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Wind Power: An opportunity for Illinois

By Don Fullerton and Maarten Vrouenraets

The scientific consensus on climate change strongly concludes that human activities causing greenhouse gas emissions are the most significant driver of observed climate change.[1] The primary greenhouse gas emitted through human activities is carbon dioxide (CO_2) from burning fossil fuels.[2] Within the United States, the largest source of this carbon pollution is power plants, which account for roughly one-third of all domestic emissions.[3]

This major influence on climate change prompted the U.S. Environmental Protection Agency (EPA) in August 2015 to issue the 'Clean Power Plan'. This rule will require 32 percent cuts in carbon pollution from the power sector below 2005 levels by 2030. The EPA intends to keep energy affordable and reliable, while cutting pollution and protecting the health and environment of American citizens.[4]

The Clean Power Plan requires each state to submit a plan to the EPA that shows how the state will reach its target. The state of Illinois faces a 31 percent reduction in CO_2 emissions by 2030 from its 2012 levels.[5] Policymakers in Illinois are required to make a plan to reduce emission rates. The proposed federal mandate suggests three building blocks for state plans[6]:

1. Make coal-fired power plants more efficient
2. Switch from coal to natural gas generation with lower CO_2 emissions
3. Expand renewable generating capacity

In this paper, we focus on building blocks (2) and (3) and what they mean for the ways Illinois can adjust its sources of energy. For background, we show historical trends for different energy sources and energy capacity globally, within the U.S., and within Illinois. Then we provide information about the cost of production for each source, since these costs are key to many decisions about energy resources. We also discuss predictions for these future costs within the U.S. And finally, we discuss what this all means for Illinois. In this way, we aim to inform policymakers about what energy sources represent the best opportunities for Illinois to realize the targets imposed by the U.S. Clean Power

[1] Intergovernmental Panel on Climate Change. (2014). Climate change 2014: Mitigation of climate change. Working Group III contribution to the IPCC Fifth Assessment Report. Cambridge, United Kingdom: Cambridge University Press. www.ipcc.ch/report/ar5/wg3.

[2] National Research Council. (2010). Advancing the science of climate change. The National Academies Press, Washington, DC, USA.

[3] Environmental Protection Agency. (2015). Carbon pollution standards. http://www2.epa.gov/carbon-pollution-standards.

[4] Environmental Protection Agency. (2015). Carbon pollution standards. http://www2.epa.gov/carbon-pollution-standards.

[5] Sierra Club. (2014). Developing a clean power plan for Illinois. http://content.sierraclub.org/creative-archive/sites/content.sierraclub.org.creative-archive/files/pdfs/0796%20Illinois%20CPP%20Fact%20Sheet_01_web_2.pdf.

[6] The same building blocks apply consistently across states, but each state's unique mix of energy sources leads to a unique goal for emission reduction. See Don Fullerton and D.H. Karney. (2014). U.S. Clean Power Plan provides opportunity for significant cuts in state budget deficits. Institute of Government & Public Affairs. Climate Change Policy Initiative. http://igpa.uillinois.edu/system/files/Clean-Power-Plan-Can-Reduce-Deficit.pdf

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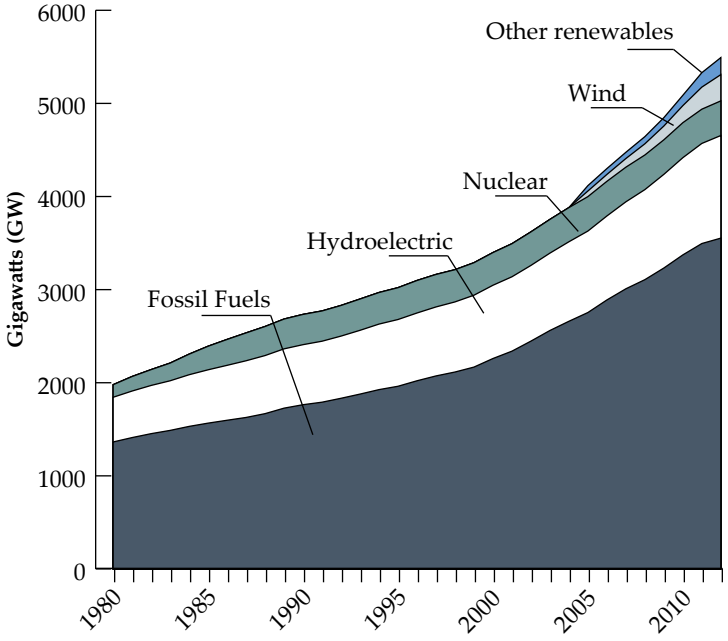
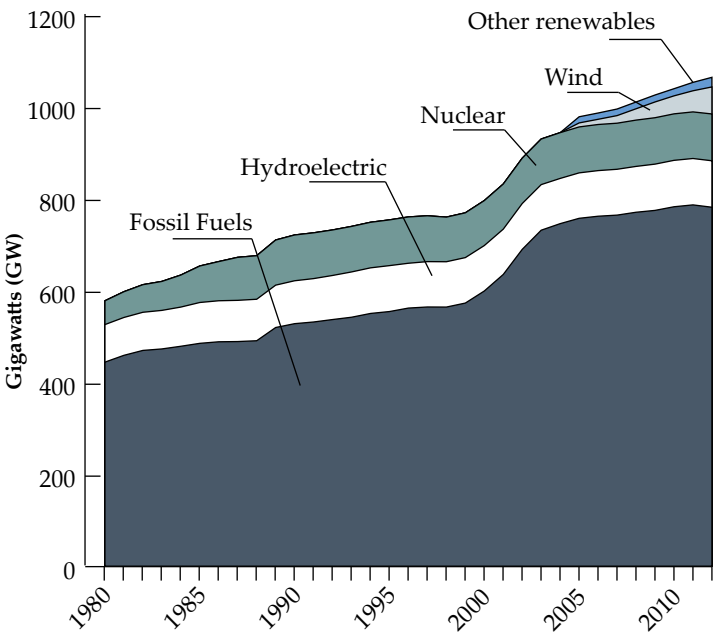
Figure 1: Worldwide electric power generation capacities by source, 1980-2012



