TESTIMONY OF THE MAYOR'S OFFICE OF SUSTAINABILTY
BEFORE THE NEW YORK CITY COUNCIL
COMMITTEE ON ENVIRONMENTAL PROTECTION

Monday February 26, 2018

I. INTRODUCTION

Good afternoon, Chair Constantinides and members of the committee. I am John Lee, Deputy Director for Buildings and Energy Efficiency at the Mayor's Office of Sustainability (MOS) and I am a registered architect in the State of New York. I am joined today by Alan Price, Director of the Office of Technical Certification and Research at the New York City Department of Buildings (DOB) and Anthony Fiore, Deputy Commissioner of Energy Management at the Department of Citywide Administrative Services. Thank you for the opportunity to testify today on the following bills:

- **Introduction 48** in relation to the creation of wind maps demonstrating wind energy generation potential within the city
- **Introduction 50** to amend the New York city noise control code, the administrative code of the city of New York and the New York city building code, in relation to small wind turbines
- **Introduction 598** in relation to green energy to amend the administrative code of the city of New York, in relation to requiring that all city-owned buildings be powered by green energy sources by 2050.
- **Introduction 96** to amend the administrative code of the city of New York, in relation to allowing residential cooperatives to consolidate required energy efficiency reports.

Climate change is perhaps the toughest challenge New York City will face in the coming decades. The global dependence on fossil fuels, and the unprecedented scale of greenhouse gas (GHG) emissions have led to increasing temperatures and precipitation, rising sea levels, and more frequent and intense flooding that threaten our communities, health, and economies. While President Trump continues to abdicate American leadership on climate change, we here in New York City are hastening our shift to towards clean energy by taking direct action to reduce fossil fuels and GHG emissions

For example, in May 2017, Mayor de Blasio signed Executive Order Number 26 committing New York City to the principles of the Paris Climate Agreement, directing City agencies to align our work with the Agreement's goal to limit global warming to 1.5 degrees Celsius. In January 2018, the Mayor and our Comptroller announced the City would be taking the fight straight to the fossil fuel industry, by seeking damages for the investments necessary to protect New Yorkers from the impacts of climate change, and divesting our pension funds from fossil fuel reserves

The leadership on climate change from our City Council has also been admirable, setting the pace for cities across the world. For instance, the building mandates introduced by the Council last year are a bold and necessary step to not only dramatically cut GHGs to help hold global temperature increases to just 1.5 degrees Celsius, but will also support the livelihoods of our residents by spurring thousands of green jobs. We are grateful for your partnership in our collective effort to fight climate change and look forward to working with you to pass the mandates this year.

II. THE INTRODUCTORY BILLS

Today's introductory bills align with Administration climate goals, and so we are pleased to testify in general support of them.

Introductions 48

In order to meet our 80 x 50 goals, we must make a significant shift to cleaner electricity production. Today, only about 6 percent of the electricity feeding New York City's grid is generated from renewable sources such as wind, solar, and hydro; so we have to continue to harness the power of the sun and the winds at the level of the utilities, and on the roofs of our homes and workplaces. To reach our clean energy targets, the City has set an ambitious target of 1000 megawatt solar power citywide by 2030. Wind turbines also have a role to play in this strategy as we have to take every opportunity to displace fossil fuel energy.

With respect to Introduction 48, the bill requires the City to periodically conduct a wind resource assessment. Given the fall in prices for solar photovoltaics, and the more favorable power production capacity of solar photovoltaics as compared to small wind turbines, most of the recent clean energy opportunities on rooftops have favored solar projects. However, not every site is ideal for solar power production, and opportunities to extract wind power at small scale have already been proven. With limited space in a dense urban space like New York City, this bill would help us identify and map areas with high potential for certain type of building-mounted wind turbines.

Introduction 50

When mounted on the rooftops of our homes and businesses, the noise and vibration nuisances from wind turbines are particularly challenging to control from an engineering perspective. Introduction 50 establishes acoustic performance and safety standards for building-mounted small wind turbines. We strongly support the codification of standards related to building-mounted wind turbines.

For example, in 2011 the Department of City Planning and the City Council revised the Zoning Resolution to clarify the land-use requirements for rooftop mounted wind turbines. Furthermore, in 2011, the Department of Buildings published a Buildings Bulletin that provides guidance to the industry and a reference safety standard IEC6100 to ensure the safe installation of small wind turbines. The guidelines include procedures for obtaining approvals and permits for building-mounted wind turbines, as administered by the Department's Office of Technical Certification and Research.

The standards proposed by Introduction 50 differ from those already published Buildings Bulletin, but these differences are minor and could certainly be reconciled. The administration and the Department of Buildings look forward to working with the City Council to resolve the technical standards and ultimately codify these very important regulations that will ensure the safe installation of clean energy production.

Introduction 598

With regard to Introduction 598, requiring that city-owned buildings be powered by green energy sources by 2050, we agree with the spirit of this bill; it is important to set targets that are bold and visionary. For example, where the City has direct control over energy supply it has already begun to take action. The City will have installed 39.14 megawatts of solar panels on City assets by the end of 2019 – enough to power 131,269 homes. In addition, the City has been actively assessing and installing other alternate clean energy technologies including fuel cells, battery storage systems, building integrated photovoltaics, wind geothermal and solar thermal systems. The Administration looks forward to working with Council on the details of this proposal and sketching out a path to achieving the ultimate aim of all these bills and the broader suite of climate change mitigation interventions the Administration and Council are progressing.

Introduction 96

Finally, we support Introduction 96's efforts to streamline the submission process of energy efficiency reports. There are a few technical edits that we will offer in order to ensure that DOB can properly enforce for compliance.

III. CONLUSION

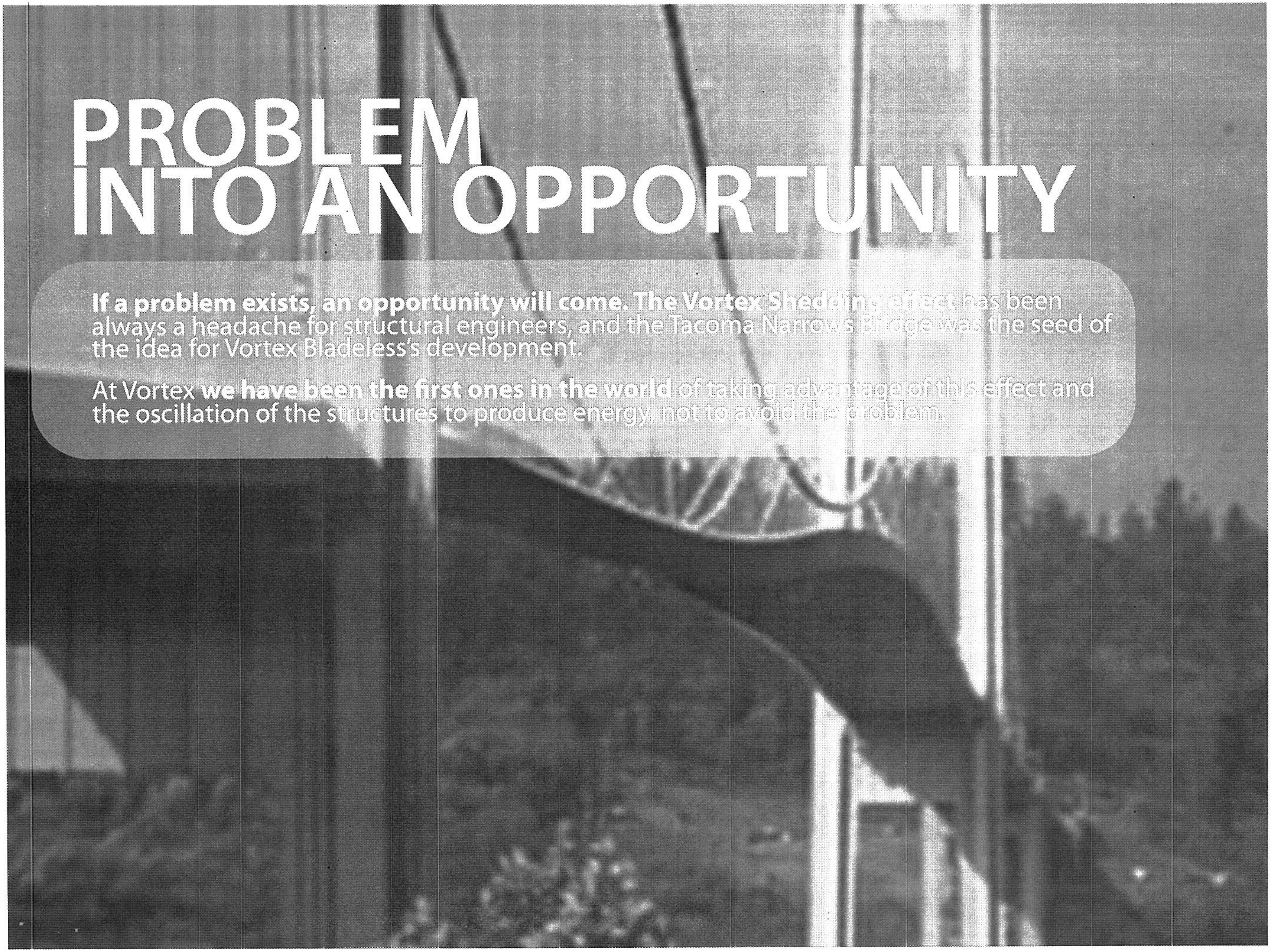
In conclusion, please allow me to applaud the Council's partnership on combatting the impacts of climate change to New York City. Working together, we are confident that we can strengthen these bills to help us achieve our 80 x 50 goals and uphold our part to limit global temperature rise to 1.5 degrees Celsius. Thank you for the opportunity to testify. I am happy to answer any questions that you may have at this time.

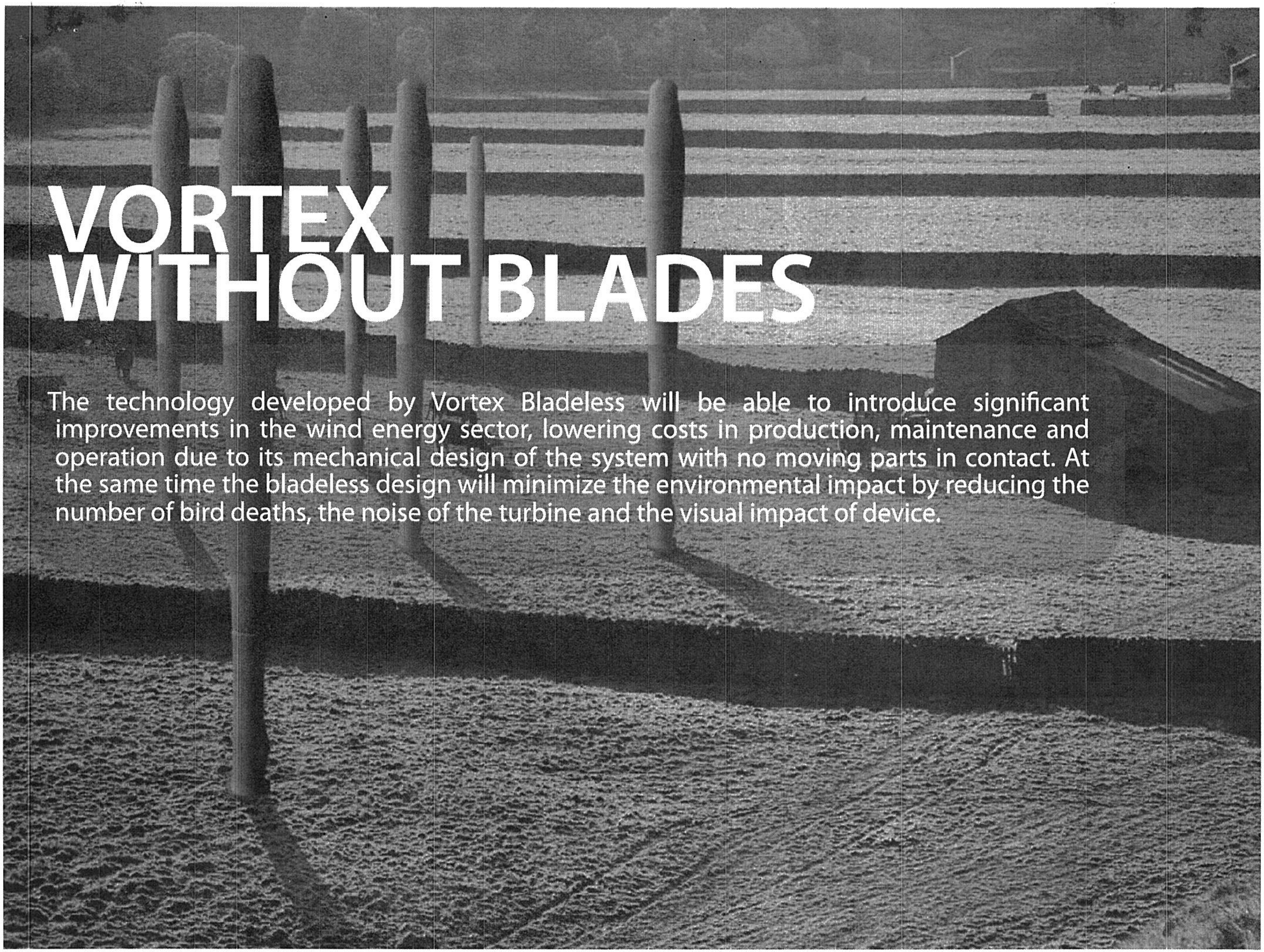

VORTEX
Bladeless
Wind turbine without blades
THE NEW PARADIGM OF WIND POWER
/ VORTEX

PROBLEM
INTO AN OPPORTUNITY

If a problem exists, an opportunity will come. The Vortex Shedding effect has been always a headache for structural engineers, and the Tacoma Narrows Bridge was the seed of the idea for Vortex Bladeless's development.

At Vortex **we have been the first ones in the world** of taking advantage of this effect and the oscillation of the structures to produce energy, not to avoid the problem.

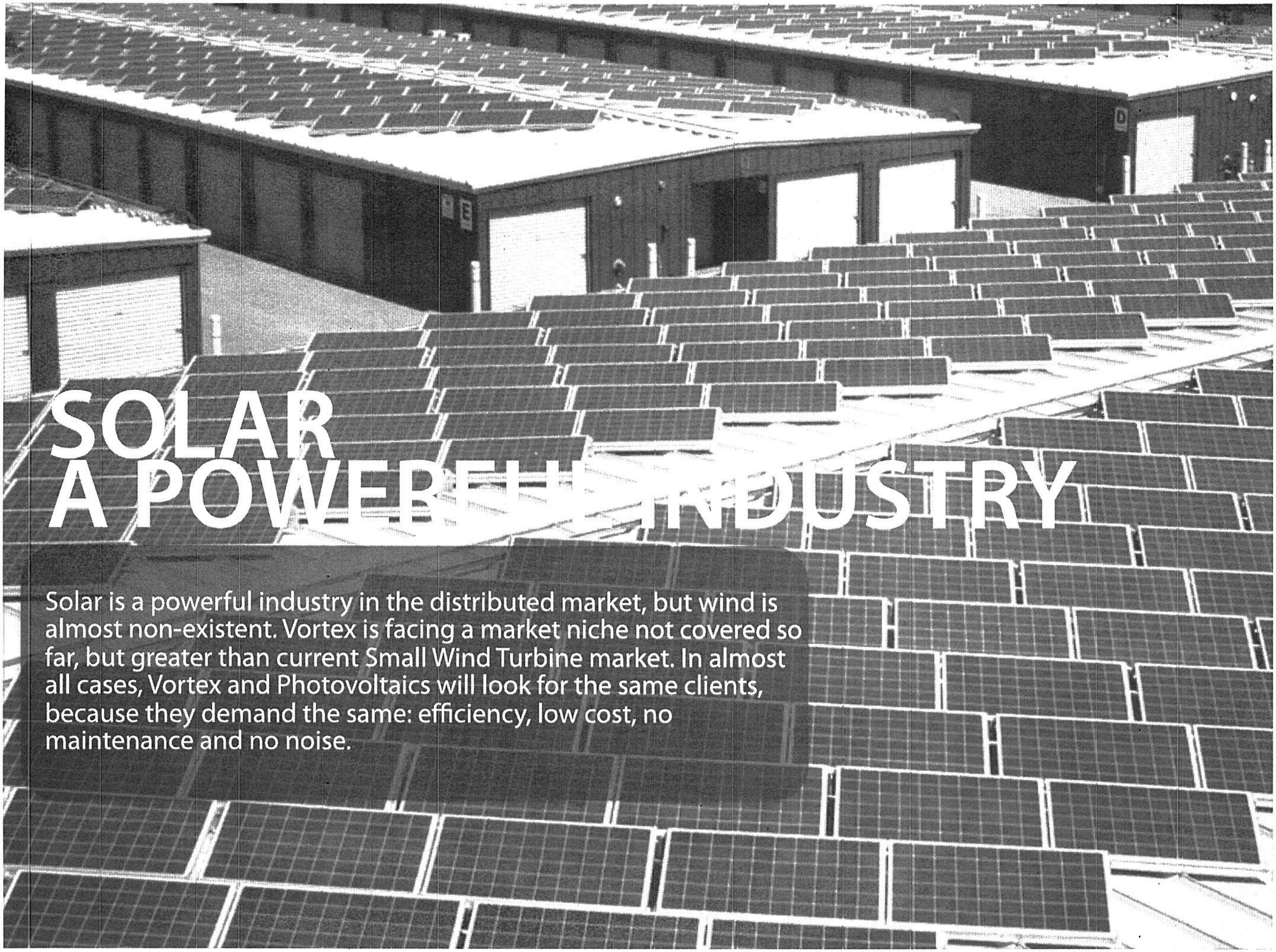




VORTEX WITHOUT BLADES

The technology developed by Vortex Bladeless will be able to introduce significant improvements in the wind energy sector, lowering costs in production, maintenance and operation due to its mechanical design of the system with no moving parts in contact. At the same time the bladeless design will minimize the environmental impact by reducing the number of bird deaths, the noise of the turbine and the visual impact of device.

VORTEX
A DISRUPTIVE CON
There are several benefits in this new technology. Imagine we take off the blade
and won't kill birds.
Imagine we take all mobile parts off there won't have almost anything to maintain.
Imagine if we invent a wind power system that allows to produce energy from 5W to a kW we will be able
to be the solution for wind energy in distribute energy and be the perfect partner for solar power.

