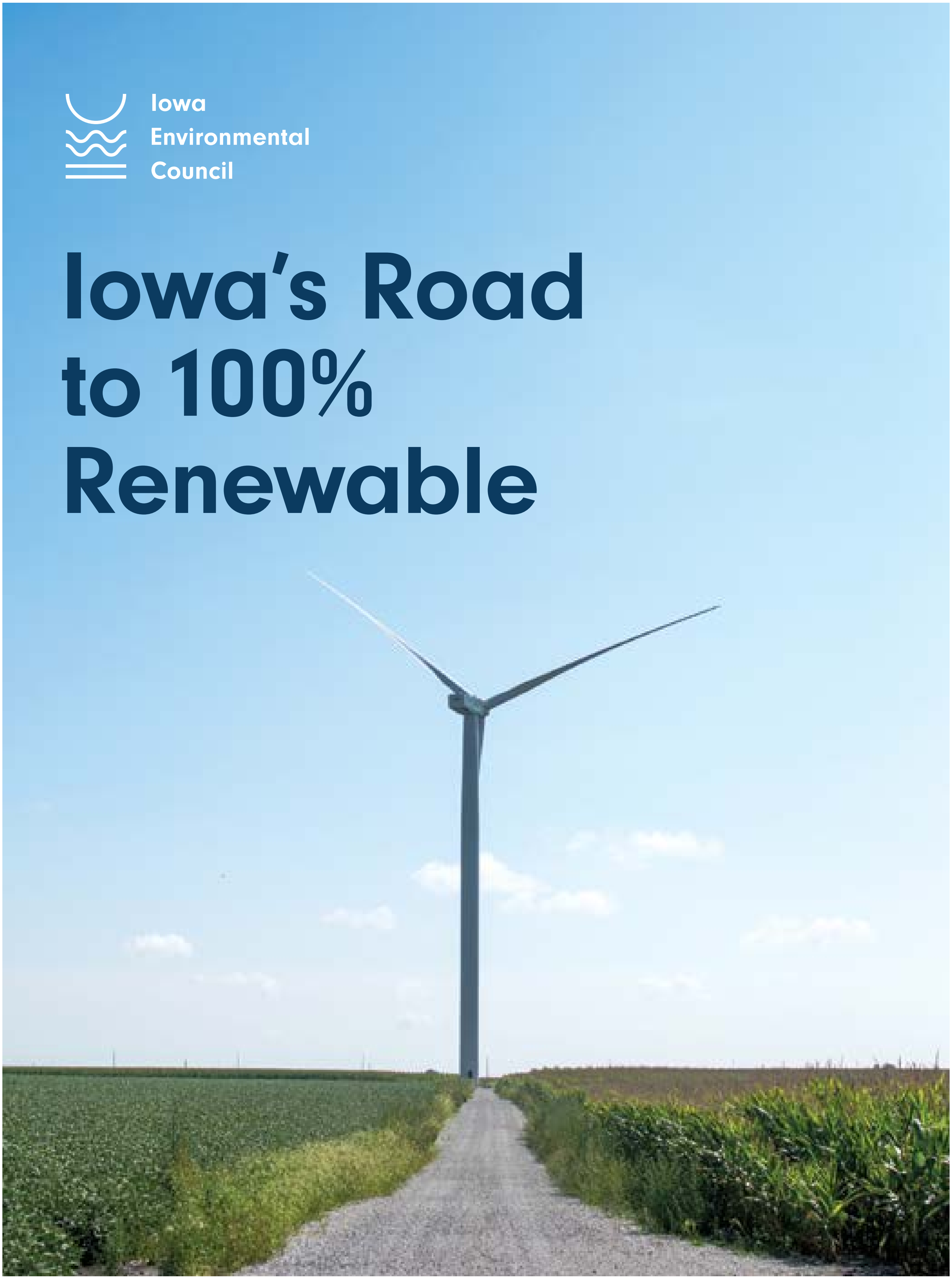
Iowa Environmental Council

Iowa's Road to 100% Renewable

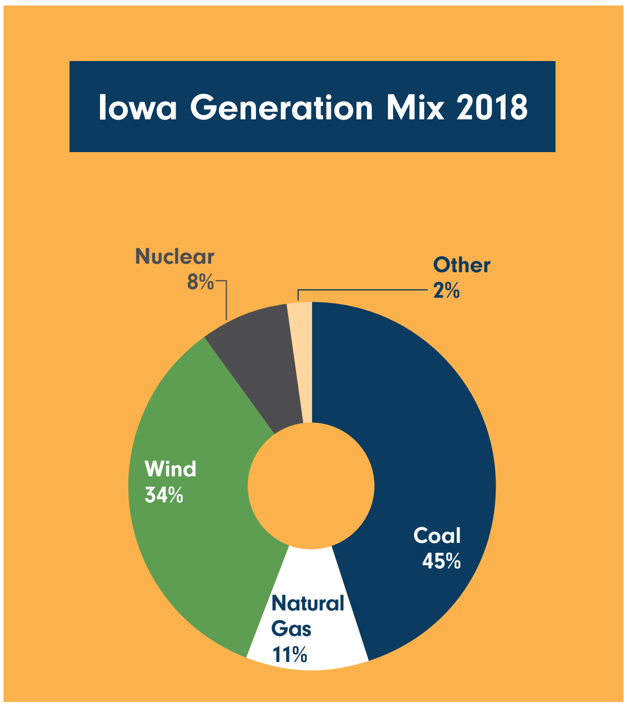


Iowa's Road to 100% Renewable

Iowa Environmental Council

Executive Summary

Over the past decade, a number of major studies have been released that model the electric energy (or "power sector") mix needed to reach high levels of renewable energy and significantly reduce carbon pollution by 2050. The Iowa Environmental Council reviewed a dozen recent studies to gain an understanding of Iowa's path to meeting our own energy needs with energy efficiency and very high levels of renewable energy — including 100% renewables — and our state's role as a renewable energy exporter to substantially reduce carbon pollution nationally.



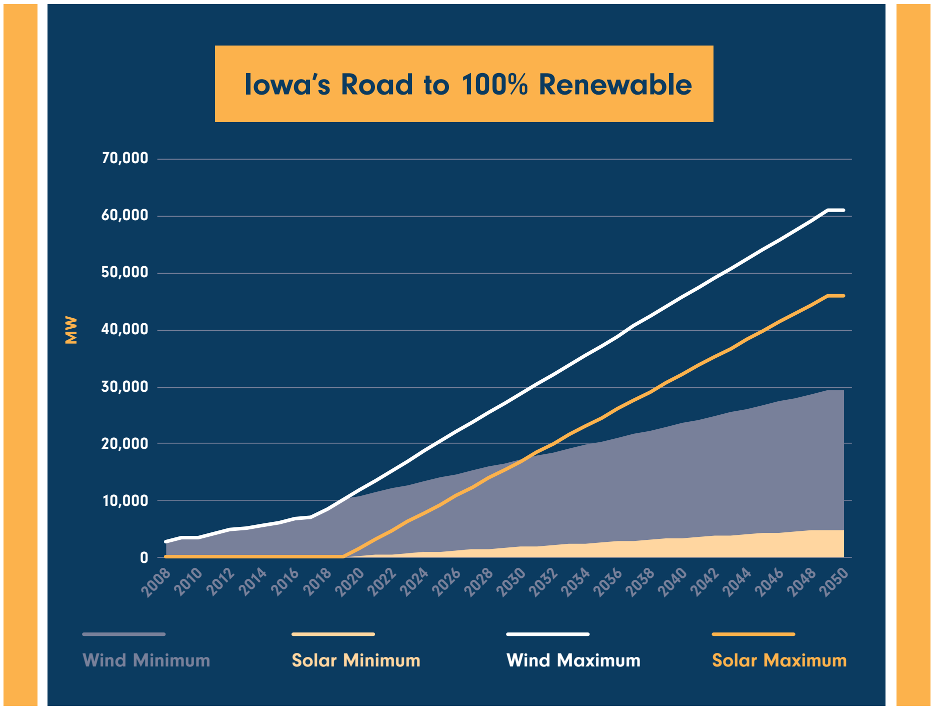
Our review found that Iowa will need to install between 30,000 and 61,000 MW of wind and 5,000 to 20,000 MW of solar, coupled with storage and increased efficiency investments, for Iowa to achieve 100% renewable energy by 2050.

The twelve studies reviewed use different models, inputs, and assumptions, and have different goals by 2050. Some studies focus on reducing power sector carbon emissions using any available technology, including energy efficiency, renewables, new nuclear, and carbon capture with sequestration. Other studies focus on meeting energy needs with high levels of renewable energy only.

Iowa has been a national leader in wind energy for more than a decade and is finally seeing significant solar development. As a result, renewable energy accounts for nearly 35% of Iowa's electricity generation, among the highest of any state.

This leadership is an important first step, but Iowa must sustain – and even ramp up – its progress on renewable energy for the next thirty years. There is consensus across studies that the 10,000 MW of wind energy that Iowa has currently installed is not nearly adequate to reduce power sector carbon pollution enough to protect the climate. Iowa should plan to reach 30,000 to 40,000 MW of wind by 2050 to reduce emissions by

80-90%. In addition, installations of both small (distributed) and large (utility-scale) solar will need to increase dramatically, from a few hundred megawatts in 2020 to 5,000 to 6,000 megawatts by 2050, at a minimum.



If a clean power sector is used as a solution to reduce carbon pollution in other energy sectors – such as with electrified transportation, building heat, or industrial processes – even more wind and solar will be required. Coupled with energy storage, this could mean that Iowa needs to reach 61,000 MW of wind and 46,000 MW of solar. If this large growth in demand takes shape, it is quite possible that 30-40,000 MW of wind and 5-6,000 MW of solar are low-end estimates of what will be needed for Iowa to reach 100% renewable energy by mid-century.

