New studies cause confusion about benefits of renewable energy

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A recent study caused widespread confusion about the climate change benefits of renewable energy by presenting its results in a misleading way. The reality is that transitioning to renewable energy and other non-emitting energy sources is the only way to effectively address climate change, as the authors of the study acknowledge.

Another study caused similar confusion a few years ago, leading some media outlets to incorrectly claim that "wind farms cause global warming." After that confusion, the author of that study responded to the "misleading" press articles and made clear that "the warming effect reported in this study is local and is small compared to the strong background year-to-year land surface temperature changes. Very likely, the wind turbines do not create a net warming of the air and instead only re-distribute the air's heat near the surface, which is fundamentally different from the large-scale warming effect caused by increasing atmospheric concentrations of greenhouse gases."

Readers should be careful not to confuse wind turbines moving atmospheric heat around, a localized, temporary, and small impact that does not affect the total heat in the atmosphere or the energy balance of the Earth, with the global warming caused by emissions of long-lasting greenhouse gases that continually and greatly warm the entire atmosphere in perpetuity.

The impact of wind plants on surface temperatures is localized and temporary, versus the global and permanent impact of emitting carbon dioxide. Because the recent study only focuses on localized impacts over a short time period, it greatly overstates the surface temperature impact of renewable resources relative to fossil fuels. If the paper instead looked across the global and long-lasting timescales that matter, renewable resources would fare hundreds of times if not infinitely better than fossil resources.

First, greenhouse gas emissions from burning fossil fuels cause **global** warming, while the study shows that the impact of wind plants on surface temperatures is highly localized to the area immediately downwind of wind plants. The study examines the impact of the U.S. electricity generation mix on surface temperatures in only the Continental U.S. While essentially the entire impact of U.S. wind plants on surface temperatures is localized to nearby areas, emissions from U.S. fossil plants raise temperatures around the globe and many miles up into the atmosphere. Because the Continental U.S. accounts for less than 1.6% of the world's surface area, the study therefore captures only 1.6% of the global climate change impact of fossil fuel use, resulting in an apples-to-oranges comparison when this is compared against essentially 100% of wind's temporary impact on local surface temperatures. This flaw in the paper alone makes the impact of wind and solar on global temperatures appear to be 63 times larger than it is in reality, compared to the impact of fossil fuels.

Said another way, China meeting its entire energy needs using renewable resources would have essentially zero impact on surface temperatures in the U.S., but if China instead continues to use fossil resources, that will greatly affect temperatures in the U.S. and around the world.

Yet the paper makes it appear that the impacts are similar by only looking at a narrow geographic area.

Second, producing electricity from fossil fuels requires the ongoing burning of additional fossil fuels in perpetuity, while using wind or solar plants to produce electricity has a one-time impact on local surface temperatures that quickly dissipates over time and space. Imagine the earth's atmosphere is a bathtub and we are trying not to allow it to overflow. As far as the impact on surface temperature, adding wind and solar generation would be like adding a few cups of water to the bathtub a single time (a more accurate analogy would be that wind just mixes the water already in the tub, which might slightly increase the temperature of the water farthest from the hot water faucet). In contrast, emitting carbon dioxide by using fossil fuel generation is like turning on the faucet and leaving it running forever. This difference can be seen in the chart on the first page of the new study: wind and solar's small localized impact on ground-level temperatures flatlines after the initial addition of those resources, while fossil fuels' impact continues to grow over time, with that growth even accelerating.

Because global warming affects the entire globe, it is also causing large positive feedbacks that exacerbate the initial warming, like a boulder picking up speed as it rolls downhill. These positive feedbacks of global warming include the melting of snow and ice in high-latitude areas, which further increases the heat absorption of the earth because there is less white-colored surface to reflect sunlight back into space; high-latitude warming that causes thawing of permafrost and undersea methane hydrate deposits, releasing methane which is a greenhouse gas that is dozens of times more potent than carbon dioxide; and the emissions of methane and carbon dioxide from decaying and burning plant matter as ecosystems are disrupted and wildfires are exacerbated by climate change.