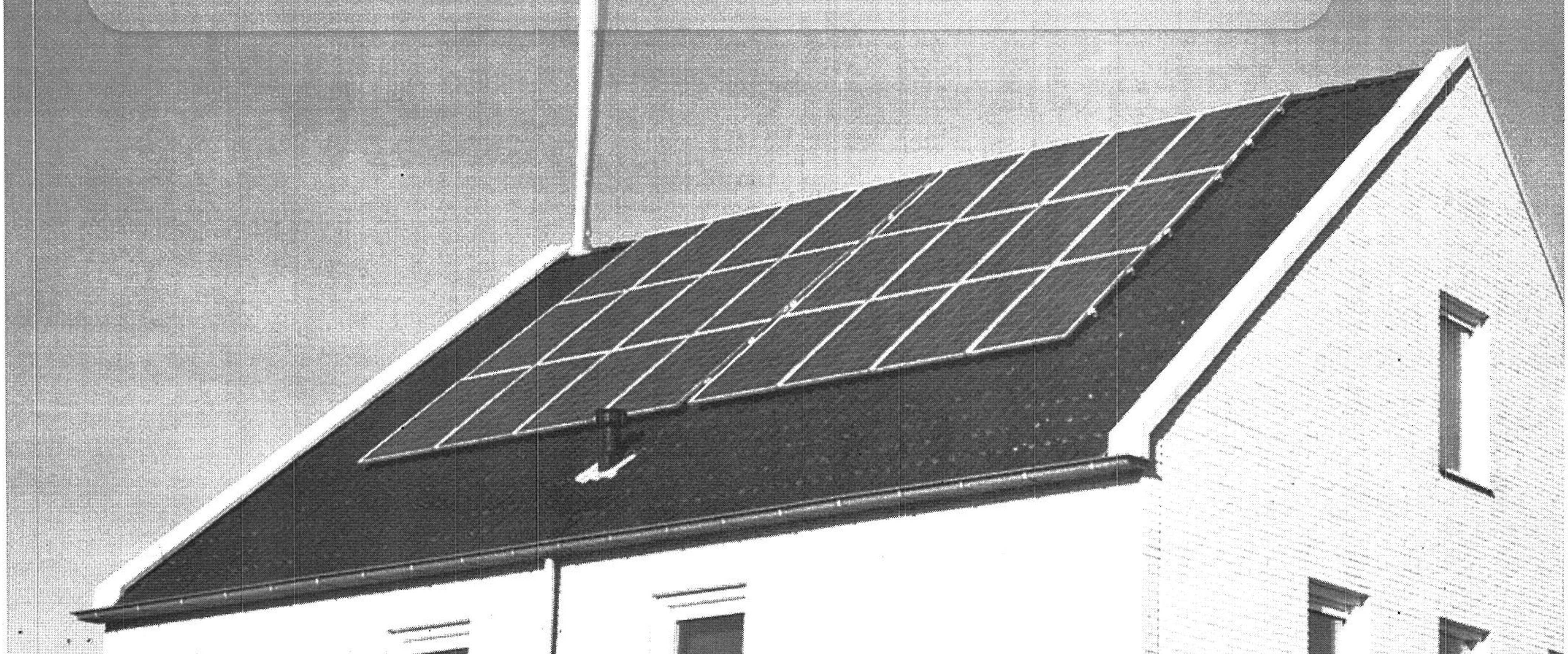


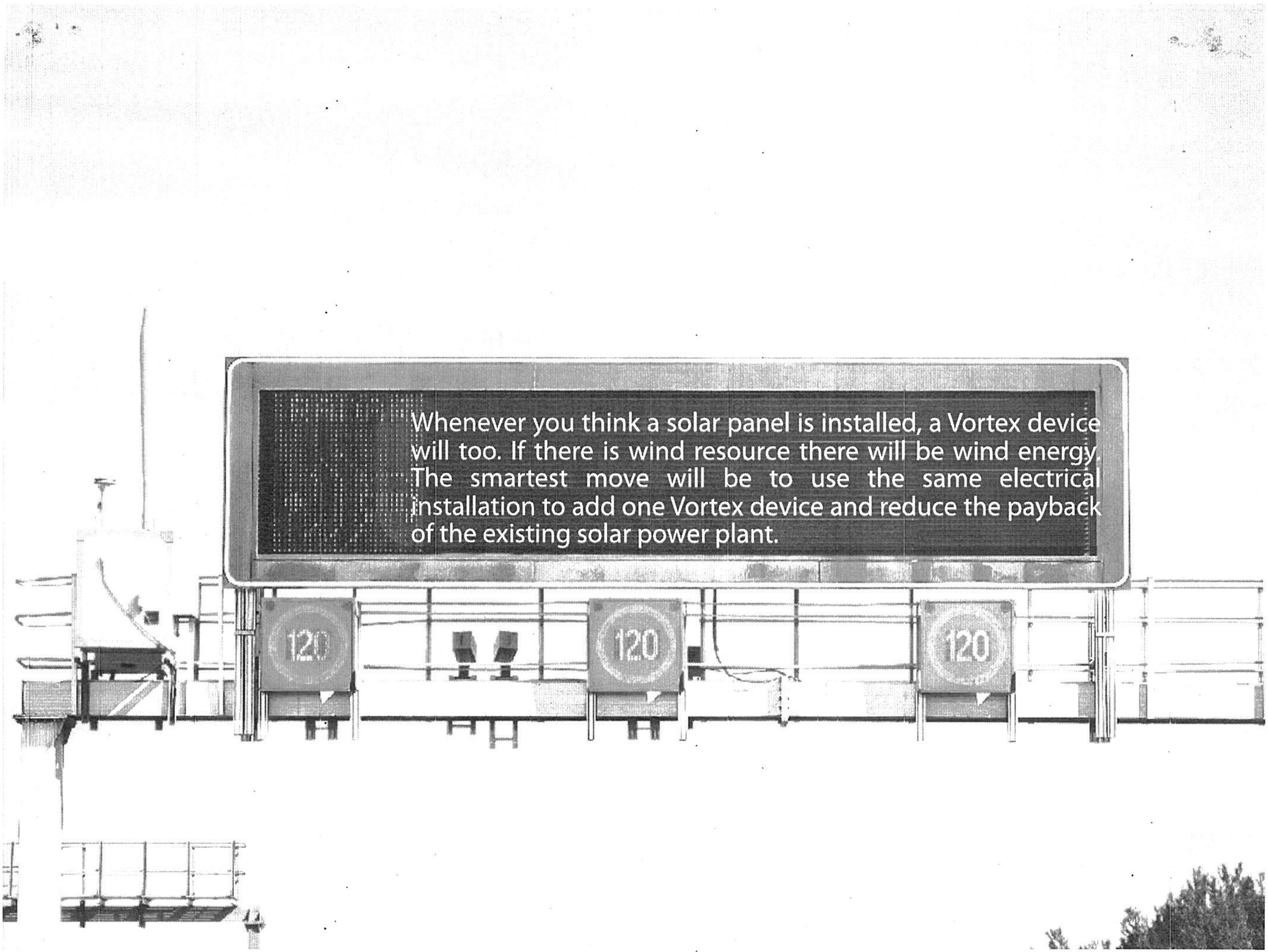
SOLAR A POWERFUL INDUSTRY

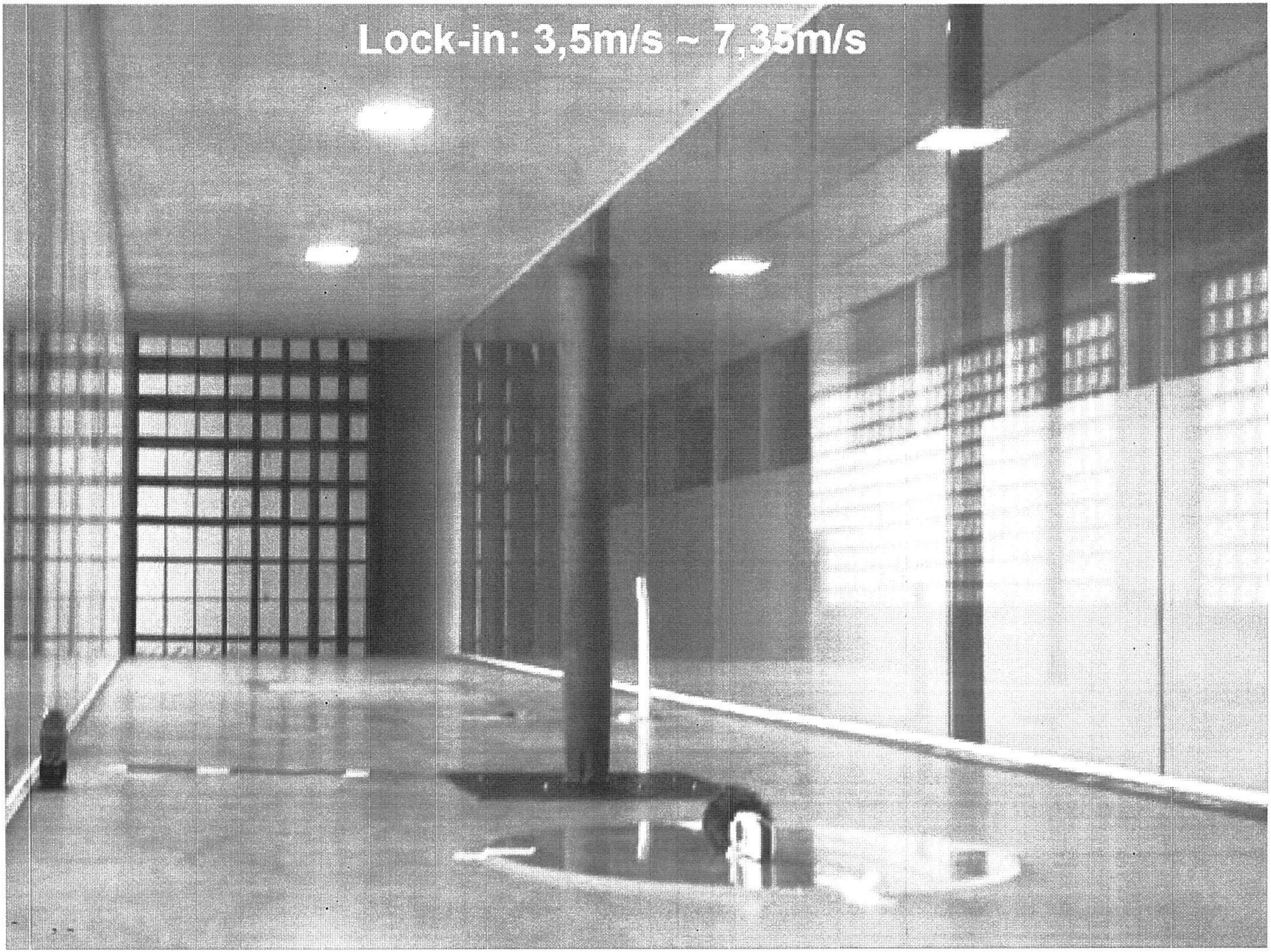
Solar is a powerful industry in the distributed market, but wind is almost non-existent. Vortex is facing a market niche not covered so far, but greater than current Small Wind Turbine market. In almost all cases, Vortex and Photovoltaics will look for the same clients, because they demand the same: efficiency, low cost, no maintenance and no noise.

VORTEX
THE WIND OF CHANGES

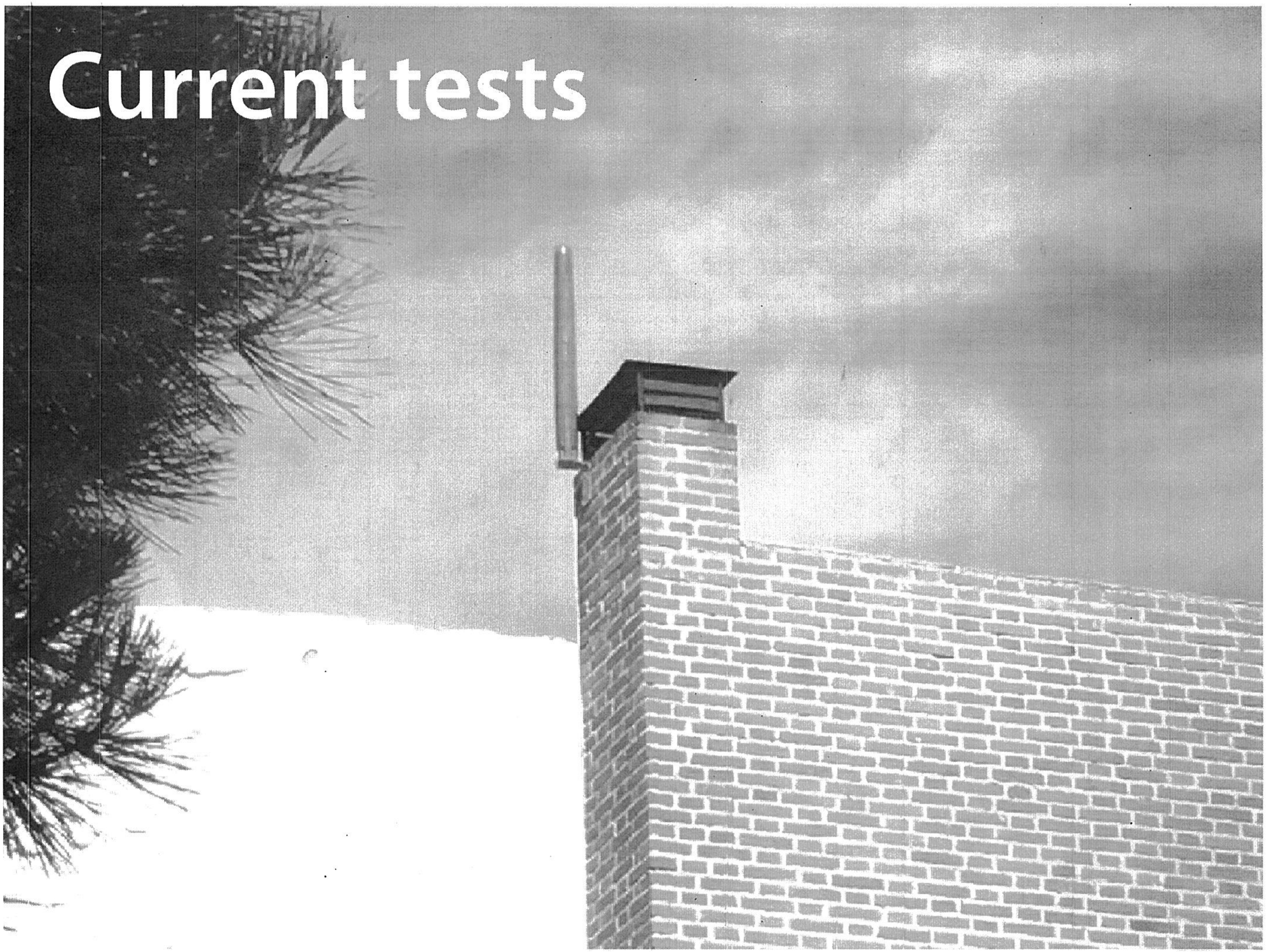
As the wind power is well introduced for utility scale generation, Vortex Bladeless has a huge opportunity in the market of the distribute energy: residential, rural and commercial uses. Solar power is solving in a proper way the goals of the distribute energy, generating power where the people live. An off-grid consumer is looking for a device with low maintenance, no noise and respectful with its environment. Wind power, with its existing small wind turbines didn't achieve these goals. This tiny market is growing, but not at the same rhythm and size as its big brothers or the solar power market.



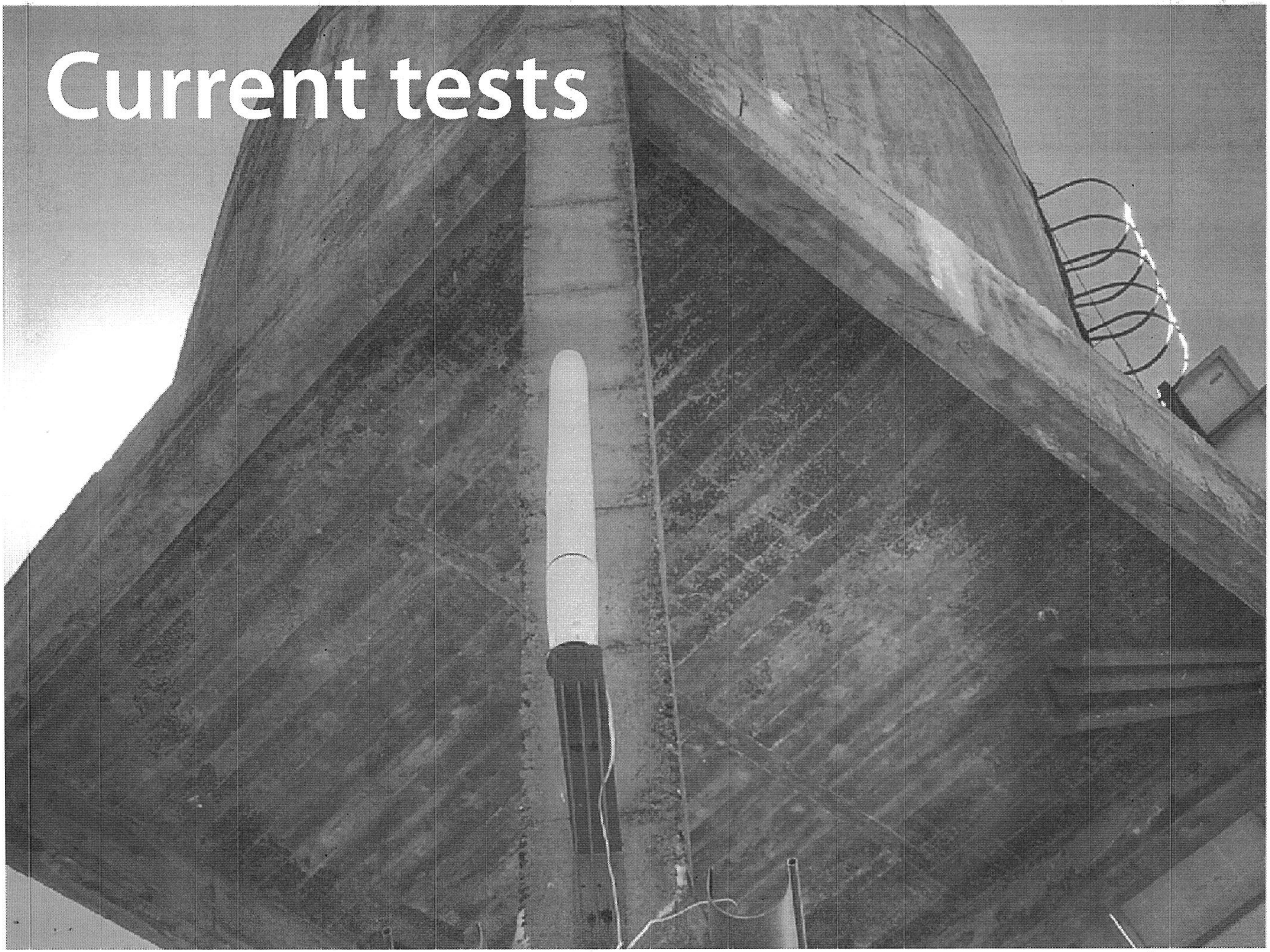

Whenever you think a solar panel is installed, a Vortex device will too. If there is wind resource there will be wind energy. The smartest move will be to use the same electrical installation to add one Vortex device and reduce the payback of the existing solar power plant.
120
120
120


Lock-in: 3,5m/s ~ 7,35m/s

Current tests



Current tests



The founder team has been working since 2008 together. Now we are 10 people directly involved.
The team is the principal asset of this project.

VORTEX
Bladeless

Advisory Board

José Creuheras
Planeta Group

Paulina Beato
SEGIB/REEE

Antonio Tuñón
Taiga Mistral

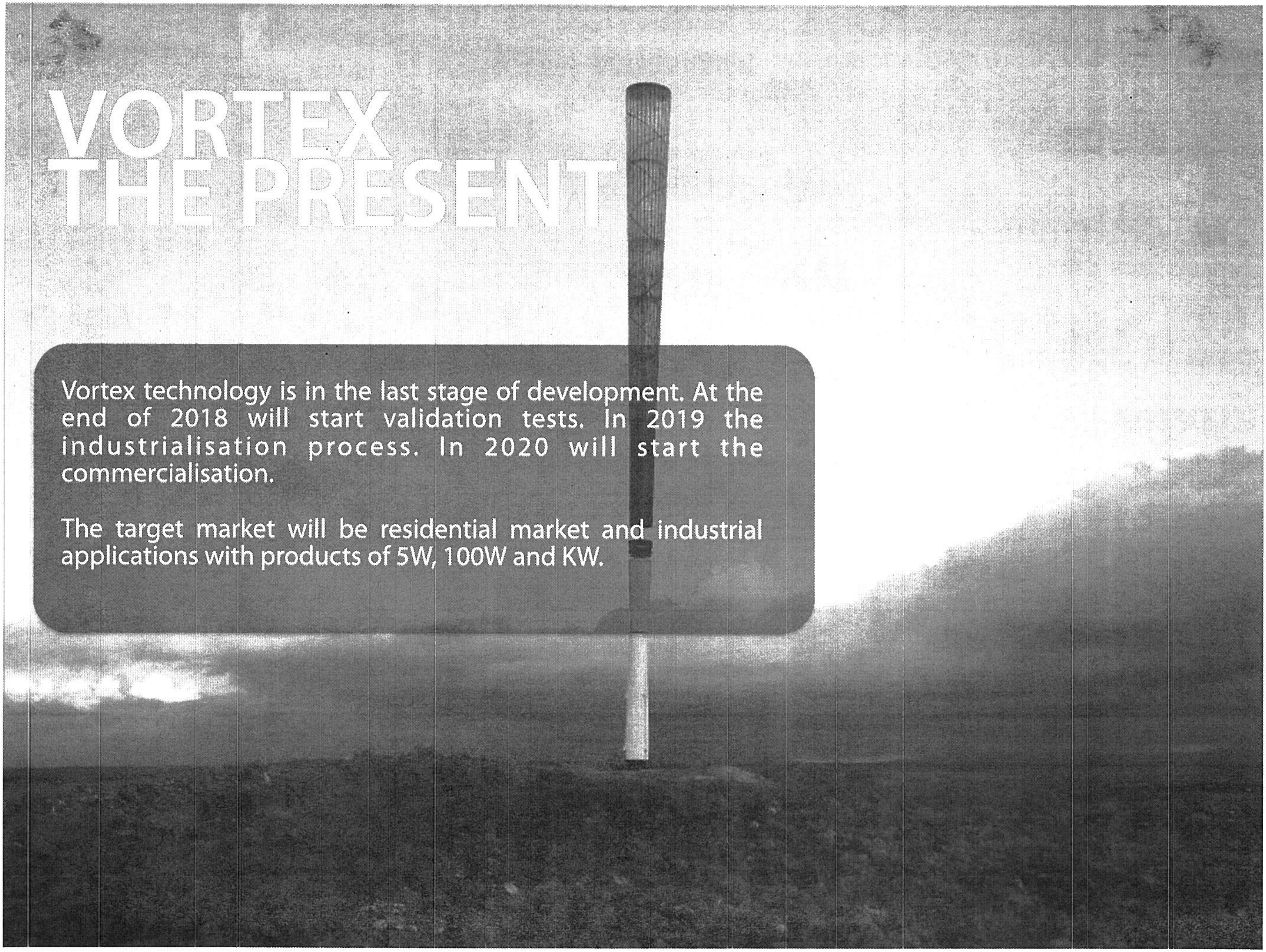
Carlos García Pont
IESE

Ignacio Cruz
Ciemat

Jeffrey Char
TEPCO Japan

Ramón Puente
Manufacturing advisor

VORTEX THE PRESENT



Vortex technology is in the last stage of development. At the end of 2018 will start validation tests. In 2019 the industrialisation process. In 2020 will start the commercialisation.