With that in mind, it is clear that Iowa will require systemic changes to our energy economy. Public and private decision makers can use various pathways to achieve the necessary renewable energy and carbon pollution cuts, but will need to make short-term decisions consistent with a long-term strategy to achieve the same.

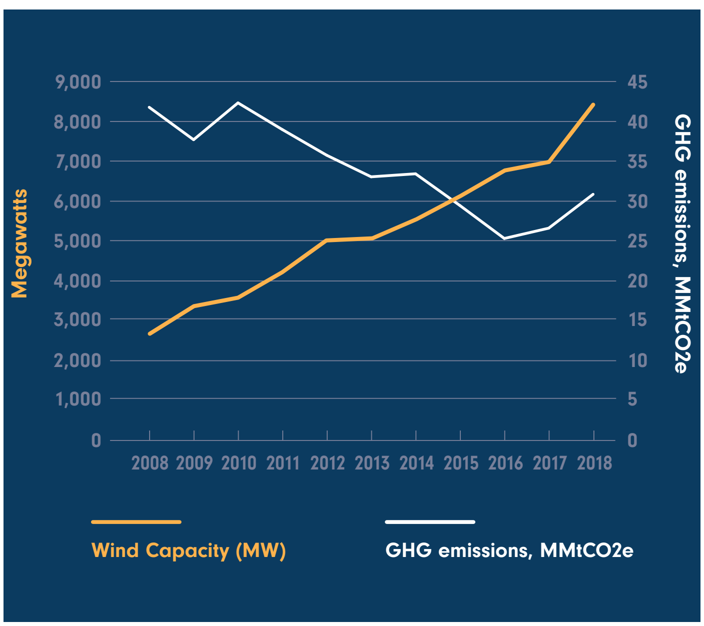
Iowans should focus on both government and private sector-enabling actions, including necessary policies, laws, and incentives. The committed actions of government, businesses, and individuals will be necessary to support the continued annual additions of both wind and solar as quickly and as expansively as possible.

Introduction

Iowa's progress in developing renewable energy over the past twenty years has allowed for a significant reduction in carbon emissions in the electric generation or power sector. Greenhouse gas emissions from the power sector in Iowa declined by nearly 40% between 2008 and 2016 as Iowa began generating more than a third of its electricity from wind.[1] This moved the power sector from Iowa's top greenhouse gas emissions source in 2008 into third place behind agriculture and direct fossil fuel use in homes, businesses, and industry in 2017.

However, coal power is still a large source of electricity generation in Iowa and natural gas use is on the rise. Power sector greenhouse gas emissions increased between 2016 and 2017 for the first time in years, and again by 16% in 2018. Significant work remains to further reduce emissions and reach very high levels of carbon-free energy.

Iowa wind capacity growth compared to power sector greenhouse gas emissions, 2008-2018



In the absence of any long-term national policy to scale up renewable energy or steeply reduce carbon emissions, states are exploring how to meet 100% renewable energy goals over the next thirty years. There are many possible pathways that would allow Iowa to steeply reduce emissions and pursue 100% renewable energy in the next critical phase of development between 2020 and 2050.

Methodology

To better understand the energy mix and scale of new renewable energy development needed for Iowa to achieve 100% renewable energy and to decarbonize the power sector by 2050, IEC reviewed twelve major analyses published between 2008 and 2019 focused on scaling up renewable energy and decarbonizing the power sector, and a paper laying out actions (pathways) to achieve it.

Some states – including Iowa – are rich in renewable energy resources and can contribute to overall decarbonization of the U.S. economy by exporting carbon-free power to states with less robust resources. We have reviewed these studies with a focus on Iowa's ability to play such a role in helping the U.S. decarbonize using high levels of renewables. We focused on study scenarios that achieved the deepest carbon reductions and, when available, achieved a greater share of those reductions with renewable energy rather than non-renewable options such as nuclear or fossil generation with carbon capture.

While the precise amounts of wind and solar vary by study or analysis, the overall necessity is for both wind and solar to scale up substantially in the coming decades in order for Iowa and the U.S. to decarbonize and approach or achieve 100% renewable energy. To reach such goals, Iowa's installed wind capacity must double by 2030 or 2035, and double again by 2050. That means Iowa must reach 20 gigawatts (GW) of wind by 2030 and between 30 and 40 GW by 2050. In addition to wind, Iowa must scale up utility-scale and distributed solar and reduce overall energy use through increased efficiency.

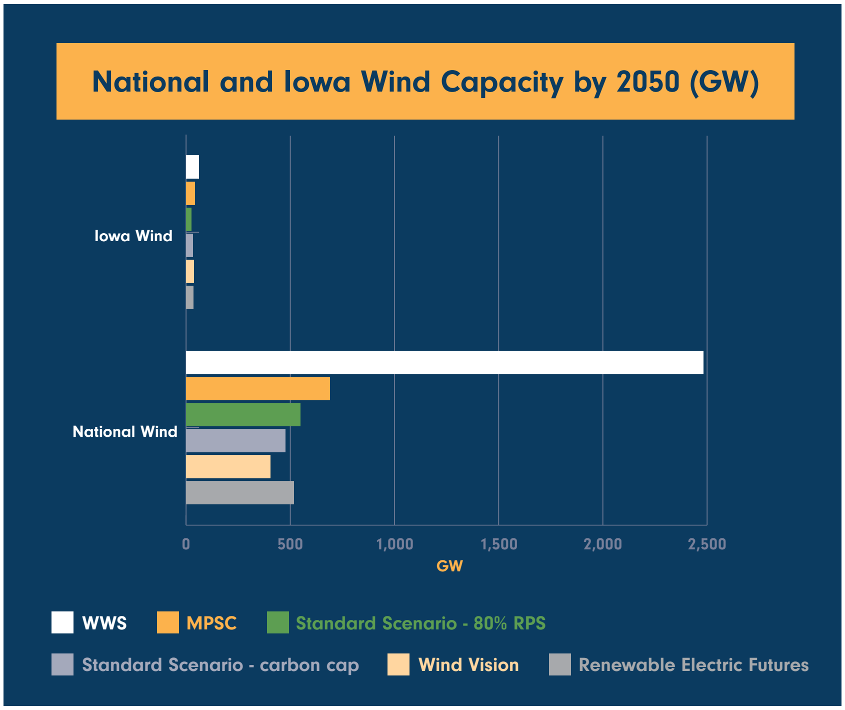
Summary of Major Findings of U.S. Power Sector Decarbonization Studies

- There is general agreement among studies that both wind and solar will need to scale dramatically between 2020 and 2050. **Across studies, wind is projected to be the largest source of energy in Iowa in 2050 while solar grows substantially.** In other words, there is a relatively strong consensus about the need to double or triple current levels of wind energy and the need to deploy large quantities of rooftop and utility-scale solar.
- Iowa's wind capacity by 2050 ranges from 25-60 GW, with several key studies finding a range of 31-37 GW. Iowa has installed about 10 GW of capacity currently, meaning an increase of 21-27 GW is necessary by 2050 and as much as 50 GW of additional capacity may be needed. **Wind occupies between 68% and 91% of Iowa's energy mix in 2050 across studies that show results for Iowa.**
- Scaling up wind energy in the state is an essential step for Iowa to decarbonize and reach 100% renewables, and an essential step for the U.S. as a whole to do the same. In scenarios where the U.S. is able to reach 100% renewable energy, wind development is concentrated in windy states, including Iowa. In other words, **reaching 100% renewables and deeply decarbonizing the Iowa and U.S. grid will be difficult or impossible without scaling up wind energy in Iowa.**

National and Iowa Wind Capacity (GW) by 2050, Studies with State Results Only

Study	National Wind (GW)	Iowa Wind (GW)
Renewable Electric Futures	517	34
Wind Vision	404	37
Standard Scenario — Carbon Cap	477	32
Standard Scenario — 80% RPS	549	25
MPSC	690	43
WWS	2,482	61

- **Studies that achieve 100% renewable energy or that use electrification as a strategy to decarbonize other sectors like transportation identify the largest national or Iowa renewable energy capacity amounts by 2050.**



In these studies, Iowa's wind capacity in 2050 is likely to be closer to 60 GW. This is compared to the 25 to 40 GW needed to decarbonize the power sector only and do so with other technologies besides renewables (e.g., coal or gas with carbon capture, nuclear).

- Studies that identify or project the lowest amounts of wind in 2050 also have the highest amounts of fossil fuels, including coal and natural gas.

- **The role of solar photovoltaic (PV) in Iowa is becoming increasingly important, with higher amounts of PV projected in more recent studies.** The newest studies show distributed generation (DG) rooftop PV at 2.4 to 2.6 GW, or 2-3% of the mix, and utility-scale PV at 2.8 to 3.4 GW, or 4% of the mix, by 2050. Even in the study with the greatest use of solar — nearly 40 GW of utility-scale solar — wind still accounts for nearly 70% of electricity generation in 2050. This study also identifies the largest amount of wind capacity by 2050: 60 GW.