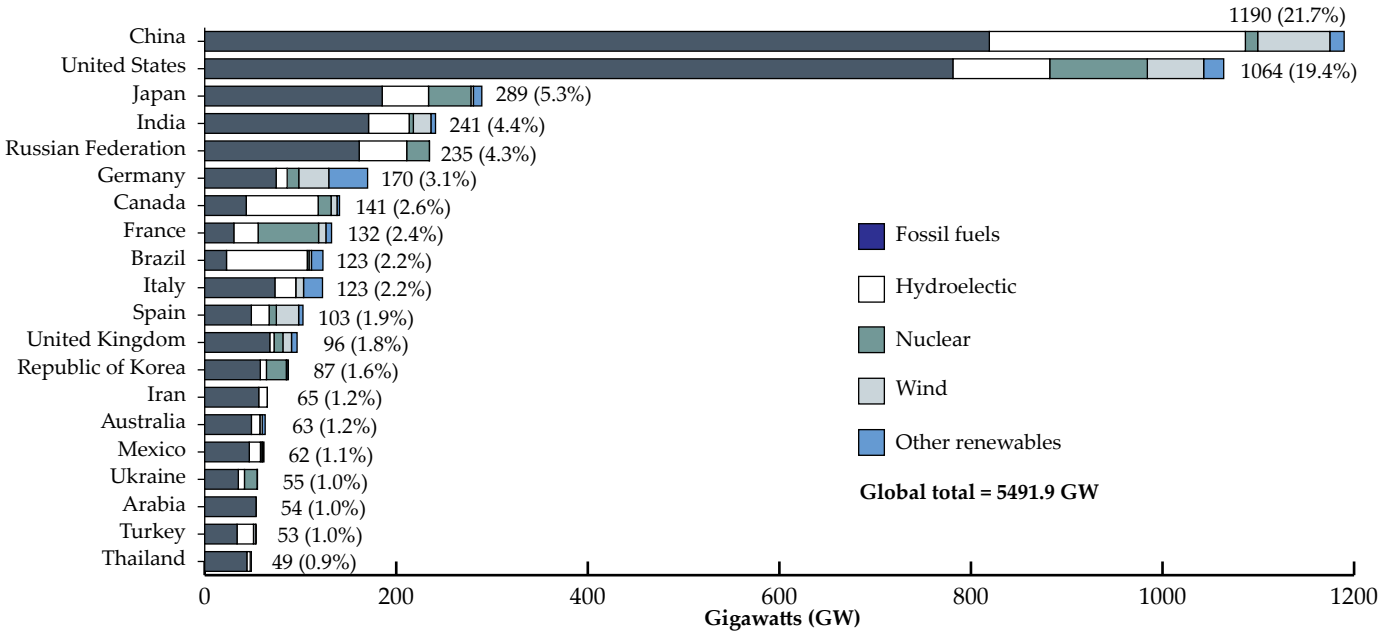
Source: The Shift Project Data Portal. (2012). World power generation capacities. http://www.tsp-data-portal.org/Historical-Electricity-Capacity-Statistics#tspQvChart.