The target market will be residential market and industrial applications with products of 5W, 100W and KW.

VORTEX IMPACT AROUND THE WORLD

CLIENTS - DISTRIBUTORS - COMPANIES - ACADEMIA - SUPPLIERS - MEDIA - PILOT TEST

NASA
GM
Altair
MOTOROLA
HYPERLOOP TECH
EXPO 2017 - Future Energy -
OMRON
TOYOTA

PEMEX
orange
acciona
e·on Energie
TOSHIBA
SAB MILLER
KEPCO
TUDelft
Formosa Plastics
velatia
TEPCO
HEXCEL
Stanford University
KIT
Virginia Tech
TUDelft Delft University of Technology
EDF
ferrovial
aena
ENERCON ENERGIE FÜR DIE WELT
BOMBARDIER
IBERDROLA
Takara Leben
AÉROPORTS DE PARIS

LISA DICAPRIO, FEBRUARY 26, 2018 STATEMENT IN SUPPORT OF Int. 48-2018, Int. 50-2018, and Resolution 0176-2018

My name is Lisa DiCaprio. I am a professor of Social Sciences at NYU where I teach courses on sustainability.

Thank you to Committee Chair Costa Constantindes for your environmental initiatives and the opportunity to speak at today's hearing in support of two urban wind turbine bills and a resolution on offshore wind.

URBAN WIND TURBINE BILLS: The urban wind turbine bills introduced by Committee Chair Costa Constantinides will facilitate the realization of NYC's urban wind potential. The legal framework for both bills, including appropriate siting, is provided by the 2012 NYC Green Zone Amendment. (See: http://www1.nyc.gov/assets/planning/download/pdf/plans/zone-green/zone_green.pdf)

Int. 50-2018 defines urban wind turbines as 100 kw or less and provides several specification, such as sound level, design standards, wind speed, and access, that will allow for the protection of public safety in the operation of urban wind turbines. For example, the wind turbines "shall be designed to withstand winds of up to and including 130 mph..."

The wind assessment map mandated by Int. 48-2018 will provide small wind companies and building owners with the information required to evaluate the feasibility of urban wind projects. This urban wind turbine bill will complement Int. 0609-2015A which mandates identifying buildings appropriate for geothermal systems. The geothermal bill, also introduced by Committee Chair Constantinides, was passed by the City Council and signed into law by Mayor de Blasio on January 5, 2016. (See: http://legistar.council.nyc.gov/LegislationDetail.aspx?ID=2119778&GUID=E12FA77F-832A-48CC-96B6-0231AB028D1C&Options=&Search)

RESOLUTION 0176-2018 IN SUPPORT OF OFFSHORE WIND:

With regard to the offshore wind resolution introduced by Council Member Donovan Richards, several environmental organizations, including the Sierra Club, have advocated for offshore wind for several years in various ways, including participation in the New York Offshore Wind Alliance (NYOWA).

As outlined in the proposed resolution, the Long Island – New York City Offshore Wind Collaborative has determined the feasibility of large-scale offshore wind in the Atlantic Ocean south of Long Island. Offshore wind is crucial for realizing the Public Service Commission's 2016 Clean Energy Standard ruling that all NYS utilities must distribute 50% of their electricity from renewable sources by 2030.

City Council support for Governor Cuomo's commitment to the development of 2,400 MW of offshore wind by 2030 is especially meaningful at this time for these four main reasons:

1. We must highlight the environmental benefits of offshore wind and oppose the Trump administration's reversal of President Obama's moratorium on offshore drilling for oil and gas along the Atlantic and Pacific coasts.

2. The New York State Offshore Master Plan (https://www.nyserda.ny.gov/All-Programs/Programs/Offshore-Wind/New-York-Offshore-Wind-Master-Plan has identified several potential locations in the Long Island – NYC area for supply chain manufacturing, which will create new employment opportunities and could establish NYC as a hub for offshore development on the Atlantic Coast. (See: The New York State Offshore Wind Master Plan: The Workforce Opportunity of Offshore Wind in New York file:///C:/Users/ed67/AppData/Local/Temp/17-25t-Workforce-Opportunity-Study.pdf)

3. By developing offshore wind farms in the Long Island – NYC area, we can create models for large-scale wind projects along the Atlantic Coast, which will provide locally-sourced wind power to several urban areas.

4. Scaling up offshore wind will reduce its cost and facilitate technological innovations.

1. First, we are already benefiting from the achievements of Deepwater Wind which developed the first wind farm in the U.S.; specifically, the wind farm on Block Island between Rhode Island and Massachusetts.

2. Secondly, we will benefit from the experience of European offshore wind farm developers. In January 2017, Statoil won the Bureau of Ocean Energy Management (BOEM) bid for the New York Wind Energy Area that comprises 79,350 acres and has the potential for generating 1 GW of electricity. Statoil will construct wind farms with turbines that have a nameplate capacity of 10 MW and integrated battery storage which will allow for the transmission of electricity into the grid without the intermittency typically associated with solar and wind power. (For information on Statoil and integrated battery storage, see: https://www.greentechmedia.com/articles/read/statoil-adds-battery-storage-to-offshore-wind#gs.smJxNfs)

With these initiatives, the City Council is demonstrating its leadership in promoting renewable energy and keeping fossil fuels in the ground.

Committee on Environmental Protection - Res 0176-2018
February 26th 2018
Ryan Chavez, Infrastructure Coordinator, UPROSE

Good morning Mr. Chairman and members of the committee. My name is Ryan Chavez and I am Infrastructure Coordinator at UPROSE. We are an environmental and social justice organization based in Sunset Park, Brooklyn and part of the leadership of the national climate justice movement.

We applaud the Governor's commitment to the development of large-scale offshore wind projects by 2030 – and this committee's resolution to support this goal.

New York's most vulnerable communities were disproportionally affected by Sandy. These same communities, like Sunset Park, have also been overburdened by fossil-fuel power plants.

Many of these same communities have previously been homes to active blue-collar industries and manufacturing. Today, communities like Sunset Park face significant displacement threats as industrial land is repositioned for upscale commercial development. Sunset Park is home to one of the City's last working waterfronts. It is also a target of rampant commercial speculation. If we allow our manufacturing and industrial properties to be rezoned or repurposed to serve dated models of commercial real estate development, we lose the opportunity to build for climate adaption locally.

Offshore wind can deliver power directly to New York City, displacing the need for dirty power plants. But just as importantly, it provides an opportunity to position the city at the center of this emerging industry, driving local economic development.

The City should do two primary things to support this industry and take advantage of its economic potential. First, the City can leverage its buying power to catalyze the construction of offshore wind farms. Second, the City can prioritize offshore wind uses at its ports and waterfront industrial sites.

This industry could revitalize our working waterfront and create thousands of blue-collar industrial jobs. The Department of Energy expects 40,000 new jobs in the sector by 2030. Those jobs will be located wherever the ports and workforce are.

This could drive our region away from fossil fuels that threaten our climate and blunt the forces of real estate speculation that are disrupting our communities. An offshore wind hub in Sunset Park would serve as an innovative model of economic development that would transform our energy system and provide pathways to the middle class at the same time. It would act a bulwark against extractive real estate interests and position the city as a leader on climate change nationally.

Siempre En Lucha Y Siempre Por Nuestra Gente
166A 22nd Street Brooklyn, NY 11232 (t) 718 492 9307 (f) 718 492 9030
www.uprose.org

These actions will bring to New York reliable locally- sourced renewable energy and new career pathways for working-class communities like Sunset Park. Unlike other large-scale sources of clean energy, the economic benefits of offshore wind will accrue in communities right here in the City.

We again commend this committee for its support for offshore wind – and encourage you to recognize and push for its full potential and impact.

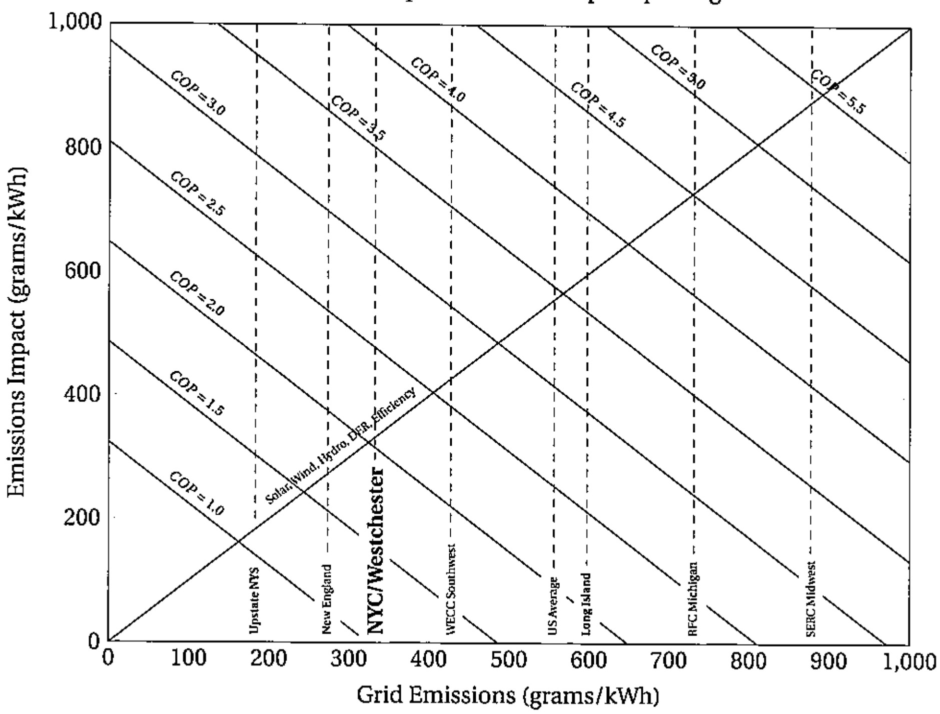
Thank you very much for the opportunity to comment.

In January 2017, Brattle group released a report, *Electrification: Emerging Opportunities for Utility Growth*[1], showing that between now and 2050, in order to achieve our carbon emission reduction goals, consumption of electricity will need to at least double. The cause of this demand growth will be **Environmentally Beneficial Electrification**, achieved by fuel-switching, from fossil fuels to electricity in electric vehicles and heat pumps.

Thus, when evaluating the need for new, alternative electricity generation, we should avoid undershooting our goals by focusing only on today's level of demand, rather, we should look forward to a future when energy will be delivered to homes and buildings primarily as electricity.

Wind power is particularly well suited to address the demand from Beneficial Electrification since wind generation is often strong at night and during the winter; when traditional electricity demand is typically lower but also when the demand for vehicle charging and heat pump operation is highest. It should also be noted that when the wind is strongest it increases building's heat loss. Thus, as the wind speed increases, one will see an increased demand for electricity for heat pumps.

Emissions Impact of Heat Pumps Replacing Oil

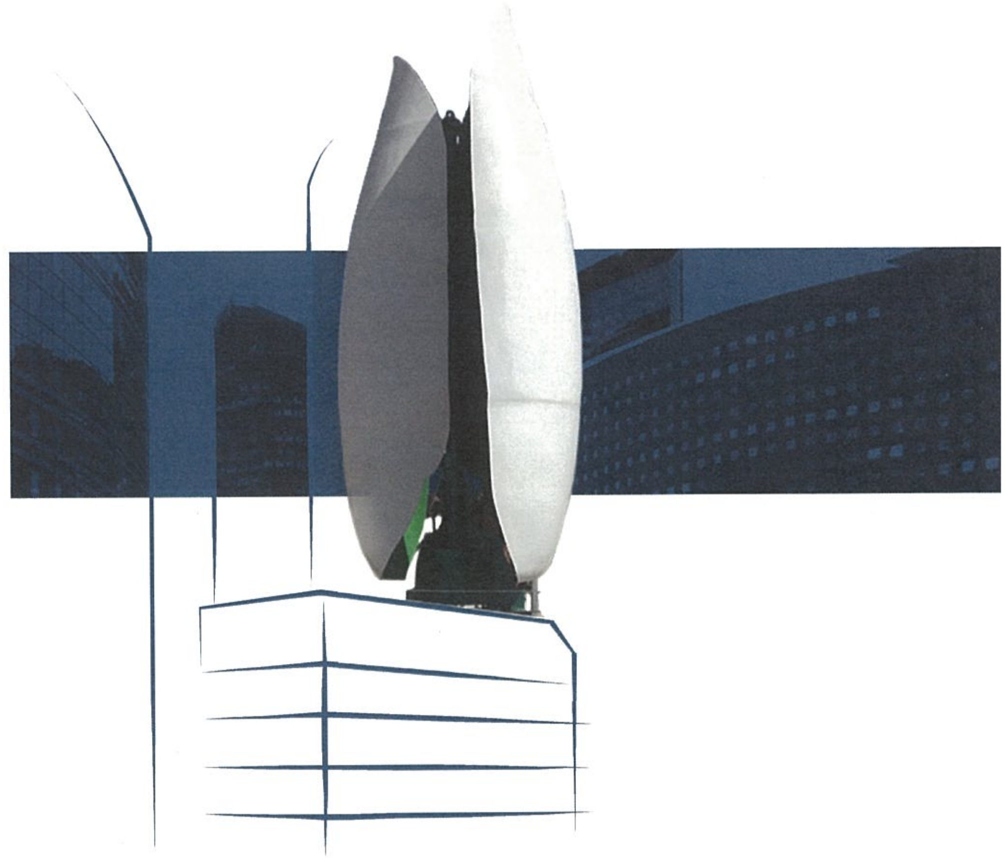


The graph above shows, for various electric grid emissions factors, the carbon reduction from replacing oil heat with electrically powered heat pumps at various coefficients of performance (Note: The Energy Star minimum COP for a closed-loop geothermal heat pump is 3.6). Also shown is the benefit from replacing grid generation with wind or solar generation. Note that an additional kWh of electrical consumption by a heat pump in NYC produces a greater reduction in carbon emissions than would an additional kWh of electricity generated using wind or solar. As the grid emissions decrease and Beneficial Electrification increases, we will benefit not just by eliminating the emissions from electricity generation, but also by eliminating emissions from combustion of fossil fuels for heating, transportation, etc.

[1] http://files.brattle.com/system/news/pdfs/000/001/174/original/electrification_whitepaper_final_single_pages.pdf

Flower Turbines, LLC

The First Wind Power Solution for Dense Urban Environments



Dr. Daniel Farb, CEO

dfarb@flowerturbines.com

+1-631-552-0284

Introduction and Qualifications

Dr. Daniel Farb

-Grew up in Manhattan; currently in Long Island/Israel; story about wind and Riverside Drive
-Yale undergrad: only student in history to take a double load in one semester, and get all As
-Medical School, Boston University
-Executive Management, UCLA
-30 patents in renewable energy
-Author of 100 books and training programs, many in management
-Tech for wind developed in Israel along with team that included professor of aerodynamics: The Tulips were second place in the Cleantech Open. Chosen as one of Israel's top 45 innovations by the Bloomfield Science Museum; still on exhibit.
-First small wind turbine connected to Israeli grid
-Eurogia label for technological excellence
-Appeared on Fox Business News as an expert on wind energy
-Wind energy expert for the Terranaut forum at Council for Foreign Relations, Washington, DC
-Spoke to Congress in 2015 about renewable energy to represent NHA
-Working with Stony Brook University professors; received some grants for developing technology in NY

nfo@flowerturbines.com | Tel: +1-631-552-0284 US

Problems With Traditional Turbines

- Too big, but even when small...
- Noise and vibration
- Density causes turbulence
- Minimum starting speed 3 meters/second (6.7 miles/hour)

info@flowerturbines.com | Tel: +1-631-552-0284 US

Flower Turbines Solution

Small ~3 meter (118") diameter footprint

Quiet, less than the wind itself

Density improves turbine performance (+20% to 50%)

1.2 meters/second (2.7 miles/hour) starting wind speed

nfo@flowerturbines.com | Tel: +1-631-552-0284 US

Types of Turbines

Efficiency When
Separated (5 diameters)

Lift
HAWT
Noisy

Lift VAWT
Noisy
Cut-in 3 m/s

Drag VAWT
Low efficiency
Too many blades

The Tulips bring drag turbines into the efficiency range of lift but keep the low noise and vibration.

info@flowerturbines.com | Tel: +1-631-552-0284 US

How It Looks

nfo@flowerturbines.com | Tel: +1-631-552-0284 US

Turbulence – Major Enemy of Efficiency

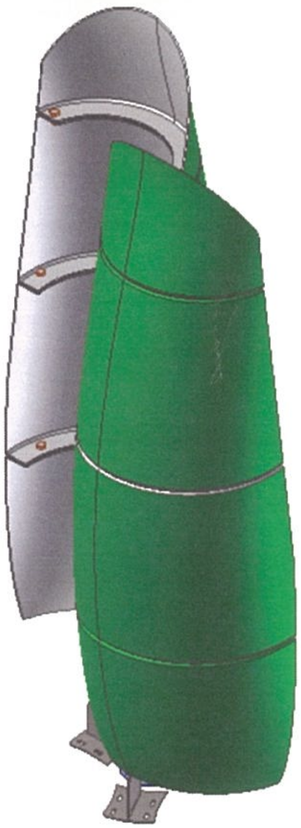
We solve the 3 sources of turbulence:

1. Within the turbine
2. Turbine to turbine
3. Building to turbine

We have a patent addressing each

info@flowerturbines.com | Tel: +1-631-552-0284 US

Decreased Blade Turbulence



Turbulent areas are divided by horizontal ribs according to a specific formula

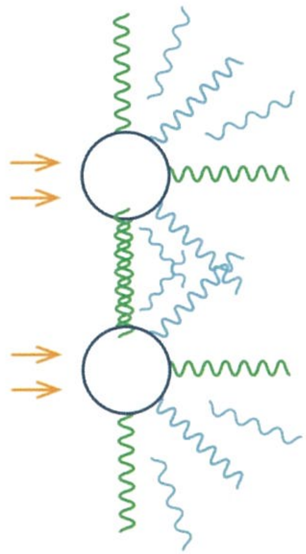
1

nfo@flowerturbines.com | Tel: +1-631-552-0284 US

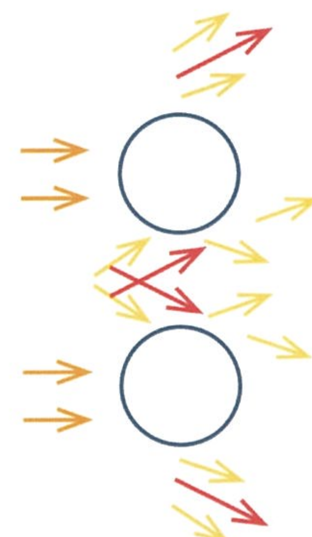
Cluster Effect

2

Theirs:
Turbulence reduces efficiency -50%



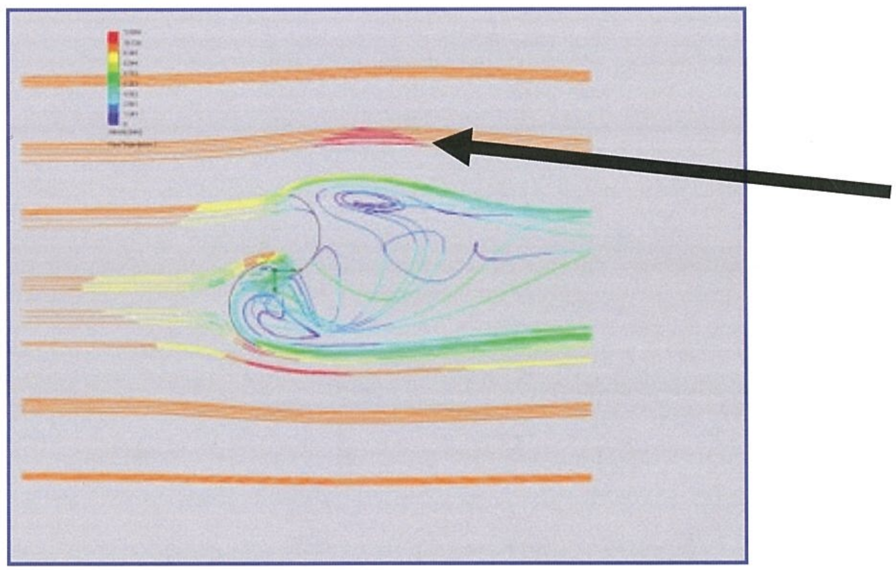
Ours:
Cluster Effect increases efficiency +20-50%



info@flowerturbines.com | Tel: +1-631-552-0284 US

Engineering Simulation

- Below is a computer simulation of flow trajectories around the 2-Bladed Wind Tulip.
- Note the higher velocity streams (*reddish brown*) starting at a calculated *"specific ratio times the diameter"* on each side of the turbine.

