducing the need for inefficient and expensive peak power plants. It also reduces the wear and tear to transmission infrastructure and energy loss. One meta-analysis found that utilities tend to exclude environmental and social benefits of solar and focus only on costs and savings that affect the direct costs of operating the grid. Further, this analysis found that studies conducted by non-utility analysts generally value solar higher than those that are conducted by utilities.[33] Despite the widespread success of net-metering programs, these debates have increased in recent years.

There are 12 states without mandatory net-metering programs in place.[34] Almost all are all falling significantly behind other states in meeting their distributed-solar capacity potential (Table 1). Five of these states, Alabama, Georgia, Indiana, Tennessee and Texas, are highlighted in this report.

Almost every state saw policy actions related to net-metering policy or rate design in 2016 and 2017, according to the NC Clean Energy Technology Center.[35,36] In 2017 alone, 31 states saw actions related to distributed solar compensation rules and 21 saw actions related to solar valuation or net-metering studies.[37] In general, states are allowing utilities to decrease rates paid to customers through net-metering and other compensation programs and apply fixed and demand charges specifically for solar customers, making solar less affordable.[38] Although this has become less common in recent years, many states have allowed utilities to put caps on the amount of net energy generated through net-metering programs. Once a net-metering program cap is reached, no new net-metering customers are able to join, which eliminates this primary compensation mechanism for homeowners to install distributed solar.

The Wild West of Solar Fights

Net-metering policy fights are spreading across the United States rapidly, and have been especially dramatic in the sunny western states.

The first big fight to see national coverage was in Arizona, which after years of debate decided in late 2016 to replace retail-rate net metering for the state with export credits based on short-term valuation methods, which is making solar more financially burdensome for utility customers in the state.[39]

Similarly, Utah started phasing out retail-rate net metering in 2017. Although existing net-metering customers' rates are being grandfathered in at the retail rate, any new customers will receive three years' of credits at a lesser rate. After that, a new fee structure, which will be determined by the state's Public Service Commission by 2020, will take effect.[40]

Nevada's solar market has seen a turbulent two years. In December 2015, NV Energy, one of Nevada's largest public utilities, relied on the refuted "cost shift" argument to convince the Nevada Public Utilities Commission (PUC) to drastically cut the state's net-metering program, causing the state's three largest providers of rooftop solar to temporarily leave the state entirely. This resulted in an immediate drop in PV solar installations; NV Energy issued permits for 33MW of solar in the fourth quarter of 2015 but only 3MW in the first quarter of 2016.[41] But due to broad and substantial public outcries, the legislature intervened and passed A.B. 405. This immediately allowed rooftop-solar customers to be reimbursed for their excess generation at 95 percent of the retail rate, although with a declining compensation rate over time.[42] In general, this move is seen as a win for solar advocates and will likely revive the threatened distributed-solar market in the state.

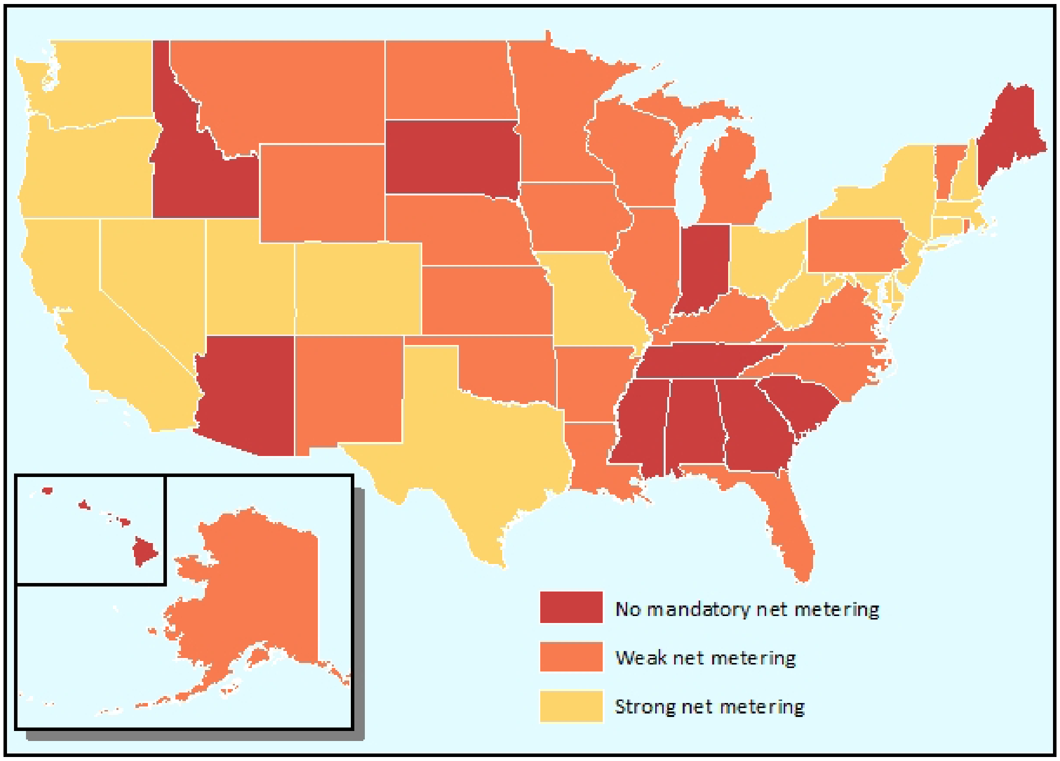


Image 3. Map of mandatory state net-metering policies

Community Solar

Community or shared-solar programs allow multiple utility customers to connect to one shared solar installation, benefiting from the power provided and financial savings. Customers who otherwise wouldn't be able to install solar panels on their homes, either because they're renters, they can't afford panels on their own or due to structural or shading issues, are able to access clean solar energy through these programs. Community solar projects can share similarities with utility-scale solar projects (e.g., large capacity size and often found as ground-mounted systems), but they are generally considered distributed solar due to their benefiting communities directly, and as they can be built near to where electricity is used.

States can encourage community solar installations through a variety of policies, including virtual net metering and specific community solar acts. Virtual net metering is a type of aggregate net metering, where credits from one PV solar system are used to offset multiple customers' electricity bills. Eighteen states and Washington, D.C., currently have community solar or virtual net-metering policies in place, but some of these policies are limited to pilot projects or only certain utilities.

Community Solar Gardens Blooming in Minnesota

Minnesota leads the country in community solar, largely due to its Solar Energy Jobs Act, enacted in 2013. Although the state-created solar garden program took a few years to get off the ground, it grew rapidly in 2017, and that growth is expected to continue in 2018. The state added 48 new solar gardens to the existing 10 from the year prior and now has enough community solar to power 32,000 homes. Minnesota's largest utility, Xcel, administers the program and independent companies install and run the solar gardens themselves. Utility customers receive a bill credit for their portion of the energy produced by the solar garden, at retail rate at first and then at a value of solar (VOS) rate. The VOS rate calculation must take into account all the benefits solar offers to the utility system, including the value of energy and its delivery, generation capacity, transmission capacity, line losses and environmental value. Two of the projects, in Montrose and Waverly, serve residential customers exclusively while the others rely primarily on businesses.[43,44]

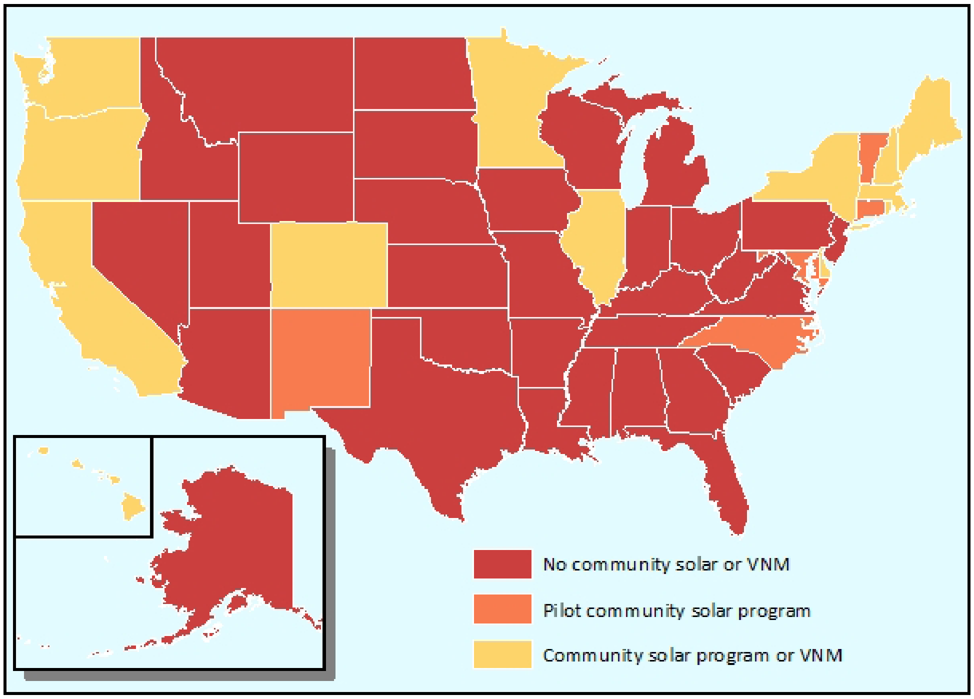


Image 4. Map of state community solar policies

Interconnection Standards

Interconnection standards are requirements to connect solar panels to the utility grid. They determine the ease and cost of installing solar energy systems for homes and businesses. Without interconnection standards, the installation process can be too unwieldy and often too expensive for homeowners or even third-party solar companies. Even with interconnection standards, if they are complicated or have unnecessary barriers in place, installation rates can be negatively affected. A barrier commonly found in interconnection standards is a provision for unnecessary liability insurance for all solar customers connected to the grid. This raises costs and ultimately decreases the benefits gained from installing solar panels. Another barrier is the requirement for a redundant external disconnect switch, which again increases costs and decreases solar benefits unnecessarily.[45]

Vote Solar and the Interstate Renewable Energy Council (IREC) assessed states' interconnection standards and net-metering standards, assigning them grades based on their overall friendliness towards distributed-solar customers.[46] 32 states and Washington, D.C., have interconnection standards with passing grades including two of the 10 states highlighted in this report (see Appendix B).

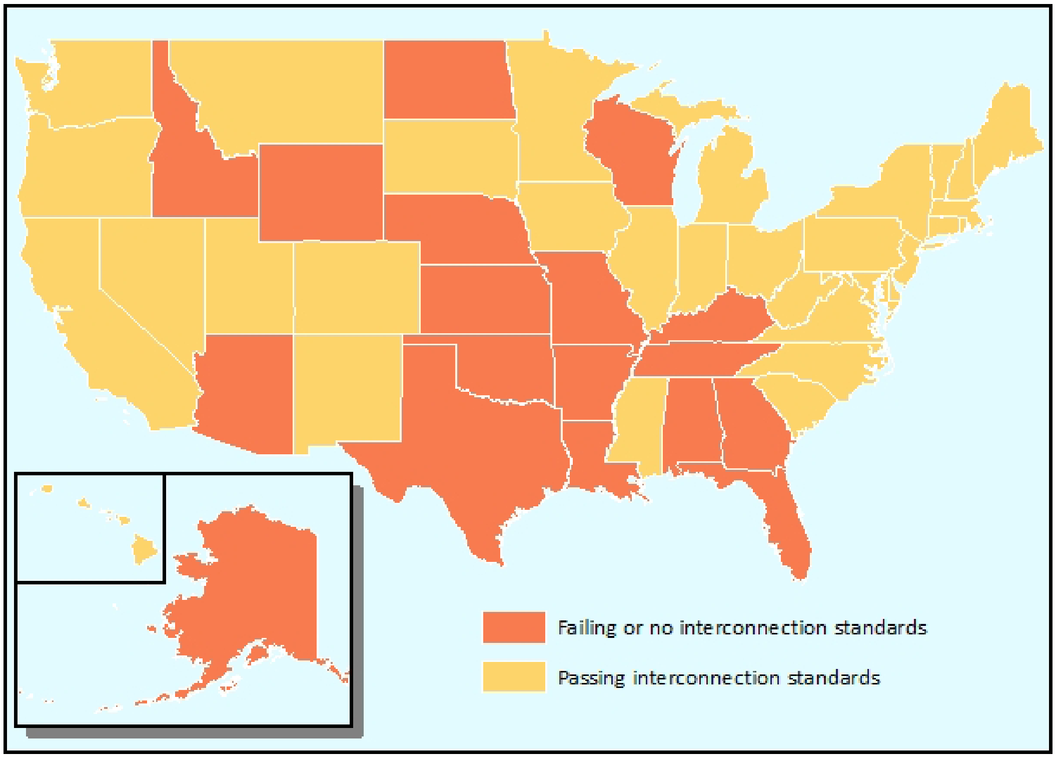


Image 5. Map of state interconnection standards

Third-party Ownership

Third-party ownership is an important driver of distributed-solar markets. Of the 1.3 GW of residential solar installed in 2014, 72 percent was third-party owned.[47] In New Jersey, a leading distributed-solar state, more than 90 percent of residential solar systems are third party owned.[48] This financing structure is common and has benefited the distributed-solar industry immensely.

Third-party ownership or third-party financing generally occurs through two models: leases and PPAs. A customer can sign a traditional lease and pay for the use of a solar system or enter into a PPA to pay a specific rate for the electricity that is generated each month.

One of the more obvious attacks on the distributed-solar market is that of third-party ownership bans. By barring these types of agreements, states restrict rooftop-solar development. The majority of the states that disallow third-party ownership have an installed residential solar capacity of 1,000 MWh or less.[49]

Six states currently explicitly disallow third party ownership of solar — both leases and PPAs. Five states disallow PPAs but allow leases. The legality of third-party ownership is unclear in 20 other states, making them risky places for solar companies to operate. Without clear third-party ownership legality, this financing model cannot benefit those who don't have the money to buy solar panels and install them outright — which, at this point, is most Americans. Of the states highlighted in this report, Alabama and Oklahoma explicitly disallow both leases and PPAs, Florida and Louisiana allow leases but not PPAs, and legality is unknown or unclear in Indiana, Tennessee and Wisconsin.

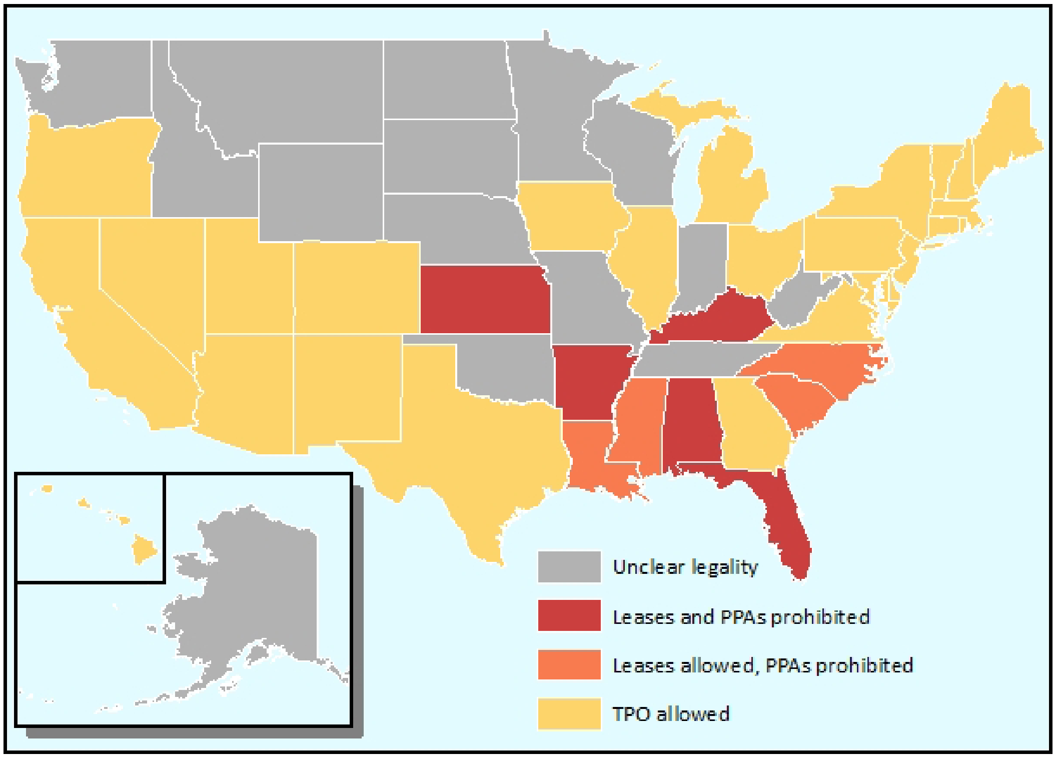


Image 6. Map of state third-party ownership laws

Solar Rights Laws

Local ordinances or private groups such as homeowners' associations are sometimes able to put barriers in place to distributed-solar development by claiming that solar panels reduce the aesthetic value of a neighborhood or by preventing shade removal around rooftops. Solar rights laws provide protections to solar customers from installation bans, unreasonable expenses and restrictions that might be imposed by these groups at the local level and thus help prevent barriers to distributed generation.

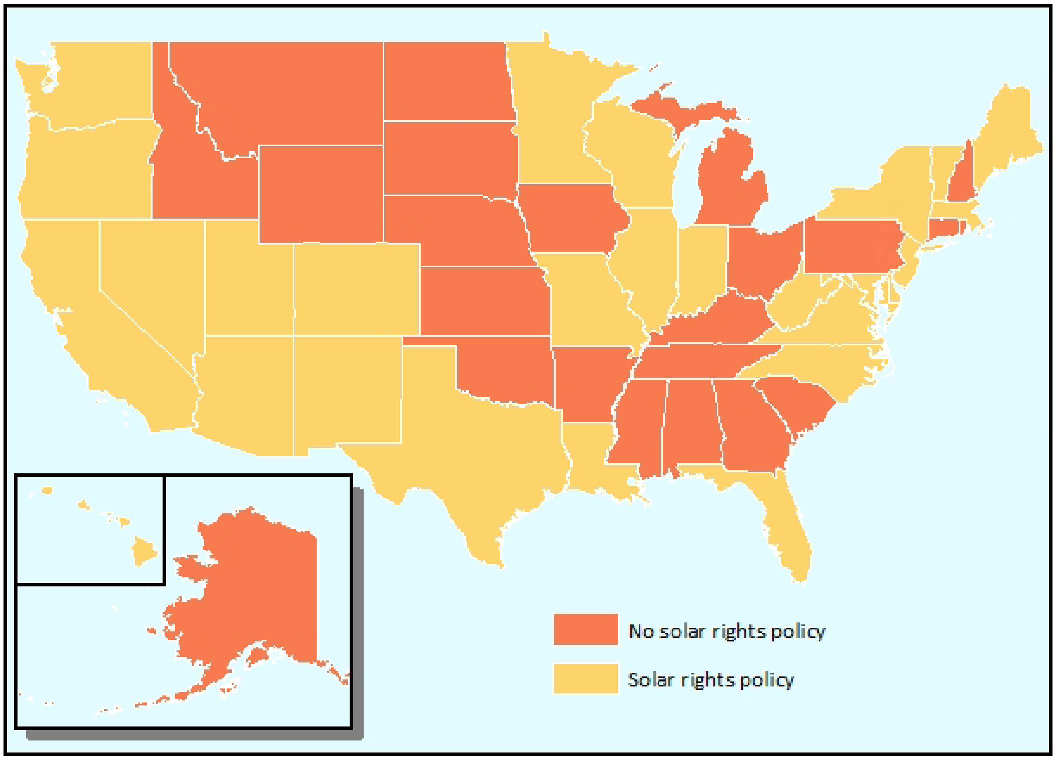


Image 7. Map of state solar-rights laws

10 SUNNY STATES BLOCKING DISTRIBUTED SOLAR

To identify the states blocking distributed-solar development through bad policy landscapes, we considered three factors:

1) Overall policy grades, determined primarily by the presence or absence of market-preparation, market-creation and market-expansion policies for distributed solar. Partial scores were given for weak net-metering and interconnection policies, previously analyzed by Interstate Renewable Energy Council (IREC) and Vote Solar in their 2015 “Freeing the Grid” report. Full methodology for creating policy grades is explained further in Appendix B.

2) Rooftop-solar photovoltaic technical potential, as determined by National Renewable Energy Laboratory (NREL).[50]

3) Minor consideration of subjective factors — including the extent to which policymakers opted to actively block distributed solar due to utility pressure when given the opportunity to create fair market policies.

Many other states could also have been included in this report, due to active distributed-solar policy fights, bad policy scores overall, lack of policies or programs directed at increasing access for low or moderate-income communities, or the absence of any distributed-solar market. Thus the present report isn’t intended to function as an inclusive summary of all states blocking access to distributed-solar development, but rather to highlight how much weak state-policy landscapes are preventing distributed-solar growth in states with high potential. It also seeks to provide clear avenues for advocacy and policy improvements in the near term.

Table 2. 10 States Blocking Distributed Solar: Key Policies

State	Mandatory RPS - Active	RPS Solar or DG Carve-Out	Mandatory Net Metering	Third Party Ownership	Community Solar	Interconnection Standards	Solar Rights Laws
Alabama	no	NA	no	no	no	no	no
Florida	no	NA	yes	no	no	no	yes
Georgia	no	NA	no***	yes	no	no	no
Indiana	no*	no	no***	no*	no	yes	yes
Louisiana	no	NA	yes	yes**	no	no	yes
Oklahoma	no*	no	yes	no	no	no	no
Tennessee	no	NA	no	no*	no	no	no
Texas	no**	no	no**	yes***	no	no	yes
Virginia	no*	no	yes	yes***	no*	yes	yes
Wisconsin	no	no	yes	no*	no	no	yes
	*voluntary by utility		**voluntary by utility	* legality is unknown or unclear	*pilot program	yes = grade of A, B, or C in IREC and Vote Solar's Freeing the Grid report	
	**RPS requirements already met or timeline passed		***policy like net metering in place that doesn't meet criteria set by DSIRE	**leases are legal, but PPAs are prohibited	**has virtual net metering (VNM)	no = no standards or grade of D or F	
				***legal but with limitations			

Alabama

Although many states have made improvements over the past two years with regard to renewable-energy policy, Alabama has done virtually nothing. Still with no RPS, net-metering or community solar laws in place, and barriers to third-party solar companies operating in the state, it's no surprise that Alabama is falling far behind its solar potential. The state legislature has made no moves to support the distributed-solar industry — and in fact has blocked net metering multiple times, most recently in 2016 — despite the opportunity for reliable, clean electricity, community resilience and job creation in a state that desperately needs it.[51]

Not only does Alabama lack all key distributed-solar policies, it also lacks any clear avenues for public involvement in the policymaking process. With the first iteration of this report, we noted that Tennessee Valley Authority (TVA) does supply a net-metering-like option to its customers, but it only operates in a small part of northern Alabama. For the rest of the state, under utility Alabama Power, no payback or financing option exists. Further, the utility charges a punitive, fixed fee of 5 dollars per kilowatt per month to solar customers.[52]

Thanks to a 2015 report by Institute for Energy Economics and Financial Analysis, we also know that the Alabama Public Service Commission does not allow the public to meaningfully comment on Alabama Power's integrated resource plan.[53] Utilities use integrated resource plans to identify affordable ways to meet the needs of the electricity market, and public input would help to create a more realistic understanding of the demand for distributed solar in the state. Public input is a key component of a fair, transparent government. Without allowing it in the IRP development process, potential solar customers have essentially no say in the types of policies that could benefit them.

Quick Facts

- #19 in technical potential (TWh) for rooftop solar
- #46 in net generation (thousand MWh of residential solar)
- Overall policy grade: F
- Renewable portfolio standard: None
- Net-metering policy: None
- Third-party ownership: None
- Community solar laws: None
- Interconnection standards: None
- Solar-access laws: None

Recommendations:

- Increase transparency by allowing public input on Alabama Power's IRP.
- Create mandatory targets by enacting a strong RPS with a distributed-solar carveout.
- Create a strong net-metering policy and an interconnection law using criteria outlined in IREC and Vote Solar's "Freeing the Grid" report.
- Allow for third-party PPAs and leasing to improve accessibility of distributed-solar resources.
- Create community solar and low-income financing programs to help diversify access to residential solar.
- Remove the $5 per kilowatt monthly fixed charge for solar customers
- Create solar rights policy to protect individual home and business owners' rights to install solar panels on their properties.

Florida

Quick Facts

- #3 in technical potential for rooftop solar
- #13 in net generation (thousand MWh of residential solar)
- Overall policy grade: F
- Renewable portfolio standard: None
- Net-metering policy: Weak
- Third-party ownership: Leases allowed, PPAs disallowed
- Community solar laws: None
- Interconnection standards: Weak

Florida, despite being known as "the Sunshine State," has one of the weakest distributed-solar policy landscapes in the United States. It remains one of the worst actors on our list, in spite of the clear public support for solar. With no RPS, PPAs or community solar policies, Florida has essentially blocked all potential distributed-solar development, especially for those who cannot afford to buy solar panels outright and install them on their own.

Florida is one of the fastest-growing states in the country, with ever-growing demand for solar resources and one of the highest technical potentials for rooftop solar in the United States. Even without an RPS, if Florida allowed for PPA financing of solar installations, Floridians could decide for themselves to put solar panels on their homes in order to save money over time, and many would.

As Florida's demand for clean and affordable energy sources has grown, it's faced some tough fights over distributed-solar policy. In 2016 Florida lawmakers introduced Amendment 1, a ballot measure that would have ensured monopoly utility control over solar power by locking out third-party competitors. The amendment, deceptively named "Rights of Electricity Consumers Regarding Solar Energy Choice," was backed by an interest group funded by state utilities and fossil fuel companies.[54] Had it been successful, Amendment 1 would have made PPAs not only illegal, but unconstitutional in the state. It also attempted to grant utilities a constitutional basis to challenge any policy that they perceived to unfairly favor solar power. Fortunately, due to a wide-reaching public-awareness campaign by a broad coalition of solar advocates, Floridians showed their support for solar by voting the ballot measure down.[55]

Despite the clear message from residents at the ballot box, Florida legislators have done little to improve the state's policy landscape for distributed-solar development. The "Sunshine State" needs to start living up to its name and its technical potential by allowing its residents to go solar.

Recommendations:

- Create mandatory targets by enacting a strong RPS with a distributed-solar carveout.
- Strengthen net-metering policy and interconnection standards using criteria outlined in IREC and Vote Solar's "Freeing the Grid" report.
- Explicitly allow for third-party PPAs to improve accessibility of distributed-solar resources.
- Create community solar and low-income financing programs to help diversify access to residential solar.

Georgia

Georgia, like Florida and Texas, is high on the list for rooftop PV technical potential but falling far behind in overall net generation. Because Georgia still has no RPS, net metering, community solar or solar-access policies, it remains on the worst offenders list.

Like Florida, Georgia's solar market has a lot of opportunity for growth. This is thanks in large part to a years-long and high-profile fight led by an unlikely team: environmentalists and an offshoot of Tea Party activists. This unlikely coalition led the fight against Georgia's utility commission and anti-solar Americans for Prosperity to require Georgia's primary utility, Georgia Power, to get more of its energy from solar, and successfully fought a proposed fee on solar customers.[56]

Quick Facts

- #10 in technical potential for rooftop solar
- #34 in net generation (thousand MWh of residential solar)
- Overall policy grade: F
- Renewable portfolio standard: None
- Net-metering policy: None
- Community solar laws: None
- Interconnection standards: Weak
- Solar-access laws: None

Due to continued successes by solar advocates in the state, Georgia made a notable improvement in its solar policies by allowing for third-party ownership of solar panels, putting it in a position to move off the list of worst solar states in coming years. Also, Georgia Power now sells rooftop-solar systems to customers.

Recommendations:

- Enact a strong RPS with a distributed-solar carveout.
- Enact a strong net-metering policy using criteria from IREC and SEIA's "Freeing the Grid" report.
- Create community solar and low-income financing programs to help diversify access to residential solar.
- Strengthen interconnection standards using criteria outlined in IREC and Vote Solar's "Freeing the Grid" report.

Indiana

Indiana's already dismal solar-policy landscape has been hit hard over the past few years. With the passage of S.B. 309 in 2017, Indiana opted to phase out retail rate net metering. A review by *The Indianapolis Star* showed that Indiana legislators received thousands of dollars in gifts from utility interest groups while writing this legislation. These interest groups used the false argument that net-metering compensation acts as a "subsidy" for solar to convince legislators to revoke the policy. Because of these insidious relationships, Indiana legislators have dealt an unfair hand to Hoosiers who want to have the freedom to go solar at a fair rate.[57]

Between a voluntary RPS, a net-metering policy that is being phased out, no community solar and unclear third-party ownership laws, plus a pending residential monthly fixed charge increase for Indianapolis Power and Light customers, Indiana is essentially blocking any chance of substantial distributed-solar development. This is true even without the threat of additional barriers and is especially problematic for low-income communities. The anti-solar landscape is taking a toll on solar job creation in the state; according to the 2017 Solar Jobs Census by The Solar Foundation, Indiana added 93 percent fewer jobs in 2017 than 2016.[58]

Quick Facts

- #14 in technical potential for rooftop solar
- #35 in net generation (thousand MWh of residential solar)
- Overall policy grade: F
- Renewable portfolio standard: Voluntary and weak
- Net-metering policy: None
- Third-party ownership: Unclear
- Community solar laws: None
- Interconnection standards: Weak

Recommendations:

- Strengthen the RPS by making it mandatory, creating a more ambitious target and including a distributed-solar carveout.
- Strengthen net-metering policy and interconnection standards by using criteria outlined in IREC and Vote Solar's "Freeing the Grid" report.
- Allow for third-party PPAs and leasing to improve accessibility of distributed-solar resources.
- Create community solar and low-income financing programs to help diversify access to residential solar.
- Prevent further attempts to create unfair fees for distributed-solar customers.

Louisiana

Louisiana is the only new state on the list in this update. It secured its spot in part because Michigan made an improvement to its RPS, and also because it's made no notable improvements to its policy in the last two years despite a dire need.

Louisiana may seem as though it's doing something right in terms of distributed-solar policy since it's ranked #12 for net generation. The installations that account for this number seem to be due to a surprisingly generous solar tax credit that covered 50 percent of installation costs up to $25,000 for solar customers who installed systems before mid-2015.[59] The state's overall policy landscape lacks an RPS, has no community solar laws and is weak on net-metering and interconnection standards. The legality of PPAs is also unclear in Louisiana.

Quick Facts

- #22 in technical potential for rooftop solar
- #12 in net generation (thousand MWh of residential solar)
- Overall policy grade: F
- Renewable portfolio standard: None
- Net-metering policy: Weak
- Third-party ownership: Leases allowed
- Community solar laws: None
- Interconnection standards: Weak

As of July 2015, the solar tax credit took a steep dive due to a suite of new restrictions, including a cap of $10,000 per PV solar system. Nothing has been done to improve the incentive since.[60] And in the summer of 2016, the state ran out of funds for the program.[61] Louisiana saw about half as many residential solar installations in 2016 as in 2015 or 2014, likely due to this decline.[62]

Now the Louisiana Public Service Commission staff has proposed to eliminate retail rate net metering and replace it with a "two channel billing" mechanism, likely at an avoided cost rate.[63] This would apply even to existing solar customers after a short five-year grandfathering period. That means that those Louisiana customers who went solar expecting to be paid back for their investment over the course of a certain number of years will now have to wait even longer for their investment to pay off. Additionally, calculating the costs and benefits of solar would be largely left to the utilities, and the draft proposal would potentially allow for utilities to impose discriminatory charges on solar customers.[64,65] It's unclear when this proceeding will be resolved, but if rooftop solar is to have a fighting chance in the state, it's clear that these proposed changes need to be rejected. On the flip side, the proposal does include community net metering, so there would be a community solar policy of some kind if the proposed rules are approved.

Recommendations:

- Create mandatory targets by enacting a strong RPS with a distributed-solar carveout.
- Create a strong net-metering policy and strengthen interconnection standards using criteria outlined in IREC and Vote Solar's "Freeing the Grid" report.
- Allow for third-party PPAs and leasing to improve accessibility of distributed-solar resources.
- Create community solar and low-income financing programs to help diversify access to residential solar.
- Reject the LPSC proposal to replace net metering.

Oklahoma

With no notable changes to its overall solar-policy landscape, Oklahoma once again makes the list of sunny states blocking distributed-solar progress through bad policy. It may not have as much technical potential for rooftop solar as the other states on this list, but Oklahoma is also nowhere near meeting its technical potential or providing fair access to distributed solar. There are fewer than 700 homes with solar statewide as of the end of 2017.[66] This low figure is problematic, as improved rooftop-solar access could benefit Oklahoma's low-income and rural residents significantly.

Unfortunately, with a voluntary and weak RPS with an expired goal of 15 percent renewable energy by 2015 and no solar carveout, there's no real mandate for the state to invest in solar. Voluntary RPSs in general don't provide the incentive needed to effectively promote solar power for either distributed or utility-scale sources. Oklahoma also lacks a third-party ownership policy, has no community solar or solar-rights policies and has very weak interconnection standards. Finally, although Oklahoma does have a net-metering program, it has a fairly low system-size limit and does not require that utilities pay customers back for the net energy they generate; this significantly decreases the payback for distributed-solar owners.

Until Oklahoma's legislature decides to create policies that encourage distributed-solar development, its residents will miss out on energy choice, clean-air benefits and electricity savings that rooftop-solar markets can provide.

Quick Facts

- #20 in technical potential for rooftop solar
- #42 in net generation (thousand MWh of residential solar)
- Overall policy grade: F
- Renewable portfolio standard: Voluntary and weak
- Net-metering policy: Weak
- Third-party ownership: None
- Community solar laws: None
- Interconnection standards: Weak
- Solar-access laws: None

Recommendations:

- Strengthen the RPS by making it mandatory, create a more ambitious target and include a distributed-solar carveout.
- Strengthen net-metering policy and interconnection standards by using criteria outlined in IREC and Vote Solar's "Freeing the Grid" report.
- Allow for third-party PPAs and leasing to improve accessibility of distributed-solar resources.
- Create community solar and low-income financing programs to help diversify access to residential solar.
- Create solar-access laws to protect individual home and business owners' rights to install solar panels on their properties.

Tennessee

Tennessee's legislature has done essentially nothing to support its distributed-solar market, despite the fact that 88 percent of Tennessee voters expressed a desire to have solar on their homes.[67] It has remained on the list of worst states, with no marked improvement since 2016. The lack of clean energy support by legislators may seem inevitable in the heart of coal country, but other coal states like West Virginia have market preparation policies in place, which provides a minimum framework to allow residents to choose to spend their own money to install solar panels.

With no RPS, net metering, third-party ownership, community solar laws, interconnection standards or solar-access laws, Tennessee has nixed any opportunity for distributed-solar development. This makes the switch to clean energy even more of a financial hurdle in Tennessee than it would be in other states with similarly poor markets. What little distributed-solar capacity there is installed in the state is due to the Tennessee Valley Authority (TVA), the power utility that services almost all of Tennessee. TVA has a voluntary net-metering-like program in place to support its distributed generation customers — a program created in response to users' requests for a net-metering program.[68] Huge changes would have to be made in the state for this market to be a viable one. And in the meantime, TVA has recently proposed a new rate structure expressly designed to make distributed solar less attractive in its service area.[69]

Quick Facts

- #15 in technical potential for rooftop solar
- #32 in net generation (thousand MWh of residential solar)
- Overall policy grade: F
- Renewable portfolio standard: None
- Net-metering policy: None
- Third-party ownership: None
- Community solar laws: None
- Interconnection standards: None
- Solar-access laws: None

Recommendations:

- Create mandatory targets by enacting a strong RPS with a distributed-solar carveout.
- Create a strong net-metering policy using criteria outlined in IREC and Vote Solar's "Freeing the Grid" report.
- Allow for third-party PPAs and leasing to improve accessibility of distributed-solar resources.
- Strengthen interconnection standards using criteria outlined in IREC and Vote Solar's "Freeing the Grid" report.
- Create community solar and low-income financing programs to help diversify access to residential solar.
- Create solar-access laws to protect individual home and business owners' rights to install solar panels on their property.

Texas

As catastrophic storms like Hurricane Harvey become more frequent and intense in southern states like Texas, improving access to distributed solar becomes even more urgent. When distributed-solar systems are designed with disaster resiliency in mind, they can provide power even when the rest of the grid goes down and communities rebuild after disaster strikes. That's why improving statewide solar policy is so important in Texas. With the state's large population, continuous development, high electricity demand and incredible technical potential for rooftop solar, it's primed for a huge distributed-solar boom.

Quick Facts

- #2 in technical potential for rooftop solar
- #6 in net generation (thousand MWh of residential solar)
- Overall policy grade: F
- Renewable portfolio standard: Extremely weak
- Net-metering policy: Voluntary
- Community solar laws: None
- Interconnection standards: Weak

Unfortunately the state's legislature and regulators have consistently blocked progress on distributed-solar policy for the last decade and have made no moves to improve the state's policy landscape since the last iteration of this report came out. Texas met its incredibly unambitious RPS goal of 10,000 MW in 2009 — more than 15 years ahead of schedule — and no tangible improvements have been made in the eight years since. A "non-wind sources" carveout for the state's RPS was approved in 2005 only to be blocked by the utilities commission after corporate interests threatened to sue. In 2007 a bill that would have mandated statewide net metering was blocked by the public utility commission. In 2009, 2011 and 2013, efforts to circumvent the commission's authority to require that retail electricity providers offer net metering to their customers failed to pass the state legislature.[70]

Although Texas' solar-rights law and allowance for third-party ownership puts it a step ahead of many other states on this list, the Lone Star State earns its spot in the top 10 ranking of states blocking solar progress due to its weak distributed-solar policy landscape overall despite the highest technical potential for rooftop solar of any state other than California. With even moderate improvements to its net-metering law and its RPS, Texas could dramatically improve accessibility to distributed-solar sources.

Recommendations:

- Update the RPS to include a new ambitious target and a strong distributed-solar carveout.
- Strengthen net-metering policy and interconnection standards by using criteria outlined in IREC and Vote Solar's "Freeing the Grid" report.
- Create community solar and low-income financing programs to help diversify access to residential solar.

Virginia

Virginia does have a couple of policies in place supporting its distributed-solar market, such as solar-access rights and strong interconnection standards. But it only has a voluntary RPS with no solar carveout, unclear legality for third-party ownership and no true community solar policy. Without mandatory and meaningful goals, the RPS doesn't provide any real incentive to promote distributed or utility-scale solar development. And like many other states on this list, Virginia has done little to improve its solar outlook since the last iteration of this report.

With S.B. 1393, enacted in March 2017, the state did require that the two investor-owned utilities in the state develop "community solar" pilot programs in the state. But these would not be community solar programs in their true form, as they would not allow for community ownership or administration of the solar installations.[71]

Quick Facts

- #13 in technical potential for rooftop solar
- #24 in net generation (thousand MWh of residential solar)
- Overall policy grade: F
- Renewable portfolio standard: Voluntary and weak
- Net-metering policy: Weak
- Third-party ownership: Unclear
- Community solar laws: None

The state's weak net metering improved slightly when the legislature signed S.B. 1395 into law in March 2015. This legislation allowed for more mid-size installations by increasing the net-metering system size limits from 500 kW to 1,000 kW. However, it is still an overall weak program because it requires that customers create a PPA with their utility prior to connecting their PV solar system to the grid. These agreements are up to the utility's discretion. This barrier prevents potential solar customers from accessing net-metering program benefits and ultimately gives all power to the utility rather than ensuring solar customers are compensated fairly for the energy they provide.

Recommendations:

- Strengthen the RPS by making it mandatory, create a more ambitious target and include a distributed-solar carveout.
- Strengthen net-metering policy by using criteria outlined in IREC and Vote Solar's "Freeing the Grid" report.
- Clearly allow for third-party PPAs and leasing to improve accessibility of distributed-solar resources.
- Create community solar and low-income financing programs to help diversify access to residential solar.

Wisconsin

No major policy improvements have been made for distributed solar in Wisconsin since the last iteration of this report. Although the state came close to an RPS success story a handful of years ago, but dropped the ball. Its target of 10 percent was actually fairly ambitious for the time, but similar to Texas, the state met its goal two years early in 2013. The Wisconsin legislature has made no moves to implement any new renewable energy goals as of yet, and therefore its existing RPS is outdated and ineffective. In addition, there is no solar carveout.

Wisconsin's net-metering program could also be strengthened by increasing or removing the system-size cap and allowing for community solar inclusion. The state's interconnection standards obtained a low grade on IREC and Vote Solar's "Freeing the Grid" report due to the fact that they require solar customers to buy extra liability insurance and install a redundant external disconnect switch, both of which create burdens for potential customers who might already find it financially challenging to install solar panels without access to third-party ownership agreements.

Quick Facts

- #16 in technical potential for rooftop solar
- #31 in net generation (thousand MWh of residential solar)
- Policy grade: F
- Renewable portfolio standard: Weak
- Net-metering policy: Weak
- Third-party ownership: Unclear
- Community solar laws: None
- Interconnection standards: Weak

Recommendations:

- Update the RPS with a more ambitious target and a distributed-solar carveout.
- Strengthen net-metering policy by using criteria outlined in Vote Solar and IREC's "Freeing the Grid" report.
- Allow for third-party PPAs and leasing.
- Create community solar and low-income financing programs to help diversify access to residential solar.
- Strengthen interconnection standards using criteria outlined in Vote Solar and IREC's "Freeing the Grid" report.

(DIS)HONORABLE MENTIONS

Although Kentucky, Michigan and South Carolina didn't make our list of the top 10 states blocking solar progress, it wasn't for lack of bad policy. Kentucky's low policy score would have guaranteed it a spot if it ranked higher in overall technical potential — it's only 26 on that list. Michigan has improved its overall ranking since the last iteration of this report by updating its RPS, but the state's solar policy landscape remains poor overall. And although South Carolina has some key policies in place, they tend to be voluntary and weak measures that don't support the solar market as well as they could.

Michigan

Michigan is known for being cold and snowy for a significant part of the year, and it's easy to underestimate the state's solar potential. However, Michigan comes in eighth for rooftop PV technical potential in the United States — above even Georgia and Virginia. With high electricity prices and such high potential for distributed solar, what's holding the state back is its bad policy. These policies don't come from lack of interest; 80 percent of Michigan voters want to see more solar, with majority support from both Democrats and Republicans.[72]

Michigan has extended its previously-met RPS to 15 percent by 2021, part of why it was knocked off the top 10 list from the 2016 rankings to a dishonorable mention. Unfortunately its net-metering policy includes barriers in the form of low system-size limits and aggregate capacity limits, and the Public Service Commission staff recently proposed changing their net-metering policy to a "net-billing" policy to compensate solar customers at a lower rate. The state's interconnection standards are complex and include a requirement for additional and redundant insurance. Furthermore, Michigan lacks both community solar laws and solar-access laws, two policies that could directly benefit lower- and moderate-income home and business owners. Communities in Michigan, particularly low-income communities and communities of color, could benefit immensely from the opportunity to generate reliable, clean electricity while increasing community resilience and creating jobs.

Quick Facts

- #8 in technical potential for rooftop solar
- #26 in net generation (thousand MWh of residential solar)
- Overall policy grade: F
- Net-metering policy: Weak
- Community solar laws: None
- Interconnection standards: Weak
- Solar-access laws: None

Recommendations:

- Maintain the state's existing net-metering policy and strengthen it and the state's interconnection standards by using criteria outlined in IREC and Vote Solar's "Freeing the Grid" report.
- Create community solar and low-income financing programs to help diversify access to residential solar.
- Create solar-access laws to protect individual home and business owners' rights to install solar panels on their properties.

South Carolina

On the surface it may appear as though South Carolina is not doing badly in terms of solar policy — as it has an RPS and net-metering program. In truth, however, both of these policies are substantially weak, and both are voluntary. South Carolina's RPS is one of the weakest in the country — calling for utilities in the state to produce just 2 percent of their total capacity from renewable-energy sources by 2021. Like many other states on this list, South Carolina's RPS does not include a solar carveout. Its net-metering program also expressly prohibits meter aggregation, which would allow for multiple homes to benefit from a shared solar installation.

South Carolina also has unclear third-party ownership legality, weak interconnection standards, no community solar programs in place and no solar-access rights. In order to even come close to its distributed-solar potential, South Carolina's legislature needs to step up its distributed-solar policy game. Since it's made no clear moves to improve its policy in the past two years, it remains a dishonorable mention on this list.

Quick Facts

- #23 in technical potential for rooftop solar
- #18 in net generation (thousand MWh of residential solar)
- Overall policy grade: F
- Renewable portfolio standard: Voluntary and weak
- Net-metering policy: Mandatory but capped
- Third-party ownership: Leasing allowed, PPAs disallowed
- Community solar laws: None
- Interconnection standards: Weak
- Solar-access laws: None

Recommendations:

- Strengthen the RPS by making it mandatory with an ambitious distributed-solar carveout.
- Strengthen the net-metering policy by making it mandatory, allowing for meter aggregation, and using criteria outlined in IREC and Vote Solar's "Freeing the Grid" report.
- Allow for third-party PPAs and leasing to improve accessibility of distributed-solar resources.
- Strengthen interconnection standards using criteria outlined in IREC and Vote Solar's "Freeing the Grid" report.
- Create community solar and low-income financing programs to help diversify access to residential solar.
- Create solar-access laws to protect individual home and business owners' rights to install solar panels on their properties.

CONCLUSION

Distributed solar is a necessary and drastically undervalued component of our clean-energy future. Rooftop-solar prices are becoming increasingly competitive with fossil fuel sources, and we know what policies work to encourage installations. While there are some federal policies that can influence distributed solar, given the anti-climate action agenda of the Trump administration and Congress, the real power lies with the states.

We do have some real success stories to look to for inspiration: Distributed-solar markets have blossomed in California, New York and other states that have adopted generally strong solar policies. Unfortunately, distributed-solar development is under attack from monopoly utilities and fossil fuel interests across the country. From net-metering fights to outright bans on third-party ownership, the number and intensity of these fights are increasing year by year.

Energy, climate, wildlife and social-justice advocates need to stand together to support policies that can maximize our solar potential and protect the rights of individuals and communities to create and benefit from clean, reliable energy where they live and work.

The states outlined in this report are far from the only states that need to improve their policies — all 50 states have room for improvement. What these states do represent is significant missed opportunity for clean energy generation. This hampers community resilience and empowerment, job creation and wildlife protection. The states on the list are missing out on avoided fossil fuel use as well as eliminated environmental costs due to poorly sited utility-scale renewable energy sources.

The lack of key solar policies and the presence of active barriers to distributed generation diffusion in these states are representative of policy issues many other states are dealing with or will likely face in the near future. The hope is that by outlining some of these issues home and business owners, solar advocates and policymakers will have an easier time identifying ways to improve distributed-solar policy in all states. Through these improvements, we can achieve the necessary transition to a just, wildlife-friendly and fully renewable energy system.

For more information on policy models that can encourage distributed-solar access, check out the recently released "Shared Renewable Energy for Low- to Moderate-Income Consumers: Policy Guidelines and Model Provisions" report by Interstate Renewable Energy Council and "Low-Income Solar Policy Guide: A road map to successful policies and programs creating access to solar technology and jobs nationwide" report by GRID Alternatives, Vote Solar and Center for Social Inclusion.

APPENDIX A: CHART OF DISTRIBUTED-SOLAR POLICIES

State	Mandatory RPS - Active	RPS Solar or DG Carve-Out	Mandatory Net Metering	Third Party Ownership	Community Solar	Interconnection Standards[10]	Solar Rights Laws	State Policy Grade	Small Scale Rooftop PV Technical Potential: Rank of Contiguous U.S.	Net Generation from Small Scale Rooftop PV: Rank of Contiguous U.S.[11]
Alabama	no	NA	no	no	no	no	no	F	19	46
Alaska	no	NA	yes	no[5]	no	no	no	F	NA	NA
Arizona	yes	yes	no[4]	yes[7]	no	no	yes	D	11	2
Arkansas	no	NA	yes	no	no	no	no	F	31	40
California	yes	no	yes	yes	yes	yes	yes	A	1	1
Colorado	yes	yes	yes	yes[7]	yes	yes	yes	A	24	8
Connecticut	yes	no	yes	yes	no[8]	yes	no	A	33	10
Delaware	yes	yes	yes	yes	yes[9]	yes	yes	A	45	22
District of Columbia	yes	yes	yes	yes	yes	yes	no	A	NA	NA
Florida	no	NA	yes	no	no	no	yes	F	3	13
Georgia	no	NA	no[4]	yes	no	no	no	F	10	34
Hawaii	yes	no	no[4]	yes	yes	yes	yes	C	NA	NA
Idaho	no	NA	no[3]	no[5]	no	no	no	F	38	36
Illinois	yes	yes	yes	yes	yes	yes	yes	A	7	33
Indiana	no[1]	no	no[4]	no[5]	no	yes	yes	F	14	35
Iowa	yes	no	yes	yes	no	yes	no	D	28	25
Kansas	no*	no	yes	no	no	no	no	F	30	37
Kentucky	no	NA	yes	no	no	no	no	F	26	39
Louisiana	no	NA	yes	yes[6]	no	no	yes	F	22	12
Maine	no[2]	no	no[4]	yes	yes	yes	yes	D	40	29
Maryland	yes	yes	yes	yes	no[8]	yes	yes	A	27	5
Massachussetts	yes	yes	yes	yes	yes[9]	yes	yes	A	25	7
Michigan	yes	yes	yes	yes	no	yes	no	D	8	26
Minnesota	yes	yes	yes	no[5]	yes	yes	yes	C	21	27
Mississippi	no	NA	no[4]	yes[6]	no	yes	no	F	32	43

1. Voluntary by utility
2. RPS requirements already met or timeline passed
3. Voluntary by utility
4. Policy like net metering in place, but doesn't meet criteria set by DSIRE
5. Legality is unknown or unclear
6. Leases are legal, but PPAs are prohibited
7. Legal but with limitations
8. Pilot program
9. Has virtual net metering (VNM)
10. Yes = grade of A, B, or C in IREC and Vote Solar's Freeing the Grid report; no = no standards or grade of D or F
11. Data is Year-to-Date for December 2017, accessed in EIA's February 2018 Electric Power Monthly

APPENDIX A (CONTINUED)

State	Mandatory RPS - Active	RPS Solar or DG Carve-Out	Mandatory Net Metering	Third Party Ownership	Community Solar	Interconnection Standards[10]	Solar Rights Laws	State Policy Grade	Small Scale Rooftop PV Technical Potential: Rank of Contiguous U.S.	Net Generation from Small Scale Rooftop PV: Rank of Contiguous U.S.[11]
Missouri	yes	yes	yes	no[5]	no	no	yes	D	12	16
Montana	no[2]	no	yes	no[5]	no	yes	no	F	41	38
Nebraska	no	NA	yes	no[5]	no	no	no	F	37	44
Nevada	yes	yes	yes	yes[7]	no	yes	yes	B	35	9
New Hampshire	yes	no	yes	yes	yes[9]	yes	no	B	42	23
New Jersey	yes	yes	yes	yes	no	yes	yes	B	17	4
New Mexico	yes	yes	yes	yes	no	yes	yes	C	36	15
New York	yes	yes	yes	yes	yes	yes	yes	A	4	3
North Carolina	yes	yes	yes	yes[7]	no[8]	yes	yes	D	9	21
North Dakota	no[1]	no	yes	no[5]	no	no	no	F	44	48
Ohio	yes	yes	yes	yes	no	yes	no	C	5	30
Oklahoma	no[1]	no	yes	no	no	no	no	F	20	42
Oregon	yes	yes	yes	yes	yes	yes	yes	A	29	19
Pennsylvania	yes	yes	yes	yes	no	yes	no	C	6	14
Rhode Island	yes	no	yes	yes	yes	yes	no	D	46	28
South Carolina	no[1]	no	yes	yes[6]	no	yes	no	F	23	18
South Dakota	no[1]	no	no	no[5]	no	yes	no	F	43	47
Tennessee	no	NA	no	no[5]	no	no	no	F	15	32
Texas	no[2]	no	no[3]	yes[7]	no	no	yes	F	2	6
Utah	no[1]	no	no[4]	yes	no	yes	yes	F	34	11
Vermont	yes	yes	yes	yes	yes[9]	yes	yes	A	47	20
Virginia	no[1]	no	yes	yes[7]	no[8]	yes	yes	F	13	24
Washington	yes	no	yes	no[5]	yes[9]	yes	yes	D	18	17
West Virginia	no	no	yes	no[5]	no	no	yes	F	39	41
Wisconsin	no	NA	yes	no	no	yes	yes	F	16	31
Wyoming	no	NA	yes	no[5]	no	no	no	F	48	45

1. Voluntary by utility
2. RPS requirements already met or timeline passed
3. Voluntary by utility
4. Policy like net metering in place, but doesn't meet criteria set by DSIRE
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7. Legal but with limitations
8. Pilot program
9. Has virtual net metering (VNM)
10. Yes = grade of A, B, or C in IREC and Vote Solar's Freeing the Grid report; no = no standards or grade of D or F
11. Data is Year-to-Date for December 2017, accessed in EIA's February 2018 Electric Power Monthly

APPENDIX B: STATE DISTRIBUTED-SOLAR POLICY GRADES: METHODOLOGY

States are credited as having the following solar energy policies if they meet these criteria:

- Renewable Portfolio Standard (or Renewable Electricity Standard): Presence of a mandatory RPS or RES included in DSIRE's database, verified by National Conference of State Legislature (NCLS 2016).
- Distributed-solar carveout: Presence of a carveout for solar or distributed generation in mandatory RPS requirement, as described in DSIRE's database
- Net-metering policies: Presence of statewide net-metering policies obtaining an "A" in IREC and Vote Solar's 2015 "Freeing the Grid" report. Those obtaining a "B" or below were considered "weak"
- Interconnection standards: Presence of statewide interconnection policies obtaining an "A" in IREC and Vote Solar's 2015 "Freeing the Grid" report were considered "strong". Those obtaining a "B" or below were considered "weak"
- Solar rights: Presence of statewide solar rights (or solar access) policy, determined by a review of "solar/wind access policy" category in DSIRE's database
- Community solar: Presence of a statewide community, shared or virtual net-metering solar program, determined by a review of DSIRE's database
- Third-party Ownership: States in which third-party leases or PPAs are explicitly legal, according to DSIRE database and summary map

Distributed-solar policy scores were determined using the following scoring system:

Criteria	Points
No mandatory RPS?	-1.0
Mandatory RPS but no solar carveout?	-0.5
No mandatory net metering?	-1.0
Mandatory net metering, but policy is "weak"? (defined above)	-0.5
No third party ownership policy?	-1.0
No community solar policy?	-1.0
No interconnection standards, or interconnection standards with "D" or "F" grade?	-0.5
No solar rights policy?	-0.5
Max deductions	-5.0

*The highest policy score that could be obtained is 5.

To select the 10 states guiltiest of blocking access to distributed solar through bad policy, we used NREL's Rooftop-solar Photovoltaic Technical Potential (GWh) rankings for small scale rooftops to narrow down the states to those in the top 25 for rooftop PV technical potential. We then ranked the states according to their distributed-solar policy scores, assigned grades based on a standard academic scale (88-100% = A, 78--87.9% = B, 68-77.9% = C, 58-67.9% = D, 0-57.9% = F) and identified 10 that had "F" grades.

Further information on these states and their solar policies, legislative history and political climate were obtained through an examination of policies on DSIRE's website and through a review of existing literature.

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2) Annual generation potential (TWh/year) obtained from Table 3 in NREL's 2016 report "Rooftop Solar Photovoltaic Technical Potential in the United States: A Detailed Assessment"; Comparative year-to-date net generation data for residential sector PV for 2017 obtained from Table 1.17.b in EIA's February 2018 Electric Power Monthly. For this Throwing Shade update, we used December 2017 year-to-date generation data rather than installed capacity data, because updated capacity data was unavailable for Georgia and Michigan.

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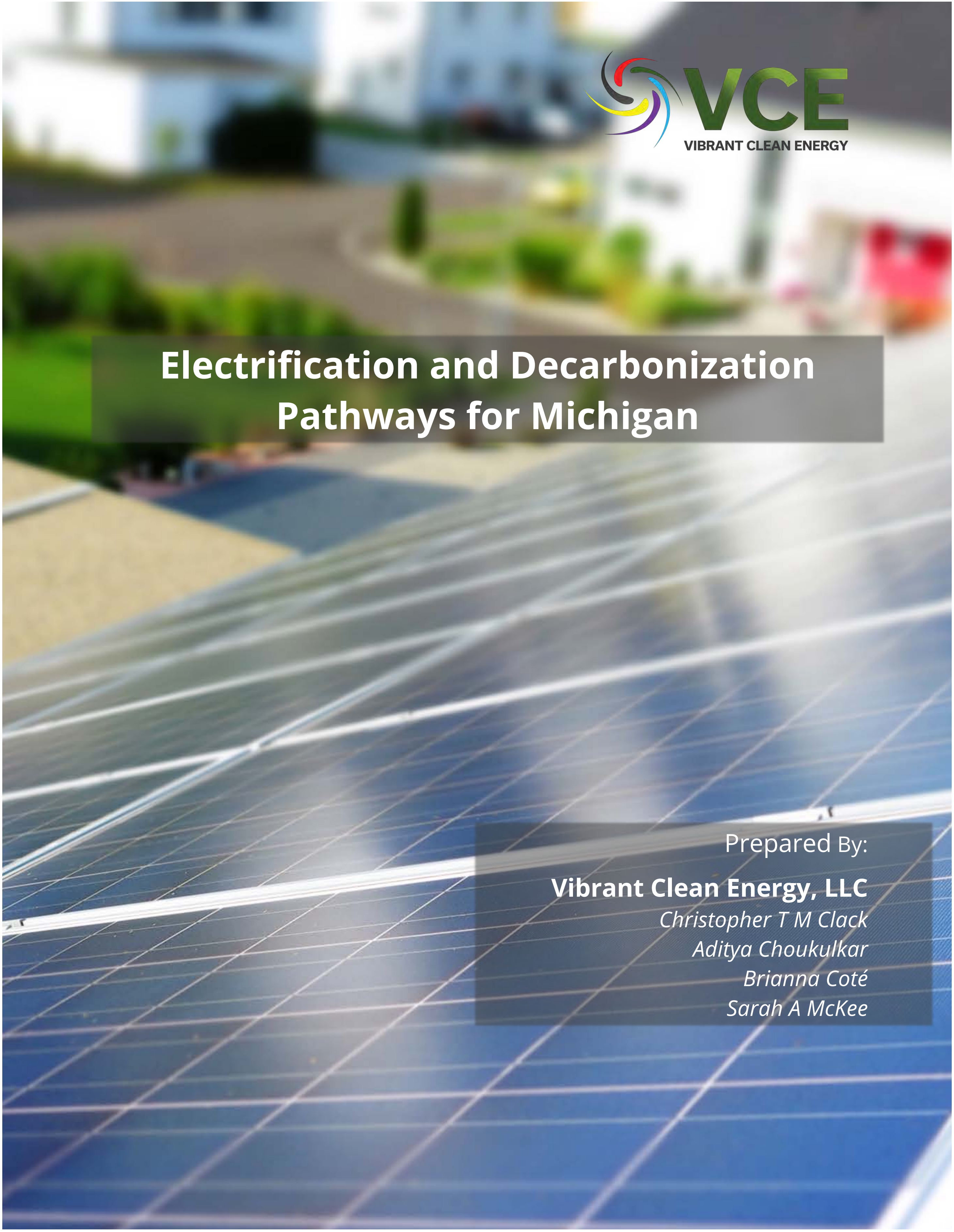

Electrification and Decarbonization Pathways for Michigan

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Table of Contents

1 Study Description

Major utilities in the state of Michigan have released their Integrated Resource Plans (IRPs) outlining their projections for meeting demand out to 2050. The Governor of Michigan, in the meantime, signed an Executive Directive for Michigan to become carbon neutral economy-wide by 2050. In the present study, Vibrant Clean Energy, LLC (VCE®) was commissioned by Vote Solar to study the IRPs released by the major utilities in the lower peninsula of Michigan and compare them against scenarios that achieve the Governor's carbon neutrality goal for the state. The modeling in this study was performed through 2050 using WIS:dom®-P, a state-of-the-art model capable of performing detailed capacity expansion and production cost while co-optimizing utility-scale generation, storage, transmission, and distributed energy resources (DERs). The modeled scenarios use the National Renewable Energy Laboratory (NREL) Annual Technology Baseline (ATB) 2020 "advanced" cost projections for installed capital and Operation and Maintenance (O&M) costs. For fuel costs, projections from the Annual Energy Outlook (AEO) 2020 High Oil and Gas supply scenario are used.[1]

The scenarios modeled in the present study are as follows:

(1) **Business-as-usual with major utilities in Michigan following their respective IRPs ("IRP"):** In this scenario, major utilities in Michigan follow their respective IRPs for capacity additions or retirements. The portions of Michigan not covered by the IRPs undergo optimal capacity expansion. The model does not co-optimize the distribution system with the utility-scale generation (as this is not included in the IRPs released by the utilities in Michigan). The model follows all existing RPS and greenhouse gas mandates passed into law. In addition, the model enforces Consumers Energy to reduce its electricity sector emission by 90% as declared by the utility in a recent announcement.[2] WIS:dom-P is constrained to follow the capacity changes in the IRP unless additional capacity is needed for reliability or to meet emission reduction goals or mandates. In this scenario, Michigan does not undergo economy-wide electrification.

(2) **Electrify and decarbonize Michigan in line with the Governor's Executive Directive without distribution co-optimization ("Decarb+nonOptDER"):** In this scenario, Michigan undergoes economy-wide electrification of energy related activities and completely decarbonizes the electricity sector by 2050. In addition, the scenario must meet 30% of demand from renewable electricity by 2025. In this scenario the distribution system is not co-optimized with the utility-scale grid. Natural gas fired power plants with carbon capture and sequestration (CCS) and advanced nuclear power plants [small modular reactors (SMR) and molten salt reactors (MSR)] are allowed to be installed after 2025 and 2035, respectively, if determined cost-optimal by WIS:dom-P.