Figure 3: U.S. electric power generation capacities by source, 1980-2012



Source: The Shift Project Data Portal. (2012). World power generation capacities. http://www.tsp-data-portal.org/Historical-Electricity-Capacity-Statistics#tspQvChart.

Figure 2: Countries with the highest power generation capacity in 2012



Source: The Shift Project Data Portal. (2012). Countries with highest installed power capacity. http://www.tsp-data-portal.org/TOP-20-Capacity#tspQvAbout

Plan. As we discuss, Illinois happens to be particularly well suited to the use of wind power.

Global electricity generating capacity

Figure 1 shows trends in capacity for the main energy sources on a global scale.[7] Generation capacity in this context is the maximum electric output that can be produced by all installed generators.[8] As can be seen, the installed fossil fuels capacity has been steadily growing globally since 1980. The three major forms of fossil fuels are coal, oil and natural gas. Other important energy sources are hydroelectric and nuclear power. The category "Other Renewables" includes biomass and waste, geothermal, solar, tidal action and wave action.[9] Finally, the amount of wind energy capacity, although still small, has been increasing rapidly over the past eight years, with average annual growth of 46.3 percent.

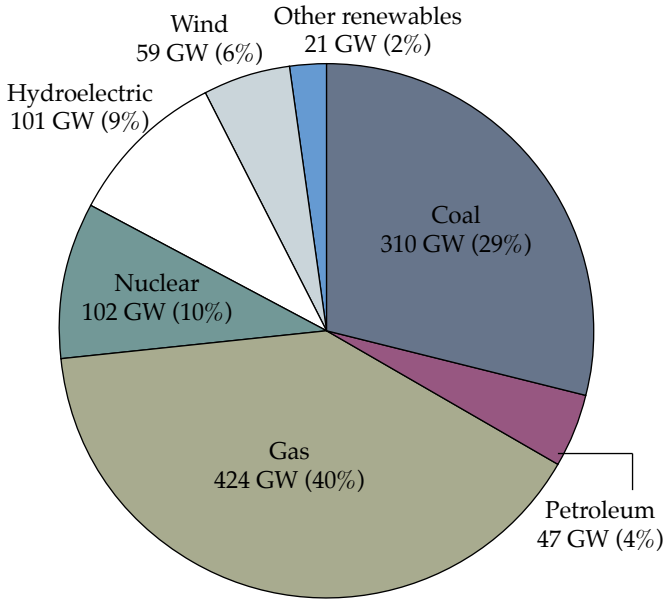
Most countries rely on fossil fuels as their principle source of energy for electricity generation. Among alternative sources, the largest now are hydroelectric, nuclear, and wind. Figure 2 shows a breakdown of installed capacity by source for the twenty countries with the highest installed capacity.[10] As can be seen, the U.S. is responsible for 1064 gigawatts (GW), or 19.4 percent of the total global installed capacity.

U.S. electricity generating capacity

The energy sources making up the installed capacity in the U.S. have changed over the last few decades, and Figure 3 shows these trends.[11] Some of these trends are similar to the development of capacity on a global scale, as several renewable sources emerged in the last decade since 2005. The installed capacities of nuclear and hydroelectric energy in the U.S. have remained constant. Although the worldwide installed capacity of fossil-fuel-based power systems grew substantially in the last decade, recent growth in the U.S. has been flat.

The total installed capacity within the U.S. was 1064 GW, as of 2012, and Figure 4 shows the breakdown among the main energy sources.[12] As in many other countries, fossil fuels constitute the largest share of U.S. electricity capacity. The largest alternative energy sources are hydroelectric, nuclear, and wind.

Figure 4: U.S. power generation capacities from all energy sources in 2012 (Total = 1064 GW)



Sources: The Shift Project Data Portal. (2012). Breakdown of electricity capacity by energy source. http://www.tsp-data-portal.org/Breakdown-of-Electricity-Capacity-by-Energy-Source#tspQvChart. And, U.S. Energy Information Administration. (2013). Annual electric generator report, Form EIA-860. http://www.eia.gov/electricity/annual/html/epa_04_02_a.html.

The importance of electricity production cost

Electricity production costs play an important role when deciding what energy sources to expand. For the four main energy sources in the U.S., Figure 5 shows historical trends for electricity production costs that include fuel and labor costs (but excludes indirect costs and capital costs).

Oil prices have fallen in recent years but generally have risen over the long run. Figure 5 shows an increasing cost of oil-based generation starting in 2004, but it shows falling costs for gas-powered electric generators. Since 2004, the production costs of coal power have increased slightly, while those of nuclear energy have remained about constant.[13]

These electricity production costs play a crucial role in determining the economic viability of each energy source. Electricity generating firms cannot quickly react to changes in production costs by building new plants. Instead, in the short run, they change the utilization of existing plants (which are usually not all running at 100 percent capacity).