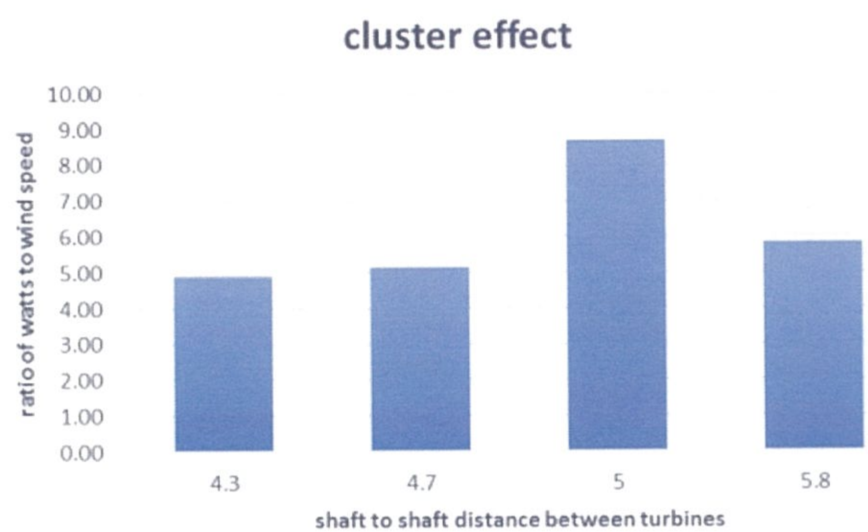


nfo@flowerturbines.com | Tel: +1-631-552-0284 US

Synergistic Clustering

We have 20-50% improvement by clustering at a distance formula.

Graph shows power spike at correct distance from one turbine to another:



info@flowerturbines.com | Tel: +1-631-552-0284 US

What's Wrong with This Picture? Whole Foods in Brooklyn

nfo@flowerturbines.com | Tel: +1-631-552-0284 US

Building to Turbine

3

Use of spoiler and other roof aerodynamics enables less turbulent rooftop wind aimed at the turbine.

info@flowerturbines.com | Tel: +1-631-552-0284 US

Flower Turbines Compares Favorably to Solar

	Solar	Flower Turbines
Number of kilowatts	20	20
Space in square meters (example: 10 story apt. building)	148.7	122
Cost of system with 30% Federal tax subsidy	$48,980	$70,000
Value of electricity per year	$4381	$6400
Payback period (years)	11	10.9
Revenue per square meter	$29	**$52** 80% Higher

* Zip Code 02532 on Cape Cod

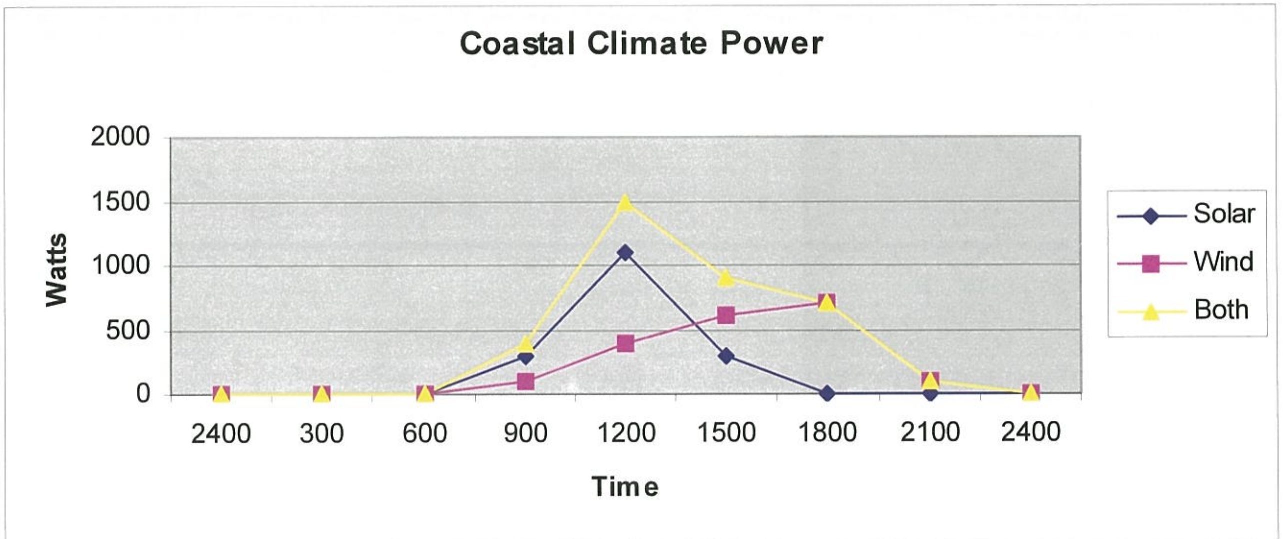
nfo@flowerturbines.com | Tel: +1-631-552-0284 US

Competition

Competition	Flower Turbines	Lift Vertical	Helix	Other Drag Vertical	HAWT
Efficiency in dense settings	✓✓✓			✓	
Starts at Low Speeds	✓✓✓			✓	
Low maintenance and opex	✓✓✓		✓	✓	
Durability in High Winds	✓✓✓	✓	✓	✓✓	✓
Quiet	✓✓✓			✓✓	
Low bird risk	✓✓✓	✓	✓	✓✓	

info@flowerturbines.com | Tel: +1-631-552-0284 US

Coastal and Grid Issues



Wind best approximates peak power demand.
Wind and solar give wider coverage.

nfo@flowerturbines.com | Tel: +1-631-552-0284 US

New York Issues

High cost of energy

Pollution and wellness

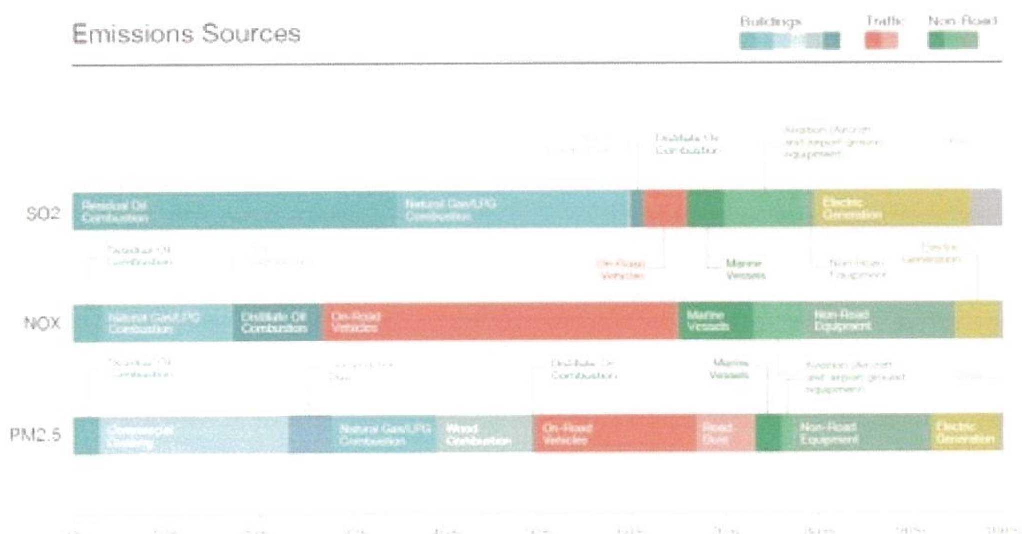
Vulnerability to breakdown in power supply; rare but significant blackouts

Regulation to produce energy locally

info@flowerturbines.com | Tel: +1-631-552-0284 US

Water Heating Issue For New York City

-Large housing stock using carbon sources—expensive and dirty
-Current cost of electricity is around $0.20/kilowatt hour; cost of diesel is around $0.40.
-Source of pollution in NY
-Vulnerability to supply disruption (Sandy, for example)



https://www1.nyc.gov/assets/doh/downloads/pdf/environmental/comm-air-survey-08-13.pdf

Blue is for Buildings

info@flowerturbines.com | Tel: +1-631-552-0284 US

Water Heating Economics

1 person using 120 therms/year	Flower Turbines	Gas	Oil	Wind with Oil as Backup	Solar
$ Cost of system	9200	5000	1400	10600	10000
$ Capex Cost for 120 therms/year in area of 6 m/s (9200=>>170 therms/year)	6494	5000	1400	7894	10000
$ Yearly cost of fuel	0	228	654	50	0
$ Maintenance per year	0	100	100	50	0
$ Cost for 20 years	6494	11560	20080	9894	10000
$ Cost for 6 years	6494	6968	5924	8494	10000

info@flowerturbines.com | Tel: +1-631-552-0284 US

How Flower Turbines Would Like to Start

For Flower Turbines:

1. Project of at least 10 in area of good wind and low buildings, flat roof, large building.
2. Projects for smaller homes, smaller turbines for slanted roofs. We need an order of 100 at one time to make smaller ones that are compatible with solar systems.
3. Rooftop hot water demonstration project of 10 turbines on apartment building with large flat roof and document decreased use of fuel.

For all companies: Low cost regulation with quick results

nfo@flowerturbines.com | Tel: +1-631-552-0284 US

Regulations Needed

Needs to be easy and cost effective

Automatic permitting level, such as drag type turbines below 10 meters above rooftop, can assume low sound

Don't add it to tax assessments

Financing—loans, or bank loan guarantees if done right, costs nothing.

PACE program. City buildings to offer opportunities

Safety criteria—tougher for skyscrapers, reasonable, clear.

Piloting sites available

Encouraging NY firms—maybe extra benefit for NY region headquarters or jobs

info@flowerturbines.com | Tel: +1-631-552-0284 US

Comments on Proposed Regulations Page 1

24-232.1: Needs to specify at which wind speed
28-319.2 Removal: Allow for refurbishment on site
426.2 Definition of 100 kw is very high and big: I recommend dividing regulation into two categories. One is areas close to people and buildings, for 5 kw per turbine; and uninhabited areas, defined as 5x turbine diameter from locations with people and buildings
426.3: This standardization effectively limits turbines such as ours because those standards require about $200,000 in testing costs, and only HAWTs have, for the most part, gone for that.
426.5 Brakes and locks: Why not say a lock and a brake and keep it simple?
426.5.1: Who is responsible? The owner? The owner of the location?

nfo@flowerturbines.com | Tel: +1-631-552-0284 US

Comments on Proposed Regulations Page 2

426.6: Specifying the visual appearance: Leave it out, or then you have to put white on a brown building. Also keeps it from being used for corporations and billboards. That could stop us from making a beautiful set of colored tulips in a park.

426.7: Why not artificially lighted?

426.8: Is the locking of the control room good enough?

426.8.2: Fencing off or restricted access should be adequate.

426.10 Shadow flicker: How about exempting those with 90% solidity that don't have flicker

426.11: Drag turbines won't interfere as long as they are lower.

426.12: Setback: What is the reason?

Question: Can one put aerodynamic spoilers on the edge?

Let's talk about height.

info@flowerturbines.com | Tel: +1-631-552-0284 US

Waterfront Regulation

The drag type will not be a safety issue and will not interfere with public's ability to enjoy the areas. It depends where on the waterfront.

This is a good area for our turbines. Let's not exclude it.

nfo@flowerturbines.com | Tel: +1-631-552-0284 US

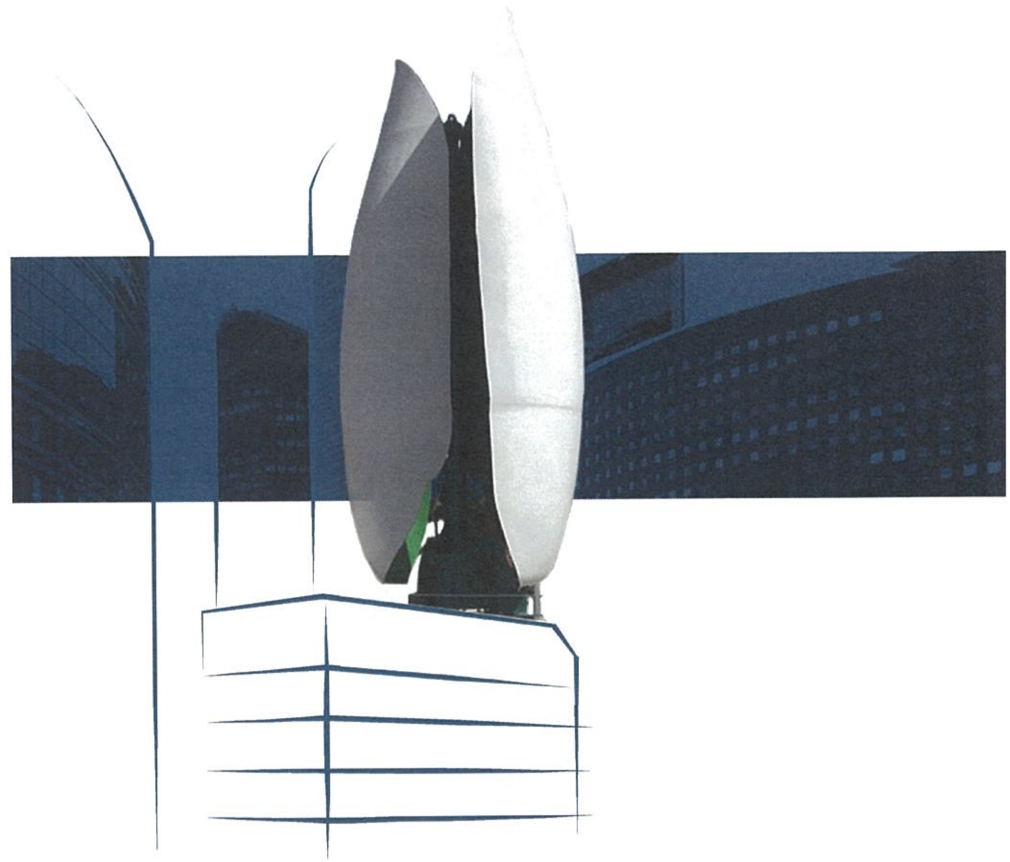
Flower Turbines, LLC

The First Wind Power Solution for Dense Urban Environments

Dr. Daniel Farb, CEO

dfarb@flowerturbines.com

+1-631-552-0284



Comments on proposed Int. 50 on small wind generators.

Noise: 24-232.1 and 426.9 both refer to a limit of 5 db above ambient. This is not a workable way to define the limits. As stated it could be interpreted to be an ongoing requirement where the neighbor could challenge again and again and force repeated testing. If at any time the ambient noise was unusually low the wind turbine would have to be shut down or removed. If ambient is used (and I don't think that it should be) then a procedure should be specified that establishes ambient at a site and as long as the turbine is certified to operate at a sound level of less than the ambient plus 5 it is allowed. All certified wind generators are tested acoustically and have a sound power rating. Better is to establish a maximum rated sound level so a certified turbine either does or does not meet the standard. The AWEA standard is sound level at 60 meters from the rotor. Requiring a level of less than 55 on that standard would be reasonable.

There are straight forward rules for converting sound levels from the certification tests to sound levels at any distance so adjusting for the distance to a property line does not present a problem. That part can work. Any requirement for on site testing is challenging. In order to do the certification testing the personnel doing the testing often have to work in the middle of the night to get enough difference between the turbine sound level and ambient. Crickets or any traffic noise prevent getting useful data. Getting good data and processing it to eliminate random noise costs thousands of dollars.

426.1 General: I suggest that "shall be designed and constructed____" be replaced with "shall be certified and Listed and installed per the requirements of the NEC and UBC."

426.3 states that the turbine shall be designed in accordance with: and then goes on to allow the commissioner to make any standards in addition to those listed. That appears to allow the commissioner to make any rules with no limits or consent of interested parties. That is not a standard it is a rule. Further the standards organizations listed are in some cases not standards writing bodies. For instance the National Renewable Energy Lab, New York State energy Research and Development authority, California Energy Commission, and Small Wind Certification Council are not a standards writing bodies. The applicable standards for small wind generators are the AWEA SWT1 standard (from American Wind Energy Association) and the IEC 61400-2 international standard (from International Electrotechnical Commission). Both cover small wind generators up to 200 square meters rotor swept area. Wind generators with more than 200 square meters of swept area are covered by the IEC 61400-1 standard. Wind generators that are over 200 m2 and under 100 kW are considered small but are certified to the same standard as the multi-MW utility turbines (IEC 61400-1). Further there are UL standards that are primarily for electrical safety. They are UL 6142 or 6141. UL 6142 is for wind generators that are serviced or operated without going inside the turbine. UL 6141 is for usually larger turbines where service work involves going inside a turbine. No other standards are necessary. These standards were developed over years with input from all stakeholders and are regularly updated. There is also a section of the National Electric Code (NEC) that covers the electrical installation of wind generators. If NYC adapts the NEC then the certification and Listing of small wind generators is already required in NYC as of the NEC 2017 edition.

426.4 sets the design wind speed for small wind generators. The Universal Building Code establishes wind speed design requirements for all locations in the United States with adjustments for height and exposure. These standards are well known to structural and civil engineers and every building constructed in NYC is being built to this code. Why add something new and duplicative or contradictory?

426.10 covers shadow flicker. It provides for the commissioner to establish rules that limit shadow flicker to the extent practicable. Shadow flicker location varies over a wide distance that varies by time of day and time of year. The impact on available sites will depend on the definition of practicable. I understand that this can be a problem if a wind generator causes flicker in a retail, residential or work space many days of the year during a prime operating time. On the other hand eliminating all instances of any person being exposed to shadow flicker will eliminate most potential sites. This proposed rule is essentially no rule or even guidance so no one will know what to expect.

426.12 on Signal interference involves another of the rules using "to the extent practicable". A small wind generator is not likely to impact any signal other than radar and microwave. In the case of microwave, it is a point to point signal so only sites where the turbine would be right in the line between two nodes would be affected. I think you can safely eliminate the other types of signal from the rule. I am not a radio expert so you will definitely want to consult one before changing this.

In summary there is a body of standards and regulations that already exist and should be carefully reviewed before adding rules that might not be workable or consistent with the existing rules. These standards are typically developed in a consensus forum by experts representing all of the stakeholder groups. I have learned to have a deep appreciation for the time and effort that goes into the development and maintenance of these standards. Having served through 4 code cycles on the NEC and participated in the sometimes contentious process finding workable solutions the value of that process is clear to me.

REagards,

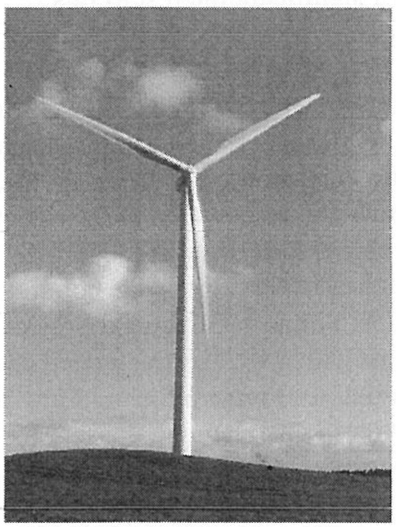
Robert Preus

Statement to the New York City Environmental Protection Committee
On Facilitating the Use of Wind Power in New York City
February 26th, 2018

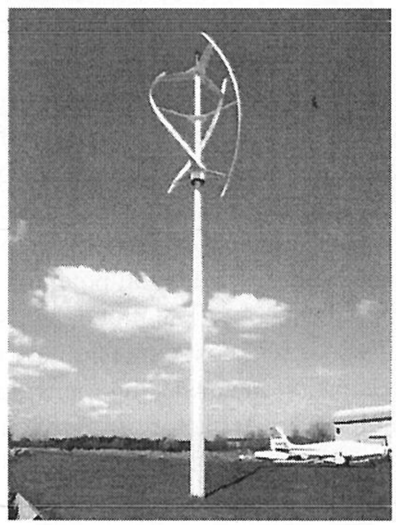
Testimony by Ian Brownstein, Stanford University and XFlow Energy Company

Good afternoon and thank you for the opportunity to testify before you today. My name is Ian Brownstein and I am a PhD Candidate in the Mechanical Engineering Department at Stanford University. My PhD research has focused wind power with an emphasis on optimizing the energy output of groupings of vertical-axis wind turbines. Additionally, I am a co-founder of the XFlow Energy Company, a startup seeking to develop high-performance vertical-axis wind turbine technologies.

