ILLINOIS
Grainger College of Engineering

Argonne NATIONAL LABORATORY

Midwest Hydrogen and Fuel Cell Partnership

Mission Document
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I. Mission Statement

The Midwest Hydrogen and Fuel Cell Partnership aims at advancing and promoting the development and adoption of hydrogen technologies to provide clean, secure, and resilient energy sources, and create economic development opportunities throughout the Midwest.

II. Why Hydrogen and Fuel Cells?

Hydrogen and fuel cells enable a secure, resilient, reliable, domestically produced, clean energy solution that impacts all sectors of the economy. Fuel cells fueled by hydrogen provide a highly efficient zero-emissions means of providing electric power for transportation, data centers, microgrids, and other needs. Hydrogen, along with other energy storage technologies, can enable higher penetration of CO_2-free power sources such as wind and solar, or nuclear energy, by providing a means to store excess power at times of high production or low electricity use rather than curtailing production. Hydrogen can be made via electrolysis at periods of high wind or high solar electricity production or by nuclear at periods of low demand from the grid and stored.

Unlike other energy storage technologies, hydrogen can be utilized for both long-term and short-term seasonal energy storage for power generation and heating purposes. Hydrogen's versatility allows us to store and move energy from the power sector to other sectors of the economy, including the transportation, industrial, agricultural, commercial, and residential sectors to meet a variety of needs.

Green hydrogen produced by electrolysis of water using electricity generated from renewables or nuclear energy can be used as a CO_2-free transportation fuel, not only for light-duty vehicles but for heavy-duty trucks, rail, maritime, and aviation, that are difficult to decarbonize with batteries.

Hydrogen can decarbonize the heating sector by substituting for natural gas and propane for providing heat for residential and industrial applications. Hydrogen generated by water electrolysis using wind energy is currently being introduced into natural gas pipelines at concentrations up to 10% in parts of Europe, reducing the carbon intensity of the gas delivered for residential and industrial heating.[i] Future heating systems could use 100% hydrogen.

Green hydrogen can help reduce the carbon footprint of the industrial sector. One example is steel manufacturing, where some steel plants in Europe are using hydrogen to replace coke or natural gas for the reduction of iron.[ii] Using hydrogen in steel production can eliminate up to 1. 6 tons of CO_2 for every ton of steel produced. In the petroleum refining industry, green hydrogen is replacing hydrogen produced by steam-methane-reforming (SMR) at a petroleum refinery in Europe. Agriculture is another significant source of CO_2 emission, with a substantial portion of agricultural emissions resulting from the production of ammonia for fertilizer where three tons of CO_2 are

produced for every ton of ammonia produced. Green hydrogen can reduce CO_2 emissions associated with the use of SMR to produce the H_2 used in ammonia production and by replacing gasoline and diesel as a fuel for farming equipment.

Hydrogen and fuel cells offer tremendous economic potential for our region. A recent study estimates that between 700,000 to 1 million new hydrogen energy and fuel cell jobs will be created in the United States over the next decade.[iii] Another report suggests that approximately 260,000 jobs will be associated with manufacturing, distribution, and sales of fuel cell-powered vehicles by 2050.[iv] With the resources and capital available in the Midwest, we should be able to compete for and gain many of these jobs.

III. Impacts of Climate Change to Midwest

The Midwest is warming due to climate change and the rate of warming is accelerating.[v] The increasing intensity and frequency of heat waves, increasing humidity, and degrading air quality will increase public health risks. Higher temperatures during the growing season are expected to have a negative impact on crop yields. Changes in climate have led to more severe flooding across the Midwest. The Midwest has seen a doubling of the frequency of heavy rainfall events since 1900 including an increase in the number of individual and multi-day rainy days resulting in an increased risk of flooding in large areas of the Midwest.[vi, v] Heavy precipitation that leads to flooding can damage homes, farms, businesses, and public infrastructure, and disrupt economic activity. Flooding is the Midwest region's most widely destructive, regularly occurring natural disaster and the second most costly natural disaster across the United States. Models predict increased CO_2 levels will lead to an even higher frequency of extreme weather events including rainfalls in excess of 2 inches and days with temperature above100°F across the Midwest. Projected changes in precipitation coupled with rising temperatures are predicted to reduce Midwest agricultural productivity to levels of the 1980s without major technological advances by 2050. [vii]