[7]The Shift Project Data Portal. (2012). World power generation capacities. http://www.tsp-data-portal.org/Historical-Electricity-Capacity-Statistics#tspQvChart.

[8]U.S. Energy Information Administration. (2015). What is the difference between electricity generation capacity and electricity generation? http://www.eia.gov/tools/faqs/faq.cfm?id=101&t=3.

[9]We cannot separately identify the amount of solar power, because the Shift Data Portal's "Solar Tide Wave" category aggregates solar power, tidal action, and wave action.

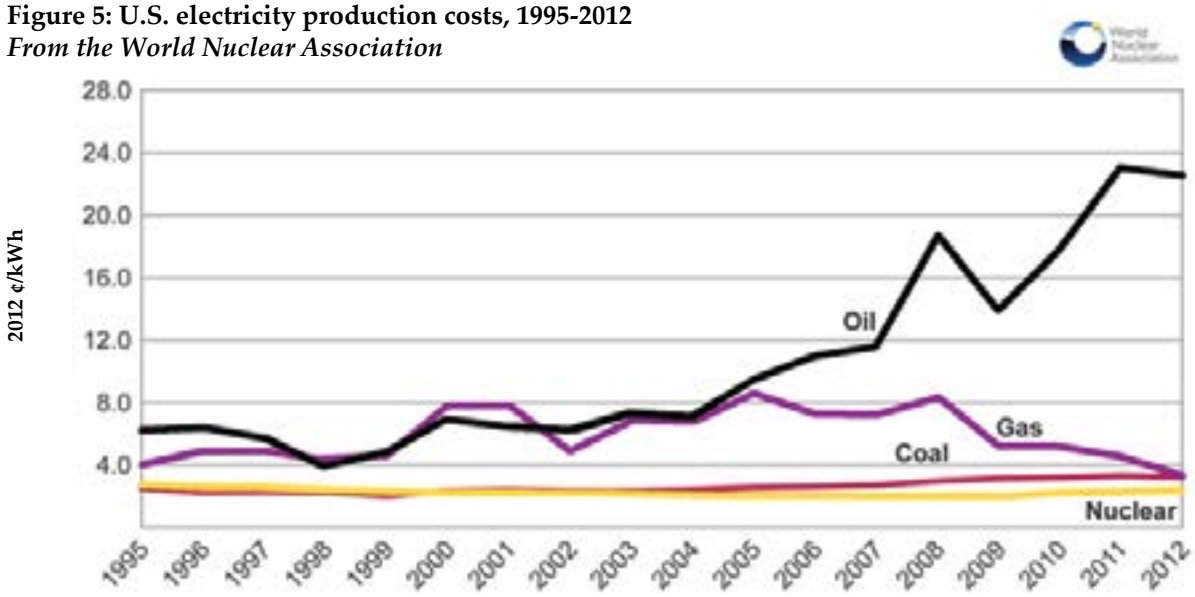
[10]The Shift Project Data Portal. (2012). Countries with highest installed power capacity. http://www.tsp-data-portal.org/TOP-20-Capacity#tspQvAbout.

[11]The Shift Project Data Portal. (2012). Historical electricity installed capacity statistics. http://www.tsp-data-portal.org/Historical-Electricity-Capacity-Statistics#tspQvChart.

[12]Two sources include: The Shift Project Data Portal. (2012). Breakdown of electricity capacity by energy source. http://www.tsp-data-portal.org/Breakdown-of-Electricity-Capacity-by-Energy-Source#tspQvChart; and, U.S. Energy Information Administration. (2013). Annual Electric Generator Report, Form EIA-860. http://www.eia.gov/electricity/annual/html/epa_04_02_a.html.

[13]World Nuclear Association. (2013). U.S. electricity production costs 1995 -2012. http://world-nuclear.org/Gallery/?galleryId=4455%20&ImageId=36370.

Figure 5: U.S. electricity production costs, 1995-2012
From the World Nuclear Association



Note from the World Nuclear Association: Production costs = operation & maintenance + fuel. (excludes indirect costs and capital). Source: Ventyx Velocity Suite/NEI, May 2013. Borrowed from World Nuclear Association. (2013). US Electricity Production Costs 1995 -2012. http://world-nuclear.org/Gallery/?galleryId=4455%20&ImageId=36370. http://www.tsp-data-portal.org/TOP-20-Capacity#tspQvAbout

Therefore we look next at changes in actual electricity generation.[14]

For the U.S., Figure 6 shows that these trends exactly mirror cost trends: falling oil-based electricity generation since 2004, growing natural gas generation, falling coal-based generation, and constant nuclear generation.[15]

These trends might be explained not just by economics but also by public policy. For example, subsidies and other incentives are used by many states to offset relatively high production costs of renewable energy compared to conventional sources.[16] Economic viability still impacts net renewable generation, however, as state budgets are limited. Indeed, economic competitiveness among renewables often determines what energy sources are subsidized.