Many people are familiar with the traditional three-bladed wind turbines which dominate the wind energy today. These turbines are known as horizontal-axis turbines since they rotate on an axis parallel to the ground. In contrast, vertical-axis wind turbines rotate on an axis perpendicular to the ground. Images of both turbines are provided below.



Example of a Horizontal-Axis Wind Turbine



Example of a Vertical-axis wind turbine

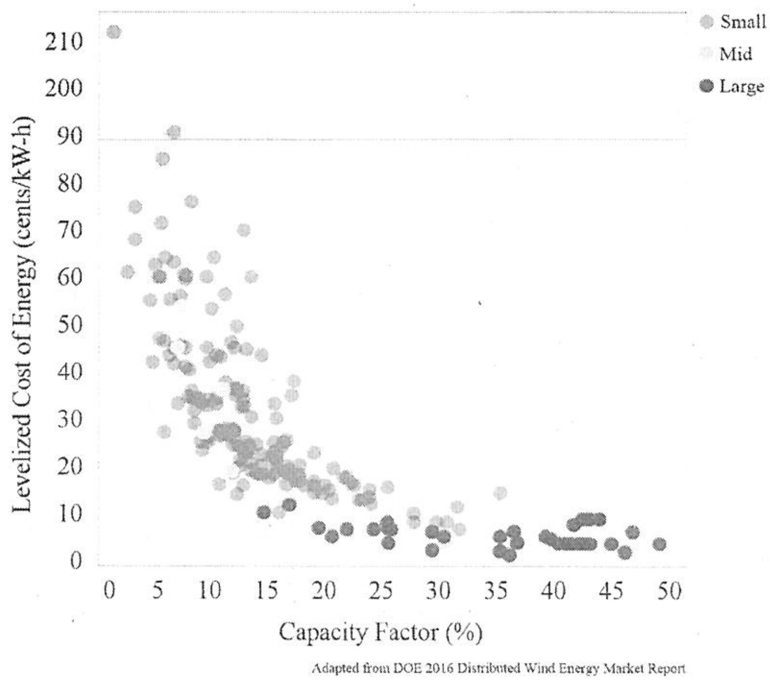
Vertical-axis wind turbines have a number of advantages for urban wind energy capture compared to the more commonly seen horizontal-axis wind turbines. Due to the differences in rotor geometry, vertical-axis wind turbines are omni-directional, meaning they do not need to turn into the wind. This means they can operate more effectively in the presence of the turbulent wind conditions typical of urban environments. Additionally, vertical-axis wind turbines are mechanically simpler than horizontal-axis wind turbines, reducing the potential maintenance costs of the turbine over its lifespan. One example of this simplicity is that the generator and electrical components of the turbine can be installed at the base of the turbine tower, providing easier access for regular maintenance and inspections. Providing this ease of inspection is essential for turbines installed on rooftops, where a crane may otherwise be needed.

Critically, vertical-axis wind turbines can extract significantly more wind per unit area of land than horizontal-axis wind turbines. This means, for a given rooftop available for wind turbine installation, a grouping of vertical-axis wind turbines could collect at least eight times more power than a similar group of horizontal-axis wind turbines. Since space for wind turbine installations is limited in New York City, this additional energy capture would go a long way in increasing the effectiveness of small wind turbines installed under the proposed legislation.

Regardless of the technology used, wind energy is only effective in locations were the wind resource is significant throughout the year. In a complex urban environment like New York City, this can only be assessed through detailed wind maps, like those which would be collected if Initiative Number 48 passes into law.

To demonstrate the importance of well characterizing New York City's wind resource on the cost of any future wind projects, the plot below was adapted from the Department of Energy's *2016 Distributed Wind Energy Market Report*. In the plots color scheme, small wind turbines are defined to be <100 kW in size, large turbines are defined to be >1 MW in size, and mid-size turbines are between 100 kW- 1 MW. Since Initiative 50 proposes that wind turbines in New York City would be <100 kW, the small turbine data are of significant interest to this conversation.

This plot shows the levelized cost of energy on its vertical axis, which is an average cost of energy produced by the turbine over its life cycle; including the costs of financing, installation, operation, and maintenance. Low values on this axis represent a lower cost of energy. The capacity factor of the location where a each turbine was installed is shown on the horizontal plot axis. The capacity factor, expressed as a percentage, is a project's actual annual energy production divided by its annual potential energy production if it were to operate continuously at its full nominal capacity. The plot demonstrates the simple but important fact that projects with less annual winds will cost exponentially more than projects with a well-characterized and significant capacity factor. Using the wind maps which Initiative Number 48 would provide, a wind project's capacity factor can be accurately estimated during its planning phase. This will allow the economic viability and potential power output of a wind project to be judged before any investment is made.



In conclusion, I am in support of Initiatives 48 and 50 because they are both essential for quickly deploying small wind turbines throughout New York City. Initiative Numer 48 will ensure that any potential small wind projects in New York City operate at a low cost of energy. Additionally, Initiative Number 50 paves the necessary guidelines for small wind turbines to be installed in the city.

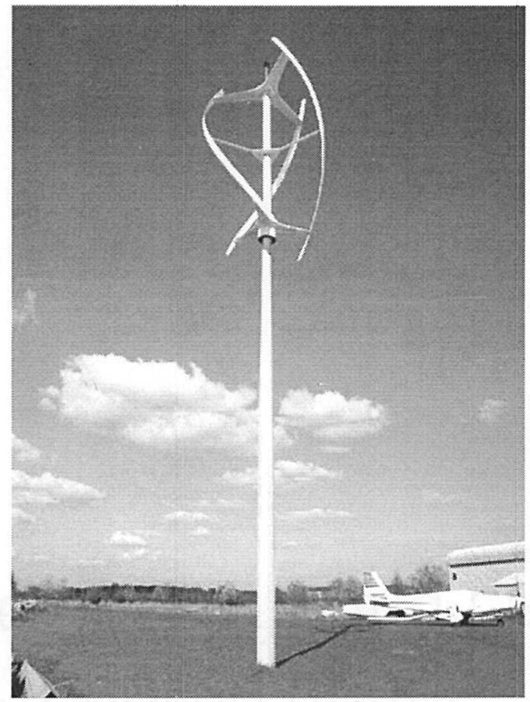
In combination, I believe these two pieces of proposed legislation will allow New York City to develop the best version of any potential wind projects in the city.

Thank you for your time,
Ian Brownstein

Ian B

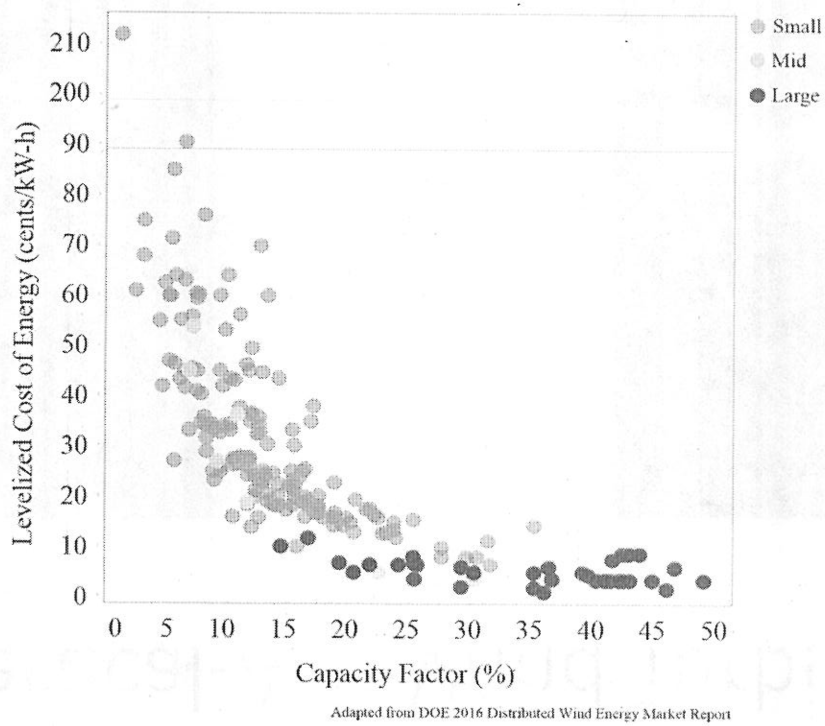
What is a Vertical-Axis Wind Turbine?

Example of a Horizontal-Axis Wind Turbine



Example of a Vertical-Axis Wind Turbine

The Wind Resource Assessments Proposed under Initiative # 48 Will Help Reduce the Cost of Wind Energy



166A 22nd Street
Brooklyn, NY 11232 NYC-EJA.org

On the ground – and at the table

New York City Environmental Justice Alliance testimony to the New York City Council Committee on Environmental Protection in relation to Facilitating the Use of Wind Power in New York City, and in support of Intro 598.

February 26, 2018

Good morning Chairperson Constantinides, Speaker Johnson, and Members of the City Council. My name is Kartik Amarnath and on behalf of the New York City Environmental Justice Alliance (NYC-EJA), I am here to testify in support of facilitating the City's use of wind power. Founded in 1991, NYC-EJA is a non-profit citywide membership network linking grassroots organizations from low-income neighborhoods and communities of color in their struggle for environmental justice. Through our efforts, member organizations coalesce around common issues that threaten the ability of low-income communities of color to thrive, and coordinate campaigns designed to affect City and State policies, including energy policies that impact these communities.

Because a number of the NYC-EJA member organizations come from communities overburdened by greenhouse emissions and co-pollutants from power plants and dirty industries clustered in their neighborhoods, our organization is a key advocate of emission reduction and renewable energy targets. Our NYC Climate Justice Agenda is a multi-year research and advocacy campaign to address the need for a comprehensive community-based approach to community resiliency. In 2017, we released a report which analyzed Mayor de Blasio's OneNYC plan and made several recommendations to strengthen the City's policies in environmental justice communities, including committing to an offshore wind power purchase agreement. We highlighted that in addition to its promising economic potential, wind power - particularly through large-scale offshore wind development - can have extensive environmental and health benefits in vulnerable communities who have been historically exposed to noxious pollutants generated from fossil fuel energy infrastructure. Resilient energy systems, including wind power coupled with energy storage, have the potential to displace inefficient and dirty peaking plants, thus significantly reducing air pollution in environmental justice communities. The City should study, prioritize, and streamline the deployment of wind power systems in the coming years. The City should also study progress made to date and strategies to reduce barriers for wind development including technical, policy, and regulatory barriers.

We recommend that any offshore wind power cost-benefit analyses include economic, social, environmental, and resiliency benefits inclusive of robust equity metrics. We are confident that a cost-benefit analysis that is truly inclusive of all co-benefits would justify the procurement of wind power, despite potentially high initial costs, due to long-term net benefits such as the establishment of local renewable energy industries that bring sustainable jobs to the City. We also support Intro 598 because requiring all city-owned buildings to be powered by green energy sources by 2050 can be an important step in catalyzing local offshore wind and renewable energy industries. In pursuit of a Just Transition, New York City should be leading the nation in the procurement of large scale renewable and resilient energy technologies that meet ambitious emission reduction targets with strong environmental justice principles and labor standards.

NYC-EJA commends the New York City Council for holding a hearing on facilitating the use of wind power, and creating an opportunity for public comment on this important strategy to increase community resiliency. A just energy policy is central to NYC-EJA 's work, and we look forward to a continued collaboration with the City to mitigate the threats of climate change while optimizing economic, health, and environmental benefits for the most burdened and climate vulnerable New Yorkers.

New York City Council Hearing, February 26, 2018, 250 Broadway, NYC
Intro 1726-2017 Detailed Wind Resource Assessment; Zone Green Text Amendment
Intro 1727-2017 Wind Turbines 100KW or Less Amendment Noise Control Code, Z.G.
Resolution to Support Gov. Cuomo in the Development of Large-Scale Offshore Wind
Costa Constantinides, Jimmy Bramer, Margaret Chin

I, Catherine Skopic, am here today as a New Yorker, US citizen, parent and artist/activist having worked with Sierra Club, Interfaith Moral Action on Climate and the People's Climate Movement.

By Divine Creator, science or both, it took **4.6 billion** years of cosmic construction to form our planet flourishing with its rich variety of life thanks to conditions such as optimal chemical make-up of our planetary core, water and position in our solar system, yet, we could destroy it all in 2 decades if we continue to burn fossil fuels. The existential threat is great for life, our children and all future generations who cannot speak for themselves and for whom I humbly speak now. Time is short to make these urgently needed major changes in our energy systems.

That's why I work with and applaud all those individuals, organizations and leaders who are dedicated to moving us forward to renewable energy such as solar, wind, geothermal, and tidal. (Incidentally, in regard to tidal, I recently learned that there is a project underway at the Bay of Fundy to harness the power of their extreme changing tides.) Here and In particular, I thank, Costa Constantinides, Margaret Chin and Jimmy Vacca of the New York City Council for having introduced these two bills enabling wind turbines to be part of our energy mix here in New York City and for their support of the resolution to support Governor Cuomo in the development of offshore wind for New York State helping us achieve the goal of 50% of New York State's electricity coming from renewable sources by 2030.

I applaud educators who are preparing students and all citizens to accept and support wind turbines as a welcome part of our energy supply helping to improve our health, protect the environment and enabling us to achieve our local and state life-saving energy goals.

You may have noticed the wind turbines I painted on my dress. This is the horizontal axis type most of us visualize when we think of wind turbines; however, there are many designs for wind turbines. Here is an example of a vertical axis (wind) turbine or VAT. These can be installed on vertical walls of buildings, originally designed into a building or made as free-standing structures combined with solar and placed in parking lots to serve as electric vehicle chargers.

In 2012, I attended the 20th Anniversary of the First United Nations Global Climate Conference in Rio de Janeiro, Brazil; the UN Global Climate Conference in Lima, Peru 2014, and the COP 21, Global Climate Conference in Paris, France 2015. There,195 countries agreed to support the Global Climate Accord with its monetary commitment to the Green Fund and its climate commitment to keep our global warming to1.5 degrees Celsius or less. Nation-wide, it is our local and state leadership on climate actions that are effectively keeping us in the Paris Accord, despite Federal withdrawal and lack of leadership. This is a global reason for supporting our New York City Council members in this significant legislation; and I applaud you all!

Respectfully and in PEACE, Catherine Skopic
Vice-Chair, Sierra Club New York City Group
Chair, Shut Down Indian Point Now
Steering Committee and Board of Directors, Interfaith Moral Action on Climate

February 26, 2018

Dear Chairman Constantinides:

My name is Ling Tsou. I'm a co-founder of United for Action, a grassroots group in New York City working to end our addiction to fossil fuel and nuclear power and advocating for renewable energy. I'm here to express our support for Int 48 and Int 50.

2017 was the third hottest year on record, ranked behind 2016 and 2015 according to scientists at the National Oceanic and Atmospheric Administration. This is part of the long term warming trend. Renewable energy such as wind and solar is our best chance to reverse global warming and reduce harmful greenhouse gas emissions. Int 48 introduces the creation of wind maps which will help demonstrate wind energy generation potential in New York City much as the creation of solar maps which helps to demonstrate the solar energy generation potential in New York City. This bill is a step in the right direction.

A group of us from United for Action visited the Sims Municipal Recycling plant in Sunset Park, Brooklyn about two years ago. We saw the wind turbine turning gracefully generating electricity for the recycling plant. Even when we were standing right beneath the wind turbine, we could not hear much of any noise from the wind turbine. The only other urban wind turbine I'm aware of in New York City is the wind turbine at the Whole Foods Supermarket at Gowanus in Brooklyn. The passage of Int 48 and Int 50 would hopefully spur the construction and development of more urban wind turbines in New York City.

Offshore wind is potentially the best option for delivering large scale renewable electricity generation to New York City and Long Island. Offshore wind power will not only reduce greenhouse gas emissions and fossil fuel use for New York City, it will also generate jobs and stimulate local economy. With climate change and sea level rising, time is of the essence. New York City needs to begin developing offshore wind power now. We commend Governor Cuomo for committing to the development of large scale offshore wind farm in New York. We support and urge New York City Council to pass Res 176 advocating for the development of large-scale offshore wind projects.

Thank you.

Three Minute Remarks for McAllister Towing & Transportation, NY, NY

By Capt. Eric Wiberg, Esq., Marketing Manager

Monday 19 February, 2018, 250 Broadway, 14th Floor, 1pm to 4pm

At 25 square miles, the Port of New York and New Jersey is one of the greatest natural harbors in the world. It has about 240 miles of channels which enables vessels of all types to load and unload cargoes of almost every variety, including passengers. However, the depths and heights are no longer large enough for the world's largest ships. As container and tanker ships outgrow the harbor, there are fewer ship calls, partly as a result of economies of scale. As markets gravitate away from choke points and towards the greatest efficiencies in cost and supply, some business has been bypassing New York.

New York has gone from being the biggest port in the world, to the biggest in the USA, to now the biggest on the US east coast. It is no longer on any top-20 lists of world's biggest ports. Much attention in recent decades has been paid and investment made in land infrastructure – bridges, tunnels, highways, parks, some of which came at the cost of commercial waterfront uses. Yet 95% of what we consume must be carried by sea, and the harbor is what made New York what it is. So, we have to keep up with global infrastructural standards.

The Offshore Wind industry, already heavily invested in New York's waters from Montauk to the approaches to New York Harbor, promises not only tens of billions of dollars of investment prospects, but also new jobs, new skills, new technology, more independence, more choices for consumers, and an environmentally gentle and sustainable alternative to coal and petroleum-fired energy providers. Those are all good things.

As a five-generation American company which has withstood wars, economic depressions, and recessions, which has embraced steam, diesel, LNG and other clean technologies, McAllister Towing stands by to contribute any way we can. We have over 650 mariners on the New York payrolls, and all of them are highly experienced, dedicated, licensed US mariners. They operate over 70 vessels from tugs to launches to 100-vehicle car and passenger ferries to rescue and fire-equipped tugs and tugs equipped to tow oil barges. We are situated from the Caribbean to Canada but have always been based in New York.

We are here to embrace Offshore Wind, to support you however we can with expertise, people, advice, and then moving equipment to and from sites, investing in new vessels and operating them. We feel the best is not just the groundbreaking and switching on a new power source, but maintaining what has been built and built more wind turbines using US resources going forward.

Thank you.

New York Reliability Council
c/o Paul Gioia, Esq.
Whiteman Osterman & Hanna LLP
One Commerce Plaza- 99 Washington Av.
Albany, NY 12260

February 12, 2018

Mr. Jonathan Ettricks
Legislative Documents Unit
City Hall, New York
NY 10007

RE: Oversight - Facilitating the Use of Wind Power in New York City.

Int. No. 48: In relation to the creation of wind maps demonstrating wind energy generation potential within the city.

Int. No. 50: In relation to small wind turbines.

Dear Jonathan.

On behalf of the New York State Reliability Counsel ("NYSRC"), I would like to thank you for the invitation to attend and testify at the Committee on Environmental Protection hearing on February 26, 2018. Since the facilitation of wind power in New York City is primarily the focus of the local distribution utilities and outside the role of the NYSRC, we respectfully decline your invitation to attend this hearing.

Sincerely Yours,

Roger Clayton, P.E. Chairman, NYSRC

cc: Paul Gioia Esq., Counsel NYSRC
Mayer Sasson, Vice Chair NYSRC
Herb Schrayshuen, Executive Secretary, NYSRC

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Deployment of Wind Turbines in the Built Environment: Risks, Lessons, and Recommended Practices

Jason Fields, Frank Oteri, Robert Preus, and Ian Baring-Gould
National Renewable Energy Laboratory

NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy
Operated by the Alliance for Sustainable Energy, LLC

This report is available at no cost from the National Renewable Energy Laboratory (NREL) at www.nrel.gov/publications.