IV. State and Local Government Actions

Illinois, Michigan, Wisconsin, and Minnesota are members of the Climate Alliance and have committed to implementing policies that advance the goals of the Paris Agreement to reduce GHG emissions by at least 26-28% below 2005 levels by 2025 and to accelerate new and existing policies to reduce carbon pollution by promoting clean energy deployment. In 2007, Minnesota passed legislation to reduce GHG emissions by 80% by 2050, with interim goals including 15% reduction by 2015 and 30% reduction by 2025.[viii] Wisconsin has set a goal for 100% renewable electricity use by 2050.[ix] Illinois[x] and Minnesota[xi] are considering legislation to adopt 100% renewable electricity use by 2050. Chicago city council passed a clean energy resolution that targets transitioning Chicago's buildings to 100% renewable power sources by 2035, and to electrify the city's bus fleet by 2040.[xii]

Meeting the Midwestern states' and the Climate Alliance's goals will require increased penetration of renewable energy while maintaining the Midwest's nuclear energy generating capacity. Energy storage will be needed to enable considerably higher renewable energy penetration than is currently deployed. Hydrogen offers an energy storage option that provides long-term storage as well as short-term storage to address seasonal variations in renewable energy production and mismatches between production and demand. Using nuclear-generated electricity to produce hydrogen can benefit the nuclear energy industry by providing a load when consumer demand is low instead of turning down power production as is currently done. The hydrogen can be used to fuel fuel cells to provide energy back to the grid later, used as a fuel for transportation and heating, or as a feedstock in the chemical, petroleum, and metals industries. This tremendous versatility of hydrogen shows its value in helping meet our climate goals.

V. Why a Midwest Hydrogen and Fuel Cell Partnership is Needed

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The Midwest is crucial to developing a hydrogen economy. Illinois is positioned at the heart of the U.S. interstate system with the third most extensive network of interstate highways. Chicago is a major transportation hub for both rail and aviation in the Midwest. Transitioning to hydrogen powered vehicles, trains, and planes and developing the infrastructure to support them can yield profound improvements in air quality and greenhouse gas reductions.

Midwestern states have established bold climate goals that will require massive deployment of renewable energy resources to meet the goals. The intermittency of wind and solar power generation will require considerable energy storage capacity to ensure grid stability. Hydrogen technology offers some of the most practical options for establishing the needed storage capacity.

So why the need for the Midwest Hydrogen and Fuel Cell Coalition?

1. There is a lack of knowledge and awareness of hydrogen and fuel cells, their benefits, safety, and hazards among the general public and many public officials and decision-makers in the Midwest. Unlike California, New York, Connecticut, Massachusetts and other states, most Midwest states lack a roadmap or plan for how to develop, integrate, and take advantage of the emerging hydrogen economy.

2. There is a lack of visibility of fuel cells and hydrogen technologies in the Midwest. There are no fuel cell cars on the roads, no hydrogen fueling stations, only a very low number of fuel cell buses operating and the lack of fuel cell companies. This provides little opportunity for the general public and government officials to see these technologies in action and learn of the economic and social benefits they can provide.

3. Organizations such as the Fuel Cells & Hydrogen Energy Association (FCHEA) are focused on developing the market for fuel cells and hydrogen in California due to its stricter environmental regulations and the Connecticut Hydrogen-Fuel Cell Coalition in Connecticut focused on driving economic development through fuel cell manufacturing. These organizations have shown little interest in the Midwest.

4. The midwestern states, collectively as a region, offer tremendous opportunities for synergies between energy and water resources, hydrogen producers and fuel cell manufacturers, and consumers of hydrogen and fuel cell technologies that individual states cannot provide.

VI. Opportunities for Hydrogen and Fuel Cells in the Midwest

1. The developing hydrogen economy and fuel cells present economic and employment opportunities for the Midwest.

    a. The Midwest is a major manufacturing center for cars and light-duty trucks with 75% of the cars and 60% of light-duty trucks currently assembled in the Midwest. As the transportation sector becomes increasingly more electrified, new opportunities will emerge for manufacturing fuel cells, electrolyzers to produce hydrogen, and other supporting technologies. The Midwest has the intellectual capital, manufacturing expertise, and capabilities to take advantage of this opportunity to compete for and win the jobs that will be created. Markets are beginning to develop in the U.S. on the West Coast and in the Northeast as well as overseas in Asia and Europe. The opportunity will be time sensitive as others move quickly to fill the emerging needs.

    b. There is the risk to the Midwest economy to not actively pursuing opportunities in hydrogen and other green transportation technologies. A 2018 report puts US heavy-duty diesel engine manufacturing at over one million engines annually providing more than one trillion dollars in US economic activity.[xiii] Over 40% of these engines are manufactured in the Midwest. As the number of bans on diesel engines increases globally, jobs associated with diesel manufacturing in the Midwest will be lost. Fuel cells and hydrogen offer a technology that can replace diesel engines in many applications and fuel cell manufacturing would dovetail with the vehicle manufacturing capabilities of the Midwest.