It should also be noted that almost all of the localized surface warming projected by the study's model occurs at night. Increasing nighttime temperatures likely have a much less negative impact on agriculture, ecosystems, and human health than increasing daily maximum temperatures. For example, one of the largest human health impacts of climate change is that warmer temperatures accelerate the chemical reactions that produce ground-level ozone, which causes smog, asthma attacks, and other health problems. The chemical reactions that produce ozone only occur when the chemicals are exposed to sunlight, so an increase in nighttime temperatures would not contribute to that problem.

Because climate models like the one used in this study are designed to understand climate trends globally and over long periods of time, they tend to be poorly suited for predicting short-lived or local impacts. In general, because of the difficulty of collecting wind speed data far above the earth's surface, vertical circulation of air within the atmosphere is poorly understood.

Previous analyses have found that large-scale wind installations could have a very small but beneficial impact on crop growth, including protecting winter crops from frost. Another study found that "the wind turbine cools the near-surface air in the summer, which helps crops to thrive." Farmers and ranchers around the country are already reaping other major benefits from wind energy, with many farmers and ranchers receiving thousands or tens of thousands of dollars in lease payments in exchange for using a small share of their land for wind energy production. Because the wind turbines themselves have a very small footprint, typically over 98% of the land can still be used for crops or ranching.

The current study also notes that at least four prior studies have found that massive installations of wind capacity could slightly counteract polar warming by slowing the migration of warm air from the equator towards the poles. This would be beneficial as polar warming has an outsized negative impact due to positive feedbacks and sea level rise from the melting of ice.

Regardless, over the global geographic scale and indefinite timescale that matter for avoiding the most harmful impacts of climate change, the climate impact of fossil fuel consumption is infinitely larger than that of renewable resources. What matters is that the lifecycle greenhouse gas emissions of wind and other forms of renewable energy are dozens if not hundreds of times smaller than fossil energy sources, and adding renewable resources directly displaces the use of fossil fuel generation on a 1:1 basis. Notably, wind's lifecycle emissions are among the lowest of all non-emitting energy sources.

As the text of today's study notes, "in addition to climate benefits," renewables also reduce air emissions of sulfur dioxide, nitrogen oxides, particulate matter, and heavy metals that cause a range of series health problems including heart attacks and death. Carbon dioxide also has harmful impacts other than climate change, such as causing ocean acid acidification that is a leading threat to many forms of sea life. As a result, the authors note that "wind's overall environmental impacts are surely less than fossil energy."

It is also important to keep in perspective that nearly all human activities, such as growing crops, building cities, managing forests, and even operating nuclear power plants, have large impacts on localized climate. Large cities are typically at least several degrees Celsius (C) warmer than surrounding rural areas because of heat-absorbing surfaces like asphalt.

If the study is correct that some local areas will experience less than a 1 degree C localized and temporary increase in surface temperatures as a side effect of successfully addressing climate change by deploying enough wind power to meet the U.S.'s entire electricity needs, that tradeoff is more than worthwhile. For comparison, most scientists expect global temperatures to increase by at least several degrees C this century if we do not rapidly reduce carbon emissions. As the study authors note, the effect of wind "is small compared with projections of 21st century warming."

Finally, it should be noted that the article studied an extreme scenario of meeting 100% of U.S. electricity needs using wind energy. As the authors note, this is roughly 18 times greater than U.S. wind generation levels in 2016. Regardless, the study found that the impact of even this extreme scenario on average surface temperatures across the Continental U.S. would only be 0.24 degrees C. Relying on any one energy source to provide 100% of electricity is not a realistic scenario, as our future energy mix will likely draw from a variety of zero- and low-emitting resources. In particular, wind and solar daily and seasonal output patterns are highly complementary, and both energy sources continue to grow rapidly as their costs decline.