National and Iowa Solar Capacity (GW) by 2050, Studies with State Results Only

Study	National Solar (GW)	Iowa DG Solar (GW)	Iowa Utility-Scale Solar (GW)	Iowa Total Solar (GW)
Renewable Electric Futures	187	0.7	0	0.7
Wind Vision	356	1.6	0	1.6
Standard Scenario — Carbon Cap	718	2.4	3.4	5.8
Standard Scenario — 80% RPS	851	2.6	2.8	5.4
MPSC	478	0	0	0
WWS	2,982	6	39.9	45.9

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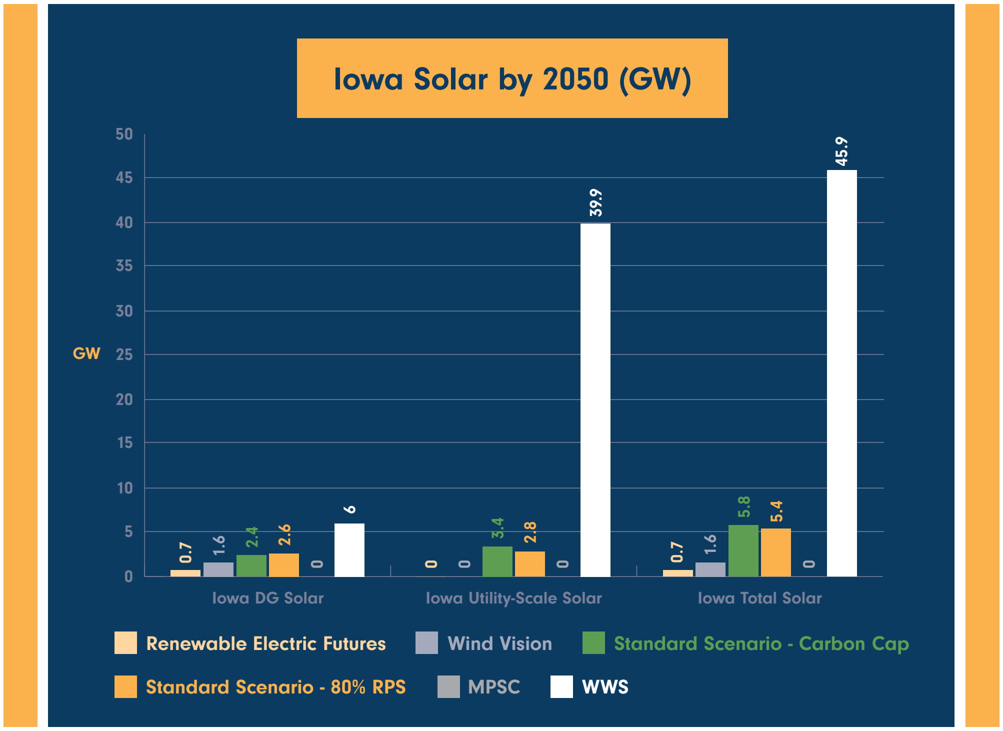
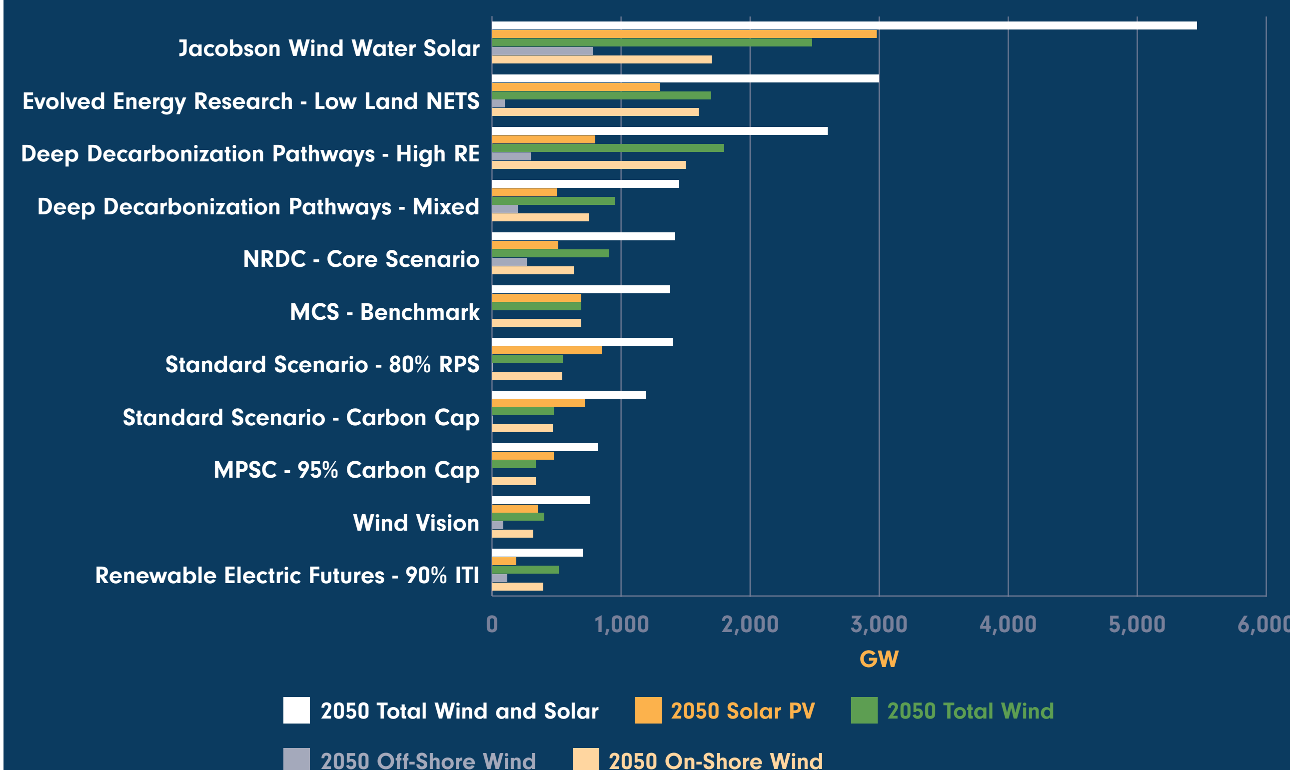


- While distributed generation (DG) solar has an important role and must be scaled up dramatically by mid-century, that role has limitations. The technical potential for rooftop solar tops out at about 36% of Iowa's annual retail sales. "Retail sales" refers to the amount of power needed to meet the electricity needs of Iowans. Other technologies are needed to reach 80-100% renewable energy.
- Not all studies include state-by-state results. Recent deep decarbonization studies without state results have projected national renewable energy levels that are equal to or higher than the most recent studies with state results. We would expect Iowa's contribution of wind and solar to be on the high end of studies with Iowa-specific results in order for the U.S. to reach needed renewable capacity.
- The roles for other low- or zero-carbon technologies are significantly more uncertain and vary considerably depending on assumptions on cost and speed of deployment. These technologies include carbon capture for coal or natural gas, nuclear, and biomass.
- Many studies, especially older studies, do not account for the increase in electricity use needed to support a large increase in electric vehicles or electric equipment to replace natural gas or propane, such as electric heat pumps. **If there is widespread adoption of such technologies to electrify and decarbonize transportation, buildings, and industrial processes, even more renewable energy will be needed to meet the higher electricity demand.** Newer studies are more likely to reflect these higher amounts of renewable energy.
- Studies that include energy efficiency, energy storage, and curtailment all find that these technologies and strategies are important to the grid and are deployed. However, a number of studies do not include some or all of these technologies or lack a robust assessment of these technologies.

Summary of National Wind and Solar Capacity (GW), by 2050

Study	2050 On-Shore Wind (GW)	2050 Off-Shore Wind (GW)	2050 Total Wind (GW)	2050 Solar PV (GW)	2050 Total Wind and Solar (GW)
Renewable Electric Futures — 90% ITI	398	119	517	187	704
Wind Vision	318	86	404	356	760
Midcontinent Power Sector (MPSC) — 95% Carbon Cap	340	n/a	340	478	818
Standard Scenario — Carbon Cap	471	6	477	718	1,195
Standard Scenario — 80% RPS	543	6	549	851	1,400
Mid-Century Strategy (MCS) — Benchmark	690	n/a	690	690	1,380
NRDC — Core Scenario	634	271	905	515	1,420
Deep Decarbonization Pathways (DDPP) — Mixed	750	200	950	500	1,450
Deep Decarbonization Pathways — High RE	1,500	300	1,800	800	2,600
Evolved Energy Research — Low Land NETS	1,600	100	1,700	1,300	3,000
Jacobson Wind Water Solar (WWS)	1,701	781	2,482	2,982	5,464

National Wind and Solar by 2050 (GW)



Key Conclusions Regarding Iowa's Role in Deep Decarbonization

The Importance of Wind in Iowa's Future Energy Mix

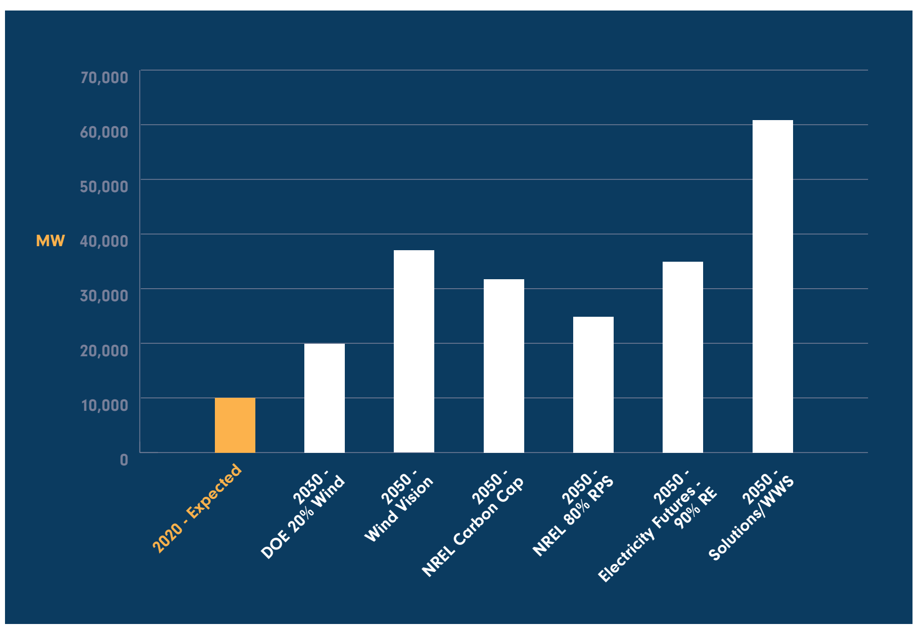
Speed. Early action is critical in reducing greenhouse gas emissions. A ton of carbon avoided in 2020 is more valuable in preventing the worst impacts from climate change than a ton avoided in 2050. The experience with wind development in Iowa is substantial, with proven deployment at the scale needed in future years.