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[1] https://www.eia.gov/outlooks/aeo/data/browser/#/?id=3-AEO2020&region=1-0&cases=highogs&start=2018&end=2050&f=A&linechart=highogs-d112619a.3-3-AEO2020.1-0~highogs-d112619a.36-3-AEO2020.1-0~highogs-d112619a.37-3-AEO2020.1-0~highogs-d112619a.38-3-AEO2020.1-0~highogs-d112619a.39-3-AEO2020.1-0~highogs-d112619a.40-3-AEO2020.1-0&map=highogs-d112619a.4-3-AEO2020.1-0&sourcekey=0

[2] https://www.usnews.com/news/best-states/michigan/articles/2021-06-23/consumers-energy-plans-to-complete-coal-phaseout-by-2025

(3) **Electrify and decarbonize Michigan in line with the Governor's Executive Directive with distribution co-optimization ("Decarb+optDER"):** This scenario is identical to "Decarb+nonOptDER" scenario with the single exception that the distribution system grids are co-optimized with the utility-scale grid.

The scenarios are initialized and calibrated with 2018 generator, generation, and transmission topology datasets. The model then determines a pathway from 2020 through 2050 with results outputted every 5 years. As part of the optimal capacity expansion, WIS:dom-P must ensure each grid meets reliability constraints through enforcing the planning reserve margins specified by the North American Electric Reliability Corporation (NERC) and having a 7% load following reserve available at all times. Detailed technical documentation describes the mathematics and formulation of the WIS:dom-P software along with input datasets and assumptions.[3]

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[3] https://vibrantcleanenergy.com/wp-content/uploads/2020/08/WISdomP-Model_Description(August2020).pdf

1.1 WIS:dom®-P Model Setup

To investigate the various scenarios, as described in the previous section, WIS:dom-P modeled the state of Michigan (upper and lower peninsula) with its existing generator topology, transmission, and weather inputs obtained from National Oceanic and Atmospheric Administration (NOAA) High Resolution Rapid Refresh (HRRR) model[4] at 3-km horizontal resolution and 5-minute time resolution. The initialized generator dataset is created by aligning the Energy Information Administration Form 860 (EIA-860) dataset[5] with the 3-km HRRR model grid. The existing generator topology in Michigan in 2018 along with existing transmission at 3-km resolution is shown in Figure 1.1.

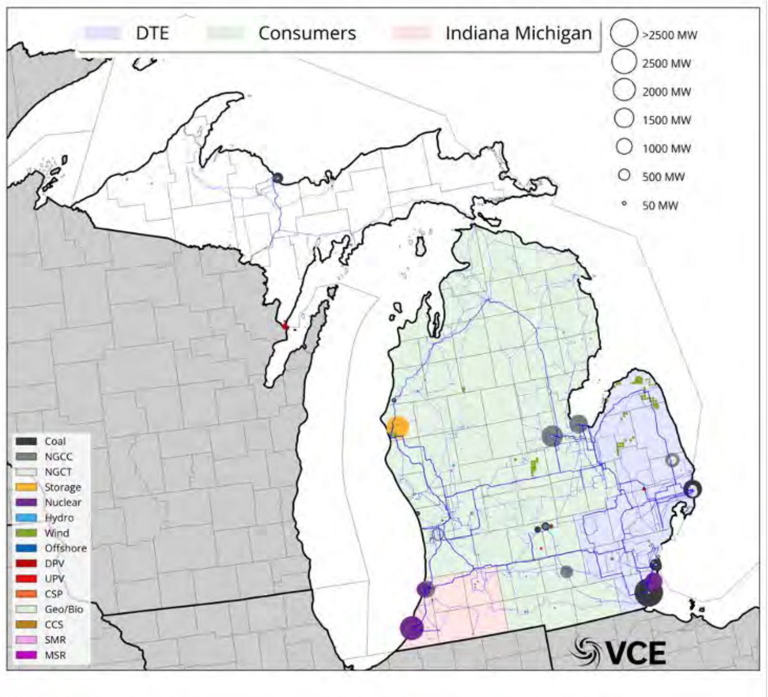

Figure 1.1: WIS:dom-P model domain and existing generators with transmission. The regions shaded show territories of the major Michigan utilities.

Existing transmission corridors between Michigan and neighboring states are modeled as imports and exports and are constrained to be consistent with limits set by MISO. The energy prices for the imports and exports are provided by a background modeling scenario ("CE-DER") from a previous study.[6] In addition, the transmission capacities between Michigan and neighboring states are assumed to remain constant over the modeling period.

Weather inputs obtained from National Oceanic and Atmospheric Administration (NOAA) High Resolution Rapid Refresh (HRRR) model[7] at 3-km horizontal resolution

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[4] https://rapidrefresh.noaa.gov/hrrr/
[5] https://www.eia.gov/electricity/data/eia860/
[6] https://www.vibrantcleanenergy.com/wp-content/uploads/2020/12/WhyDERs_TR_Final.pdf
[7] https://rapidrefresh.noaa.gov/hrrr/

and 5-minute time resolution are used in WIS:dom-P for applications with load, transmission and most noticeably with the dispatch and placement of solar and wind. The average fixed latitude tilt solar capacity factors and 100-m hub-height wind capacity factors calculated from the HRRR model output over the model domain are shown in Fig. 1.2. Michigan's wind resource is highest over the eastern part of the lower peninsula (the "thumb") and western portion of the upper peninsula along with a significantly stronger offshore resource. The solar resource is highest over the over the western part of upper peninsula and central portion of the lower peninsula.

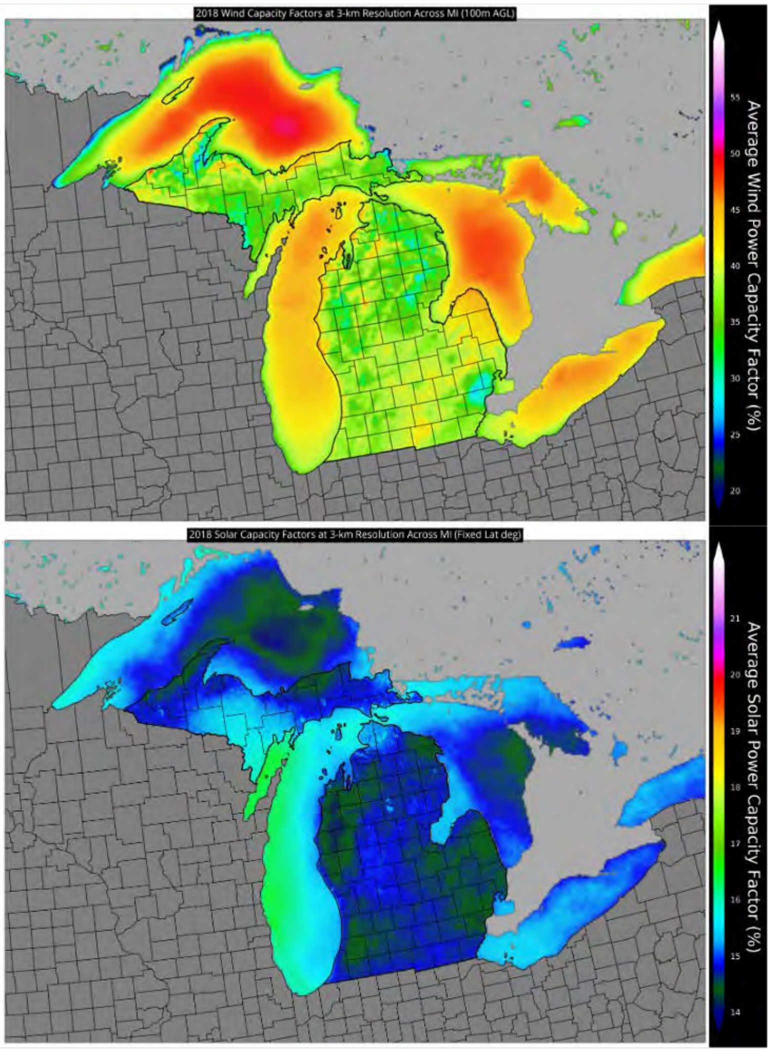

Figure 1.2: Average capacity factors for 100-m hub-height wind (top) and fixed axis latitude tilt solar (bottom) over the state of Michigan calculated from the HRRR model outputs.

2 Modeling Results

2.1 System Costs, Retail Rates & Jobs

In order to study the impact of each scenario on customer bills, the energy burden on customers is calculated for each of the scenarios modeled. The energy burden calculations include customer spending on traditional electricity, space and water heating, transport and industrial operations. The energy burden calculations are combined for residential and commercial customers, while the energy burden for industrial customers is calculated separately. The annual energy burden for an average residential and commercial customer in the "IRP" (top panel) and "Decarb+optDER" (bottom panel) scenario is shown in Fig 2.1.

In the "IRP" scenario, the economy-wide energy related activities are assumed to continue to operate on the current fuel mix and use coal[8], natural gas[9] and oil[10] cost projections from AEO High Oil and Gas Supply scenario. The energy burden in the "IRP" scenario reduces from approximately $4,950 in 2018 to $4,126 in 2030 as a result of reduced retail rates and reduced petroleum prices. After 2030, the energy burden remains almost constant as any reductions in the electricity sector spending (due to reduced retail rates) is offset by increased spending in the heating and transportation sector due to increasing natural gas and petroleum costs.

In the "Decarb+optDER" scenario, the energy burden reduces from approximate $4,950 in 2018 to $3,305 in 2030 as a result of the greater reduction in retail rates and electrification of some of the energy related activities, which cost less due to the lower-cost electricity rates and higher energy efficiency. After 2030, the rate of reduction of the energy burden slows down as any savings from electrification of heating and transport are offset by the increase in spending in the traditional electricity sector due to load growth from electrification of cooking and clothes drying as well as from the increasing electricity rates. Cumulatively by 2050, the "Decarb+optDER" scenario results in savings of $24,741 per customer compared to the "IRP" scenario. This cumulative savings translates to an annual savings of $773 per average residential and commercial customer. Therefore, the "Decarb+optDER" scenario achieves the Governor's goals of electrification and decarbonization of economy-wide energy related activities while reducing costs on energy related activities for residential and commercial customers.

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[8] https://www.eia.gov/outlooks/aeo/data/browser/#/?id=15-AEO2020&region=0-0&cases=highogs&start=2018&end=2050&f=A&linechart=~highogs-d112619a.37-15-AEO2020&map=&ctype=linechart&sourcekey=0

[9] https://www.eia.gov/outlooks/aeo/data/browser/#/?id=13-AEO2020&region=0-0&cases=highogs&start=2018&end=2050&f=A&linechart=~highogs-d112619a.35-13-AEO2020~highogs-d112619a.36-13-AEO2020&map=&ctype=linechart&sourcekey=0

[10] https://www.eia.gov/outlooks/aeo/data/browser/#/?id=12-AEO2020&region=0-0&cases=highogs&start=2018&end=2050&f=A&linechart=~~highogs-d112619a.12-12-AEO2020~highogs-d112619a.17-12-AEO2020&map=&ctype=linechart&sourcekey=0

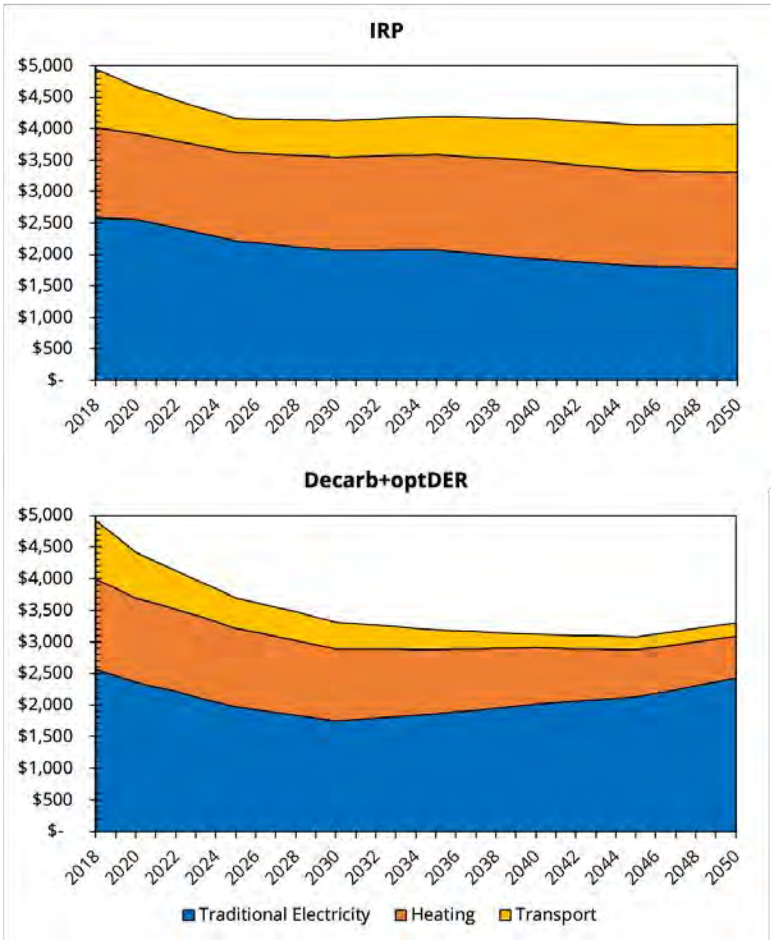

Figure 2.1: Annual spending for an average residential and commercial customer in Michigan in the "IRP" scenario (top panel) and the "Decarb+optDER" scenario (bottom panel).

The "Decarb+optDER" scenario also results in savings for industrial customers who electrify most of their operations with some high heat processes using green hydrogen. As a result of electrification, industrial customers save a cumulative of $2.23 million per customer in the "Decarb+optDER" scenario between 2018 and 2050, which is equivalent to an annual savings of $69,680 per customer. This annual savings is roughly 10% of the average annual operating cost over the modeling period. These savings in industrial energy spending can result in increased profits or be passed on to customers through reduces prices for goods.

The change in total resource costs (which are electricity sector and hydrogen[11] costs) and retail rates in Michigan for the scenarios modeled is shown in Fig. 2.2. In the "IRP" scenario, the total resource costs reduce from approximately $10.7 billion in 2018 to about $7 billion in 2050. The cost reductions come from retirement of expensive coal generation and replacing it with mostly variable renewable energy (VRE) generation along with some imports from other MISO load zones. As a result, the retail rates in

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[11] Hydrogen is produced only in the "Decarb+nonOptDER" and "Decarb+optDER" scenarios. No hydrogen is produced in the "IRP" scenario.

the “IRP” scenario also decrease from approximately 11.4 ¢/kWh in 2018 to about 8 ¢/kWh in 2050.

In the two electrification and decarbonization scenarios (“Decarb+nonOptDER” and “Decarb+optDER”), the total resource costs reduce more than the “IRP” scenario until 2030 despite serving additional electricity demand due to electrification. Therefore, the retail rates in the electrification scenarios are substantially lower than the “IRP” scenario bringing significant cost savings to customers. The retail rates in the electrification scenarios drop from 11.4 ¢/kWh in 2018 to approximately 7 ¢/kWh in 2030.

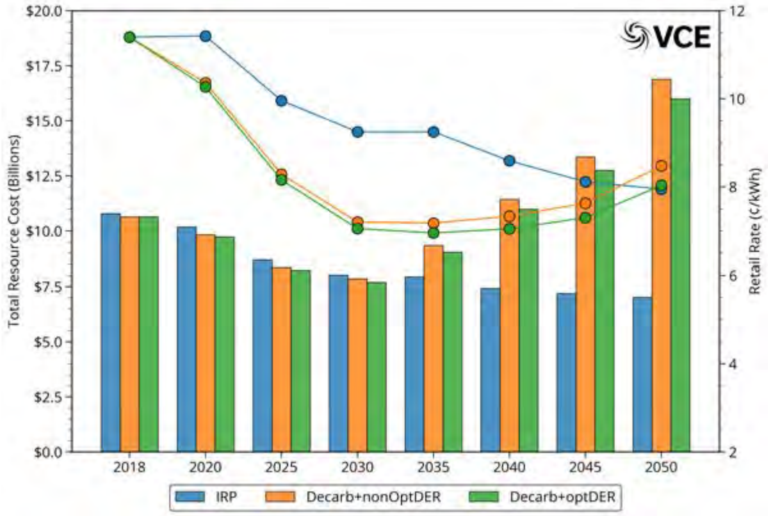

Figure 2.2: Total system cost (bars) and retail rates (solid lines) in Michigan for the scenarios modeled.

After 2030, the rate of electrification accelerates brings in significant new demand into the electricity sector, and the electrification scenarios experience greater investment in the electricity sector to build clean generation to meet the Governor’s goal of electrifying and decarbonizing the economy. As a result, by 2050, the annual system cost in the “Decarb+nonOptDER” scenario is $16.8 billion, while in the “Decarb+optDER” scenario it is $15.9 billion due to savings from the distribution system co-optimization. These systems costs are however spread over a much larger load which results from electrification of energy related activities in the rest of the economy. The retail rates also start to increase slowly after 2030 as a result of the additional investments in the electricity sector and decarbonizing the economy. By 2050, the retail rates in the “Decarb+nonOptDER” scenario are slightly higher than the “IRP” scenario at 8.4 ¢/kWh, while the retail rates in the “Decarb+optDER” scenario are almost the same as the “IRP” scenario at 8 ¢/kWh. Therefore, in the “Decarb+optDER” scenario, Michigan can electrify and decarbonize its economy without causing increases in rates for customers compared to the “IRP” scenario. It is to be noted that the maximum import and exports from Michigan are held constant at 2018 levels. Therefore, it may be possible to reduce costs and thus retail rates further if the transmission capacity were allowed to grow beyond 2018 levels with the rest of MISO and possibly PJM.

The contributions to the cost per kWh of electricity delivered broken out by sectors in the scenarios modeled is shown in Fig. 2.3. In 2018, almost half the cost of electricity is due to fossil fuel generators, with coal being the largest contributor to cost of energy. In the "IRP" scenario, as the coal is gradually retired, the cost of energy reduces as the VRE generation provides energy at much lower cost.

In the electrification scenarios ("Decarb+nonOptDER" and "Decarb+optDER"), the cost of energy reduces faster than the "IRP" scenarios because the fossil fuel generation is retired at a faster rate and the cost of energy is distributed over a larger demand. The cost of energy in the electrification scenarios stays below the costs in the "IRP" scenario until 2045. After 2045, as Michigan decarbonizes the electricity sector completely, the cost of energy in the electrification scenarios increases slightly compared to the "IRP" scenario. The cost of energy increase in the electrification scenarios could be tied to limiting the amount of imports and exports out of Michigan to 2018 levels and allowing the expansion of transmission to other load zones in MISO could help Michigan achieve decarbonization at a lower cost. Compared with the "Decarb+nonOptDER" scenario, the "Decarb+optDER" scenario has lower cost of energy throughout the modeling period. The co-optimization of the distribution system ensures that the distribution system costs in the "Decarb+optDER" scenario remain lower as a result of deferring distribution system capital investment.

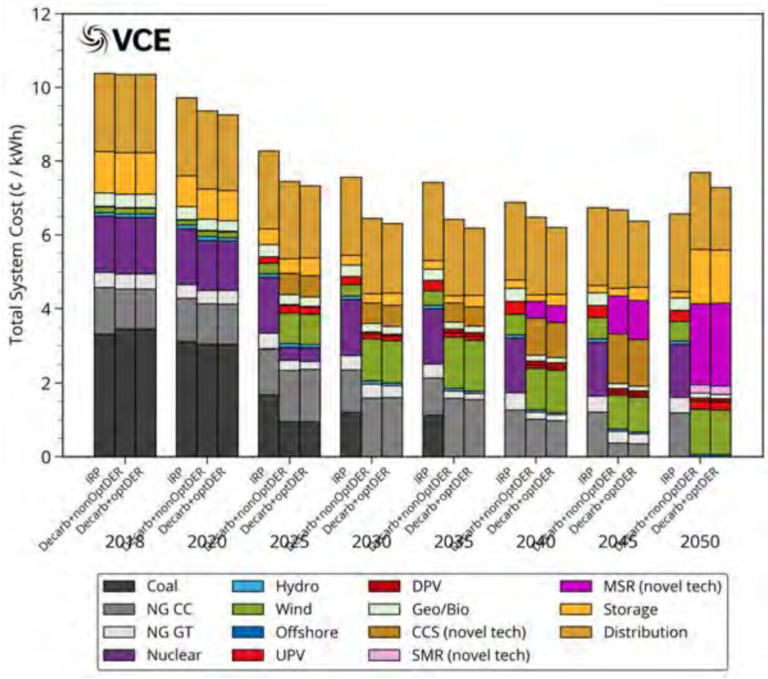

Figure 2.3: Contribution to total system cost per kWh load from each energy system sector for the scenarios modeled.

The total full-time equivalent electricity sector jobs in the scenarios modeled is shown in Fig. 2.4. The total full-time equivalent jobs in the electricity sector in the "IRP" scenario increase from about 45,000 in 2018 to 90,000 in 2050 driven largely by jobs supported by the solar industry. In the electrification scenarios, the job growth over the investment periods is higher than the "IRP" scenario due to the larger VRE deployment. By 2045, the electrification scenarios see 150,000 and 159,000 jobs in the “Decarb+nonOptDER” and “Decarb+optDER” scenarios, respectively. The largest job growth is observed in the distributed solar sector. Between 2045 and 2050, the electrification scenarios deploy large amounts of solar and storage in order to meet the 100% decarbonization goal. As a result, these scenarios see a large increase in workforce in the electricity sector to support this increase in generation deployment. By 2050, the storage industry supports the largest number of jobs in the electrification scenarios, followed by the solar industry. The “Decarb+optDER” scenario see slightly less jobs created in the distribution sector due to the distribution co-optimization deferring investments in the distribution grid.

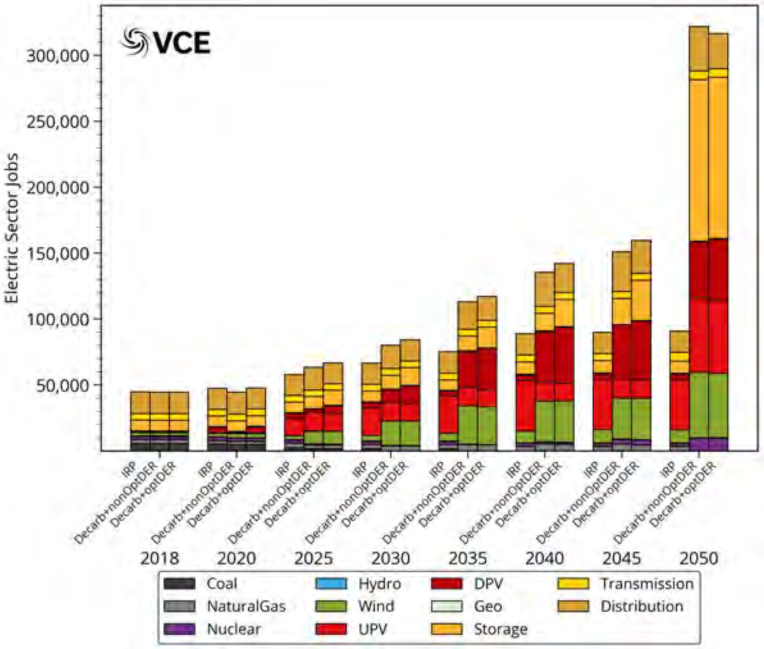

Figure 2.4: Direct full-time equivalent jobs created in the electricity sector by industry for the scenarios modeled.

2.2 Changes to Installed Capacity & Generation

The changes to installed capacity and generation mix in Michigan for the three scenarios modeled are shown in Fig. 2.5. The "IRP" scenario is the slowest to retire coal generation keeping it online until 2040. The retired coal generation in the "IRP" scenario is replaced with some new natural gas combined cycle (NGCC) generation and VRE generation with solar being the dominant addition. WIS:dom-P models both utility scale photvoltaic (UPV) and distributed photovoltaic (DPV). The distributed solar (DPV) includes both rooftop solar and community solar installations. In the electrification scenarios, the capacity turnover takes on very similar paths. Coal is completely retired by 2030 along with some older natural gas generation. Wind makes up a significant portion of new VRE generation added due to the better wind resource available in Michigan along with wind generation's better correlation with electrification load, especially in winter. The electrification scenarios deploy carbon capture and sequestration (CCS), molten salt reactors (MSR) and small modular reactors (SMR) to provide dense clean dispatchable generation. All CCS in the electrification scenarios is retired by 2050 as they are not 100% emission free.

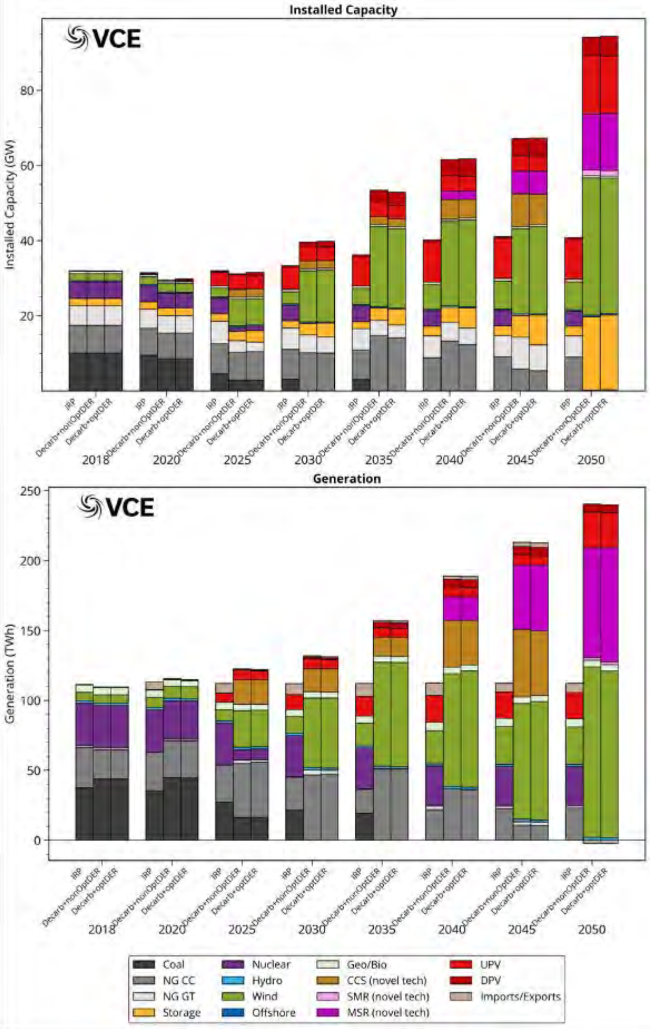

Figure 2.5: WIS:dom-P installed capacities (top) and generation (bottom) for the scenarios.

The VRE generation deployed in the "IRP" scenario is higher than that proposed in the IRPs of the major utilities in Michigan. The larger deployment in mainly to satisfy the 90% decarbonization by 2040 goal of Consumers Energy utility. In order to meet its 90% decarbonization goal, Consumers Energy utility needs to deploy about 1,400 MW of additional wind generation, 1,300 MW of additional utility-scale solar and 236 MW of additional storage over that proposed in its IRP. Furthermore, Consumers Energy depends on imports of clean generation from DTE which deploys an additional 3,000 MW of wind and 487 MW of utility-scale solar to export clean energy to Consumers Energy. Therefore, the IRP proposed by Consumers Energy through 2034 falls well short of reaching its own 90% decarbonization goal by 2040.

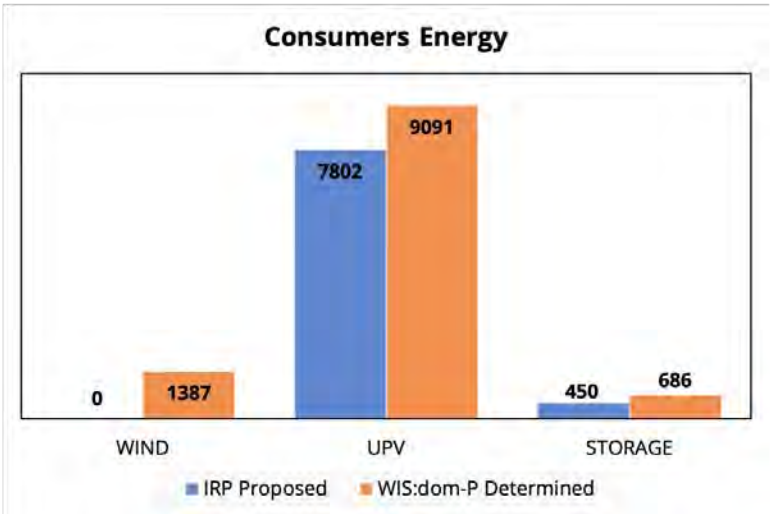

Figure 2.6: Additional VRE deployed by WIS:dom-P to ensure Consumers Energy meets it 90% decarbonization by 2040 goal.

The storage power and energy capacities installed over the investment periods in the scenarios modeled is shown in Fig. 2.7. In the "IRP" scenario, very little new storage is added until 2040 at which point about 700 MW of storage is added to the grid. In comparison, the electrification scenarios add significantly more storage over the investment periods along with a large deployment of storage between 2045 and 2050 to meet the 100% decarbonization goal. By 2045, the "Decarb+nonOptDER" scenario deploys 5,800 MW of storage to the grid to effectively utilize the installed VRE generation. The average storage duration in 2045 in the "Decarb+nonOptDER" scenario is 7.5 hours to help cover lulls in the VRE generation. The "Decarb+optDER" scenario, on the other hand, has a total of approximately 8,000 MW of storage deployed by 2045, out of which 2,000 MW is on the utility grid and the rest is on the distribution grid with an average duration of 7.5 hours.

Between 2045 and 2050, the electrification scenarios deploy large amounts of storage to the grid with the total storage installed reaching about 19,500 MW in both the electrification scenarios. In the "Decarb+optDER" scenario, 8,300 MW of the total storage is on the distribution grid. The average duration of the storage installed is approximately 24 hours. The long storage duration is specifically aimed at meeting load during the long lulls in wind generation that occur over the course of the year.

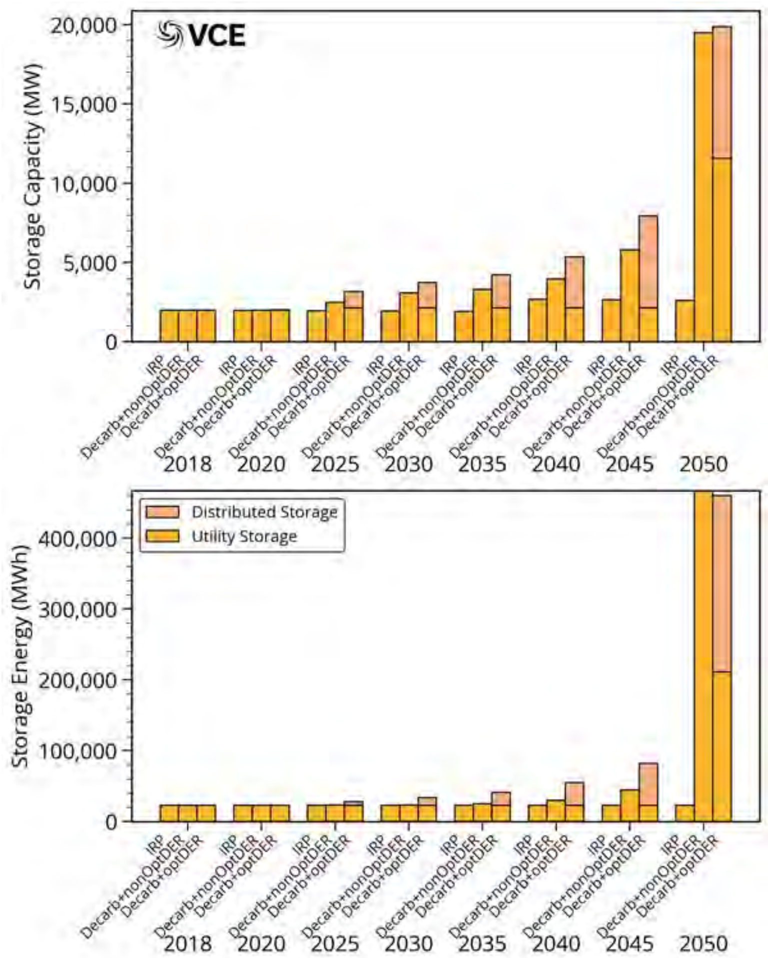

Figure 2.7: Utility storage and distributed storage installed in each investment period for the "Optimized DER" scenario.

Although the wind resource is significantly better in Michigan compared with the solar resource, the electrification scenarios add substantially more solar generation on the grid compared with the "IRP" scenario. The "IRP" scenario installs about 11,000 MW of solar by 2040. About 1,800 MW of this is additional solar added by WIS:dom-P over the values prescribed by the IRPs in order to ensure Consumers Energy meets its 90% decarbonization goal.

The electrification scenarios install more wind generation over solar until 2045 due to the better wind resource in Michigan. After 2045, the electrification scenarios install about 12,000 MW of solar to help meet the 100% decarbonization goal. The "Decarb+optDER" scenario installs slightly more distributed solar compared with the "Decarb+nonOptDER" scenario as the distribution co-optimization uses the distributed solar along with the distributed storage to defer distribution system upgrades and save costs.

2.3 CO_2 Emissions & Pollutants

The percentage reductions in economy-wide carbon dioxide (CO_2) emissions from 2005 levels for energy related activities is shown in Fig. 2.8. The "IRP" scenario reduces the economy-wide emissions by 25% from 2005 levels by 2025 and, thus, falls short of the Governor's goal of 28% reduction by 2025. By 2050, the annual economy-wide emissions reduce by 38% from 2005 level in the "IRP" scenario as a result of retirement of coal generation and replacing it with VRE generation. The additional VRE installations by WIS:dom-P over the IRP proposed values help the "IRP" scenario reach the 38% reduction by 2050. The electrification scenarios, by contrast, reduce annual economy-wide emissions by 37% by 2025, exceeding the Governor's goal. This reduction in annual emissions is possible through a combination of electrification and decarbonization of the electricity sector. By 2050, the electrification scenarios reduce annual economy-wide emissions by almost 97% from 2005 levels as the economy-wide energy related activities are electrified and the electricity sector is 100% decarbonized.

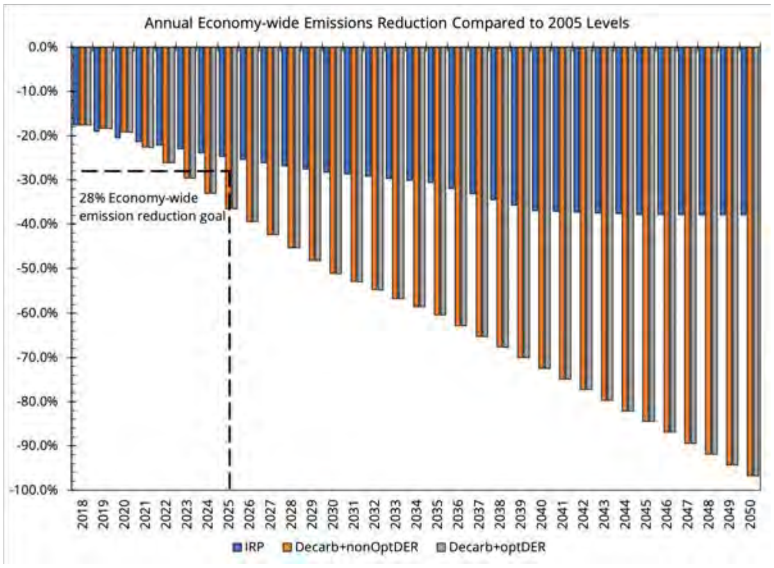

Figure 2.8: Percentage reduction in economy-wide energy related carbon emissions from 2005 levels. The black dashed line indicates the Governor's emission reduction goal of 28% by 2025.

Figure 2.9 shows the cumulative economy-wide CO_2 emissions from the three scenarios modeled. The "IRP" scenario, which does not electrify economy-wide energy related activities, has the highest cumulative CO_2 emissions of 4,374 million metric tons (mmT) by 2050. The "Decarb+nonOptDER" and the "Decarb+optDER" scenarios, which have similar emission reduction profiles, cumulatively emit 2,650 mmT of carbon dioxide by 2050. Therefore, electrification and decarbonization of the electricity sector can cumulatively reduce Michigan CO_2 emissions by 1,724 mmT by 2050, which is more than 10 times the economy-wide emissions in 2018. A majority of these emission savings (1,650 mmT) come from electrification of economy-wide energy related activities. Therefore, electrificatinon is a key element for effective decarbonization.

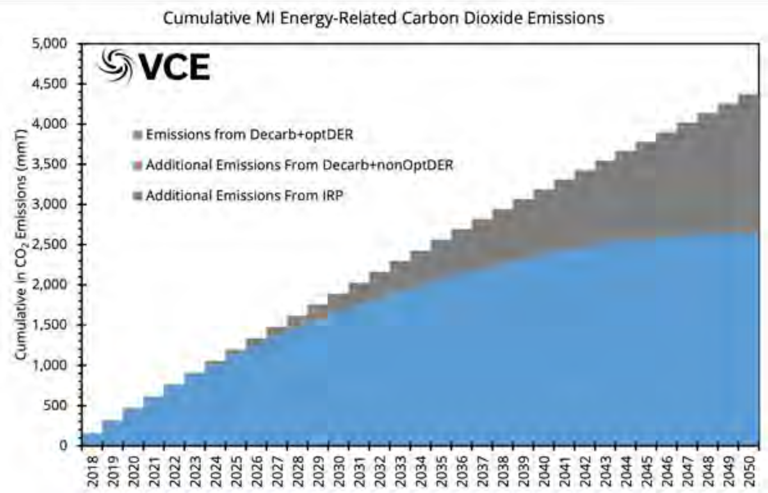

Figure 2.9: Cumulative economy-wide carbon dioxide emissions for the three scenarios modeled.

In addition to reducing CO_2 emissions, the modeled scenarios also reduce emissions of criteria air pollutants emitted by fossil fuel generation. The air pollutants tracked by WIS:dom-P emitted by the electricity sector are shown in Fig. 2.10. In the "IRP" scenario, the SO_2, PM_{10}, and $PM_{2.5}$ emissions reduce steadily from 2018 to 2035 as coal generation is retired and then sharply reduce to zero by 2040 as all coal generation gets retired. In the electrification scenarios, all coal generation is retired by 2030 and hence the SO_2, PM_{10}, and $PM_{2.5}$ emissions see rapid declines to zero by 2030. In the "IRP" scenario, some NO_x, CH_4 and VOC emissions remain due to presence of natural gas generation on the grid, while in the decarbonization scenarios these emissions are reduced to zero by 2050 as a result of the decarbonization goal. Hence the electrification scenarios not only reduce greenhouse gas emissions, but also eliminate emissions of criteria air pollutants, which will result in better health outcomes for local populations.

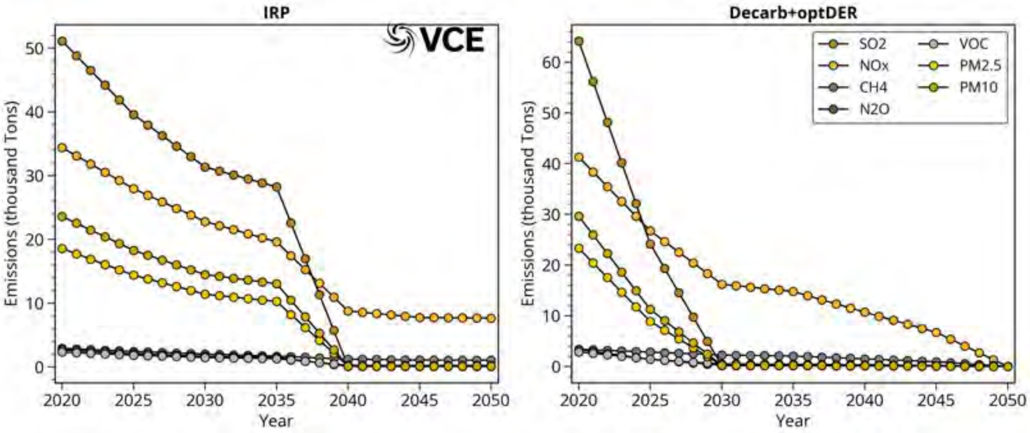

Figure 2.10: Emissions of criteria air pollutants from the electricity sector in the "IRP" scenario (left) and the "Decarb+optDER" scenario (right).

2.4 Siting of Generators (3-km)

WIS:dom-P uses weather datasets spanning multiple years at 3-km spatial resolution and 5-minute temporal intervals over the contiguous United States. WIS:dom-P performs an optimal siting of generators on the 3-km HRRR model grid. The WIS:dom-P installed capacity layout at 3-km resolution along with the transmission paths above 115 kV in 2050 for the "IRP" scenario is shown in Figure 2.11 (left panel), while the installed capacities for the "Decarb+optDER" scenario is shown in Figure 2.11 (right panel). The greater VRE deployment in the "Decarb+optDER" scenario is apparent along with deployment of dense clean dispatchable generation in the location of retired fossil fuel generation.

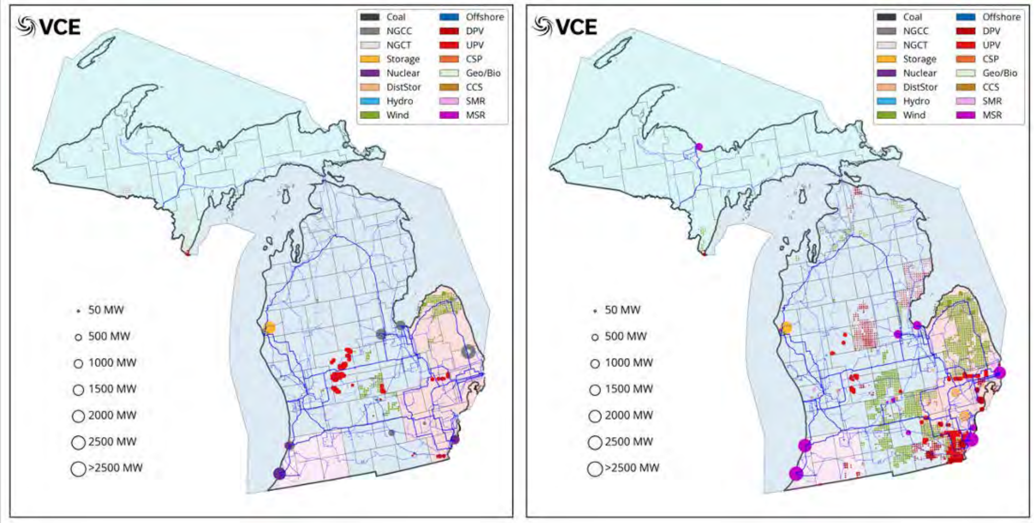

Figure 2.11: Installed generation layout in 2050 in the "IRP" scenario (left) and "Decarb+optDER" scenario (right) at 3-km resolution along with transmission paths above 115 kV.

As seen from Fig. 2.11 (left panel), the "IRP" scenario installs almost all the wind in DTE territory, and most of the solar deployed in Consumers territory. The VRE generation is more widely distributed in the "Decarb+optDER" scenario. The DTE region still installs most of the wind generation, with substantial wind installed in the Consumers regions as well. Most of the utility-scale solar is installed in the DTE region, while the Consumers region is dominated by distributed solar. The locations of retired fossil fuel generators are used to build MSRs and SMRs.

When making the siting decisions, the model takes into account several criteria to determine the optimal siting for generators. In addition to accounting for expected generation and distance from the load (for transmission considerations), the model ensures that generation is not sited in unsuitable locations. The model also ensures that the technical potential of each grid 3-km grid cell is not exceeded. The technical potential for the various VRE technologies in each grid cell is determined according to factors such as population, land cover, terrain slope, and others. In addition, each technology is limited by a maximum packing density to ensure that generators do not hamper performance of other generators in the grid cell, such as through wakes for wind turbines and excessive shading for solar panels. More information about these criteria and the WIS:dom-P model can be found in the technical documentation.[12]

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[12] https://vibrantcleanenergy.com/wp-content/uploads/2020/08/WISdomP-Model_Description(August2020).pdf

energynews.us

Utility-linked group seeks to dismantle net metering in Michigan

Andy Balaskovitz

13–16 minutes

A group with millions of dollars in undisclosed donations says state policy makes "private renewables" bad for low-income residents and communities of color.

Nonprofit advocacy groups linked to DTE Energy are waging a public campaign to significantly reduce the amount customers are paid for their solar power, in line with the utility's request before Michigan regulators.

While these groups — classified as 501(c)(4) social welfare organizations — have been prominent in statewide elections and lobbying lawmakers on behalf of utility interests, the latest involves policy decisions at the Michigan Public Service Commission.

For the past two years, regulatory staff, clean energy advocates and utilities have wrangled over an appropriate level of compensation for those who send solar power back to the grid. Under net metering, they receive bill credits at the retail rate of power. Energy laws passed in 2016 with bipartisan support directed the MPSC to study the costs and benefits of net metering customers and require utilities to file new distributed generation programs. DTE is the first major utility to do so.

******More:* *Michigan researchers say state's utilities 'manipulate' system to their advantage*******

DTE and its allies say net metering customers are being subsidized by all other ratepayers for their cost of using the grid. DTE proposes compensating customers for excess power at wholesale rates along with a monthly fee, similar to utility efforts in other states to curtail net metering.

Its supporters also say net metering unfairly disadvantages low-income residents who can't afford their own solar panels, another strategy utilities have carried out in other states.

Solar advocates dispute these claims and have called DTE's proposal "outrageous." Critics of the utility campaign contend that the benefits net metering customers provide more broadly to the grid have not been fully studied in Michigan, such as helping reduce demand during peak periods in the summer and lower costs for all customers. Advocates also note that in the same rate case DTE is proposing to increase average residential rates by 9.1 percent, with low-income customers being hit the hardest. Net metering customers made up 0.12 percent of DTE's 11,000-megawatt load in 2017.

State regulators are expected to rule on the case in the coming months.

DTE's allies

Two of the three board members of nonprofit groups supporting DTE's proposal — Alliance for Michigan Power, Michigan Energy

First and Michigan's Energy Promise — are also DTE executives.

The groups have websites backing DTE's position on net metering and other issues before the MPSC, such as avoided costs. Michigan's Energy Promise touts the benefits of "universal renewables" like solar and wind farms over "private renewables" like rooftop solar. (These terms were coordinated under a 2014 project by the national utility trade group Edison Electric Institute.)

There's a right way and a wrong way to expand renewables for our state. Our state's energy strategy should st focused on the **fairest**, **most efficient**, and **most cost-effective** approaches to expanding renewables. **Unive renewables win that contest hands down.**

Universal Renewables

Private Renewables

This screen capture from the Alliance for Michigan Energy website shows the terms "universal renewables" and "private renewables," which have been promoted by a utility industry trade group.

Michigan Energy First was created in 2014. Tax filings from fiscal year 2017 list the group's president as Renze Hoeksema, who is also DTE's director of state government affairs; and its treasurer as Theresa Uzenski, the utility's manager of regulatory accounting. A third official is Eric Doster, an attorney linked to a similar advocacy group funded by Consumers Energy.

Filings show Michigan Energy First — which funds groups across a variety of political issues — brought in $28 million between 2014 and 2018, including $15 million in 2017, but Doster declined to say where that funding came from. Michigan's Energy Promise and Alliance for Michigan Power are projects of Michigan Energy First. Michigan's Energy Promise was formed two months ago.

DTE spokesperson Peter Ternes said DTE is "part of the Alliance for Michigan Power coalition." Hoeksema and Uzenski "serve in an advisory capacity" on the organizations' boards, he added, and the groups approach DTE "to provide information" about issues.

"I think they're wanting to make sure accurate information is getting out to the public," Ternes said. "I think it's clear they're supporting issues that align with the utility industry."

Since 501(c)(4) organizations don't have to disclose their donors, watchdog groups have criticized them as "dark money" entities advocating for utility interests.

The groups are also well-funded. Consumers contributed $43.5 million to Citizens for Energizing Michigan's Economy over a recent four-year span, including $20 million in 2017, for issue advocacy. Consumers maintains the funding comes from shareholders, not ratepayers.

Earlier this year, the MPSC clamped down on Consumers' contributions to these nonprofit entities, blocking the company from contributing to any 501(c)(4) for at least 18 months.

Doster disputes the characterization of these organizations as "utility front groups," adding that Michigan Energy First, for example, advocates on a variety of issues, including auto insurance reform. He says attacks against the groups are attempts to "limit free speech."

Racial divide

Michigan's Energy Promise also frames the net metering issue around fairness, mirroring utility efforts in recent years telling low-income residents and communities of color that the policy harms them most. The group has allied with groups like the Detroit branch of the NAACP, the Arab American and Chaldean Council, the Urban League of Detroit and Southeast Michigan and various churches and faith-based groups. (In 2017, the national NAACP urged members to advocate net metering in Michigan.)

“It’s a wide and broad coalition, including leaders in specific communities in Detroit that need the most help so they’re not easily preyed upon,” said Michigan Energy Promise spokesperson Ron Fournier. “Specifically African American ministers who are tired of people coming into their community selling them services and contracts they don’t need.”

Fournier is the president of Truscott Rossman, a high-level public relations firm in Michigan that represents other utility-linked groups.

Michigan’s Energy Promise claims some solar companies exploit the elderly and poor with offers, and that rooftop solar harms first responders’ ability to respond to emergencies in homes.

In a recent op-ed published in Bridge Magazine, Bishop W.L. Starghill Jr. called net metering an “energy inequality.” Starghill is with the Michigan Democratic Black Caucus and a representative for Michigan’s Energy Promise.

“The private solar lobbyists in Lansing are pushing for a system that allows private homeowners to put a Cadillac-style energy system on their rooftops and pass the bill for maintaining the roads on to the rest of us,” he wrote.

Contention over race, equity and solar power is not unique to Michigan. In Illinois, ComEd formed a solar advocacy alliance aimed at helping low-income residents while the utility pushed controversial legislation. Duke Energy used similar tactics in North

Carolina to support the company’s campaign against rooftop solar, which drew pushback from at least one African-American minister.

“It appears evident that this ‘solar hurts the poor’ strategy has been coordinated by Duke and its cohorts in the corporate electric power industry and used in many states recently,” the Rev. Nelson Johnson wrote in a 2015 letter to Duke’s president and CEO. “This cynical corporate activity is an affront to the people of this state, and it is your personal responsibility to stop it.”

Other community advocates say arguments over cost-shifting are “disingenuous.”

Jackson Koeppel, executive director of Soulardarity, said DTE’s proposed rate increase in the same case would disproportionately raise rates for low-income customers, focus infrastructure spending on outlying communities and reduce the number of customer call centers in favor of digital communication with customers.

“What they’ve put forward in the rate case is really egregious,” Koeppel said. “With the formation of this new front group and framing it so solar is fair to all customers is completely disingenuous.”

In interviews with Energy News Network in recent weeks, multiple Detroit advocates voiced frustration over DTE’s unwillingness to partner on community solar projects, which would provide clean energy access to renters in particular.

Michigan Interfaith Light and Power delivered a letter to Gov. Gretchen Whitmer in January asking her for state agencies to intervene in the rate case and oppose DTE’s proposal.

The group’s executive director, Leah Wiste, said hundreds of faith leaders support net metering, with several churches participating in the program. Wiste argues DTE’s revenues are hardly impacted by net metering, if at all.

“This whole idea that somehow independent solar producers are being subsidized or are doing this on the backs of the poor is just baloney,” she said. “You don’t have to look far for proof that if they actually cared about the poor they wouldn’t be proposing these massive rate hikes that will hit low-income customers the hardest.”

Wiste added that attempts to portray net metering as a social equity problem is “exploiting some class and racial divides.”

Value of solar

After 2016, the Legislature directed the MPSC to study the cost of service for solar customers. It agreed that an inflow-outflow model that charges solar customers for using the grid at retail rates (inflow) and credits them for the power sent back (outflow).

However, there wasn’t a consensus at the time on what the outflow rate, or value of the solar sent back to the grid, should be. (Existing net metering customers will be grandfathered for 10 years.)

DTE contends it should be at the lowest wholesale rate of power — the locational marginal price — because solar customers need access to the grid 24/7, and there isn’t a defined amount of power they will send back compared to, say, an independently owned hydro station that would be credited at avoided costs under the federal Public Utilities Regulatory Policy Act (PURPA). The company also wants a “system access charge” based on the size of the installation.

DTE says net metering households each shift $444 to $1,700 annually to other customers. At the end of 2107, DTE had 1,705 customers enrolled in net metering, according to the MPSC. By DTE's calculation, the annual net metering subsidy ranges from $757,000 to $2.9 million annually. DTE has 2.2 million electric customers.

In the rate case, MPSC staff support the inflow/outflow model but with a compensation rate about 25 percent less than retail, much higher than DTE's request. This is known as the power supply component of retail rate, minus the cost of transmission.

Rob Ozar, the MPSC's assistant director of energy resources division, estimated the average net metering customer's subsidy — or less revenue that the utility takes in — to be about $225 annually, though that could vary based on system size and energy usage. Additionally, MPSC officials have said there isn't enough data to accurately quantify whether net metering customers provide a net benefit to the grid. Advanced meters should help in providing clearer data on grid usage.

"We're thinking of this right now as a transition charge until some years down the road when we have really good data and can do more sophisticated analysis to determine the marginal avoided cost," Ozar said.

MPSC staff also disagrees with the company's proposed fee.

Environmental groups have argued that net metering should remain in place while the outflow question is settled.

An administrative law judge is expected to issue a ruling this week, ahead of the full commission's decision.

The case hits on an issue followed closely by Commissioner Dan Scripps, who was appointed in February by Gov. Gretchen Whitmer. Scripps is the former president of the Institute for Energy Innovation, which published a report in 2017 that concluded Michigan's net metering program provides a net benefit to ratepayers.

"Customers with rooftop solar systems are not only paying their fair share, they're actually helping to reduce costs for their neighbors as well," Scripps said in a statement at the time. "Specifically, the benefits of solar DG exceed the retail cost of electricity and the value of solar is greater than the compensation solar DG customers receive under net metering programs."

MPSC spokesperson Nick Assendelft said bylaws do not specify circumstances in which a member would recuse themselves. He added that no one has requested that Scripps do so in the case.

"Mr. Scripps has a deep knowledge of the highly specialized energy landscape. His decisions in cases before the MPSC will be fair, fact-based and impartial," Assendelft said.

Fournier, of Michigan's Energy Promise, maintains that efforts to preserve net metering are driven by "out-of-state" interests — namely Vote Solar, a national nonprofit supporting the solar industry. He says it's clear net metering is a "de facto" subsidy on non-solar customers.

"I would dispute any out-of-state special interest who says net metering is fair to all ratepayers. That's demonstrably untrue," he said. "The only green these people care about is money."

Becky Stanfield, Vote Solar’s senior director of Midwestern states, responded: “The money that we care about is the money that DTE wants to take from Michigan families — including thousands of our in-state members — to line the pockets of its corporate shareholders.

“DTE’s anti-competition, anti-consumer rate proposal is exactly why the overwhelming majority of Michiganders want affordable solar options to reduce their reliance on the monopoly utility. These misleading, hysterical attacks from DTE’s new dark money front groups are a desperate attempt to preserve their profits and their outdated monopoly business.”

COMMUNITIES LEAP
U.S. DEPARTMENT OF ENERGY

HPC3
HIGHLAND PARK COMMUNITY CRISIS COALITION

Soulardarity

PARKER VILLAGE

Distribution Grid Impact Study in Highland Park, Michigan

Understanding Rooftop Solar, Behind-the-Meter Energy Storage, Electric Vehicle Charging, and Building Electrification

Erik Pohl, Kapil Duwadi, Tucker Oddleifson, Shibani Gosh, Vignesh Ramasamy, Patrick Gibbs

National Renewable Energy Laboratory

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Slide Deck Contents

Terminology

- **Current Model:** Distribution circuit load flow model reflecting the current design, construction, and voltage class (4.8 kV).
- **DER:** Distributed energy resource, defined by the Federal Energy Regulatory Commission (FERC) as follows: "DERs are small-scale power generation or storage technologies (typically from 1 kW to 10,000 kW) that can provide an alternative to or an enhancement of the traditional electric power system. These can be located on an electric utility's distribution system, a subsystem of the utility's distribution system or behind a customer meter. They may include electric storage, intermittent generation, distributed generation, demand response, energy efficiency, thermal storage or electric vehicles and their charging equipment." [1]
- **Primary Line:** Medium voltage overhead wire or underground cable.
- **SARDI:** System average risk duration index measuring the sum of customers hours impacted by voltage and thermal violations and normalized by total customer hours (expressed as a percentage).
- **Secondary Line:** Low-voltage overhead wire or underground cable. Secondary Lines may be connected directly to the low-voltage side of the service transformer or may be connected to other secondary lines in a network and may serve one or more customers.
- **Service Drop:** Low-voltage overhead wire or underground cable, directly connected to a customer's house. A service drop generally serves only one customer.
- **Transformer:** A power systems device to convert, in our models, medium voltage (e.g., 4.8 or 13.2 kV) down to low voltage (e.g., 120/240V). This represents the transition point from the primary distribution network to the secondary distribution network. A transformer may serve one or many individual customers.
- **Upgraded Model:** Distribution circuit load flow model reflecting the likely future design, construction and voltage class (13.2 kV), per the recommendations of DTE engineers.

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[1] "FERC Order No. 2222: Fact Sheet." 2020. Federal Energy Regulatory Commission. September 17, 2020. https://www.ferc.gov/media/ferc-order-no-2222-fact-sheet.

Project Overview

Communities LEAP Scoping Context

Through the Communities LEAP (Local Energy Action Program) Pilot, the National Renewable Energy Laboratory (NREL) engaged the Highland Park Stakeholder Coalition to scope four technical assistance work areas to address their energy needs and goals.

This slide deck addresses the highlighted tasks under work area "B."

A . City-Wide Solar Street Lighting and Policy Analysis	B. Grid Analysis	C. Community Choice: Home Energy Improvements	D. Bonus Bucket! Transportation and Mobility with MCC
• Task 1: Solar Street Lighting Financial Model Review • Task 2: Due Diligence References • Task 3: Implemented Case Studies • Task 4: Master Plan Gap Analysis • Task 5: Zoning Code + Applications Gap Analysis • Task 6: Review Proposed Solar Ordinance	• Task 1: Determine Existing Load Profile + Feeder Model (reference case) • Task 2: Grid Analysis (limitations and capacity under three growth scenarios) • Task 3: Feasibility Analysis 3 Actionable Behind Meter Projects (within City's authority under current grid configuration)	• Task 1: Support a coalition-facilitated selection process • Task 2: Housing Characteristics and Energy Burden Analysis	• Task 1: Coordinate with Michigan Clean Cities on feasibility study for Perimeter Loop micro-mobility utilizing EV shuttles

Project Context

Highland Park, Michigan, community members face frequent, long-duration power interruptions due largely to the aging distribution system serving the area and the legacy design standards used in its construction.

While degrading physical infrastructure such as poles, crossarms, and transformers can result in this substandard reliability, another notable characteristic of this legacy system is the lower, 4.8 kV, voltage class. This is a legacy construction standard which many utilities, DTE Energy included, are phasing out in favor of higher, 15 or 25 kV, voltage classes instead.[1] The existing 4.8 kV distribution system serving Highland Park may limit significant adoptions of clean-energy technologies like high percentages of building electrification or electric vehicle (EV) adoption.

The following analysis seeks to quantify these limitations under a variety of clean-energy technology adoption scenarios. It compares the overall system risks of the present system to those of a hypothetical, upgraded 13.2 kV system, using NREL-developed risk metrics and offers upgrade cost considerations.

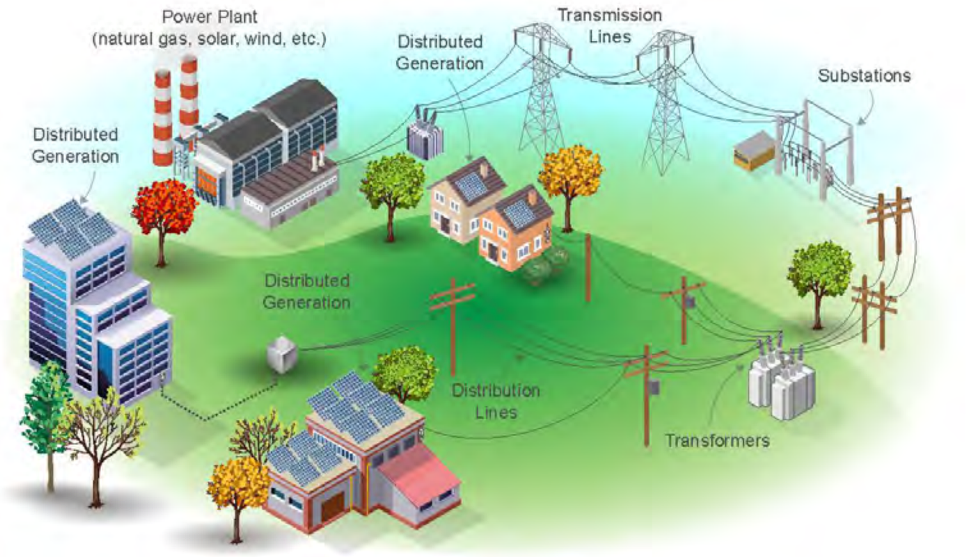

Illustration of the “grid” from utility power plant, transmission, distribution, to distributed energy resources. Illustration by Alfred Hicks, NREL 65851

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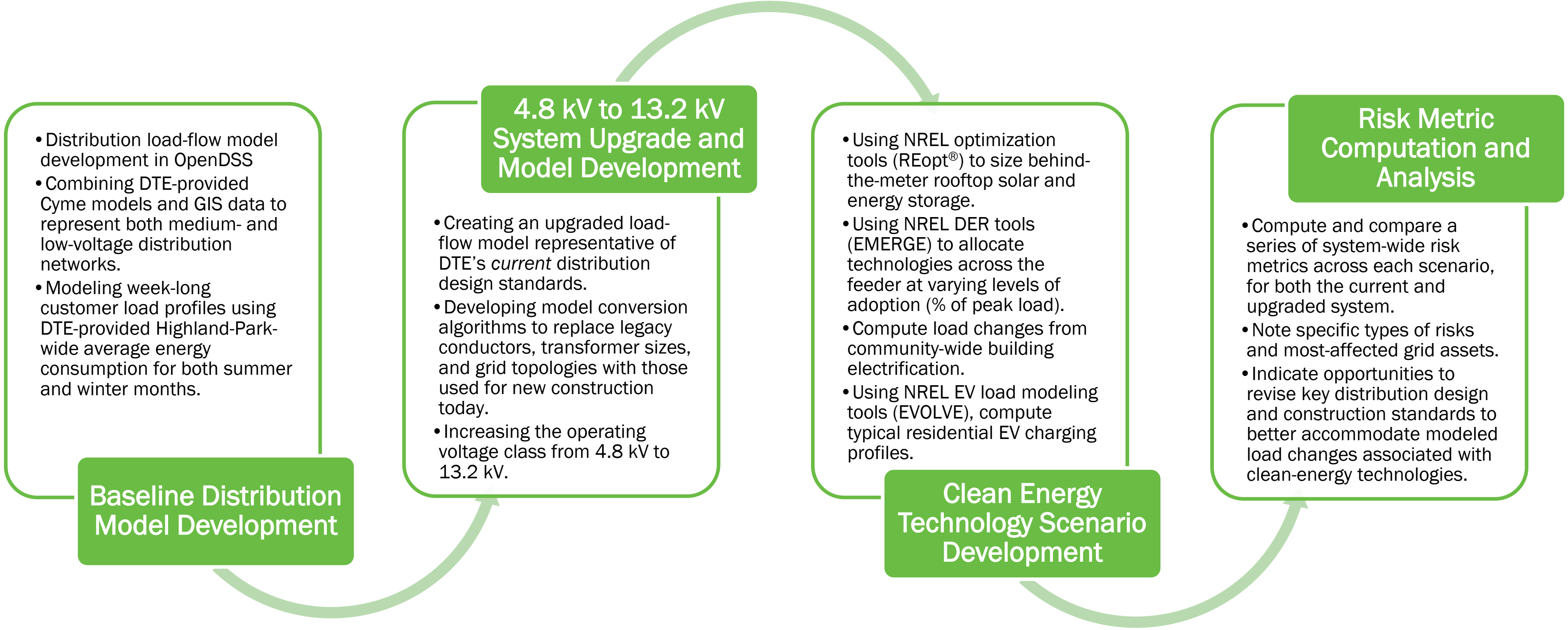
[1] Wang, Joy. “DTE Electric 4.8kV Technical Conference.” n.d. https://www.michigan.gov/mpsc/consumer/electricity/dte-electric-4-8kv-technical-conference.

