Is the Growth of Rooftop Wind Still in the Wind?

By Martin Flusberg
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Rooftop Wind

Utility-scale wind has become a major source of energy in the US, growing from about .1% of generation at the turn of the century to over 10% by the end of 2022. During that period, utility-scale solar has also grown significantly - growing from essentially 0% of energy generation in 2000 to 3.5% in 2022 - but still lags wind by a large margin.

At the same time, Rooftop Solar has grown even faster, growing more than 30% in 2022 over the previous year to the point where over 4% of homes - and numerous commercial buildings - are powered by rooftop PV systems.

But what has happened with Rooftop Wind?

Rooftop Wind goes by multiple names. A very common name, particularly early on in the surge of interest in Rooftop Wind, is Small-Wind (which is not limited to turbines installed on a rooftop). Another term – although also not used exclusively for rooftop installs – is Building-Integrated Wind. The National Renewable Energy Lab (NREL) tends to use a variation of that: Built Environment Wind Turbines (BEWT).

There has been talk for quite a while about the potential for Rooftop Wind, which can generate energy for up to 24-hours per day whereas solar is limited to daylight hours (when the sun is shining). Wind speed typically increases with height, so putting wind turbines on tops of buildings—especially tall buildings—was expected to allow them to take advantage of that without the need for a tower.

Significant interest in Rooftop Wind – for commercial, industrial, and residential uses - began in the late aughts. In the US interest accelerated in October 2008, when Congress expanded tax credits for wind turbines, first as part of the Emergency Economic Stabilization Act and later as part of the American Recovery and Reinvestment Act. The laws allow consumers to write off 30 percent of the total purchase and installation costs of any small-wind turbine.

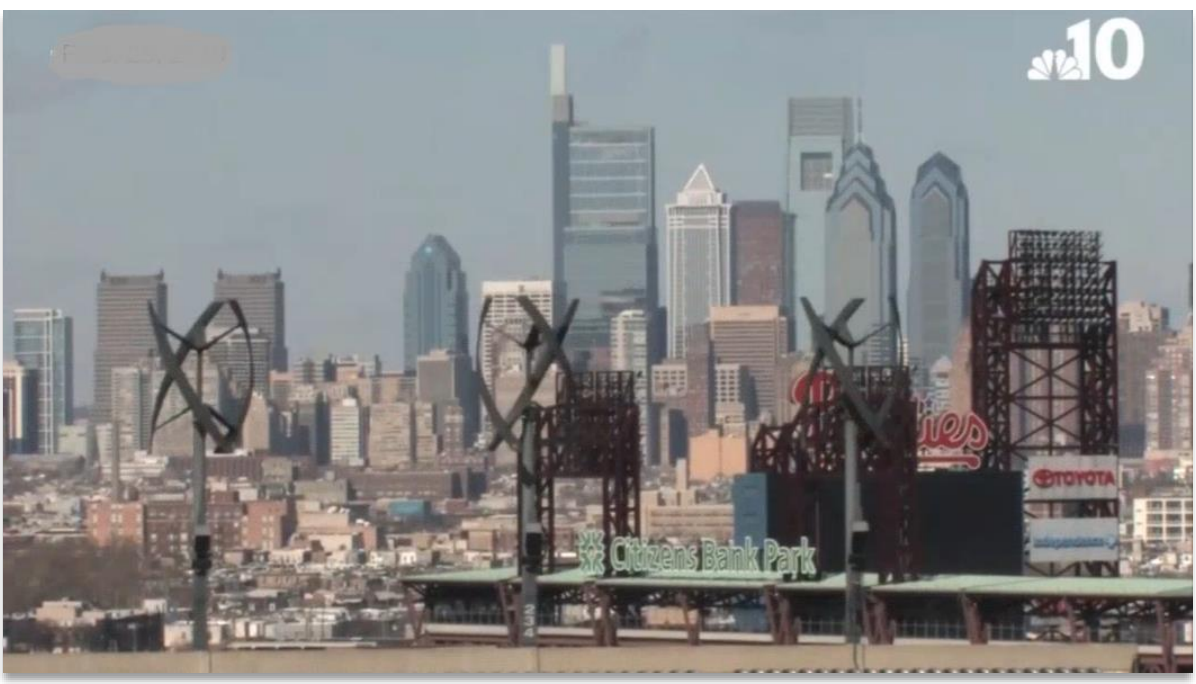
An example of the interest in rooftop wind can be found in a February 2009 article in the NY Times titled "*Bringing Wind Turbines to Ordinary Rooftops",* which reported on multiple companies that were installing rooftop wind turbines on homes across the US. A 2009 article in Popular Mechanics entitled "*Has Affordable, Efficient Rooftop Wind Power Arrived?"* suggested that rooftop wind turbines have a huge residential potential in urban and suburban areas.