2. Hydrogen offers a pathway to more fully utilize the Midwest's abundant wind and solar resources and existing nuclear energy capacity to enable increased penetration of CO_2-free energy on the grid.

    a. The Midwest has some of the best wind resources in the Nation. Across the country the electrical energy production mix is undergoing a transition, converting from coal to natural gas and renewables. Midwestern states

are among the top wind producers, with Iowa, having more than 10,000 MW of installed capacity, ranking second amongst the 50 states. Iowa produced over 21 million MWhs of electric energy from wind power accounting for 41% of the state's electric power generated in 2019[xiv]. Illinois with more than 5600 MW and Minnesota with more than 3800 MW, ranked 6th and 7th, respectively in installed wind capacity.[xv] Hydrogen production by electrolysis could enable greater utilization of installed capacity and even greater penetration of new wind capacity. Fuel cells or turbines using hydrogen could serve as peaker plants to supply electricity back to the grid when wind is not available or it can be used to decarbonize other sectors of the economy, such as transportation or heating.

b. The Midwest has a large installed nuclear power base, employing approximately 15,000 people.[xvi] Illinois has more reactors than any state with 11 reactors located at 6 plants across the state employing nearly 5900 employees. In 2018, Illinois had the largest total nuclear net summer electricity generation capacity at about 11,580 megawatts.[xvii] Michigan is also a large producer of nuclear electricity. Cheap natural gas and renewable electricity have put economic pressures on many of the nuclear plants located in the region. Using nuclear power to produce hydrogen via electrolysis during off-peak hours could provide stable demand while still providing reliable CO_2-free base load power.

c. The Midwest offers a delivery and distribution network that spans all modes of transport offering a wide range of opportunities for demonstrating and deploying hydrogen and fuel cells. Chicago operates one of the greatest multimodal ports in North America with access to road, rail, lake, river, and air transportation. To illustrate, Anheuser-Busch plans to deploy a network of 28 hydrogen refueling stations across the Midwest including at least two in Illinois to support the 800 hydrogen powered semi-trucks that it is purchasing from Arizona-based fuel cell truck manufacturer, Nikola.[xviii]

3. The Midwest has the resources and infrastructure to take advantage of the opportunities presented by a hydrogen economy to provide new jobs.

a. The Midwest has the intellectual capital to develop the needed technology. It is home to some of the top public and private research universities in the world as well as three U.S. Department of Energy National Laboratories. In addition, the Midwest is the center of the U.S. automotive industry and home to other major companies in transportation, manufacturing, energy, chemicals, materials, and agriculture.

b. The Midwest is home to many highly skilled, but displaced, workers from the coal mining and coal-power generation sectors. Many of these workers would be excellent candidates for employment in the emerging hydrogen economy.

c. The Midwest region has excellent water resources available for producing hydrogen. It is home to the Great Lakes, the largest collection of fresh water in the world.

4. Hydrogen and fuel cells can help improve air quality and improve the health of our residents in the Midwest.

    a. More than 20 million people in the Midwest experience air quality that fails to meet national air quality standards with six Midwestern cities ranked among the 25 worst U.S. cities for air quality based on particulate emissions.[iii]

    b. Particulate matter from diesel emissions has been linked to respiratory and cardiovascular morbidities. A recent study found that PM2.5 emissions had increased by 5.5% from 2016 to 2018 after having declined by 24.2% from 2009 to 2016 in the Midwest and West.[xix] The study found that the increase in emissions was associated with 9,700 additional premature deaths, representing damages of $89 billion.

    c. Another study found there was significant geographic variation in the death related to PM2.5 exposure, with age-standardized death rates due to nonaccidental causes and noncommunicable diseases appearing to cluster in parts of the Midwest, Appalachia, and the South.[xx]

    d. Hydrogen and fuel cells can replace diesel engines in many applications, including heavy-, medium- and light-duty trucks, decreasing PM emissions and improving our air quality and health.

    e. Hydrogen and fuel cells offer a path to reduce emissions across all sectors of the economy and can play a large role in helping Midwestern states meet their emissions goals.