Project Approach: Understanding the Analysis

Using data provided by DTE, NREL modeled a typical distribution feeder in one of Highland Park's mixed-use areas. This model was used to baseline and characterize typical vulnerabilities of the existing distribution grid and assess how it would perform under various load growth and distributed energy resource (DER) adoption scenarios. The results of this study compare the risks of the existing 4.8 kV grid to an upgraded 13.2 kV grid under changing loads due to electrification, EV charging adoption, and DER adoption.



Baseline Distribution Model Development

- Distribution load-flow model development in OpenDSS
- Combining DTE-provided Cyme models and GIS data to represent both medium- and low-voltage distribution networks.
- Modeling week-long customer load profiles using DTE-provided Highland-Park-wide average energy consumption for both summer and winter months.

4.8 kV to 13.2 kV System Upgrade and Model Development

- Creating an upgraded load-flow model representative of DTE's *current* distribution design standards.
- Developing model conversion algorithms to replace legacy conductors, transformer sizes, and grid topologies with those used for new construction today.
- Increasing the operating voltage class from 4.8 kV to 13.2 kV.

Clean Energy Technology Scenario Development

- Using NREL optimization tools (REopt®) to size behind-the-meter rooftop solar and energy storage.
- Using NREL DER tools (EMERGE) to allocate technologies across the feeder at varying levels of adoption (% of peak load).
- Compute load changes from community-wide building electrification.
- Using NREL EV load modeling tools (EVOLVE), compute typical residential EV charging profiles.

Risk Metric Computation and Analysis

- Compute and compare a series of system-wide risk metrics across each scenario, for both the current and upgraded system.
- Note specific types of risks and most-affected grid assets.
- Indicate opportunities to revise key distribution design and construction standards to better accommodate modeled load changes associated with clean-energy technologies.

Key Takeaways

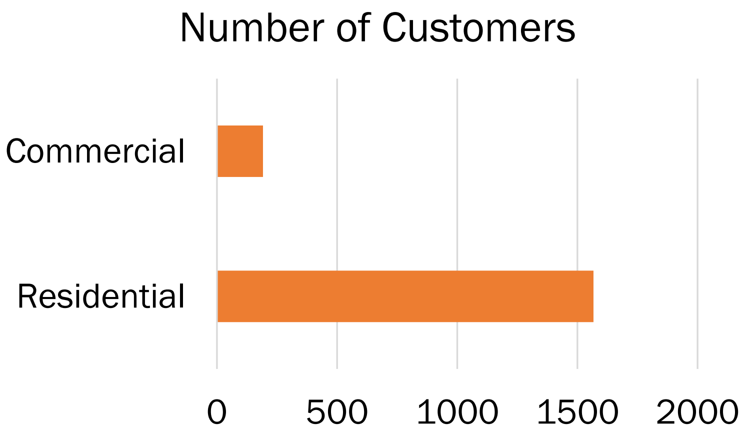
- **The System Today (Current Model):**
  - The legacy 4.8 kV voltage class serving Highland Park is not, as we have modeled it, a major limitation to the widespread adoption of cost-optimal* rooftop solar and/or behind-the-meter energy storage. Within our modeling framework, these technologies namely impact secondary, low-voltage assets, which may be remedied without the need for a system-wide upgrade to a 13.2 kV voltage class.
  - Our model of the current 4.8 kV system indicates it is not capable of supporting community-wide electrification efforts. Widespread building electrification, and the resulting large increase in wintertime load, dramatically increases the prevalence of voltage violations and thermal overloading on the current 4.8 kV distribution system. These impacts illustrate the need for system-wide upgrades to a 13.2 kV voltage class to accommodate these technologies.
  - Low to Moderate DER adoption does not adversely impact the grid but does improve undervoltage and asset overloading issues. However, these benefits are insufficient to defer grid upgrades. Higher DER penetration is shown to increase overvoltage and asset overloading in future electrification scenarios.
- **The System of Tomorrow (Upgraded Model):**
  - In all cases, upgrading the system to a higher voltage class and using modern design standards significantly reduces system risks associated with the adoption of DERs or building electrification.
  - The persistent violations remaining on the upgraded system are largely concentrated in the low-voltage secondary networks and service transformers. This illustrates the need for more robust secondary design standards to accommodate the large increases in load. Such standards may include larger secondaries, service drops, and transformers, or serving fewer customers per transformer.
  - Further study is required to estimate the cost of system-wide upgrade needs specific to Highland Park. See slide 69 for cost considerations.

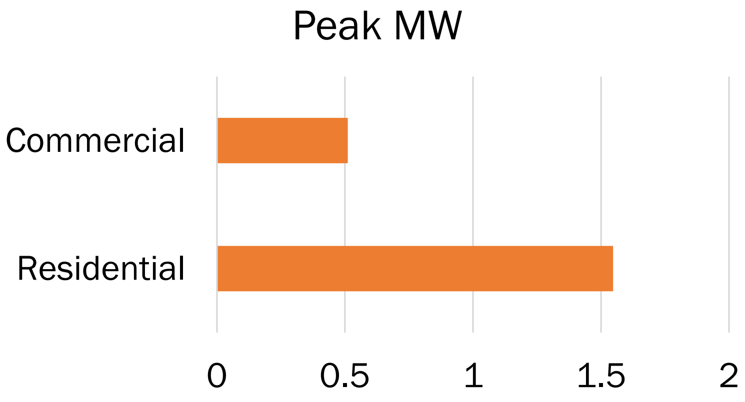
**Cost-optimal refers to the size of rooftop solar and/or energy storage systems which minimizes the financial burden on participating community members. This optimization was performed using NREL's REopt tool and is detailed in the accompanying slide deck.*[1]

[1] Oddleifson, Tucker, Kapil Duwadi, Erik Pohl, Patrick Gibbs, Shibani Ghosh, Chrissy Scarpitti, and Liz Weber. 2024. "Prefeasibility Analysis of Behind-the-Meter Distributed Energy Resources in Highland Park, MI." February. https://www.nrel.gov/docs/fy24osti/87988.pdf.

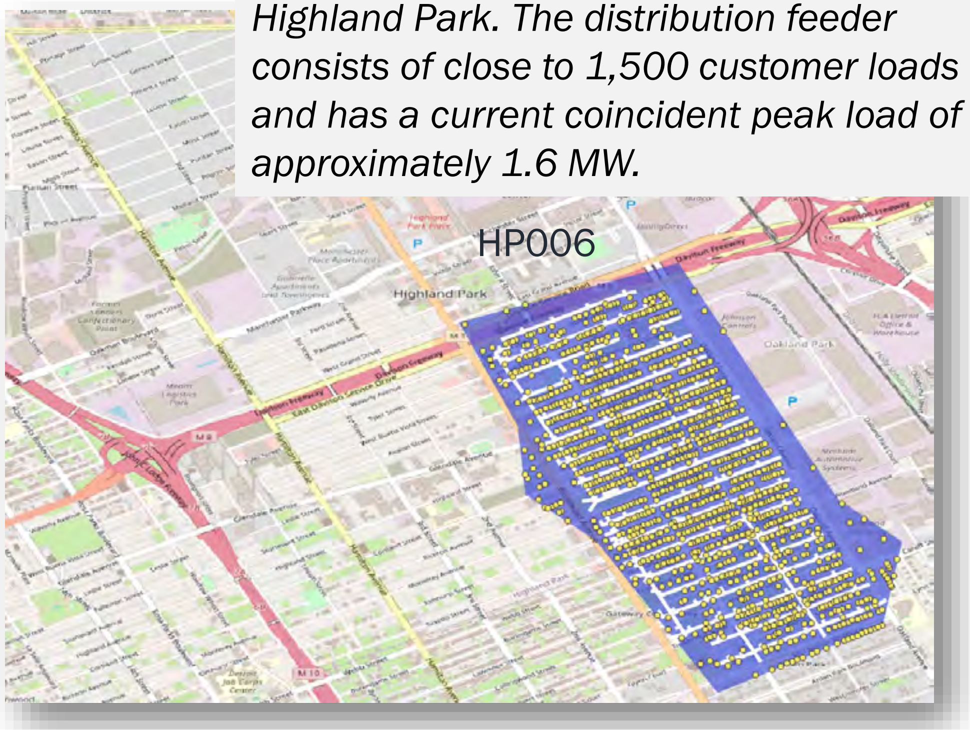
Methods of Analysis

Understanding the Grid As It Is – Location and Customer Class





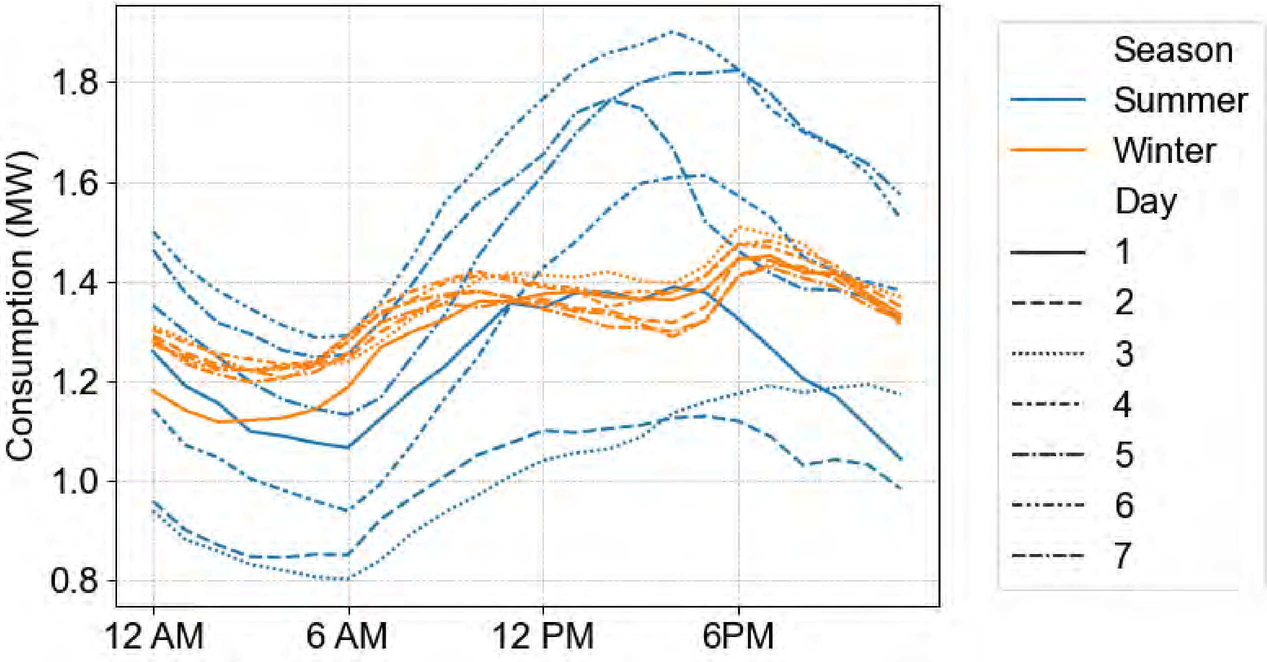
For this study, we looked at a mixed-use feeder (though majority residential) within Highland Park. The distribution feeder consists of close to 1,500 customer loads and has a current coincident peak load of approximately 1.6 MW.



Model includes only a portion of Highland Park

Understanding the Grid As It Is – Seasonal Load Profiles

We used average timeseries load consumption data (also known as load profiles) for residential and commercial customer groups provided by DTE Energy as an input to our timeseries power flow analysis. To understand the grid impacts under the various scenarios described in later slides, we looked at weeklong simulation results for a summer and winter peak consumption week. The resulting load profiles, shown here, illustrate that during our summer week, the system generally sees peak load in the afternoon to early evening, while winter days more consistently peaked around 6 to 7 p.m.

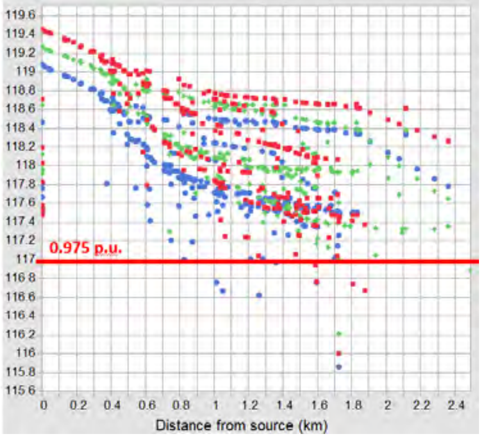


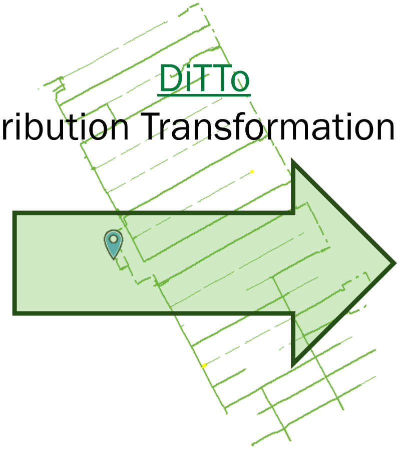
*Summer Week: July 1–July 7, Winter Week: Feb. 5–Feb. 11

Understanding the Grid As It Is – Distribution System Model

The first step of our analysis was to convert the DTE-provided load flow model of a Highland Park feeder to a format compatible with NREL's analysis tools. The model was provided in the format used by Eaton's CYME distribution modeling software. Using an NREL-developed software called DiTTo (Distribution Transformation Tool), we converted this model to be analyzed in the open-source tool, OpenDSS, developed by the Electric Power Research Institute (EPRI). The provided CYME model also contained only information of the medium-voltage distribution network, with no depiction of the low-voltage secondary networks, serving individual customers. As such, we leveraged DTE-provided GIS data depicting the topology of these networks and Microsoft's opensource parcel data to add these missing components to the feeder model.

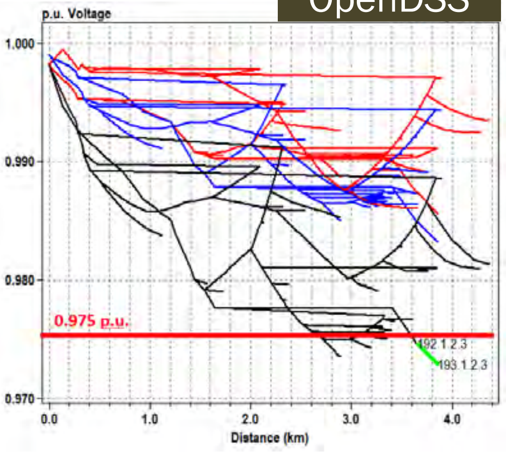
CYME





DiTTo
(Distribution Transformation Tool)

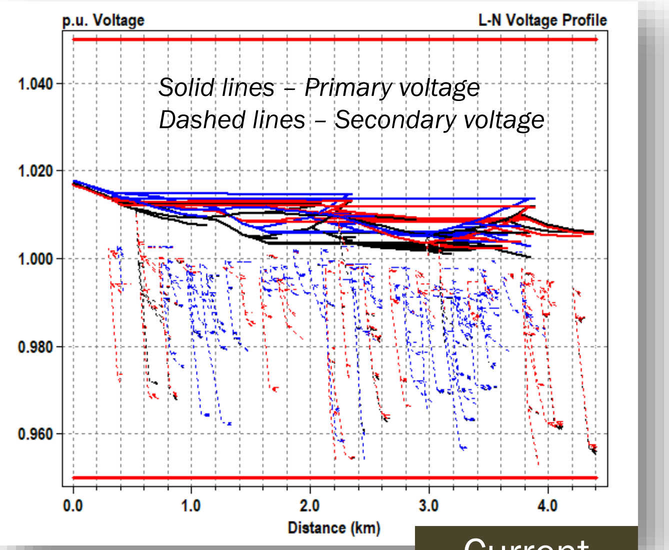
OpenDSS



Upgrading the Grid – Current and Upgraded Models

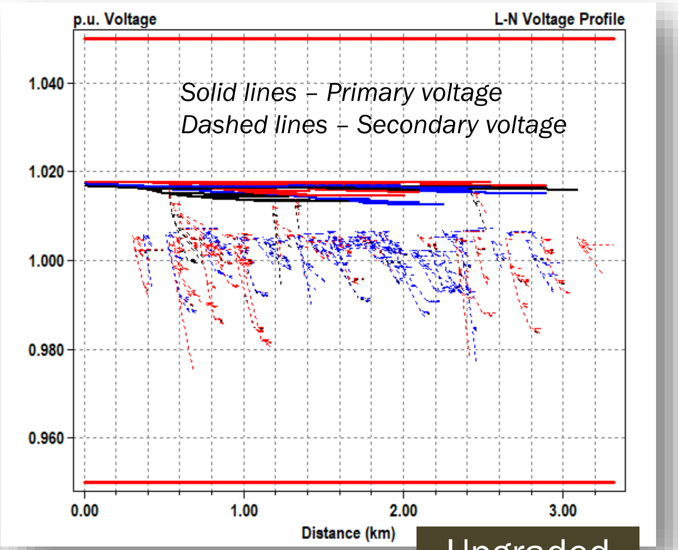
	Primary Backbone	Secondary Main	Service Drop	Transformers
Current Model	OH (4/0 Cu, #2 Cu, #4 Cu, #6 Cu) UG (4/0 Cu, 450 kcmil Cu)	Open-wire 1/0 ACSR, Open-wire 4/0 ACSR	#2 AL Triplex	Original sizes
Upgraded Model	OH (636 Al, 1/0 ACSR) UG (1000 kcmil AL, #2 AL)	1/0 AL Triplex, 4/0 AL Triplex	#2 AL Triplex	<50 kVA TO 50 kVA (31/112 Transformers Replaced)

The table above lists the distribution assets that were replaced in our upgrade process. Another key characteristic of the Current Model was the presence of looped primary circuits (i.e., parallel paths from the source to loads, without any breakpoints). This is also a legacy design practice and was remedied in our Upgraded Model, by installing normally-open switches where loops exist, creating a truly radial distribution feeder topology.



Solid lines – Primary voltage
Dashed lines – Secondary voltage

Current



Solid lines – Primary voltage
Dashed lines – Secondary voltage

Upgraded

Understanding DER Impact: Scenarios

In all scenarios, the size of rooftop solar and energy storage systems are prescribed by NREL's REopt software. The key assumptions used in this tool are explained in detail in the accompanying slide deck.[1]

NREL's EMERGE software is used to perform timeseries power flow analysis (summer and winter week) at 20%, 40%, 60%, 80% and 100% (% of peak load) adoption scenarios. Future electrification scenarios include electric heating as well as high efficiency appliances, and enclosures.

The table on the right shows all the scenarios and load multipliers used to size the solar and energy storage. For electric vehicles, a fixed charger size was used (1.2 kW for Level 1 and 7.6 kW for Level 2) assuming a mix of 20% Level 2 and 80% Level 1 chargers. The time-series load profiles for EVs are generated using NREL's EVOLVE tool.

Analysis Scenarios *Battery sizing is based on 24-hour outage survival resilience objective	PV Multiplier (Res, Comm) *multiplied with customer peak load (kW) to size PV	Battery Multiplier (Res, Comm) *multiplied with customer peak load (kW) to size battery
Solar Only, Current Model, Base Electrification	(0.547, 2.68)	N/A
Solar + Battery, Current Model, Base Electrification	(1.3088, 2.68)	(0.93, 0.2625)
Solar Only, Upgraded Model, Base Electrification	(0.547, 2.68)	N/A
Solar + Battery, Upgraded Model, Base Electrification	(1.3088, 2.68)	(0.93, 0.2625)
Solar Only, Current Model, Future Electrification	(0.2, 2.68)	N/A
Solar + Battery, Current Model, Future Electrification	(0.86, 2.68)	(0.356, 0.2625)
Solar Only, Upgraded Model, Future Electrification	(0.2, 2.68)	N/A
Solar + Battery, Upgraded Model, Future Electrification	(0.86, 2.68)	(0.356, 0.2625)
Solar + Battery, Current Model, Future Electrification, Electric Vehicles	(0.86, 2.68)	(0.356, 0.2625)
Solar + Battery, Upgraded Model, Future Electrification, Electric Vehicles	(0.86, 2.68)	(0.356, 0.2625)

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[1] Oddleifson, Tucker, Kapil Duwadi, Erik Pohl, Patrick Gibbs, Shibani Ghosh, Chrissy Scarpitti, and Liz Weber. 2024. "Prefeasibility Analysis of Behind-the-Meter Distributed Energy Resources in Highland Park, MI." February. https://www.nrel.gov/docs/fy24osti/87988.pdf.

System Average Risk Duration Indices (SARDI): An Overview

- SARDI (System Average Risk Duration Indices) metrics define a system-level risk to quantify the impacts to system performance and reliability affecting customers.
    - SARDI metrics are analogous to the commonly-used reliability index SAIDI (System Average Interruption Duration Index).
- As suggested by the *System Average* prefix to SARDI, this approach calculates an average risk across all customers and all distribution assets.
- Voltage violations* indicate customers or assets operating at a voltage that is outside of what the industry generally defines as acceptable thresholds. On U.S. power systems, these thresholds often align with the standard from the American National Standards Institute (ANSI), C84.1,[1] and is +/- 5% from nominal values.
- Thermal violations* indicate an asset that has exceeded its rated capacity. This could be an overloaded overhead wire, underground cable, or transformers. These violations can occur on both the primary (medium-voltage) distribution assets, or the secondary (low-voltage) distribution assets.
- The *risk* on a circuit, as calculated using our SARDI approach, is determined by various factors including:
    - Depth of violation: e.g., 5% overloaded vs. 50% overloaded
    - Duration of violation: e.g., overloaded for 2 hours out of the year vs. 2 hours every day
    - Importance of asset: e.g., If this asset failed, how many customers would be affected? Generally, assets like wires and cables located nearer the substation serve larger numbers of customers and, as such, receive a higher weighting based on downstream customer count.

**Unless otherwise stated, grid impact in this study focuses only on voltage violations and thermal overloading of conductors and transformers.*[2]

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[1] American National Standards Institute, Inc. 2016. "ANSI C84.1-2016: American National Standard for Electric Power Systems and Equipment - Voltage Ratings (60 Hertz)." American National Standards Institute, Inc.

[2] Duwadi, Kapil, Killian McKenna, Akshay Jain, Kajal Gaur, Adarsh Nagarajan, and David Palchak. 2021. "An Analysis Framework for Distribution Network DER Integration in India: Distributed Solar in Tamil Nadu." *Renewable Energy*, March. https://www.nrel.gov/docs/fy21osti/78114.pdf.

System Average Risk Duration Indices (SARDI): An Overview Cont'd

SARDI metrics can be further split up and calculated for different types of violations on different types of assets. The following are used in this analysis.

- **SARDI Voltage:** Percentage of time duration within the modeling timeframe for which the average customer is at risk of experiencing a voltage violation.
- **SARDI Line:** Percentage of time duration within the modeling timeframe for which the average customer is at risk of experiencing a thermal violation on an upstream overhead wire or underground cable.
- **SARDI Transformer:** Percentage of time duration within the modeling timeframe for which the average customer is at risk of experiencing a thermal violation on an upstream transformer.
- **SARDI Aggregated:** Percentage of time duration within the modeling timeframe for which the average customer is at risk of experiencing *any* type of violation.

$$\mathrm{SARDI}_{voltage} = \frac{\sum_{t=0}^{T} N_{VAC}^{t} \times \Delta T \times 100}{N_c \times T}$$

$$\mathrm{SARDI}_{line} = \frac{\sum_{t=0}^{T} N_{LAC}^{t} \times \Delta T \times 100}{N_c \times T}$$

$$\mathrm{SARDI}_{transformer} = \frac{\sum_{t=0}^{T} N_{TAC}^{t} \times \Delta T \times 100}{N_c \times T}$$

$$\mathrm{SARDI}_{aggregated} = \frac{\sum_{t=0}^{T} N_{AC}^{t} \times \Delta T \times 100}{N_c \times T}$$

$N_{VAC}^{t} = number\ of\ unique\ customers\ affected\ by\ voltage\ violation$
$N_{LAC}^{t} = number\ of\ unique\ customers\ affected\ by\ line\ overload$
$N_{TAC}^{t} = number\ of\ unique\ customers\ affected\ by\ xfmr\ overload$
$N_{AC}^{t} = number\ of\ unique\ customers\ affected\ by$
$voltage, line, or\ transformer\ violation$
$\Delta T = simulation\ timestep$
$N_c = total\ number\ of\ customers$

Generalized Grid Impacts from Distributed Energy Resources

- **Voltage Impacts:**
  - While loads (energy consumption) pull system voltages *down* and can result in undervoltages (voltages *below* the minimum acceptable tolerance), distributed energy generation at the grid edge has the opposite effect, raising voltages most severely at their point of connection (often referred to as the point of common coupling or PCC). The extent of these effects are determined by a number of factors including the location on the grid, size of the DER, ratio of distributed generation to load at a given time, and system impedances. This effect is generally more pronounced during periods with relatively low load, when more solar generation is pushed back onto the grid rather than consumed onsite. It is not uncommon for utility engineers and power-system modelers to look at a worst-case scenario when studying DER grid impacts which is often when loads are at a minimum and distributed generation is at a maximum (also referred to as minimum daytime load or MDL).
- **Thermal Loading Impacts:**
  - Adding distributed generation can reduce the loading of grid assets as they can produce energy at the location at which it is consumed rather than requiring the load to draw from the grid. However, at high adoption levels or when energy demand does not coincide with high solar production, the reverse power flow from distributed generation can *increase* loading on assets in the opposite direction.
  - **System Losses:**
  - Distributed generation has the potential to reduce system losses by providing energy generation at the same location at which it is consumed, reducing the power drawn from the grid. At especially high adoption levels, or on circuits where energy demand does not coincide with high solar production hours, the reverse power flow from distributed generation can *increase* losses as well.
- **DER Impacts not explored in this study:**
  - System protection, grid reliability, system operations, switching procedures, or effects on the bulk power system stability and reliability.

Assumptions in Distribution Modeling

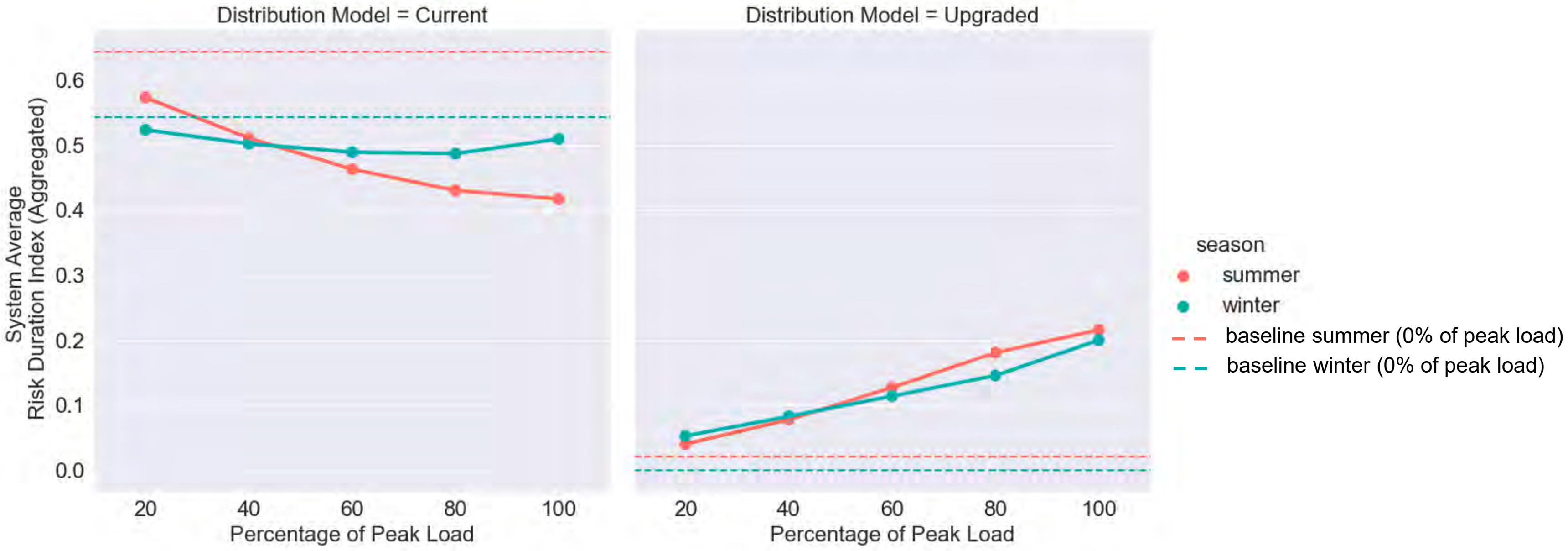
- **Significant assumptions:**
  - The average load profiles used represent a "typical" residential and commercial customer, provided by DTE, and are applied to *all* loads in each customer class. In reality, every customer load profile varies, which would ultimately affect the coincident peak demand seen on segments of the feeder and individual grid assets. Unique customer loads profiles can only be captured through fine-time-resolution data from advanced metering infrastructure (AMI) or other recording meter.
  - Peak load allocation algorithms in CYME modeling software are used to find out the peak load for each customers based on substation SCADA and individual monthly energy consumption. In reality, *energy* consumption is not a perfect indicator of peak *power* demand.
  - For secondary modeling we mapped spot loads from CYME to buildings available from Open Street data and Microsoft Parcel Data. There may be a mismatch in the number, location, or size of buildings, resulting in potentially inaccurate load-flow results or customer counts.
  - The analysis tools used in this study (EVOLVE, EMERGE, and REopt) also include assumptions regarding typical customer behaviors, geographic patterns of DERs adoption, and technical characteristics of DERs. Given the inherent uncertainties in predicting these items and the lack of granular, locationally accurate datasets to inform this study, these assumptions may differ from the actual current and future conditions within Highland Park.
  - As mentioned on the previous slide, there are multiple types of DER impacts not explored in this study.
- **Interpretation of study results:**
  - The results of this study can reasonably illustrate high-level trends under the scenarios we generate, but in general cannot pinpoint the more granular impacts on individual lines, transformers, or single customers.
  - Scenarios can forecast changes to customer loads profiles based on a set of initial conditions and assumptions but cannot predict the future with a high degree of certainty.
  - Results can also reasonably illustrate the *types* of violations on a system (i.e., namely impacts on the secondary (low-voltage) networks rather than primary networks, or voltage impacts instead of thermal overloads). These findings can provide valuable insights for utility planning, design, and operations.

Scenario Analysis Results

Rooftop Solar Only (Base Electrification): Grid Impacts

Rooftop Solar (Base Electrification): SARDI Aggregated

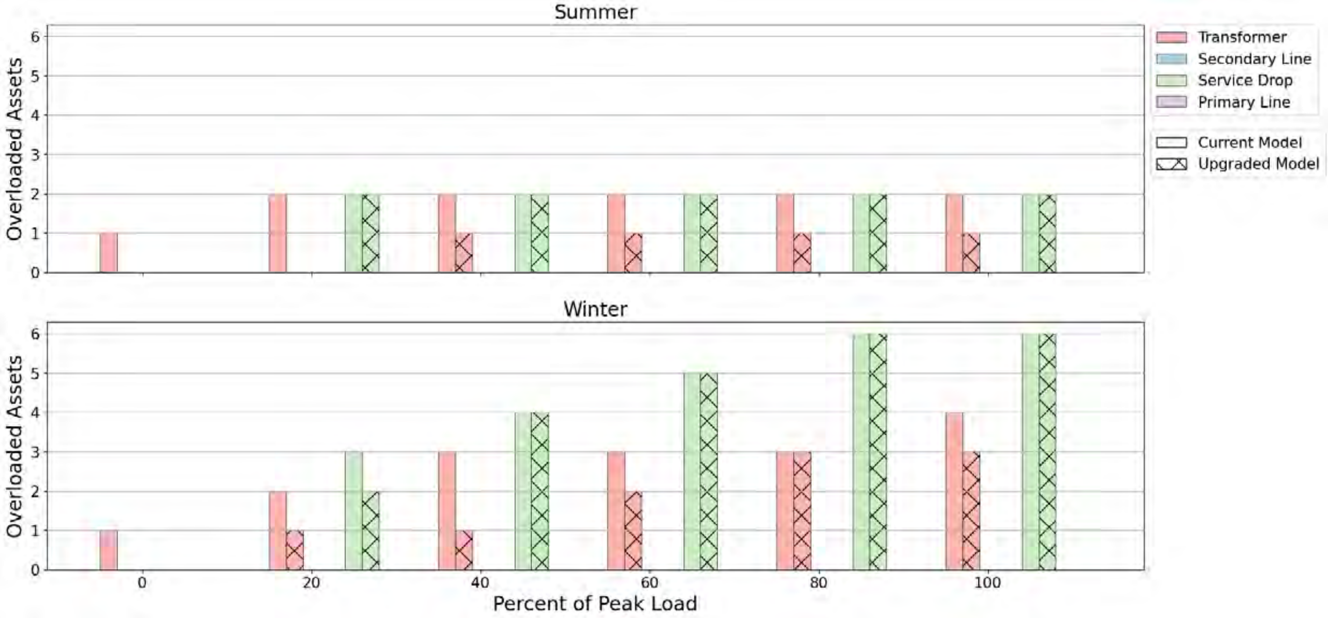
The SARDI aggregated metric is relatively small for our solar-only scenario under the current base electrification. With no solar added to our Current Model, we see a baseline risk of roughly 0.65% and 0.55% in summer and winter, respectively. As we add solar to our Current Model, system-level risk tends to decrease, rising slightly at high adoption rates in the winter. On the Upgraded Model, we start from a lower baseline of near 0% for both summer and winter and see an increase in risk with increasing solar adoption, though overall, a lower risk across all adoption levels compared to our Current Model. Note this risk is mainly due to thermal overloading of lines and/or transformers. We did not observe voltage violations in these scenarios.



Percentage of Peak Load is defined as % of peak load before introducing distributed energy resources. The line plots shown take the average SARDI ranking across 25 simulation samples.

Rooftop Solar (Base Electrification): Number of Overloaded Assets

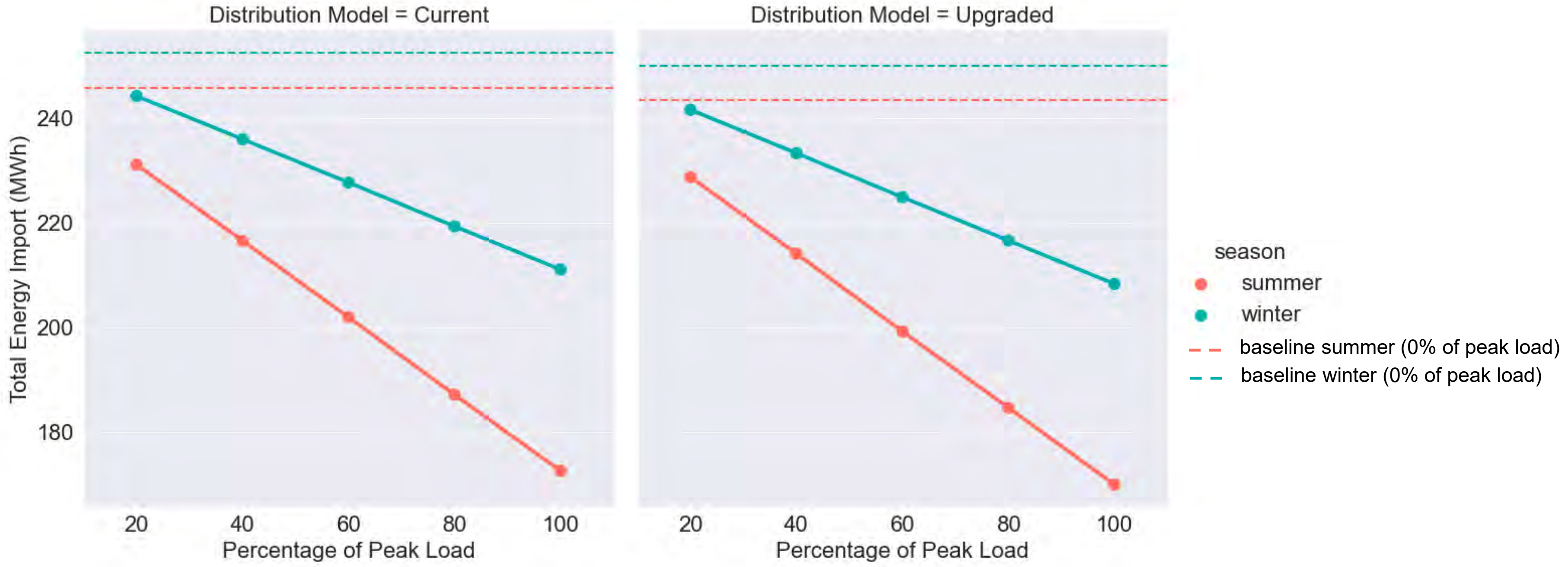
The relatively low SARDI score is further reflected in the small number of overloaded assets shown below. Overloads are exclusive to a handful of transformers and service drops and tend to improve or stay the same when upgrading the system. It is important to recognize that despite upgrading our feeder from 4.8 kV to 13.2 kV, the voltages of our secondary (low-voltage) lines do not change (120/240V in both models) and so the improvements here are relatively small and namely reflect changes in transformer sizes in select cases (i.e., when the existing transformer had a capacity of less than 50 kVA). There are no overloaded primary lines, even at 100% solar adoption. There are generally more overloaded assets in the wintertime (bottom) due to lower energy demand and higher back feed of solar generation onto the distribution network, illustrated particularly at high levels of solar adoption.



Percentage of Peak Load is defined as % of peak before introducing distributed energy resources. The bar plots shown take the max number of overloaded assets across 25 simulation samples.

Rooftop Solar (Base Electrification): Total Energy Import

As one would expect, energy import (energy produced by bulk system generation and transported across high-voltage transmission networks) reduces with increasing distributed solar adoption. We see a greater reduction during the summer due to increased irradiance from the sun and more daylight hours. The further reduction in imports (albeit very slight) we see on our Upgraded Model is due to reduced line and transformer losses in the upgraded system, illustrated in more detail on slide 27.



Percentage of Peak Load is defined as % of peak load before introducing distributed energy resources. The line plots shown take the average SARDI ranking across 25 simulation samples.

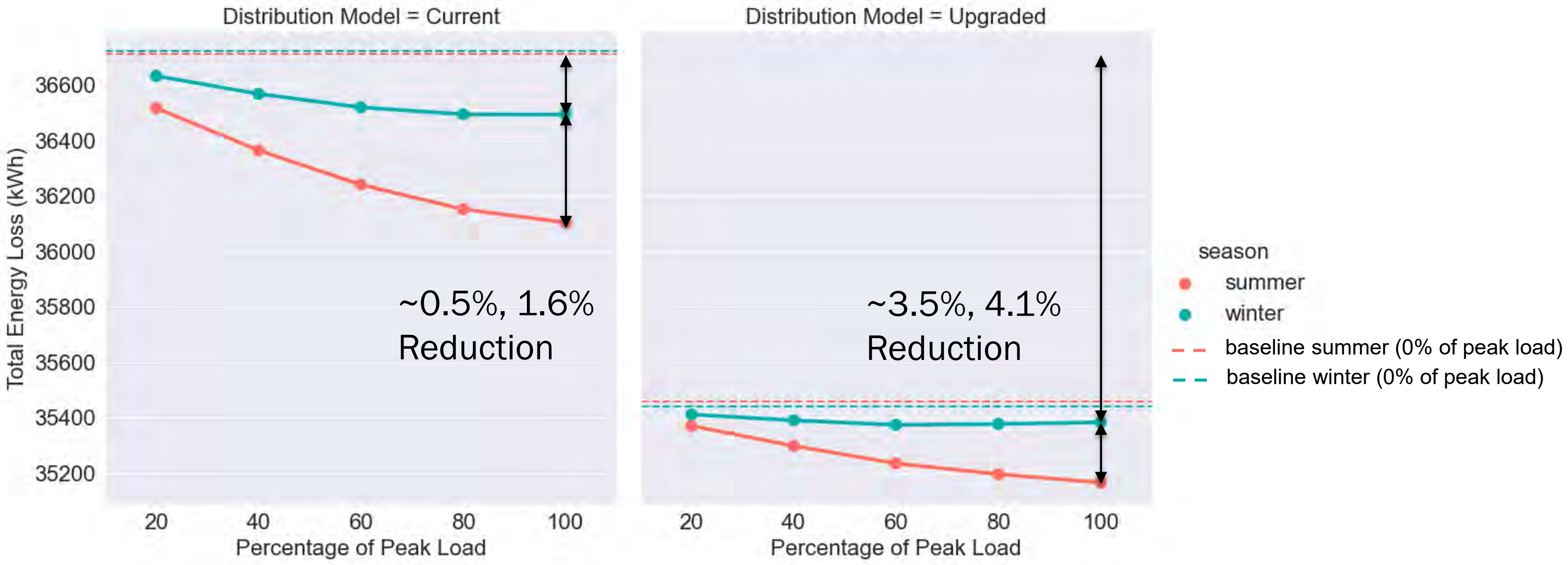
Rooftop Solar (Base Electrification): Total PV Generation

Conversely to energy imports, distributed solar generation increases with increasing solar adoption. We see higher solar generation in the summer due to higher solar irradiance and longer days. Here there is no difference in generation between our Current and Upgraded Models because the peak load (and thus the assigned solar system sizes) is the same in both models for the current electrification scenario.

Percentage of Peak Load is defined as % of peak load before introducing distributed energy resources. The line plots shown take the average SARDI ranking across 25 simulation samples.

Rooftop Solar (Base Electrification): System Losses

System losses tend to reduce with increasing solar adoption as confirmed by the plots below. In our Current Model, we see a peak loss reduction of about 0.5% and 1.6% at 100% solar adoption in the winter and summer, respectively, compared to the baseline. The Upgraded Model sees a *further* reduction in losses for a peak of 3.5% and 4.1% reductions for winter and summer, respectively, when compared to baseline in our Current Model. The additional reduction is largely resultant from lower current flow due to operating at a higher voltage class, as well as larger assets with lower impedances per DTE's upgrade design guidance (see slide 14). For reference, the Current Model's system losses with no solar adoption is ~36.7 MWh (winter) or ~14.7% of energy imported (winter). The Upgraded Model's system losses are ~35.4 MWh (winter) or ~14.1% of energy imported (winter).



Percentage of Peak Load is defined as % of peak load before introducing distributed energy resources. The line plots shown take the average SARDI ranking across 25 simulation samples.

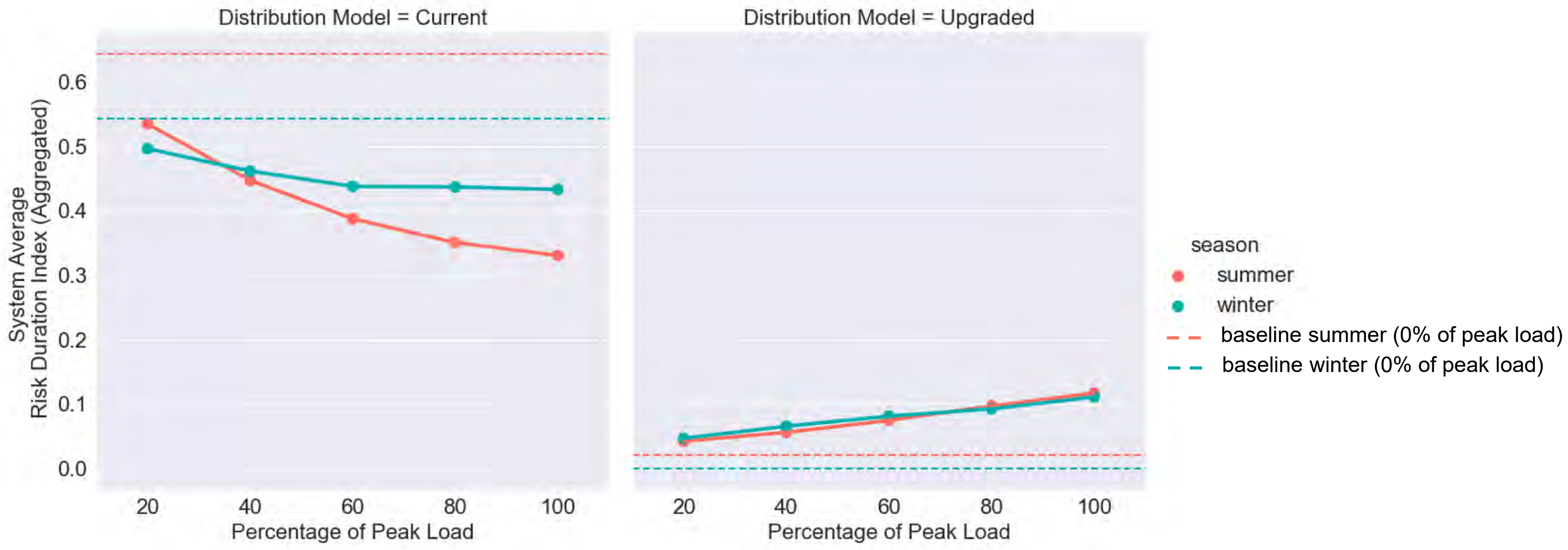
Key Takeaways

- While only minimal system risks are seen in this solar-only scenario, the SARDI aggregated metric shows that adding rooftop solar generally reduces the risk associated with asset overloading in the current model.
- Adding solar in the upgraded model increases overall system risk, though values are still lower than what the *current* grid is experiencing.
- All overloaded assets, with and without solar, are limited to the low-voltage secondary distribution network (from distribution transformer to customer meter), a trend which continues throughout this analysis illustrated on the following slides. No thermal impacts are seen on the medium-voltage primary network.
- Assuming customers would choose this cost-optimal solar size (as recommended by REopt), total energy import would be reduced by about 24% in summer and 14% in winter with a 100% solar adoption level.
- The adoption of distributed solar reduces energy losses by up to 1.6% on the current system and up to 4.1% in the upgraded feeder, when compared with the current model baseline.

Rooftop Solar and Energy Storage (Base Electrification): Grid Impacts

Rooftop Solar and Energy Storage (Base Electrification): SARDI Aggregated

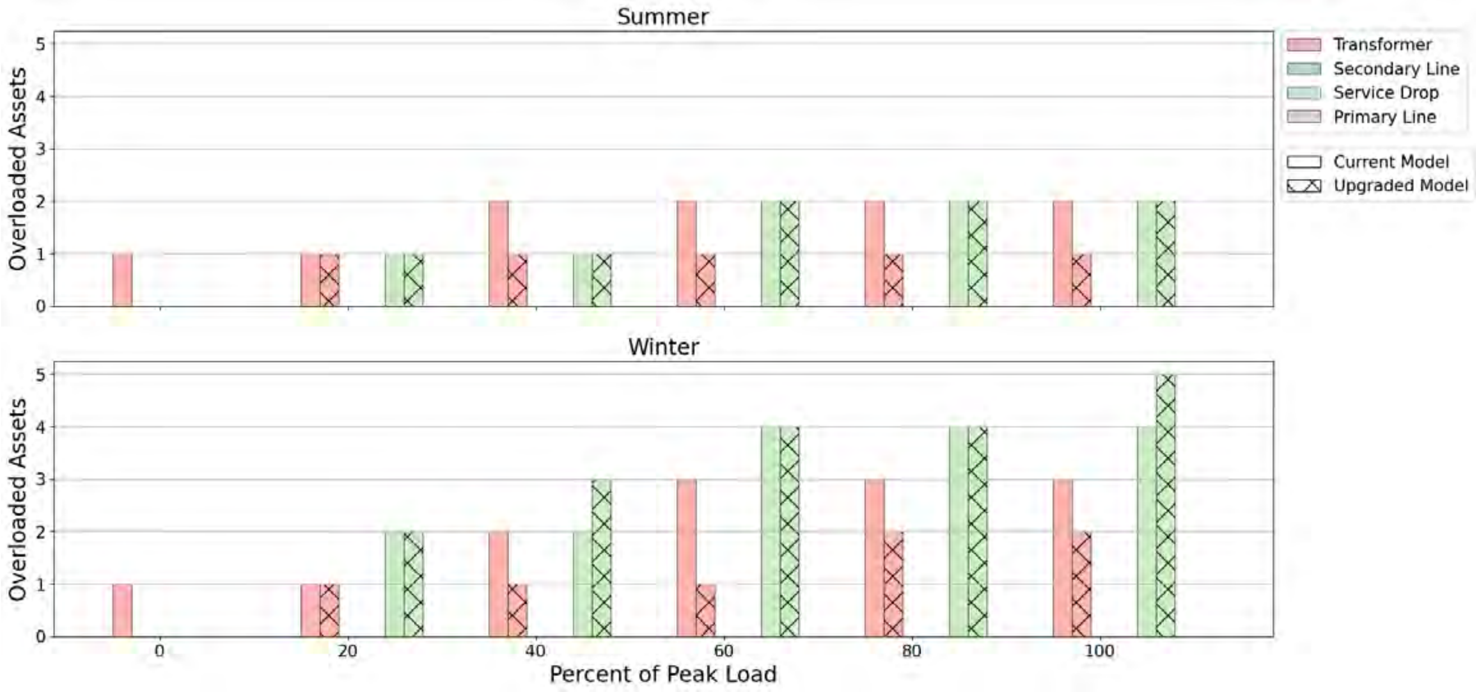
In our solar + storage scenario, we see almost identical trends to our solar-only model shown previously. We see small overall risk levels of about 0.65% in our baseline, decreasing with higher solar adoption levels and overall lower risk levels in our Upgraded Model. The slight improvements from added energy storage are illustrated on a later slide in more detail. Note, this risk is mainly due to thermal overloading of line and/or transformers. We did not observe voltage violations in these scenarios.



Percentage of Peak Load is defined as % of peak load before introducing distributed energy resources. The line plots shown take the average values across 25 simulation samples.

Rooftop Solar and Energy Storage (Base Electrification): Number of Overloaded Assets

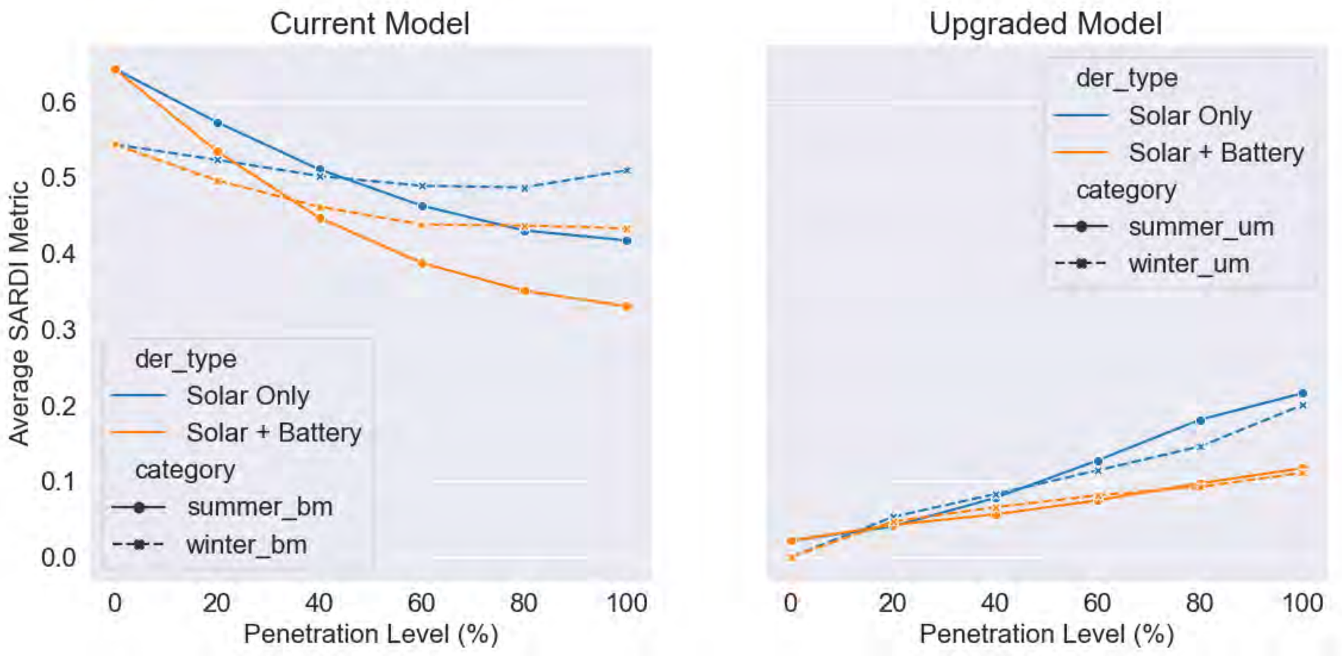
We see an almost identical number of overloaded assets compared with our solar-only model with the addition of energy storage. At high levels of adoption, we see a slight reduction in overloaded assets, illustrated in more detail on the following slide.



Percentage of Peak Load is defined as % of peak load before introducing distributed energy resources. The bar plots shown take the max number of overloaded assets across 25 simulation samples.

Solar vs. Solar and Energy Storage (Base Electrification): Comparison

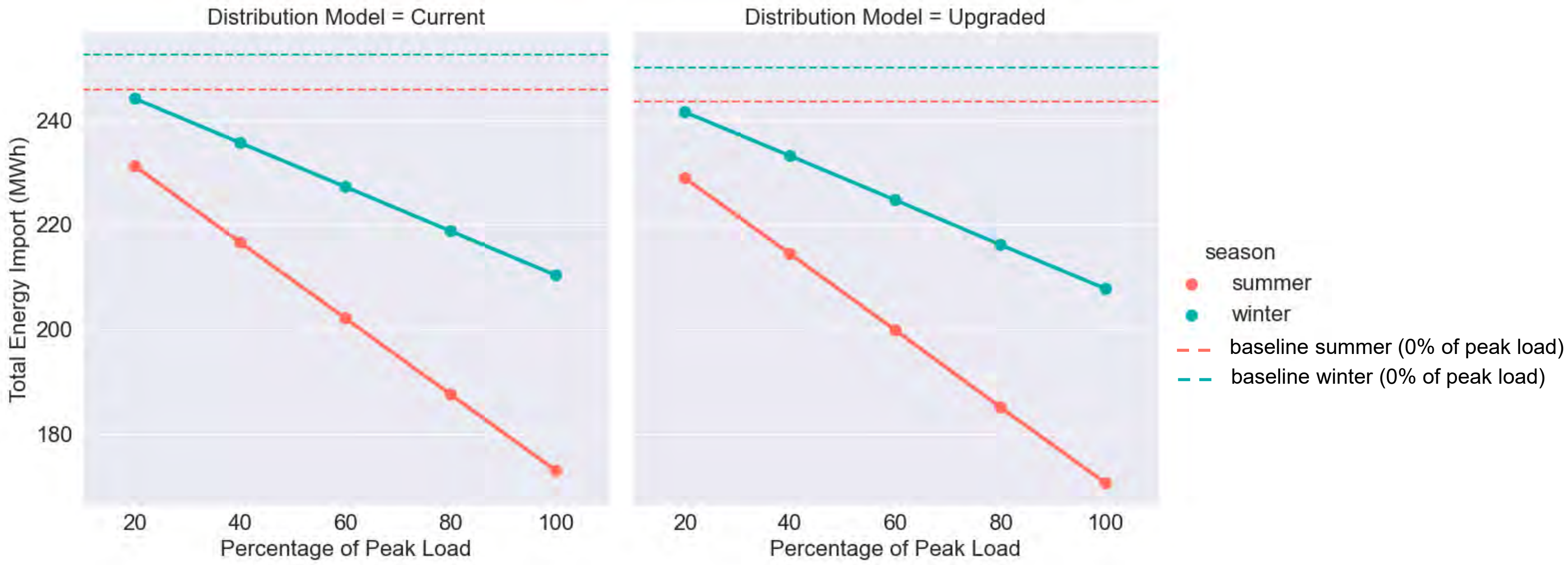
Incorporating behind-the-meter energy storage in our models further reduces system risk in both the Current and Upgraded models. The added storage enables homeowners to consume more of the energy their rooftop solar generates by storing energy during periods of low load, rather than exporting energy back onto the distribution system. This ultimately results in fewer solar-caused violations and the associated risks.



Percentage of Peak Load is defined as % of peak load before introducing distributed energy resources. The line plots shown take the average values across 25 simulation samples.

Rooftop Solar and Energy Storage (Base Electrification): Total Energy Import

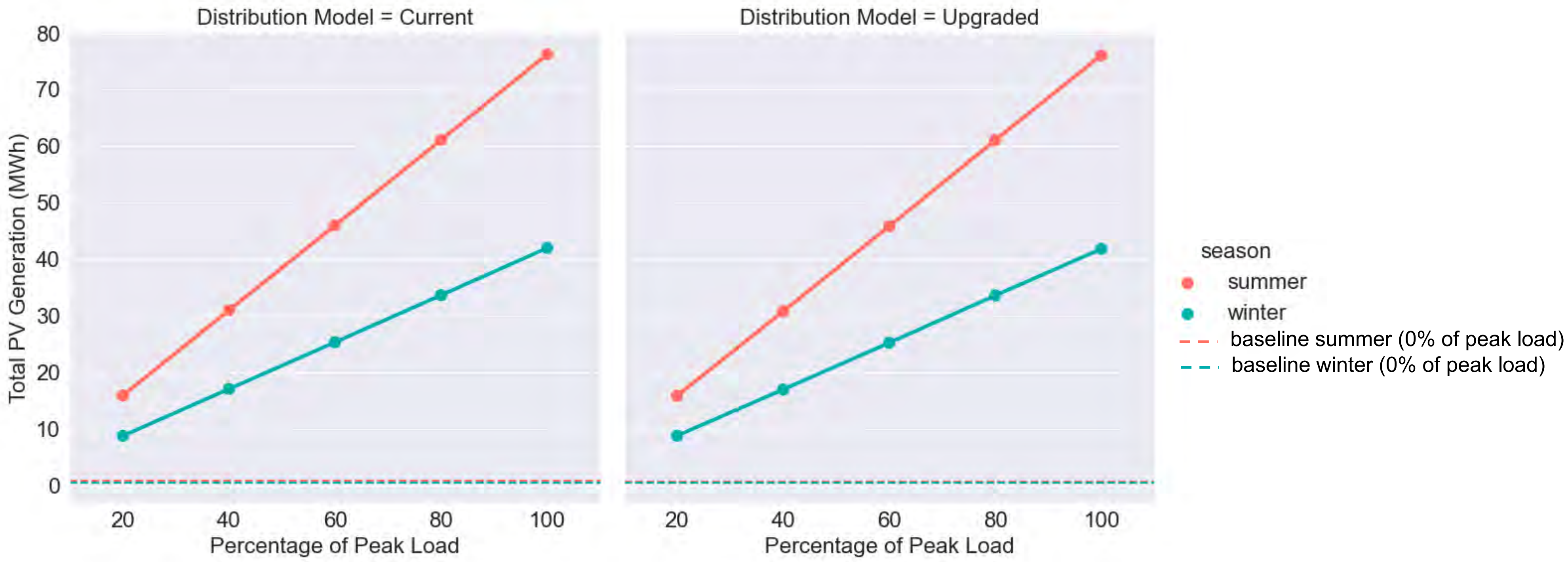
We see almost identical trends to our solar-only model, illustrating that behind-the-meter energy storage, as we have implemented it, does not have major impacts on overall energy consumption from the bulk power system. Batteries may charge from onsite solar or from the grid, however, given that this stored energy is discharged at a later time, we see no net changes in overall energy consumption, compared with the solar-only scenario.



Percentage of Peak Load is defined as % of peak load before introducing distributed energy resources. The line plots shown take the average values across 25 simulation samples.