Starting in 2008, Rooftop Wind Turbine projects began to show up all over the US in commercial, and industrial environments as well. For example, in 2008 the Massachusetts Port Authority installed sixteen 12-foot-high turbines on a building at Logan International Airport.

In another major project, in 2009 the Philadelphia Eagles installed fourteen turbines at Lincoln Field as the start of a project that was projected to lead to as many as 80 turbines.

These are a small sampling of commercial and industrial Rooftop Wind projects that happened in the 10 years or so after the American Recovery and Reinvestment Act.

Wind Turbines at Logan Airport



Lincoln Field Wind Turbines. Image courtesy of Channel 10 TV Philadelphia

Reaction to Early Deployments of Rooftop Wind

The reality is that it didn't take all that long for questions to be raised about the efficacy of Rooftop Wind. For example, NBC published an article in 2011 entitled *"Rooftop Pipedream: be Wary of the Booming Market for Pint-sized, Roof-mounted Windmills".*

The article noted that dozens of companies launched new turbines aimed at urban and rural consumers alike after the Recovery Act and that the market for small windmills in the US grew 13% in 2009, bringing the total capacity of small turbines to over 100 megawatts, which accounted for 3 percent of total US wind energy at that point in time. As another sign of the turbines' increasing popularity, the article also noted that small-wind units appeared at the Consumer Electronics Show in Las Vegas for the first time in 2011.

But the article goes on to say that research had indicated that only tower-mounted turbines, suitable for homes with an acre or more of land, had really been proven to work in the residential world. Rooftop turbines, on the other hand, only seemed to work in very specific settings, and almost never in urban areas. They cite a 2008 article titled *New Study Says City-Based Rooftop Wind Power Doesn't Pay Off* that draws from a report from the UK's Carbon Trust which stated that domestic windmills in urban locations are actually net carbon *emitters*, as more energy goes into their production, shipping, and maintenance than is saved by their use.

The issue, according to the report, is that for a turbine to generate enough power to be effective it needs to be consistently hit with wind at speeds above 5 miles per hour. But there are too many physical obstacles in cities – specifically taller buildings – that get in the way. This is especially an issue with single family residential buildings. Making the residential situation worse, most residential roofs are simply too weak to support rooftop turbines, which create additional drag and can cause vibrations that range from annoying to potentially dangerous.

An even earlier article that appeared in 2009 in Building Green entitled "*Folly of Building-Integrated Wind"* provided a broader perspective of the issues challenging Rooftop Wind. It pointed out that rooftop turbines need to overcome multiple challenges to meet performance expectations:

- **Turbulent Air Flow.** The best wind-turbine performance happens when all of the air flows in a single direction. But as wind flow comes over the edge of a roof it separates into streams which creates turbulence which has the effect of "confusing" the turbine, affecting its performance. It also creates stress on the drive gear. The constantly changing wind speeds further affects performance of the turbines.

- **Noise and Vibration**. Wind turbines generate noise and vibration which are obstacles to integrating them into buildings. Making it worse, vibration from wind turbines is variable. Metal roof decks can actually amplify the vibrations. In many early installations of roof turbines tenants complained about the vibrations – in some cases forcing the units to be shut down.

- **Safety**. One concern regarding wind turbines is that blades might fly off. In a large field such an accident would be unlikely to cause serious damage, but on building it could injure people, wildlife, or property. It is not unheard of for large, free-standing wind turbines to occasionally shed a blade.

Although there is no evidence of injury or damage from building-integrated wind, this has remained a concern. And even if the blades do not fall off, they represent a potential hazard to wildlife.

In 2016, Paul Gipe, an author, advocate, and analyst of the renewable energy industry, posted an article on LinkedIn entitled *"Rooftop and Building Integrated Wind Turbines are a Failure Says NREL".* Gipe admits that that is not quite what NREL said but suggests that their findings in effect demonstrate the failure. As part of this he reported on the results of multiple installations mentioned by NREL that failed to produce the expected level of energy generation.