Levelized cost of electricity (LCOE)

Another important measure of cost is designed to include not just current fuel and labor costs but also capital costs over the life of each generating plant. The 'Levelized Cost of Electricity' (LCOE) represents the cost per kilowatt-hour of building *and* operating a generating plant over an assumed financial life and duty cycle. Key inputs to calculating LCOE are capital costs, fuel costs, fixed and variable operations and maintenance costs, financing costs, and an assumed utilization rate for each plant type.[17]

In addition to reporting power generation capacities for all energy sources in past years, the U.S. Energy Information Administration (EIA) predicts future LCOE for the main energy sources in coming decades. Their predictions are subject to considerable uncertainty, and they represent national averages. The LCOE can vary significantly on a regional basis because of variations in local labor costs and availability of fuel or "other energy resources."[18] For example, some states have more wind than others.

EIA expects that the renewable energy sources with the lowest LCOE by 2019 will be geothermal (47.9 $/MWh), wind (80.3 $/MWh), and hydropower (84.5 $/MWh). These expected costs are unsubsidized costs. The only sources expected to have lower unsubsidized LCOE than wind and hydro energy are natural gas sources: the Conventional Combined Gas Cycle (66.3 $/MWh) and the Advanced Combined Gas Cycle (64.4 $/MWh).[19]

The EIA expects this cost advantage for the Combined Gas Cycle to disappear by 2040. In that year, the renewable energy sources with the lowest expected LCOE are geothermal (67.8 $/MWh), wind (73.1 $/MWh) and advanced nuclear (83 $/MWh). In other words, by 2040, both geothermal and wind power are expected to outperform both the Conventional Combined Gas Cycle (81.2 $/MWh) and the Advanced Combined Gas Cycle (77.8 $/MWh).[20]

[14]U.S. Energy Information Administration. (2014). Annual energy outlook 2014. http://www.eia.gov/forecasts/aeo/electricity_generation.cfm.

[15]U.S. Energy Information Administration. (2015). Net generation by state by type of producer by energy source. EIA-906, EIA-920, and EIA-923. http://www.eia.gov/electricity/data/state.

[16]Illinois Department of Commerce and Economic Opportunity. (2015). Renewable Energy. https://www.illinois.gov/dceo/whyillinois/KeyIndustries/Energy/Pages/RenewableEnergy.aspx.

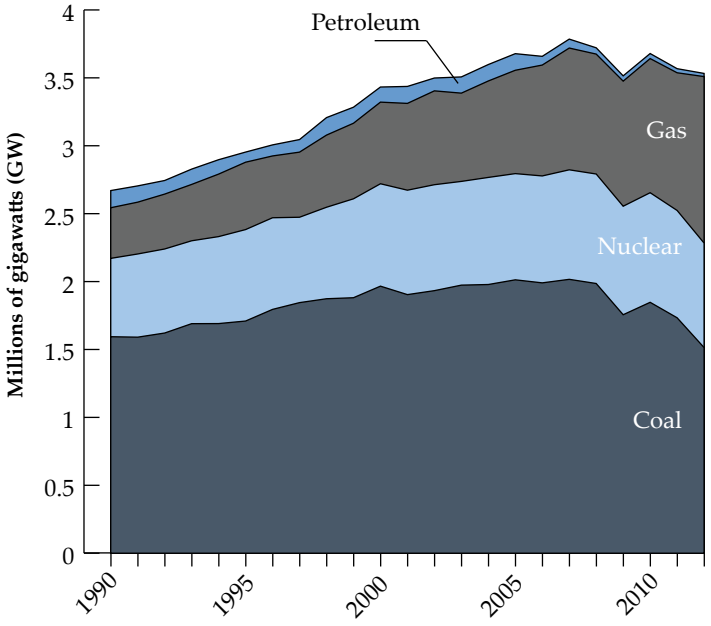
[17]U.S. Energy Information Administration. (2014). Annual energy outlook 2014. http://www.eia.gov/forecasts/aeo/electricity_generation.cfm.

[18]U.S. Energy Information Administration. (2014). Annual energy outlook 2014. http://www.eia.gov/forecasts/aeo/electricity_generation.cfm.

[19]U.S. Energy Information Administration. (2014). Annual energy outlook 2014, April 30, 2014. DOE/EIA-0383. Table 1. Estimated levelized cost of electricity (LCOE) for new generation resources, 2019.