Rooftop Solar and Energy Storage (Base Electrification): Total PV Generation

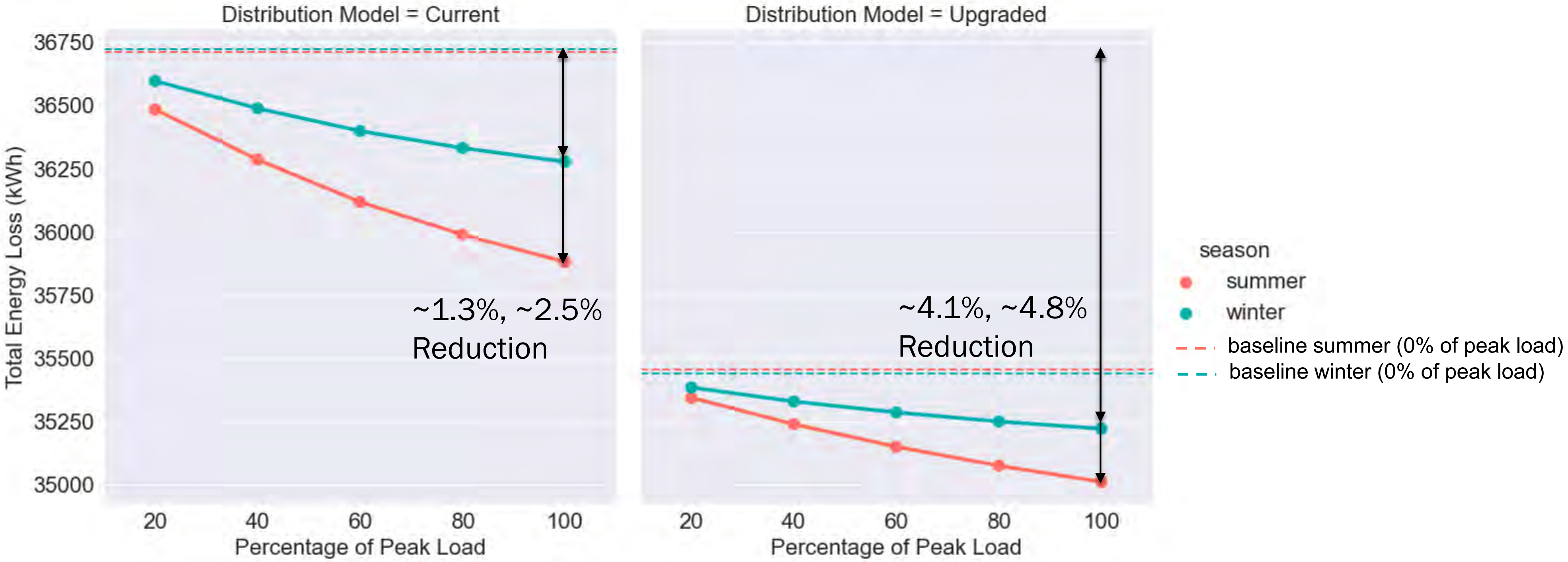
Our modeling of PV systems does not change between our solar-only vs. solar + storage models. As such, we see no differences in generation from PV compared across the two scenarios.



Percentage of Peak Load is defined as % of peak load before introducing distributed energy resources. The line plots shown take the average values across 25 simulation samples.

Rooftop Solar and Energy Storage (Base Electrification): System Losses

Adding behind-the-meter energy storage results in slight improvements in system losses when compared to our solar model, due largely to a reduction in solar exports and increased onsite consumption. The additional loss reduction is, albeit, slight, with a peak reduction of 2.5% vs. 1.3% and 4.8% vs 4.1% in our Current and Upgraded models, respectively.



Percentage of Peak Load is defined as % of peak load before introducing distributed energy resources. The line plots shown take the average values across 25 simulation samples.

Key Takeaways

- Again, while only minimal system risks are seen in this scenario, the SARDI aggregated metric shows that adding energy storage alongside rooftop solar can further reduce risk.
- Overloaded assets are exclusive to the low-voltage network and service transformers. No impacts to the medium-voltage primary network are seen.
- Adding behind-the-meter energy storage results in slight improvements in system losses when compared to our solar scenario, due largely to a reduction in solar exports and increased onsite consumption.
- Overall, the current 4.8 kV system does not appear to be a severe limitation to the adoption of distributed cost-optimal rooftop solar plus behind-the-meter storage systems for this region of Highland Park. Larger rooftop solar systems or utility-scale installations may be more limited by the legacy distribution voltage class.

Rooftop Solar Only (Future Electrification): Grid Impacts

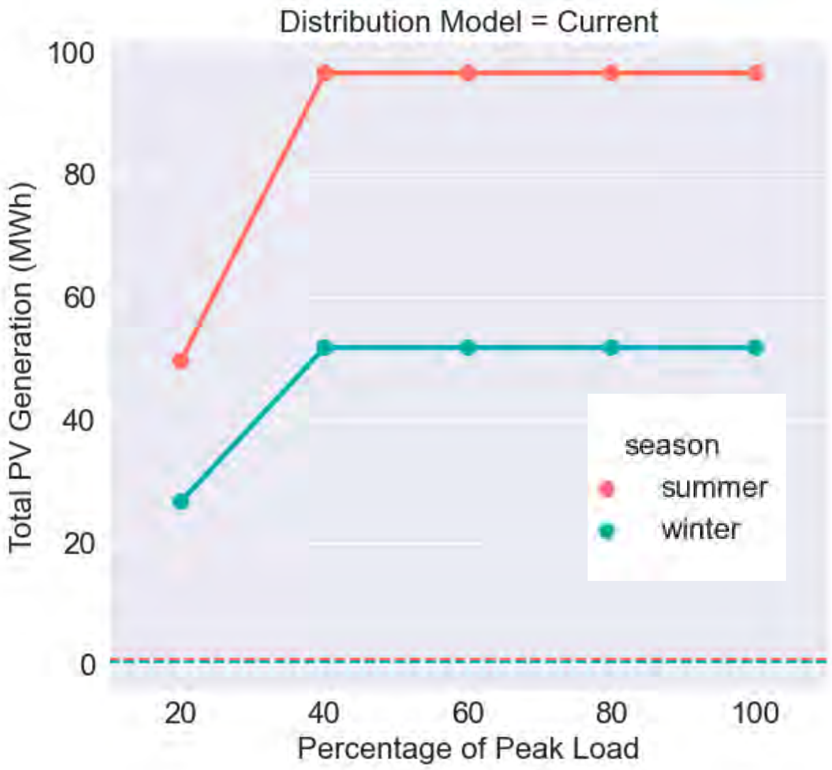
Rooftop Solar (Future Electrification): Notes

A nuance of our scenario development approach, seen in our Rooftop Solar (Future Electrification) scenario is shown in the plot of total PV generation.

With the added loads of building electrification, we cannot meet more than 40% of the system peak load with cost-optimal rooftop solar installed at every residence. This results in a leveling off of solar generation and the resulting risk metrics beyond 40% adoption. This result is due, in part, to the relatively small individual solar PV systems installed at each house, prescribed as the cost-optimal size from the accompanying REopt analysis.

Additionally, the overall much higher loads from electrified heating produces a circuit where to meet 40% of the system peak load in installed solar capacity using cost-optimal system sizes, 100% of customers on this circuit need to have solar installed. Beyond this point, there are physically no more rooftops on which to install more solar, and as such, solar generation and the risk metrics do not change beyond this point. Details on why the smaller PV systems are still the cost-optimal option are presented in the accompanying presentation describing the REopt analysis.[1]

One should also note that nearly all the increased energy consumption due to electrification occurs in the wintertime. As such, summer metrics are relatively unchanged from previously shown scenarios. This trend will largely hold true for the remaining future electrification scenarios.



Percentage of Peak Load is defined as % of peak load before introducing distributed energy resources. The line plots shown take the average values across 25 simulation samples.

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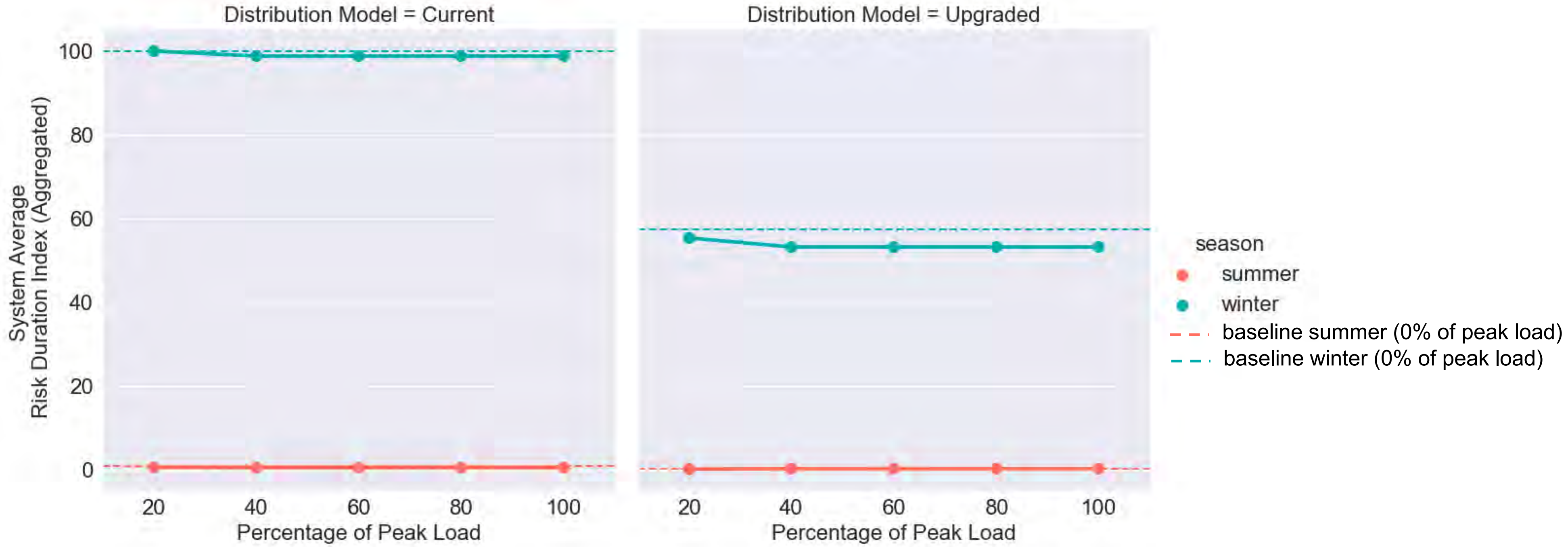
[1] Oddleifson, Tucker, Kapil Duwadi, Erik Pohl, Patrick Gibbs, Shibani Ghosh, Chrissy Scarpitti, and Liz Weber. 2024. "Prefeasibility Analysis of Behind-the-Meter Distributed Energy Resources in Highland Park, MI." February. https://www.nrel.gov/docs/fy24osti/87988.pdf.

Rooftop Solar (Future Electrification): SARDI Aggregated

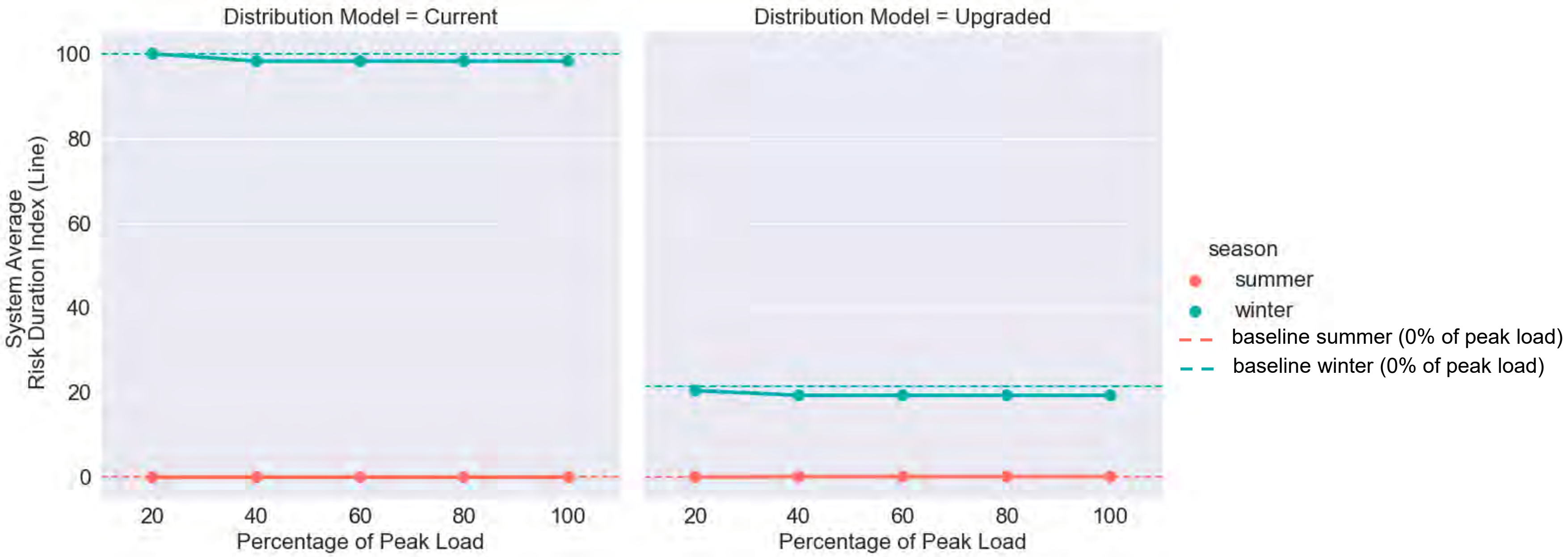
The added loads in our Future Electrification scenarios result in far higher risk levels during the winter months, when electric heating loads are present. A SARDI Aggregated score of 100 indicates that 100% of the customers are located downstream of an at-risk asset for 100% of the modeling timeframe. The significant drop in SARDI Aggregated score in the Upgraded model is driven primarily by a reduction in line overloads. The following slides provide a more detailed breakdown of this score.



Percentage of Peak Load is defined as % of peak load before introducing distributed energy resources. The bar plots shown take the max number of overloaded assets across 25 simulation samples.

Rooftop Solar (Future Electrification): SARDI Line

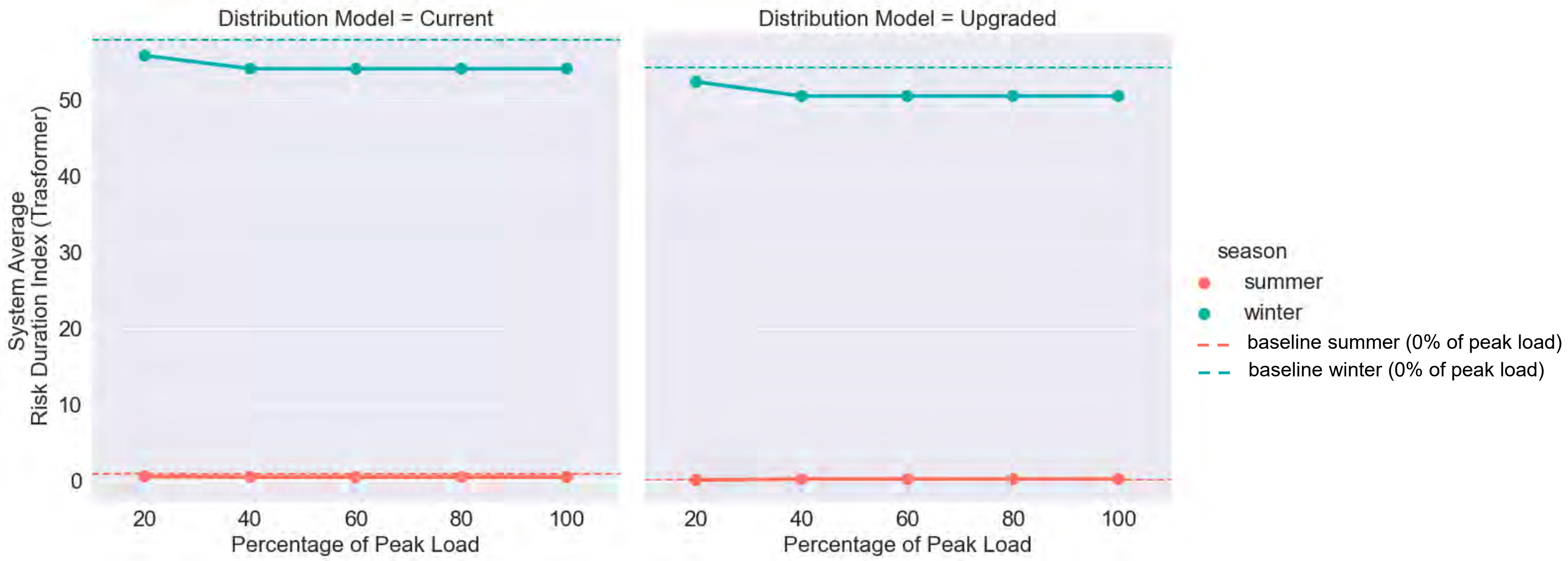
The high SARDI Aggregated score is driven in a large part by overloaded cables and wires, including central assets located in close proximity to the substation. On our Current Model, we see practically no changes to our summer risk levels (once again, almost zero). During the winter, we see an initial SARDI Line of 100%, followed by a slight decrease as solar alleviates some of these overloads until reaching saturation around 40% peak load. Once upgraded to a higher voltage class, we see a substantial drop in SARDI Line, with most remaining violations being located on the low-voltage networks. The remaining risks are indicative of potentially inadequate design standards if planning for a high-electrification future.



Percentage of Peak Load is defined as % of peak load before introducing distributed energy resources. The line plots shown take the average values across 25 simulation samples.

Rooftop Solar (Future Electrification): SARDI Transformer

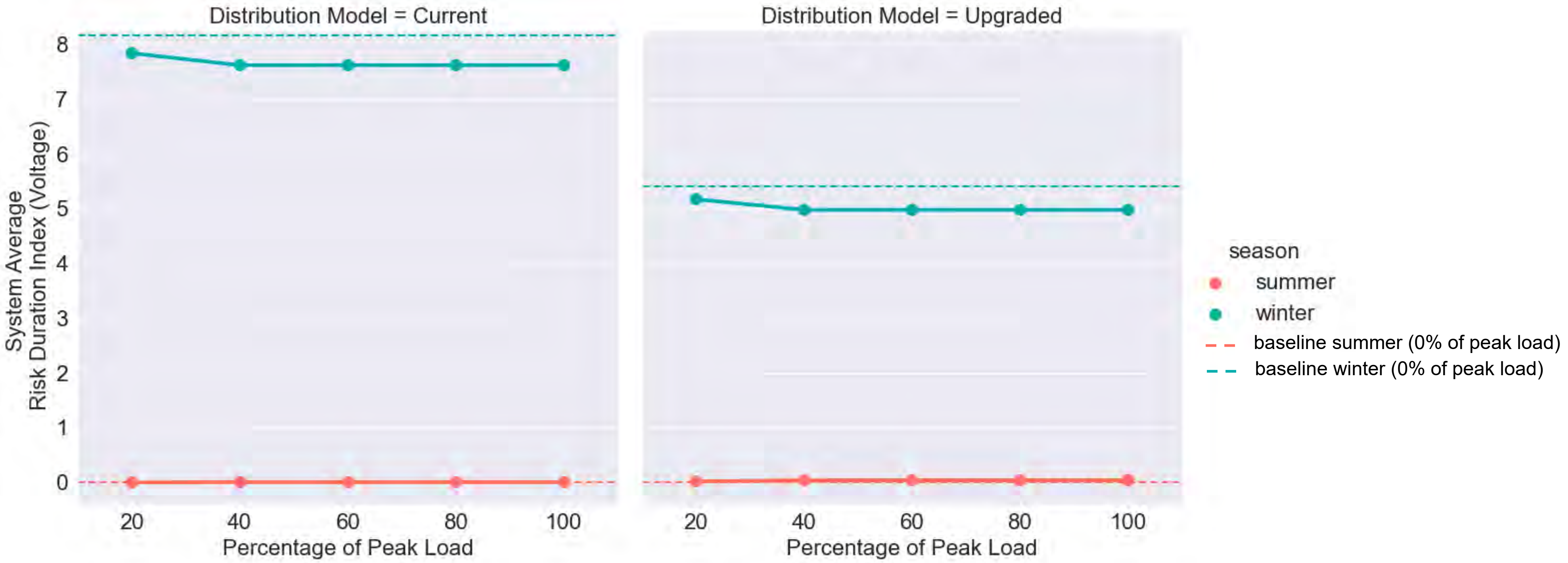
While our Upgraded Model includes larger transformers for those that were previously less than 50 kVA (replaced with a 50 kVA), the persistent high SARDI Transformer score in our Upgraded Model indicates that this rule of thumb may not be sufficient for high-electrification futures. The result suggests that further upgrades (i.e., swapping 50 kVA to 100 kVA transformers or splitting up customer counts onto *additional* transformers) may be needed to accommodate larger household loads.



Percentage of Peak Load is defined as % of peak load before introducing distributed energy resources. The line plots shown take the average values across 25 simulation samples.

Rooftop Solar (Future Electrification): SARDI Voltage

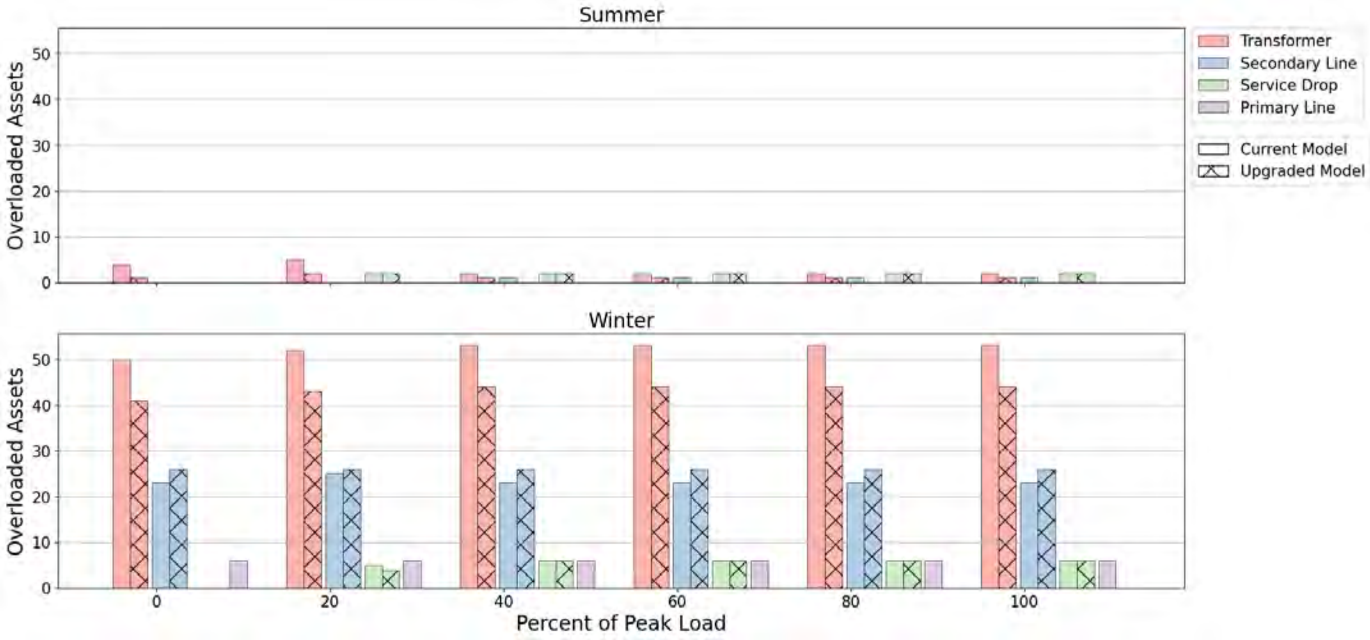
Our SARDI Voltage score in this scenario is relatively low, indicating that line ampacities and transformer kVA ratings are the main bottleneck for high-electrification futures. That said, the findings below illustrating persistent voltage violations after upgrading can still inform future design standards, possibly prescribing larger secondaries, added voltage regulation, or additional transformers to limit overall secondary lengths and resulting voltage drop.



Percentage of Peak Load is defined as % of peak load before introducing distributed energy resources. The line plots shown take the average values across 25 simulation samples.

Rooftop Solar (Future Electrification): Number of Overloaded Assets

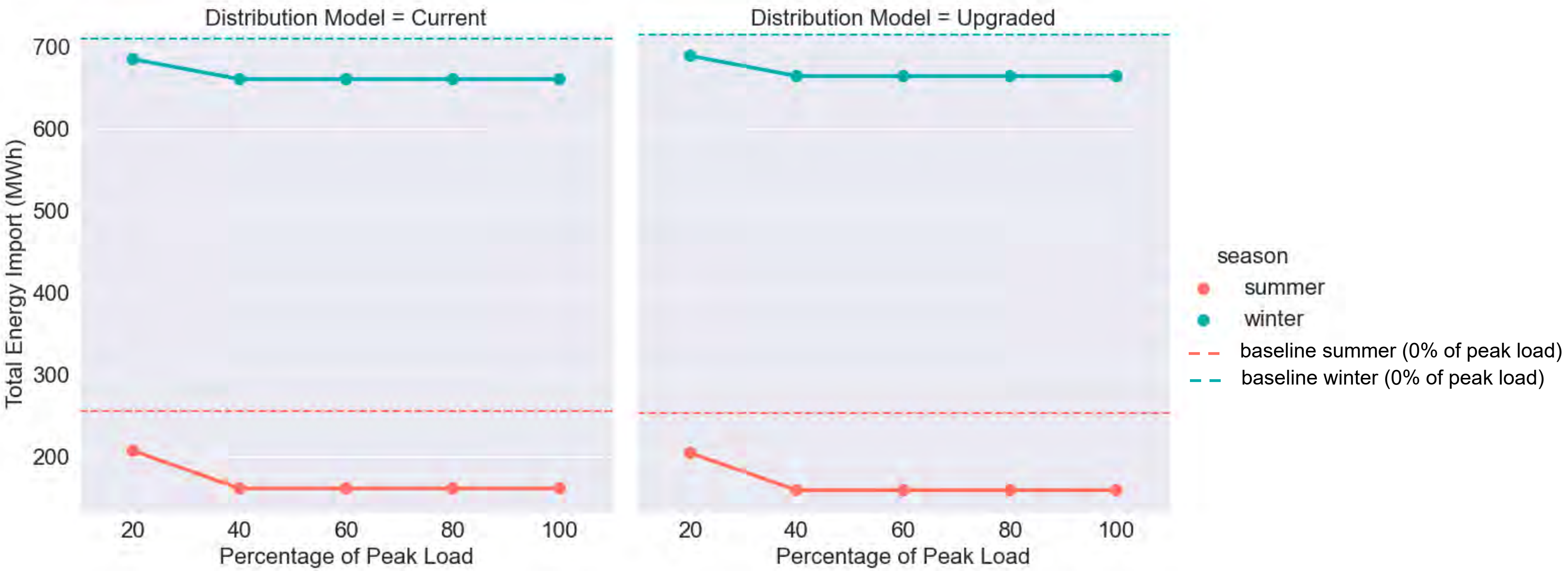
In our Future Electrification models, we see a much larger number of overloaded service transformers and secondary lines, almost exclusively in the wintertime. As previously noted, there are primary lines near the feeder head in our Current Model which are overloaded resulting in a SARDI Line of 100. While these primary line violations are remedied in our upgraded model, the majority of the overloaded service transformers, secondary lines and service drops remain overloaded in our upgraded model, again illustrating the need for more robust design standards if planning for a high-electrification future.



Percentage of Peak Load is defined as % of peak load before introducing distributed energy resources. The bar plots shown take the max number of overloaded assets across 25 simulation samples.

Rooftop Solar (Future Electrification): Total Energy Imports

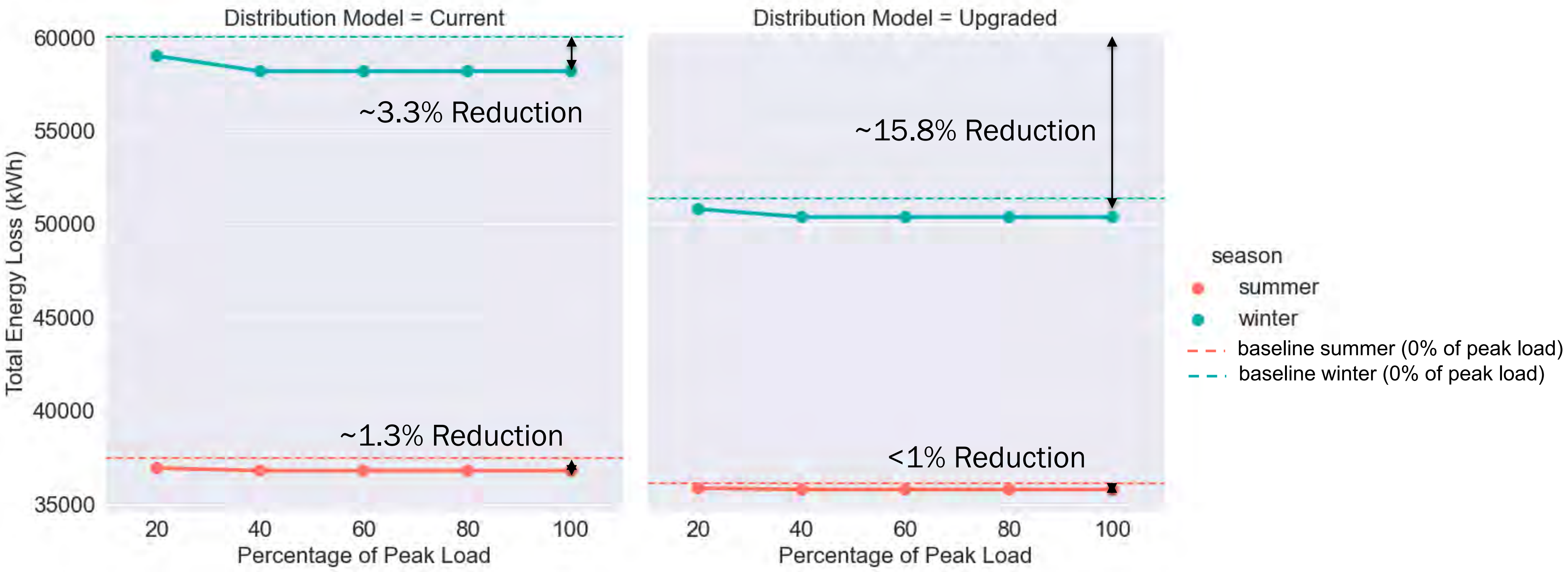
We see a dramatic increase in energy import (nearly 3X) in the wintertime due mainly to electric heating loads, and practically no increase in summertime consumption.



Percentage of Peak Load is defined as % of peak load before introducing distributed energy resources. The line plots shown take the average values across 25 simulation samples.

Rooftop Solar (Future Electrification): System Losses

The significantly higher losses are a result of much higher loads from building electrification and wintertime heating loads. We see a large improvement in system losses when upgrading the circuit to a higher voltage class.



Percentage of Peak Load is defined as % of peak load before introducing distributed energy resources. The line plots shown take the average values across 25 simulation samples.

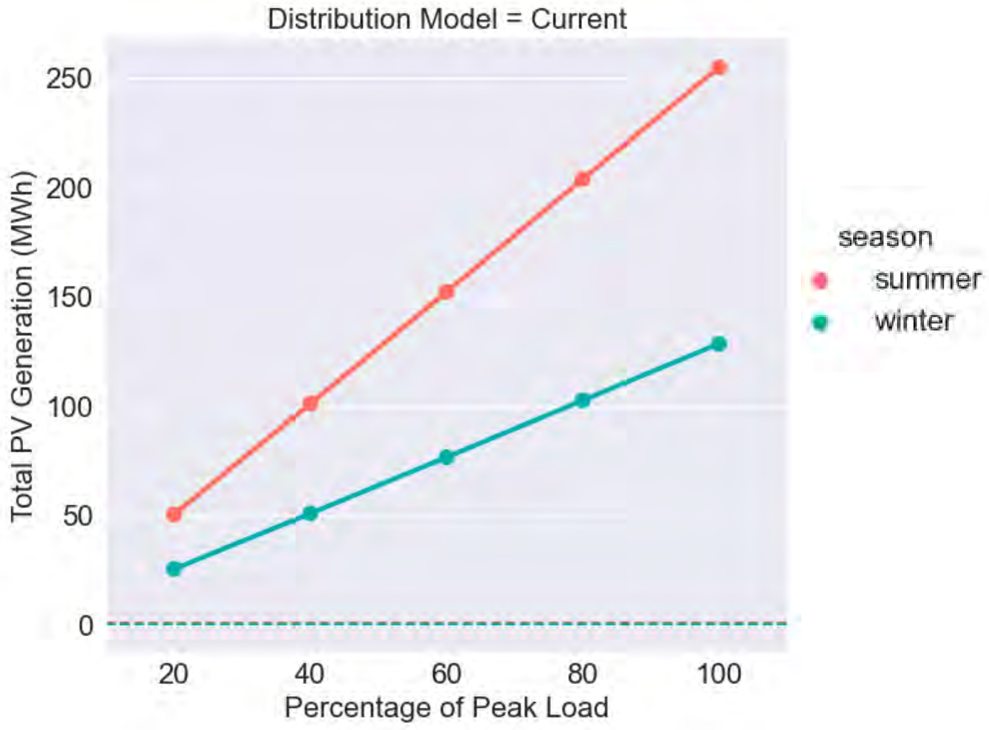
Key Takeaways

- Significant load increases in our Future Electrification scenarios drastically increase the baseline system risk. This effect takes place almost exclusively in the wintertime, with little change in the summertime, due to the addition of electric heating loads, in place of gas furnaces.
- With no solar, we see a SARDI aggregated metric of 100, indicating that all customers are served by an at-risk asset for the duration of the modeling timeframe.
- The cost-optimal solar sizing algorithm used in REopt results in relatively small solar installations on each house when compared with the large increase in winter loading. This creates a saturation effect, around 40% adoption, at which point every house has solar installed. As a result, increasing solar adoption beyond this point is not possible, and risk metrics remain constant beyond this point.
- Upgrading the system produces large improvements in risks and system losses, however significant system risks remain on the Upgraded Model, namely in the form of overloaded secondary lines and overloaded transformers.
- Remaining high risk metrics in our upgraded model indicate the need for revised utility design standards, particularly for secondary systems. Revisions may include larger standard secondary conductors, fewer customers per transformer, or adding additional transformers to limit secondary lengths.

Rooftop Solar and Energy Storage (Future Electrification): Grid Impacts

Rooftop Solar and Energy Storage (Future Electrification): Notes

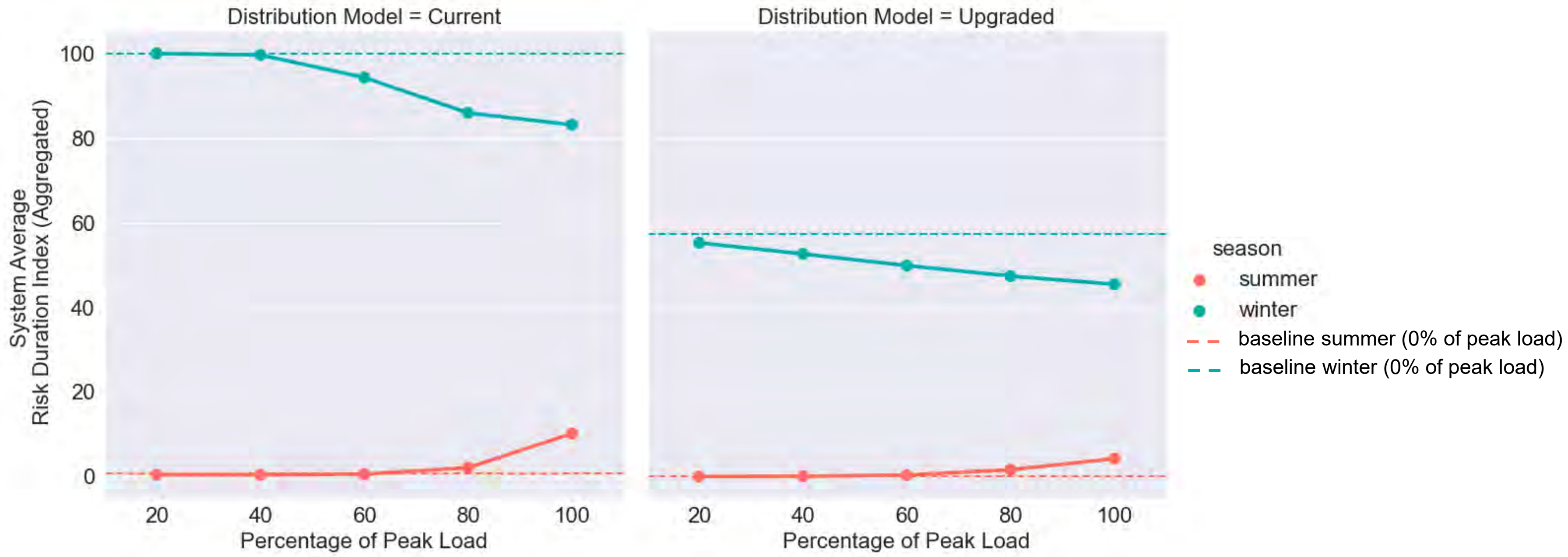
A notable difference resulting from the addition of energy storage, is that it increases the cost-optimal solar size recommended by REopt. As a result, we no longer see the saturation effect causing solar generation to level out, as we did in the previous solar-only scenario. This means that we can effectively meet even 100% of the system peak load with installed solar capacity, thanks to the increased self-consumption enabled by energy storage and larger individual solar installations. This phenomenon and solar sizing strategies are explained in more detail in the accompanying REopt analysis.



Percentage of Peak Load is defined as % of peak load before introducing distributed energy resources. The line plots shown take the average values across 25 simulation samples.

Rooftop Solar and Energy Storage (Future Electrification): SARDI Aggregated

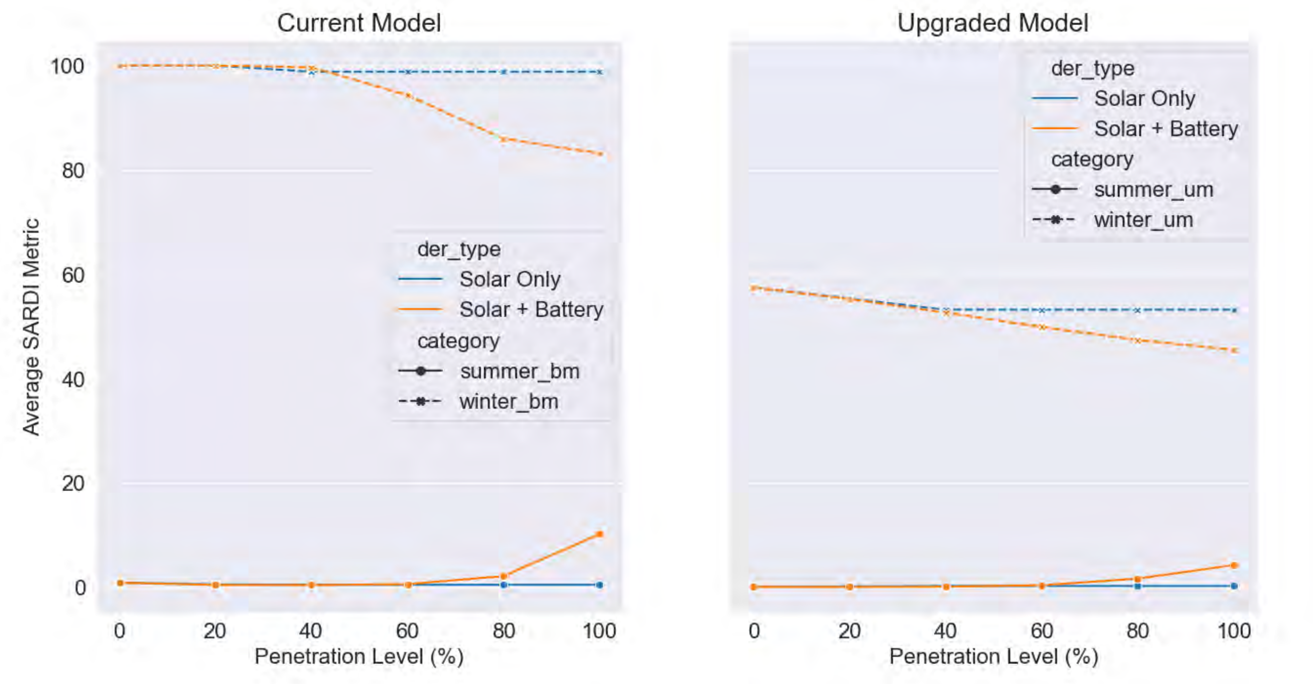
In contrast to our solar-only scenario, we see a consistent decrease in our wintertime risk with increasing solar adoption in both models. The opposite is true in the summertime. PV systems which are sized to accommodate the larger winter loads and energy storage will export more to the grid during the summertime given the higher irradiance and lower loads in the absence of electric heating. As such, at high levels of adoption, we see an uptick in risk. Our Upgraded Model overall shows a lower risk level, but similar to the solar-only scenario, there are still non-zero risks.



Percentage of Peak Load is defined as % of peak load before introducing distributed energy resources. The line plots shown take the average values across 25 simulation samples.

Rooftop Solar and Energy Storage (Future Electrification): Comparison

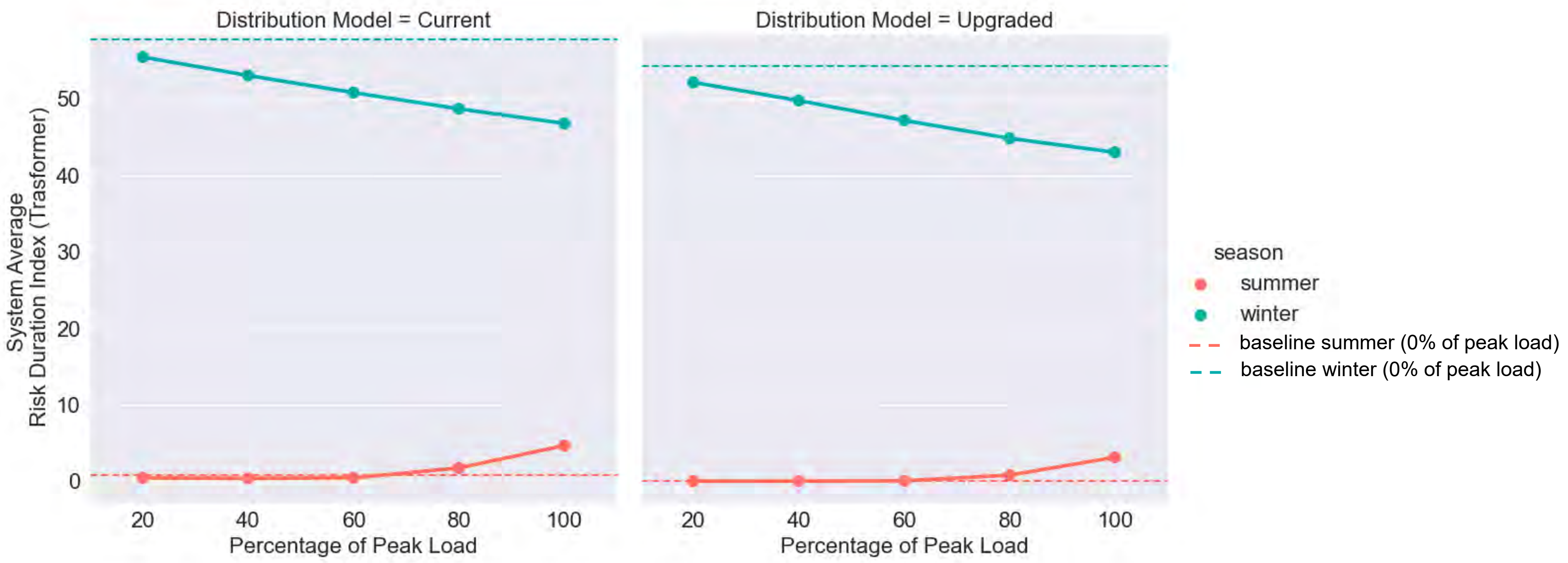
The comparison plots below show that adding energy storage, and enabling larger cost-optimal PV systems increases the benefits we see from DERs in the winter. At the same time, these large PV systems end up increasing risk in the summer at high adoption levels by causing a combination of overvoltages and asset overloading from energy export.



Percentage of Peak Load is defined as % of peak load before introducing distributed energy resources. The line plots shown take the average values across 25 simulation samples.

Rooftop Solar and Energy Storage (Future Electrification): SARDI Transformer

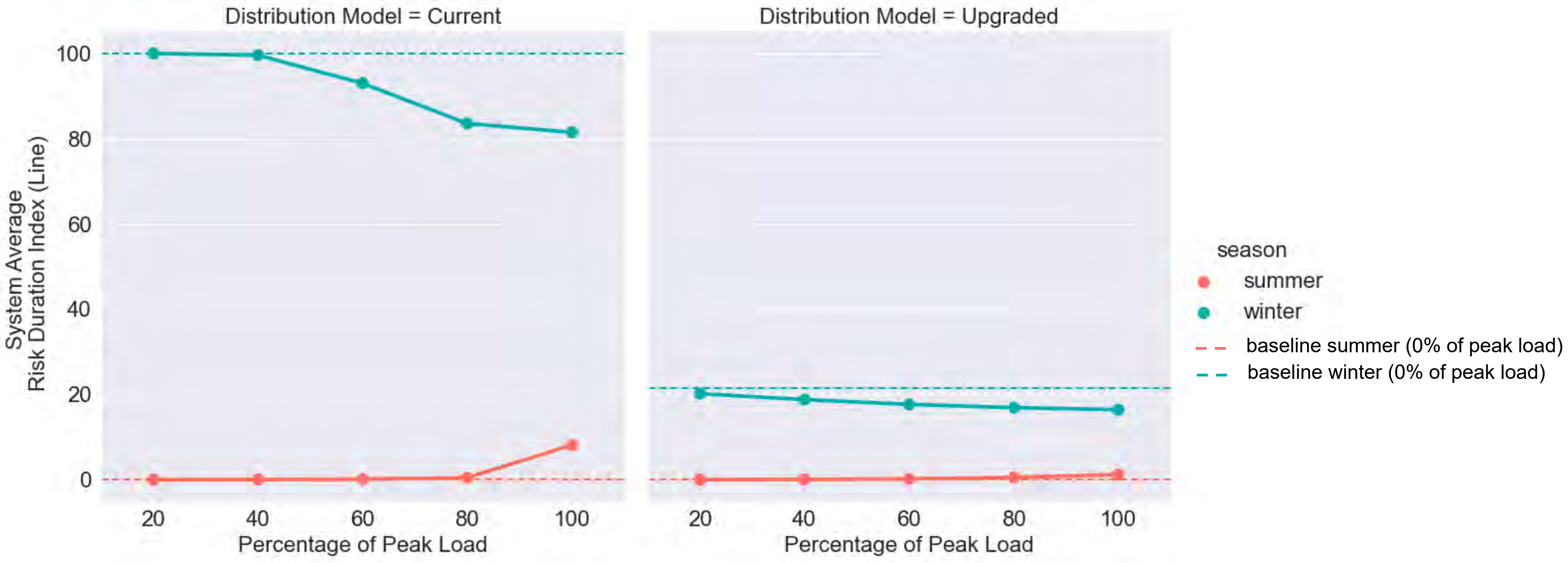
When breaking down our SARDI Aggregated, we see similar trends across each of the more specific SARDI metrics, generally decreasing risk in the winter, and increasing risk in the summer at high levels of adoption. For SARDI Transformer, we see only a small change when upgrading the feeder, given the relatively minor changes that were made to transformer sizes.



Percentage of Peak Load is defined as % of peak load before introducing distributed energy resources. The line plots shown take the average values across 25 simulation samples.

Rooftop Solar and Energy Storage (Future Electrification): SARDI Line

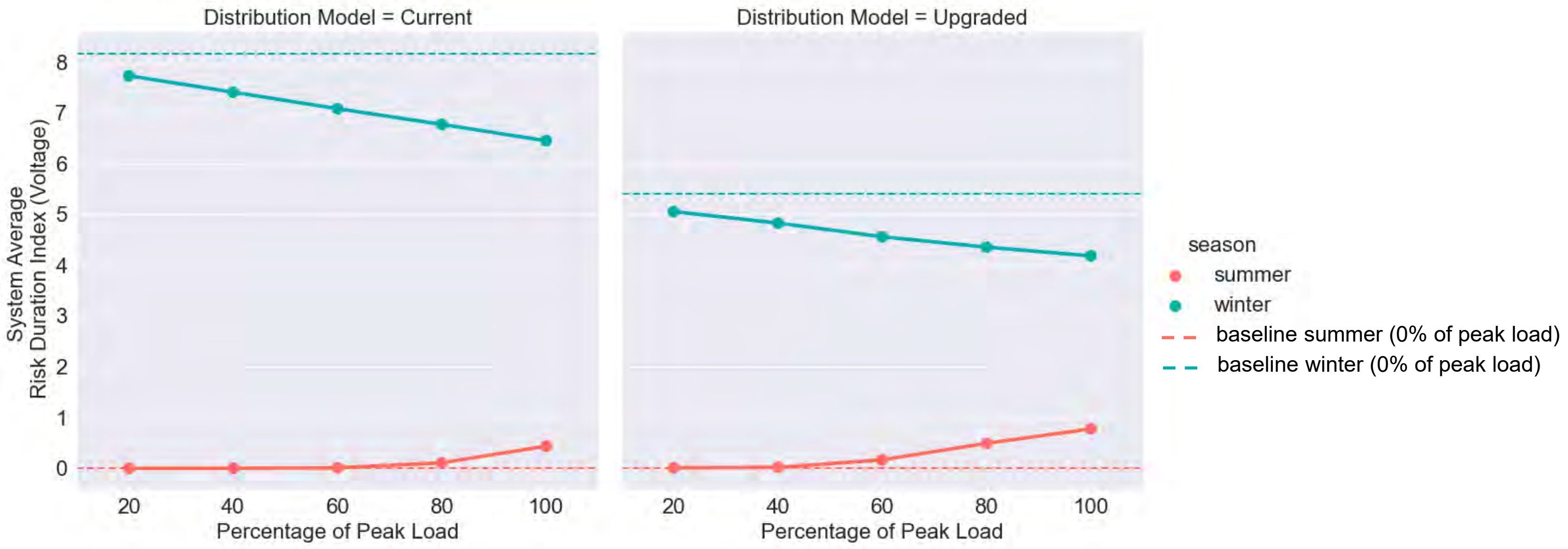
For SARDI Line, we see a much more substantial improvement when upgrading the feeder with larger conductors and a higher voltage class, though as with the previous solar-only scenario, there are remaining violations on the upgraded system.



Percentage of Peak Load is defined as % of peak load before introducing distributed energy resources. The line plots shown take the average values across 25 simulation samples.

Rooftop Solar and Energy Storage (Future Electrification): SARDI Voltage

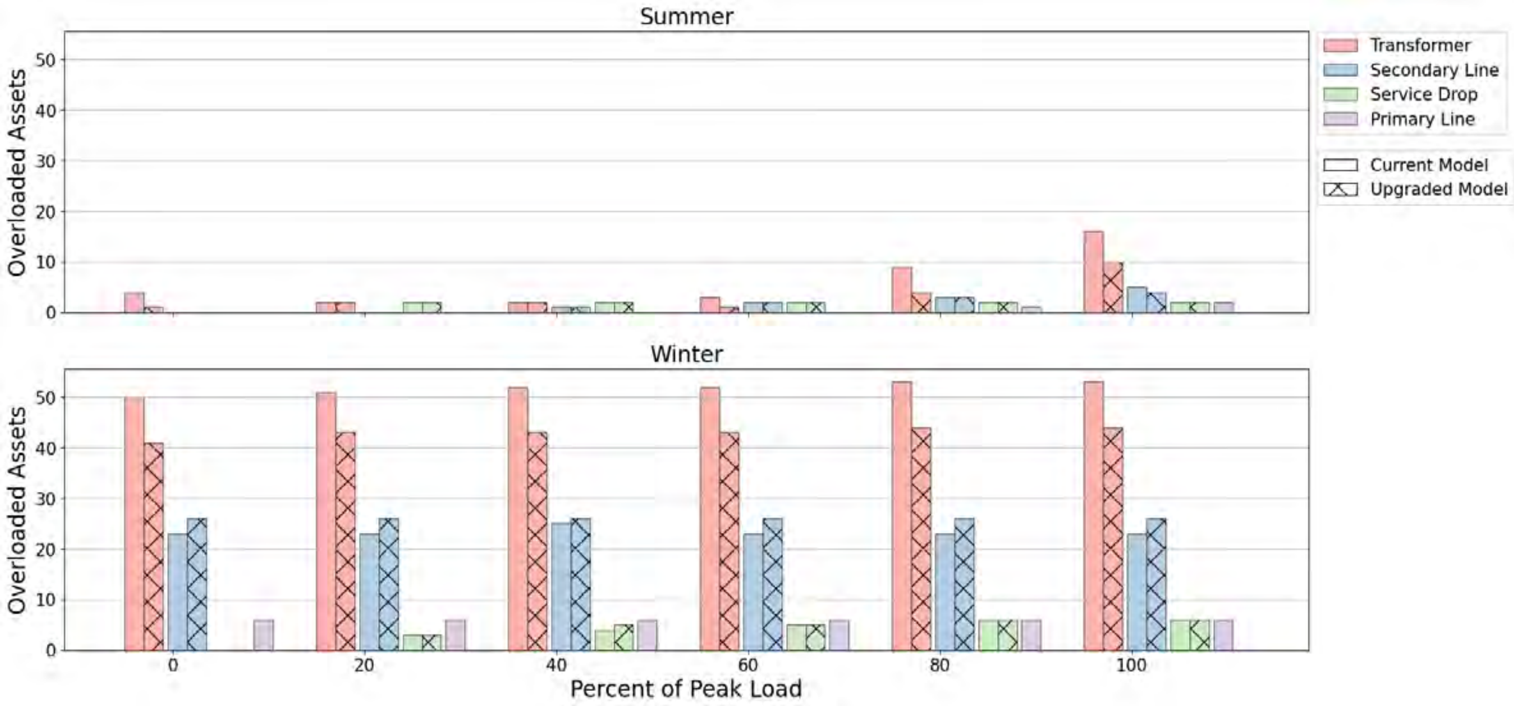
We see improvements in SARDI Voltage on the upgraded model, though some risks remain. A key distinction to be made here is that while the voltage violations in the wintertime are mostly *undervoltages* due to high loading and *improve* with additional distributed generation, the voltage violations in the summer are *overvoltages*, resultant from high amounts of solar export during periods of low load and *worsen* with additional generation. This is a great example of how distributed generation can both alleviate grid issues or cause them, depending on the pre-existing conditions that exist.



Percentage of Peak Load is defined as % of peak load before introducing distributed energy resources. The line plots shown take the average values across 25 simulation samples.

Rooftop Solar and Energy Storage (Future Electrification): Number of Overloaded Assets

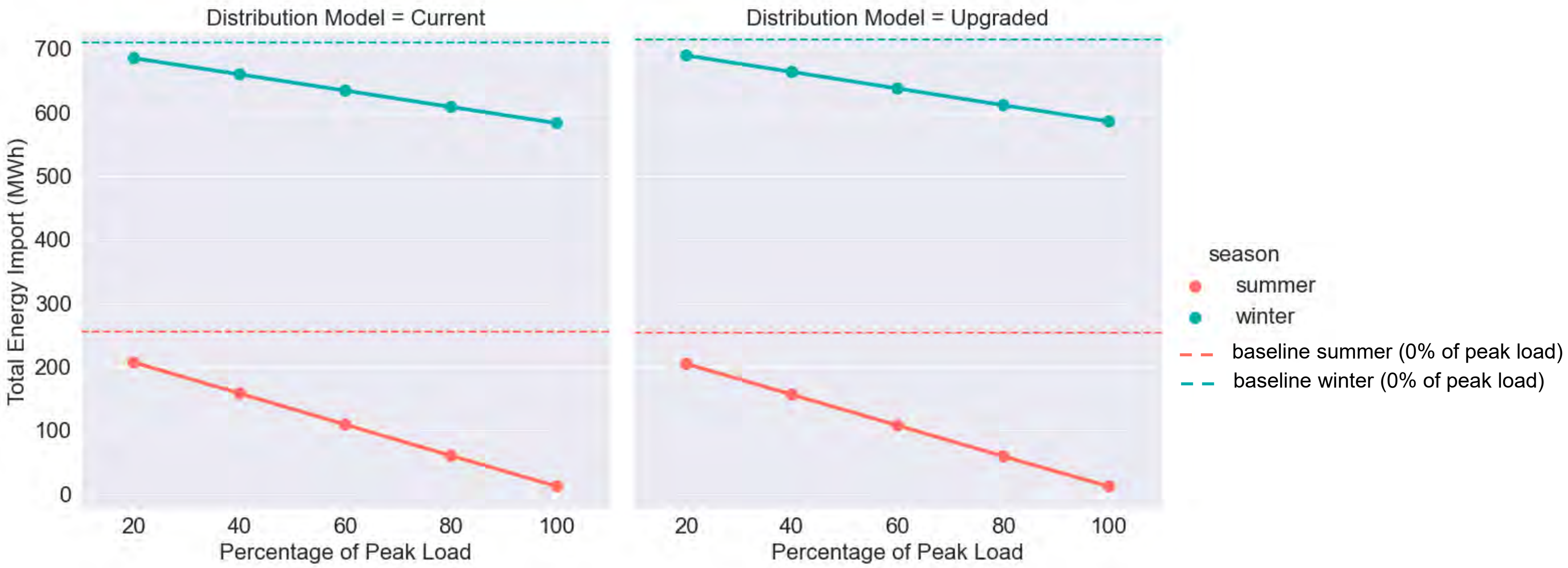
Adding energy storage to our solar-only scenario produces only small changes in the number of overloaded assets. We do begin to see a rise in overloads during the summer at high levels of DER adoption, due to the larger PV systems and increased export, as illustrated by our SARDI graphs on previous slides.



Percentage of Peak Load is defined as % of peak load before introducing distributed energy resources. The line plots shown take the average values across 25 simulation samples.

Rooftop Solar and Energy Storage (Future Electrification): Total Energy Import

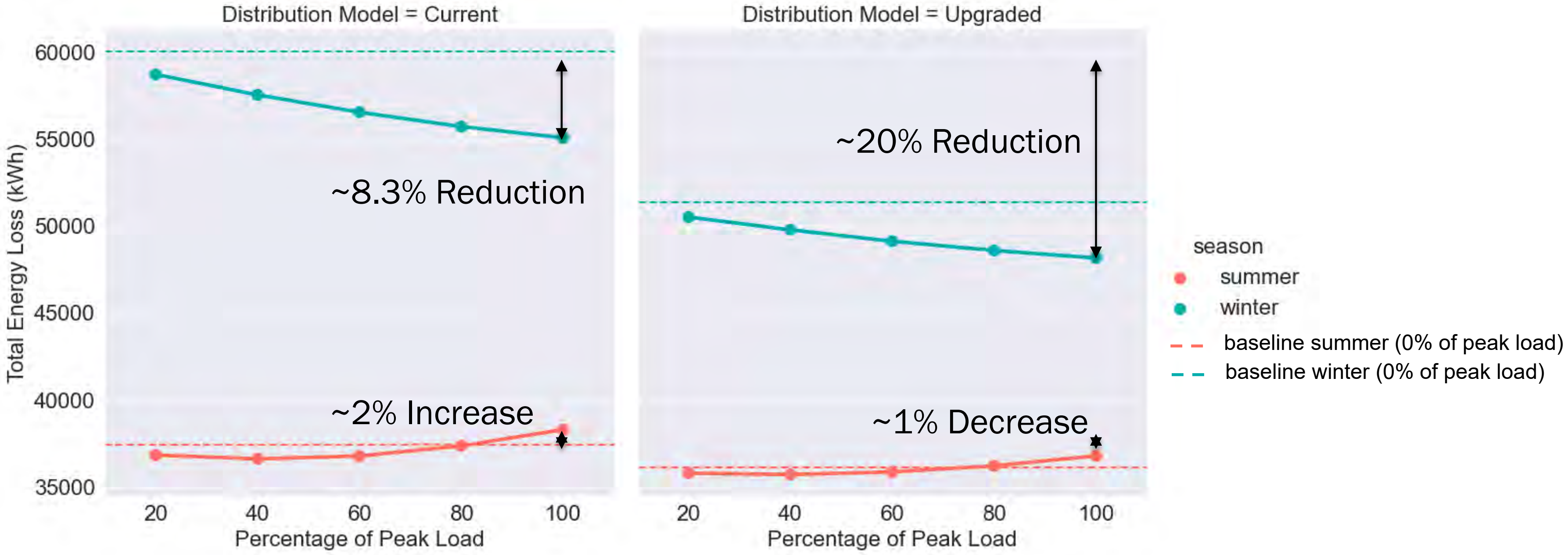
As we increase DER adoption we see energy import decline, so much so that in the summer, imports almost reach zero. While this does not mean no energy produced from bulk generation was consumed on this feeder, it means that the *net* consumption is almost zero. At times, the aggregate distributed generation on this feeder was likely exporting *to* the bulk system (i.e., reverse power flow at the substation) and at other times, energy was imported *from* the bulk power system.



Percentage of Peak Load is defined as % of peak load before introducing distributed energy resources. The line plots shown take the average values across 25 simulation samples.

Rooftop Solar and Energy Storage (Future Electrification): System Losses

Overall, we see a larger reduction in losses in the winter, compared to our solar-only model, given the larger PV systems and ability to meet 100% of the peak load in installed solar capacity. We also see a net increase in losses at high adoption levels in the summer due to the higher solar export.



Percentage of Peak Load is defined as % of peak load before introducing distributed energy resources. The line plots shown take the average values across 25 simulation samples.

Key Takeaways

- Adding battery storage allows for a larger cost-optimal rooftop solar installation at each house, alleviating the saturation effect we saw in the previous solar-only scenarios, and allowing for more significant improvements in system risk at higher levels of adoption.
- Improvements in system risk due to solar and storage adoption are seen in the wintertime, while high levels of solar adoption start to increase risk during the summertime, due to the increased export of distributed generation.
- Again, upgrading the system results in significant risk reduction, though issues in the form of overloaded secondary assets and transformers remain. Upgrading the system also reduces the negative impacts of high amounts of DER adoption seen in the summertime.
- Substantial loss reduction is seen in both models in the wintertime, though increases in losses are seen at high adoption rates in the summertime, resulting from increased export of distributed generation.
- The remaining risk levels in our upgraded model indicate the need for more robust secondary design standards.