We expect needing to deploy more than a gigawatt of wind capacity in a single year in Iowa with some frequency (e.g., over multiple years) between 2020 and 2050. We know this can be done because it has already been accomplished.

Cost-effectiveness.
Wind is the lowest-cost source of new generation and is cheaper than existing coal plants in many places.[3] Wind in Iowa has already kept electricity prices low compared to our neighbors. Relying on wind as a major source of renewable energy and to decarbonize will reduce costs for everyone.

Availability, including complementing solar.
Wind project capacity factors are now between 40% and 50%, as technology has improved. Separate from capacity factor, most new Iowa wind projects generate at least some electricity in nearly every hour of the year. Wind complements solar on a daily and seasonal basis in Iowa, as wind projects tend to generate well at night and during the fall and winter.

Iowa's Projected Actual 2020 Wind Capacity Compared to 2030 and 2050 Wind Capacity Amounts, by Study



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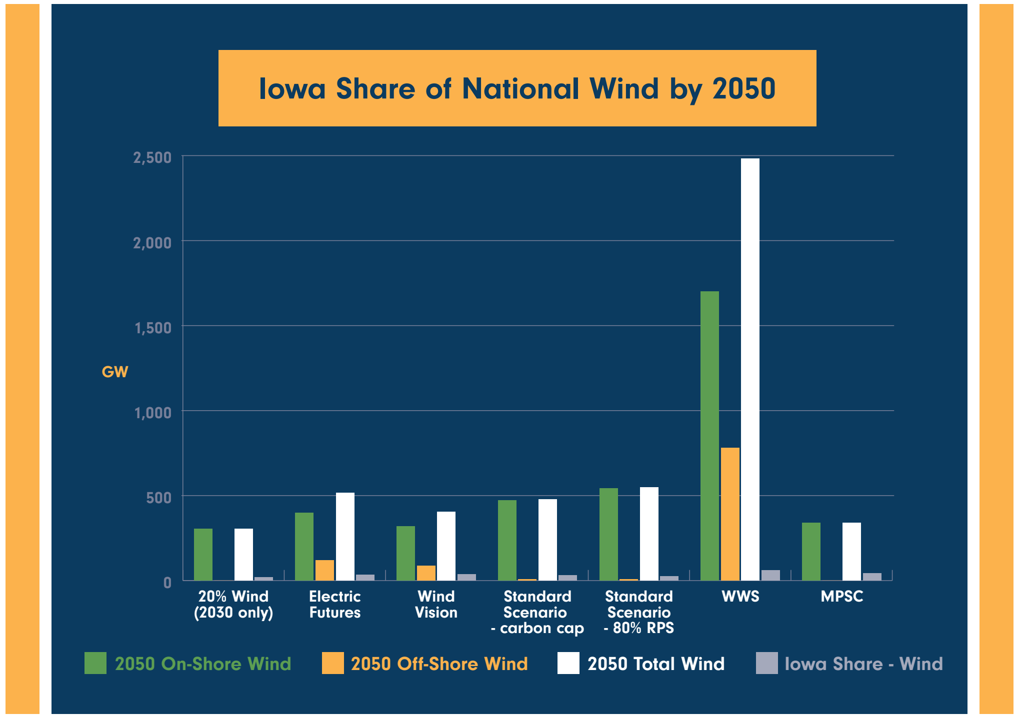
The Importance of Iowa Wind in the Future National Energy Mix

At a national level, studies range from projections of 304 GW to 1,701 GW of on-shore wind deployment between 2030 and 2050.

The low-end wind projection achieves 20% wind energy while still relying significantly on fossil fuels. The high-end wind projection is part of the mix needed to achieve 100% renewable energy in all U.S. states.

Across all studies, Iowa wind accounts for an outsized share of the total wind capacity needed to reach high levels of renewable energy and decarbonize the grid at a national level. In these scenarios, Iowa wind makes up between 4% and 12% of total U.S. wind capacity. Iowa is also a top-five wind state across studies.



Iowa Share of National Wind Needed by 2050, Studies with State Results Only

Study	2050 On-Shore Wind	2050 Off-Shore Wind	2050 Total Wind	Iowa Share — Wind	Iowa % of National On-Shore Wind
20% Wind (2030 only)	304	n/a	304	20	7%
Electric Futures	398	119	517	34	9%
Wind Vision	318	86	404	37	12%
Standard Scenario — carbon cap	471	6	477	32	7%
Standard Scenario — 80% RPS	543	6	549	25	5%
WWS	1,701	781	2,482	61	4%
MPSC	340	n/a	340	43	13%

Improving Flexibility and Renewable Integration: Energy Storage and Other Options

Major studies generally agree that greater flexibility in grid operation is beneficial when higher levels of renewable energy are in use. There are many options to improve or increase flexibility, including those in use today or expected to be in use in the near future. These include:

Energy storage. Energy storage technologies allow renewable energy generation such as wind or solar to be stored for future use. The range of technologies includes compressed air, pumped hydro, thermal mediums, and small-scale or large/utility-scale batteries. Not all studies include energy storage or include a full range of storage technologies. Storage technologies, particularly batteries, have been improving in performance and declining in cost in recent years, meaning more recent studies are a better indicator of potential use.

The NREL *Standard Scenarios* analysis shows Iowa adding 2.44 GW to 6.18 GW of storage capacity by 2050 for the National RPS and Carbon Cap scenarios respectively.[4] Earlier studies, including Wind Vision and Renewable Electricity Futures, showed Iowa adding 1.7 GW to 2.2 GW of storage capacity across major scenarios.

Demand response and curtailment programs. Current demand response programs in Iowa are voluntary for utility customers, focused on reducing demand during a narrow set of circumstances, such as hot summer days with high peak loads. For residential customers, the programs primarily focus on reducing air conditioning use during the day or early evening. For large industrial customers, the programs reduce energy use from a range of activities at peak demand times.

Demand response programs could be used to reduce loads at other times, such as low renewable energy availability. These programs could also be expanded to address more types of electricity use, including water heating and appliance use, particularly with increases in electrification. Adding substantial solar PV capacity is expected to bring many of the same benefits as demand response during summer peaks, providing an opportunity to refine or adjust demand response programs to the services needed to reach high levels of renewable energy.

New and expanded transmission. Studies agree that adding more transmission capacity increases the amount of renewable energy that can be added to the grid and improves how renewable energy operates. In Iowa and much of the country, the windiest areas are geographically distant or isolated from the areas that use most of the electricity. Transmission lines facilitate substantial amounts of renewable energy development that cannot otherwise occur, including higher-performing and lower-cost renewable resources. This reduces overall costs of reaching high levels of renewable energy and achieving deep cuts in emissions. In addition, larger geographic areas linked by transmission will have access to more renewable energy more times of the year.

Electrification. New technologies are improving the opportunities to use renewable electricity as a fuel instead of directly burning fossil fuels like natural gas, gasoline, diesel, or propane. Electric heat pumps and water heaters can reduce or eliminate direct natural gas or propane use in buildings, just as electric vehicles can eliminate consumption of gasoline or diesel. However, a substantial shift from fossil fuels to electricity is expected to increase overall electricity demand even with high levels of energy efficiency. Studies vary on the levels of projected electrification. Studies that did not incorporate much or any electrification are likely underestimating the amount of wind and solar needed in 2030, 2040, and 2050 if electrification increases. Electrification offers additional opportunities for flexibility from demand response programs as well as more types of electric equipment that could be curtailed or shifted under those programs.

Renewable Energy in Iowa Today — Our Starting Point for 2050

Iowa is seeing a wave of wind development as the federal production tax credit begins to phase out, having reached the major wind energy benchmark of 10,000 megawatts of installed capacity. This wind capacity should allow Iowa to generate more than 40% of its electricity from wind.

Iowa's first utility-scale solar project, CIPCO's 100 MW project in Louisa County, should be operational in 2020.[5] A number of utility-scale solar projects totaling approximately 750 MW are under construction across Iowa as well.[6]

Iowa is a regional leader for distributed generation (DG), or customer-owned solar, with more DG than most neighboring and Midwest states, but is far behind national leaders on both distributed and utility-scale solar.[7] Iowa had 111 MW of distributed solar as of October 2019.[8]

The Technical Potential for Renewables and Efficiency Iowa

Technical potential studies identify the real-world maximum potential for an energy resource. Technical potential studies start with the total resource potential, or the amount of energy that is physically available, and then account for constraints like geography or system performance. For example, assumptions on the average capacity factor for wind and solar impact the technical potential, and average capacity factors have improved over time.

Technical potential is useful to understand what could be achieved without additional limitations such as economics, market adoption, or public policy. The National Renewable Energy Lab (NREL) has conducted several technical potential studies for the full range of renewable energy technologies in recent years, including a major study as part of the Renewable Electricity Futures study in 2012 and an updated study in 2015.[9] The following chart identifies Iowa's low-end and high-end potential by renewable energy technology.