Technical Report
NREL/TP-5000-65622
June 2016

Contract No. DE-AC36-08GO28308

Deployment of Wind Turbines in the Built Environment: Risks, Lessons, and Recommended Practices

Jason Fields, Frank Oteri, Robert Preus, and Ian Baring-Gould
National Renewable Energy Laboratory

Prepared under Task No. WE152e22

NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy
Operated by the Alliance for Sustainable Energy, LLC

This report is available at no cost from the National Renewable Energy Laboratory (NREL) at www.nrel.gov/publications.

National Renewable Energy Laboratory
15013 Denver West Parkway
Golden, CO 80401
303-275-3000 • www.nrel.gov

Technical Report
NREL/TP-5000-65622
June 2016

Contract No. DE-AC36-08GO28308

This report is available at no cost from the National Renewable Energy Laboratory (NREL) at www.nrel.gov/publications.

Available electronically at SciTech Connect http:/www.osti.gov/scitech

Available for a processing fee to U.S. Department of Energy and its contractors, in paper, from:

U.S. Department of Energy
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831-0062
OSTI http://www.osti.gov
Phone: 865.576.8401
Fax: 865.576.5728
Email: reports@osti.gov

Available for sale to the public, in paper, from:

U.S. Department of Commerce
National Technical Information Service
5301 Shawnee Road
Alexandria, VA 22312
NTIS http://www.ntis.gov
Phone: 800.553.6847 or 703.605.6000
Fax: 703.605.6900
Email: orders@ntis.gov

Cover Photos by Dennis Schroeder: (left to right) NREL 26173, NREL 18302, NREL 19758, NREL 29642, NREL 19795.

NREL prints on paper that contains recycled content.

Acknowledgments

The National Renewable Energy Laboratory (NREL) acknowledges the U.S. Department of Energy's Wind and Water Power Technologies Office for supporting this work under the Office of Energy Efficiency and Renewable Energy's distributed wind research, development, and testing activities. We would especially like to thank the following associates who contributed to the case studies:

- Mike Ewert and Jeff White, National Air and Space Administration (NASA) Johnson Space Center
- Renee Loveland, Gerding Edlen (Twelve West)
- Josue Sanchez, L&M Development Partners (Pearson Court Square)
- Marian Tomusiak, Boston Museum of Science Wind Turbine Lab
- Elliot Matz and John Coburn, Brooklyn Navy Yard
- Bryan Wagoner and James Power, Wayne County Airport Authority (Detroit Metro Airport).

NREL would also like to thank Mike van Bavel and Bobby Ghuneim from Dynamax Inc. They were a great help in executing the NASA Building 12 measurement program.

List of Abbreviations and Acronyms

BEWT	built-environment wind turbine
CFD	computational fluid dynamics
HAWT	horizontal-axis wind turbine
IEA	International Energy Agency
IEC	International Electro-technical Committee
kW	kilowatt
kWh	kilowatt-hours
LCOE	levelized cost of energy
LEED	Leadership in Energy & Environmental Design
LES	large eddy simulation
NASA	National Air and Space Administration
NREL	National Renewable Energy Laboratory
NTM	Normal Turbulence Model
TFPZ	turbine failure projectile zone
TI	turbulence intensity
VAWT	vertical-axis wind turbine

Executive Summary

Built-environment wind turbine (BEWT) projects are wind energy projects that are constructed on, in, or near buildings. These projects present an opportunity for distributed, low-carbon generation combined with highly visible statements on sustainability, but the BEWT niche of the wind industry is still developing and is relatively less mature than the utility-scale wind or conventional ground-based distributed wind sectors. The findings from this report cannot be extended to wind energy deployments in general because of the large difference in application and technology maturity.

This paper investigates the current state of the BEWT industry by reviewing available literature on BEWT projects as well as interviewing project owners on their experiences deploying and operating the technology. The authors generated a series of case studies that outlines the pertinent project details, project outcomes, and lessons learned. This paper integrates those information sources into recommended practices that can be utilized by future stakeholders to evaluate the feasibility of BEWTs for their unique applications and sites. It should be noted that due to the lack of available information, the case studies were limited to building-mounted designs with limited coverage of building-integrated turbines (in which the architectural structure is shaped to support wind generation). The recommended practices are still largely applicable to any built-environment technology or approach.

Lessons learned from the case studies include the following:

- Project planning
    - Project feasibility and planning processes are insufficient and not well defined. A few project developers undertook rigorous pre-construction planning, and those projects tended to have more positive outcomes.
- Project costs
    - Additional expenses related to installation and operations in the built environment can create high-cost projects.
- Project performance and reliability
    - Consolidation of small turbine manufacturers has been common and can lead to loss of warranty and difficulty in service parts availability.
    - BEWT project performance is often over-estimated when compared with actual production. ***None of the case study projects met their energy production estimates***, largely due to the complexity of conducting accurate resource and production assessments in complex built environments. Onsite atmospheric measurements are recommended, along with detailed loss calculations to account for real-world operating conditions.

In general, the BEWT industry has experienced mixed results, with some positive project outcomes and several negative outcomes for stakeholders. We see that projects with positive outcomes usually share the following commonalities:

- Project goals have been well developed and quantified. These goals typically include some education or marketing component and do not rely solely on energy production.
- BEWT project developers conducted rigorous due diligence and devoted time to planning before deployment.
- BEWT projects are placed on taller buildings relative to surrounding obstacles (Encraft 2009).
- Project developers selected certified horizontal axis wind turbines (HAWTs) with a strong track record of previous deployments.

It should also be noted that based on several key factors (i.e., wind speeds are typically lower and costs for implementing projects in built environments are typically higher), projects in the built environment can be difficult to justify on a cost of energy or energy offset basis. Understanding the expected production of a wind turbine in the built environment is a very complex undertaking; the use of onsite resource measurements combined with high-fidelity models is likely the only way to understand the expected turbine production.

While the BEWT industry is evolving, it appears that these projects are still an emerging wind energy application. Stakeholders considering a BEWT project should review the case study outcomes, lessons learned, and recommended practices to help inform their decision processes.

Table of Contents

List of Figures

List of Tables

1 Introduction

Built-environment wind turbines (BEWTs) are wind turbines located in an urban or suburban environment (built environment). BEWTs may be mounted on buildings or among buildings, as shown in Figure 1. They can also be integrated into a building and included in the building design from architectural, structural, and economic perspectives. A BEWT attached to a building may be an attractive prospect for a project developer because it offers an opportunity for locally produced energy similar to a solar photovoltaic system. However, unlike solar photovoltaic systems, BEWT systems have additional challenges that should be considered.

The purpose of this document is to summarize the current state of BEWT deployment as well as provide practical recommendations for entities considering a BEWT project. This document examines the challenges and risks inherent to BEWT design and installation and provides guidelines for addressing those challenges. We review the best available information on the complexities of wind resource assessment in the built environment, along with the challenges of structural integration, among others. These complexities will be demonstrated through a number of real-world case studies so the reader can more clearly understand the opportunities and challenges associated with BEWT projects.

The typical motivation for the installation of a standard open-field distributed wind turbine is often primarily energy production leading to an overall reduction of energy costs. However, BEWT projects may pose challenging economics on the basis of energy production alone. In addition to the value of the energy generated, some of the other possible benefits are:

- Leadership in Energy & Environmental Design (LEED) certification credits
- Marketing or public relations value for a commercial building
- Meeting carbon reduction targets or renewable energy targets[1]
- Supporting local and/or onsite generation
- Utilization of federal, state, and utility incentives
- Education and outreach.

Figure 1. Illustration of turbine installations in the built environment

[1] BEWT projects may not be optimal for obtaining carbon reduction or renewable energy targets as those are usually tied to energy production.

2 BEWT Fundamentals

BEWTs refer to a market niche, not a particular size or category. As shown in Figure 1, BEWTs can be mounted on the side of a building, integrated into buildings, or ground mounted among buildings in an urban environment. Most BEWTs are small wind turbines that are ~10 kilowatts (kW) nameplate or less. Table 1 lists the wind turbines deployed in the built environment in the United States and provides a representation of the turbine diversity. In general, BEWTs are conventional wind turbine designs installed in the built environment. A few BEWT-specific offerings have appeared in the market, but they are generally short-lived and without a strong market history. Most of the BEWT-specific offerings appeared around 2009 at the height of the distributed wind boom. Even though most BEWTs use conventional designs, many of those conventional turbines were designed for an open-flow field environment, not a built environment. Figure 2 shows an example of an open-flow field environment.

2.1 BEWT Case Studies

National Renewable Energy Laboratory (NREL) researchers generated a series of practical case studies with a goal of creating an informative product that accurately portrays the experiences of current built-environment wind projects from concept through installation. The case studies were selected based on the availability of public information on the projects and the identification of project representatives who could be interviewed. With the exception of the National Air and Space Administration (NASA) Building 12 installation, NREL researchers did not directly measure any project data; all pre- and post-construction energy estimates were provided by project owners. Table 2 provides a summary of these projects, which are introduced in the next section. Full details on each can be found in Appendix A. While the installations encountered significant performance variations compared to estimated generation, some did provide positive benefits beyond energy production. These six BEWT sites from project developers who participated in this study represent seven small wind turbine models and 32 wind turbines. Notably absent from these case studies are building-integrated turbines; none are known to be installed in the United States at this time.

Figure 2. Conventional open-flow field environment. ***Photo from Gwen Bassetti, NREL 26429***

Figure 3. Example of a built environment installation on Boston City Hall. *Photo by Joe Smith, NREL 18462*

Of the six projects that are profiled, the NASA Building 12 project is unique among the case studies as it involved detailed pre-construction and post-construction measurements. NREL researchers initiated a measurement campaign consisting of multiple rooftop anemometers and other atmospheric instrumentation located on the prospective turbine pad mounts and in the immediate rooftop vicinity. The Building 12 measurement program consisted of two phases: Phase 1[2] is the pre-construction measurement campaign, and Phase 2 is the post-construction measurement campaign. The full installation and commissioning documentation and datasets are also available.[3] The power data for Phase 2 were measured by the NASA enterprise Supervisory Control and Data Acquisition system and contain inputs directly from the turbine inverters. As of the writing of this document, Phase 2 data collection is ongoing, so this report contains a subset of the total data.

[2] Phase 1 data are available at http://en.openei.org/doe-opendata/dataset/nasa-building-12-wind-turbines-phase-1-data
[3] http://en.openei.org/wiki/NASA_Building_12_Wind_Turbines

Table 1. Turbine Models Used in U.S. Built-Environment Installations

Turbine Manufacturer	Turbine Model	Turbine Orientation	Turbine Capacity	Currently Active?
Aerotecture	610V Aeroturbine	VAWT*	1 kW	Defunct
Aerotecture	712V Aeroturbine	VAWT	2.5 kW	Defunct
AeroVironment	AVX1000	HAWT**	1 kW	Active but exited wind energy
Bergey	Bergey Excel	HAWT	10 kW	Active
Britwind (formerly Evance)	R9000	HAWT	5 kW	Active (Re-structured)
Cascade	Swift	HAWT	1 kW	Active but exited wind energy
Gaia Wind	Gaia Wind 133	HAWT	11 kW	Active
Helix Wind	Eolico 5 KW	VAWT	5 kW	Defunct
Home Energy	EnergyBall V200	HAWT	2.5 kW	Defunct
Honeywell	Windtronics	HAWT	2 kW	Active but exited wind energy
JLM Energy	Zefr	HAWT	240 W	Defunct
Kingspan (formerly Proven Energy)	KW6 (Proven 6)	HAWT	6 kW	Active (Re-structured)
Primus WindPower (formerly Southwest Windpower)	Air X	HAWT	400 W	Active (Re-structured)
Tangarie	GALE	VAWT	5 kW	Defunct
Urban Green Energy	Eddy GT	VAWT	1 kW	Active
Urban Green Energy	VisionAIR5	VAWT	3.2 kW	Active
Venger	V1	HAWT	2 kW	Defunct
Windspire Energy (formerly Mariah Power)	Windspire	VAWT	1.2 kW	Active (Re-structured)
Wing Power Energy	Unknown	VAWT	2kW	Unknown

Turbine Manufacturer	Turbine Model	Turbine Orientation	Turbine Capacity	Currently Active?
Xzeres (formerly Southwest Windpower	Skystream 3.7	HAWT	2.4 kW	Active (Re-structured)
Zephyr	AirDolphin Z1000	HAWT	1.1 kW	Active

*VAWT: vertical-axis wind turbine
**HAWT: horizontal-axis wind turbine

Table 2. Overview of BEWT Project Case Studies

Project Name	Twelve West	Detroit Metro Airport	Museum of Science	Brooklyn Navy Yard	Pearson Court Square	NASA Building 12
Location	Portland, OR	Romulus, MI	Boston, MA	Brooklyn, NY	Long Island City, NY	Houston, TX
Turbine Type	Skystream 3.7 (4)	Windspire (6)	Windspire (1) Skystream 3.7 (1) Swift (1) Proven 6 (1) AeroVironment AVX1000 (5)	AeroVironment AVX 1000 (6)	VisionAIR5 (3)	Eddy GT (4)
Capacity	9.6 kW	7.2 kW	15.6 kW	6 kW	9.6 kW	4 kW
Year Installed	2009	2010	2009	2008	2014	2014
Operational	Operating	Operating at reduced capacity	Operating at reduced capacity	Not operating	Operating	Operating
Roof Mounted?	Yes	No	Yes	Yes	Yes	Yes
Owner View	Success	Underperform	Success	Underperform	Success	Underperform

3 Lessons Learned

Several unique considerations for BEWT projects were revealed during the literature review and the development of the aforementioned case studies. These lessons learned can provide insight for the next generation of built-environment wind projects, potentially leading to a higher level of successful deployments of this technology. Insights include:

- Project planning
  - Project feasibility and planning processes are insufficient and not well defined.
  - Multi-objective projects tend to be perceived as more successful.
  - The order in which objectives are prioritized can and should influence project outcomes.
  - Potential liability and safety issues should be understood and addressed during the planning process.
  - Concerns regarding a project's impact on local aviation procedures can add unanticipated steps to the permitting process.
- Project costs
  - Additional expenses related to installation in the built environment can create high-cost projects.
  - The potential additional complexities of performing maintenance on BEWTs can lead to cumbersome and expensive practices. Additionally, increased turbulence levels common in built-environment areas may result in additional maintenance requirements and decreased turbine reliability.
- Project performance and reliability
  - Consolidation of small turbine manufacturers has been common and can lead to loss of warranty and difficulty in service parts availability.
  - BEWT project performance is often over-estimated when compared with actual production. Onsite atmospheric measurements are recommended along with detailed loss calculations to account for real-world operating conditions if accurate production estimates are desired.
  - Although certified turbines should be selected for all small and distributed wind projects, current national and international turbine standards do not reflect wind conditions often seen in the built environment.

Each of these insights is described in greater detail in the following sections.

3.1 Project Planning Lessons Learned

3.1.1 Project feasibility and planning processes are insufficient and not well defined.

The project feasibility and planning process is hampered by few BEWT installations and a lack of experienced project developers. Limited public information is available on existing BEWT projects, making it difficult for potential developers to understand challenges. The lack of representative projects also means that there are few experienced installers, even in a given region. The development process also has unique architectural and engineering requirements not typically needed in more conventional turbine installations, again further limiting the experience base. Most projects seem to have been completed by teams with no previous built-environment wind project experience. The built-environment wind resource is complex, leading to estimated production that tends to be higher than actual production.

The complex nature of the built environment increases the necessity of thoroughly understanding a location's wind resource and the influence that surrounding structures and vegetation may have on it. In terms of positive resource and location understanding, one project stands out from the rest. Project developers for the Twelve West installation[4] conducted an in-depth modeling study with Oregon State University's Aero Engineering Lab to understand the project's wind resource and the influence from surrounding structures. Project developers believe this was essential to their installation's success. The data from this effort helped developers choose an installation location that would allow the project to maximize production while still being located in a highly visible area of the building.

Twelve West – Portland, OR

The Twelve West installation had project goals in addition to onsite generation. These included installing a project that was capable of raising awareness about renewable energy while elevating the visibility of the building and underscoring the building's sustainability commitment. Installed in conjunction with the design and construction of a 23-story, LEED Platinum certified mixed-use apartment and office building, the Twelve West installation in Portland, Oregon, consists of four Skystream turbines. Having conducted a thorough site assessment that included modeling to simulate the flow patterns of the site, the project generates approximately 5,500 kilowatt-hours (kWh)/year compared to an estimated annual production of approximately 9,000 kWh. In terms of generation, when compared to the other case studies this project's actual production came closest to the values that were estimated prior to installation. Although the project production was below estimates, due to the multiple project goals, developers view the project as a success.

On the opposite end of the spectrum, NASA Building 12 project developers had already committed to their project by purchasing turbines prior to assessing the site's wind resource. This led to the installation of turbines in a location with a low wind resource, which has contributed to the project's lack of generation.

There is a body of research on the behavior of wind around a building. In the sections that follow, we will draw on that research to outline an organized process for assessing a BEWT project. We will also discuss risk of inaccuracy in applying available turbine performance information to a BEWT project.

[4] See sidebar for an overview of each case study and Appendix A for detailed information on the projects discussed here.

3.1.2 Multi-objective projects tend to be perceived as more successful.

A majority of the project developers who participated in these case studies felt that their installations' success was attributed to the multi-objective approach they established for their developments. In addition to onsite generation, the Twelve West installation moved forward with the goals of installing a project that was capable of raising awareness about renewable energy while elevating the visibility of the building and underscoring the building's sustainability commitment. Project developers feel that the installation continues to meet these objectives and that the overall success of the project can be directly attributed to their multi-objective approach.

Project developers at the Boston Museum of Science adjusted their project goals from generation to education after realizing early in the process that the site did not have the resource necessary to be considered successful from a generation perspective. Primary objectives for the project became:

- Creating a roof-top location where a variety of commercially available small wind turbines could be tested in the built environment
- Providing data and experience for the general public and industry professionals
- Constructing an exhibit that would become a landmark for Boston and the region
- Generating clean energy while making a statement on its importance.

In the case of Pearson Court Square, the project was initiated with three goals in mind: furthering the building's sustainable practices, garnering attention and publicity, and generating energy onsite. While it is still too early in the process to determine the installation's energy generation, the other project objectives have been met. In terms of attention and publicity, the project was highlighted in numerous domestic publications (10 to 15, including the New York Times) and three local television news reports. The project also gained international attention via a German radio station's reporter who visited the site and conducted an interview with Pearson Court Square representatives.

From a generation viewpoint, NASA's Building 12 project has under-produced, but the project will provide data that will help researchers understand how to effectively site wind turbines in the urban environment, as well as assess performance and safety. This further exemplifies the multi-objective approach that assists in a project's success.

NASA Building 12 – Houston, TX

The Building 12 installation was originally designed as an effort to further the sustainability practices of NASA Johnson Space Center through a high-visibility education and demonstration project. It was hoped this project could provide onsite generation while aiding in compliance with mandates regarding renewable energy production at federal buildings. Completed in December 2014, the NASA Building 12 installation consists of four Urban Green Energy Eddy GT turbines. The project was constructed as part of a larger Building 12 renovation that included other sustainability initiatives such as a green roof. Developers originally intended to utilize Tangarie GALE 5-kW VAWTs, but the manufacturer went out of business after the order was placed. Although a resource assessment was conducted prior to turbine installation, project developers had already committed to the turbine purchase prior to its completion, resulting in the final installation being located in a low-wind-resource site.

3.1.3 The order in which objectives are prioritized can influence project outcomes.

While it may be necessary to have multiple objectives for a single project, it is also important to understand the influence that objective prioritization can have on project outcomes. The impact of this type of decision can be seen with the Brooklyn Navy Yard turbine array. Project developers had to choose between siting the turbine installation where it would be most visible or where the resource was strongest. In this case, visibility was considered the primary objective, a decision that could have contributed to the overall underperformance of the installation. The Brooklyn Navy Yard developers did not have accurate pre-construction energy estimation tools; thus the energy impact of their decision to site for visibility was likely not completely transparent to them. In this case, project performance was greatly diminished by the selection of a very visible site.

> **Museum of Science – Boston, MA**
>
> The Museum of Science's Wind Lab in Boston, Massachusetts, was developed as part of its environmental sustainability initiative, creating a roof-top installation where a variety of commercially available small wind turbines could be tested in the built environment while providing data and experience for the general public and industry professionals. Project goals also included the creation of an exhibit that would become a landmark for the city and region and generate clean energy while making a statement on its importance. Consisting of five types of roof-mounted turbine models, the project was originally intended to offset some of the host building's energy needs. When the initial project assessment revealed that the installation could not be scaled to provide a significant amount of the museum's electricity needs, the project moved forward as a test lab instead of a generation-focused installation.