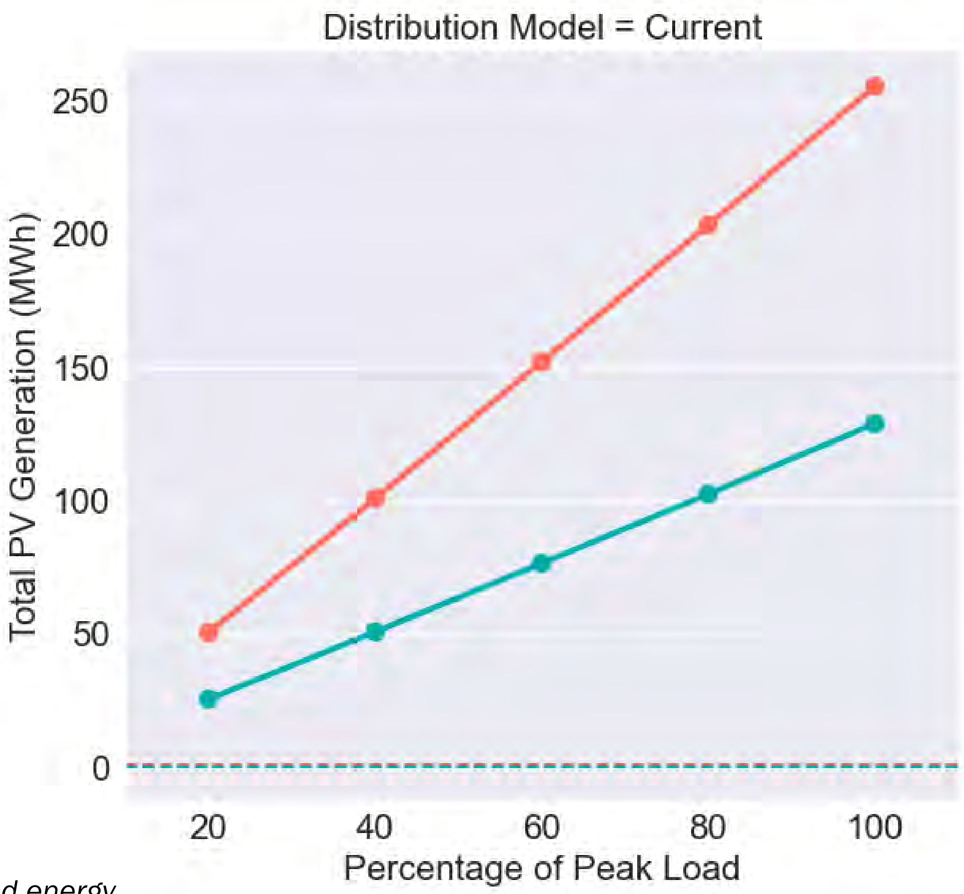
Rooftop Solar, Energy Storage and Electric Vehicles (Future Electrification): Grid Impacts

Rooftop Solar, Energy Storage, and Electric Vehicles (Future Electrification): Notes

The impacts of electric vehicles (EVs) largely depend on the time of day when customers charge. If charging lines up with solar generation, this has the potential to reduce grid impacts of both technologies, whereas if EV charging times line up with peak electric heating, this has the potential to exacerbate the grid issues of both technologies.

The following analysis assumes an 80%/20% split of level 1 (1.2 kW) and level 2 (7.6 kW) chargers, respectively. The difference in peak power demand between the two charger sizes is substantial. As a result, a high percentage of level 1 chargers only may not produce substantial additional risks when compared with building electrification. Alternatively, if a large number of level 2 chargers are installed, this would have a much more substantial impact, and may prove to be a larger concern than electric heating. At each adoption level plotted, EV chargers are installed at the same locations as those with solar and storage.

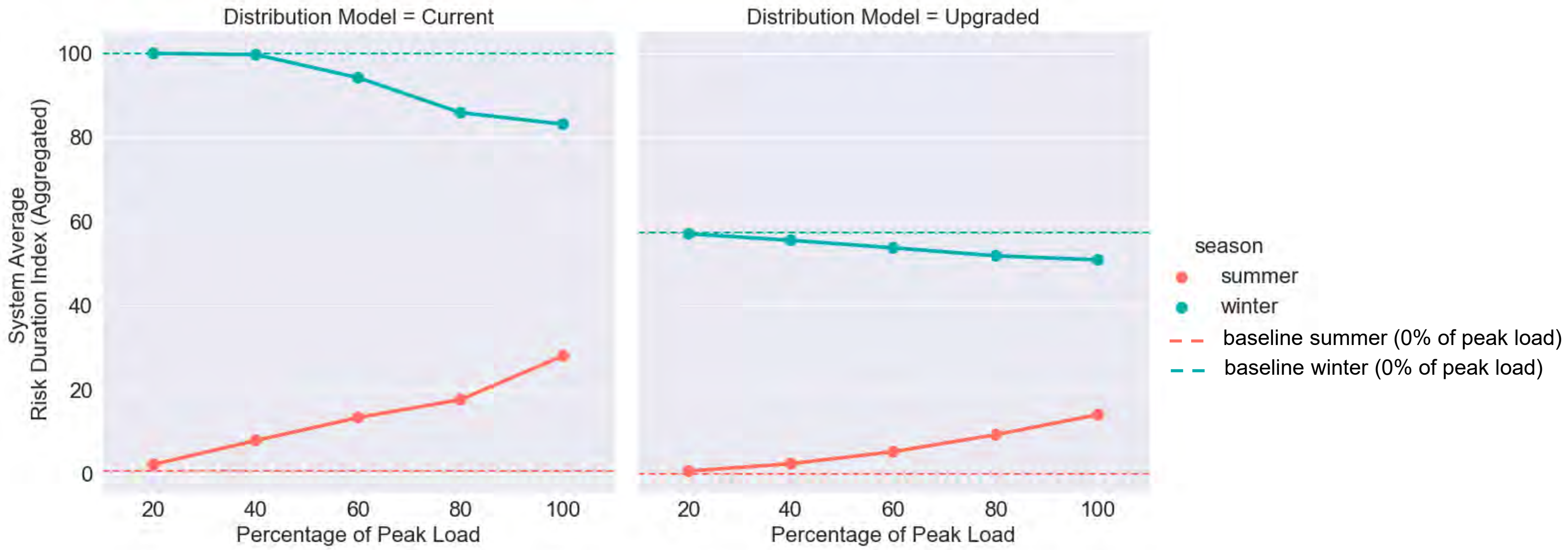
The addition of EVs does not change the algorithms or multipliers used to size solar or energy storage systems at these premises. As such, the solar generation plot to the right is identical to that of the solar + storage scenario prior.



Percentage of Peak Load is defined as % of peak load before introducing distributed energy resources. The line plots shown take the average values across 25 simulation samples.

Rooftop Solar, Energy Storage, and Electric Vehicles (Future Electrification): SARDI Aggregated

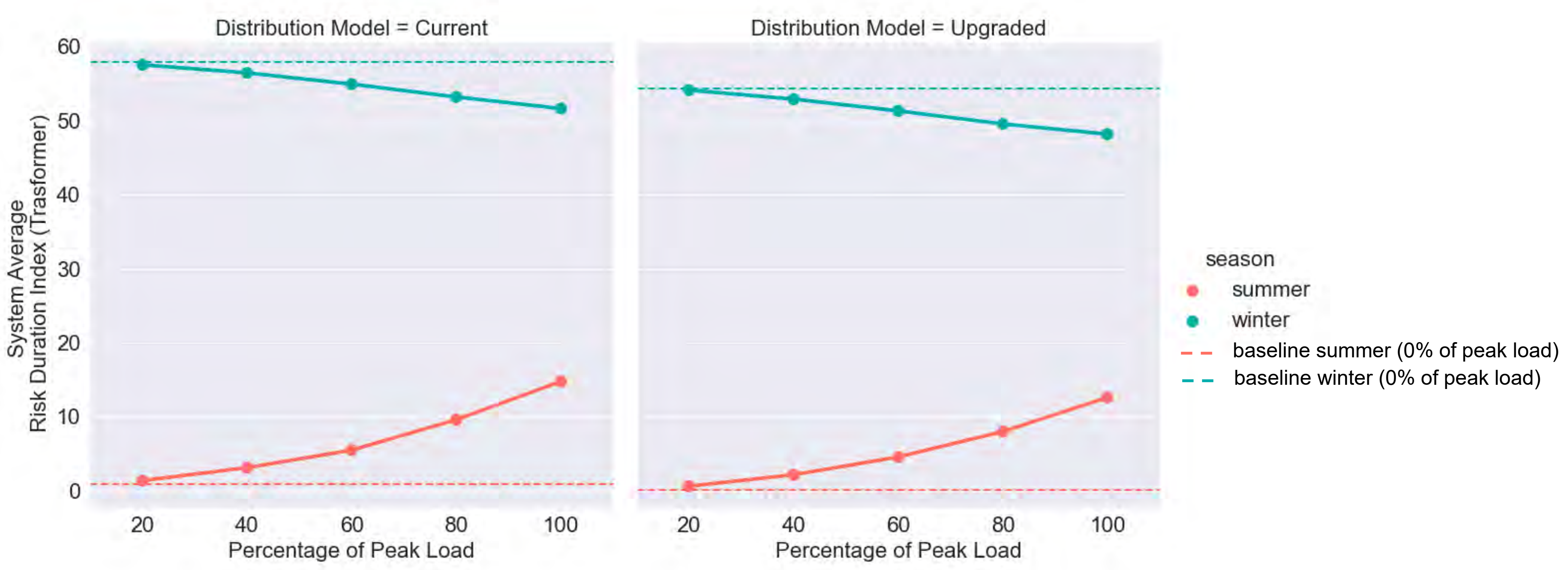
Adding the 80%/20% mix of level 1 and level 2 chargers results in almost no change in aggregated risk in the winter. This indicates that EV charging loads, as we have modeled them, for the most part, do not line up with peak heating hours and that over the modeled timeframe, building electrification presents greater risks. During the summer, we see a marked increase in risk, given the absence of any other electrification impacts. The persistent risks in our Upgraded Model indicate design standards which are not robust enough to accommodate high electrification or EV adoption, again almost exclusively on the secondary systems.



Percentage of Peak Load is defined as % of peak load before introducing distributed energy resources. The line plots shown take the average values across 25 simulation samples.

Rooftop Solar, Energy Storage, and Electric Vehicles (Future Electrification): SARDI Transformer

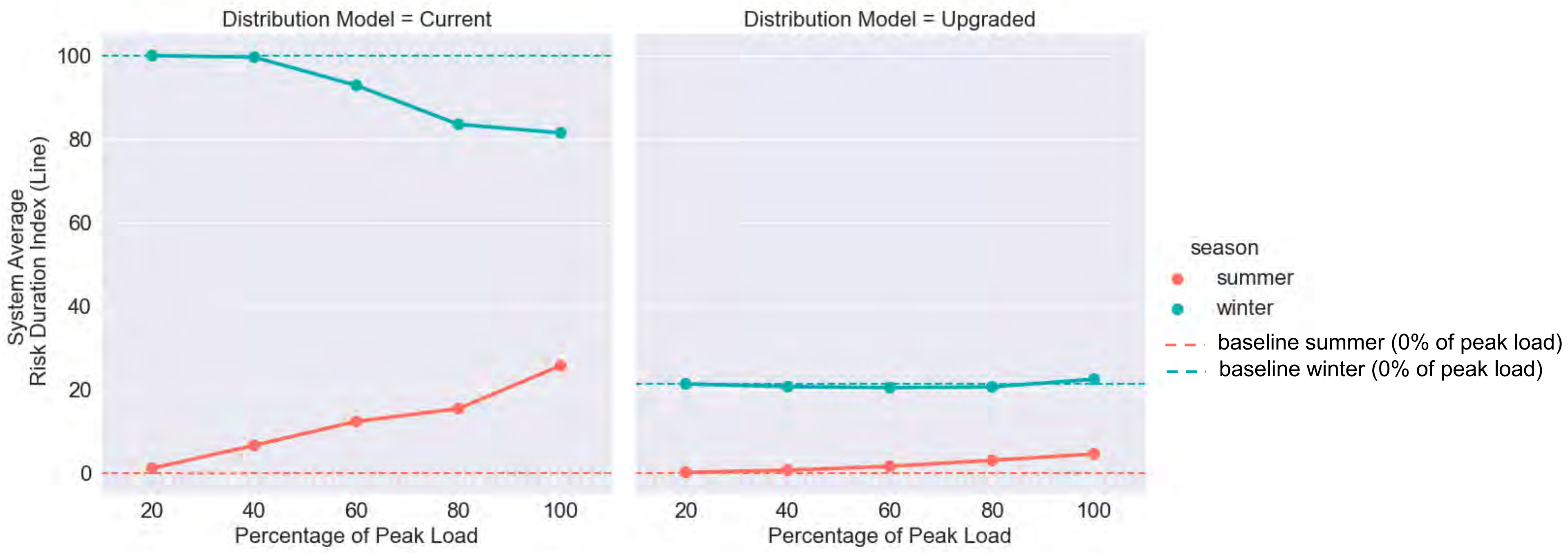
The winter trends largely mirror those in our solar-only and solar and energy storage scenarios, whereas in the summer we see a more substantial increase in risk to transformers with increasing adoption levels.



Percentage of Peak Load is defined as % of peak load before introducing distributed energy resources. The line plots shown take the average values across 25 simulation samples.

Rooftop Solar, Energy Storage, and Electric Vehicles (Future Electrification): SARDI Line

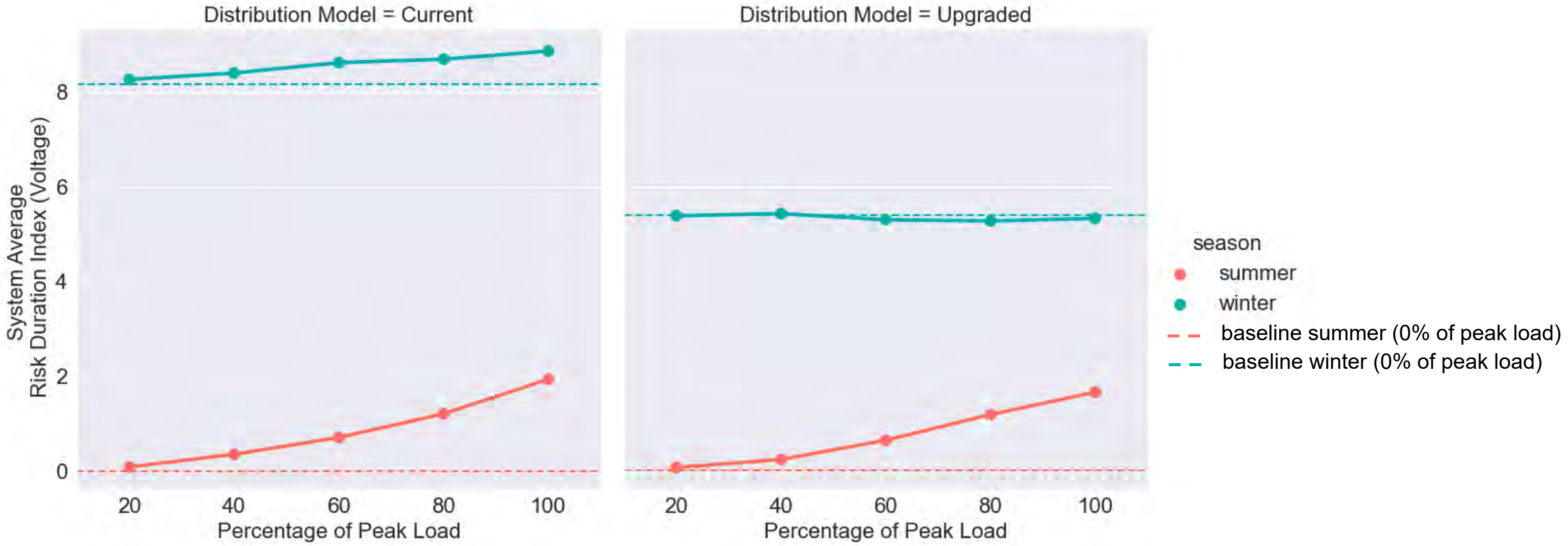
The SARDI Line metric for this scenario again looks very similar to those for the solar and energy storage scenario during the winter months, though there is slightly less of a risk improvement in our Upgraded Model. This indicates that at high levels of EV adoption, we start to see increases in risk that are not being mitigated by the presence of distributed generation and/or energy storage. Similar to the other SARDI metrics, we see an increase in risk from EV adoption in the summer across both the Current and Upgraded Models.



Percentage of Peak Load is defined as % of peak load before introducing distributed energy resources. The line plots shown take the average values across 25 simulation samples.

Rooftop Solar, Energy Storage, and Electric Vehicles (Future Electrification): SARDI Voltage

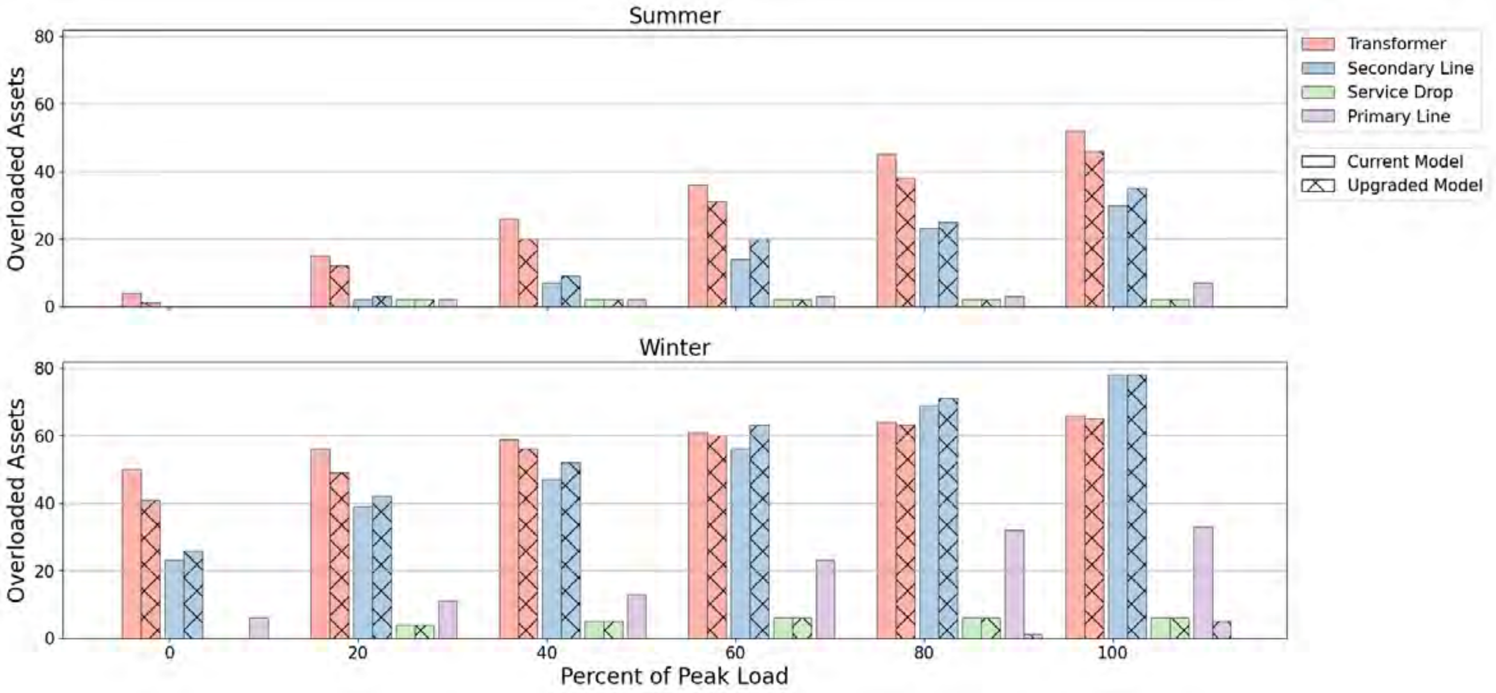
While our aggregated SARDI metric trends down in the winter, our SARDI *Voltage* trends *up* in our Current Model. Given that this is opposite to what we saw in our solar and energy storage scenario, this is likely a result of undervoltages occurring during charging hours. This may be a result of times when charging hours overlap with heating hours. The steeper increase in voltage violations in the summer, compared with the previous scenarios is indicative that there may be a combination of both overvoltages from solar export *and* undervoltages from EV charging loads.



Percentage of Peak Load is defined as % of peak load before introducing distributed energy resources. The line plots shown take the average values across 25 simulation samples.

Rooftop Solar, Energy Storage, and Electric Vehicles (Future Electrification): Number of Overloaded Assets

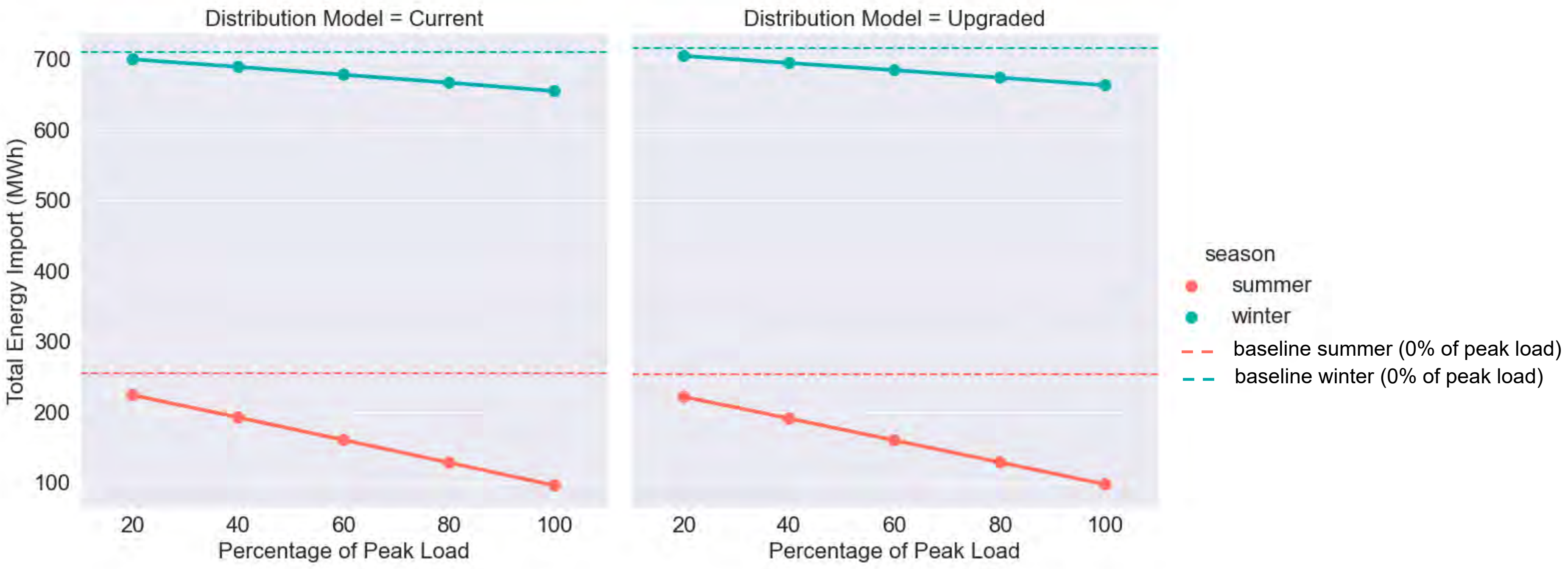
The results below show a substantial increase in the number of overloaded assets in both the summer and winter months compared with our solar + energy storage scenario.



Percentage of Peak Load is defined as % of peak load before introducing distributed energy resources. The line plots shown take the average values across 25 simulation samples.

Rooftop Solar, Energy Storage, and Electric Vehicles (Future Electrification): Total Energy Import

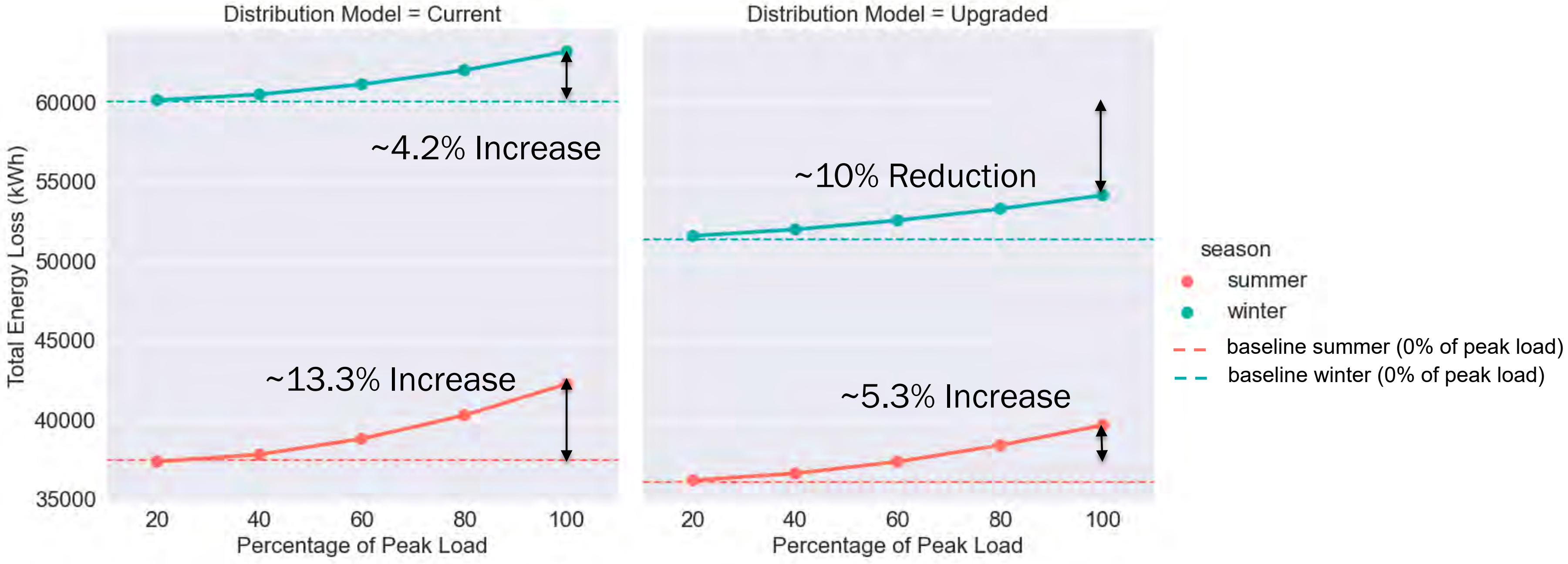
Compared with our previous scenario, we see a flatter, but still downward slope to our energy import. While added distributed generation decreases overall energy imports, this effect is partially offset by the added loads from increasing electric vehicle adoption at the same households.



Percentage of Peak Load is defined as % of peak load before introducing distributed energy resources. The line plots shown take the average values across 25 simulation samples.

Rooftop Solar, Energy Storage, and Electric Vehicles (Future Electrification): System Losses

Contrary to all other scenarios evaluated within this study, here we see an increase in losses, in both seasons, across both models as DER adoption increases. That said, we still see a net reduction in our wintertime Upgraded Model when compared to the baseline in our Current Model.



Percentage of Peak Load is defined as % of peak load before introducing distributed energy resources. The line plots shown take the average values across 25 simulation samples.

Key Takeaways

- Our modeled EV adoption assumes an 80%/20% split of level 1 and level 2 chargers, respectively. Level 1 chargers have a peak charging demand of 1.2 kW, while level 2 chargers can charge at a peak of 7.6 kW.
- EV charging patterns are modeled using NREL's EVOLVE tool, approximating customer behaviors and typical coincidence of charging demand across the region of Highland Park.
- The addition of EV chargers further exacerbates system risk, with notable increases in risk during the summertime at high adoption levels.
- The added demand from EV charging results in increased system losses. This increase is likely reduced, but not entirely offset, by the addition of distributed generation from rooftop solar.
- Our upgraded model shows less, but still significant levels of risk, indicating the need for revised design standards to accommodate the modeled levels of DER/EV adoption.

Risk Metrics Summary Table

Analysis Scenarios *Battery sizing is based on 24-hour outage survival resilience objective	SARDI Aggregated (100% Average) (Summer/Winter)	SARDI Transformer (100% Average) (Summer/Winter)	SARDI Line (100% Average) (Summer/Winter)	SARDI Voltage (100% Average) (Summer/Winter)
Baseline Risk, Current Model, Base Electrification	0.64/0.54	0.64/0.54	0.00/0.00	0.00/0.00
Solar Only, Current Model, Base Electrification	0.42/0.51	0.41/0.50	0.01/0.01	0.00/0.00
Solar Battery, Current Model, Base Electrification	0.33/0.43	0.33/0.43	0.00/0.01	0.00/0.00
Baseline Risk, Upgraded Model, Base Electrification	0.02/0.00	0.00/0.00	0.00/0.00	0.02/0.00
Solar Only, Upgraded Model, Base Electrification	0.22/0.20	0.16/0.17	0.13/0.10	0.03/0.02
Solar Battery, Upgraded Model, Base Electrification	0.12/0.11	0.05/0.06	0.07/0.08	0.02/0.01
Baseline Risk, Current Model, Future Electrification	0.87/100.00	0.87/57.87	0.00/100.00	0.00/8.17
Solar Only, Current Model, Future Electrification	0.47/98.82	0.44/54.12	0.02/98.26	0.01/7.62
Solar Battery, Current Model, Future Electrification	10.17/83.16	4.67/46.82	8.11/81.50	0.44/6.45
Baseline Risk, Upgraded Model, Future Electrification	0.085/57.44	0.075/54.31	0.00/21.44	0.01/5.40
Solar Only, Upgraded Model, Future Electrification	0.23/53.20	0.18/50.53	0.14/19.35	0.04/4.98
Solar Battery, Upgraded Model, Future Electrification	4.24/45.48	3.14/43.05	1.18/16.42	0.78/4.18
Solar Battery EV, Current Model, Future Electrification	28.11/83.18	14.75/51.63	25.68/81.47	1.93/8.87
Solar Battery EV, Upgraded Model, Future Electrification	14.13/50.92	12.59/48.17	4.56/22.46	1.66/5.33

Estimate of Upgrade Costs

Key Considerations for System Upgrade Costs

- A significant portion of DTE's legacy 4.8 kV distribution system was built nearly a century ago and is in a state of severe decay today. Hardening such a system, while also bringing it up to current construction standards, would likely entail a nearly full rebuild of all distribution assets.
- Beyond the reconductoring, transformer replacements, and modifications to grid topologies represented in this study, some of the more significant cost adders associated with such an upgrade include a full substation rebuild, replacement of poles and crossarms, vegetation management, increasing the number and size of service transformers, implementing grid modernization technologies, and the labor.
- Further study is required to estimate the cost of system-wide upgrade needs specific to Highland Park. Components listed on slide 13 are the minimum upgrades necessary to study the impact of an upgraded 13.2 kV system but does not include costs for other necessary infrastructure.
- As part of a comprehensive rebuild, it would be advantageous to also incorporate modern grid technologies (e.g., SCADA, grid automation, modern system protection, etc.) to ensure superior reliability in the long run and contribute to wider grid modernization initiatives.
- For such a comprehensive upgrade as described above, DTE's estimate is \$2.4–\$3.0 million per mile.[1]
- This project did not estimate the total length/size of DTE's distribution system in Highland Park. This grid impact analysis only considered a portion of the Highland Park distribution network (see slide 10).

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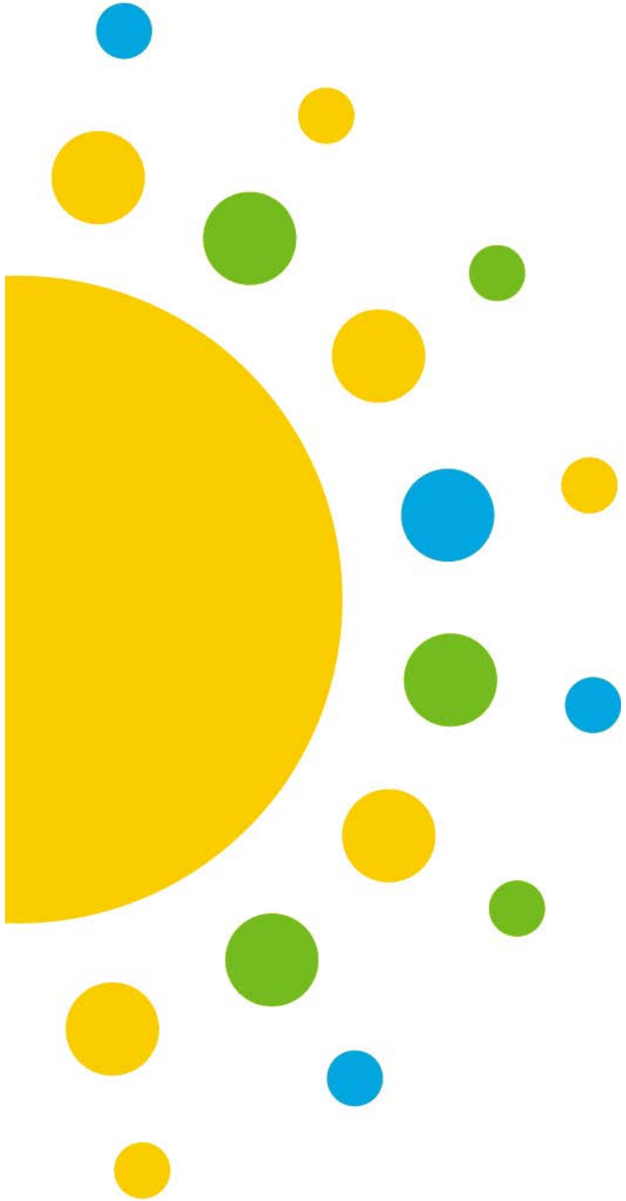
[1] Wang, Joy. "DTE Electric 4.8kV Technical Conference," n.d. https://www.michigan.gov/mpsc/consumer/electricity/dte-electric-4-8kv-technical-conference.



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EARLY LIFE

Meta-analysis of the effects of indoor nitrogen dioxide and gas cooking on asthma and wheeze in children

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Background Since the meta-analysis on the association between indoor nitrogen dioxide (NO_2) and childhood respiratory illness in 1992, many new studies have been published. The quantitative effects of indoor NO_2 on respiratory illness have not been estimated in a formal meta-analysis since then. We aimed to quantify the association of indoor NO_2 and its main source (gas cooking) with childhood asthma and wheeze.

Methods We extracted the association between indoor NO_2 (and gas cooking) and childhood asthma and wheeze from population studies published up to 31 March 2013. Data were analysed by inverse-variance-weighted, random-effects meta-analysis. Sensitivity analyses were conducted for different strata. Publication bias and heterogeneity between studies were investigated.

Results A total of 41 studies met the inclusion criteria. The summary odds ratio from random effects meta-analysis for asthma and gas cooking exposure was 1.32 [95% confidential interval (CI) 1.18–1.48], and for a 15-ppb increase in NO_2 it was 1.09 (95% CI 0.91–1.31). Indoor NO_2 was associated with current wheeze (random effects OR 1.15; 95% CI 1.06–1.25). The estimates did not vary much with age or between regions. There was no evidence of publication bias.

Conclusions This meta-analysis provides quantitative evidence that, in children, gas cooking increases the risk of asthma and indoor NO_2 increases the risk of current wheeze.

Keywords Asthma, wheeze, gas cooking, indoor pollution, infant, review

Introduction

The association between adverse health consequences and indoor nitrogen dioxide (NO_2) exposure has been the subject of many studies. Indoor NO_2 exposure may increase the risk of acute and chronic respiratory illnesses, reduce lung function and initiate and exacerbate asthma, especially in children.[1–4] One reason is the long periods of time that children spend indoors.[5]

In 1992, Hasselblad *et al.*[2] carried out a meta-analysis including 11 studies, which concluded that children exposed to a long-term increase of 15 ppb NO_2 indoors suffer a 20% increase in respiratory illness risk. This early quantitative analysis became a benchmark study for the relationship between indoor NO_2 and respiratory illness in children, and an important reference for the outdoor NO_2 Air Quality Guideline value established by the World Health Organization (WHO) in 1997[6] and confirmed in 2005.[7] More recently, WHO has reviewed studies on indoor NO_2 exposure, but without doing a formal meta-analysis.[8] Recent journal reviews of the issue[1,4,9–11] have also been qualitative. In view of the dearth of quantitative meta-analyses based on recent studies, we decided to review studies on asthma, wheeze, gas cooking and indoor NO_2 in children with the purpose of obtaining quantitative effect estimates.

Methods

Selection criteria

We searched for studies from which quantitative effect estimates of the relationship between gas cooking, indoor NO_2 and respiratory health effects in children could be obtained. We attempted to identify all population studies in relation to this topic. The literature was searched with PubMed and ISI Web of Knowledge from 1977 up to 31 March 2013 with the following search terms: (i) indoor nitrogen dioxide and children; (ii) personal nitrogen dioxide and children; (iii) gas cooking and children; (iv) gas appliance and children; (v) unvented and children; (vi) gas heating and children; and (vii) gas heater and children. The seven search results were combined with the Boolean operator 'or'. All of the 34 epidemiological studies included in Table 5.2 of the recent WHO guidelines for indoor air quality and citations from previous reviews and identified articles were considered as well. Duplications were removed.

To be eligible for inclusion, studies had to: (i) be published in English; (ii) be primary study, not reviews; (iii) examine respiratory disease in infancy or in childhood (defined by a maximum age of subjects $\leqslant$18 years) as outcomes; (iv) examine exposure to indoor NO_2 or household gas cooking or gas heating; (v) be conducted within family houses, not in schools or classrooms; and (vi) report an odds ratio or other effect estimator[12] or sufficient data to estimate them. Articles fulfilling all six criteria were included for further review (Figure 1).

All studies were reviewed according to the six inclusion criteria. Commentaries, and studies not performed in children or exposures not relevant or without respiratory outcomes, were excluded. The remaining articles were reviewed independently by the three authors. Articles that did not report on the association between selected exposure variables and

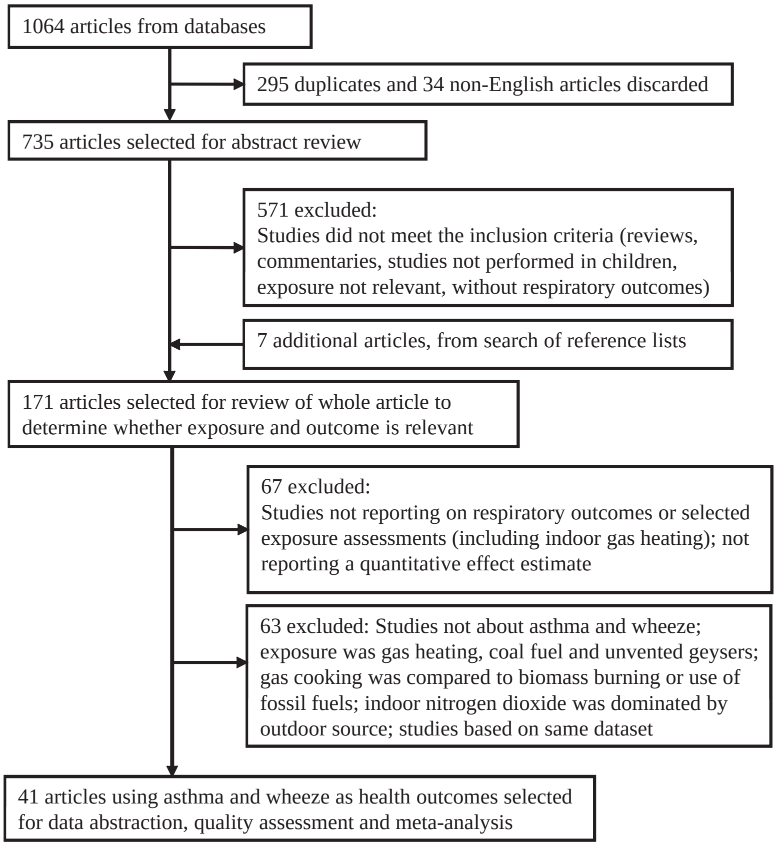


Figure 1 Study selection flow chart

respiratory outcomes in children, that could not isolate indoor gas appliances from other combustion/energy sources (that is studies where gas, coal, wood, kerosene or fireplace cooking/heating were combined into one exposure group), that compared gas cooking with biomass burning or use of fossil fuels and that included indoor and/or personal NO_2 concentrations that were mainly affected by outdoor pollution from traffic (that is studies with personal monitoring of NO_2 where the sampling period covered both indoor and outdoor activities; and studies with indoor NO_2 measurements, in the absence of indoor sources, i.e. studies in populations with low prevalence (<10%) of gas stoves) were excluded (Figure 1).

Respiratory outcome selection

The respiratory outcomes of the studies that met the inclusion criteria included various symptoms such as rhinitis, phlegm, cough, chest illnesses, asthma and wheeze as well as lung function parameters. We restricted our review to the respiratory outcomes of wheeze and asthma, the two outcomes most frequently used in epidemiological studies among children. Both self-reported and doctor-diagnosed (either from self-reported questionnaire or clinical evaluation) asthma and self-reported wheeze were selected, in spite of the fact that the precise definition of such assessments might have some variability between studies. Furthermore, according to the occurrence time of asthma and wheeze, we categorized them into 'current asthma', 'lifetime asthma', 'current wheeze' and 'lifetime wheeze' to overcome the dilemma of various definitions of those health outcomes. 'Current' was defined as having incident asthma (or wheeze) with the symptoms occurring within the 12 months prior to the questionnaire. 'Lifetime asthma' was defined as ever having been diagnosed with asthma by a doctor; 'lifetime wheeze' was defined as wheeze ever. If studies defined wheeze in more than one way,[13] we selected wheeze without colds to avoid inclusion of symptoms related primarily to respiratory infections. We acknowledge that respiratory infections could be an interesting outcome by themselves.

Data abstraction

Studies on gas heating often lacked information on whether the heater was directly vented to the outside, in which case it would not be a source of indoor air pollution. For this reason, we did not include gas heating[14–19] in the meta-analysis; indoor NO_2 and gas cooking were the exposure variables that we focused on.

Ideally, meta-analysis would combine estimates only from studies with exactly the same exposure variables; we included studies for meta-analysis that were as similar as practicable with respect to these. One study about unvented kitchen geysers[20] was excluded because the reference category included gas cooking. One study[21] that compared the risk effect of gas cooking vs other cooking fuels was excluded because it compared two sources of combustion products. One study[22] that did not distinguish gas cooking from coal cooking was excluded. The concentrations of indoor NO_2 in some studies[23–26] were clearly dominated by traffic outdoors, because the percentage of study homes with household gas stoves was small; we excluded those studies as well. One panel study[27] was not included as this study provided insight only into the short-term exposure and its health effects. Two publications by Garrett *et al.*[28,29] were based on the same study population and data except for different confounder adjustment; we only included one study.[29] In this review, we refer to each population as a separate study and used the corresponding effect estimates; thus we excluded the combined risk estimates from Moshammer *et al*.[30] because we had already included the individual studies on which this paper was based. The study by von Maffei[31] was excluded because it was unclear whether it was current or lifetime asthma. In the end, 41 studies were selected for further analysis.

Selected articles were appraised using a data extraction form. Information on authors, publication year, country of origin, study design, population characteristics (gender and age), exposure definition (including proportion of gas cooking), definitions of respiratory outcomes in each reviewed article and the meta-analysis, risk measure and confounding factors was extracted.

If unadjusted and adjusted results were both reported, we extracted the one adjusted for potential confounding factors. Where more than one adjusted result was presented, we chose the one with adjustment of smoking in the family.[32] When a study reported only the number of cases and controls among the exposed and unexposed, we calculated the crude odds ratio and its corresponding 95% confidence interval (CI) following.[12] When a multi-city study provided risk estimates for single cities in addition to a combined estimate, we selected the combined estimates. If there were no combined estimates, risk estimates for single cities were used. If more than one follow-up analysis had been reported for the same population, we used results where health outcomes and exposure were measured in the same period[33–35] [e.g. questionnaire and indoor NO_2 measured in the same year; results linking childhood (adolescent) exposure to childhood (adolescent) health outcomes]. If results were presented separately for different locations of indoor NO_2 (kitchen, living room and bedroom), we extracted the results from living room, which were most frequently reported in other studies.[36] In Hoek *et al.*'s[36] study, we assumed that the majority of NO_2 concentration was in the range of 10–100 $\mu g/m^3$, based on the data that the geometric mean of NO_2 in the living room was 68.4 $\mu g/m^3$, and recalculated the effect estimates. The 95% confidence intervals were either extracted directly from the original articles or calculated by standard error transformation.

Statistical methods

We conducted meta-analyses to obtain summary risk estimates for the association between asthma, wheeze and household NO_2 exposure and its surrogate, gas cooking. For every single exposure variable, to distinguish the differing reporting times of symptoms between studies, we reported not only the overall meta-OR combining all the studies but also the subgroup meta-ORs in both ‘current’ and ‘lifetime’ asthma (or wheeze). When a study reported risk estimates for different strata of the population, e.g. for boys and girls,[34,37–39] children with asthmatic mothers or non-asthmatic mothers[40] and children living in single- or multi-family houses,[41] we included these directly into the meta-analysis without combining them first. The risk estimates for the exposure ves non-exposure categories of gas cooking were summarized.

For NO_2 exposure, we calculated two types of pooled risk estimates: (i) for the comparison of asthma and wheeze risk at high vs low exposure independently of the exact definition of high and low exposure, and (ii) for asthma and wheeze risk per 15-ppb increase in continuous NO_2 concentration. For inclusion in the meta-analysis, we converted all results in $\mu g/m^3$ to 15 ppb using standard pressure and temperature. In the high vs low exposure meta-analysis, the included studies reported different specific ranges for NO_2, which precludes a direct comparison of effect estimates from these studies. Some studies categorized NO_2 levels into more than two categories; from these, we selected ORs for the highest compared with the lowest exposure category. We appreciate that this analysis is semi-quantitative.

Heterogeneity

We used standard chi-square tests to examine the heterogeneity among studies; results were defined as heterogeneous for $P < 0.10$.[42] The I^2 statistic was used to quantify the extent of inconsistency among the studies. The I^2 values <25% reflect low inconsistency, values of 25–75% reflect moderate inconsistency, whereas values >75% indicate high inconsistencies among studies.[43] Due to the heterogeneity among studies which were performed independently by different researchers in different populations, pooled risk estimates were calculated by random-effect models with inverse-variance weights.[44] Summary estimates from fixed-effect models were also presented in the Forest plots for comparison.

Influence analysis

To evaluate the influence of individual studies on the summary effect estimate, we performed influence analysis. This method recalculated the summary estimate, omitting one study at a time.

Sensitivity analysis

Sensitivity analyses were employed to test whether the risk estimates varied by study region and age of the participants. Age was categorized into ⩽6 years, 6–10 years and >10 years. Further subdivision of the youngest category was not possible because of the number of studies performed within that age range. Study regions were divided into Europe, North America, and Asian and Pacific area.

We noticed that the proportion of gas cooking varied considerably between studies. In order to examine whether observed exposure health relationships of a study were associated with the percentage exposed to gas cooking, stratified analyses were performed using 30% of cooking with gas stoves as a cut-off.

In our database, there were some studies which were conducted a long time ago. Since then, the actual use and the emissions of gas cookers as well as disease management strategies may have changed. To examine the influence of older studies, we compared risk estimates between older and newer studies as part of a sensitivity analysis. For operational purposes, the publication year 2000 was used as the cut-off.

Subsequently, exploratory univariate meta-regressions were performed to assess whether heterogeneity in associations between gas cooking and asthma and wheeze between studies was related to age of the participants, study region, proportion of gas cooking and year of publication.

Furthermore, random effects models were performed to determine the potential impact by asthmatic subjects. Asthmatic children may be more sensitive to the effects of indoor NO_2. Therefore, we repeated analyses of the associations of gas cooking and indoor NO_2 with wheeze by excluding two studies which focused on asthmatic children only at the initial recruitment.

Assessing publication bias

Publication bias was evaluated with funnel plots and the Egger’s and Begg’s tests.[45]

All statistical analyses were performed using STATA (version 10; StataCorp LP, College Station, TX, USA), employing the ‘metan’, ‘metabias’ and ‘metainf’ commands for meta-analyses and bias evaluation. ‘Metareg’ was used to test differences in effect size between subgroups of studies.

Results

A flow chart of the selection stages of the studies for analysis is shown in Figure 1. We extracted data from 41 studies published since 1977 assessing the relationship between household NO_2 or gas cooking and asthma and wheeze (Supplementary Table 1, available as Supplementary data at IJE online).[13,29,32–41,46–74] Among those 41 studies, 19 studies were conducted in Europe (UK, Austria, Germany, Netherlands, Czech Republic, Spain and Russia), 14 in North America (USA and Canada), 3 in Asia (China and Japan), 4 in Australia and 1 in New Zealand. Among them, four studies contributed information on infants[32,40,65,75] and two studies on asthmatic children;[41,46] the rest were studies on general populations of school-age children. There were 16 cross-sectional, 18 cohort, and 7 case-control studies. However, most of the reports from cohort studies were based on cross-sectional rather than longitudinal analysis. Three studies included the association between previous gas cooking exposure and the development of respiratory symptoms: De Bilderling *et al.*[33] and Ponsonby *et al.*[32] used a cohort design to link early exposure estimates to subsequent risk of wheeze and asthma, and Wong *et al.*[35] used a survey study with a retrospective questionnaire. The other reviewed studies focused mainly on whether the presence of respiratory symptoms was associated with current exposure

The meta-analysis of findings from 19 studies on the association between gas cooking and asthma (Figure 2) demonstrates an increased odds of current asthma [random effects meta-odds ratio (OR) 1.42; 95% CI, 1.23–1.64, $P = 0.000$, $n = 11$ studies) and lifetime asthma (1.24; 95% CI, 1.04–1.47, $P = 0.014$, $n = 8$ studies) in children exposed to gas cooking. The overall odds ratio was 1.32 (95% CI, 1.18–1.48, $P = 0.000$; $I^2 = 19.8\%$, heterogeneity P-value $= 0.204$) for the association between asthma and gas cooking (Figure 2a) and 1.09 (95% CI, 0.91–1.31, $I^2 = 35.5\%$, heterogeneity P-value $= 0.185$) per 15-ppb increase in NO_2 exposure (Figure 2b). Indoor NO_2 was positively associated with the odds of current wheeze (random effects meta-OR 1.15 per 15 ppb, 95% CI, 1.06–1.25, $P = 0.001$) (Figure 3b). There was only one study reporting lifetime wheeze in children exposed to indoor NO_2; combining it into the meta-analysis yielded a pooled random effects OR of 1.12 (95% CI, 1.04–1.21, $P = 0.002$, $I^2 = 11.3\%$, heterogeneity P-value $= 0.337$). The combined analysis of 28 studies, including >11 000 children with wheeze, demonstrated no increased risk in children who had ever been exposed to gas cooking (random effects meta-OR = 1.06, 95% CI, 0.99–1.13, $I^2 = 42.8\%$, heterogeneity P-value $= 0.006$) (Figure 3a). Results for current wheeze (random effects meta-OR = 1.07, 95% CI, 0.99–1.15, heterogeneity P-value $= 0.002$) were similar to results for all wheeze. We observed heterogeneity among those studies, with I^2 of 50.4% and 42.8% for current and all wheeze, respectively. Therefore, the combined estimates for lifetime wheeze based on the random effects model were likely to represent the effect more accurately. The Forest plots ordered by publication date (Figures 2 and 3) show that there was no obvious trend in risk estimates over time. An influence analysis showed that no single study dominated the combined estimates.

Four of the 41 studies compared children exposed to high $NO_2$with children exposed to low NO_2.[49,53,65,69] We did not find an increase in asthma[49,53] (random effects meta-OR = 1.10, 95% CI, 0.35–3.40, $I^2 = 49.5\%$, heterogeneity P-value $= 0.159$) and in wheeze[53,65,69] (random effects meta-OR = 0.81, 95% CI, 0.59–1.12, $I^2 = 0.0\%$, heterogeneity P-value $= 0.715$) among children with the highest compared with the lowest NO_2 exposure. The results, however, should be interpreted with caution because the number of studies included was small.

We performed additional analyses to examine the pooled estimates for wheeze when restricted to general populations of children, excluding studies based on asthmatic children.[41,46] Restricting the analysis to general populations of children did not change the effect estimates (Table 1). When we excluded crude effect estimates from five studies[38,39,52,59,68] without confounder adjustment, the summary effect of gas cooking exposure on asthma in children became somewhat stronger (Table 1).

Risk estimates for asthma were not different in children aged ⩽6 years,[32,52,60,70,72] 6–10 years[37,49–51,58,59,64] or >10 years[29,39,54,56,57,66,68] (Table 2). Stratification by study region showed that the ORs for the association of all asthma with gas cooking exposure tended to be higher in Europe (random effects meta-OR = 1.34, 95% CI, 1.15–1.57) and the Asian-Pacific region (random effects meta-OR = 1.29, 95% CI,1.15–1.45), and lower in North America (random effects meta-OR = 1.12, 95% CI, 0.73–1.73). However, the ORs did not differ significantly between regions. The trend was similar for all wheeze (Table 3).Taking the proportion of participants using gas for cooking into account (Table 2), there was a tendency for the risk estimates to be higher in the studies which had less than 30% of participants using gas cooking. No stratified analyses by age, study region, proportion of gas stoves or year of publication were performed for indoor NO_2 as the numbers of studies in the different strata were too small to obtain enough statistical power.

Almost half of the included studies were published before 2000. The estimated effects of gas cooking on asthma were higher in studies that were published before the year 2000; however, the estimates did not differ in the strata of published year ($P > 0.05$) (Table 2).

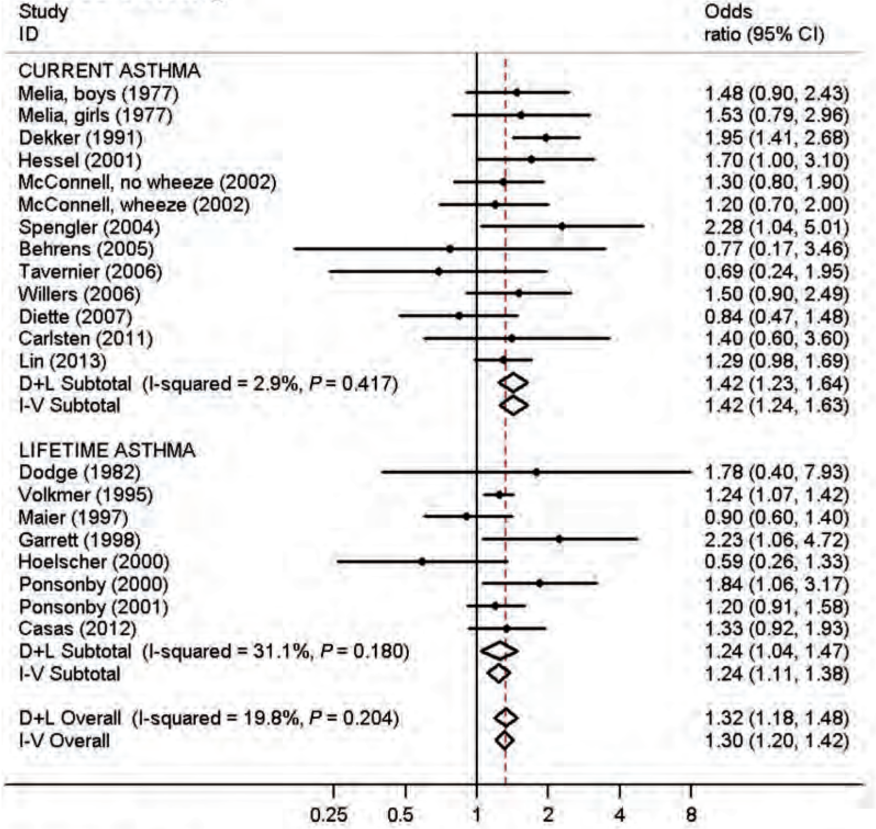
Results of stratified analyses and meta-regressions for current asthma, lifetime asthma, current wheeze and lifetime wheeze are also presented in Tables 2 and 3.

The funnel plots (Supplementary Figure 1, available as Supplementary data at *IJE* online) and P-values from Begg's ($P_{asthma} = 0.971$, $P_{wheeze} = 0.975$) and Egger's ($P_{asthma} = 0.890$, $P_{wheeze} = 0.644$) tests provided no evidence of publication bias.

Discussion

Our meta-analyses suggest that children living in a home with gas cooking have a 42% increased risk of having current asthma, a 24% increased risk of lifetime asthma and an overall 32% increased risk of

(a) Gas cooking



(b) Indoor NO2

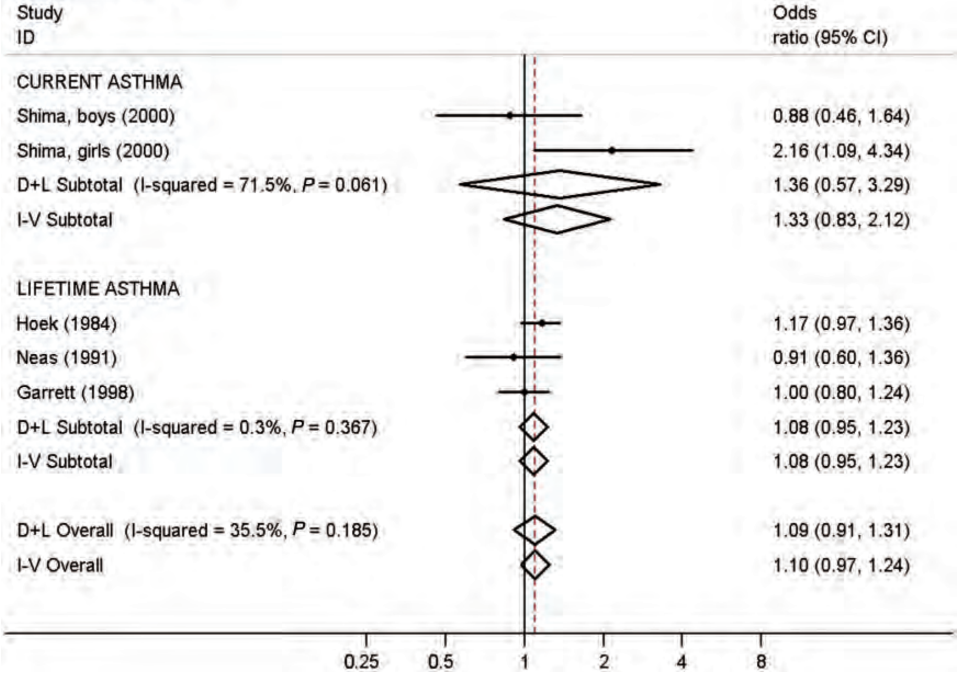
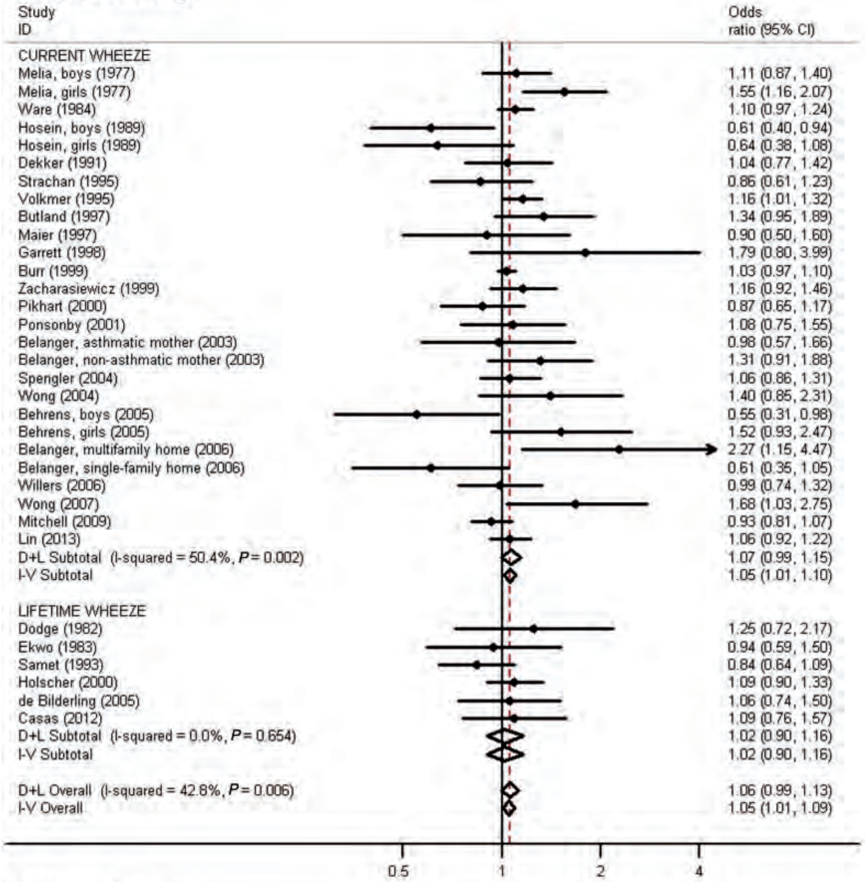


Figure 2 Meta-analysis of studies assessing association between asthma (current/lifetime) and gas cooking (a) or indoor NO_2, (b) in children. The odds ratio for each study is indicated by a black dot, and the horizontal line shows the corresponding 95% CI. The combined estimate is indicated by the diamond-shaped box. D + L Subtotal/Overall = random effect meta-analysis; I-V Subtotal/Overall = fixed effects meta-analysis

(a) Gas cooking



(b) Indoor NO2

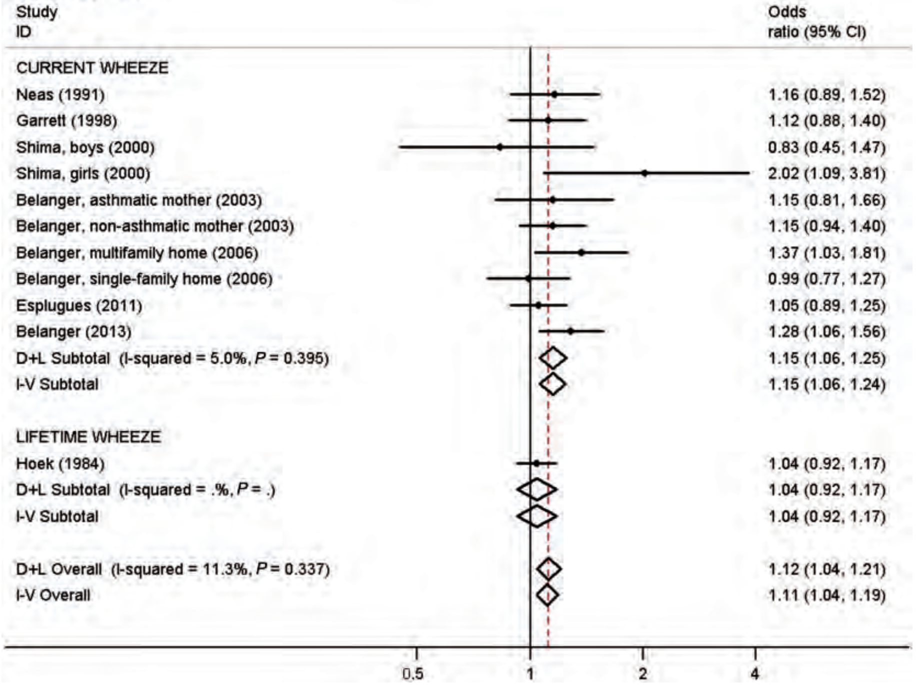


Figure 3 Meta-analysis of studies assessing association between wheeze (current/lifetime) and gas cooking (a) or indoor NO_2, (b) in children. The odds ratio for each study is indicated by a black dot, and the horizontal line shows the corresponding 95% CI. The combined estimate is indicated by the diamond-shaped box. D + L Subtotal/Overall = random effects meta-analysis; I-V Subtotal/Overall = fixed effects meta-analysis

Table 1 Meta-analysis results of studies restricted to unselected children and of studies with confounder adjustment

Variable	Number of studies included	Summary odds ratio (95% CI)	I^2 (heterogeneity P-value)
Unselected children[a]			
Gas cooking			
Current wheeze	21	1.06 (1.01–1.10)	45.1% (0.008)
All wheeze[b]	27	1.05 (1.01–1.09)	36.5% (0.024)
Indoor NO_2[a]			
Current wheeze	5	1.12 (1.01–1.23)	0.0% (0.530)
All wheeze[b]	6	1.09 (1.01–1.17)	0.0% (0.547)
Studies with confounder adjustment			
Asthma			
Gas cooking			
Current asthma	8	1.49 (1.28–1.73)	0.0% (0.548)
Lifetime asthma	7	1.29 (1.09–1.52)	23.6% (0.249)
All asthma [b]	15	1.37 (1.22–1.53)	14.4% (0.288)
Indoor NO_2			
Current asthma	1	1.36 (0.57–3.29)	–
Lifetime asthma	3	1.08 (0.95–1.23)	0.0% (0.367)
All asthma [b]	4	1.09 (0.91–1.31)	35.5% (0.185)
Wheeze			
Gas cooking			
Current wheeze	19	1.05 (1.01–1.10)	40.6% (0.026)
Lifetime wheeze	6	1.02 (0.90–1.16)	0.0% (0.654)
All wheeze[b]	25	1.05 (1.01–1.09)	30.5% (0.065)
Indoor NO_2			
Current wheeze	7	1.15 (1.06–1.24)	5.0% (0.395)
Lifetime wheeze	1	1.04 (0.92–1.17)	–
All wheeze[b]	8	1.11 (1.04–1.19)	11.3% (0.337)

[a] Without two studies performed in asthmatics only [Belanger *et al.* 2006 (gas cooking) and Belanger *et al.* 2013 (NO_2)]. The health outcome in these two studies was 'current wheeze'. Results for 'lifetime wheeze' are the same as in Figure 3, as all studies were performed in unselected children and are therefore not presented here.
[b] Current + lifetime.
[c] Per 15-ppb increase in NO_2.

having current and lifetime asthma; per 15 ppb increase in indoor NO_2 level, children have a 15% increased risk of having current wheeze. The meta-analyses found no increase in the risk of asthma in relation to indoor NO_2 exposure and no increase in the risk of wheeze in relation to gas cooking exposure. The risk estimates for asthma were somewhat higher in studies which had <30% of participants using gas cooking compared with those ⩾30%. The results did not vary much between age groups (⩽6 years, 6–10 years and >10 years) or among regions (Europe, Asian-Pacific region and North America). There was no indication of publication bias when considering all the evidence.