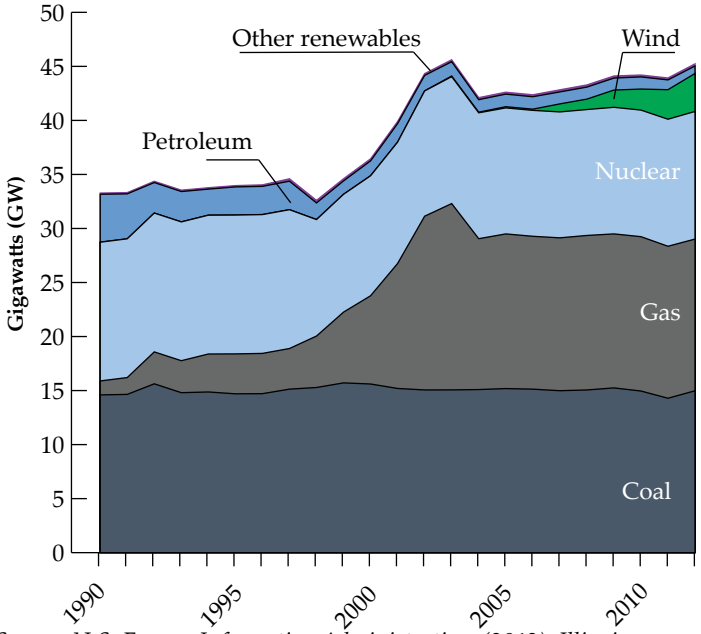
[20]U.S. Energy Information Administration. (2014). Annual energy outlook 2014. Early Release, December 2013. DOE/EIA-0383ER. Table A5. Estimated levelized cost of electricity (LCOE) for new generation resources, 2040.

Figure 6: U.S. net electricity generation by energy source, 1990-2012



Source: U.S. Energy Information Administration. (2015). Net generation by state by type of producer by energy source. EIA-906, EIA-920, and EIA-923. http://www.eia.gov/electricity/data/state/.

Figure 7: Illinois power generation capacities, 1990-2012



Source: U.S. Energy Information Administration. (2012). Illinois electricity profile 2012. Table 4. electric power industry capability by primary energy source, 1990-2012. http://www.eia.gov/electricity/state/illinois/.

Because of technological innovation and learning over time, all technologies are expected to experience reductions in capital cost. Thus, the LCOE of most energy sources will fall over time. The capital costs of newer, advanced technologies are expected to fall faster than those of conventional technologies. The LCOE for natural gas-fired power plants is expected to rise over time, because rising fuel costs offset any decline in capital costs.[21]

Total capacity in Illinois

For the main energy sources within Illinois, Figure 7 shows trends in electricity installed capacity.[22] It shows that nuclear energy has been a stable renewable source, and it shows a decline in the use of oil. Just within the last decade, Illinois has adopted wind as a major renewable energy source.

Total capacity in Illinois is 45.14 GW, as of 2012, and Figure 8 shows how that capacity is distributed over the main energy sources.[23] Hydroelectric power is a very small energy source within Illinois, but the figure shows that wind power has joined nuclear power as a second significant source of renewable energy.

The state of Illinois can meet its target requirement of the Clean Power Plan by using all of the three building blocks described above, but this paper is not about making coal-fired power plants more efficient, nor about reducing electricity demand altogether. Instead, we focus on switching from coal to natural gas, and expanding renewable generating capacity.

Natural gas

Compared to coal-fired electricity generation, natural gas generation has lower CO_2 emissions per kilowatt hour. The research from EIA shows that Conventional Combined Gas Cycle and Advanced Combined Gas Cycle are the gas-fired power plants with the lowest LCOE. Thus, these Combined Gas Cycle systems seem to provide Illinois with the best opportunities to switch to natural gas generation in a cost effective way. In fact, these Combined Gas Cycle systems have the lowest costs of all non-renewable sources of energy.

Renewable energy

By 2040, on a national level, the EIA expects geothermal and wind to develop into the only renewable sources with lower LCOE than Combined Gas Cycle. However, the choice among renewable sources also must depend on region-specific resources. While the national average cost of geothermal is low, the EIA notes that this source has limited availability at that cost.[24] And these limitations in Illinois probably explain our negligible geothermal generation. While other states in the U.S. are endowed with natural advantages of solar and geothermal power potential, Illinois