Range of Technical Potential Results for Iowa

	Low-End Iowa Potential GW	Low-End Iowa Potential Generation (TWh)*	High-End Iowa Potential GW	High-End Iowa Potential Generation (TWh)
Wind	276	1,045	571	1,724
Utility-scale solar	4,036	7,021	4,454	7,532
Distributed/rooftop solar	7.2	8.6	18	23.2
Hydro	1.0	2.8	1.1	6.3
Biopower	3.3	26	3.6	28.9

**TWh stands for terrawatt hour.*

For context, Iowa generated about 63 terrawatt hours (TWh) from all sources in 2018 while retail sales were at about 51 TWh.[10] Even at their high end potential, as compared to 2018 retail sales, distributed/rooftop solar and biopower each could meet about half of Iowa's annual retail sales and hydropower could meet less than 13% of retail sales. Wind and utility-scale solar offer the potential to meet Iowa's retail sales many times over. NREL completed a stand-alone study on rooftop solar technical potential in 2016. This study is similar but finds slightly less technical potential for rooftop solar in Iowa, estimating 14 GW of capacity potential and 16.6 TWh/year of generation potential.

The technical potential of energy efficiency and demand-side management to meet future energy demand in Iowa has been well-documented. Iowa's investor-owned utilities commissioned a potential study in 2017 for the years 2018-2028.[11] This study does not evaluate the entire state, but only the service territories for MidAmerican Energy, Alliant Energy (Interstate Power and Light), and Black Hills Energy — about 75% of retail sales and customers, but half or less of the geographic footprint of the state.

This study found the potential for 10.5 TWh of electric energy efficiency savings available during the ten-year period.[12] This is equivalent to 26% of retail sales over ten years and a range of annual savings between 2.25% and 3.5% (as a percent of annual retail sales).[13] The technical potential for demand savings — from demand response and efficiency measures – is 2.4 GW.[14] For natural gas, the study found the potential for 28,262 MDth (thousand decatherms) in savings during the ten-year period, which is equivalent to 25% of retail sales.[15]

Conclusion/Recommendations

Iowa has been a national leader in wind energy for more than a decade and is finally seeing significant solar development. As a result, renewable energy accounts for nearly 35% of Iowa's electricity generation, among the highest of any state. This leadership is an important first step, but Iowa must sustain — and even ramp up — its progress on renewable energy for the next thirty years.

There is consensus across studies that the 10 GW of wind energy that Iowa currently has installed is not nearly enough wind to decarbonize the grid and protect the climate. Iowa should plan to reach 30 to 40 GW of wind by 2050 to reduce emissions by 80-90%. In addition, distributed and utility-scale solar must scale up dramatically, from a few hundred megawatts in 2020 to 5-6 GW by 2050, at a minimum.

In addition, if the power sector is needed to support decarbonization in other energy sectors – such as with electrified transportation, building heat, or industrial processes – even more wind and solar will be required. This could mean that Iowa needs to reach 60 GW of wind and 10 to 20 GW of solar, or more. The Jacobson/Solutions Project study that relies on wind, solar, and hydro to support all energy uses shows Iowa needing as much as 61 GW of wind and 46 GW of solar by 2050.

Other recent studies that examine both deep decarbonization and widespread electrification do not offer state results, but the national results are fairly consistent with the Jacobson study. These studies include those from the Deep Decarbonization Pathways Project and Evolved Energy Research. It is quite possible that 30-40 GW of wind and 5-6 GW of solar are low-end estimates of what will be needed for Iowa to decarbonize by mid-century.

With such a scale in mind, it is clear that Iowa will require systemic changes to our energy economy. Public and private decision-makers can use various pathways to achieve the necessary renewable energy and decarbonization, but will need to make short-term decisions consistent with a long-term strategy to achieve the same.[16]

Iowans should focus on government and private sector-enabling actions, including necessary policies, laws, and incentives. The committed actions of government, businesses, and individuals will be necessary in order to support the continued annual additions of both wind and solar as quickly and expansively as possible.[17]

Summary of Major Studies with Iowa-Specific Energy Mix by 2050

DOE, 20% Wind by 2030

This 2008 landmark wind energy study examined the feasibility of and steps for meeting 20% of the U.S. electricity supply from wind by 2030.[18]

The study projected that a handful of windy states will contribute large shares of the wind capacity necessary to get the U.S. to 20% wind. Iowa is one of these states.

By 2022, the study projects that Iowa would need about 11 GW of wind capacity.[19] By 2030, this would grow to nearly 20 GW of wind capacity. A handful of states have similar large wind capacity amounts by 2030, including California (16.7 GW), Illinois (14.7 GW), Michigan (20.4 GW), Oklahoma (38.5 GW) and Texas (20.5 GW).[20]

As discussed previously, Iowa is on track to reach the 2022 milestone, but will need to nearly double wind capacity between 2022 and 2030 to meet the 2030 milestone. Even at these levels, wind energy would only account for 20% of U.S. electricity supply, meaning large additional increases of renewable energy would be needed between 2030 and 2050 to reduce emissions and reach very high renewable energy levels.

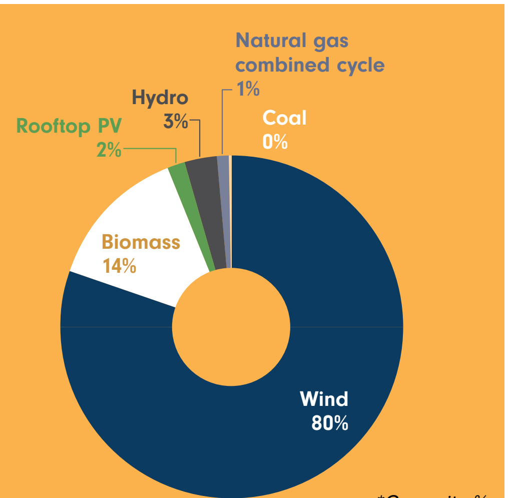
NREL/DOE, Renewable Electricity Futures

NREL and U.S. DOE completed this analysis in 2012 to evaluate the feasibility for the U.S. to meet energy needs with very high levels of renewable energy, including 80% and 90% renewables, by 2050.[21] In addition to a comprehensive report, NREL developed an interactive on-line tool that provides state-by-state energy mixes in 2050 under a range of scenarios.[22] The tool also shows annual national carbon dioxide emissions through 2050 under each scenario.

Iowa's mix varies by scenario, but nearly all scenarios show a significant increase in wind generation through 2050, including all of the primary or most likely scenarios. We have included the 2050 mix for one of the two 90% renewable energy scenarios:

90% Renewable Energy Incremental Technology Improvement (RE-ITI) Scenario Results for Iowa

	Capacity (GW)	Capacity %*	Generation (TWh)	Generation %
Wind	34.1	80%	119.3	70.2%
Biomass	5.8	14%	42.9	25.2%
Rooftop PV	0.7	2%	0.8	0.5%
Hydro	1.2	3%	6.6	3.9%
Natural gas combined cycle	0.5	1%	0.3	0.2%
Coal	0.08	0%	0.2	0.1%



*Capacity %

Compared to other states, Iowa also has among the highest amounts of wind capacity by 2050. Iowa's wind generation helps the U.S. both achieve a high renewable mix and reduce carbon dioxide emissions.

U.S. DOE, Wind Vision

The U.S. DOE completed an ambitious and longer-term wind analysis in 2015.[23] This analysis looks at similar near-term wind deployment as the 20% Wind by 2030 report with a longer view towards higher wind levels in 2050.

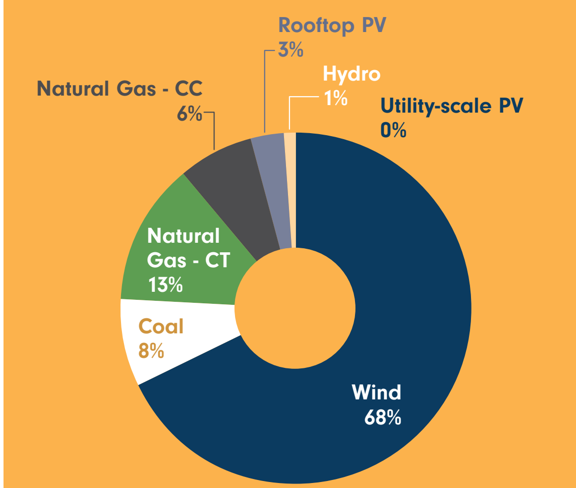
The primary study scenario is 35% wind by 2050 with one sensitivity reaching 41% wind. To reach 35% wind, the U.S. would see 404 GW of installed wind capacity by 2050. At a national level, annual wind additions range from 12 GW per year between 2021-2030 to 17.5 GW per year between 2031-2050. DOE provides an interactive on-line tool to see state by state results for each future year under different scenarios.[24]

Wind Vision — Summary of Iowa Results

	Capacity (GW)	Capacity %*	Generation (TWh)	Generation %
Wind	37.0	67.9%	165.4	78.4%
Coal	4.2	7.8%	31.0	14.7%
Natural Gas - CT	7.2	13.1%	0.4	0.2%
Natural Gas - CC	3.5	6.4%	9.8	4.6%
Rooftop PV	1.6	2.9%	1.6	0.8%
Hydro	0.7	1.2%	2.7	1.3%
Utility-scale PV	0.0	0.0%	0.0	0.0%

For the main study scenario, Iowa would see a total installed wind capacity of 37 GW by 2050. Iowa also ranks third nationally for total wind capacity and for total wind generation behind Texas and Illinois and so significantly helps the U.S. reach high levels of wind generation.

While 35% wind by 2050 nationally is a big increase from today, it is not enough to push coal or natural gas generation to zero or near-zero levels. The grid mix in Iowa in 2050 in the primary Wind Vision scenario still shows coal and gas accounting for about 28% of generation in Iowa.