The present study extends the previous meta-analysis of indoor NO_2 by Hasselblad *et al.*[2] which reported that indoor NO_2 increased lower respiratory tract illnesses (LRI) by 18% (OR = 1.18, 95% CI, 1.11–1.25) in children for each 15-ppb increase in indoor NO_2. The LRI definitions used in the reviewed studies in the Hasselblad meta-analysis[2] often included relatively minor symptoms probably related to transient respiratory tract infections. The results of this and our study are therefore not directly comparable. Our meta-analysis did not focus on LRI but on asthma and wheeze (without colds), included data from only those studies with gas cooking without other combustion sources as exposure variable, and indoor NO_2 only when dominated by indoor sources. The definitions of 'asthma' and 'wheeze' differed in various studies; we categorized them into current and lifetime symptoms to standardize the

Table 2 Random effects meta-analysis and univariate meta-regression of studies on gas cooking and asthma stratified by age, study region, proportion of gas cooking and year of publication

	Number of studies	Summary odds ratio (95% CI)	I^2 (heterogeneity *P*-value)	Ratio of odds ratios (95% CI)[a]
Current asthma				
Age of participants				
⩽6years	3	1.22 (0.95–1.56)	0.0% (0.504)	1.00 (ref)
6–10 years	4	1.51 (1.12–2.02)	33.5% (0.211)	1.25 (0.82–1.90)
>10 years	4	1.54 (1.16–2.06)	0.0% (0.500)	1.27 (0.80–2.03)
Study region				
Europe	7	1.34 (1.13–1.60)	0.0% (0.666)	1.00 (ref)
North America	3	1.36 (0.76–2.43)	68.7% (0.041)	1.13 (0.74–1.71)
Asia-Pacific	1	1.50 (1.01–2.23)	0.0% (0.937)	1.11 (0.65–1.89)
Proportion of gas cooking[b]				
<30%	4	1.79 (1.38–2.33)	0.0% (0.615)	1.00 (ref)
⩾30%	6	1.32 (1.12–1.56)	0.0% (0.655)	0.74 (0.52–1.05)
Publication year				
Before 2000	2	1.76 (1.37–2.25)	0.0% (0.597)	1.00 (ref)
2000 or later	9	1.30 (1.10–1.53)	0.0% (0.601)	0.74 (0.53–1.03)
Lifetime asthma				
Age of participants				
⩽6years	2	1.38 (0.98–1.94)	0.0% (0.506)	1.00 (ref)
6–10 years	3	1.16 (0.95–1.41)	0.0% (0.375)	0.83 (0.41–1.67)
>10 years	3	1.28 (0.50–3.29)	65.3% (0.056)	0.92 (0.33–2.53)
Study region				
Europe	1	1.33 (0.92–1.93)	–	1.00 (ref)
North America	3	0.86 (0.60–1.24)	0.0% (0.412)	0.65 (0.31–1.37)
Asia-Pacific	4	1.32 (1.10–1.59)	28.7% (0.240)	0.96 (0.55–1.68)
Proportion of gas cooking[b]				
<30%	3	1.27 (0.87–1.84)	53.8% (0.115)	1.00 (ref)
⩾30%	3	1.07 (0.65–1.76)	10.4% (0.188)	0.98 (0.62–1.53)
Year of publication				
Before 2000	4	1.24 (0.93–1.65)	37.2% (0.189)	1.00 (ref)
2000 or later	3	1.25 (0.93–1.68)	44.0% (0.148)	1.02 (0.68–1.54)
All asthma[c]				
Age of participants				
⩽6 years	5	1.26 (1.12–1.42)	0.0% (0.506)	1.00 (ref)
6–10 years	7	1.31 (1.08–1.59)	38.8% (0.133)	1.03 (0.79–1.35)
>10 years	7	1.45 (1.07–1.97)	26.6% (0.217)	1.27 (1.05–1.54)
Study region				
Europe	8	1.34 (1.15–1.57)	0.0% (0.763)	1.00 (ref)
North America	6	1.12 (0.73–1.73)	66.7% (0.010)	0.92 (0.69–1.23)
Asian–Pacific	5	1.29 (1.15–1.45)	0.0% (0.442)	1.01 (0.76–1.35)
Proportion of gas cooking[b]				
<30%	7	1.45 (1.12–1.87)	40.1% (0.124)	1.00 (ref)
⩾30%	10	1.25 (1.13–1.38)	0.0% (0.617)	0.86 (0.68–1.06)
Publication year				
Before 2000	6	1.42 (1.13–1.80)	50.0% (0.062)	1.00 (ref)
2000 or later	13	1.28 (1.13–1.45)	0.0% (0.467)	0.93 (0.75–1.16)

[a] Ratios of odds ratios are the odds ratio from studies with the characteristic divided by the odds ratios from studies of the reference category and were calculated from coefficients of meta-regression b as exp(b). Ratios above 1.0 indicate a larger odds ratio for studies with the characteristic.

[b] Information of proportion of gas cooking was not available in two studies (Garrett *et al.* 1998; Tavernier *et al*. 2005). Belanger *et al.* (2006) was counted twice in this analysis as results were presented for multi-family and single-family homes separately, and proportions for gas cooking were ⩾30% for multi-family homes and <30% for single-family homes, respectively.

[c] Current + lifetime.

Table 3 Random effects meta-analysis and univariate meta-regression of studies on gas cooking and wheeze stratified by age, study region, proportion of gas cooking and year of publication

	Number of studies	Summary odds ratio (95% CI)	I^2 (heterogeneity *P*-value)	Ratio of odds ratios (95% CI)[a]
Current wheeze				
Age of participants				
⩽6 years	4	1.16 (1.03–1.30)	3.7% (0.386)	1.00 (ref)
6–10 years	11	1.05 (0.96–1.15)	32.6% (0.129)	0.90 (0.70–1.17)
>10 years	7	1.02 (0.86–1.21)	68.5% (0.001)	0.88 (0.67–1.16)
Study region				
Europe	9	1.07 (0.97–1.18)	48.7% (0.035)	1.00 (ref)
North America	6	0.96 (0.78–1.19)	61.3% (0.008)	0.92 (0.72–1.18)
Asia-Pacific	7	1.14 (0.99–1.31)	47.9% (0.074)	1.08 (0.85–1.37)
Proportion of gas cooking				
<30%	4	0.91 (0.73–1.14)	49.4% (0.079)	1.00 (ref)
⩾30%	15	1.09 (1.01–1.18)	49.2% (0.008)	1.16 (0.95–1.42)
Publication year				
Before 2000	11	1.08 (0.98–1.19)	52.5% (0.014)	1.00 (ref)
2000 or later	11	1.06 (0.93–1.20)	50.7% (0.015)	0.96 (0.81–1.14)
Lifetime wheeze				
Age of participants				
⩽6 years	1	0.84 (0.64–1.10)	–	1.00 (ref)
6–10 years	1	1.09 (0.76–1.67)	–	1.30 (0.62–2.69)
>10 years	4	1.08 (0.92–1.26)	0.0% (0.890)	1.28 (0.78–2.12)
Study region				
Europe	3	1.08 (0.93–1.27)	0.0% (0.990)	1.00 (ref)
North America	3	0.91 (0.74–1.13)	0.0% (0.441)	0.84 (0.58–1.22)
Asia-Pacific	0	-	-	-
Proportion of gas cooking[b]				
<30%	1	1.09 (0.76–1.57)	-	1.00 (ref)
⩾30%	4	1.08 (0.92–1.26)	0.0% (0.890)	0.99 (0.52–1.88)
Publication year				
Before 2000	3	0.91 (0.74–1.13)	0.0% (0.441)	1.00 (ref)
2000 or later	3	1.08 (0.93–1.27)	0.0% (0.990)	1.19 (0.82–1.73)
All wheeze[c]				
Age of participants				
⩽6 years	5	1.10 (0.93–1.29)	44.3% (0.110)	1.00 (ref)
6–10 years	12	1.05 (0.97–1.15)	26.7% (0.175)	0.96 (0.78–1.18)
>10 years	11	1.04 (0.92–1.17)	55.8% (0.006)	0.95 (0.77–1.18)
Study region				
Europe	12	1.07 (0.99–1.15)	34.0% (0.103)	1.00 (ref)
North America	9	0.97 (0.82–1.13)	53.2% (0.015)	0.92 (0.77–1.10)
Asia-Pacific	7	1.14 (0.99–1.31)	47.9% (0.074)	1.06 (0.88–1.27)
Proportion of gas cooking[b]				
<30%	6	0.94 (0.78–1.14)	43.0% (0.104)	1.00 (ref)
⩾30%	20	1.09 (1.01–1.16)	39.1% (0.030)	1.14 (0.96–1.34)
Publication year				
Before 2000	14	1.06 (0.97–1.16)	48.1% (0.017)	1.00 (ref)
2000 or later	14	1.06 (0.96–1.17)	40.3% (0.044)	0.98 (0.86–1.13)

[a] Ratios of odds ratios are ratios of the odds ratio from studies with the characteristic divided by the odds ratio from studies of the reference category and were calculated from coefficients of meta-regression b as exp(b). Ratios above 1.0 indicate a larger odds ratio for studies with the characteristic.

[b] Information on proportion of gas cooking was unavailable in three studies (Garrett *et al.* 1998; Samet *et al.* 1993; Zacharasiewicz *et al.* 1999).

[c] All (current + lifetime).

health effects and thus to reduce the heterogeneity between studies.

Although asthma and wheeze are associated, they present distinct entities. In a Dutch birth cohort study, for example, it was found that only 11% of children with symptoms suggestive of asthma, including wheeze, at preschool age had asthma at age 7–8 years.[76] Moreover, one-time wheeze was sufficient to characterize a child as having wheezed in many of the studies included in the meta-analysis and typically no distinction was made between wheeze with and without respiratory infections. This may explain why our meta-analysis revealed stronger associations with gas cooking for asthma compared with wheeze.

Gas cooking produces NO_2 and other pollutants such as ultrafine particles. Our finding of an association between gas cooking and asthma in the absence of an association between measured NO_2 and asthma suggests that gas cooking may act as a surrogate for causal variables other than air pollutants produced by gas combustion. This is supported by an Australian study, where the association between gas cooking and respiratory symptoms remained significant after adjustment for measured NO_2.[29] Residual confounding by (unmeasured) factors that are associated with gas cooking might be another explanation for our finding of an association between asthma and gas cooking, but not with indoor NO_2. However, this is not very likely as we used effect estimates from the included studies which were almost always adjusted for known determinants of childhood asthma. It is also possible that no relationship between indoor NO_2 and asthma was found because there were fewer studies that had direct NO_2 measurements, and study populations were usually smaller in these studies. Point estimates for the association of NO_2 and gas cooking with current asthma were actually very similar to those for gas cooking and asthma, but confidence intervals were wider for NO_2. As gas cooking is a strong determinant of indoor NO_2, it has been argued that one is actually more likely to find associations with gas cooking than with NO_2 because much larger studies can be (and have been) conducted using the surrogate exposure variable.[77]

Heterogeneity among reviewed studies existed in various factors such as stove type, age of population, size of population exposed to gas cooking, susceptibility of study population, study region, study design, sampling season, other indoor factors and diagnosis of asthma and wheeze. We therefore conducted meta-regression to explore whether the heterogeneity could be explained by age, study region, study design or size of the population exposed to gas cooking. None of these factors appeared to be associated with the magnitude of the effect estimates extracted from the study papers. We did note that the association between gas cooking and asthma was somewhat stronger in studies published before the year 2000 than in later studies. Possibly, gas cooking in newer studies is associated with lower indoor pollution levels because of the introduction of microwaves displacing some of the meal preparation, changes in stove performance or kitchen ventilation etc.[53,72] Exposure assessment (questionnaire reports of gas cookers and passive measurements of NO_2) and statistical analysis (mostly logistic regression) were mostly rather straightforward and, therefore, they do not seem a likely source of heterogeneity between the reviewed studies.

The findings of our meta-analysis on asthma were also not different when we excluded studies where less than 30% of the population used gas for cooking, by restricting the study population to general population of children, and by excluding studies without adjustment for potential confounders. The exclusion of single studies from the analysis did not change the pooled estimates. Also, *P*-values from the Egger's and Begg's tests, as well as the absence of funnel plot asymmetry, suggested that no publication bias exists in our results.

Our analysis was based on observational studies and we cannot exclude that associations between gas cooking and asthma are in part due to information bias, e.g. because parents may suspect risks are associated with gas cooking. However, with studies coming from so many different settings, we do not think this is a likely explanation for the observed associations.

Although the effects of gas cooking and indoor NO_2 on asthma and wheeze were found to be relatively small (all random-effects meta-odds ratios were less than 1.5) the public health impact may still be considerable because gas cooking is widespread. A recent large population study found that 60–70% of European children lived in gas-cooking homes.[78] It is not clear to what extent the observed associations with gas cooking are attributable to NO_2 alone or also to other pollutants associated with the use of gas for cooking. In outdoor air pollution studies, NO_2 often is used as a marker of a complex, traffic-related air pollution mixture, which makes extrapolation of our results to outdoor air pollution difficult. Indoors, gas cookers can be replaced by electric cookers, and gas cooking fumes can be removed by using ventilation hoods.

Conclusion

In summary, this meta-analysis provides quantitative evidence that gas cooking increases the risk of asthma in children, and indoor NO_2 increases the risk of current wheeze in children.

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All authors had full access to all the data and take responsibility for the integrity of the data, the accuracy of the data analysis and the accuracy and completeness of references. W.L., U.G. and B.B. conducted the literature search independently and decided on inclusion of studies. Discrepancies among the authors were discussed and adjudicated. W.L. and U.G. extracted the data. W.L. did the statistical analyses and wrote the manuscript. U.G. and B.B. critically reviewed the manuscript and provided important intellectual content.

Conflict of interest: None declared.

KEY MESSAGES

- The last meta-analysis of the respiratory health effects of indoor NO_2 exposure was published almost 20 years ago. The current paper provides an up-to-date review of the literature with childhood respiratory health data that used either indoor NO_2 or the use of gas for cooking as the exposure metric.
- Household gas cooking is associated with increased odds of current asthma and lifetime asthma in children. The risk of overall asthma in children with gas cooking exposure was 1.32 (95% confidence interval, 1.18–1.48).
- The risk of childhood current wheeze increases by 15% per 15-ppb increase in indoor NO_2 levels.

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Commentary: Gas cooking and child respiratory health—time to identify the culprits?

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In this issue of the *IJE*, Lin and colleagues[1] report the results of a meta-analysis of the effect of indoor nitrogen dioxide (NO_2) and gas cooking on asthma and wheeze in children. Effect estimates summarizing 19 studies show that the risk of asthma increases by 32% when a gas cooker is present in the home, and 7 studies combined show that the risk of wheeze increases by 15% for a 15 ppb increase in NO_2. The presence of gas cookers inside the home is common in developed countries (around 50–70%) and has long been established as a main source of indoor air pollution, in particular NO_2.[2] Young children are among

Detroit:
The Current Status of Asthma Burden

2021 Update

Michigan Department of Health & Human Services

Prudence Kunyangna
Beth Anderson
http://www.michigan.gov/asthma
MDHHS - Michigan Asthma Surveillance, Data and Reports

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Data Sources

- United States Census Bureau
- Michigan Behavioral Risk Factor Survey (MIBRFS), MDHHS
- Michigan Inpatient Database, MDHHS/Michigan Health and Hospital Association
- Michigan Health Data Warehouse, MDHHS
- Michigan Death Files, MDHHS

What is Asthma?

- Asthma is a chronic lung disease that inflames and narrows the airways. Asthma causes recurring periods of wheezing, chest tightness, shortness of breath, and coughing. The coughing often occurs at night or early in the morning.[1]
- Asthma has no cure. However, with today's knowledge and treatments, most people who have asthma are able to manage the disease.
- Michigan’s efforts to address asthma are coordinated through the Michigan Department of Health and Human Services Asthma Program and partners.

Notes:
Sources:[1] http://www.nhlbi.nih.gov/health/health-topics/topics/asthma/

Executive Summary/Key Findings
2021 Report

The asthma burden in Detroit was found to be greater than the overall asthma burden in Michigan.

- The prevalence of current asthma among Detroit adults was 46% higher than in Michigan as a whole.
- The rate of hospitalizations for asthma was at least four times greater for Detroit residents than for Michigan residents as a whole, from 2016-2019.
- In 2019, the rate of asthma hospitalizations for Black residents in Detroit was more than three times the rate for white persons.
- The rate of emergency department visits among children covered by Michigan Medicaid was twice as high in Detroit as the rate for the state as a whole.
- Reliance on the emergency department for asthma care was over 50% higher for children enrolled in Medicaid with persistent asthma in Detroit as compared with their counterparts in the state as a whole from 2016-2019.
- Rates of asthma hospitalization, emergency department use, and persistent asthma tended to be lower in the southwestern parts of the city.

Executive Summary/Key Findings 2021 Report, Cont'd

- "Detroit: The Current Status of Asthma Burden-2016 Update" report showed the prevalence of current asthma among adults being 29% higher than Michigan, and this update shows that has increased to 46%.

- There now is a significant difference between the prevalence of asthma among children in Detroit (14.6%) compared to Michigan (8.4%), where there wasn't one in 2016.

- Unfortunately, due to a change in the International Classification of Diseases (ICD) from version 9 to version 10, asthma hospitalization and Medicaid data can not be compared between the last report (2016) and this version (2021).

1. Population demographics[1] of Detroit, Michigan, July 1, 2019

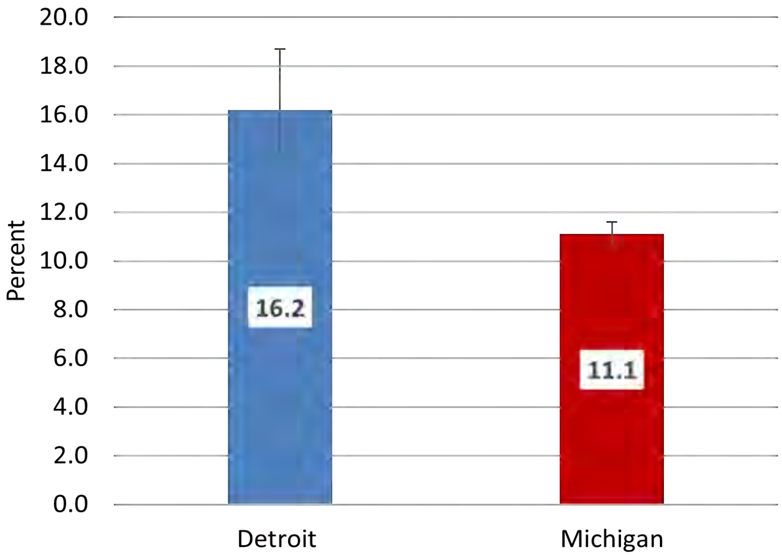
Measure	Detroit Population Estimate
Total population	670,031
% less than 18 years	25.0%
% Black	78.3%
% of those 25 years and older with less than high school diploma	19.0%
Persons without health insurance, under age 65 years	9.6%
Median household income	$30,894
% in poverty	35.0%
% of housing units that were vacant	25.7%

Data Notes:
1. Source: United Sates Census Bureau

- The total resident population of Detroit, Michigan, in 2019 was over 670,000; 78.3% of this population was Black.
- In 2019, the median household income was $30,894, with 35.0% of the population living in poverty.
- Of the population <65 years of age, 9.6% did not have health insurance in 2019.
- Among the population ≥25 years of age, 19.0% had not earned a high school diploma.
- The prevalence of vacant housing units was 25.7% in 2019.

Current Asthma Prevalence

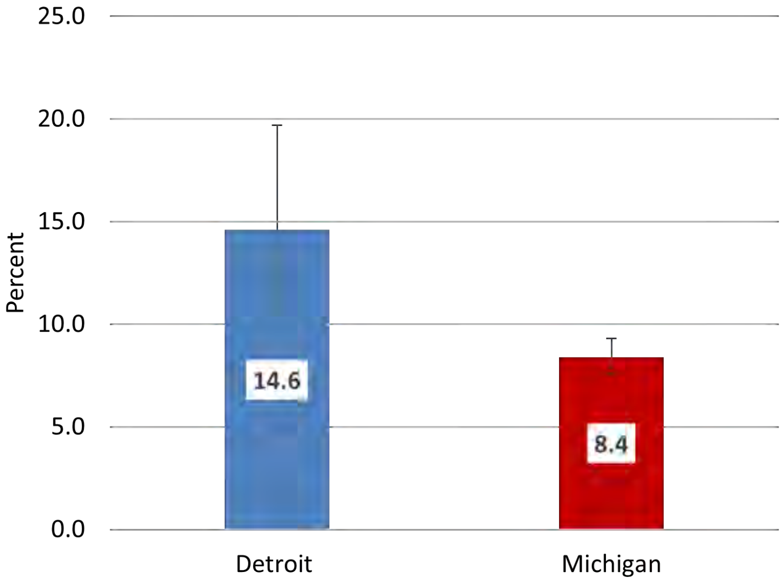
2. Prevalence of Current Asthma[1] for Adults (≥18 Years), Detroit and Michigan, 2017-2019



- From 2017-2019, 16.2% of Detroit adults and 11.1% of Michigan adults had current asthma.
- There was a significant difference in current asthma prevalence rates between Detroit and Michigan adults. Detroit had a 46% higher prevalence of current asthma among adults compared to adults in Michigan as a whole.

Data Notes:
1. Source: 2017-2019 Michigan Behavioral Risk Factor Surveys, MDHHS.

3. Prevalence of Current Asthma[1] for Children (<18 Years), Detroit and Michigan, 2017-2019



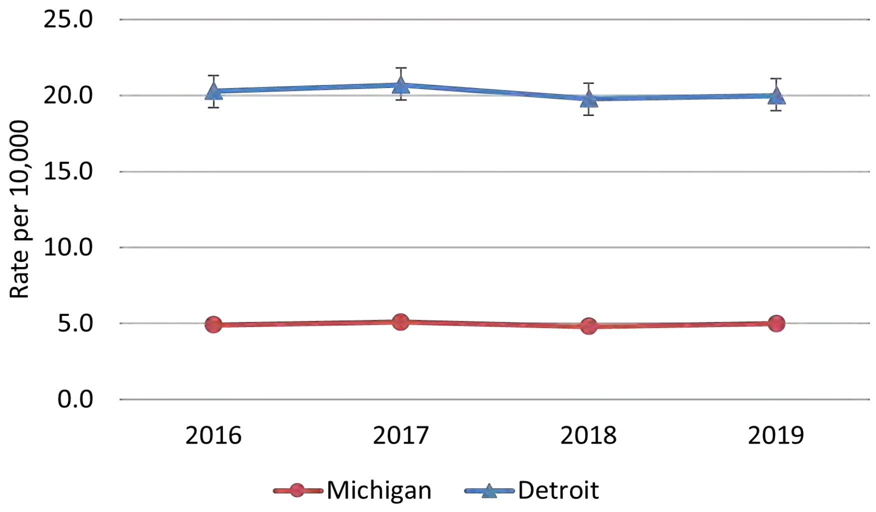
- From 2017-2019, 14.6% of Detroit children and 8.4% of Michigan children had current asthma.
- There was a significant difference in current asthma prevalence rates between Detroit and Michigan children. Detroit had a 74% higher prevalence of current asthma among children compared to children in Michigan as a whole.

Data Notes:
1. Source: 2017-2019 Michigan Behavioral Risk Factor Surveys, MDHHS

Asthma Hospitalization

Due to a change in International Classification of Diseases (ICD) for asthma hospitalizations in 2015 from version 9 to version 10, asthma hospitalization data in this report should not be compared to estimates in the previous 2016 Detroit Report.

4. Rates[1] of Asthma Hospitalization[2], Detroit and Michigan, 2016-2019

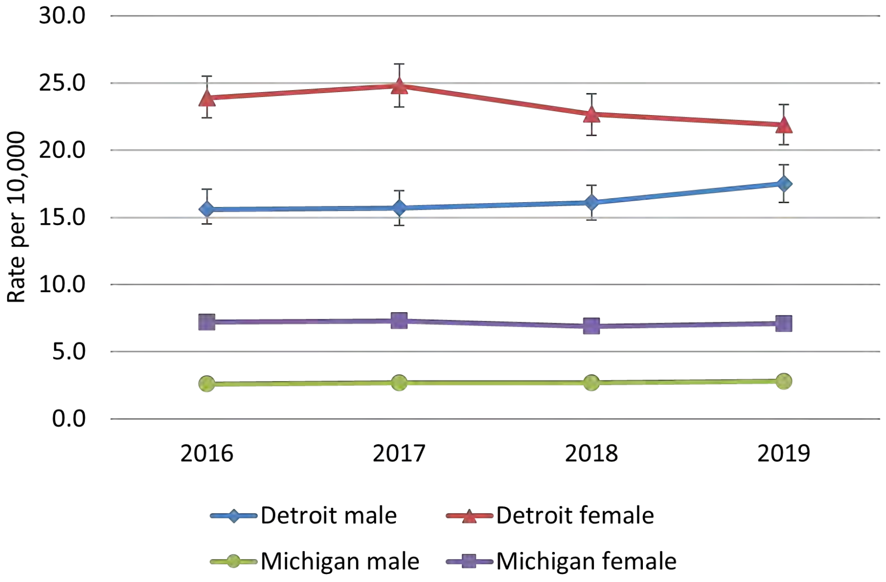


- In 2019, there were 1,458 asthma hospitalizations for Detroit residents. The rate of asthma hospitalizations was 20.3 per 10,000 population.
- The asthma hospitalization rate in Detroit in 2019 was four times the rate in Michigan as a whole.
- Between 2016 and 2019, the rates of asthma hospitalization in Detroit and Michigan did not change significantly ($p>0.05$).[3]

Data Notes:

Source: Michigan Inpatient Database, 2016-2019, MDHHS
1. Age-adjusted to the 2000 US Standard Population
2. Asthma as primary diagnosis ICD-10 –CM=J45.XX
3. Spearman's correlation and rank correlation test

5. Rates[1] of Asthma Hospitalization[2] by Sex, Detroit and Michigan, 2016-2019



- In 2019, the rate of asthma hospitalizations among Detroit females was 21.9 per 10,000. Among males in Detroit, the rate was 17.5 per 10,000. Females in Detroit had a 25% higher rate of asthma hospitalization compared to males.

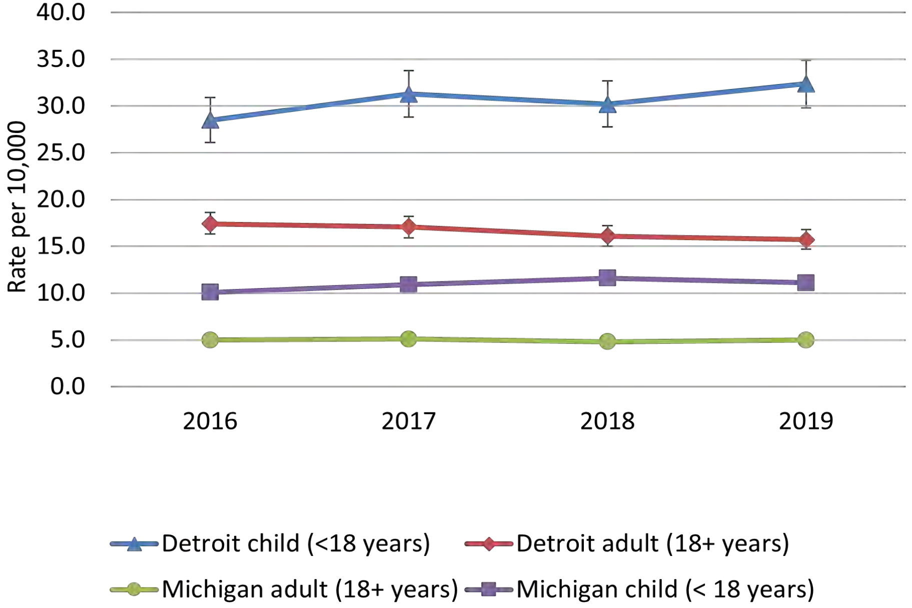
- In Michigan as a whole, the rate was 153.6% higher among females than among males (male rate was 2.8 and female rate was 7.1).

- For each respective sex, asthma hospitalization rates in Detroit were over three times higher than that in Michigan as a whole.

- Between 2016 and 2019, the rate of asthma hospitalizations for males and females in Detroit and Michigan as a whole did not change significantly ($p>0.05$).[3]

Data Notes:
Source: Michigan Inpatient Database, 2016-2019, MDHHS
1. Age-adjusted to the 2000 US Standard Population
2. Asthma as primary diagnosis, ICD-10 –CM=J45.XX
3. Spearman's correlation and rank correlation test

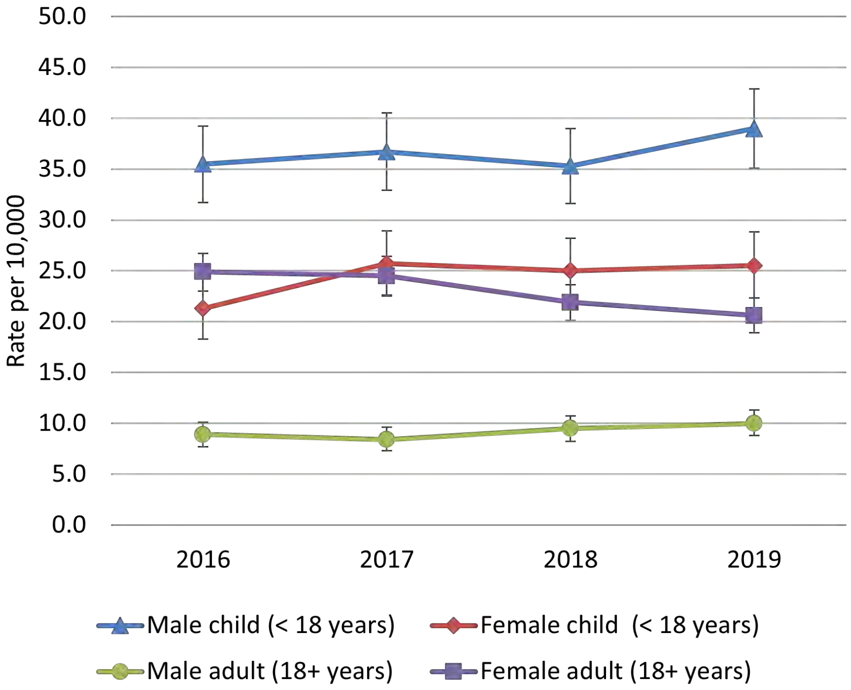
6. Rates[1] of Asthma Hospitalization[2] by Age Group, Detroit and Michigan, 2016-2019



- In Detroit, the rate of child asthma hospitalization was consistently higher compared to adults from 2016 to 2019; likewise in Michigan, child hospitalization rates were consistently higher than that of adults for all four years.
- In 2019, the rate of asthma hospitalizations among Detroit children was 32.4 per 10,000. Among adults, the rate was 15.7 per 10,000.
- Asthma hospitalizations rates in Detroit were at least two times higher among Detroit children than Michigan children and three times higher than that in Michigan as a whole for adults and for all four years.
- Between 2016 and 2019, adult and child hospitalization rates for Detroit and Michigan did not change significantly ($p>0.05$).[3]

Data Notes:
Source: Michigan Inpatient Database, 2016-2019, MDHHS
1. Age-adjusted to the 2000 US Standard Population
2. Asthma as primary diagnosis ICD-10 –CM=J45.XX
3. Spearman's correlation and rank correlation test

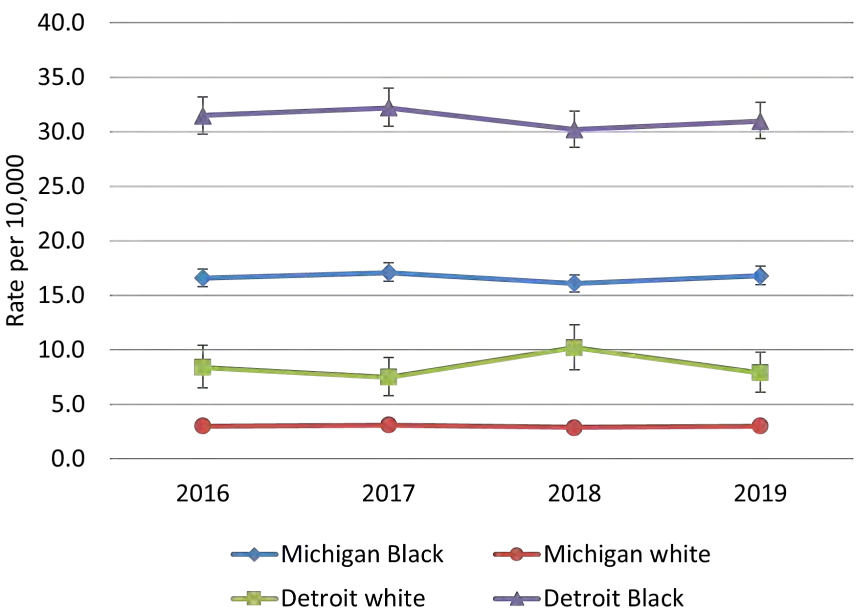
7. Rates[1] of Asthma Hospitalization[2] by Sex-Age Group, Detroit, 2016-2019



- In 2019, the rate of asthma hospitalization among Detroit male children was 39.0 per 10,000. The rate among female Detroit children was 25.5 per 10,000.
- In 2019, the rate of asthma hospitalization among Detroit male adults was 10.0 per 10,000. Among Detroit female adults, the rate was 20.6 per 10,000.
- Asthma hospitalization rates were over 100% higher among adult females than males in 2019. Among Detroit children, the male rate was about 50% higher than females.
- From 2016 to 2019, the rates of asthma hospitalization for female adult decreased by 20.8%. Male child, male adult and female child rates did not change significantly ($p>0.05$).[3]

Data Notes:
Source: Michigan Inpatient Database, 2016-2019, MDHHS
1. Age-adjusted to the 2000 US Standard Population
2. Asthma as primary diagnosis ICD-10 –CM=J45.XX
3. Spearman's correlation and rank correlation test

8. Rates[1] of Asthma Hospitalization[2] by Race, Detroit and Michigan, 2016-2019



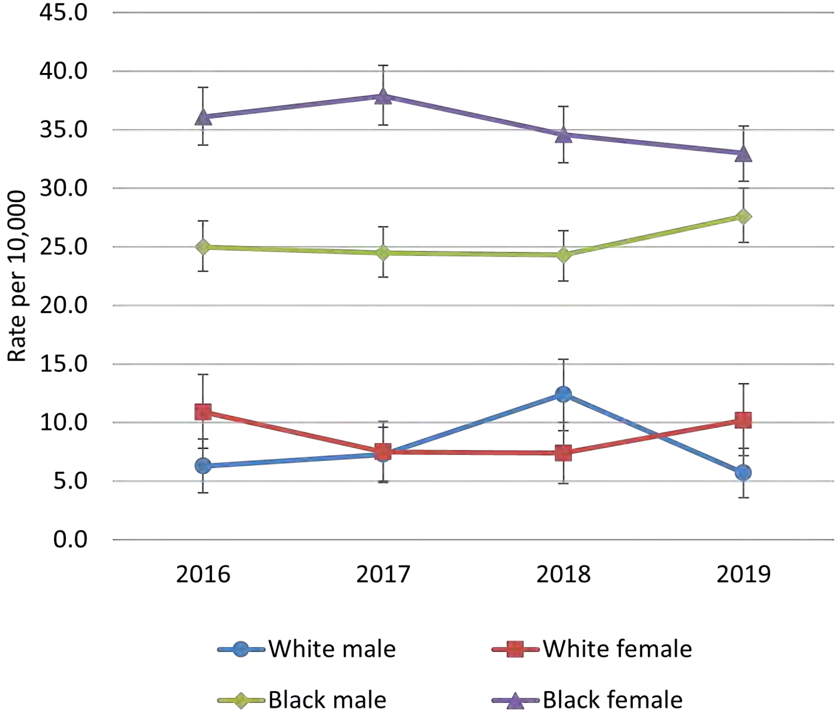
- In 2019, the rate of asthma hospitalization among Black persons in Detroit was 31.0 per 10,000. The rate among white persons in Detroit was 7.9 per 10,000.

- Asthma hospitalization among Detroit Blacks were over three times that of Detroit whites. Michigan Blacks had over five times the hospitalization rate of Michigan whites.

- Between 2016 and 2019, the rates of asthma hospitalization for Black persons and white residents in Michigan and Detroit did not change significantly ($p>0.05$).[3]

Data Notes:
Source: Michigan Inpatient Database, 2016-2019, MDHHS
1. Age-adjusted to the 2000 US Standard Population
2. Asthma as primary diagnosis, ICD-10 –CM=J45.XX
3. Spearman’s correlation and rank correlation test

9. Rates[1] of Asthma Hospitalization[2] by Sex-Race Group, Detroit, 2016-2019



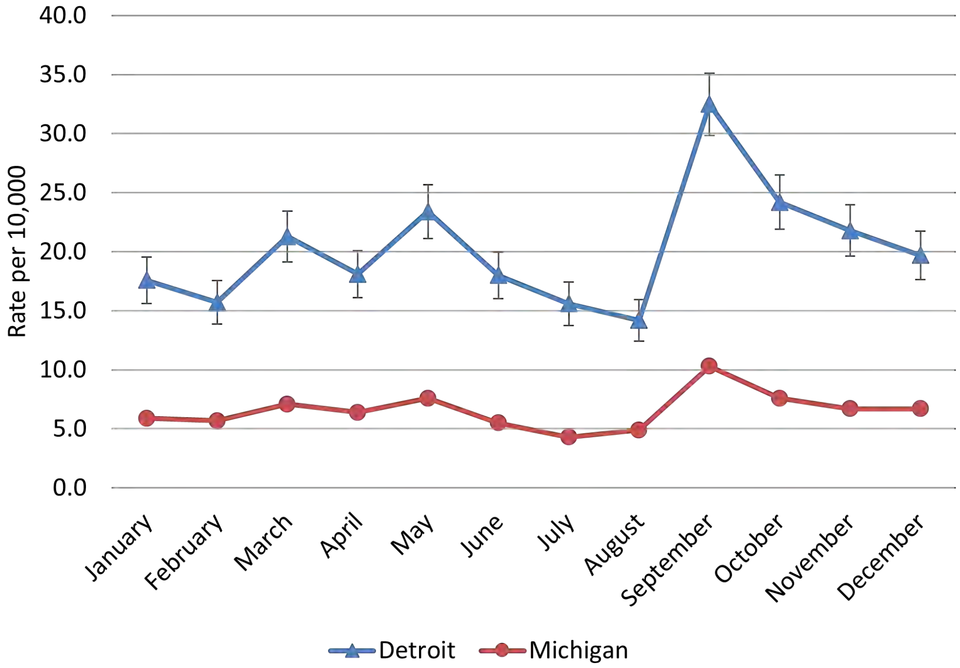
- In 2019, the rate of asthma hospitalizations among Detroit white males was 5.7 per 10,000. The rate among Detroit white females was 10.2 per 10,000.

- In 2019, the rate of asthma hospitalizations among Detroit Black males was 27.6 per 10,000. Among Detroit Black females, the rate was 33.0 per 10,000.

- Between 2016 and 2019, rates of asthma hospitalizations for Black males and females did not change significantly (p>0.05)[3] . The rate for white males declined by 50% from 2018-2019 while the rates for white females did not change significantly (p>0.05).[3]

Data Notes:
Source: Michigan Inpatient Database, 2016-2019, MDHHS
1. Age-adjusted to the 2000 US Standard Population
2. Asthma as primary diagnosis, ICD-10 –CM=J45.XX
3. Spearman’s correlation and rank correlation test

10. Rates[1] of Asthma Hospitalization[2] by Month of Admission, Detroit and Michigan, 2017-2019

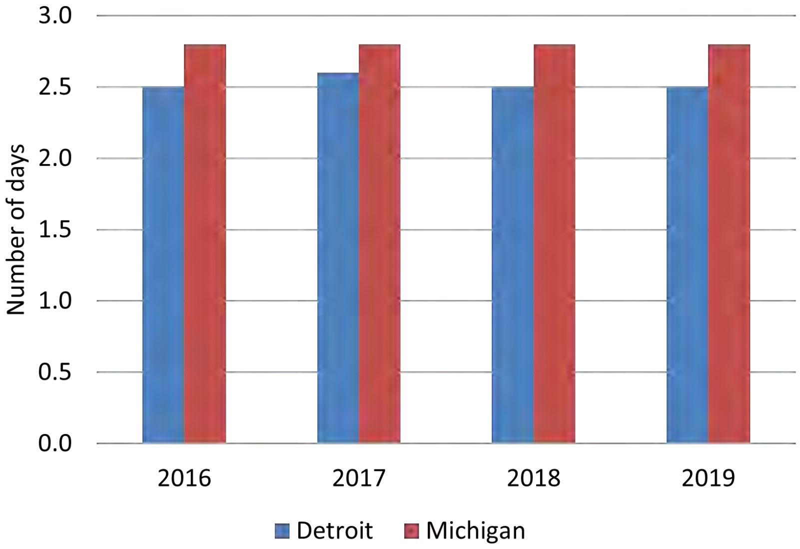


- Rates of asthma hospitalization in Detroit were approximately three to four times the rates for Michigan as a whole, throughout the year.

- Seasonal trends in asthma hospitalization for Detroit and Michigan followed a similar pattern throughout the year. The lowest rates in July and August were immediately followed by an increase in September. The highest rates for both Detroit and Michigan were in September.

Data Notes:
Source: Michigan Inpatient Database, 2016-2019, MDHHS
1. Age-adjusted to the 2000 US Standard Population
2. Asthma as primary diagnosis, ICD-10 –CM=J45.XX

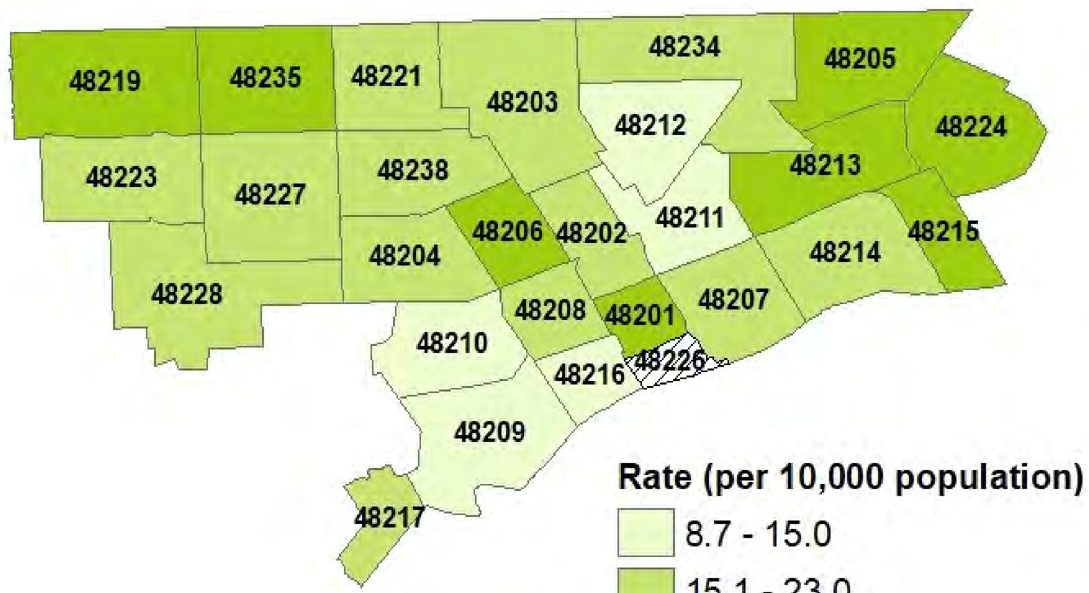
11. Average Length of Stay for Asthma Hospitalization[1], Detroit and Michigan, 2016-2019



- In 2019, the average length of asthma hospitalization in Detroit was 2.5 days and that for Michigan was 2.8 days.
- From 2016-2019, the average length of asthma hospitalization in Detroit was generally shorter compared to that for Michigan.
- The average length of hospital stay did not change significantly from 2016-2019 for both Detroit and Michigan.

Data Notes:
Source: Michigan Inpatient Database, 2016-2019, MDHHS
1. Asthma as primary diagnosis, ICD-10 –CM=J45.XX

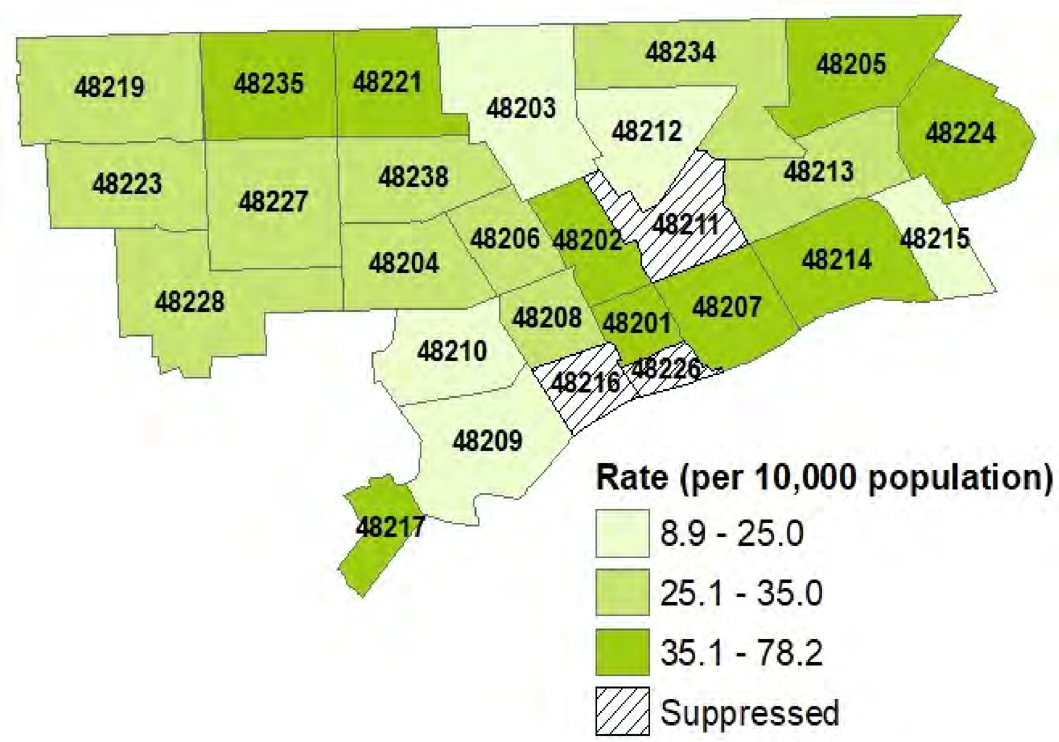
12. Rates[1] of Asthma Hospitalization[2] by ZIP Code of Residence, Detroit, 2016-2019



- ZIP codes 48201 and 48206 in central Detroit, 48219 and 48235 in western Detroit and 48205, 48213,48224, and 48215 in eastern Detroit had the highest asthma hospitalization rates (all ages) in the city.
- Lower rates of asthma hospitalization occurred in ZIP codes 48212 and 48211 in the central part of Detroit and three other ZIP codes in the southwestern and part of the city.
- Data was suppressed for ZIP codes with asthma hospitalization counts less than 20.

Data Notes:
Source: Michigan Inpatient Database, 2016-2019, MDHHS
1. Age-adjusted to the 2000 US Standard Population
2. Asthma as primary diagnosis, ICD-10 –CM=J45.XX

13. Rates[1] of Asthma Hospitalization[2] by ZIP Code of Residence for Children (<18 Years), Detroit, 2016-2019

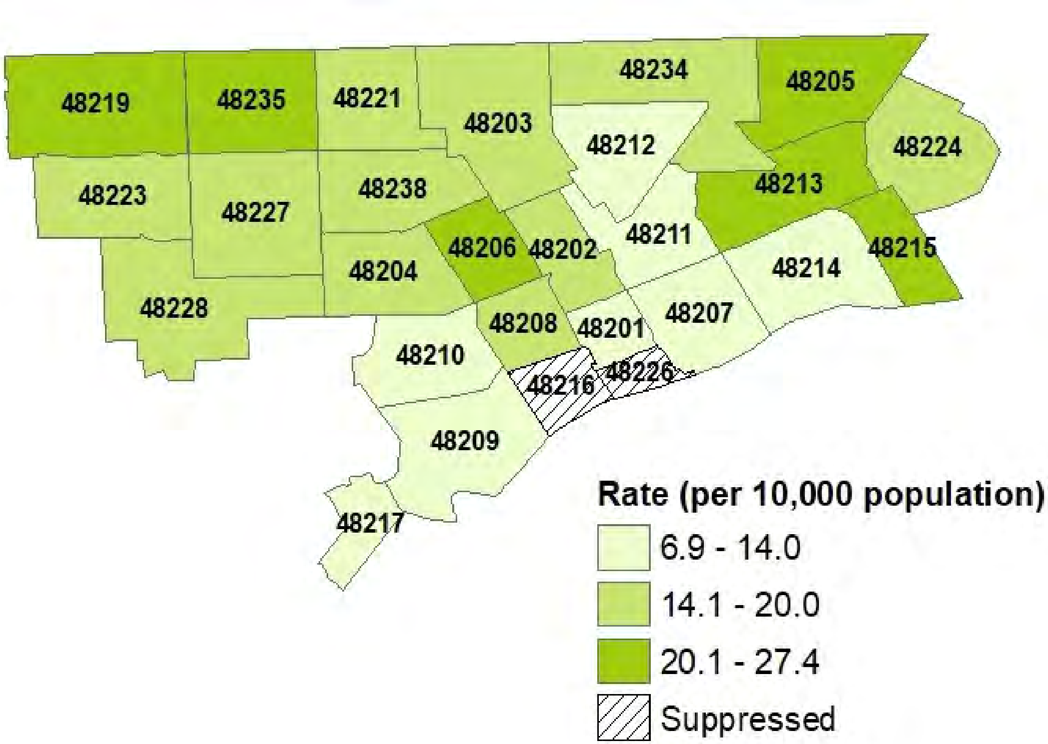


- ZIP codes with the highest child asthma hospitalization rates tended to occur in the central, western and eastern parts of the city.
- Lower child asthma hospitalization rates mostly concentrated in ZIP codes in the northcentral and southwestern parts of the city.
- Data was suppressed for ZIP codes with asthma hospitalization counts less than 20.

Data Notes: Source: Michigan Inpatient Database, 2016-2019, MDHHS

1. Age-adjusted to the 2000 US Standard Population
2. Asthma as primary diagnosis, ICD-10 –CM=J45.XX

14. Rates[1] of Asthma Hospitalization[2] by ZIP Code of Residence for Adults (≥18 Years), Detroit, 2016-2019



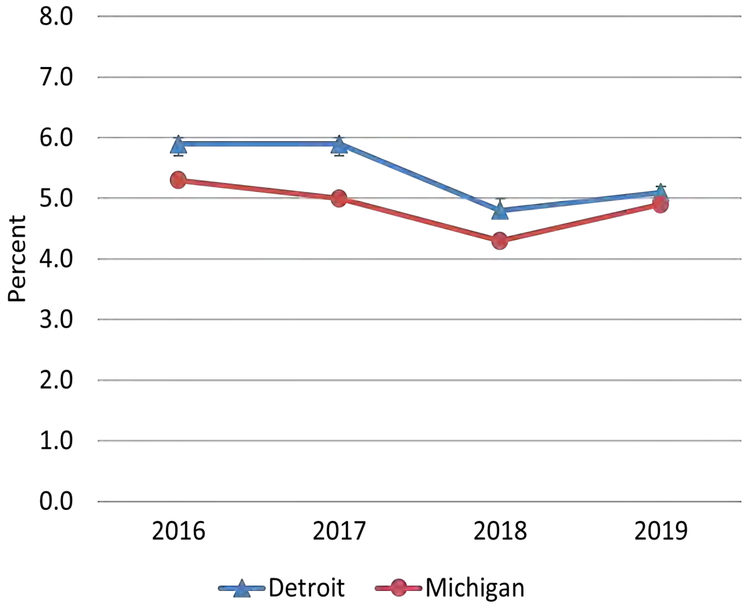
- Higher adult asthma hospitalization rates were concentrated in western and eastern Detroit.
- Lower rates occurred in ZIP codes in central Detroit, southeastern and southwestern parts of the city.
- Data was suppressed for ZIP codes with asthma hospitalization counts less than 20.

Data Notes:
Source: Michigan Inpatient Database, 2016-2019, MDHHS
1. Age-adjusted to the 2000 US Standard Population
2. Asthma as primary diagnosis, ICD-10 –CM=J45.XX

Medicaid Rates

Due to a change in International Classification of Diseases (ICD) for asthma Medicaid rates in 2015 from version 9 to version 10, asthma Medicaid data in this report should not be compared to estimates in the previous 2016 Detroit Report.

15. Prevalence[1] of Persistent Asthma[2], Children (5-17 Years) on Medicaid[3], Detroit and Michigan, 2016-2019



Data Notes:
Source: Michigan Health Data Warehouse, MDHHS
1. Age-adjusted to the 2000 US Standard Population
2. Based on annual NCQA HEDIS definition
3. Medicaid population of children 5-17 years is restricted to those who are continuously enrolled in Medicaid with full coverage and no other insurance

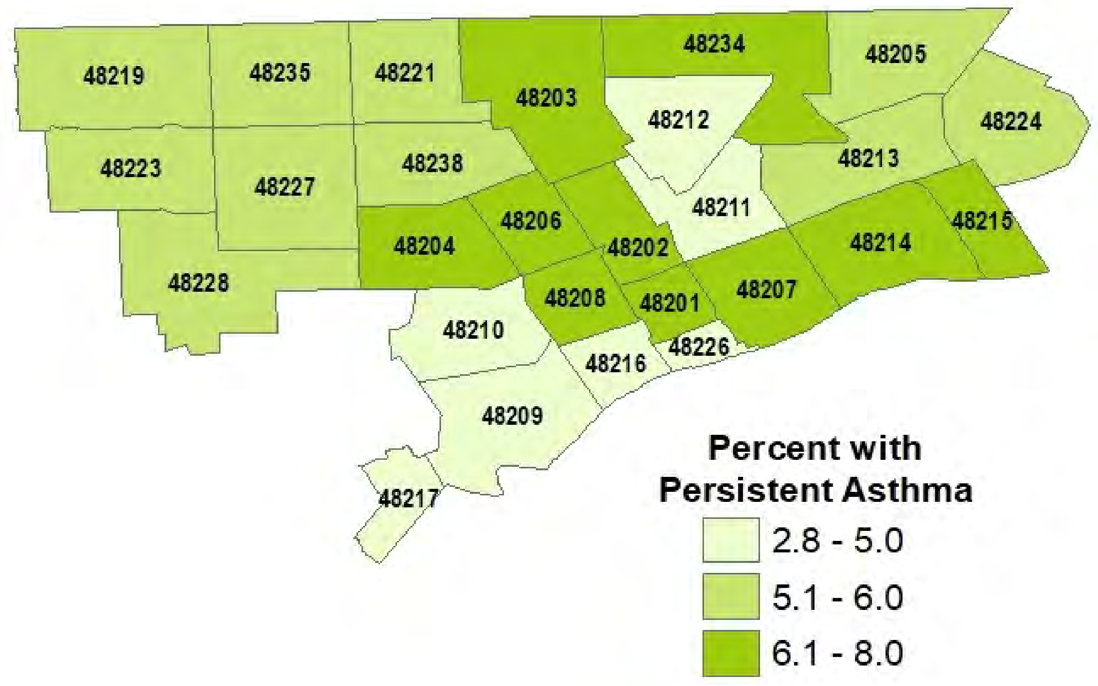
For the following analyses, the Medicaid study population of children 5-17 years was restricted to those who were continuously enrolled in Medicaid (11+ months) with full coverage and no other insurance.

Not included in this data are children with asthma who:

- ➢ Were younger than five years.
- ➢ Were not enrolled in Medicaid continuously.
- ➢ Did not have a paid Medicaid health utilization claim from 2016 through 2019.

- The prevalence of asthma in Detroit has been consistently higher than in Michigan as a whole. The difference between prevalence in Detroit and Michigan as a whole decreased from 2016 to 2019.
- More than 4,000 Detroit children aged 5-17 years covered by Medicaid have health care utilization consistent with persistent asthma.

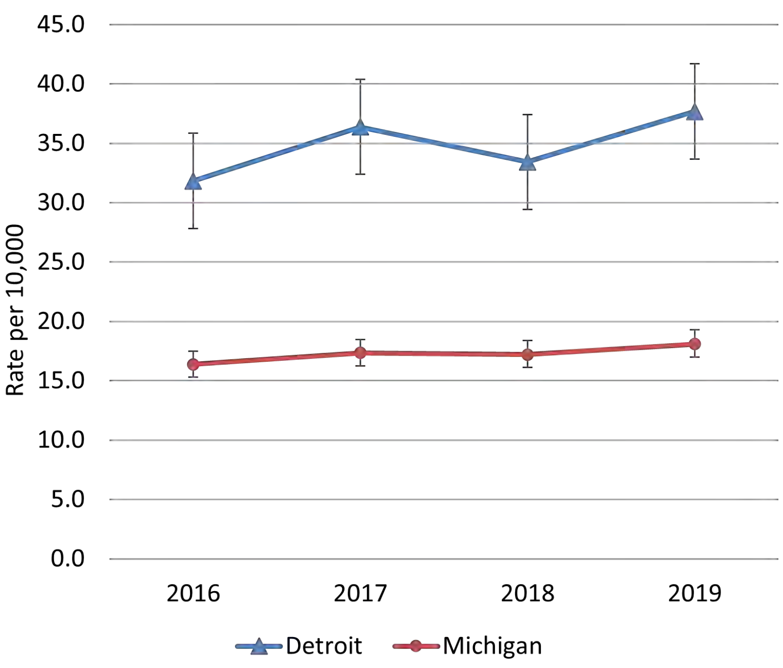
16. Prevalence[1] of Persistent Asthma[2] by ZIP Code of Residence, Children (5-17 Years) on Medicaid[3], Detroit, 2016-2019



- The highest rates of persistent asthma among children in Detroit occurred around the center and the eastern parts of the city.
- The ZIP codes of lowest prevalence were primarily located in the southwestern parts of the city and two other ZIP codes in central Detroit, 48212 and 48211 .