3.1.4 Potential liability and safety issues should be understood and addressed during the planning process.

There are potential risks when people work on top of a building for turbine installation and servicing. There is also a possibility that ice or wind turbine parts could be shed and fall onto people or traffic. This was identified as a key challenge in NREL's *Built-Environment Wind Turbine Roadmap* (Smith et al. 2012). These risks may be no greater than other accepted risks for a large-building owner, but they may lie outside of standard insurance coverage. Additionally, while researching the case studies, NREL researchers found at least one BEWT project that involved active litigation between the project financial sponsor and the installer and turbine manufacturer. Conversely the safety and liability issues were not mentioned in the case studies except for requirements related to equipment survival during extreme wind speeds (e.g., NASA cited having to withstand 130-mph winds as part of the design criteria for the turbine and mounting) (Smith et al. 2012).

3.1.5 Concerns regarding a project's impact on local aviation procedures can add unanticipated steps to the permitting process.

While permitting for a vast majority of these projects seems to have been a straightforward process, project developers for two of the roof-mounted installations were required to ensure that the turbines would have minimal aviation impacts.

Due to the Boston Museum of Science's close proximity to Logan Airport and the significant project height (combination of building and turbine), project developers needed Federal Aviation Administration approval prior to installation. Similarly, the Twelve West installation required Federal Aviation Administration approval due to its significant project height (combination of building and turbine). Although this requirement did not stop either project from moving forward, it was a condition that no one anticipated and that developers for future projects should be aware of prior to beginning the permitting process.

3.2 Project Costs Lessons Learned

3.2.1 Additional expenses related to installation in the built environment can create high-cost projects.

BEWT installation costs are high due to the combination of logistics expenses, building reinforcement requirements, and extensive planning and permitting often required. Logistics of getting equipment and workers onto the roof and providing for safety can be a significant additional expense compared to ground mounting a small wind system. If a wind system is being added to an existing building that was not designed for it, the structural reinforcements required to distribute the load to the existing structure can often exceed the cost of the wind generators. The Boston Museum of Science experienced escalated project cost due to the design, materials, and construction of support structures necessary to safely deploy its rooftop installation. Nearly one-quarter of the project's $350,000 budget (2009) was spent on structural steel, a larger portion of the budget than was utilized for project equipment (i.e., towers and turbines).

Pearson Court Square – Long Island City, NY

Installed to provide onsite generation through a project that would further the host building's sustainable practices while increasing marketing and publicity, the Pearson Court Square wind energy project in Long Island City, New York, was commissioned in the summer of 2015. Consisting of three Urban Green Energy VisionAIR5 turbines, the installation is expected to produce approximately 6,000 kWh annually, depending on wind conditions and site obstructions.

3.2.2 The potential additional complexities of performing maintenance on BEWTs can lead to cumbersome and expensive practices.

A variety of factors can influence the costs and effort needed to properly maintain a project: turbine type and size, tower type, building height and infrastructure, availability of qualified technicians and parts, and turbulence intensity (TI) of the wind resource. Depending on the turbine type and installation location, crane services may be required. Coordinating these services can lead to project downtime for unexpected issues as well as additional crane mobilization costs. The installation design should include a plan to not only access the turbines but also to remove and replace any part of the system, even the entire turbine assembly if required. Two of the projects reviewed experienced turbine maintenance issues: Detroit Metro Airport (lack of parts due to manufacturer bankruptcy) and Boston Museum of Science (fixed budget, unanticipated coordination, and lack of qualified local technicians).

3.3 Project Performance and Reliability Lessons Learned

3.3.1 Consolidation of small turbine manufacturers has been common and can lead to loss of warranty and difficulty in service parts availability.

The rate of consolidation for small turbine manufacturers has made it difficult for some BEWT developers to obtain parts essential to keeping a system operational. Four of the five turbine manufacturers that were utilized in the Boston Museum of Science project have gone bankrupt since the turbines were installed, creating difficulties in maintenance and part replacements. Due to the original turbine manufacturer going out of business, NASA Building 12 project developers had to choose an alternative turbine manufacturer and model after placing the initial order. Detroit Metro Airport also experienced manufacturer viability issues. Airport officials are considering moving forward with the goal of keeping at least three turbines generating electricity by shutting down and borrowing parts from the remaining turbines. While some of the assets of these companies were purchased by other businesses and most of the turbines remain in production, the warranties and previously established contacts have largely been voided, further increasing costs and adding to maintenance complexity. Since most small wind generators are produced by small startup companies, this risk may be unavoidable. However, project developers may find it worthwhile to investigate the history and financial status of a turbine supplier.

Brooklyn Navy Yard – Brooklyn, NY

Designed to promote emerging wind energy technology that highlights the host building's emphasis on sustainable design through a project that could potentially pay for itself over a reasonable amount of time based on energy savings, the Brooklyn Navy Yard installation in Brooklyn, New York, is an AeroVironment array made up of six AVX1000 turbines. The project was installed in 2008 in conjunction with the design and construction of the three-story, 89,000-square-foot Perry Avenue building. Project managers elected to construct this installation in an area of high visibility as opposed to the location with the best wind resource, which is a possible contributing factor to the project’s low energy production during operation. Due to high maintenance costs and poor system performance, the owners have not kept the installation in working order or continued to track data.

3.3.2 BEWT project performance is often over-estimated when compared with actual production.

In every built-environment case study NREL conducted and in most examples from the Warwick wind trials (Encraft 2009), the predicted energy was over-estimated compared with actual results. This over-estimation can stem from a variety of sources such as incorrect wind resource assumptions and no accounting for physical losses. Many of the case study stakeholders recommended a long-term onsite measurement program to assess the site winds. Additionally, the NASA Building 12 case study revealed that even with detailed measurements, the expected performance is well below what is predicted with the measurements. This indicates that the measurements combined with turbine power curve do not fully account for the potential energy at a site; other factors known as losses must be accounted for in the energy estimation process.

3.3.3 Current national and international standards do not reflect wind conditions often seen in the built environment.

Certified turbines have been designed and certified to a national or international set of guidelines. These turbines generally incorporate the highest productivity and reliability standards offered by the distributed wind industry. These standards were, however, developed for turbines to be installed in open-field applications and may not be completely applicable for the built environment. While BEWT conditions may differ from the conditions specified in the standard, the use of certified turbines is still recommended as they are the most rigorously designed and tested turbines available on the market.

Detroit Metro Airport – Detroit, MI

Installed as a pilot program to determine whether small wind technology should be further deployed at the Detroit Metro Airport in Michigan, this installation originally consisted of six Windspire turbines. Of all the case studies compiled, this project is the only one that was not roof mounted; it was installed on airport property in an area among buildings that are taller than the turbines. Although actual production was not tracked, the project was originally estimated to generate approximately 2,000 kWh annually. Airport officials believe that when operating, the contribution has been significantly less than estimated. Hampered by maintenance issues and a lack of available parts due to manufacturer bankruptcy, according to airport officials the project never met expectations.

4 Recommended Practice

This section discusses the general evaluation and planning process that is recommended for potential BEWT project stakeholders. Substantive documents exist that deal with this topic for traditional open-field projects, and we will reference them and highlight the differences between a BEWT project and a conventional open-field wind project. A BEWT project is subject to all of the criteria of an open-environment project evaluation and more due to the additional complexities associated with the urban environment. The typical planning process for a standard small wind installation project[5] includes the following phases:

- Understand customer needs through establishing baselines; develop project goals
- Perform a technical evaluation:
    - Site evaluation
    - Turbine selection
    - Wind resource assessment
    - Production estimate.
- Estimate project costs
- Conduct a cost/benefit analysis.

The built environment adds new dimensions and challenges to these planning process phases. This document aims to illuminate those dimensions and challenges with the best available information. Although largely relevant to the installation of all small wind turbines, the following parameters must be considered even more carefully when siting BEWT projects:

- Wind resource
    - Wind speed frequency distribution
    - Predominant wind direction
    - TI
    - Inflow angles.
- Building characteristics and geometry
    - Building shape (square, rectangular, irregular)
    - Roof shape (flat roof, pitched roof, parapets)
    - Building orientation with respect to predominant winds
    - Building structural considerations.
- Turbine technology
    - Turbine safety limits
        - Wind speed
        - Turbulence
        - Extreme direction change.
    - Turbine orientation (HAWT vs. VAWT)

[5] See *Small Wind Site Assessment Guidelines:* http://www.nrel.gov/docs/fy15osti/63696.pdf

- Tower height.

- Installation and maintenance
  - Initial construction costs
  - Ongoing operations and maintenance costs.
- Building occupant comfort and safety
  - Noise emissions
  - Vibration emissions
  - Turbine failure projectile zone (TFPZ) (Olsen and Preus 2015).

4.1 Establish Baselines and Goals

Energy projects can be a significant investment of time and money. It is therefore recommended that developers of potential projects define clear goals and gather enough information to make informed decisions with a rigorous cost-benefit approach. Potential project goals can include any or all of the following:

- Low-cost energy generation
- Carbon reduction targets or renewable energy targets[6]
- LEED certification credits
- Marketing or public relations value for a commercial building
- Support of local and/or onsite generation
- Utilization of federal, state, and utility incentives
- Education and outreach.

Some benefits may be harder to quantify, but being aware of the full range of outcomes is important for project sponsors. The following key steps will help ensure a well evaluated project:

- Identify reasons and goals for undertaking a BEWT project (e.g., carbon reduction, cost of energy reduction, etc.)
- Establish baselines and expectations for the goals identified (e.g., baseline current energy and carbon/environmental footprints)
- Perform a broad-based feasibility study to match goals with the appropriate projects and technology
- Conduct a detailed cost-benefit analysis on the most viable options.

4.2 Perform a Technical Evaluation

Once project goals have been identified, the technical evaluation begins. The following key parameters should be considered in addition to any identified goals for BEWT projects:

- Project siting
- Comfort and safety/liability
- Wind resource

[6] BEWT projects may not be optimal for obtaining carbon reduction or renewable energy targets as those are usually tied to energy production.

- Turbine certification and selection
- Energy production.

Each of these items is discussed in further detail below.

4.2.1 Project Siting

Properly siting a wind turbine in the complex urban environment requires knowledge of several parameters of the site, the turbine, and long-term project operations. Every turbine may respond differently to the same wind in terms of power production, loads, and reliability. A successful BEWT project developer combines these factors with knowledge of the building structure, defined goals, and long-term operations and maintenance plans. When identifying suitable locations for a BEWT project, the following parameters should be accounted for:

- Installation, operations, and maintenance
- Comfort and safety of building occupants, equipment safety, and liability
- Building geometries (see Section 4.2.3.3)
- Wind resource as a driver for energy production and reliability (see Section 4.2.3)
- Other project goals such as visibility.

4.2.1.1 Installation, Operations, and Maintenance

BEWT projects are not usually ground-mounted projects. As such, they require special considerations that tend to drive project costs higher than traditional open-field projects. Wind turbines are dynamic systems experiencing dynamic loads that can vary with the wind powering the turbines. These loads require specialized foundations, either as part of the building design process or as an installation retrofit. This can result in extra engineering, permitting, materials, and labor costs that can increase the total installed cost and the levelized cost of energy (LCOE).

A long-term maintenance plan should also be developed with safe, cost-effective turbine access included. If the installation is building mounted, additional time and cost should be planned for the logistics of providing service support. The exact level of additional time and cost depends on the access requirements and what methods are available for accessing the nacelle. Maintenance access will also need to balance productivity, visibility, and other goals. Limiting the number or magnitude of expensive crane mobilizations and men working at height can greatly improve project success and decrease LCOE.

4.2.2 Comfort and Safety of Building Occupants, Equipment Safety, and Liability

The comfort and safety of people in the vicinity of the BEWT project should also be considered. The BEWT will emit sound and vibration as part of the normal operation, which can transfer through the building structure. Developers should inquire with prospective turbine manufacturers as to the turbine's certified sound levels, dynamic motion of the machine, and any potential sound/vibration mitigation options for mounting or operation. The structural engineering analysis should include consideration of sound and vibration transfer.

There are currently no accepted design methodologies or standards for BEWTs or their installation, which means there are limited means to provide confidence in the safety and suitability of turbine or installation design. We recommend that BEWT project developers engage a qualified third party to evaluate the turbine and the installation in light of the site-specific resource to minimize the potential for premature turbine failure or reduced reliability. Potential BEWT projects should include analysis of where components or ice throw may land if dislodged (the TFPZ). The site-specific fatigue and extreme loads combined with the traffic density of the TFPZ will yield an overall risk model of the BEWT deployment. The TFPZ, potential turbine loads, and the risk profile can all be affected or minimized by properly siting the turbine for safety and reliability.

The liability of turbine deployment and/or failure is still largely unknown and remains site specific. Consulting a qualified legal expert to assess any liabilities that may arise from deployment of a BEWT project is recommended.

4.2.3 Wind Resource

Accurately assessing the wind resource in the built environment is perhaps the single most challenging element of a BEWT project. The wind resource combined with turbine parameters affects energy production as well as turbine reliability and safety. The distinction for BEWT projects is that when a fluid (in this case air) flows over buildings, trees, or other structures (generically called roughness elements), they extract momentum from the air. This extraction of momentum results practically in lower mean wind speeds and higher mixing known as turbulence. These roughness elements do occur in traditional open-flow field projects but typically with a much lower density and impact on the wind.

The current tools used for modeling the resource of small wind projects can have very high uncertainty in complex terrain. BEWTs are considered to be located in extremely complex terrain, and there is a demonstrated over-prediction of energy outcomes in the urban environment (Encraft 2009). Additionally, the current commonly used models may not provide the complete atmospheric parameters required to properly estimate turbine production and reliability.[7] Based on these findings and the observation that none of the projects highlighted in the case studies produce near the values predicted, even for projects in which detailed computational fluid dynamics (CFD) modeling was conducted, we recommended in situ measurement program as the best option to quantify the wind resource. Beyond measurements, high-fidelity physics-based modeling offers the most likely successful resource quantification approach. Advanced modeling approaches such as CFD or a large eddy simulation (LES) are required to properly characterize the site-specific resource. The challenge is that even the advanced models don't capture the full array of flow physics and are expensive to run, potentially costing more than the wind turbine itself. There are ongoing R&D activities within academic and industry institutions to be able to cost effectively perform these investigations, but they are largely limited to the realm of research at this time.

Research gathered through the International Energy Agency (IEA) *Wind Task 27: Wind turbines in highly turbulent environments*[8] demonstrates a multitude of challenges for prospective BEWT designers. These challenges include different turbulent decay characteristics, inflow angles, and more (Tabrizi et al. 2014.) Figure 4 is an example of the complexity of wind flow around buildings. The primary flow direction of this figure aligns with the x axis and goes from right to left over and around the building. The top, sides, and lee of the building demonstrate highly turbulent and non-laminar flow.

[7] A full list of important atmospheric and turbine variables to consider in BEWT projects is included in Table 3. Summary of IEC 61400-2 Wind Characteristics that Differ between Built-Environment and Open-Field Sites
[8] International Energy Agency, Task 27: http://www.ieawind.org/task_27_home_page.html

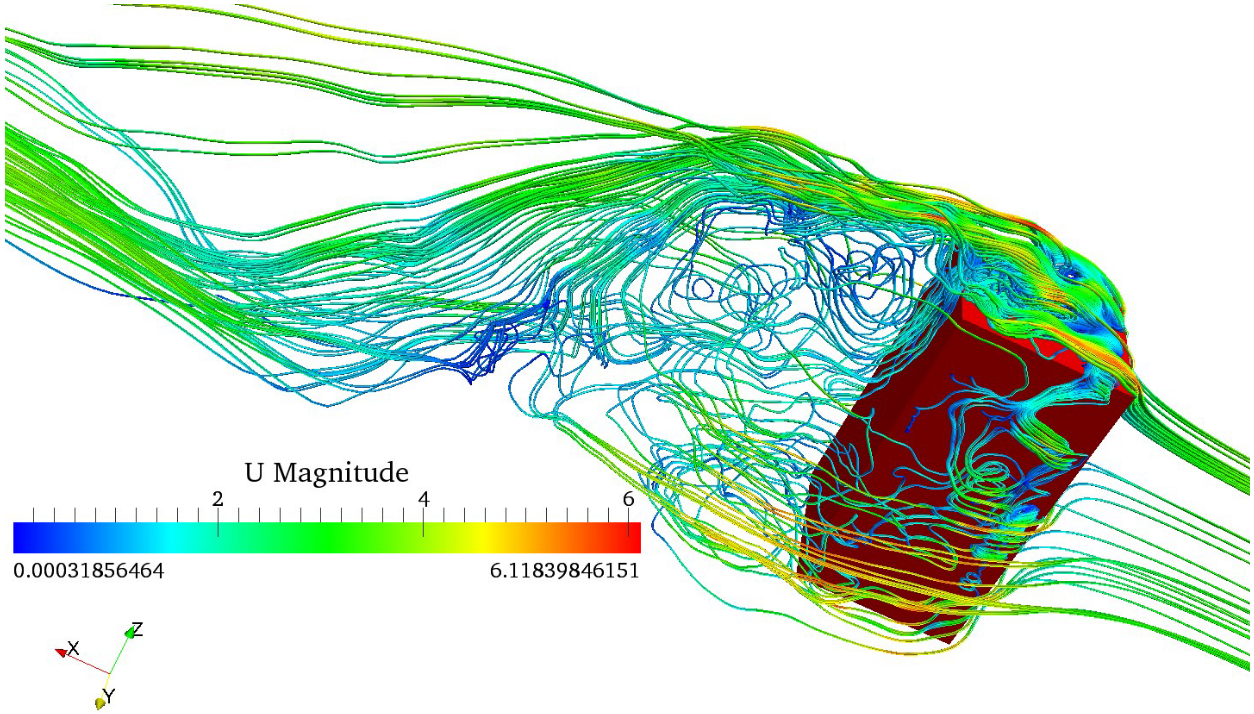


Figure 4. LES simulation of wind flow around building (Toja Silva 2015)

There are, however, some emerging rules of thumb that although not validated may help project sponsors if they choose to undertake a BEWT project. These rules mainly address how high the turbine tower needs to be with respect to the building in order to escape the highly turbulent and variable winds associated with installing wind turbines in close proximity to buildings or other structures.

All BEWT projects are likely to be in high-TI environments even if they are ground mounted. For a ground-mounted installation, start with standard wind resource assessment techniques (as outlined in the *Small Wind Site Assessment Guidelines*), paying special attention to object shading adjustments and displacement height[9] issues. If the object is a large building close to the wind turbine, an object shading tool such as the Danish Wind Shade Calculator[10] will not work well. Unless the wind turbine is higher than the building, little wind will reach the turbine from the direction of the building.

The cubical configuration of a simple building will have a zone of accelerated flow velocity and large vertical flow components at the upwind edge of the building, a large region of separated flow and eddies on the top surface and in the leeward side of the building (Figure 4). The height of the region of separated flow on top of the building can be approximated with CFD analysis, an empirical method (Wilson 1979), or measurements. It is important to note that the turbulence characteristics of the wind before it arrives at the building will impact the actual wind behavior, which will impact the accuracy of CFD and empirical analysis. Since the wind can come from any direction, optimal siting is complex because the region of separated flow will also change based on wind direction and building geometry. It requires that the flow be analyzed for at least all directions with significant wind energy input.

[9] Displacement height is the adjusted ground level height for calculating apparent hub height based on ground clutter that raises the height at which there is nearly zero wind velocity (e.g., in forests or densely developed areas with many buildings).
[10] The Danish Wind Shade Calculator is a free tool that can be used to run shade analysis for wind projects; available at http://www.motiva.fi/myllarin_tuulivoima/windpower%20web/en/tour/wres/shelter/index.htm

For building-mounted BEWT projects, the same displacement height principles as with any standard wind turbine siting apply, except that the height of local buildings will create that displacement height. For applications in which production, safety, and reliability are important, the difficult work is determining the best location on the building and the expected wind resource at that location. A great source of information on wind resource distribution on a rectangular building is *Building-Mounted Micro-Wind Turbines on High-Rise and Commercial Buildings* (Blackmore 2010). This publication provides analysis of normalized wind speed and TI by location across the top of rectangular buildings of height 80 meters at a distribution of wind directions. Some results are provided for shorter buildings. The work is based on wind tunnel experiments at a scale of 1:200. Limited comparison to CFD and empirical rules is described. While this work is very valuable, it should be used as a guide for siting since the results are averaged and few buildings are simple rectangles. A few cautionary comments and prime points that are useful guides are:

- Taller buildings generate higher separation bubbles.
- Reaching 90% of average ambient wind speed happens at a lower height than reduction of TI to 110% of ambient.
- Unless installing rotors less than 2 meters diameter, the heights for reaching acceptable wind speed and TI should be the bottom of the rotor-swept area.
- There is no optimal location for all wind directions.
- While Blackmore uses an average of all four corners and other reference locations for rule-of-thumb minimum heights, these heights vary significantly from one point to the other, so this is not good guidance for micrositing.
- Contour plots of normalized wind speed and TI are for the model of an 80-meter-tall by 40-meter-wide by 20-meter-deep building with a flat top and no structures on the top.
- It does not appear that Blackmore investigated the results at multiple wind speeds and the effect different wind speeds may have on the height of the separation bubble.