VII. Challenges and Barriers to Adoption of Hydrogen and Fuel Cells across the Midwest

1. Deployment of hydrogen and fuel cells is held back by the high initial costs.
    a. Fuel cells are expensive, primarily due to them being a nascent technology and not having achieved the benefits from economy-of-scale manufacturing, making them uneconomical for many applications today.

b. Hydrogen costs, especially green hydrogen, are high. Two factors, production and delivery costs, contribute to the high cost. Today, the cost of green hydrogen is considerably higher than the cost of hydrogen produced from low cost natural gas via SMR. The cost of producing green hydrogen is expected to drop as additional renewable energy generating capacity is brought on-line and the need for energy storage increases. Today, most of the hydrogen consumed in the U.S. is produced onsite where it is used in petroleum refining and ammonia production. Delivery costs will decrease as increasing demand will drive the need for hydrogen pipelines. A Hydrogen Council report found that a hydrogen supply and distribution system at scale will unlock hydrogen's competitiveness in many applications. Efforts will be directed at increasing the scale of hydrogen production and distribution.[xxi]

c. Lack of government support and equal incentives compared to other green technologies.

d. Costs of the incumbent technologies that use fossil fuels do not reflect the true societal/environmental costs. The cost of petroleum products such as gasoline and diesel, do not include the costs of subsidies provided to the oil and gas industry and the impact of CO_2 emissions on global warming. Some countries globally are considering implementing carbon taxes or credits to try to incorporate some of these costs.

e. Infrastructure costs, such as hydrogen refueling stations, for fuel cell-powered vehicles (FCV) are high. The infrastructure cost per vehicle is initially high but will decrease as market penetration of fuel cell-powered vehicles increases leading to higher utilization of refueling stations. In comparison, infrastructure costs for Battery Electric Vehicles (BEV) are low at low penetration but increase with increasing penetration as the demand outpaces current grid capacity and grid upgrades such as new substations are required. Two major advantages of FCVs over BEVs are their longer-range and faster refueling times which allows for long trips. However, this advantage will not be fully realizable until the hydrogen infrastructure is developed both regionally and nationally.

2. Lack of public knowledge and awareness of the environmental benefits and economic potential of hydrogen and fuel cells.

a. Many state and local funding agencies have little knowledge of hydrogen and fuel cell technologies.

b. Lack of general public awareness of hydrogen and fuel cell technologies leads to fears about new technologies including public perception of hydrogen safety issues, i.e. the "Not in My Backyard" (NIMBY) syndrome.

c. Previous attempts at launching a hydrogen economy have been unsuccessful as the technologies were in early stages of development and not ready for commercialization. The performance and durability of fuel cell and hydrogen technologies have vastly improved and are now competitive in a growing number of applications. Economy of scale manufacturing should reduce costs to make them competitive in an increasing number of new markets.

d. Most people do not recognize that FCVs, like BEVs, are electric vehicles.

e. Uncertain regulatory environment due to a lack of consistent rules, regulations, and standards for siting, building, and operating hydrogen refueling stations; installing hydrogen pipelines, etc.

3. Lack of regulatory drivers and incentives to reduce CO_2 emissions.

VIII. Partnership Goals

1. Develop a Midwest-specific regional plan to grow the hydrogen economy by leveraging the region's unique renewable resources; its intellectual talent; its major national role in manufacturing, agriculture, electrical power generation, and chemical production; and as a key hub in the national transportation and shipping networks.

2. Improve energy security and resiliency in the Midwest by leveraging the current infrastructure while increasing the deployment and utilization of clean energy sources using hydrogen as an energy carrier or energy storage medium and reliable fuel cell power generation.

3. Spur economic growth and job creation in the Midwest through increased deployment of fuel cells and hydrogen technologies that use regionally produced renewable and nuclear energy.

4. Retain high-paying jobs in the nuclear power industry by utilizing nuclear power for hydrogen production leading to a more consistent market for nuclear electricity that allows profitable operation of nuclear power plants.

5. Improve air quality in the Midwest by reducing CO_2 and other gas emissions from the transportation and power generating sectors that currently rely on fossil fuels by enabling a higher penetration of renewable energy while sustaining existing nuclear power generating capacity through the deployment of clean hydrogen and fuel cell technologies.