Data Notes:
Source: Michigan Health Data Warehouse, MDHHS
1. Age-adjusted to the 2000 US Standard Population
2. Based on annual NCQA HEDIS definition
3. Medicaid population of children 5-17 years is restricted to those who are continuously enrolled in Medicaid with full coverage and no other insurance

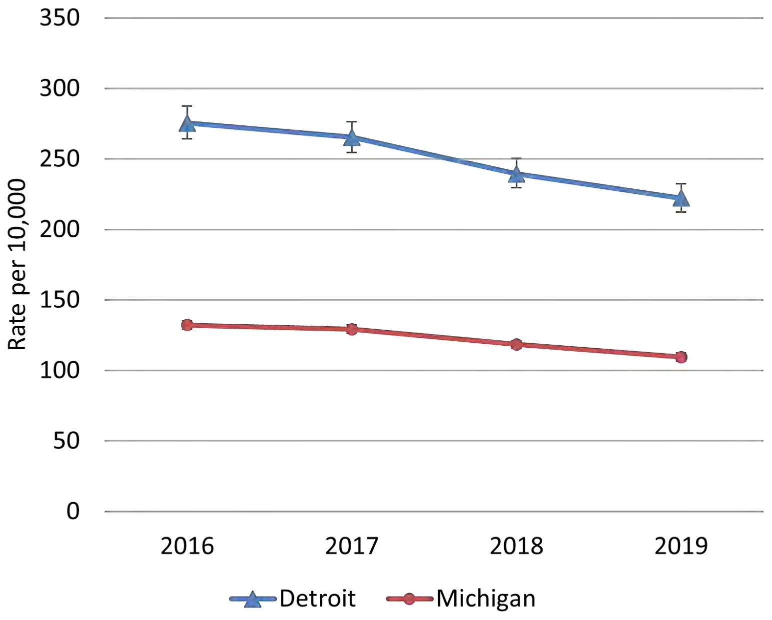
17. Rate[1] of Asthma[2] Hospitalizations, Children (5-17 years) on Medicaid[3], Detroit and Michigan, 2016-2019



Data Notes:
Source: Michigan Health Data Warehouse, MDHHS
1. Age-adjusted to the 2000 US Standard Population
2. Based on annual NCQA HEDIS definition
3. Medicaid population of children 5-17 years is restricted to those who are continuously enrolled in Medicaid with full coverage and no other insurance
4. Spearman's correlation and rank correlation test

- In 2019, the total number of hospitalizations for Detroit children covered by Medicaid was about 305. The rate was 38.0 hospitalization visits per 10,000 children on Medicaid in Detroit.
- The rate for Michigan was 18.1 per 10,000 children on Medicaid. There was a total of 926 hospitalizations in Michigan children covered by Medicaid.
- The rate of asthma hospitalization visits for children in Detroit in 2019 was over twice the rate for children in Michigan.
- Rates did not change significantly ($p>0.05$)[4] for both Detroit and Michigan from 2016-2019.

18. Rate[1] of Asthma[2] Emergency Department Visits, Children (5-17 Years) on Medicaid[3], Detroit and Michigan, 2016-2019



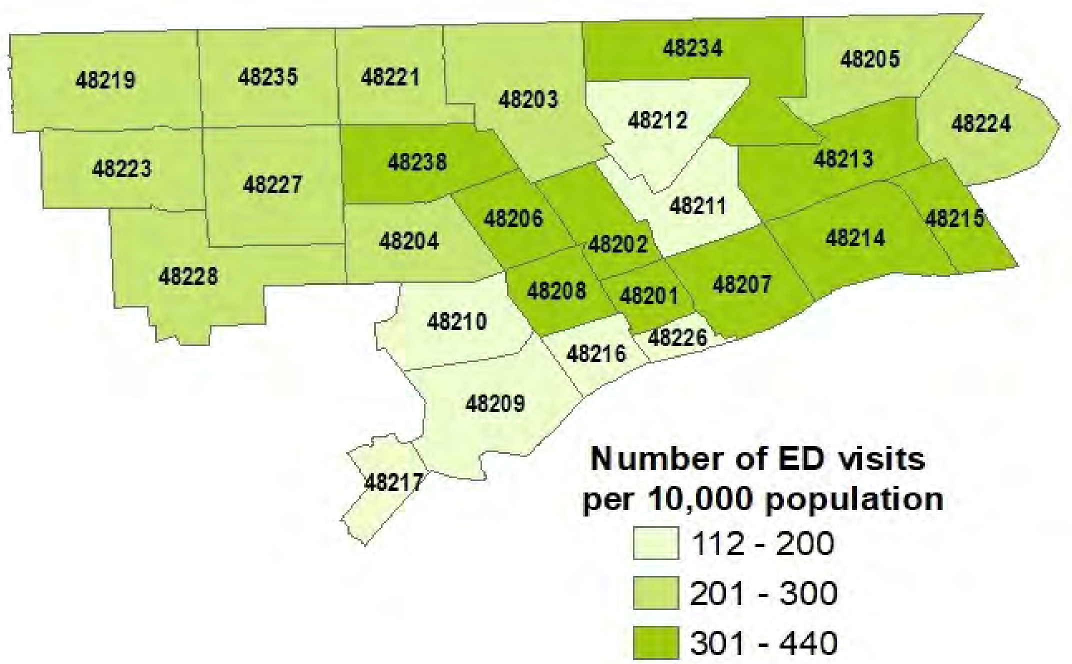
Data Notes:
Source: Michigan Health Data Warehouse, MDHHS
1. Age-adjusted to the 2000 US Standard Population
2. Asthma as primary diagnosis ICD-10 –CM=J45.XX
3. Medicaid population of children 5-17 years is restricted to those who are continuously enrolled in Medicaid with full coverage and no other insurance

- In 2019, the total number of emergency department (ED) visits for Detroit children covered by Medicaid was about 1,800. The rates for Detroit and Michigan were 222 and 110 ED visits per 10,000 children on Medicaid, respectively.

- The rate of asthma emergency department visits for children in Detroit in 2019 was about twice the rate for children in Michigan.

- From 2016 to 2019, the disparity between Detroit and Michigan in the asthma emergency department (ED) visit rate decreased, from 143 to 112 per 10,000.

19. Rate[1] of Asthma[2] Emergency Department Visits by ZIP Code of Residence, Children (5-17 Years) on Medicaid[3], Detroit, 2016-2019

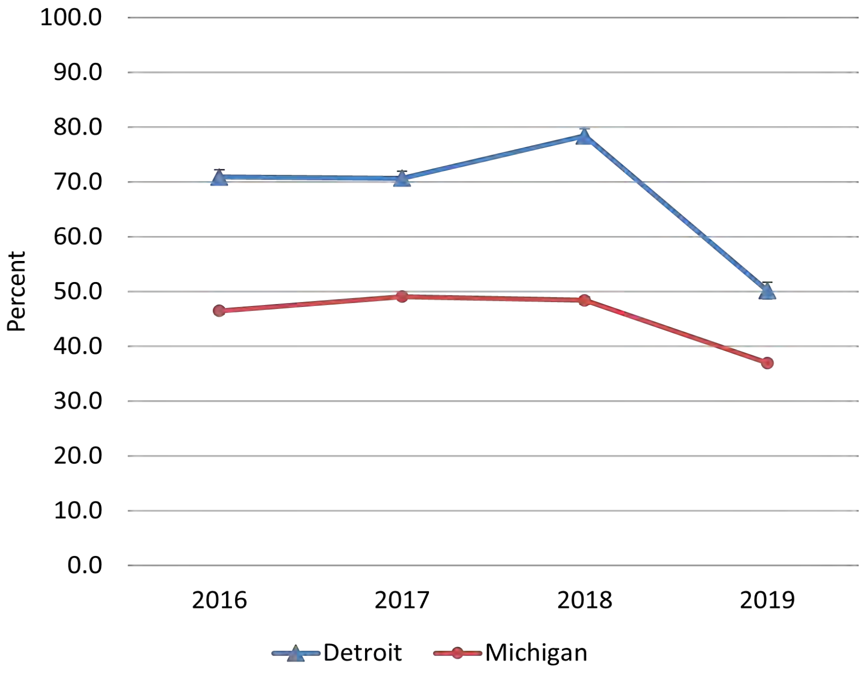


- With few exceptions, ZIP codes in the center and eastern parts of Detroit tended to be the ZIP codes with the highest emergency department visit rates for asthma in the city.

Data Notes:
Source: Michigan Health Data Warehouse, MDHHS
1. Age-adjusted to the 2000 US Standard Population
2. Asthma as primary diagnosis ICD-10 –CM=J45.XX
3. Medicaid population of children 5-17 years is restricted to those who are continuously enrolled in Medicaid with full coverage and no other insurance

The following asthma statistics are among children in Medicaid with asthma, not the entire child Medicaid population.

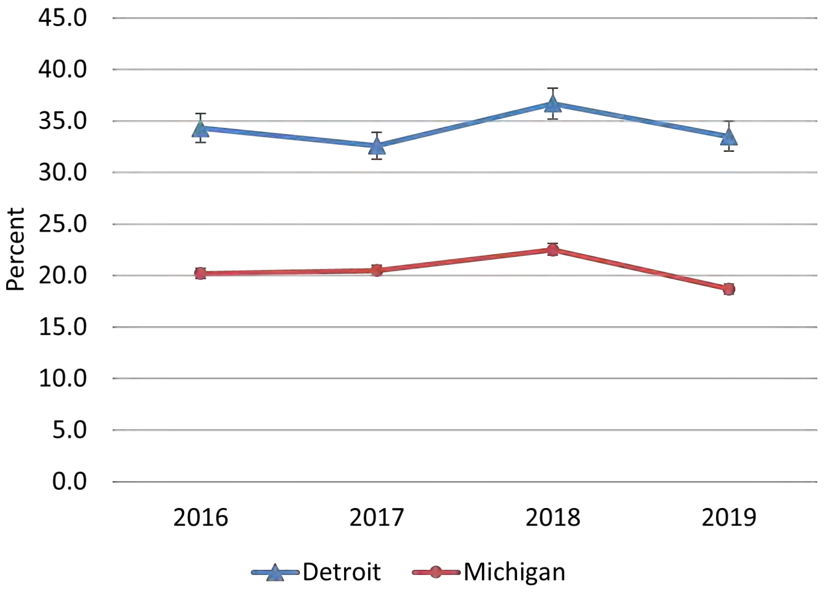
20. Percent[1] of Children (5-17 Years) with Asthma[2] with ≥2 Outpatient Visits for Asthma on Medicaid[3], Detroit and Michigan, 2016-2019



- In 2019, 50.2% of Detroit children covered by Medicaid and 37% of Michigan children with persistent asthma had at least two outpatient visits for asthma.
- There was a significant decline in the rates of two or more outpatient visits from 2016-2019 among both Detroit and Michigan children with asthma under Medicaid.
- The proportion of Detroit children covered by Medicaid with persistent asthma with at least two office visits for asthma was significantly higher ($p<0.05$)[4] compared to that for the state as a whole.

Data Notes:
Source: Michigan Health Data Warehouse, MDHHS
1. Age-adjusted to the 2000 US Standard Population
2. Asthma as primary diagnosis ICD-10 –CM=J45.XX
3. Medicaid population of children 5-17 years is restricted to those who are continuously enrolled in Medicaid with full coverage and no other insurance
4. Spearman's correlation and rank correlation test

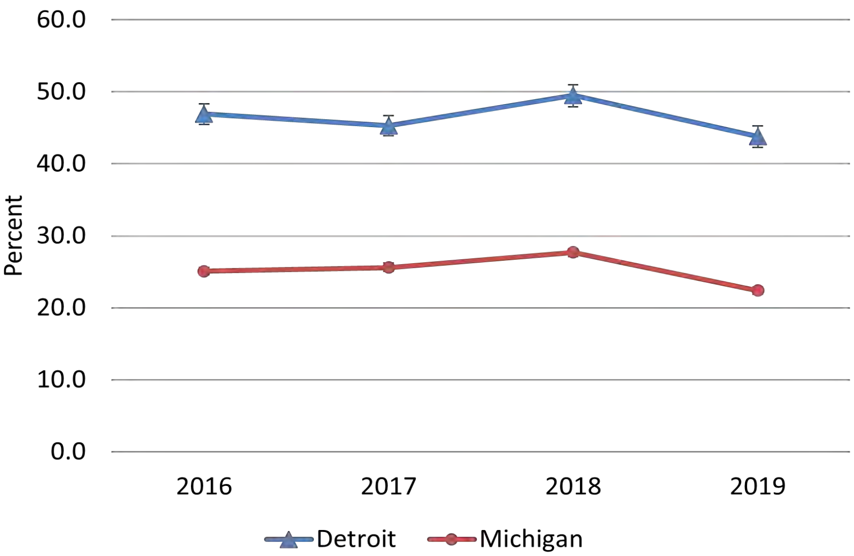
21. Percent of Reliance on Emergency Department for Primary Care[1] among Children (5-17 Years) with Asthma[2] on Medicaid[3], Detroit and Michigan, 2016-2019



- Reliance on the emergency department for primary care is a measure of the proportion of all outpatient visits for asthma that are emergency department visits.
- In 2019, the proportion of outpatient visits for asthma that occurred in the emergency department for Detroit and Michigan children covered by Medicaid with persistent asthma was 33.5% and 18.7%, respectively.
- Emergency department reliance for primary care was about 79% higher among children in Detroit compared to the state as a whole in 2019.
- From 2016 to 2019, emergency department reliance dropped in Michigan by 8%, but did not change significantly ($p>0.05$)[4] in Detroit.

Data Notes:
Source: Michigan Health Data Warehouse, MDHHS
1. Proportion of all outpatient visits for asthma that are emergency department visits (Asthma as primary diagnosis, ICD-10 –CM=J45.XX), age-adjusted to the 2000 US Standard Population
2. Based on annual NCQA HEDIS definition
3. Medicaid Population of children 5-17 years is restricted to those who are continuously enrolled in Medicaid with full coverage and no other insurance.
4. Spearman’s correlation and rank correlation test

22. Percent[1] of Children (5-17 Years) with Asthma[2] with ≥1 Emergency Department Visits for Asthma[3], Medicaid[4], Detroit and Michigan, 2016-2019



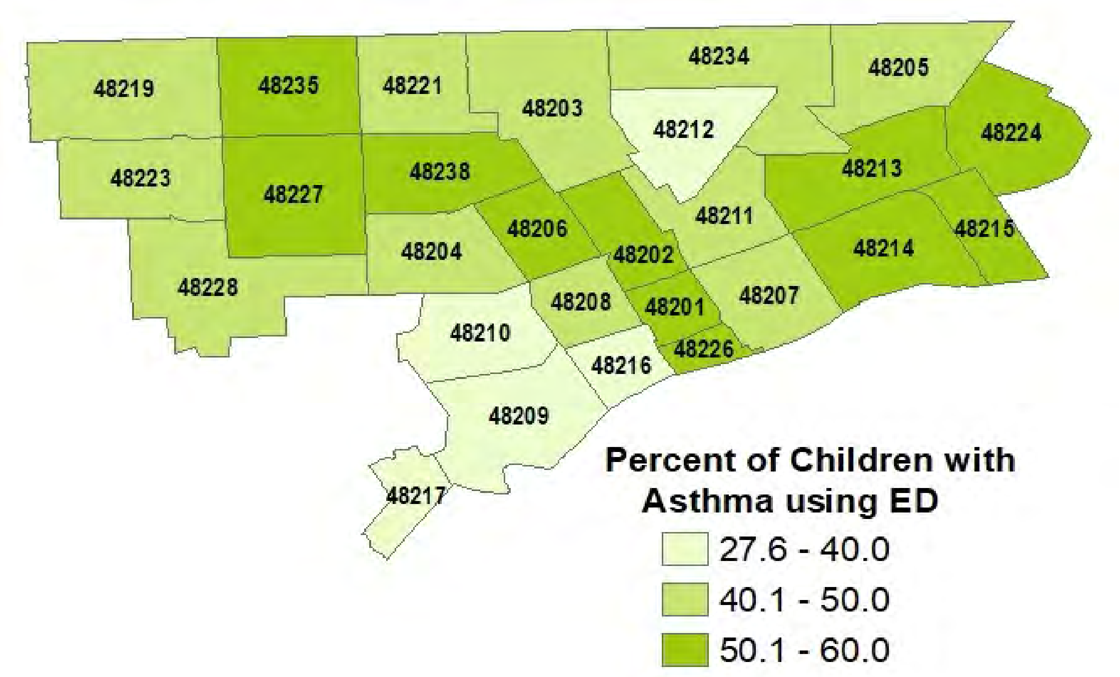
- It is the goal of asthma therapy that persons with asthma experience minimal or no emergency department visits for asthma.[5]

- In 2019, 43.8% of Detroit children enrolled in Medicaid with persistent asthma had one or more emergency department visits for asthma.

- The proportion of Detroit children covered by Medicaid with persistent asthma with at least one emergency department visit for asthma in 2019 was almost two times the rate for Michigan as a whole.

Data Notes:
Source: Michigan Health Data Warehouse, MDHHS
1. Age-adjusted to the 2000 US Standard Population
2. Based on NCQA HEDIS Definition
3. Asthma as primary diagnosis ICD-10 –CM=J45.XX
4. Medicaid population of children 5-17 years is restricted to those who are continuously enrolled in Medicaid with full coverage and no other insurance.
5. National Heart, Lung, and Blood Institute. *Guidelines for the Diagnosis and Management of Asthma: Expert Panel Report 3*. National Institutes of Health Publication Number 09-5846. October 2007.

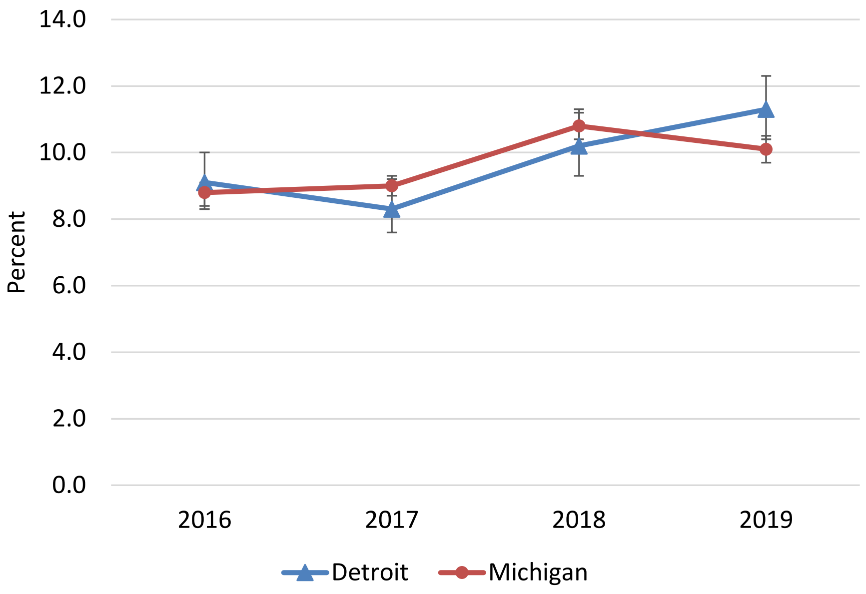
23. Percent[1] of Children (5-17 Years) with Asthma[2] with ≥1 Emergency Department Visits for Asthma[3] by ZIP Code of Residence, Medicaid[4], Detroit, 2016-2019



- ZIP codes with the lowest rates were concentrated in the southwestern part of the city. One ZIP code 48212 in the central part of the city also recorded lowest rate.

Data Notes:
Source: Michigan Health Data Warehouse, MDHHS
1. Age-adjusted to the 2000 US Standard Population
2. Based on NCQA HEDIS Definition
3. Asthma as primary diagnosis, ICD-10 –CM=J45.XX
4. Medicaid Population of children 5-17 years is restricted to those who are continuously enrolled in Medicaid with full coverage and no other insurance.

24. Percent[1] of Overuse of Short-Acting β-Agonist Medication among Children (5-17 Years) with Persistent Asthma[2], Medicaid[3], Detroit and Michigan, 2016-2019

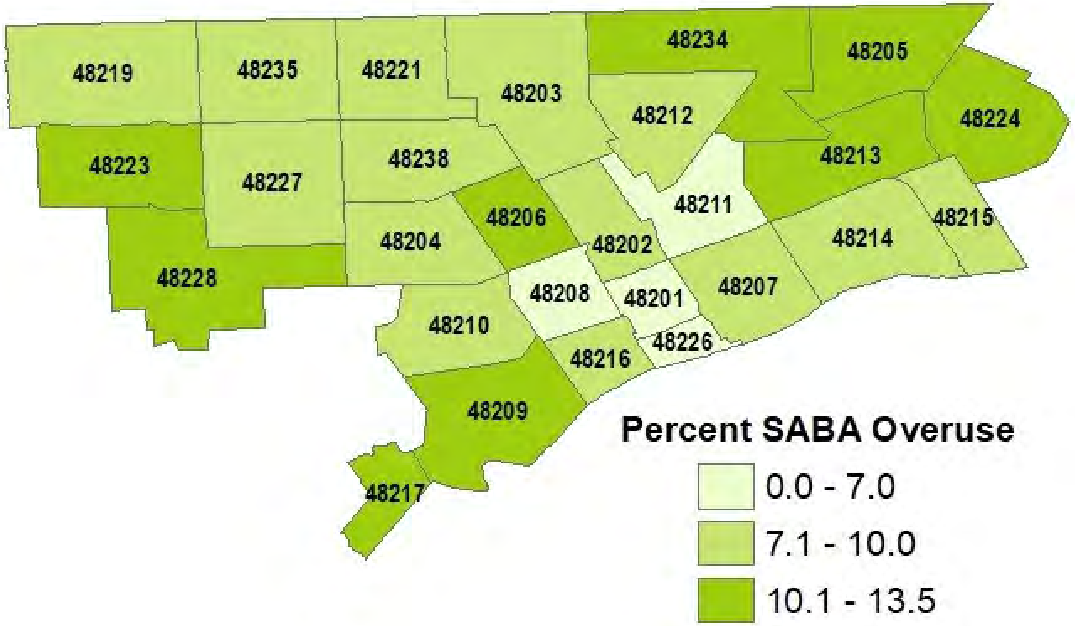


- It is the goal of asthma therapy that there be minimal use of short-acting β-agonist medication[4] – less than one canister per month. For this indicator, overuse is defined as filling seven or more prescriptions for short-acting β-agonist in a year.
- In 2019, the prevalence of short-acting β-agonist medication overuse among Detroit children and Michigan children covered by Medicaid with persistent asthma was 11.3% and 10.1% respectively.

Data Notes:
Source: Michigan Health Data Warehouse, MDHHS

1. Age-adjusted to the 2000 US Standard Population
2. Based on NCQA HEDIS Definition
3. Medicaid Population of children 5-17 years is restricted to those who are continuously enrolled in Medicaid with full coverage and no other insurance.
4. National Heart, Lung, and Blood Institute. *Guidelines for the Diagnosis and Management of Asthma: Expert Panel Report 3*. National Institutes of Health Publication Number 09-5846. October 2007.

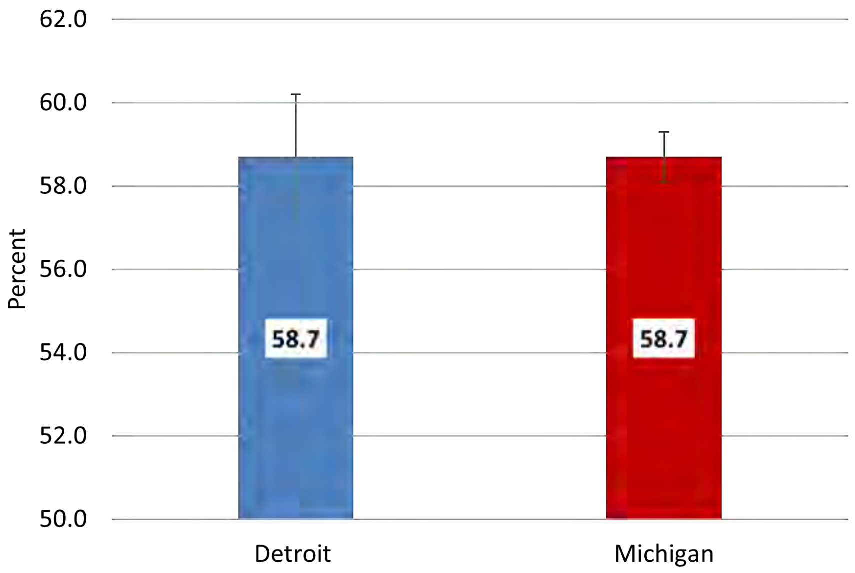
25. Percent[1] of Overuse of Short-Acting β-Agonist (SABA) Medication among Children (5-17 Years) with Asthma[2] by ZIP Code of Residence, Medicaid[3], Detroit, 2016-2019



- Highest rates of SABA overuse were mostly concentrated in the northeastern, western and southwestern parts of the city.
- ZIP codes 48208, 48201, 48226 and 48211 had the lowest rates of SABA overuse.

Data Notes:
Source: Michigan Health Data Warehouse, MDHHS
1. Age-adjusted to the 2000 US Standard Population
2. Based on NCQA HEDIS Definition
3. Medicaid population of children 5-17 years is restricted to those who are continuously enrolled in Medicaid with full coverage and no other insurance.

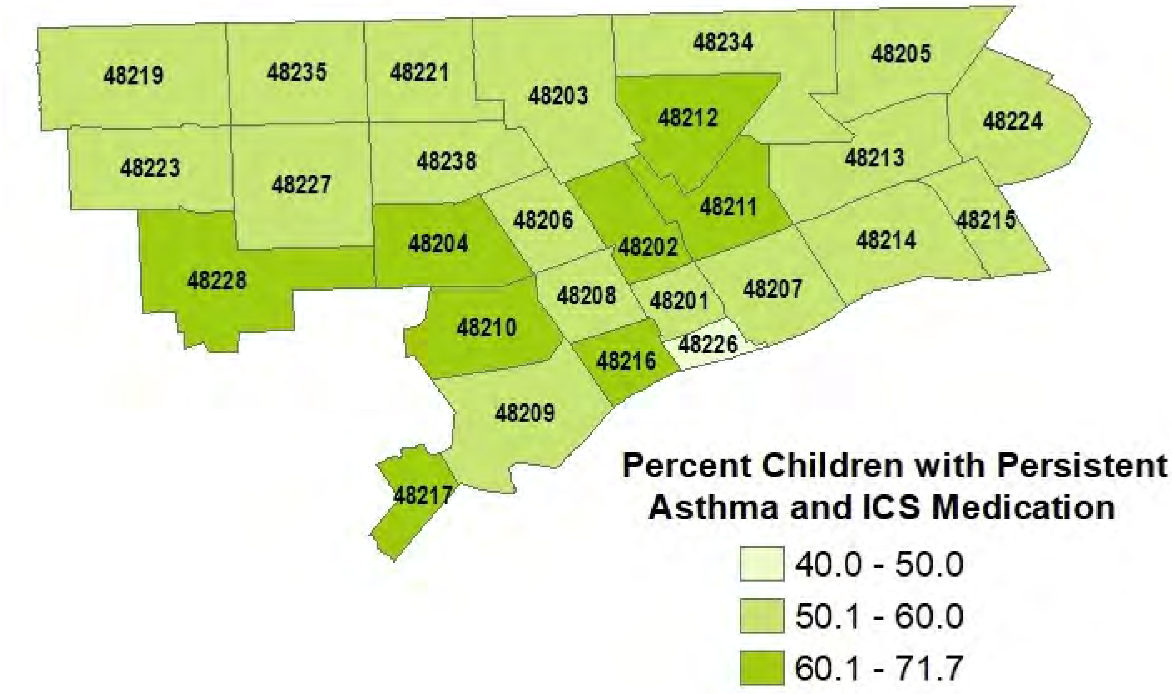
26. Percent[1] of Children (5-17 Years) with Asthma[2] with ≥1 Inhaled Corticosteroid Medication, Medicaid[3], Detroit and Michigan, 2019



- Long-term asthma control medications, such as inhaled corticosteroids, are recommended for children with persistent asthma.[4]
- 58.7% of children in Detroit and Michigan in 2019 filled a prescription for inhaled corticosteroids.
- There was no statistical difference between the rate for Detroit and Michigan in 2019.

Data Notes:
Source: Michigan Health Data Warehouse, MDHHS
1. Age-adjusted to the 2000 US Standard Population
2. Based on NCQA HEDIS Definition
3. Medicaid Population of children 5-17 years is restricted to those who are continuously enrolled in Medicaid with full coverage and no other insurance.
4. National Heart, Lung, and Blood Institute. *Guidelines for the Diagnosis and Management of Asthma: Expert Panel Report 3*. National Institutes of Health Publication Number 09-5846. October 2007.

27. Percent[1] of Children (5-17 Years) with Asthma[2] with ≥1 Inhaled Corticosteroid Medication by ZIP Code of Residence, Medicaid[3] Detroit, 2016-2019

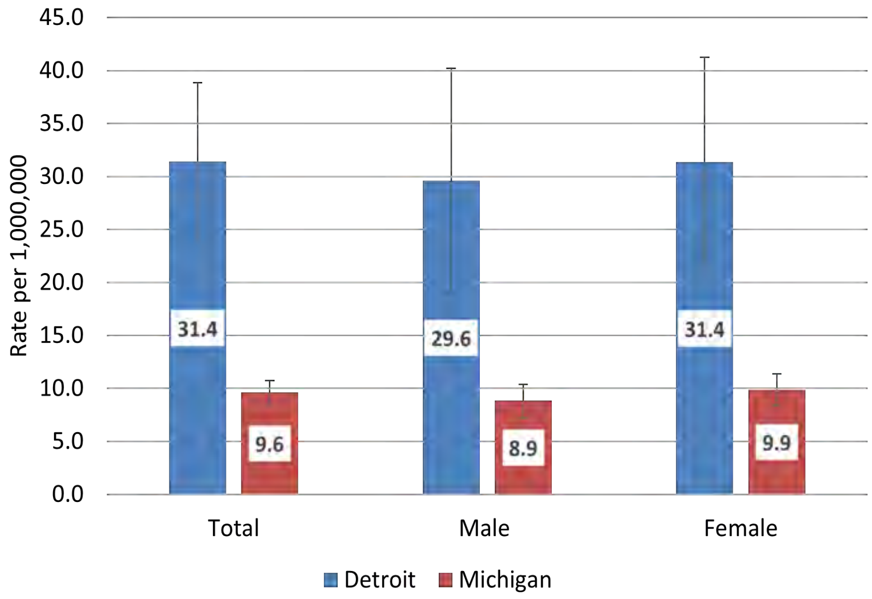


- ZIP codes with the highest percent of children filling inhaled corticosteroids tended to be in the southwestern and central areas of Detroit. Only one ZIP code 48226 recorded the lowest rate.

Data Notes:
Source: Michigan Health Data Warehouse, MDHHS
1. Age-adjusted to the 2000 US Standard Population
2. Based on NCQA HEDIS Definition
3. Medicaid Population of children 5-17 years is restricted to those who are continuously enrolled in Medicaid with full coverage and no other insurance.

Asthma Mortality

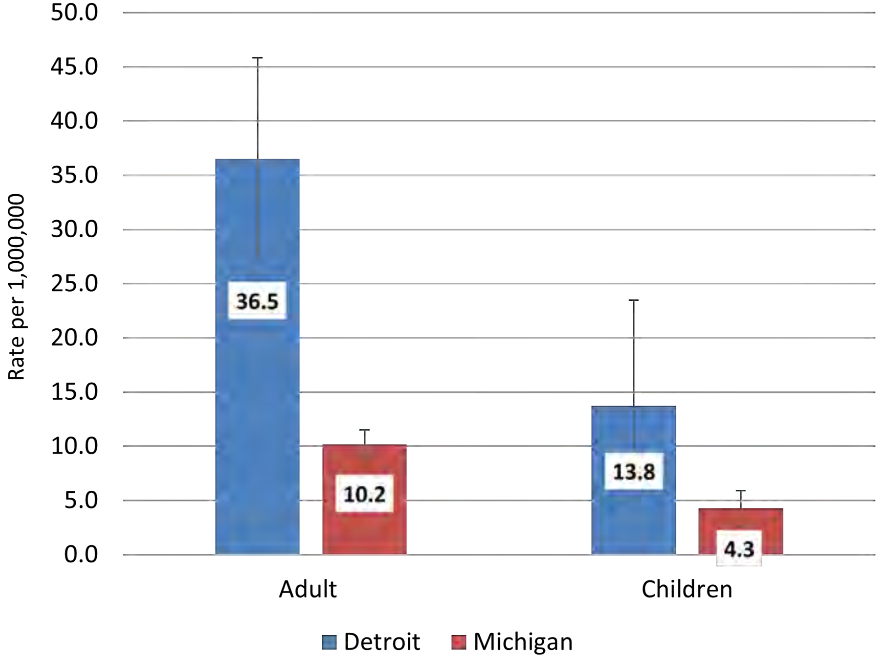
28. Rates[1] of Asthma Death[2] by Sex, Detroit and Michigan, 2017-2019



- Between 2017 and 2019, 71 Detroit residents died due to asthma. The rate of asthma mortality among Detroit residents was 31.4 per 1,000,000 population.
- The rate of asthma mortality in Detroit in 2017-2019 was about three times the rate for Michigan as a whole.
- Between 2017 and 2019, the rate of asthma mortality among Detroit males was 29.6 per 1,000,000 and the rate for Detroit females was 31.4 per 1,000,000.
- The rates of asthma mortality for Detroit males and females were not significantly different during this time period.

Data Notes:
Source: Michigan Death Files, MDHHS
1. Age-adjusted to the 2000 US Standard Population
2. Asthma as the underlying cause of death, ICD-10:J45-J46

29. Rates[1] of Asthma Mortality[2] by Age Group, Detroit and Michigan, 2017-2019



- The rate of asthma mortality for Detroit children between 2017 and 2019 was 13.8 per 1,000,000. The rate of asthma mortality among children in Detroit was not significantly different than rates for children in Michigan but was three times higher.

- Among Detroit adults, the rate of asthma mortality between 2017 and 2019 was 36.5 per 1,000,000.

- The rate of asthma mortality for Detroit adults was over three times the rate for adults in Michigan as a whole.

Data Notes:
Source: Michigan Death Files, MDHHS
1. Age-adjusted to the 2000 US Standard Population
2. Asthma as primary cause of death, ICD-10:J45-J46

Conclusion

- The disparity in the asthma burden in Detroit warrants continued attention. Public health efforts should continue to be directed to persons with asthma in Detroit to improve asthma control and prevent severe outcomes.
- MDHHS will share this update with its partners in the City of Detroit and across the state.

Methods

Prevalence of Asthma

Michigan prevalence estimates for asthma were based on self-reporting from the Michigan Behavioral Risk Factor Survey (MiBRFS) using two questions:

1. Have you ever been told by a doctor, nurse, or health professional that you had asthma? (lifetime asthma)
2. Do you still have asthma? (current asthma)
   "Lifetime asthma prevalence" was the percentage of respondents who reported "yes" to question #1. "Current asthma prevalence" was the percentage of respondents who reported "yes" to both questions #1 and #2.

MiBRFS data were collected by telephone interview of a sample from both cell phone and landline telephone numbers (visit https://www.michigan.gov/documents/mdhhs/2019-MiBRFS-Standard-Tables_711893_7.pdf, page 3 for more information). All measures of asthma prevalence were accompanied by 95% confidence intervals. Annual estimates of asthma prevalence for adults (≥18 years) were provided by MiBRFS, by sex, race/ethnicity, education, and household income. The MiBRFS was also the source for estimates of prevalence of asthma among children (<18 years) by asking the adult respondent to act as the proxy for a selected child in the household. Annual estimates of prevalence for children were provided for by sex, race/ethnicity, proxy's education, and household income.

Methods continued

Asthma Hospitalization

An asthma hospitalization was defined as an inpatient stay with a primary discharge diagnosis of asthma (ICD-10 –CM=J45.XX). These data represent the number of hospitalizations for asthma, not the number of persons with a hospitalization for asthma.

Age-adjusted asthma hospitalization rates were calculated and presented per 10,000 population. Rates were age-adjusted, using the 2000 US standard population, so that valid comparisons could be made between populations of different age distributions. All hospitalization rates were accompanied by 95% confidence intervals. In addition to asthma hospitalization rates, the average length of stay and hospitalization rates by month of admission were calculated.

Asthma hospitalization rates were calculated for demographic and geographic subgroups, including ZIP codes of residence (for Detroit), age, race, sex, and month of admission, to identify disparities and patterns. Maps generated using geographic information systems (GIS; ArcGIS^{TM}) were used to visually display the data and to identify areas of high burden. Census data from 2010 were used to calculate the Detroit hospitalization rates. Yearly bridged-race population estimated provided by the National Vital Statistics System maintained by the Centers for Disease Control and Prevention were used to calculate Michigan’s rates.

Temporal trends in asthma hospitalization rates were statistically evaluated using the Spearman correlation coefficient and its accompanying rank correlation test. A p-value of <0.05 for this test was considered statistically significant.

The data source for these analyses was the Michigan Inpatient Database, which includes virtually all hospital discharges for Michigan residents during the study period.

Methods continued

Asthma Management for Children Covered by Medicaid

- From the Michigan Medicaid beneficiary and administrative claims data (2016-2019), the study population was identified by the following parameters within each year: children 5-17 years of age who had continuous Medicaid enrollment (11+ months), full Medicaid coverage, and no other insurance. Both fee-for-service and managed care beneficiaries were included, but Title V beneficiaries were excluded.

- By using these restrictions, these data undercount the number of children with asthma covered by Medicaid. Not included were children with asthma who: 1) were not enrolled in Medicaid continuously or 2) did not have a paid Medicaid health utilization claim from 2016 through 2019.

Within this population, the following indicators of total asthma burden were measured:

- *Persistent asthma prevalence*: Utilization consistent with the diagnosis of asthma was defined according to HEDIS® specifications; in the year of the prevalence measurement, having (1) ≥4 asthma medication dispensing events OR (2) ≥1 emergency department visits for asthma OR (3) ≥1 hospitalization for asthma OR (4) ≥4 outpatient visits for asthma and ≥2 asthma medication dispensing events (National Committee for Quality Assurance. Appropriate Medications for People with Asthma. HEDIS ® 2003, Volume 2: Technical Specifications. Washington, DC; 2003). Prevalence of persistent asthma was the percentage of beneficiaries in the study population who meet the HEDIS definition of persistent asthma.

- *Rate of asthma emergency department visits:* An asthma emergency department visit was defined as a visit occurring in a hospital emergency department with a primary diagnosis of asthma (ICD-10 –CM=J45.XX). These data represent the number of persons visiting the emergency department for asthma. The number of asthma emergency department visits, divided by the study population then multiplied by 10,000, generated this measure.

Methods continued

Asthma Management for Children Covered by Medicaid, continued

- Children with utilization consistent with persistent asthma, as defined above, formed the annual study population upon which indicators of asthma management are measured within that year, including:

- *Percentage with an emergency department visit:* The percentage of children covered by Medicaid with persistent asthma who have had one or more annual asthma emergency visits (ICD-10 –CM=J45.XX).

- *Emergency department reliance*: The percentage of all ambulatory asthma visits (ICD-10 –CM=J45.XX, outpatient and emergency department) among children covered by Medicaid with persistent asthma that occur in the emergency department. It estimates the reliance on the emergency department for primary care.

- *Short-acting β-agonist overuse*: The percentage of children with persistent asthma in Medicaid who have filled seven or more prescriptions for short-acting β-agonists in a year – an indicator of overuse of this medication.

- *Proportion using an inhaled corticosteroid medication*: The proportion of children with persistent asthma in Medicaid who filled one or more prescriptions for an inhaled corticosteroid medication in a year – inhaled corticosteroids are the preferred, first-line medication recommended for persons with persistent asthma. For this metric, inhaled corticosteroid medication includes bronchodilator combination therapy

Methods continued

Asthma Management for Children Covered by Medicaid, continued

For all of the above, indicators were age-adjusted using the 2000 US standard population and were accompanied by a 95% confidence interval. Both geographic (ZIP Code) and demographic (age, race, and sex) subpopulation analysis were conducted to identify disparities. Maps generated using geographic information (GIS; ArcGIS^{TM}) systems were used for visual display of the data and to identify areas of high burden.

Asthma Death

An asthma death was defined by the underlying cause of death (ICD-10=J45 or J46). Asthma mortality rates were calculated for the three-year period 2017-2019 and were presented per 1,000,000 population. Rates were age-adjusted, using the 2000 US standard population, so that valid comparisons could be made between populations of different age distributions. Rates were calculated by age, race, and sex, to identify disparities and patterns. All mortality rates were accompanied by 95% confidence intervals.

The data source for these analyses was the Michigan Death Files, which included all deaths for Michigan residents during the study period.

Methods continued

Defining Detroit

- The definition of Detroit was slightly different for each data type presented in this report. The definitions were as follows:
  - Current asthma prevalence from survey: On the MiBRFS, Detroit adults were identified by their affirmative response to the question, “Do you live in the city of Detroit?”
  - Hospitalization and Medicaid data: Detroit was defined by ZIP code tabulation areas (ZCTAs) for the city. These areas included Highland Park and Hamtramck.
  - Mortality: Detroit was defined by the Detroit minor civil division, which excluded Highland Park and Hamtramck.

This report was supported by the Cooperative Agreement Number 5 NUE1EH001380-03-00, funded by the Centers for Disease Control and Prevention. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the Centers for Disease Control and Prevention or the Department of Health and Human Services.

MDHHS-Pub-1465 (10/14)

MPSC Case No: U-21291
Requester: FLO
Question No.: FLODG-3.12
Respondent: H. J. Decker
Page: 1 of 1

Question: 12. Have DTE Gas and Consumers Energy Company (Consumers Energy) completed a cost--benefit analysis from the customer pen;pective comparing the rapid retirement of DTE's gas system and electrification of all customers with the continued operation of both DTE Gas's and DTE Electric' s infrastructures?

Answer: The Company has not conducted a cost-benefit analysis from the customer perspective comparing the rapid retirement of DTE’s gas system and electrification of all customers with continued operations.

Attachment: None

Co-Respondent(s): S. N. Kehoe,R. M. Telang

MPSC Case No: U-21291
Requester: FLO
Question No.: FLODG-3.13
Respondent: E. D. Janness
Page: 1 of 1

Question: 13. Have DTE Gas and DTE Electric conducted any shared planning processes to optimize the cost-effectiveness of investments in distribution infrastructure between DTE Gas and DTE Electric?

Answer: Yes.

Attachment: None.

MPSC Case No: U-21291
Requester: FLO
Question No.: FLODG-3.15
Respondent: E. D. Janness
Page: 1 of 1

Question: 15. Have DTE Gas and DTE Electric conducted any shared planning processes to analyze the combined customer impact of investments in distribution infrastructure between DTE Gas and DTE Electric?

Answer: Yes.

Attachment: None.

MPSC Case No: U-21291
Requester: FLO
Question No.: FLODG-3.17
Respondent: E. D. Janness
Page: 1 of 1

Question: 17. Other than information disclosed above, have DTE Gas and DTE Electric had any communication regarding their individual distribution investment planning processes? If the answer is yes, please describe the format of those communications.

Answer: No.

Attachment: None.

MPSC Case No: U-21291	
Requester: FLO	
Question No.: FLODG-3.19	
Respondent: G. H. Chapel	
Page: 1 of 1	

Question: 19. To what extent is DTE Gas communicating with DTE Electric about models and/or forecasts for future energy demand?

Answer: The demand forecasts for DTE Gas are developed independently of the sales forecasts for DTE Electric.

Attachment: None

NRDC<http://nrdc.org/>

Explainer

Decarbonization: Why We Must Electrify Everything Even Before the Grid Is Fully Green

To decarbonize and fight climate change, electrification and clean energy development must happen together—and fast.

December 1, 2022

An airplane flies over electric power lines near Los Angeles International Airport on August 31, 2022. That month, California announced a statewide electricity Flex Alert, urging conservation to avoid blackouts and grid outages. | *Patrick T. Fallon/AFP via Getty Images*

Courtney Lindwall <http://nrdc.org/bio/courtney-lindwall>
Contributor

You've probably heard by now that "the future is electric": out with the gas furnaces and water heaters, in with energy-efficient electric vehicles (EVs) and induction stoves. And that transformation away from fossil fuels and toward a greener tomorrow can't come soon enough. To put a point on it, we need to decarbonize everything from our homes to the power grid in order to hit net-zero emissions by 2050. So far, this is one of the best ways to help keep global warming to no more than 1.5 degrees Celsius <https://www.nrdc.org/stories/ipcc-climate-change-reports-why-they-matter-everyone-planet#:~:text=at%201.5%20degrees%20celsius%2c%20the,lower%20than%20at%202%20degrees.&text=other%20species%20are%20also%20worse,could%20nearly%20all%20be%20dead.> and rein in the worst of climate change.

But what does making this shift really entail?

First, a couple of definitions. *Decarbonization* refers to the process of reducing or eliminating carbon emissions from a given technology or sector, with the focus being on the biggest polluters, like transportation, buildings, and power. It's a massive undertaking—though one that's well on its way. *Electrification,* meanwhile, requires ditching technologies that run on fossil fuels and swapping them out for alternatives that run efficiently on electricity. It *also* means generating all that electricity from clean energy rather than fossil fuels.

That might have you asking if we should be getting more of our power from renewable energy sources before we start looking to plug everything in? The short answer is that we need to move full steam ahead with both, simultaneously. Let's look at why.

Why does electrification need to happen alongside clean energy growth?

There's an understandable, though ultimately unfounded, concern when it comes to decarbonization. It goes like this: If we electrify too quickly without ramping up the production of clean energy first, we run the risk of unintentionally increasing emissions. That's because the increased demand for electricity could actually require burning more fossil fuels in the short term.

But this view ignores the projected pace of clean energy growth. Renewables already generate 20 percent of all the nation's electricity, having increased 42 percent <https://www.c2es.org/content/renewable-energy/#:~:text=renewable%20energy%20is%20the%20fastest,percent%20from%202000%20to%202020).> between 2010 to 2020. And tax incentives from the historic Inflation Reduction Act are expected to double wind and solar generation by 2030, meaning the United States is within striking distance of its nationwide target <https://www.whitehouse.gov/briefing-room/statements-releases/2021/04/22/fact-sheet-president-biden-sets-2030-greenhouse-gas-pollution-reduction-target-aimed-at-creating-good-paying-union-jobs-and-securing-u-s-leadership-on-clean-energy-technologies/> of 100 percent carbon-free electricity by 2035. "A lot of people have an idea of what the grid looks like that's based in the early 2000s—not today or five years from now," says Joe Vukovich <https://www.nrdc.org/experts/joe-vukovich>, a staff attorney at NRDC who works on energy efficiency. In reality, a decarbonized grid is not generations away; it'll likely be here before your next car is out of commission.

Constructed in 2015, Block Island Wind Farm served as the first offshore wind farm in the United States. | ***Courtesy of Deepwater Wind***

Waiting until we hit 100 percent clean energy to move forward on electrification also ignores just how long full electrification may take across a variety of sectors. A new car or home appliance can last for more than a decade. Hurdles also remain in making efficient electric technologies easily available and affordable across the entire country, which will require investment and serious policy shifts. "These are slow-moving systems," says Alejandra Mejia Cunningham <https://www.nrdc.org/experts/alejandra-mejia>, NRDC's building decarbonization advocate. "We simply don't have time to do just one thing at a time."

Should you buy an electric vehicle if your electricity still comes from fossil fuels?

On average, replacing your gas-powered car with an EV in the United States will slash carbon pollution by about two-thirds <https://theicct.org/publication/a-global-comparison-of-the-life-cycle-greenhouse-gas-emissions-of-combustion-engine-and-electric-passenger-cars/> when calculated over the car's life span—even when accounting for the grid's current makeup and the emissions associated with the vehicle and battery production. And as the amount of renewables on the grid continues to increase (coupled with the fact that EVs are more efficient <https://www.nrdc.org/stories/electric-vs-gas-it-cheaper-drive-ev> in the first place), EVs on the road actually become cleaner over time. So driving one off the lot today is already the better choice.

Plus, you're helping to build momentum for the transformation of the market, which will reduce prices for people beyond the early adopters. "There is a magnifying effect when you vote with your dollars and switch to an EV," says Kathy Harris, NRDC's clean vehicles and fuels advocate. "Policymakers and manufacturers alike will see this is where America wants to go."

Electric vehicles in the Optical Characterization and Thermal Systems Laboratory at the National Renewable Energy Laboratory's Energy Systems Integration Facility in Colorado. The lab's EV grid integration research helps determine how EVs can be added to the grid, potentially combining building and EV charging. Dennis Schroeder/NREL, 62132

That, in turn, will also help speed up the deployment of much-needed EV charging infrastructure <https://www.nrdc.org/experts/max-baumhefner/kamala-and-joe-were-ready-install-ev-charging> and bring charging stations to underserved regions. Alongside investments into EVs made by the historic Bipartisan Infrastructure Law <https://www.nrdc.org/experts/stephanie-gidigbi-jenkins/meeting-moment-how-bipartisan-infrastructure-deal-can-put>, this will help accelerate our path to a clean transportation future.

What about electrifying your home appliances?

All homes and buildings should run on 100 percent clean power by 2050, which means ditching all fossil fuel appliances by then too. From that end goal, we can work backward. Appliances like gas-powered water heaters last at least a decade. Some building heating systems can last as long as 30 or even 50 years. "We need every new appliance to be both efficient and electric by the early 2030s because we don't want to be ripping out perfectly useful appliances closer to 2050 in order to electrify," Mejia Cunningham says. "We need to take advantage of the natural replacement cycle today."

The good news is that electric heat pumps installed now (the highest-priority replacement because heating and cooling are far and away the biggest energy sucks for homes) will reduce heating-related climate emissions <https://www.nrdc.org/experts/alex-hillbrand/climate-math-home-heating-electrification-0> in every region of the country when assessed over the lifetime of the appliance. In some regions, the reduction could be as much as 72 percent. That figure only takes into account clean energy policies already committed to by law—not just what advocates are hoping for. When you also factor in the expected exponential growth of renewable energy, we're looking at nearly guaranteed emissions savings for home electrification projects you take on today.

Could electrification worsen pollution in environmental justice communities?

Low-income communities and communities of color are more likely to live near fossil fuel facilities and bear the brunt of their health-harming air pollution. As the country decarbonizes and we come to rely more on our wall plugs and less on gas stations and heating oil, we have to ensure we don't make that worse.

This is why equity has to be baked into our approach at every step of the way, Mejia Cunningham explains. Focusing on energy efficiency in tandem is a big piece of the equity puzzle, so that we're reducing overall energy consumption and not increasing air pollution from power plants while we electrify. It also means finding ways to address "load flexibility"—that is, making sure we're not all heating our homes and water at five in the evening when the sun is going down, which could spike energy use at particularly dirty "peaker" power plants <https://www.popsci.com/environment/peaker-plants-101/> that are often placed in environmental justice neighborhoods.

Upfront investments into clean energy and electrification should also be directed to low-income communities and communities of color so that they are not left bearing the cost of fossil fuel infrastructure at the end of its life. "You don't want the people who are least able to afford to electrify to be the ones left holding the bag," Vukovich says. And the most impacted communities need seats at the table as state and local policy decisions are made about new electrification standards and their implementation.

An Association for Energy Affordability crew member works on a weatherization project at an apartment in New York City. | *Natalie Keyssar for NRDC*

Done right, decarbonization of our building, transportation, and power sectors promises to bring big benefits to environmental justice communities, from lower energy costs to reduced indoor and environmental air pollution exposure, thanks to burning fewer fossil fuels.

How can we all actively speed up decarbonization?

The brunt of the work must be done at the policy level—and it's a lot of work. Wide-scale decarbonization means everything from overhauling local building codes to ensuring the grid can reliably and efficiently <https://www.nrdc.org/stories/face-winter-storm-our-grid-reliable> meet higher electricity demands. It also means investing in job training so that we have technicians ready to install and maintain new clean energy technologies. Basically, we must continue to advocate for these kinds of decarbonization initiatives at the federal and local levels.

But individual consumers hold a lot of power when it comes to decarbonization too. According to analysis from the electrification nonprofit Rewiring America, decisions made by individual households are collectively responsible for about 42 percent of all U.S. energy-related emissions <https://content.rewiringamerica.org/reports/no-place-like-home-slides.pdf>—like our choice of which car to drive or appliance to install. Now, that doesn't mean homeowners should just replace perfectly good heaters or that drivers should ditch working gas-powered cars, especially if they can't afford to upgrade today, Mejia Cunningham explains. Instead, do some prep work so that your next big purchase can be one that's good for the climate and your wallet.

Look into which EV models might work for your commute. For your home, consider an energy audit to help you prioritize electrification and efficiency upgrades. And save money where you can through the steep tax credits and rebates in the Inflation Reduction Act <https://www.nrdc.org/stories/consumer-guide-inflation-reduction-act> for climate-friendly purchases like solar panels and heat pumps. Finally, it's worth remembering the power of your voice. The more you spread the word about your climate-friendly choices, the more you might inspire others to follow your lead.

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ABELL FOUNDATION

DECEMBER 2023

By Arjun Makhijani, Ph.D.

The Trouble with STRIDE:

Meeting climate goals and addressing natural gas system stranded costs

The Abell Foundation
Suite 2300
111 S. Calvert Street
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Preface

This report is concerned with two things: (i) the need to drastically reduce natural gas consumption to meet the climate targets set in the 2022 Maryland law called the Climate Solutions Now Act, including the associated problem of stranded costs; and (ii) the impact of continued investments in existing natural gas system on rates especially, but not only, as they concern low- and moderate-income households.

It builds on a comprehensive report, *Energy Affordability in Maryland: Integrating Public Health, Equity, and Climate*, published by the Institute for Energy and Environmental Research and PSE Healthy Energy in February 2023.[1] That report was funded by the Town Creek Foundation and the Abell Foundation. Part of IEER's agreement with the Abell Foundation was to produce a more detailed report focused on the problem of natural gas rates and stranded costs in the residential sector, given the magnitude of the energy cost burdens and inequities that are emerging due to continuing investments in existing natural gas infrastructure authorized by a 2013 law called the Strategic Infrastructure Development and Enhancement Act (STRIDE). While STRIDE is the focus of this report (which draws heavily on the larger February 2023 report), I want to note that the actual problem of stranded costs is much bigger since investments in new natural gas infrastructure continue, despite the imperative dictated by the Climate Solutions Now Act of 2022 for Maryland to achieve net zero greenhouse gas emissions by 2045.

I would like to thank Abell Foundation for funding this effort. I especially want to thank its Senior Program Officer, Beth Harber for supporting this work from its inception, including reviewing Energy Affordability in Maryland, and sharing her insights with me on a variety of issues. Andrew Green, Vice-President of Abell Foundation, also reviewed the report and provided many useful substantive and editorial suggestions. I am also grateful for important insights from David Lapp, Maryland's People's Counsel. As is clear from the contents of this report, I have found the analysis in the reports of the Office of People's Counsel very useful, insightful, and vigilant in the interests of residential ratepayers. I have benefited from reviews of a draft of this report by Paula Carmody, Joseph Cullen, Laurel Peltier, Emily Scarr, and representatives of Baltimore Gas & Electric. They have all helped improve this report. As is always the case, as the author, I alone am fully responsible for any errors and omissions as well as the contents of this report, including its findings and recommendations.

ARJUN MAKHIJANI
President,
Institute for Energy and Environmental Research

Executive Summary

Baltimore Gas and Electric's replacement of its natural gas infrastructure became a public flashpoint this summer as some Baltimore residents raised loud objections to the installation of regulators on the outside of their homes. The debate about safety, historic preservation, and aesthetics led to threats to cut off gas supplies, litigation, and even the arrest of three protesters in Federal Hill before the Public Service Commission stepped in.

But questions about the replacement of gas lines extend far beyond the dispute between BGE and a few neighborhoods. Rather, it and the state's other major regulated gas suppliers are engaged in a decades-long, state-sanctioned gas infrastructure spending spree that directly contradicts Maryland's legislatively-mandated climate goals and threatens to saddle a dwindling number of ratepayers with billions in costs for decades to come, with the impacts likely disproportionately felt by those least able to afford them.

The replacement of natural gas infrastructure in the name of preventing leaks and promoting safety has been a public policy issue for decades, and in the 2000s and early 2010s, Maryland utilities made several attempts through the Public Service Commission and the General Assembly to follow other states in adopting customer surcharges to expedite such efforts. In 2013, they succeeded with the passage of the Strategic Infrastructure Development and Enhancement ("STRIDE") Act. Although climate change had been a concern of the General Assembly for years prior to that law, the legislature's debate over the STRIDE Act did not contemplate the possibility that Maryland's greenhouse gas emission reduction goals would require a substantial transition away from the use of natural gas for heating, cooking and other purposes in residential and commercial buildings. Subsequent climate-related legislation—including a 2021 law requiring the Public Service Commission to take climate change into account in its decisions and the 2022 Climate Solutions Now Act, mandating a 60% reduction in greenhouse gas emissions by 2031 and net-zero emissions by 2045—did not repeal or alter the terms of STRIDE. Thus, despite Maryland's stated need to reduce natural gas use in buildings by 90% by 2050 in order to achieve its climate goal, the state's gas utilities continue to spend billions on new and replacement natural gas infrastructure, with customers on the hook to repay those investments plus a rate of return, potentially over the next six decades. Continuing those investments at a time of declining gas use will cause skyrocketing rates by the mid-2030s, threatening the health, well-being, and security of tens of thousands (or more) of Maryland's low- and moderate-income families.

Main findings

- **Maryland is on a course of huge natural gas stranded costs:** More than $2 billion in STRIDE authorized investments have already set a course for significant stranded costs, assuming achievement of the state's legally mandated climate goals. More than $4 billion in additional spending is proposed well into the 2040s, whether through the STRIDE provisions or rate cases. If allowed, ratepayers will be paying for these investments for another six decades.
- **There is no evidence that STRIDE has improved the safety of Maryland's natural gas system:** There were no deaths due to material and aging related causes and one serious injury in the nine years before STRIDE; the data show the same in the nine years after STRIDE. State as well as national data show that material and aging-related issues cause a small fraction of serious natural gas-related accidents. The number of serious injuries and deaths from natural gas accidents related to other causes has actually gone up in Maryland since STRIDE—no deaths and four serious injuries in the nine years before STRIDE compared to nine deaths and 58 serious injuries in the nine years since.
- **A 2023 proposal by the state's largest gas utility, BGE, to condition heat pump rebates on customers continuing to maintain natural gas heating as backup is unsound technically and economically:** BGE's proposal would keep customers tied to the natural gas system and saddle residential consumers with high costs. It is based on technically deficient analysis and an approach that was rejected for residential customers by the Building Energy Transition report of the Maryland Commission on Climate Change in favor of essentially complete electrification of that sector.
- **Low-income households, especially low-income renters, would bear the brunt of the skyrocketing rates** because they are the most likely to be stuck with natural gas—and the ill-health and indoor air pollution that often go with it—compounding the inequities they already suffer.
- **Allowing continued investments in the natural gas system will result in a completely unsustainable economic and social situation for all Marylanders**, including non-low-income ones, while natural gas utilities continue to profit handsomely—unless countervailing action is taken.

Recommendations

1. The Public Service Commission should agree to the request of the Office of People's Counsel to initiate a comprehensive proceeding on natural gas so that:
    - The state's climate goals can be achieved equitably and as economically as possible so far as natural gas is concerned.
    - Maryland's expenses (not necessarily investments) made on the grounds of safety are actually reducing the risk of serious accidents.
    - The state's stranded costs are minimized.
2. The STRIDE program as it stands should be ended; so should attempts to continue it by other means—as for instance in the ongoing BGE multi-year rate case.
3. The Public Service Commission should order utilities to identify specific areas where there are material- and aging-related risks of serious accidents and ensure accountability that repairs and investments made actually reduce the rates and severity of such accidents—giving priority to the documented causes and risks.
4. Safety risks in the infrastructure should be specifically identified before investments that would be put in the rate case are authorized. The identified areas should be priorities for complete electrification.
5. A commitment to a fully electric residential sector by 2045 with complementary investments in efficiency, greatly expanded demand response capability, and community solar should be adopted.
6. All low-income homes should be fully electrified as early as possible—at the latest by the mid-2030s.
7. New buildings in the residential and commercial sector should be mandated to be all-electric—by 2025 for the residential sector.
8. It is essential to ensure that efficiency and electrification retrofits are of high quality. This will require contractor and workforce development to expand the state's capacity to properly install and maintain cold climate and geothermal heat pumps.
9. Early integration of demand response capabilities, and the capacity of customers to benefit financially from participation, would spur the energy transition and should be a priority.

The 2013 STRIDE Law on Natural Gas Investments

What is STRIDE?

Natural gas is a household fuel in about half the homes in Maryland; it is the main space heating fuel in about a million of them. The vast majority of them are supplied by three regulated, investor-owned utilities: Baltimore Gas and Electric, Washington Gas, and Columbia Gas; BGE is the largest, supplying almost 60% of gas customers in the state. The fuel itself is procured on the interstate wholesale market by the state's utilities, which then distribute in areas where they own the pipeline infrastructure. In return for the grant of a monopoly in their respective areas and the opportunity to earn a guaranteed rate of return, utilities are subject to regulatory oversight by the Maryland Public Services Commission (hereafter "the Commission").

Starting in the 2000s, Maryland's gas utilities made several attempts to gain permission to place a surcharge on customers' bills to help accelerate the replacement of natural gas pipes, particularly those made of materials now considered obsolete, such as cast iron. The Commission denied these requests, and the utilities turned to the General Assembly, which initially also rejected the idea. However, amid increasing urging from the National Transportation Safety Board (NTSB) for utilities to replace aging gas transmission and distribution infrastructure after high profile gas line explosions in 2010 in San Bruno, California (eight killed) and in 2011 in Allentown, Pennsylvania (five killed), the utilities' efforts succeeded. Then-Transportation Secretary Ray LaHood visited the San Bruno site in 2011; he promised to improve safety and "fix America's pipeline system," including advocating for new federal legislation.[2] That year, Mr. LaHood also urged "all parties to step up efforts to identify high-risk pipelines and ensure that they are repaired or replaced."[3] Investments in natural gas pipeline distribution infrastructure nationally accelerated in the years that followed, increasing from an average of $5.2 billion a year during 2002-2012 to $13.7 billion a year from 2013-2020; a doubling of the annual rate when adjusted for inflation.[4]

Specifically, the Maryland legislature enacted the 2013 Strategic Infrastructure Development and Enhancement Act, which goes by its acronym STRIDE.[5] An NTSB official testified in favor of the bill's passage in House and Senate committee hearings. In the Senate Finance Committee, she acknowledged that both rates and safety were at issue but said, "I am not here about rates; I am here about safety" and went on to urge the replacement of cast iron pipes.[6]

STRIDE permitted replacement of existing natural gas distribution pipelines and the recovery of the investments plus a rate of return without the utilities having to go through a normal rate case before the Commission. The initial recovery from ratepayers was to be via a surcharge capped at $2 per month for residential customers, and a proportionally higher surcharge for commercial customers, until the (adjusted) amount was folded into the rate base. The Commission did not oppose the law, but it testified that it already had the authority to allow investments in question to be made and recovered via rates. Indeed, the Commission had considered just such a case in 2011 and allowed the expenditure made to be recovered via rates but denied Washington Gas' request to recover future such investments via a surcharge prior to presenting them in a rate case.[7]

The Office of the People's Counsel, AARP and others objected to STRIDE on the grounds that it would upset Maryland's traditional rate-setting system, and lawmakers engaged in extended debate about it on the floor of both the House and the Senate, but no one raised the possibility that it could lead to stranded costs amid an eventual shift away from the use of natural gas for heating and cooking.