For example, in one case 4 turbines were installed on the roof of a newly built, LEED-certified green building in Portland, Oregon. The designers estimated that the turbines would generate 9,500 kWh per year; in fact, they produced only 5,500 kWh. The installation cost $240,000 which implies a very long payback period.

Rooftop Turbines – Portland, Oregon LEED Building

Gipe provides another example where rooftop turbines were expected to produce 7.8 kWh – and managed to produce only .12kWh.

Turbine manufacturers publish power curves that show projected electricity outputs at different wind speeds. There is also a rated power output at a specific wind speed, though the wind speed used differs among manufacturers. The Building Green article referenced above quoted Ron Stimmel of the American Wind Energy Association (AWEA) as saying "it's very, very difficult to get them (small building-integrated wind turbines) to perform at anywhere near their rated capacities (percent of electricity generated compared with the output if the system were operating at the rated level)", and "I have yet to find one that achieves its expected performance".

The article points to a 2008 Madison Gas and Electric (MG&E) project aimed at determining whether small-scale, building-integrated wind performed as advertised. They installed a vertical-axis wind turbine made by the Finnish company Windside on a pole, with the top at 42 feet —about the height it would be on a three-story commercial building. The turbine was rated at 10 kW, but MG&E reported that they had not seen it produce more than 600 watts—6% of its rated output—even on a very windy day. An external review found that it had produced only 33 kWh total in four months—about a quarter kWh per day. This suggests the unit operated at a capacity factor of just 0.11% - as compared to freestanding wind turbines that typically operate at a 10% to 30% capacity factor.

Another example provided in this article was the Warwick Wind Trials Project in the U.K. which measured turbine performance of 26 building-mounted wind turbines from October 2007 through October 2008 - and found an average capacity factor of 0.85%. The measured electricity production was compared with predicted production based on the manufacturers' supplied power curves and both predicted and measured wind speeds. The study found that predicted performance exceeded actual performance by a factor of 15 to 17.

Given issues that were experienced, quite a few of the early, much touted projects ended up with the turbines being removed. For example, the Lincoln Park turbines noted earlier were removed 10 years after installation because of continuing repair issues. (The Philadelphia Eagles did, however, install 11,000 solar panels at Lincoln Park and were awarded LEED Gold certification).

Ongoing Evolution in Rooftop Wind Turbine Design

Although early analyses of Rooftop Wind were fairly negative, that did not stop continued interest and continued development aimed at improving the technology.

Horizontal vs. Vertical Axis

Several of the examples of commercial/industrial Rooftop Wind Turbines shown above used the same design as used for large scale wind farms – known as Horizontal-Axis Wind Turbines (HAWT). But it soon became apparent that HAWT is not suitable for rooftops for all of the reasons noted earlier.

An alternative to HAWT is the Vertical-Axis Wind Turbine (VAWT). Vertical-axis wind turbines have actually been around since the 1920's. They generally have less rotation than HAWT and therefore produce less energy. They did see some usage around the world for many years but were essentially phased out of use in tower-mounted wind farms in the 1990s.

But VAWT makes much more sense in a small wind rooftop environment and has become the standard for Rooftop Wind after the early failures of HAWT projects. The key factors:

- They are less affected by turbulent airflows.
- They are often able to operate at lower wind speeds.
- They give off less vibration and are quieter than HAWT units.

VAWTs come in many different layouts: here are just a few examples of units that have been used; some newer designs are shown later:

While Vertical-Axis turbines have definitely performed better as a whole on rooftops than Horizontal-Axis, the performance varies significantly by brand, location, height, and more, and in general the performance has not been at the hoped for levels.

But interest in Rooftop Wind continues, as does development of Rooftop Wind technologies. For example, in December 2022 NREL announced it planned to award $2.9 million to 11 manufacturers of small and medium-scale wind turbines. These awards will support further technology innovation and are intended to expand the deployment of distributed wind turbines for use by homeowners, farmers, businesses, and others.

In the last several years several new technologies have been introduced that have the potential to significantly improve the performance of Rooftop Wind. A few of those new technologies, focused on commercial and industrial use, are discussed below.