NREL, 2018 Standard Scenarios Report: A U.S. Electricity Sector Outlook

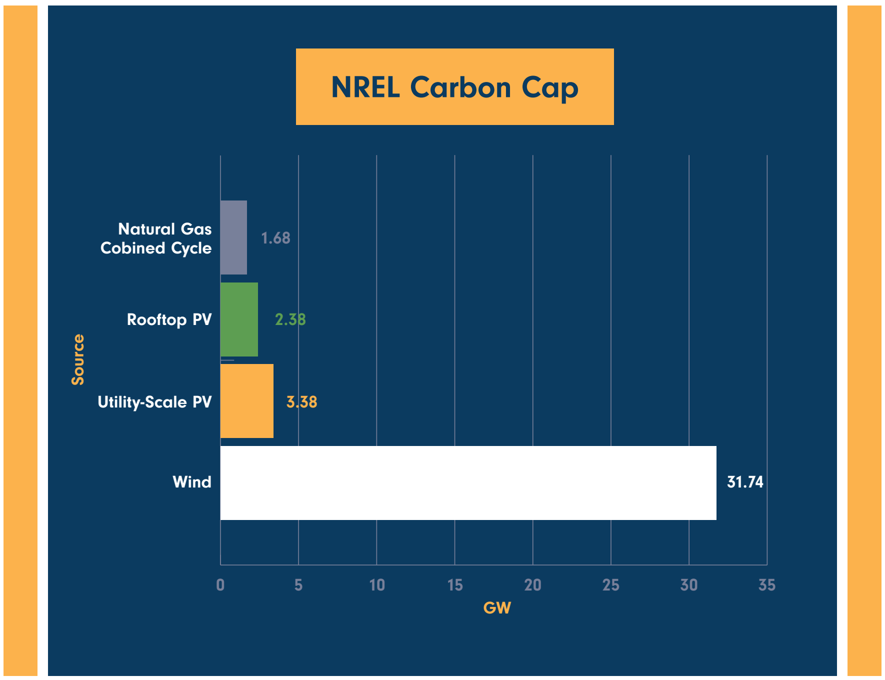
In 2016, National Renewable Energy Lab (NREL) began releasing an annual report providing a range of scenarios for the future of the U.S. electricity system.[25] NREL also provides an interactive on-line tool capable of projecting the energy mix in each U.S. state through 2050 under the same wide range of scenarios.[26] NREL published the most recent report in late 2019.

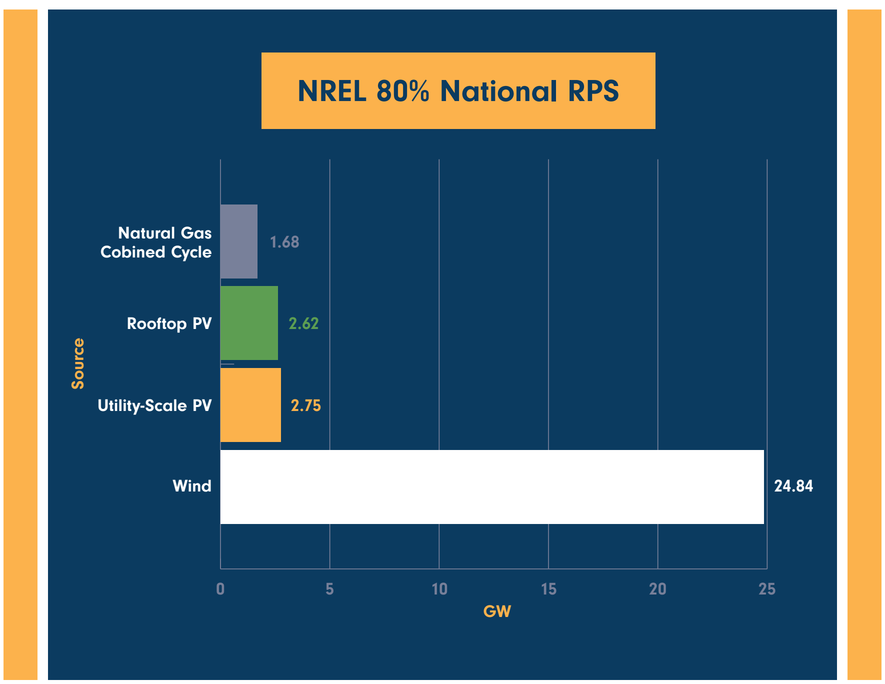
Iowa Mix under the National Carbon Cap – Sources Above 1% Capacity

	Capacity (GW)	Capacity %	Generation (TWh)	Generation %
Wind	31.74	78%	125.43	91%
Utility-scale PV	3.38	8%	6.08	4%
Rooftop PV	2.38	6%	2.68	2%
Natural gas combined cycle	1.68	4%	2.11	1.50%

Two scenarios are particularly relevant for deep decarbonization and high renewables. The Carbon Cap scenario implements an electric sector cap of 30% below 2005 levels by 2030 and 83% below 2005 levels by 2050. The National Renewable Portfolio Standard (RPS) scenario implements an 80% renewable energy requirement by 2050 with eligible technologies including wind, solar, hydro, geothermal, biopower, and landfill gas.

The National RPS scenario is consistent with the 80% renewable scenarios in the 2012 NREL Renewable Electricity Futures report discussed above, with the advantage of newer cost and performance information for renewable energy. Iowa's mix in 2050 includes more rooftop and utility-scale solar PV than the 2012 NREL report and considerably less biopower. There is still a large increase in wind generation.



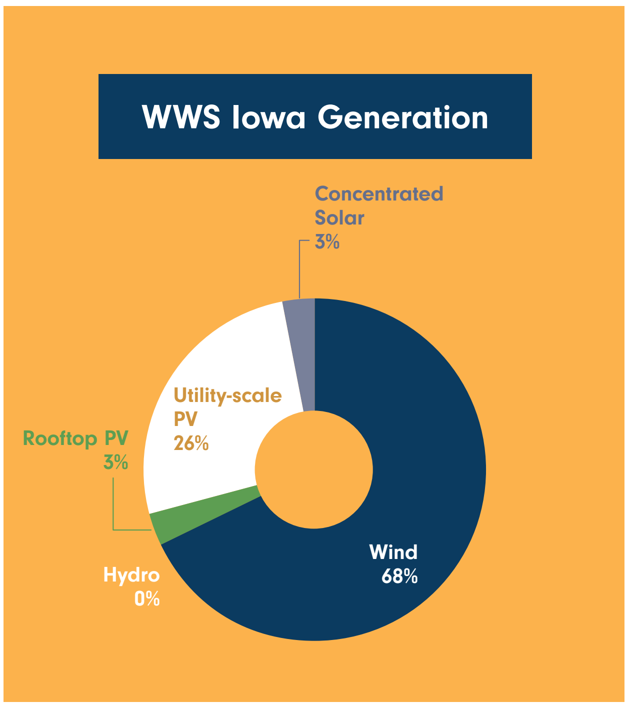


Iowa Mix Under an 80% National RPS – Sources Above 1% Capacity

	Capacity (GW)	Capacity %	Generation (TWh)	Generation %
Wind	24.84	76%	101.37	91%
Utility-scale PV	2.75	8%	4.85	4%
Rooftop PV	2.62	8%	3.22	3%
Natural gas combined cycle	1.68	5%	0.11	0.10%

The Solutions Project/WWS Analysis

The Solutions Project, a non-profit foundation that aims to achieve 100% renewable energy, has identified the energy mix in each state needed to get the U.S. to 100% renewable energy.



This information is based on academic research led by Mark Jacobson at Stanford University.[27] Iowa's energy mix in 2050 would be 68% wind, 25.8% solar plants (utility-scale), 3% concentrating solar plants, 1.5% residential rooftop solar, 1.5% commercial and government rooftop solar, and 0.3% hydropower.[28]

Energy demand in 2050 would be reduced by 28% through energy efficiency and grid efficiencies from renewable energy. However, total electricity production increases to support full electrification of additional sectors of the economy, including transportation and industry. Fossil fuels and nuclear power do not contribute at all. As a result, this study projects the most renewable energy capacity by 2050.

The WWS Iowa mix in 2050

	Capacity (GW)	Capacity %	Generation (TWh)	Generation %
Wind	60.8	56%	182.26	68%
Hydro	0.1	0%	0.66	0%
Rooftop PV	6	6%	8.04	3%
Utility-scale PV	39.9	37%	69.03	26%
Concentrated Solar	2.2	2%	8.04	3%

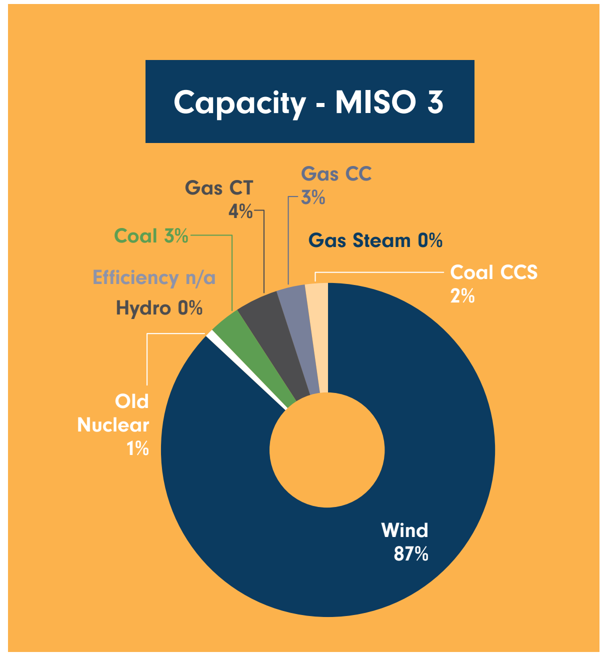
Midcontinent Power Sector Collaborative

The Midcontinent Power Sector Collaborative released *The Road Map to Decarbonization in the Midcontinent* in 2018, which identifies a range of possible pathways to reach 80% and 95% decarbonization in the electric sector by 2050.[29] The report uses extensive modeling results and an interactive modeling tool is available.[30] The tool provides results by MISO zone, rather than by state, as well as national results. Iowa overlaps closely with MISO Zone 3.