Second study on wind resource quantity could also be misinterpreted

The authors of the study discussed above concurrently released a second study on a related topic. The second study examines how densely wind turbines can be installed without significantly degrading the performance of wind turbines that are downwind due to wind "shading" and turbulence effects. The study argues that 0.5 Watts per square meter of land area is the average amount of wind capacity that can be installed in a wind plant.

When a wind project is being planned, tens of millions of dollars in revenue hinge on optimizing and accurately predicting the project's output. As a result, wind project developers and investors work extensively with atmospheric scientists and other experts to develop precise estimates of wind project output and determine the optimal plant layout. In fact, AWEA hosts a major conference every year devoted entirely to the topic of wind project resource assessment. In many parts of the country, thousands of wind turbines have already been installed in relatively densely clustered areas, and wind energy output has not suffered significantly.

The 0.5 Watt per square meter result from today's study is contradicted by the findings of earlier analysis by the National Renewable Energy Laboratory. That study compiled real-world data from 25,438 MW of U.S. wind plants, and found that the total land area within those projects is 8,779 square kilometers. That corresponds to a density of 2.9 Watts per square meter, six times larger than found in today's paper, and consistent with the 3 Watts per square meter assumption frequently used by DOE, national laboratories, and other analysts.

While today's study also examined real-world wind plants, it may have gone awry by assuming that all space between wind turbines in a wind plant was necessary to prevent production losses at downwind turbines. In reality, a number of complex factors go into turbine siting within wind plants, such as the ability of the developer to sign leases with individual landowners; avoiding areas that have unsuitable geology for turbine foundations; legally required setbacks from homes, buildings, and other features; wildlife concerns; the value of placing turbines at only the best wind resource sites within the plant; adjusting turbine locations to optimize access road and electrical system layout; and others. As a result, it is incorrect to assume that all area between wind turbines is part of the wind plant and was left undeveloped solely to avoid production losses at downwind turbines. The study authors also note that under their method, the calculated "areas for wind turbines on the edge of wind power plants are very large," which may have also skewed the results upward.

For context, the total land area within the 25 GW of wind projects in the NREL study is roughly the equivalent of a 93 kilometer by 93 kilometer area, or less than 1/1000th of total U.S. land area. As noted above, and in today's study, most wind plants directly use only a small share of the land within their footprint, with the remainder available for whatever its prior use was, such as farming or ranching. As a result, DOE found that obtaining 20% of U.S. electricity from wind energy would use less land than the city of Anchorage, Alaska. Other national laboratory analysis found that meeting 80% of U.S. electricity needs with renewable energy would take up less land than is currently occupied by golf courses.

Regardless, even if the maximum density is only 0.5 Watts per square meter, the U.S. would still have more than enough high-quality wind resources to meet its energy needs many times over. Recent DOE analysis found that technological advances through larger, taller, and more productive wind turbines have expanded the area with economically viable wind resources from 1.6 million square kilometers in 2008 to over 4.6 million square kilometers. Even if the conservative resource level of 0.5 Watts per square meter is accurate, 4.6 million square kilometers corresponds to 2,300 GW of wind capacity, enough to supply U.S. electricity needs several times over.

The study authors agree that the resource quantity is not a binding limit on wind's ability to help meet humanity's energy needs and solve climate change. I personally attended an academic symposium on these topics with the study authors several years ago. Dr. Keith, one of the authors, led a discussion of these topics, and noted that studies to date had found no limiting resource constraints if we attempted to meet all of humanity's energy needs with wind energy. He then asked the dozens of experts in attendance if they disagreed with that conclusion, including his current coauthor, and none did.

There is value in studies like these for better understanding how wind plants affect the atmosphere. For example, many experts in the wind industry are studying how wind plants can be better designed and located to increase wind output by minimizing wake effects at downwind turbines. However, members of the public should be careful not to misinterpret the findings of studies like those released today. If read closely and in their entirety, these studies only confirm that wind must play a central role in helping to meet America's energy needs and solve climate change, given our abundant and productive wind resources and the benefits they provide.