Integrating Wind and Solar

Several companies have developed unique approaches that move beyond the idea of wind being able to complement solar by more directly combining rooftop wind and solar – with the emphasis more on the solar than wind-side. Here are 3 actually quite different examples:

Accelerate Wind won the NREL 2021 Prototype Design Development Award for a design that takes advantage of increased wind velocities at building parapets—where the wind rises up the façade of a large building and curls over the edge. Their turbines are meant to supplement solar panels and be sold and installed by the solar installer. The unit includes an airfoil shape that hangs over the roof, preventing flow separation and capturing the higher wind speeds that occur naturally at a roof's edge. It

Rendering of Multi-unit Accelerate Wind Installation

integrates with a crossflow wind turbine from XFlow Energy Company. Each unit generates 5kW. There are several field tests happening.

PowerNEST (based in the Netherlands) integrates wind and solar, but this one has a novel approach, actually relying on solar to generate virtually all of the electricity. It uses fins on the edges of the rectangular frame to direct air to vertical turbines that sit underneath a roof of solar panels. The wind helps cool the panels and increase their efficiency. The company says the system can capture 6 to 10 times more electricity than rooftop solar panels alone. The company has several demonstration projects operating the Netherlands.

PowerNEST Turbines

Unéole (based in France) has created a wind turbine integrated with solar panels that they claim generates 40% more energy than solar alone. It is intended for urban use.

The cube-like device is made of recycled metal materials. A row of wind turbines is located beneath a platform of solar panels. When the sun is down - or weak, the Uneole wind turbines generate the electricity. The device is certified as silent by Cerema, a French agency that tested for electromagnetic waves which might cause issues.

Sample Uneole Unit

Uneole Rendering of Rooftop Install

Currently, a test device is installed above the CD2e LumiWatt site in Loos-en-Gohelle, Pas-de-Calais, France.

Other Newer Rooftop Wind Technologies

Other new developments are focused on increasing the performance of Rooftop Wind Turbines; a few interesting examples are provided below:

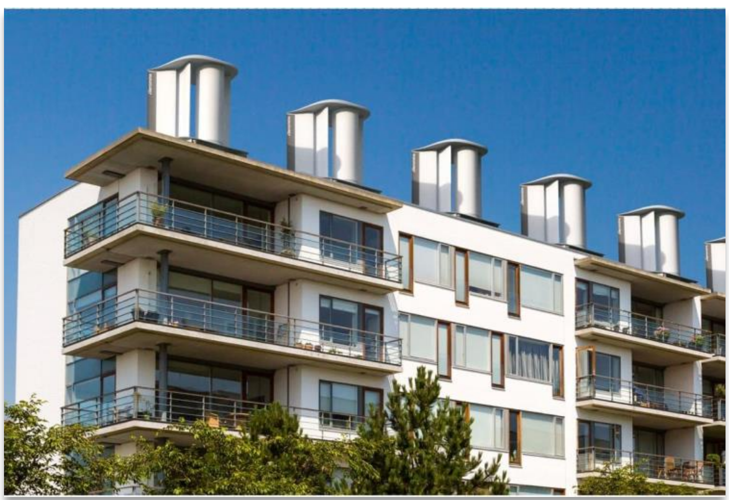
Aeromine borrows from a fundamental principle of flight. The Aeromine technology does away with traditional wind turbine blades and instead uses a pair of vertically mounted airfoils (or wings). When air flows past the wings, an area of low-pressure forms between them, and an aerodynamically shaped tower placed between the airfoils feeds the suction created by this low pressure through pipework so that it pulls air past a small turbine in the unit’s base. This design can pull wind energy from a larger area than turbine blades can on their own.

This design does not generate the same level of vibration and noise as standard turbines. The design is also intended to keep the wings isolated from contact with people or wildlife.

BASF Aeromine Installation

The unit is about 10 feet tall, sitting on a 6-foot base. According to Aeromine, each device can produce 5kW of electrical power, and multiple units can be placed 15 feet apart along the leading edge of a building rooftop. The company states that installing 40 Aeromine units on a 140,000-square-foot building only uses 4 percent of the area of the roof to generate the same amount of energy as solar panels, and that one Aeromine unit produces about the same amount of energy as 16 solar panels.

BASF is currently testing a unit at its manufacturing facilities in Wyandotte, Michigan.