The model was run for MISO Zone 3 using standard assumptions with a straight line carbon reduction to a 95% carbon cap in 2050. Some scenarios in the model produce considerably higher amounts of renewable energy capacity for Iowa and for the U.S. as a whole, while others are lower. Some scenarios result in Iowa reaching 60 GW to 70 GW of wind or 3 GW to 4 GW of solar (although scenarios with the most solar tend to have much less wind, the scenarios with the most wind tend to have no solar).[31]

Generation and Capacity in MISO 3 (similar to Iowa), 95% Carbon Cap in 2050

	Capacity (GW)	Capacity %	Generation (TWh)	Generation %
Wind	42.8	87%	153.4	94%
Old Nuclear	0.6	1%	4.8	3%
Efficiency	n/a	n/a	4.4	3%
Hydro	0.0	0%	0.0	0%
Coal	1.5	3%	0.0	0%
Gas CT	1.9	4%	0.0	0%
Gas CC	1.7	3%	0.0	0%
Gas Steam	0.0	0%	0.0	0%
Coal CCS	0.8	2%	0.0	0%

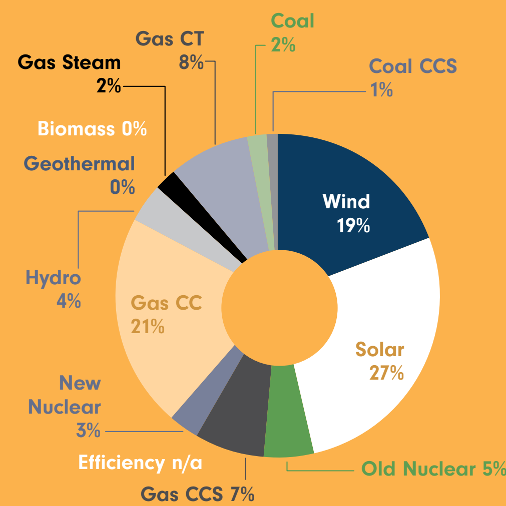


The U.S. model results show a mix of generation and capacity, and while wind is the leading source of generation in 2050, there are substantial contributions from solar, existing (or 'old') nuclear, and natural gas with carbon capture. In Iowa, however, wind dominates the generation mix with a small contribution from existing nuclear. While Iowa retains capacity from a range of resources, many of those resources are not actually used in 2050. Energy efficiency's contribution is included as well, although the efficiency resource is somewhat limited compared to other resources in the model.

Generation and Capacity in U.S., 95% Carbon Cap in 2050

	Capacity (GW)	Capacity %	Generation (TWh)	Generation %
Wind	339.6	19%	1249.7	26%
Solar	478.1	27%	789.7	16%
Old Nuclear	92.9	5%	730.4	15%
Gas CCS	126.9	7%	667.1	14%
Efficiency	n/a	n/a	561.0	11%
New Nuclear	45.2	3%	336.5	7%
Gas CC	379.5	21%	280.5	6%
Hydro	73.2	4%	254.1	5%
Geothermal	2.4	0%	14.7	0%
Biomass	3.3	0%	7.2	0%
Gas Steam	38.8	2%	0.7	0%
Gas CT	133.1	8%	0.3	0%
Coal	38.5	2%	0	0%
Coal CCS	21.7	1%	0	0%

Capacity - National 95% Carbon Cap



Major Studies with Regional or National Results Only

Deep Decarbonization Pathways Project

The Deep Decarbonization Pathways Project (DDPP) published an analysis in 2015 showing four main pathways or strategies for the U.S. to decarbonize by 2050.[32] This analysis is comprehensive in that it evaluates decarbonizing the power sector, as well as transportation, industry, and buildings. However, DDPP did not publish state-by-state information regarding energy mixes in 2050, so Iowa-specific results are not available. DPPP also did not publish detailed results showing the capacity or generation from each resource (e.g., wind, solar, etc.) in 2050, but rather summary charts and graphs. We have estimated numbers to compare this analysis with others we discuss, which did include specific numbers by resource.

Of the four main scenarios, three rely heavily on new renewable energy generation and specifically wind: Mixed, High Renewables, and High Nuclear. Only the High CCS scenario does not show a substantial increase in wind and solar by 2050, although both technologies do increase.

In the Mixed, High Renewables, and High Nuclear scenarios with a massive increase in renewable energy capacity, wind capacity in 2050 is roughly twice as large as solar capacity. In the High Renewables scenario of the DDPP, on-shore wind accounts for about 1,500 GW of capacity and solar accounts for about 800 GW of capacity in 2050.[33] There is also roughly 300 GW of off-shore wind. In the Mixed scenario, on-shore wind is approximately 750 GW, off-shore wind approximately 200 GW, and solar PV approximately 500 GW.[34] The generation results show wind contributes 4-5 times the annual electricity production as solar across all four scenarios.

While state-by-state results are not available, Iowa would be likely to see a large increase in wind generation to contribute to the national totals given its substantial wind resource. The High Renewables case with 1,500 GW of new wind has over three times the wind capacity as the Wind Vision study. In that study, Iowa hosted 37 GW of wind. Under the DDPP High Renewables case, Iowa would likely need to increase this to 60 GW or higher, in line with the WWS analysis that shows Iowa having 60 GW of wind by 2050.

U.S. Mid-Century Strategy for Deep Decarbonization

The Obama administration released the U.S. Mid-Century Strategy (MCS) in November 2016 as part of its commitment under the Paris Agreement.[35] The study identifies several scenarios for the U.S. to achieve an 80% or greater reduction in greenhouse gas emissions below 2005 levels by 2050.

All four scenarios would scale wind and solar energy dramatically. The MCS Benchmark scenario would deploy 30 GW of wind and solar annually between 2016 and 2035 and over 50 GW annually between 2036 and 2050.[36] The study does not provide exact numbers for total capacity in 2050 for wind or solar, but based on the report's annual projections, we estimate that approximately 1,380 GW of wind and solar capacity by 2050 would be installed between 2016 and 2050. The report indicates that capacity additions will be split evenly between wind and solar, which means 690 GW of wind and 690 GW of solar by 2050.

The MCS also projects that by 2050, wind will account for nearly 30% of electricity generation – the highest of any source.[37] Solar is nearly 16% and nuclear about 17%, with additional contributions primarily from gas (with and without carbon capture), coal with carbon capture, biomass, hydro, and geothermal.[38]

The MCS does not provide state-by-state results, but we would expect windier states to have a larger share of the 690 GW than less windy states. Wind Vision forecasts around 400 GW of land-based wind by 2050 with an Iowa share of 37 GW. Because MCS projects more wind, we would expect the Iowa share of the 690 GW is likely to be at least equal to the Wind Vision study results, but likely higher and possibly approaching the 60 GW that Iowa hosts in the WWS analysis.

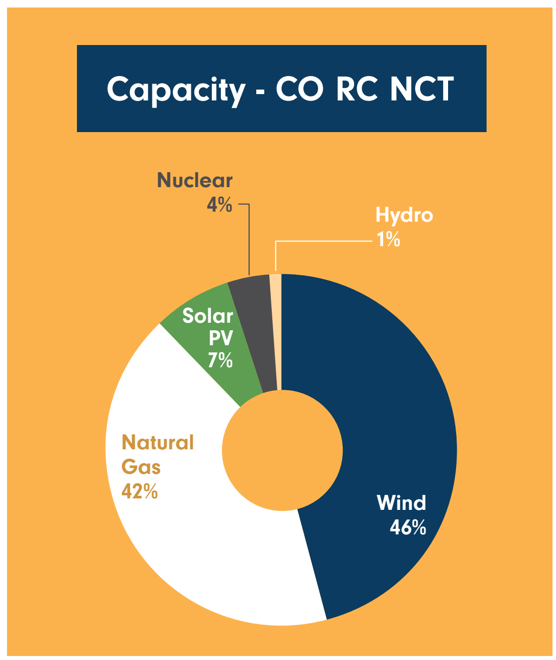
Vibrant Clean Energy/MISO

The Midcontinent Independent System Operator (MISO) commissioned a study to evaluate high-renewable and low-carbon scenarios in the MISO footprint.[39] The footprint includes most of Iowa and stretches in a patchwork fashion from North Dakota to Michigan and from Canada to Louisiana. Vibrant Clean Energy (VCE) conducted the study in 2016 and included an 80% reduction in greenhouse gas emissions from 2005 levels. The study did not specifically address the increase in electricity demand to support vehicle electrification or electrification of other sectors (e.g., space heating, industrial processes).

VCE projects that by 2050, wind and solar would contribute more than 60% of electricity generation in the MISO footprint, with nuclear contributing another 10%, natural gas contributing about 30%, and coal power phased out.[40] VCE does not provide state-by-state results, but provides capacity mix percentages along with approximate GW capacity by technology.