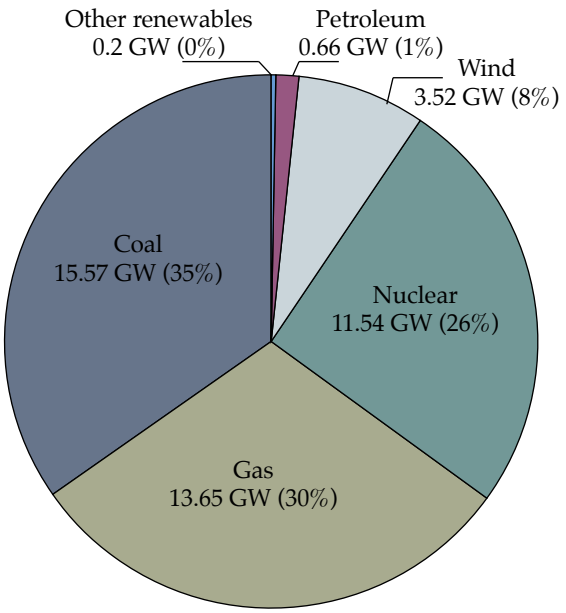
[21]U.S. Energy Information Administration. (2014). Annual energy outlook 2014. http://www.eia.gov/forecasts/aeo/electricity_generation.cfm.

[22]U.S. Energy Information Administration. (2012). Illinois electricity profile 2012. Table 4. Electric power industry capability by primary energy source, 1990-2012. http://www.eia.gov/electricity/state/illinois/.

[23]U.S. Energy Information Administration. (2012). Illinois electricity profile 2012. Table 4. Electric power industry capability by primary energy source, 1990-2012. http://www.eia.gov/electricity/state/illinois/.

[24]U.S. Energy Information Administration. (2014). Annual energy outlook 2014. http://www.eia.gov/forecasts/aeo/electricity_generation.cfm.

Figure 8: Illinois power generation capacities in 2012 (Total = 45.14 GW)



Source: U.S. Energy Information Administration. (2012). Illinois electricity profile 2012. Table 4. Electric power industry capability by primary energy source, 1990-2012. http://www.eia.gov/electricity/state/illinois/.

has wind as its comparative natural advantage.

A recent study conducted by Lazard shows that the LCOE for wind energy is the lowest in the Midwest, as compared to other U.S. regions.[25] And these low costs are probably why Illinois has already emerged as an energy leader in wind power.[26] Moreover, Illinois has strong winds near demand centers like Chicago, and it has the necessary electrical infrastructure needed to move the power.[27] These considerations might grant a window of opportunity for Illinois to expand further its renewable generating capacity in a cost effective way.

Wind Energy within the state of Illinois

In further developing wind power potential for Illinois, policymakers will need to consider the pros and cons of three types of windmill locations.

A. Onshore

So far, in Illinois, the current wind energy capacity of 3.52 GW has been built using onshore windparks.[28] Each windpark is formed by constructing several or many wind turbines near each other, and many of these windparks are located in rural areas with land rented from farm owners.[29] The state of Illinois can further exploit the value of its extensive agricultural land by expanding these windfarms in collaboration with local farmers.

B. Offshore Lake Michigan

Besides expanding wind capacity onshore, Illinois can make use of Lake Michigan to build offshore wind capacity. We later distinguish between "nearshore" and "further offshore," as discussed below. These offshore windparks offer several advantages,[30] including:

1. Offshore windparks can be located close to populated coastal regions where space onshore is not available, energy demand is high, and new transmission needs are low.

2. Offshore wind speeds generally are higher and steadier and can be exploited by larger turbines.

3. These larger wind turbines can be transported more easily over water than over land.

4. Offshore windparks have minimal visual impact when located more than six or eight nautical miles from the coast.

On the other hand, the biggest disadvantage of an offshore windpark project is the high levelized cost of electricity. The EIA expects that the LCOE of offshore wind energy will be 204.1 $/MWh for 2019, and 170.3 $/MWh for 2040.[31] These costs are more than twice as high as those expected for onshore windparks.

By choosing offshore wind energy, however, Illinois could exploit the benefits listed above and further expand its role as a wind energy leader. To date, no offshore wind projects have been built in the U.S.[32] By establishing the Lake Michigan Offshore Wind Energy Advisory Council, however, our state has already expressed interest in the possibility of offshore windparks. In its 2012 report, this council did not specify a minimum distance from shore for offshore windparks.[33]

[25]Lazard. (2014). Lazard's levelized cost of energy analysis. Version 8.0, page 8. http://www.lazard.com/PDF/Levelized%20Cost%20of%20Energy%20-%20Version%208.0.pdf.

[26]Progress Illinois. (2013). IL advances offshore wind energy research, but lake turbines still 'light-years' away, experts say. http://progressillinois.com/quick-hits/content/2013/08/23/il-advances-offshore-wind-energy-research-lake-turbines-still-light-ye.

[27]Progress Illinois. (2013). Report: Illinois ranks No.5 for reducing pollution, saving water from wind power. http://www.progressillinois.com/quick-hits/content/2013/11/21/report-illinois-ranks-no-5-reducing-pollution-saving-water-wind-power.