6. Raise public awareness of the benefits of hydrogen and fuel cells through education and outreach programs.

7. Facilitate communication and collaboration amongst the hydrogen and fuel cell community in the Midwest.

8. Facilitate development of policy rules, standards and goals for adoption of hydrogen and fuel cell technology.

9. Facilitate adoption of hydrogen and fuel cell technologies through demonstration projects in the Midwest.

10. Leverage the Midwest's investment capital and entrepreneur/incubator community to develop the hydrogen infrastructure, expand hydrogen and fuel cell manufacturing capabilities, and create a supply chain in the Midwest.

11. Assist states in achieving their clean energy and climate change mitigation goals.

12. Collaborate and coordinate with other regional hydrogen and fuel cell coalitions to promote hydrogen and fuel cell technologies across the U.S.

IX. Methods to Address Barriers and Achieve Goals

1. Market Development

    a. Work with stakeholders to develop new and expand existing markets for hydrogen in the transportation and industrial sectors to increase demand to reduce production and delivery costs of hydrogen.

    b. Advocate for investments for initial deployments and advance further development of hydrogen and fuel cell technologies. The Hydrogen Council has identified areas where investments are needed in green hydrogen production, carbon capture and sequestration, hydrogen refueling and distribution networks to accelerate adoption.

    c. Work with stakeholders to reduce capital investment costs by developing new or expanding existing markets to realize the benefits from economy of scale particularly during the early stages of deployment. As an example, the European Fuel Cell and Hydrogen Joint Undertaking (FCH-JU) coordinated the effort of numerous cities and countries to purchase many of the same model of fuel cell-powered buses to reduce cost. [xxii][NEW REFERENCE:]

    d. Develop interactions with wind, solar, and nuclear industry to maximize utilization of the Midwestern renewable and nuclear assets to deliver cheap electricity for hydrogen production.

2. Technology Development

a. Support regional research institutions to pursue both government and private sector funding to develop new or improve existing hydrogen and fuel cell technologies.

b. Work with entrepreneurs participating in incubator/innovator programs to help bring their technologies to market.

c. Facilitate communication of the needs of new and existing hydrogen and fuel cell technology stakeholders to researchers, technology developers, and technology providers.

3. Technology Deployment

a. Work with state and local governments, industry, and other stakeholders to develop a roadmap for accelerating the development of a hydrogen economy in the Midwest.

b. Advocate for deployment of hydrogen refueling infrastructure in the Midwest. Take advantage of the region's existing transportation hubs to become hubs for hydrogen and fuel cell vehicles.

c. Promote networking between existing stakeholders of hydrogen and fuel cell technologies with potential new stakeholders or other interested groups. Leveraging the expertise, capabilities, and products of existing stakeholders can lead to more rapid adoption by new stakeholders.

d. Advocate for hydrogen and fuel cell demonstration projects to enable existing stakeholders to explore new opportunities and new stakeholders to evaluate hydrogen and fuel cell technologies.

4. Increase Public Awareness

a. Organize regional workshops and events to inform regional decision and policy makers and potential stakeholders about the benefits of hydrogen and fuel cells

b. Develop and disseminate educational and informational materials for the general public describing the benefits of hydrogen and fuel cell technologies.

c. Participate in regional clean-energy events to inform attendees and early-adopters about the benefits of hydrogen and fuel cell technologies.

5. Regulatory Environment

a. Advocate for government incentives and regulations to accelerate the deployment of hydrogen and fuel cell technologies.

References

[i] C. Wulf, J. Linssen, P. Zapp, Energy Procedia, 155, 367-378, 2018 https://reader.elsevier.com/reader/sd/pii/S1876610218309883?token=EDAFFD8B14F5A1E9D8C2A0C0BE95F3ABCA42CCEBD84244FE25FA0570EE600D7F56491C50C416FD54CE98B1374B104D74

[ii] https://www.cleanenergywire.org/news/thyssenkrupp-tests-use-hydrogen-steel-production-bring-down-emissions, https://fuelcellsworks.com/news/arcelormittal-commissions-midrex-to-design-demonstration-plant-for-hydrogen-steel-production-in-hamburg/

[iii] R. Bezdek, Renewable Energy, Renew. Energy Environ. Sustain. 4, 1 (2019); http://www.stateoftheair.org/city-rankings/most-polluted-cities.html