Cost Optimization, Reduction Case, Non-Constrained Transmission (CO RC NCT) Scenario in 2050

Technology	% of total capacity	GW (approximate)
Wind	46%	161
Natural gas	42%	147
Solar PV	7%	24.5
Nuclear	4%	14
Hydro	1%	3.5



VCE also shows that scenarios with transmission expansion have reduced costs and emissions compared to scenarios where transmission expansion is constrained.[41]

Union of Concerned Scientists

The Union of Concerned Scientists (UCS) released a working paper in 2016 that identifies several pathways to achieve a 90% or greater reduction in carbon emissions in the power sector by 2050.[42] The analysis includes a scenario focused on significant wind and solar development but also examines scenarios with higher contributions from nuclear power as well as carbon capture and storage. The analysis also accounts for a possible future with greater levels of electrification and thus higher electricity sales, although those increases are somewhat offset by higher levels of energy efficiency. The study presents high-level generation from different technologies in 2030 and 2050 for each scenario but does not include the capacity by technology at a national level or by state in 2050.

In the "Optimistic Wind and Solar Case," non-hydro renewables account for 75% of electricity generation in 2050 with hydro, natural gas, and nuclear providing the remaining 25% of generation.[43] In the other emissions reduction scenarios, renewables range from 62% to 70% of the generation in 2050. Coal power is phased out in all four emissions reduction scenarios. The study supports reaching deep decarbonization with an electricity system dominated by renewables.

Natural Resources Defense Council

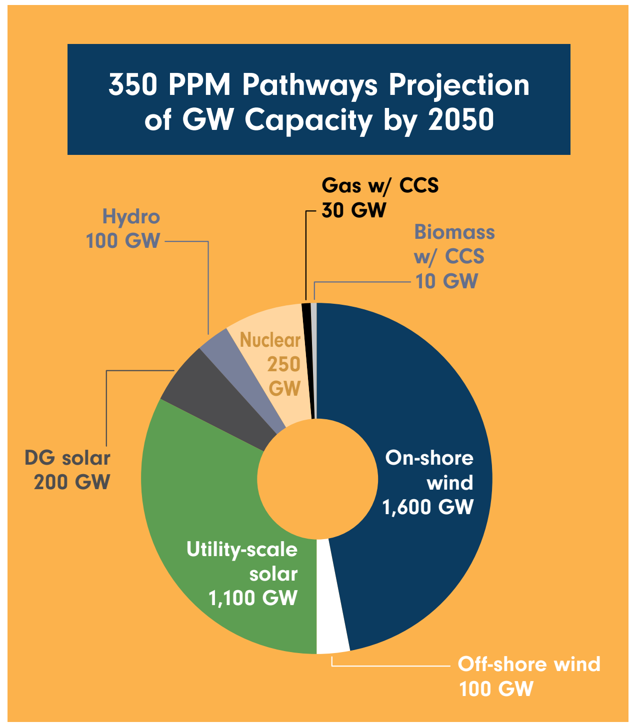
NRDC released *America's Clean Energy Frontier: The Pathway to a Safer Climate Future* in 2017.[44] The analysis focuses on the NRDC Core Scenario, which reduces emissions 80% below 1990 levels by 2050 and meets that target with an emphasis on renewables and efficiency. The report includes substantial electrification, but tempers a major increase in electricity demand with robust efficiency.

By 2050, the analysis projects renewable energy will account for 70% of electricity generation.[45] The remaining 30% is met with a mix of hydro, nuclear, biomass, combined heat and power, natural gas, and fossil fuel generation with carbon capture. Wind contributes substantially more than solar in the Core Scenario, but both technologies require significant ramp up compared to current levels.[46] NRDC projects installed U.S. wind capacity of 905 GW and installed U.S. solar capacity of 515 GW by 2050.[47]

Evolved Energy Research

Evolved Energy Research released their deep decarbonization analysis in May 2019 for the Deep Decarbonization Pathways Project, making it the most recent analysis we reviewed. This analysis, *350 PPM Pathways for the United States*, examines six pathway options or scenarios to achieve net negative CO2 emissions by 2050.[48]

The scenario that achieves the most emissions reductions and lowest 2050 emissions, Low Land NET (negative emissions technology), also includes the most renewable deployment by 2050.[49] The capacity in 2050 under this scenario is approximately 1,100 GW of utility-scale solar, 200 GW of distributed solar, 100 GW of offshore wind, and 1,600 GW of on-shore wind. In addition, the analysis shows about 100 GW of hydro, 250 GW of nuclear, 30 GW of gas with carbon capture, and 10 GW of biomass with carbon capture.



About

The primary authors for this paper are Nathaniel Baer, Steve Guyer, Kerri Johannsen, and Michael Schmidt with the Iowa Environmental Council. We appreciate the assistance provided by the authors and organizations of the reviewed studies as we researched and drafted this paper.

Endnotes

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2 Jacobson et al, *100% clean and renewable wind, water, and sunlight (WWS) all-sector energy roadmaps for the 50 United States*, Energy & Environmental Science (2015) at http://web.stanford.edu/group/efmh/jacobson/Articles/I/USStatesWWS.pdf.
See also *100% Wind, Water, and Solar (WWS) All-Sector Energy Roadmaps for Counties, States, Cities, and Towns* at http://web.stanford.edu/group/efmh/jacobson/Articles/I/WWS-50-USState-plans.html. In particular, see 50-state-xlsx-spreadsheets and worksheet 'Intermediate details by state.'

3 Vibrant Clean Energy, Energy Innovation, *The Coal Cost Crossover: Economic Viability of Existing Coal Compared to New Local Wind and Solar Resources* (2019) at https://energyinnovation.org/wp-content/uploads/2019/03/Coal-Cost-Crossover_Energy-Innovation_VCE_FINAL.pdf.

4 NREL, *Standard Scenarios Results Viewer* at https://openei.org/apps/reeds/. We selected the 2018 publication year and, under Scenario 1, the 80% National RPS and Carbon Cap options.

5 CIPCO, *Plans for Iowa's Largest Solar Project Announced by Central Iowa Power Cooperative* (2018) at https://www.cipco.net/content/plans-iowa%E2%80%99s-largest-solar-project-announced-central-iowa-power-cooperative.

6 As of January 2020, the Midcontinent Independent System Operator generator interconnection queue for Iowa included nearly 2,900 MW of utility-scale solar projects at https://api.misoenergy.org/PublicGiQueueMap/index.html. Approximately 750 MW of these solar projects are part of Iowa Utilities Board dockets GCU-2019-0002, GCU-2019-0003, and GCU-2019-0004, approved for construction by the Iowa Utilities Board in the fall of 2019 and are being developed by Invenergy.

7 Energy Information Administration (EIA), *Electric Power Monthly*, Table 6.2B. Iowa's 118.1 MW of estimated distributed/small-scale solar was higher than distributed solar estimates for Indiana, Michigan, Minnesota, Nebraska, Wisconsin, Kansas, North Dakota and South Dakota. http://www.eia.gov/electricity/monthly/?scr=email.

8 *Id.*

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11 Dunsky Energy Consulting, *Assessment of Iowa's Energy Efficiency Potential* (2017).

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16 LEGAL PATHWAYS TO DEEP DECARBONIZATION IN THE UNITED STATES, summary and recommendations available at https://biotech.law.lsu.edu/blog/deep_decarb_summary_booklet_online.pdf.

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24 DOE, *Wind Vision Study Scenario Viewer* at https://openei.org/apps/wv_viewer/#. We selected: Study, Central (fuel selection), Central (wind selection).

25 NREL, *Standard Scenarios Annual Report* (2018) available at https://www.nrel.gov/analysis/data-tech-baseline.html.

26 NREL, *Standard Scenarios Results Viewer* at https://openei.org/apps/reeds/. We selected the 2018 publication year and, under Scenario 1, the 80% National RPS and Carbon Cap options.

27 Jacobson et al, *100% clean and renewable wind, water, and sunlight (WWS)* all-sector energy roadmaps for the 50 United States, Energy & Environmental Science (2015) at http://web.stanford.edu/group/efmh/jacobson/Articles/I/USStatesWWS.pdf. See also *100% Wind, Water, and Solar (WWS) All-Sector Energy Roadmaps for Counties, States, Cities, and Towns* at http://web.stanford.edu/group/efmh/jacobson/Articles/I/WWS-50-USState-plans.html. In particular, see 50-state-xlsx-spreadsheets and worksheet 'Intermediate details by state.'

28 The Solutions Project, *100% Iowa*, at https://thesolutionsproject.org/why-clean-energy/#/map/states/location/IA.

29 MPSC, GPI, *A Road Map to Decarbonization in the Midcontinent* (2018) available at http://roadmap.betterenergy.org/.

30 Available at http://roadmap.betterenergy.org/electricity/95-percent-decarbonization/.

31 This appears to be the result of the economics of the modeling combined with its national scope and region-specific inputs. For example, as renewable costs increase, more wind is developed in the places where it is less expensive, such as Iowa. There may be less wind overall in the U.S. but more wind in Iowa in such a scenario. As renewable costs decrease, more wind and solar is developed nationally and more solar is developed in Iowa, but less wind is often developed in Iowa – either because wind is cheaper in more places or because the renewable mix is more dominated by solar.

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33 Technical Report at 36, Figures 29-30.

34 *Id.*

35 The White House, *United States Mid-Century Strategy for Deep Decarbonization* (2016) available at https://unfccc.int/process/the-paris-agreement/long-term-strategies.

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37 MCS, *Appendix C, Table C.3: Electricity Generation.*

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42 Union of Concerned Scientists, *The US Power Sector in a Net Zero World* (2016) available at https://blog.ucsusa.org/rachel-cleetus/decarbonize-us-power-sector.

43 *Id.* at 8.

44 Available at https://www.nrdc.org/resources/americas-clean-energy-frontier-pathway-safer-climate-future.

45 *Id.* at 24.

46 *Id.* at 73, Exhibit D-4.

47 *Id.* at 80, Exhibit F-1.

48 Available at https://www.evolved.energy/single-post/2019/05/08/350-ppm-Pathways-for-the-United-States.

49 *Id.* at 41, Figure 11.

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