[28]U.S. Department of Energy. (2014). Installed wind energy capacity. http://apps2.eere.energy.gov/wind/windexchange/wind_installed_capacity.asp.

[29]Illinois Windmills. (2015). Wind farms. http://www.illinoiswindmills.org/index_files/windfarms2.

[30]Bureau of Ocean Energy Managment. (2015). Offshore wind energy. http://www.boem.gov/Renewable-Energy-Program/Renewable-Energy-Guide/Offshore-Wind-Energy.aspx.

[31]U.S. Energy Information Administration. (2014). Annual energy outlook 2014. http://www.eia.gov/forecasts/aeo/electricity_generation.cfm.

[32]Cape Wind. (2015). Cape wind project overview and benefits. http://www.capewind.org/what.

[33]Illinois Department of Natural Resources. (2012). Lake Michigan Offshore Wind Energy Advisory Report.

The Danish Energy Agency defines a "nearshore" wind park as one that is approximately one to eight nautical miles from shore (with a minimum distance of two nautical miles in areas featuring a fragile natural environment).[34] Building upon Denmark's experience as the leading offshore wind power generator, Illinois could similarly use eight nautical miles to distinguish between windparks that are "nearshore" as opposed to "further offshore."

C. Nearshore Lake Michigan

Two of the most important factors in the costs of offshore windparks are distance to the shore and water depth.[35] In general, the higher LCOE of distant offshore windparks make them financially unattractive.[36] Therefore, as a distinct alternative, Illinois can consider nearshore windparks that are one to eight nautical miles from the shoreline. Research on the costs of different windpark locations in the Dutch part of the North Sea shows that nearshore locations can result in LCOE up to 40 percent lower than those of further offshore locations that were considered potential construction sites.[37] However, cost differences on Lake Michigan between nearshore and further offshore are yet to be determined.

A disadvantage of nearshore windparks is the visual impact from the shoreline. This social cost can be ameliorated, however, as shown by creative Danish governance. Hans Christian Soerensen, board member of the Middelgrunden Wind Turbine Cooperative, explained how the Danish cooperative model involves private individuals in the ownership of wind turbines in order for the project to be accepted and to avoid "not in my back yard" objections.[38] Furthermore, private-public partnerships are frequently used to finance windparks.[39] Thus, although the largest wind energy capacity within Denmark has been realized with the use of onshore and nearshore windparks, recent surveys show that most of the Danish population would welcome more wind energy in the electricity system.[40]

Wind energy is an opportunity

The U.S. Clean Power Plan will require Illinois to reduce CO_2 emissions significantly before 2030. To comply with this federal mandate, Illinois has an opportunity to choose from among various energy sources for future expansions. Instead of future coal-fired power plants, Illinois can build natural gas plants with less CO_2 per unit of electricity, or it can invest in renewable technology like solar, geothermal or wind. The geography and climate of Illinois give it a special advantage in the use of wind power.

To determine the costs and benefits of each option, the state could begin to look for suitable agricultural locations for onshore windparks, and also to map lakebed geographical settings and possible park locations both nearshore and further offshore. Lake Michigan has appropriate locations that are not too deep and not too far from big demand centers like Chicago. The state also could conduct surveys of residents to determine the aesthetic costs of windparks nearshore. Research on the North Sea shows promising results, however, and an increasing number of European countries select their nearshore coastal zone to build windparks. •

[34]Erin Gill. (2012). Danish offshore strategy moves closer to shore. Wind Power Monthly. http://www.windpowermonthly.com/article/1161698/danish-offshore-strategy-moves-closer-shore.

[35]T. Prässler and J. Schaechtele. (2012). Comparison of the financial attractiveness among prospective offshore windparks in selected European Countries. Elsevier , 86-101.

[36]Progress Illinois. (2013). IL advances offshore wind energy research, but lake turbines still 'light-years' away, experts say. http://progressillinois.com/quick-hits/content/2013/08/23/il-advances-offshore-wind-energy-research-lake-turbines-still-light-ye.

[37]Herman and Pierik. (2003). Locaties en opwekkosten 6000 MW offshore windenergie. ECN. Page 16.

[38]CleanTechnica. (2011). Cooperative wind farm ownership beats NIMBYism. http://cleantechnica.com/2011/11/09/cooperative-wind-farm-ownership-beats-nimbyism/.

[39]DAC and Cities. (2015). Copenhagen: Cities can run on wind energy. http://www.dac.dk/en/dac-cities/sustainable-cities/all-cases/energy/copenhagen-cities-can-run-on-wind-energy/.

[40]Denmark. (2015). Wind energy. http://denmark.dk/en/green-living/wind-energy/.