[iv] M. Mintz, Employment Impacts of Hydrogen and Fuel Cell Technologies, DOE Fuel Cell Technologies Office, 2017 Annual Merit Review, https://www.hydrogen.energy.gov/pdfs/review17/sa035_mintz_2017_o.pdf

[v] The average Midwest air temperature increased by more than 1.5°F from 1900 to 2010, and the rate of this warming from 1980 to 2010 was three times as high as the average warming from 1900 to 2010.v Projections for regionally averaged temperature increases by the middle of the century (2046-2065) relative to 1979-2000 are 3.8°F-4.9 F, and projections for the end of the century (2081-2100) are 5.6°F to 8.5°F hotter than 1979-2000. 2014 National Climate Assessment. U.S. Global Change Research Program. 1800 G Street, NW, Suite 9100, Washington, D.C. 20006, USA National Academy of Science Advisory, The National Climate Assessment, https://nca2014.globalchange.gov/highlights/regions/midwest

[vi] Kunkel, K. E., L. E. Stevens, S. E. Stevens, L. Sun, E. Janssen, D. Wuebbles, S. D. Hilberg, M. S. Timlin, L. Stoecker, N. E. Westcott, and J. G. Dobson, 2013: Regional Climate Trends and Scenarios for the U.S. National Climate Assessment: Part 3. Climate of the Midwest U.S. NOAA Technical Report NESDIS 142-3. 103 pp., National Oceanic and Atmospheric Administration, National Environmental Satellite, Data, and Information Service, Washington, D.C. [Available online at http://www.nesdis.noaa. gov/technical_reports/NOAA_NESDIS_Tech_Report_142-3- Climate_of_the_Midwest_U.S.pdf]

[vii] Angel, J., C. Swanston, B.M. Boustead, K.C. Conlon, K.R. Hall, J.L. Jorns, K.E. Kunkel, M.C. Lemos, B. Lofgren, T.A. Ontl, J. Posey, K. Stone, G. Takle, and D. Todey, 2018: Midwest. In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II* [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 872–940. doi: 10.7930/NCA4. 2018.CH21

[viii] https://www.pca.state.mn.us/air/state-and-regional-initiatives

[ix] (https://climate-xchange.org/2019/08/27/wisconsin-becomes-first-midwest-state-to-go-carbon-free-by-2050/, and https://www.renewwisconsin.org/governor-evers-announces-goal-of-100-clean-energy-by-2050/

[x] http://blogs.edf.org/energyexchange/2019/11/26/illinois-clean-energy-jobs-act-will-improve-the-states-economic-climate/, and https://news.wttw.com/2020/02/04/could-springfield-pass-clean-energy-jobs-act-session

[xi] https://e360.yale.edu/digest/minnesota-governor-announces-goal-for-100-percent-clean-energy-by-2050, and https://mn.gov/commerce/media/news/?id=17-374074

[xii] https://www.smartcitiesdive.com/news/chicago-clean-energy-commitment/552622/ and https://www.sierraclub.org/sierra/chicago-commits-100-renewable-clean-energy

[xiii] https://www.dieselforum.org/news/diesel-engine-manufacturing-powers-state-economies-and-american-jobs (retrieved Feb 26, 2020)

[xiv] AWEA 3rd quarter 2019 Public Market Report" (PDF). American Wind Energy Association (AWEA). January 2020. Retrieved February 20, 2020.

[xv] AWEA 3rd quarter 2019 Public Market Report" (PDF). American Wind Energy Association (AWEA). January 2020. Retrieved February 20, 2020.

[xvi] NEI.org state fact sheets, for IL, MI, MN, OH, WI, IN https://www.nei.org/resources/fact-sheets

[xvii] https://www.eia.gov/energyexplained/nuclear/us-nuclear-industry.php

[xviii] https://www.cnet.com/roadshow/news/budweiser-beer-nikola-hydrogen-electric-semi-truck/]

[xix] Karen Clay, Nicholas Z. Muller, Recent Increases in Air Pollution: Evidence and Implications for Mortality, NBER Working Paper No. 26381, Issued in October 2019, https://www.nber.org/papers/w26381.pdf

[xx] Bowe B, et al. JAMA Netw Open. 2019; doi:10.1001/jamanetworkopen.2019.15834.

[xxi] https://hydrogencouncil.com/wp-content/uploads/2020/01/Path-to-Hydrogen-Competitiveness_Full-Study-1.pdf

[xxii] https://www.fch.europa.eu/news/new-fch-ju-study-joint-procurement-fuel-cell-buses