Rendering of Multi-unit Installation by Aeromine

Flower Turbines creates vertical wind turbines that are intended to look like large, skinny tulips. They're designed to be installed on the ground or on a flat roof. The vertical-axis turbines are purportedly able to start generating power at low wind speeds of just 1.6 mph - much lower than traditional wind turbines. The company sells 3.3-foot, 10-foot, and 19-foot-tall turbine models in the U.S and Europe which generate from several hundred watts to 5kW in the tallest model. They claim that the units are quiet and safe for wildlife and currently have installations in the Netherlands, Germany, and Israel.

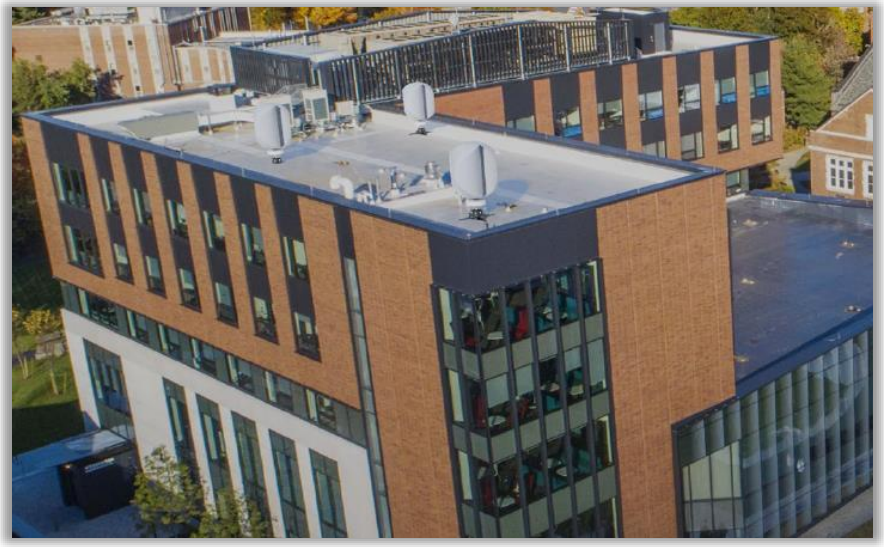
Flower Turbines likes to play up the tulip shape and sells units in multiple colors. Below is a rendering from Flower of what an installation at a gas station might look like.

Rendering of Flower Turbine Gas Station Install

ARC Industries has developed a VAWT – called the Orb - with a number of features that should result in better performance than traditional designs. (Full transparency alert: I have been advising ARC). The turbine design is different from previous rooftop turbines and better designed to capture wind on rooftops, including updrafts at the edges (and including at lower heights). The blades (patent pending) leverage passive vortex forces on their insides. The Orb also utilizes a new passive, variable transmission, axial flux generator technology for which ARC has received a patent. This has an extremely high efficiency and is designed to work at lower RPMs – allowing it to work at lower wind speeds and achieve a higher capacity. They also have a patent on a different type of bearing technology. The unit is very quiet and ARC believes that the shape of the turbine makes it easily seen by wildlife, which is not the case with more traditional turbine designs.

Orb Installed at Burlington (VT) Airport

The unit is approximately 8 feet tall. It kicks in at wind speeds of 4mph and has an output per unit of 3kW. This is 7.5 to 12 times the output of a standard solar panel. ARC believes that the units should be installed together with solar. The first pilot test – through Burlington (VT) Electric – is installed on the roof of a parking garage at Burlington International Airport – a roof that is covered with solar panels.



Rendering by ARC Industries of Multi-unit Rooftop Install

Future of Rooftop Wind

While the results of Rooftop Wind projects to-date have been anything but stellar, the potential market is very large, interest remains very high, and investment in technology enhancements is continuing at a brisk pace. The Inflation Reduction Act extended renewable energy tax credits, including residential and business versions, which will help constrain costs over the next 10 years. The data seems clear that the performance of rooftop wind will be a factor of turbine design, location, including height and location relative to other buildings, wind levels in the area, and much more. The data also seems to suggest that Rooftop Wind is more likely to see success in commercial and industrial rather than single-family residential buildings, at least in urban areas. But as noted above there are some new technologies that look like they will deliver enhanced performance and the performance of Rooftop Wind Turbines should continue to improve in general. Given the potential role of wind to augment (and in some cases replace) building-integrated solar and therefore accelerate the transition to renewable energy there is every reason to believe that, although it will still take several years, Rooftop Wind will see it's day in the sun – er wind.