STRIDE has several features that are important in the context of safety, accountability, and climate:

- It incentivizes pipeline replacements that can be recovered with a profit via rates as distinct from smaller repairs whose costs are passed on to ratepayers and operating maintenance expenses without any return on investment.
- The law lists reducing pipeline leaks of greenhouse gases as a permissible goal for infrastructure replacement under STRIDE. However, no consideration of the eventual need to greatly reduce natural gas consumption is reflected in the law—despite the fact that climate change had been a concern of the state's legislature for many years prior to 2013.
- The commission could deny utilities' proposals on grounds that they were not "reasonable and prudent." Upon such a finding, the utilities would have to refund any collected revenues to ratepayers.

Table 1 shows the six tranches of STRIDE and the actual (for STRIDE I and II) and estimated future capital expenditures, based on an analysis commissioned by the Office of the People's Counsel. The amounts shown do not include the rate of return that the utilities would earn on the unamortized portion for much of the rest of the century. (Figures are in millions.) Anticipated future spending tranches are italicized.

Table 1: STRIDE investments—actual and projected (future tranches italicized).

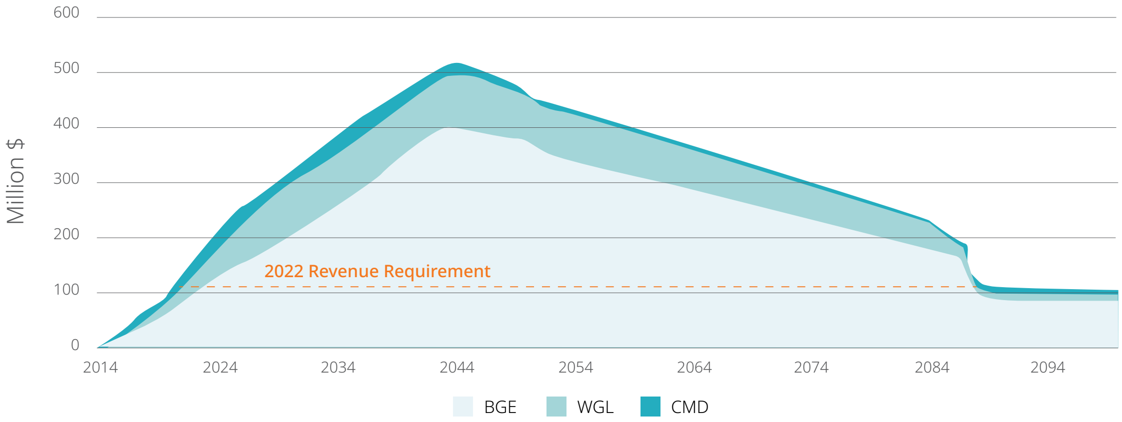
	BGE	WGL	Columbia
Actual STRIDE I, 2014-2018	$522.73	$218.50	$66.19
Actual/authorized, STRIDE II, 2019-2023	$827.28	$363.07	$87.22
Future: STRIDE III, 2024-2028	$693.39	$439.44	$57.38
Future: STRIDE IV, 2029-2033	$803.83	$194.82	$ -
Future: STRIDE V, 2034-2038	$931.86	$74.00	$ -
Future: STRIDE VI, 2039-2043	$1,034.00	$ -	$ -
Total, per utility	**$4,813.58**	**$1,302.19**	**$210.79**
Grand total all three utilities STRIDE I and II			**$2,084.99**
Grand total, all three utilities, all STRIDE tranches			**$6,326.56**

Source: Office of People's Counsel 2022.[8]

Even if no further investments are made under STRIDE, cost recovery and profits will continue into the 2060s. If the other four tranches are authorized, Maryland gas ratepayers will be paying for STRIDE expenditures and the associated profits until the 2080s.

The Office of People's Counsel (OPC) has estimated how STRIDE would impact revenue requirements in the coming decades if the remaining four tranches are also approved. Figure 1 is reproduced from the 2022 OPC report.

Figure 1: Revenue requirements if all six STRIDE tranches are approved by the Maryland Public Service Commission.



Source: OPC 2022

Those revenue requirements will translate directly to higher gas rates for consumers, with energy cost burdens eventually reaching extreme levels for low-income households. Table 2 shows energy bills in 2021 and 2035 assuming the same usage (since low-income households may not be able to make significant investments to reduce usage) for a family of three at 50% and 100% of the 2021 poverty level using an estimated rate for 2035 for BGE (See page 18).

Table 2: Estimated energy costs in 2021 and 2035 for Maryland low-income households.

	Annual energy bill		**Energy cost burden 50% of 2021 poverty level**		**Energy cost burden at 100% of 2021 poverty level**	
Year	2021	2035	2021	2035	2021	2035
Natural gas (Notes 1 and 2)	$950	$2,430	8.7%	22.1%	4.3%	11.1%
Electricity (Note 2)	$890	$890	8.1%	8.1%	4.1%	4.1%
Total energy cost burden	$1,840	$3,320	16.8%	30.2%	8.4%	15.1%

Notes:

1. Using the estimated average for the year 2035 for BGE natural gas customers (see Figure 5).

2. Natural gas use taken as the average per household using that fuel in 2021 in all cases. Average natural gas use in a low-income households (at roughly 100% of the poverty level) is estimated to be slightly higher than the overall average. Electricity use for natural gas heated low-income households estimated at 6,800 kWh/year (rounded), about one-fourth lower than the average (adjusted downward using Makhijani, Mills, and Makhijani 2015, Table III-19). The average household size in Maryland is about 7% smaller than the three-person household assumed in this table. Electricity rates are assumed to be stable in constant 2021 dollars. Rates in constant dollars declined from 2012 to 2022 (including the sudden increase in 2022) but declined slightly over the period since the year 2000.[10]

By 2035, natural gas cost burdens alone would increase to extreme levels at 50% of the 2021 poverty level to 22.1%—about two-and-half times the 2021 burden. The total energy burden, including electricity, would increase to more than 30%. At 100% of the poverty level, many households would go from being energy cost burdened to highly cost burdened (defined as burdens greater than 10% of income).

At the high end of natural gas rates in 2050, as estimated by the Office of People's Counsel, the natural gas bill alone would be 94% of the entire income of a family of three living at 50% of the poverty level;[i] the total energy cost would be about 108% of income. The situation will become intolerable for tens of thousands of Maryland families well before that time; it will also place unsustainable pressures on the rest of society in terms of added emergency room health care, housing support, energy bill payment assistance, and other expenditures.

STRIDE has not measurably improved safety

The federal government continues to urge states to replace aging gas infrastructure for safety reasons, and utility officials testified at the time of STRIDE's enactment that Maryland had a larger share of cast iron pipes as part of its system than most other states. Since safety is the ostensible purpose for STRIDE investments, one fundamental question to ask, especially given the scale of the expenditures, is whether there has been a measurable decline in serious accidents and their consequences as a result of the law. A "serious accident" is defined as one that involves a death or serious injury. We use the number of fatalities and serious injuries to assess the impact.

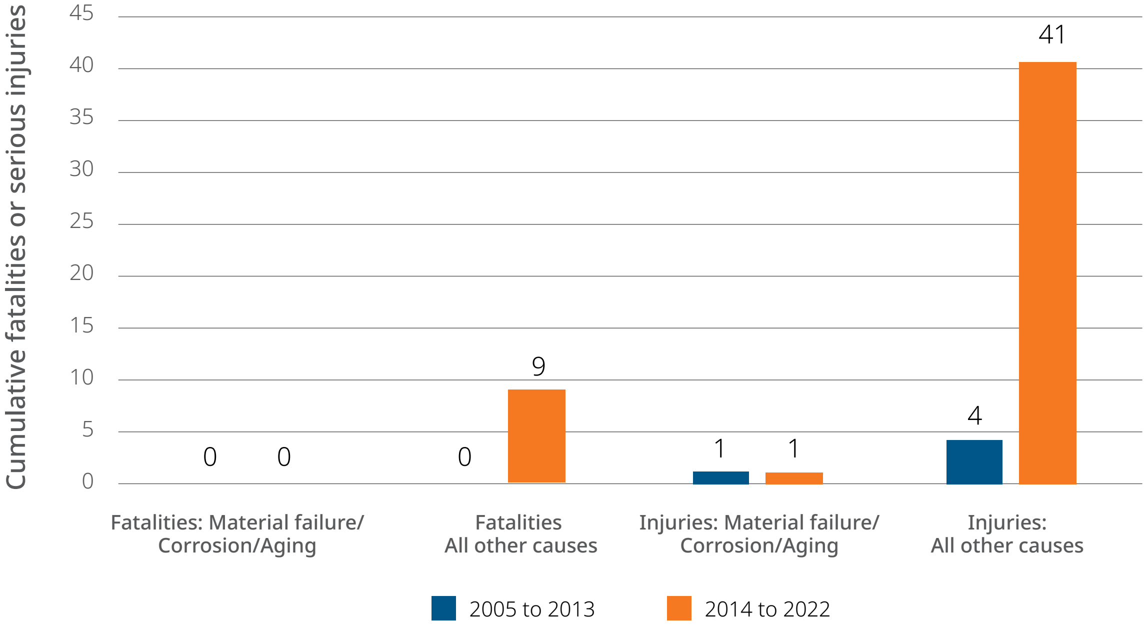
Data from the federal Pipeline and Hazardous Materials Safety Administration (PHMSA) of the U.S. Department of Transportation indicate that about two thirds of serious accidents between 2005 and 2021 (inclusive) nationally were due to "other outside force damage" (26.6%), "excavation damage" (25%), and "incorrect operation" (14.8%). Approximately 18% were due to "natural force" damage or miscellaneous causes listed as "other causes." In the most frequent category—"other outside force damage"—69% of the accidents were due to vehicular damage to the infrastructure. Only about one-seventh of the accidents had a material-related cause such as defective welds or corrosion—not necessarily related to aging.

Maryland data from 2005 to 2022 provide insights into whether large STRIDE investments already authorized—$2.1 billion, or about $1,750 per gas customer—have made a difference to safety. This period is appropriate since it includes nine years after STRIDE's enactment (2014-2022, inclusive) and nine years before STRIDE (2005-2013, inclusive). Both periods are long enough to allow a comparison.

---

[i] Both poverty level values and rates are in constant dollars and so have not been escalated for inflation.

Figure 2: Fatalities and injuries due to natural gas distribution system accidents in Maryland before (up to and including 2013) and after the STRIDE law (2014-2022 inclusive).



Sources: Data extracted from PHMSA[11]

Figure 2 shows accidents in each of these two periods classified into material-related causes (whether due to aging or not) and all other causes.

There were no fatalities due to material-related causes, including aging pipelines, between 2005 and 2022, and only two serious injuries—one before STRIDE and one after. By this measure the system was safe in terms of material defects before the STRIDE law and remained so after it. **Hence, investments under the STRIDE law, which is aimed at addressing material-related issues, have had no demonstrable impact on the frequency of severe accidents.**

All nine fatalities were due to other causes—*and all were in the period after the STRIDE law was passed*. Seven of the nine fatalities occurred in a single accident, a 2016 explosion in an apartment building in Silver Spring (Montgomery County). The accident did not involve the distribution pipeline system. Rather it was due to "the failure of an indoor mercury service regulator with an unconnected vent line…."[12] The other fatalities were also not due to material-related causes. The one in 2014 was due to a gas explosion in a building;[13] the one in 2021 was due to an excavation accident—one of the most common types of natural gas-related accidents. A worker was killed in that case.

We also considered PHMSA's broader category of "significant incidents," which includes not only incidents involving fatalities and serious injuries but also incidents causing damage in excess of $50,000. We considered costs of all significant pipeline incidents, including gas and liquid fuel pipelines, and also considered only significant incidents related to the natural gas system. Table 3 shows the results in constant 2017 dollars. It is clear that STRIDE, besides not reducing serious accidents, has also not reduced the costs of significant incidents. On the contrary, costs of all significant events almost doubled in the post-STRIDE period. The cost of significant natural gas distribution system incidents increased by 50%.

Table 3: Frequency, total cost, and annual average cost of significant pipeline incidents—all significant incidents and natural gas distribution system significant incidents only.

Significant incidents included	Number of significant incidents		Cumulative cost, 2017 dollars		Annual average cost, 2017 dollars	
	2005-2013	**2014-2022**	**2005-2013**	**2014-2022**	**2005-2013**	**2014-2022**
All pipeline	19	18	$9,202,814	$17,276,025	$1,022,535	$1,969,757
Natural gas distribution only	15	10	$8,477,173	$13,031,775	$941,908	$1,447,975

Note: St. Louis Federal Reserve GDP deflators[14] were used to convert current dollars reported in PHMSA's data to constant 2017 dollars.

The STRIDE law says the Commission may approve a surcharge if it determines that the proposed costs are "reasonable and prudent" and that the proposal is "designed to improve public safety or infrastructure reliability over the short term and long term." The term "safety" is not defined in the law. No metric for the improvement of public safety as a result of the investments is set forth as a marker that would indicate that the billions that ratepayers would be required to pay have measurably yielded a safety return. The term "reliability" is not defined, nor were there any metrics for measuring it set forth in the law. The Commission has the power to "review a previously approved plan," and, if it finds that the investment "no longer meets the requirements" of improving public safety or infrastructure reliability, it could "alter or rescind approval of that part of the plan."[15] To date, the Commission has not significantly altered or rescinded any gas utility plan it had approved under STRIDE.

The law requires either safety or infrastructure reliability improvements in the short-term and long-term. Safety as measured by serious accidents and their outcomes has, if anything, deteriorated in the nine years since STRIDE went into effect. Costs of significant natural gas distribution system incidents have gone up by about 50%. Is everything to be ascribed to infrastructure reliability without any metrics? What customer benefits correspond to the billions that ratepayers will pay?

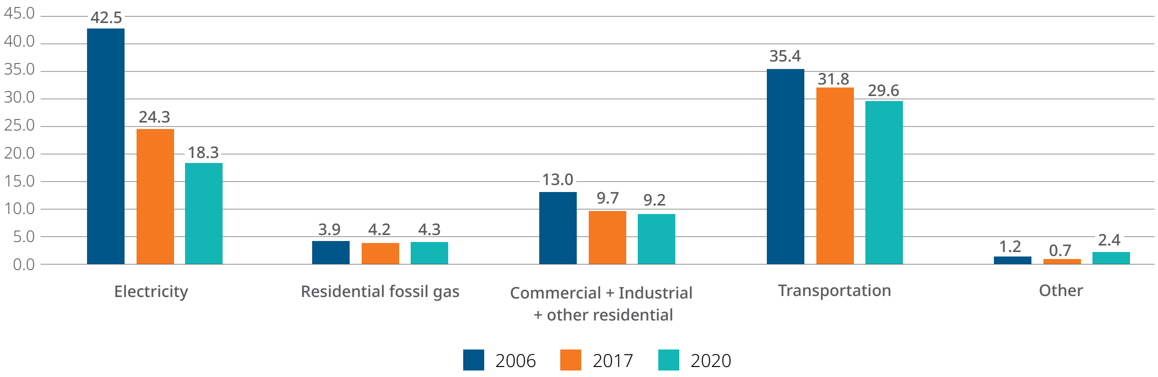
Maryland Climate Goals and STRIDE

Two laws have been passed since 2013 that are material to revisiting STRIDE. The first is a law passed in 2021 that requires the Public Service Commission to take climate change into account in its proceedings and decisions according to the most recent scientific evaluation of the matter by the Intergovernmental Panel on Climate Change.[16] That science indicates that limiting average global temperature rise to 1.5° C is essential; this indicates global net-zero greenhouse gas emissions by about 2050. Having contributed most to the problem, wealthy countries like the United States have greater responsibilities in meeting that target under the foundational treaty on climate—the 1992 United Nations Framework Convention on Climate Change.

Maryland's Climate Solutions Now Act of 2022 sets goals that are consistent with recent science. It sets a goal of net-zero greenhouse gas emissions by 2045 and an intermediate term goal of 60% reduction of emissions relative to 2006 by the year 2031.[17]

Figure 3 shows the evolution of CO_2 emissions from the energy sector as estimated by the Maryland Department of Environment. It is notable that emissions have been declining in the major sectors of emissions except the residential uses of natural gas.

Figure 3: Maryland energy sector CO_2 emissions by consuming sector for the years 2006 (baseline), 2017, and 2020.

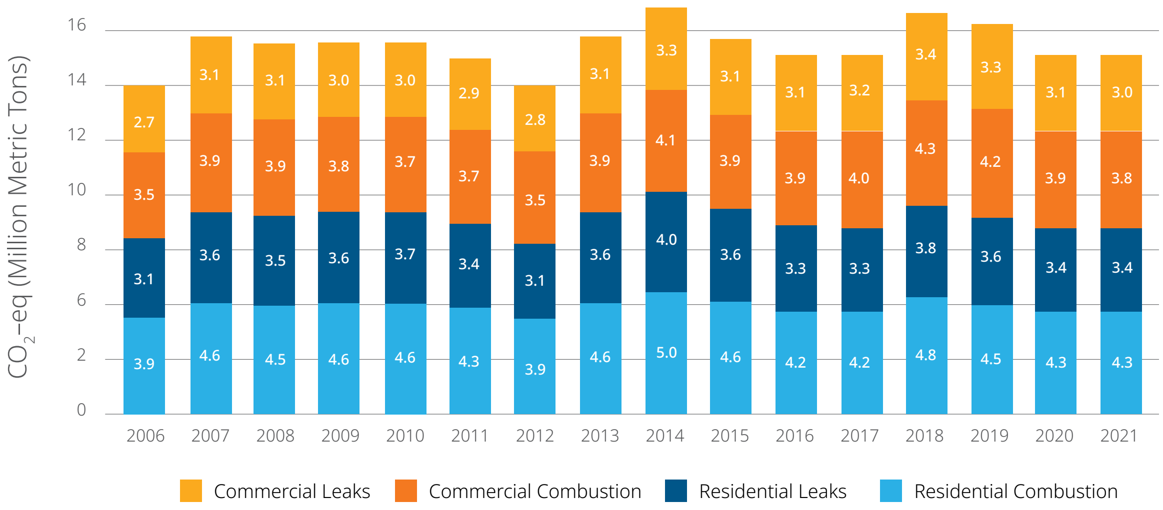


Note: While labeled CO2-eq in the official inventory, natural gas leaks are accounted for in a separate category called "natural gas industry" not shown in Figure 3.

Source: Maryland Department of Environment greenhouse gas inventories.[18]

The emissions shown in Figure 3 do not include the impact of natural gas system (methane) leaks. Figure 4 shows greenhouse gas emissions from residential and commercial buildings when leaks are factored in using a 20-year global warming potential (GWP) for methane, as required by the 2022 Climate Solutions Now Act.

Figure 4: Residential and commercial sector emissions due to natural gas use. Overall leak rate for natural gas taken as 2.7%.



Source: Reproduced from Makhijani et al., 2023, Figure 4-2, p. 100. Leak rate based on natural gas sold and calculated from the Alvarez et al. 2018[19] rate of 2.3% based on natural gas production.

The STRIDE law includes the reduction of greenhouse gas leaks as one of its goals. BGE has claimed in its recent natural gas rate case before the Commission that STRIDE pipe replacements between 2017 and 2021 reduced natural gas leaks by nearly 47,000 tons of CO_2-equivalent annually.[20] This estimate was not based on measurements, but rather calculated based on formulas provided by the EPA for national averages of leaks from different types of pipes, as allowed by federal regulation.[21] But even taking it at face value, it is a meager return on the vast sums invested.

The 2017-2021 period was a mix of STRIDE I and II—with BGE capital expenditures about $750 million total in this period.[22] Over time, ratepayers would pay roughly $2.2 billion, including BGE's profit. The cost of achieving this carbon reduction via leak reduction would depend on how long the gas pipelines were in use. If natural gas or other forms of methane (such as the so-called "renewable natural gas") were to enable continued use of these pipelines, the 47,000 tons per year might extend for as long as 50 years (assuming no deterioration in the replaced pipes). But if pipelines become stranded costs, as is more likely if the Climate Solutions Now Act is rigorously implemented, it might be as little as 25 years, possibly less depending on the geography and pace of distribution system retirement.[ii] Using this range, the cost to ratepayers of avoiding CO_2-equivalent emissions would be between $1,000 and $1,900 per ton (rounded). This is extremely expensive greenhouse gas mitigation. For instance, the cost of one of the most expensive methods—capture from the air (known as direct air capture)—is estimated to be in the range $250 to $600 per metric ton.[23] Far cheaper methods of mitigation are widely available. Thus, even by the leak mitigation metric, STRIDE investments cannot be said to be successful—much greater carbon reductions could be had for the same investment.

The relatively constant, or even slightly rising emissions due to natural gas use since 2006 in the buildings sector present a contrast with the other major sectors, where there have been moderate to large reductions in emissions since 2006. Given that there are difficult sectors for emissions reduction, such as cement production, high temperature industrial heat, and aircraft fuel, the elimination of natural-gas-related emissions from the buildings sector will have to be nearly if not entirely complete to meet the requirements of the 2022 Climate Solutions Now Act. Reinforcing that case is the stark fact that phasing out natural gas will occur as an economic imperative in the medium term—well before 2045—as discussed below.

The need to reduce natural gas-related emissions from the buildings sector almost completely has been recognized as a climate imperative in the most recent study commissioned by the Maryland Department of Environment. Maryland's Climate Pathway,[24] published in 2023, estimates that the Climate Solutions Now Act will require actions in the buildings sector such as replacing appliances that use natural gas with those that use electricity and electrifying heating, in addition to making efficiency improvements for these end uses. The study estimates that to meet the targets of the Climate Solutions Now Act, natural gas-related greenhouse gas emissions in the buildings sector would decline by about 90% between 2006 and 2050, with the corresponding declines in natural gas use in commercial buildings estimated to be close to 100% and that in the residential sector estimated to be about 80%.[25,iii]

[ii] As discussed below, retirement of gas infrastructure is and should be an option. For instance, that is the purpose of a pilot project proposed by Public Service Company of Colorado in a commercial area in Boulder.

[iii] The analysis in this report shows that retaining any significant natural gas use, much less 20%, would result in serious negative economic and social impact, so that essentially complete electrification of the residential sector is essential.

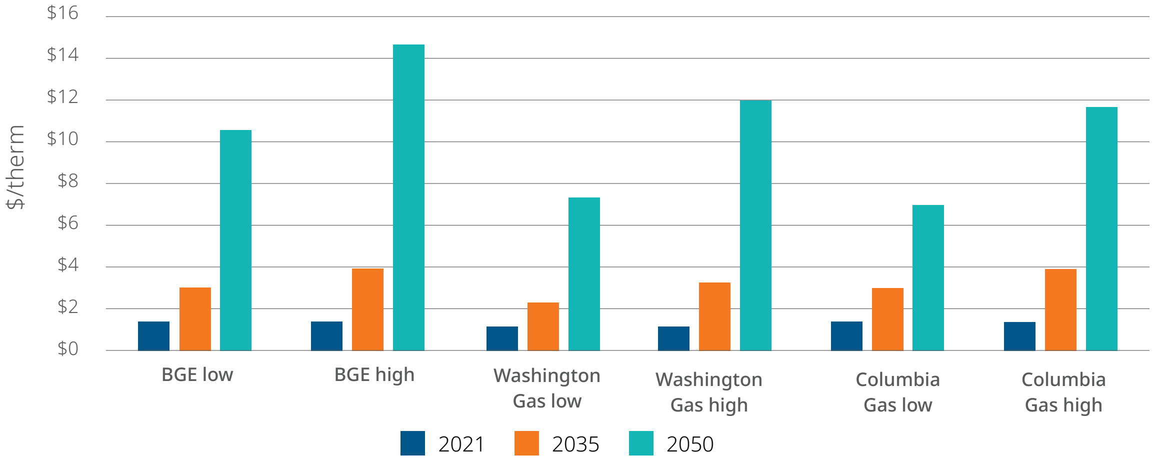
Natural gas rates

In the absence of affirmative policy action, declines on the order of 90% in residential natural gas use in the next 25 years or so will entail significant stranded costs, skyrocketing rates, or both. For instance, Figure 1 above shows that if STRIDE investments continue, natural gas ratepayers will be paying for them for another six decades. The same dynamic applies to new pipelines and new natural gas connections. Maryland's Climate Pathway, commissioned by the Department of Environment to inform the state's "thinking and next steps to confront the climate crisis" recognized the problem in a section entitled "System Fragility Under Rapidly Declining Usage" of natural gas. But the study did not substantively address how to solve the problem; it only called for future research:

> *A rapid decline in natural gas consumption means that natural gas customers remaining in the system would likely experience higher utility bills due to infrastructure costs being spread over a smaller customer base. This would have a disproportionate impact on LMI [low- and moderate-income] consumers and renters who are unable to switch to alternative energy sources because they don't own their own equipment or can't afford to electrify their equipment.*
>
> *Mitigation of cost impacts for LMI customers will become essential in these circumstances to ensure an equitable transition. Research on methane leak detection and prevention strategies has also highlighted the challenges faced in pursuing these strategies as the system loses customers and has limited capital resources. However, continuously expanding natural gas infrastructure would delay the inevitable transition to clean energy and could cause major economic losses from stranded assets. Further research is needed on mid-transition system dynamics to address these issues effectively and determine the rate impacts on customers of lower system throughput.*[26]

This is an excellent problem statement—with one important omission. It does not mention the vast STRIDE investments in existing infrastructure; since these are recoverable through rates with a return on investment until fully depreciated, the impact on rates will be compounded, as has been demonstrated in a 2022 study by the Office of People's Counsel (OPC). Figure 5 shows the impact on rates as estimated by OPC's modeling of natural gas use reduction compatible with the Climate Solutions law.

Figure 5: Natural gas residential rate changes with continued STRIDE investments between 2021 and 2050.



Note: $/therm calculated in constant 2020 dollars

Source: OPC 2022[27] p. 19

Makhijani et al. (2023) found very similar results when they analyzed the problem in a comprehensive study examining the policies needed to achieve equity in the energy transition for low- and moderate-income households—and the severe increases in energy cost burden of a failure to achieve equity. The study also found that "renewable natural gas" and other fuels claimed to be low-emissions replacements for natural gas would result in an even worse problem because these fuels are more expensive than natural gas.[28]

STRIDE is not the only mechanism through which customers are threatened with long-term costs associated with replacing natural gas infrastructure that Maryland's climate goals will render obsolete. BGE has now shifted its pipeline replacement program to its 2023 long-term rate case where that activity is mixed up with a range of other investments, including the replacement of regulators. BGE's pipeline replacement program includes supply of gas at higher pressures. As a result, BGE is now replacing gas regulators to match the pressure changes on the grounds of safety, reliability, and reducing leaks. The regulators alone have cost about $81 million in the period 2020-2022 (inclusive)—an average of $27 million per year, or more than $6,000 per residence.[29] Like the STRIDE pipeline replacements, the regulator replacement costs would be added to the rate base, adding to the already huge stranded cost risks of the STRIDE program.[30] It is not that replacement of specific regulators (or pipe sections for that matter) does not have the potential to increase safety. But the failure of STRIDE investments to improve safety generally shows that risk should be identified in the specific instance where the replacements are made.

Despite the above, gas utilities are proposing to increase the pace of investments in replacing natural gas infrastructure relative to the STRIDE proposals previously filed with the Commission, according to a report by the Office of People's Counsel. For instance, Washington Gas's updated STRIDE proposals indicate a 33% increase in revenue requirements compared to the prior plan.[31] These utility plans have not yet been approved by the Commission and have therefore not been analyzed in this report.

Energy cost burdens

The average use of natural gas in households that have natural gas in Maryland is about 710 therms (71 million Btu) per year. This means that an average natural gas bill for a BGE customer in 2021 would have been about $950 per year. The bill would increase to about $2,100 per year by 2035 and $7,500 per year by 2050 in the absence of countervailing action(s) as per the OPC "low" estimate of BGE rates. At the "high" end, the corresponding bills in 2035 and 2050 would be about $2,800 and $10,300, respectively (in constant 2020 dollars).[iv] At the high end the estimated natural gas bill in 2050 would be almost equal to half the federal poverty level for a family of three in 2021. In other words, for tens of thousands of Maryland families with very low incomes, natural gas bills alone would equal or exceed their entire income (see below for details). Electricity bills would be on top of that.

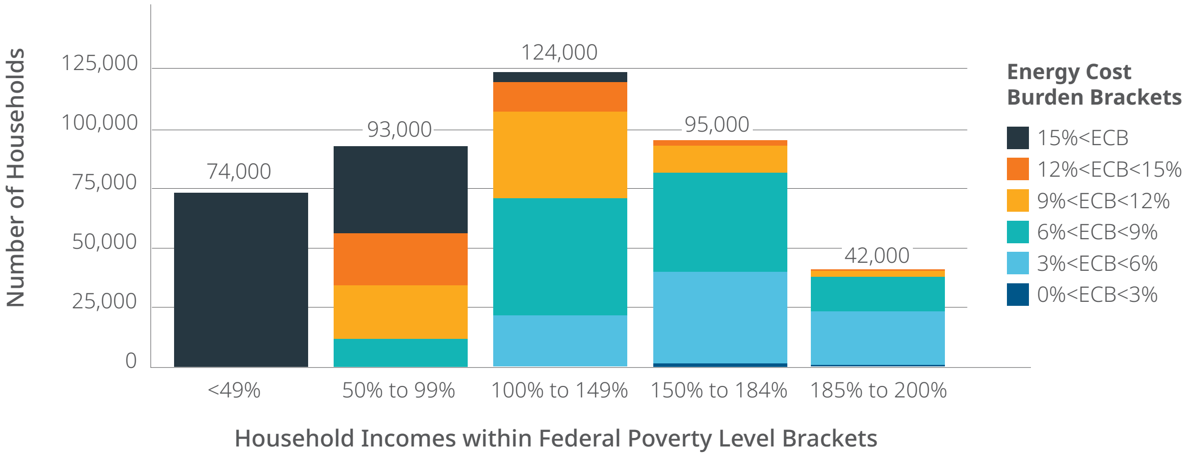
Rising costs would—as is generally recognized, and as was noted in the Maryland's Climate Pathway study quoted above—spur a conversion to electricity. Initial costs of heat pumps for space heating and water heating are estimated to be somewhat lower than comparable natural gas systems for both new housing and retrofits. At the 2020 rates used in the study, the energy cost of electricity would typically be a few dollars per month higher in case of heat pump retrofits ($600 over the life of the system).[32] These small cost differences would be quickly overwhelmed by rising natural gas rates in the 2030s. This would likely cause a mass exodus from the gas system for homeowners who could afford it. Renters, especially low- and moderate-income renters, would be left facing bills they could not afford because they would not be in a position to make the shift to electrification or even to invest heavily in improving building envelope performance. The classic "split incentive" problem in which the landlord has no incentive to invest because the renter benefits from efficiency investments would become a gaping inequity; large numbers of households would fall into economic distress, ill-health, and all too often homelessness.[v]

Figure 6 shows energy cost burdens of low- and moderate-income households in Maryland as estimated in Makhijani et al. 2023.

[iv] All values are rounded to the nearest $100. The calculations assume no efficiency improvements in natural gas use and no deterioration of equipment relative to 2021. Since the poverty level is adjusted for inflation, no adjustment in the 2021 dollar levels are necessary since all calculations are in constant dollars.

[v] The severe damage to families from unaffordable energy bills is discussed at length in Makhijani, Mills, and Makhijani 2015 and also in Makhijani et al. 2023.

Figure 6: Energy cost burdens of households with incomes below 200% of the federal poverty level.



Note: About 50,000 households with burdens >6% and income >200% FPL not shown.

Source: Makhijani et al. 2023, Chapter 2.

Tens of thousands—and potentially hundreds of thousands—of Maryland households could fall into energy poverty in the 2030s in the face of rising heating bills. By 2035, energy cost burdens for a family of three at the poverty level would increase by seven percentage points if they had average natural gas use.[vi] As a result natural gas bill increases alone would cause the energy affordability threshold of 6% of income to be exceeded for tens of thousands of families before 2035.

Another way to look at it is that a rise of about $1,500 in typical natural gas bills[vii] would more than wipe out the entire benefit of energy assistance programs.[33] The rise in natural gas costs would effectively mean some combination of a downward economic spiral for low-income and many moderate-income families, increasing need for energy assistance (with corresponding burdens for other ratepayers and/or taxpayers), or some combination of the two. In contrast, gas companies, guaranteed a return on investments approved by regulatory authorities, would, in theory, continue to be made whole.

This is an unsustainable scenario in which almost the entire society suffers serious adverse consequences for the sake of maintaining the profits of a line of business that state law and sound science require to be retired and replaced with cleaner fuel.

[vi] Using the average of low and high estimates for BGE shown in Figure 5.

[vii] Using the average of the low and high estimates of rates in 2035 cited above.

Indoor air pollution and natural gas health risks

Low-income communities and communities of color tend to be disproportionately impacted by, and are more susceptible to, environmental risk factors and adverse health outcomes. Because Maryland has a higher proportion of people of color than the national average, and Baltimore City has a higher poverty rate than the state or national average, its residents may be particularly vulnerable to degraded indoor air quality. Additionally, those with underlying respiratory or cardiovascular conditions may also be particularly vulnerable to indoor air pollution. The issue is illustrated by the fact that Baltimore low-income homes have a considerable problem of indoor carbon monoxide (CO) pollution due to natural gas use.

The Maryland Department of Housing and Community Development (DHCD) performed combustion appliance safety inspections for vented appliances in households by measuring indoor CO concentrations near combustion appliances. Combustion appliances are a significant source of CO indoors. CO is an odorless, colorless, toxic gas. Exposure to CO can be fatal at high concentrations over short durations; it is associated with various adverse health effects at lower levels according to the Agency for Toxic Substances and Disease Registry of the Centers for Disease Control and Prevention, including:[34]

- Miscarriage at higher levels.
- Permanent harm to the heart and brain even at lower levels.
- Harm to children's mental development when breathed in during pregnancy even at lower levels.

CO is also one of the criteria air pollutants for which the U.S. EPA establishes air quality standards—but only for outdoor air. Thus the public is unprotected by any government regulation or standard from indoor air pollution, including from among the most serious air pollutants like carbon monoxide.

Outdoor air standards nonetheless provide metrics for the levels that could produce harm:

- Nine parts per million of CO should not be exceeded for eight hours more than once a year.
- Thirty-five parts per million should not be exceeded for an hour more than once a year.
- Seventy parts per million requires evacuation.

All of these levels have been exceeded in some low-income Maryland homes. Table 4 shows the data from low-income homes in Baltimore that were retrofitted. The measurements were taken as part of the retrofit procedure; the retrofit would, among other things, remediate the high CO problems.

Table 4: Carbon monoxide pollution frequency (and percentage) in low-income Baltimore homes being retrofitted.

Appliance Type	> 9 ppm (%)	> 35 ppm (%)	> 70 ppm (%)	Maximum
Cook stove	39 (5.4%)	27 (3.7%)	19 (2.6%)	91.9
Furnace	26 (1.8%)	23 (1.6%)	14 (1.0%)	90.1
Gas oven	23 (5.6%)	1 (0.2%)	1 (0.2%)	80.6
Hot water tank	9 (0.7%)	8 (0.6%)	6 (5.4%)	87.9
Gas fireplace	1 (4.5%)	0 (0.0%)	0 (0.0%)	18
Total	98 (2.1%)	59 (1.3%)	40 (0.9%)	-

Source: Maryland DHCD data as compiled by and analyzed in Makhijani et al. 2023, op. cit., Chapter 3.

These are high frequencies of a problem that may well be causing many serious adverse health outcomes in Baltimore City. Perpetuating natural gas use will tend to perpetuate these problems, which would be aggravated by the disproportionate and severe adverse economic impact of rising natural gas rates on low-income households and renters.

Retaining back-up residential natural gas heating is unnecessary

BGE, by far Maryland's largest natural gas company, recently filed a multi-year rate case that includes a proposal to help households with natural gas heating convert to electric heat pumps. The company proposes to provide rebates—up to $7,500 per household—for converting natural gas to heat pump heating. There is general agreement that such conversions are necessary to fulfill climate goals. But BGE's proposal has a catch: the customer would have to keep their natural gas heating system as a supplemental source of heat for the coldest hours. BGE's reason: Relying only on air-source heat pumps would require electrical resistance supplemental heat, which would aggravate electric peak loads and require costly investments.

The full text and context of BGE's testimony is worth quoting because it flies in the face of concerns about this very approach raised by the Mitigation Working Group of the Maryland Commission on Climate Change, which is the state's official advisory body on climate-related matters. BGE's rationale in its rate case for requiring natural gas heating in the context of electrification is as follows:

> *It is important to note, however, that today's ASHP [air-source heat pump] technology is limited in home heating effectiveness below certain temperatures. ASHPs operate less efficiently at low temperatures, i.e., using significantly more electricity per degree of heating as they attempt to provide heat required for a home at those extreme temperatures. Thus, in our region ASHPs typically require a backup heat source to ensure customers' winter safety and comfort, which backup may be either electric—in the form of more inefficient electric resistance heating—or gas. The State's ambitious CSNA [Climate Solutions Now Act] goals will require broad deployment of ASHPs throughout Maryland and BGE's territory, specifically, so inefficient backup electric-sourced heating with ASHPs threaten to significantly impact our electric grid during winter peaking periods. In order to avoid more expensive grid infrastructure upgrades and overall higher costs to our customers, BGE therefore proposes that customers supplementing natural gas furnaces with ASHPs must maintain a natural gas furnace as the backup heating system to receive BGE's BE Program rebates.*[35]

The technical reference for this reasoning is a report commissioned by BGE that was published in October 2022.[36] A similar study published a year before, commissioned by the Maryland Department of Environment from the same company ("E3")—with the same two principal authors—had recommended the same approach for the same reasons; that study also concluded hybrid heat pump-natural gas heating would be the lowest cost approach.[37] The Mitigation Working Group (MWG) of the Maryland Commission on Climate Change concluded that such a policy would be complicated to implement and raised equity concerns; in response E3 developed a new "MWG Policy scenario" in which essentially all residential buildings would be electrified by 2045 while commercial buildings would retain some flexibility. The scenario was described in the Building Energy Transition report of the Maryland Commission on Climate Change as the lowest cost scenario.

The "lowest cost" claim for the MWG Policy scenario is based in part on allowing substantial continued use of natural gas in the commercial sector and the purchase of offsets to supposedly compensate for those emissions—a dubious proposition at best and one that E3 did not model for other proposed net-zero scenarios to provide an apples-to-apples cost comparison. The analysis in this report shows clearly that the residential sector would confront a grave crisis of affordability and equity should natural gas infrastructure remain in place as most households electrify. The commercial sector would likely confront very similar issues due to inexorable arithmetic of drastically declining natural gas use. However, the commercial sector is beyond the scope of this report and deserves a much more detailed analysis in its own right. The Maryland's Climate Pathway report posited essentially a total phase out of natural gas in the commercial sector by 2050; it did not detail costs and acknowledged the challenges of converting old buildings.[38]

Maryland is not alone in confronting this issue. The Public Service Company of Colorado, which supplies gas and electricity (and can be regarded as a Colorado equivalent of BGE), evaluated natural gas infrastructure upgrades versus full electrification and elimination of the gas infrastructure in a commercial section of Boulder, Colorado; it recommended the electrification option as a pilot project. The company also stated, in its regulatory filing justifying the expenditure, that the project was "scalable, and results are applicable to other customers with gas loads that are traditionally viewed as hard to electrify."[39]

The analysis in this report shows that electrification of the residential sector is the more economical option and also the more equitable one. It is in accord with the residential sector analysis of the MWG Policy scenario according to which natural gas use would end totally or nearly completely by 2045. Low-income households would be retrofitted and electrified with higher priority. Specifically the Buildings Energy Transition Plan recommended the following:[40]

- An all-electric construction code with "zero direct emissions" should be put in place for residential buildings by 2024.
- All existing homes should have "zero direct emissions" by 2045.
- All low-income homes should have "comprehensive retrofits" by 2030.
- "The state assist households with high energy burden to transition off the gas system before gas rates increase above current levels."

It is critical to note that the recommendations distinguish between "zero direct emissions"—that is zero emissions at the point of use—from "net-zero emissions" with considerable leeway for offsite offsets for onsite emissions. The recommendations include the possibility of "net-zero emissions" in existing commercial buildings but not in existing residential sector buildings. These findings were endorsed by the Maryland Climate Commission in its 2022 report to the state's legislature; the commission attached the Buildings Energy Transition Plan to its report.

The BGE proposal in its 2023 rate case is especially noteworthy—and problematic. BGE, in effect, rejected the residential recommendation of zero residential emissions and support for early full electrification and disconnection of natural gas from low-income homes. Rising costs, especially for low-income Marylanders, were a central concern that was reflected in the report's recommendations for existing buildings in the residential sector.

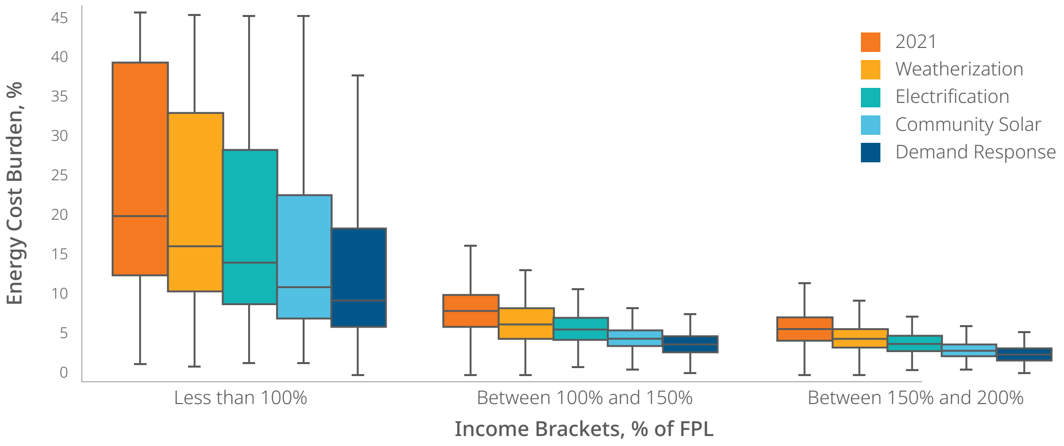
The BGE-commissioned E3 study has extensive discussion of the winter peak demand that would be created by electrification of heating. The BGE-commissioned study downplays the potential of demand response to further reduce peak electric demands, despite the fact that it is considered on a par with dispatchable electric generation resources by the Federal Energy Regulatory Commission.[41]

The issue of hybrid systems was also analyzed in Makhijani et. al. (2023) report, which concluded that it would be cheaper to install geothermal heat pumps than to use natural gas as supplementary heat to avoid utility system peaks. Even that is not necessary, given the advances in air-to-air heat pumps that are incorporated in what have come to be called "cold climate heat pumps." Energy Star has even developed certification or cold climate heat pumps optimized for winter performance.[42] They have been demonstrated to work *without auxiliary heat* in Minnesota and North Dakota at temperatures below -20º F[43]—far lower than anything that would be encountered in Maryland.

On a deficient and incomplete analysis, BGE proposed *requiring* households to have natural gas supplemental heat in return for rebates for heat pumps. Egregiously, BGE sought to add the rebate amounts to its rate base so that it could earn a profit on rebates and property that, in the vast majority of cases, would not be owned by BGE but by its customers. In all $272 million was proposed to be added for electrification rebates, of which 96%, or about $262 million, was in the buildings sector. The utility rebates in efficiency programs are recovered at cost from ratepayers as part of Maryland's EMPOWER program. Charges for arrears in recovery have been added, but as these mounted the commission ruled that recovery should occur in the same year. These facts were among the reasons that the Office of People's Counsel petitioned the commission to reject that part of BGE's rate case filing.[44] In deciding in the Office of People's Counsel's favor, the commission noted that the total amount would be large—about $400 million—and so in part for that reason should be taken up in a separate proceeding where stakeholders could present alternatives.[45]

Indeed, more economical, equitable, and environmentally responsible alternatives have already been identified. A comprehensive energy equity study analyzing the energy transition in the Maryland residential sector published by the Institute for Energy and Environmental Research and PSE Healthy Energy in 2023[46] showed that a combination of building envelope improvements, efficient electrification of space and water heating, community solar, and demand response coupled with energy assistance could fully address both climate and equity goals (Figure 7). A remarkable result is that even before the full transition is complete, the funds needed for energy assistance would be less than those available in 2021 while all households would have affordable energy. Only the lowest income households would need bill-payment assistance.

Figure 7: Components of achieving climate and equity goals for low- and moderate-income households in Maryland.



Source: Makhijani et al 2023

Conclusions

Declining natural gas use, skyrocketing rates, and stranded costs are poised to place enormous economic pressures on a dwindling number of natural gas customers. Without strong countervailing action, this problem is on course to become severe in the early to mid-2030s, especially for low- and moderate-income households unable to convert from natural gas to electricity because they cannot afford it or because they are renters.

An increase in bills of $1,000 to $2,000 per year by the mid-2030s would devastate tens of thousands of households and seriously increase financial stress for hundreds of thousands more. As it is, large percentages of energy burdened households suffer ill-health because they cannot afford to keep their homes warm enough, among other reasons. Nationally, about 5% of households who receive federal heating bill assistance lose their homes each year due to rent/utility bill payment conflicts. While there are no comparable statewide data for Maryland, there were about 6,400 evictions in Baltimore City alone in the year between July 2018 and June 2019, representing roughly one in 12 low-income renters.[47] While it is difficult to disentangle all the financial pressures that result in evictions, national data make it clear that rent payment conflicts with utility bills are among the major reasons.[48]

The middle estimate of natural gas rate increases (discussed on pp. 16-18) would increase the energy cost burden of a family of three at 50% of the poverty level by a devastating 13.5 percentage points. The cost to them in terms of economic and social dislocation and ill-health would be incalculable. The cost to society could run into tens of millions of dollars in the form of needs for housing support, more emergency room visits, and dislocation of families.[49]

The Maryland's Climate Pathways study (quoted on p. 16) called for research on and analysis of the problem of rising rates and stranded costs in the middle of the energy transition period—which would be the 2030s. *But the core of the needed research has already been done*. The Office of People's Counsel published two studies on the topic in October 2022 and November 2022; it was also addressed in detail in Makhijani et al. (2023).[50,viii]

The math is straightforward; so are the conclusions. It is an economic, social, and political imperative that natural gas use in the residential sector be phased out as early as possible and at the latest by Maryland's net-zero date of 2045. To insulate low-income households from catastrophic economic consequences of declining natural gas use, electrification with disconnection of gas should be completed before 2035 to the greatest extent possible.[ix]

[viii] Interestingly, Maryland's Climate Pathway also does not address the STRIDE law or the investments in it that are a principal part of the state's stranded cost problem.

[ix] The Buildings Transition report of the Mitigation Working Group recommended completion by 2030. While this would be desirable, it also critical to ensure quality installation and educational efforts of both the contractor and consumer communities. In the latter case, demand response participation and education for that should be integrated into the installation process.

To achieve this, state policymakers need to take several steps:

- The STRIDE program must be repealed.
    - STRIDE investments have not prevented or mitigated natural gas system-related fatalities. Rather, all fatalities in 2005-2022 timeframe occurred in the post-STRIDE period. None were related to material causes such as aging, corrosion, or defective welds.
    - The STRIDE law creates an economic landscape in which continued large-scale use of natural gas would be necessary to avoid huge stranded costs and steep natural gas rate increases in the 2030s.
    - STRIDE law and other continued major investments in the regulated gas infrastructure are in serious conflict with state's climate and equity goals, which require a near total elimination of the use of natural gas in residential (and in some scenarios, commercial) buildings by 2045.
- Efforts to achieve the same ends as the STRIDE program through other means—for example, BGE's current rate case—should also be blocked.
- The PSC should order an urgent and detailed identification of specific geographic areas with clear safety issues, with actual field data and gas company records.
    - The most urgent specific safety problems should be addressed by appropriate combinations of repairs and investments.
    - At the same time these very areas would be targeted for priority electrification especially if there are investments with profits attached rather than repairs.
- All low-income homes should be fully electrified as early as possible—at the latest by the mid-2030s.
- Maryland should require new residential and commercial buildings to be all-electric by 2025. Electric technologies, especially for home heating, are now more cost-effective for customers, and new federal incentives can reduce costs further.
- The Maryland Public Service Commission should agree to the February 2023 request of the Office of People's Counsel to initiate a broad proceeding on natural gas that includes economic and climate considerations and that considers both the steps needed in the short-term as well as the long-term climate and economic imperatives discussed above.[51]

It is now widely recognized that all-electric, efficient new residential construction as well as all-electric retrofits (along with efficiency improvements) are central to meeting climate goals efficiently, expeditiously, and economically. Yet Maryland follows a course set out by the General Assembly a decade ago that actually accelerates investment in gas infrastructure and directly conflicts with its more recently adopted climate goals, threatens consumers with exploding costs, and perpetuates health and economic disparities. With each passing year, this problem gets worse, both because of continued STRIDE-related investments and investments in expanding natural gas infrastructure with more long-term economic threats to consumers and a greater challenge to meet Maryland's climate goals. State policymakers must step in—and soon.

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Building Decarbonization has a Natural Gas Pipeline Problem

by isaac sevier

May 17, 2023

Key Takeaways

- In current policy and investment strategy, building decarbonization is treated primarily as an appliance swapping project. This micro-approach misses systemic nature of the reduction of natural gas demand explicit in the swap: drawing down demand is ultimately a natural gas pipeline network decommissioning project.

- Entrusting private firms to carry out treatment of building appliances at a household level may work, but is mismatched with the requirements for decommissioning a large, linked infrastructure system with dozens of competing incentives and regulations. We can learn from the systemic risks and failures evident in the coal industry's collapse.

- Opportunities are already arising for public ownership of gas infrastructure. Public ownership must develop a system-wide plan for decommissioning 3 million miles of interconnected pipelines that can deliver a just transition for communities and people most at risk of harm from a market-based transition.

A disorderly, market-based process to reduce greenhouse gases by removing appliances that burn natural gas from every home and building in the United States has begun. This strategy, such as it is, intends to replace appliances that use natural gas with ones that use electricity from more renewables and other carbon free energy sources over time. Most policy advocates and community groups today are focused on the appliance aspects of the transition. The explicitly linked decay of gas demand connects these randomly distributed appliance swaps at the household level to a large, interconnected, complex fossil fuel pipeline network. The emphasis on heat pumps, stoves, water heaters, and other potentially zero-emissions appliances neglects accounting for the ultimate goal: a gas system decommissioning project.

This fossil fuel system is immense and complex: half a million gas wells are spread across 34 states, carrying gas through 3 million miles of interconnected pipelines. This infrastructure is owned by over 1500 gas pipeline companies and serves nearly 78 million customers across homes, businesses, and industrial uses. The engineering part of transitioning to a post-gas future has two halves: in front of the meter (from the well to the gas meter) and behind the meter (from the gas meter to a kitchen stove, for example). Behind the meter, relatively small Inflation Reduction Act investments and other policies are already at work. The federal incentives average out to just $70 per U.S. household. In front of the meter is an industrial engineering challenge of tremendous scale and risk -- think steelworker crews with hard hats and backhoes, not electricians and contractors renovating your home. Much of this work on large scale infrastructure will occur in our cities, our streets, and our front yards.

On our way through this first decade of transition, community-led and engineering-informed planning and action with supply-side requirements in mind is imperative. We must mobilize now so that we have plenty of time to do it right.

An Engineering Systems Approach to Decommissioning the Gas Network

The United States needs a nationwide plan for how to decommission every foot of the gas pipeline network. Physical pipelines end in millions of discrete locations across the country, but market-wide building codes and household incentive programs pipeline network, th Without greater coordination and design, the future of the gas system and its business model could resemble the present of Detroit's water system: many miles of pipelines delivering a critical service to too few customers to sustain operations under its current operational model. The financial obligations of this possible outcome would rest primarily on the 22% of all households who already can't pay their existing energy bills and can't afford to switch to electrified appliances.

HOME DONATE STAFF JOIN THE TEAM SUBSCRIBE PROJECTS

A system-wide plan is the only responsible path forward capable of evaluating the pipeline network and the groups of households linked together on its discrete branches. A community-led and engineering-informed plan would be equipped to include risk evaluation, risk mitigation, and project execution needs for decommissioning this system lying beneath our homes, schools, hospitals, and workplaces. With a systemic approach, the questions of a "utility death spiral" can be eliminated with a block-by-block catalog of demand reduction, a schedule of construction and industrial work crews, and revenue forecasts for corporate actors currently reacting to a lack of regulatory uniformity and market certainty.

Last year, Emily Grubert and Sara Hastings-Simon began to outline assumptions that should be examined and tested through the transitional period, and reinvigorated the urgency of questions for building decarbonization policymakers and planners. These complicate the legal and regulatory paths to decommissioning that Heather Payne catalogs in parallel. When we layer these points of view together, we can begin to more clearly see questions that need to be proactively addressed:

- What critical maintenance work must happen for the gas system to prevent catastrophic failure, even as the system's retirement is planned?
- How much will critical maintenance cost, and who bears those costs before and after decommissioning?
- Where are there trade-offs between critical maintenance investments and programmatic building conversion investments?
- Which pipelines, in which census tracts, towns, cities, and regions are trimmed from the system, at what time, and in what sequence?
- What preparation needs to be done inside people's homes and other buildings before or concurrent to each pipeline shutdown? How does this need to be done so that no one is left behind, where they have neither gas or ability to replace gas appliances with electric appliances?

Creating an accessible and comprehensive planning process will require unprecedented coordination across multiple scales and geographies of regulatory policy, financial institutions, engineering planning and project management. While the system is vastly interconnected, oversight and planning that governs those 1500 gas pipeline companies and operators takes place at the Department of Transportation, Department of Energy, within each state's respective Public Utilities Commission, and across other regulators at the state and local levels. For community members who want to help drive the clean energy transition or for public servants trying to lead in their cities or states, this complexity of scale and policy is a huge barrier that needs solutions.

A Market Fundamentalism Plan Is No Plan at All

It isn't smart governance to assume that "market forces will provide" and then rely on profit-oriented actors to safely decommission the sprawling, complex, and interconnected gas system. The aforementioned investments and expanding policies like gas bans in new building construction will increase pressure on the gas system's operating model over the next decade. From a historical perspective, having no plan for the coal industry's business model erosion caused catastrophic and costly failure for communities, the environment, and workers. There are three significant issues in various combinations:

1. The protracted and predictable collapse of businesses that should have borne legal and fiscal liability for their operations
2. Asset sell-off from larger corporations to smaller, less-capitalized firms while marginal profits decline and marginal liabilities increase
3. Insufficient bond funding or private insurance capacity to cover even basic abandonment and clean up liabilities

Corporations are already reacting and following this observed pattern. The Wall Street Journal reported in April 2023 that two large, well capitalized firms, Dominion Energy (operating 14,000 miles of gas pipelines) and National Grid (operating 35,560 m in North Carolina, C larger pipelines in Texas and Pennsylvania. Where companies are not offloading assets, their lobbyists are promoting poorly supported claims about renewable natural gas to try making the gas system's future appear more climate friendly.

It is possible to foresee the range of operational scenarios of the gas system in light of how big players are already positioning themselves. Through their exploration of selling assets, gas companies are signaling that they've performed engineering and business model analyses already. They are not waiting to act, and are beginning to actively unload those liabilities, in a predictable pattern of corporate behavior. Off the balance sheets and in the physical world, these actions make the prospects for proper pipeline decommissioning and investments in critical maintenance seem low. This disorderly process only grows the risk of companies skirting monitoring and regulation resulting in improperly abandoned pipelines or leaky pipelines that can cause explosions or release unmonitored methane to the environment.

A Managed Transition Requires Public Ownership and Attention to Detail

Corporate executives aren't waiting to act; neither should federal, state, and city public servants and the communities who are endangered by regulatory inaction. Regulatory conditions governing fossil fuel infrastructure, financing, and ownership haven't incorporated the lessons from the failures of the coal industry. It is unreasonable to expect private corporations to responsibly put themselves out of business without any rules in place that could achieve this outcome. Now is the time to avoid repeating the same mistakes.

As private actors signal their intent to follow the same kinds of steps taken as coal demand declined, governments should step in and municipalize ownership of the gas pipeline network. With state ownership, governments can re-organize operational priorities according to democratically defined priorities, and integrate the necessary steps for a system-wide, orderly, and safe transition. In the earlier examples of gas companies selling their assets, one firm issued the announcement claiming the sale of its pipeline assets will support their build out of renewable energy sources. Assuming public ownership as these opportunities arise could be considered a transfer that contains multiple benefits: supporting private development of renewables and enabling robust management of the decommissioning process.

The plan for a managed transition for the gas pipeline system should be detailed enough to emphasize correcting historical environmental and housing injustices, as a matter of what Olufemi O. Taiwo calls a "constructive" approach to reparations. Planned objectives can include avoiding worsening energy injustices from price spikes and shutoffs; eliminating catastrophes caused by pipeline deferred maintenance; and preventing avoidable deaths from a lack of service caused by poverty and inability to transition.

Cities and states can begin to assemble the building blocks for a system-wide plan without greater coordination, using information already available to them or obtainable from firms they regulate. This information gathering process will take significant time and energy, and each set of information can significantly enrich the analysis of tradeoffs for possible decommissioning paths. These planning pre-requisites would include research that:

- Accounts for the age and quality of the existing gas grid, especially at the oldest locations on the gas distribution system. Older pieces may be the best candidates for immediate decommissioning but serve as critical connectivity to pipelines constructed more recently.
- Accounts for the distributive impacts of building electrification and the people living in them. Poorer people tend to live in older housing stock due to a complicated history of redlining, and decarbonizing the oldest homes along the oldest sections of the pipeline can begin to close the gap of home quality and energy burdens.
- Accounts for the need to preserve affordable housing and decommodify housing. New investments can support green social housing strategies, and can be prioritized based on socioeconomic analysis.
- Accounts for other socioeconomic data about residential tenancy, demographics, and energy burden.

With greater coordination, communities and policymakers should begin to:

- Develop robust industrial-engineering quality assessments of how to safely decommission the gas grid at a local, regional, then national scale.
- Identify current
  technical analys
- Propose financial facilities, legislation, and regulatory policies to enact a managed transition that avoids leaving it to private negligence.

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The last year for IRA implementation funds to be issued is now just 10 years away, with the majority of its investments only addressing one half of the building decarbonization challenge. A community-led and engineering-informed plan could design away from an outcome of eco-apartheid, represented by a hobbled pipeline system where everyone wealthy has disconnected and is fully electrified but the remainder of the pipeline system's challenges are left for the poor to bear. We would arrive together - engineers, public servants, lawmakers, organizers, and advocates - right on time to meet the challenge that remains for us if we begin to design and organize for this now.

DONATE SUBSCRIBE

MPSC Case No: U-21291
Requester: FLO
Question No.: FLODG-3.9
Respondent: R. M. Telang
Page: 1 of 1

Question: 9. Is there a specific date (month and year) by which DTE Gas intends to cease operations? If so, has DTE Gas initiated an engineering analysis of the phased retirement of the gas distribution system?

Answer: No.

Attachment: None.

MPSC Case No: U-21291
Requester: CEO
Question No.: CEODG-1.15a
Respondent: H. J. Decker
Page: 1 of 1

Question: 15. Does the Company believe there will be an increase in building electrification over the next 30 years?

a. Please provide all sources and documents relevant to the Company's response.

Answer: The Company recognizes there are nascent efforts to increase building electrification. At this point, it is premature to speculate on the impact these efforts will have on building electrification in our service territory. Examples of electrification efforts:

https://www.energy.gov/eere/buildings/residential-cold-climate-heat-pump-challenge

https://www.whitehouse.gov/ostp/news-updates/2022/12/14/fact-sheet-new-innovation-agenda-will-electrify-homes-businesses-and-transportation-to-lower-energy-bills-and-achieve-climate-goals/

Attachment: None

MPSC Case No: U-21291	
Requester: MNSC	
Question No.: MNSCDG-5.10b	
Respondent: K. M. Fedele	
Page: 1 of 1	

Question: 10. Has DTE identified which assets (or types of assets) on its gas system are most likely or least likely to remain used and useful in the event of widespread electrification of gas- fueled end uses (such as space and water heating)?

b. If not, why not?

Answer: There is no State or Federal guideline or legislation providing guidance or requirements regarding future natural gas usage. DTE Gas has no way to determine what the future holds when potential electrification is nebulous.

Attachment: None.

STATE OF MICHIGAN
BEFORE THE MICHIGAN PUBLIC SERVICE COMMISSION

In the matter of the application of **DTE GAS COMPANY** for authority to increase its rates, amend its rate schedules and rules governing the distribution and supply of natural gas, and for miscellaneous accounting authority.

Case No. U-21291

ALJ Jonathan F. Thoits

PROOF OF SERVICE

I, Mark Templeton, certify that an electronic copy of the Official Exhibits FLO-7 to FLO-23 (Part 2 of 13) on Behalf of Frontline Organizations was served on the following on June 24, 2024.

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The statements above are true to the best of my knowledge, information, and belief.

UNIVERSITY OF CHICAGO LAW SCHOOL
ABRAMS ENVIRONMENTAL LAW CLINIC
Counsel for Soulardarity, Urban Core
Collective, and We Want Green, Too

Date: June 24, 2024

/s/ Mark N. Templeton
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