While this information does not provide a simple set of rules to microsite a wind generator on a building, it does provide some basic guidance.

To use this information for micrositing, we suggest one of the following options:

- If the building is generally rectangular and a high-quality wind rose is available, use the information provided by Blackmore to identify areas of the building that have acceptable TI values (18% or below) at the maximum turbine height you can consider. This will need to be performed for each significant wind direction. Determine if any sites are available, and then evaluate whether they are structurally capable of supporting the turbine and tower.
- Select some good candidate sites that are open and structurally capable of supporting the turbine. Use the TI contours suggested by Blackmore and the wind speed to determine the minimum acceptable tower height. Due to the large uncertainty caused by differences in the real building, the local environment, and the models used in the wind tunnel, this should be used for preliminary assessment only, and we recommend that wind speed and direction measurements be taken at the specific location.
- If the building has a more complex shape or there are significant other large buildings in the area, a CFD model of the building and surrounding area will give a more accurate picture of the wind resource. It will also show the wind speed distribution over the building. Multiple simulations will be needed to understand wind flow from each primary wind direction. While this analysis can be

expensive, the results are likely to be more accurate, providing a better assessment of the resource at locations of interest.

If having a reliable energy projection is important, then site-specific wind speed and TI data collection at any proposed turbine location is required, regardless of the initial site assessment methods. If the rotor for the turbine being proposed is more than 2 meters in diameter, we also recommend that data be collected at least at the bottom and top of the rotor swing to determine TI at both levels and shear between them. It is also valuable to measure the vertical component of the wind resource. Very high shear can exist in the transition zone from the separation bubble to linear flow found on the top of flat roofs, and a passively yawed turbine can have significant yaw error when operating in a high-shear environment, further reducing energy capture.

If turbine visibility is a more important goal than performance, start with acceptable locations for visibility and do the wind resource analysis in those locations. While the best locations for energy production may have been eliminated, this analysis will allow developers to determine the minimum acceptable height and approximate energy production. In some cases, siting turbines for appearance will result in a project that has virtually no energy production value.[11] Wind generators that are mounted on the top of parapets are especially sensitive to mounting in relationship to wind orientation, as can be seen in the Brooklyn Navy Yard case study.

If monitoring the system or the ability to determine if it is producing power according to the manufacturer's published power curve is desired, it will be necessary to have a reference anemometer that measures the wind speed entering the turbine. In a conventional open-flow field installation, it is common to install an anemometer at 2 to 4 rotor diameters upwind in the primary wind direction at hub height. With a building-mounted wind generator, that may not give an accurate result and in some cases may be physically impossible. Investigate alternative siting, such as cross wind from the turbine planned location. Then install the monitoring anemometer at the same time as the anemometer in the turbine location. This allows a direct comparison of the wind speed at both locations. Analysis will be required to assess the correlation by wind direction. A related issue for monitoring and performance is that many commercial building roofs have large heating ventilating and air conditioning, or HVAC, systems on the roof. In addition to being physical obstacles to air flow, this equipment can significantly impact air flow to the turbine or anemometer.

4.2.3.1 Frequency Distribution

Numerous measurement experiments have demonstrated that the wind resource in the built environment is relatively energetically weak (Encraft 2009, Tabrizi et al. 2014). The wind speed frequency distributions, which are an indicator of energy content in the wind, are usually shifted to the lower wind speeds, which results in lower energy production. This is driven by the fundamental physics of fluid flow and turbulence. As shown in Encraft 2009, some tall buildings can escape or minimize the impacts of the turbulent boundary layer created by the urban environment. Figure 5 demonstrates the relationship between measured wind speeds and the turbine power curve at the NASA Johnson Space Center Building 12 site. The overlap between the two data distributions represents the potential energy at a given site. The NASA site with low winds is a relatively poor power-producing site.

[11] It is worth noting that if the ultimate goal of a project is to demonstrate a dedication to green energy or sustainability, turbines may be installed in a location that maximizes visibility over production. This placement can lead to turbines that spend a large amount of time motionless and do not produce much energy. The end result could be a perception that wind turbines do not work, enforcing the opposite impression than was desired.

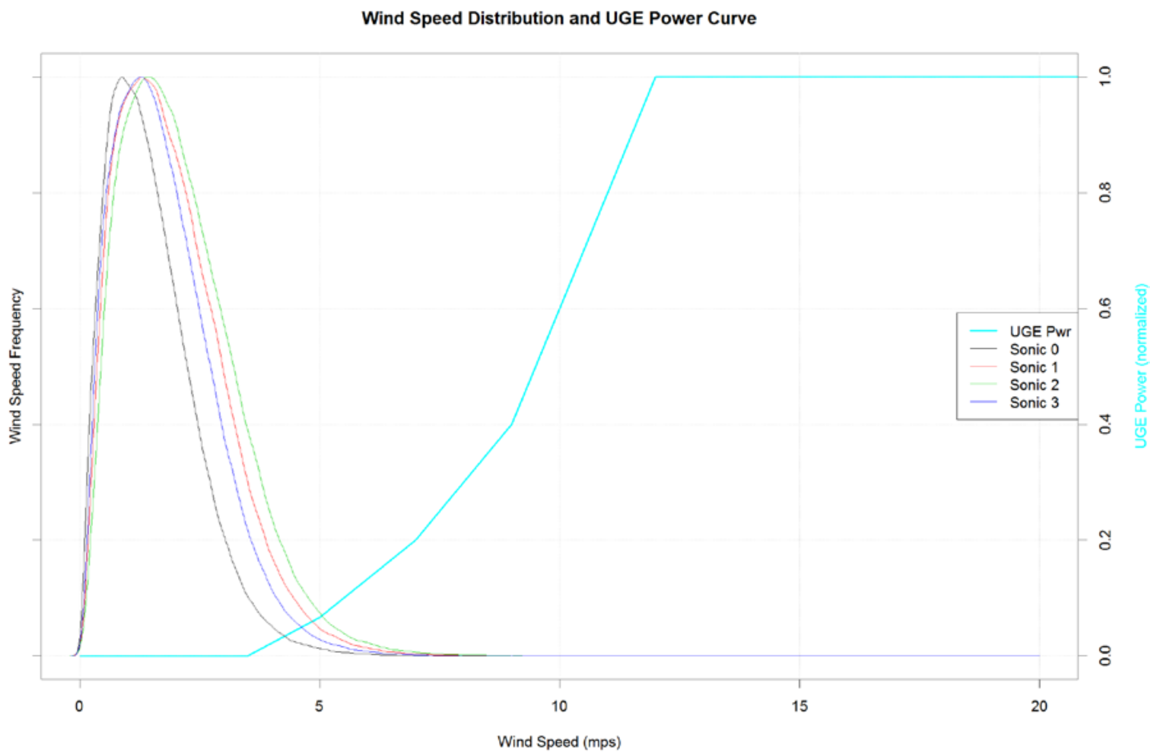


Figure 5. NASA Building 12 frequency distribution of the wind speeds at the four planned turbine locations and power curve for the UGE turbines that were installed

4.2.3.2 Turbulence

Turbulence in wind applications relates to the variability of the winds. The traditional International Electro-technical Committee (IEC) definition of turbulence for wind energy applications is described as TI.

$$TI = \frac{\sigma_U}{\overline{U}}$$

$$where\ \overline{U}\ is\ mean\ wind\ velocity\ and\ \sigma_U is\ standard\ deviation\ of\ the\ wind\ velocity$$

The Normal Turbulence Model (NTM) specifies the appropriate level of TI by wind speed as part of the turbine design process for the IEC 61400-2 standard. Installing turbines at locations with a TI above the NTM will likely result in high turbine maintenance and reduced reliability. Although sites in the built environment with a TI at or below the NTM can likely be found, this will be difficult because of the highly turbulent nature of winds in these areas. Measurements taken at several built-environment installation sites highlight this complication, registering TI well above the NTM guidance. High TI will lead to increased fatigue loads over time, which has implications for component reliability, maintenance costs, safety, and overall turbine lifetime. Figure 6 shows an example of the low wind and higher turbulence measured in the built environment and how it often exceeds the NTM from the IEC 61400-2 classification. This is typical in urban environments due to the high concentrations of roughness elements, which lead to turbulent flows. The IEC 61400-2 standard includes a very useful informative section, Annex L, which also deals with turbines in the built environment.[12]

[12] IEC 61400-2:2013 http://asc.ansi.org/RecordDetails.aspx?action=pl&ResourceId=488010&ResourceGuid=5a323577-b074-48a8-a8e5-69d307be5e0f&NativeKey_I=IEC+61400-2+Ed.+3.0+b%3a2013&NativeKey_II=1507253

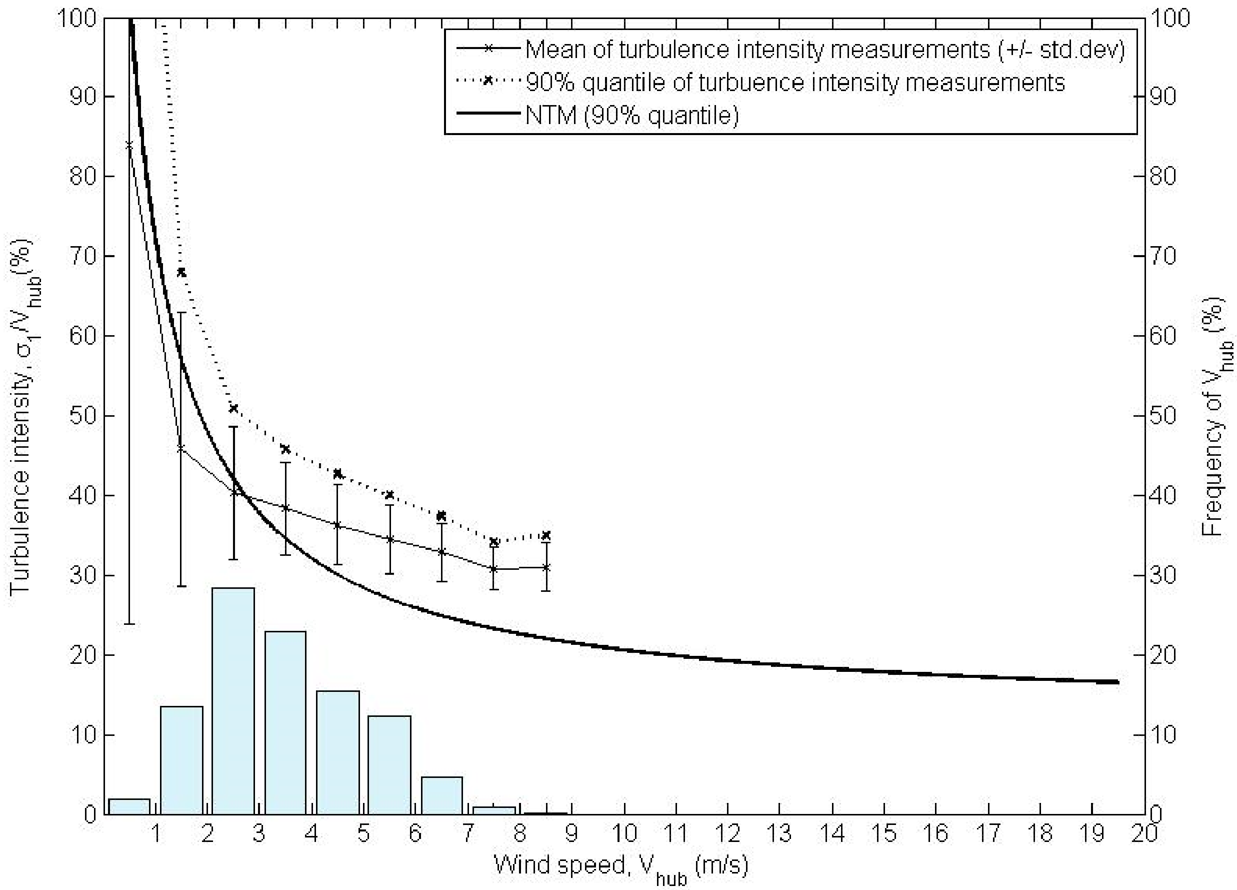


Figure 6. Turbulence intensity and wind distribution, 2 m above rooftop in Melville, Western Australia, during January-February 2009 (Whale, Ruin, and Tokuyama 2012)

4.2.3.3 Wind Direction and Variability

Wind direction and variability are very important considerations for siting and the design of a wind turbine. While most turbine designs can swivel around the top of the tower to match incoming winds, the wind direction in the built environment can be more stochastic and change more quickly than in typical ground-mounted installations. The practical implications of rapidly changing wind direction are that energy production is likely to be reduced and higher loads will be placed on a turbine. Figure 7 shows CFD simulations, which demonstrate the directional variability of resource on a building based on wind direction. This figure demonstrates that depending on the incoming wind direction and speed, a variety of mounting heights are needed to escape the building's turbulent effects. In general, as you increase the ratio of turbine height to building roof area, the suitable area for turbine placement on this square rooftop increases.

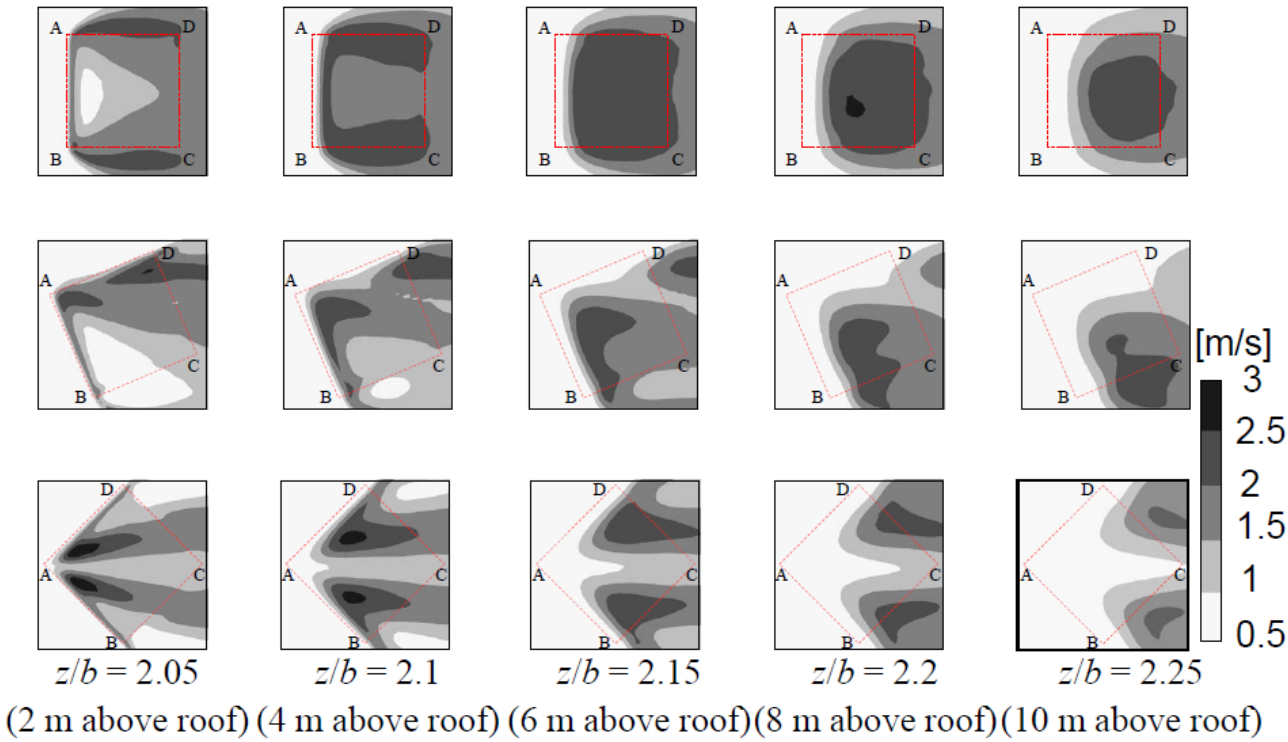


Figure 7. Standard deviation of stream-wise wind velocity based on building orientation and the ratio of building height (z) versus breadth (b) (Kono and Kogaki 2012)

4.2.4 Turbine Certification and Selection

The main standard for small wind turbine design is the IEC 61400-2. This standard describes appropriate input parameters and calculation approaches for turbine loading and resultant expected lifetime. There are other national standards, such as the American Wind Energy Association's small wind turbine standard 9.1 used in the United States, but most of them rely on the fundamental methods in the IEC 61400-2. We strongly recommend that turbines that have been certified to the IEC or other appropriate national standard be used, especially for projects in the built environment. This will help ensure that the turbine is reliable and productive. Additionally, many of the U.S. incentive schemes are increasingly requiring the use of certified turbines.

While the use of certified turbines is recommended, there are still some important caveats to understand about the current standards and certification approach. Built environments, in contrast to traditional open environments, are likely to be characterized by lower wind speeds, higher turbulence, and the potential for significant off-axis flow such as vertical wind velocities. The current standards for design and testing of wind turbines assumes relatively low values for these conditions, such as a TI of below 18%. Installation of even certified turbines at sites outside of the conditions set forth within the standards will in all likelihood result in high turbine maintenance and reduced reliability. Additionally, turbines are typically tested in low-turbulence sites with no upwind obstructions, so the structural loading and power generation may not represent the performance in the built environment. There is also little track record of any turbine in this environment, so the reliability and performance impacts are unknown. A wind turbine certified to the IEC standards is considered certified, but only for limited conditions that a BEWT site would not adhere to. Therefore it is currently impossible to have a BEWT-certified turbine. However, installing a turbine that has been certified to an international or domestic standard is much more likely to provide a better result than a turbine that has not gone through such a process. Finally, as urban environments are often characterized by denser populations than open-field environments, and installing a turbine in these environments yields significant new safety concerns that may not be accounted for in the current wind turbine designs that were never intended to be deployed close to people or in urban environments. Table 3 is a summary of the IEC 61400-2 standard wind characteristics, which differ between the built environment and traditional open environments.

Table 3. Summary of IEC 61400-2 Wind Characteristics that Differ between Built-Environment and Open-Field Sites

IEC Chapter Index	Topic
3.56	Wind profile, wind shear law
3.6	Wind speed distribution
6.2	Small wind turbine classes
6.3.1	Inclination flow
6.3.2.1	Wind speed distribution
6.3.2.2	Normal Wind Profile Model
6.3.2.3	Normal Turbulence Model
6.3.3.2	Extreme Wind Speed Model
6.3.3.3	Extreme Operating Gust
6.3.3.4	Extreme Direction Change
6.3.3.5	Extreme Coherent Gust
6.3.3.6	Extreme Coherent Gust with Direction Change

4.2.5 Energy Production

Developing energy projections starts with a resource assessment (typically annual or multi-year), including quantities such as wind speed and wind direction. The energy estimation process then combines that information to the power curve of the wind generator and then applies adjustments to address losses that may degrade turbine production. Losses can include a variety of impacts such as icing, turbine downtime, and electrical efficiencies. To maximize the accuracy of the energy projection, it is necessary to have an accurate, certified power curve and a systematic survey of the potential losses. Since power curves are generated in low-TI environments, there is some unavoidable uncertainty for a high-TI environment.

If the turbine must operate some of the time in a TI outside its design specification, it can have an impact on energy production. There are no definitive methods for adjusting turbine energy production for varying turbulence levels. There are, however, a number of investigations into the impacts of turbulence on wind turbine power curves, including the Power Curve Working Group.[13] The impact of turbulence on power production is site specific, but preliminary estimates for utility-scale turbines show as much as a 30% deviation from expected power with varying turbulence levels (Blodau 2013). As of the writing of this document, methods in test and realistic correction methods, such as turbulence re-normalization, are better understood. In lieu of rigorous verified methods, common practice in the distributed wind turbine industry is to multiply the estimated energy by the TI (5) and deduct that from the energy production estimate based only on wind speed resource. This applies to ground-mounted BEWT installations as well.

[13] The Power Curve Working Group is a wind industry collaborative that aims to facilitate stakeholder collaboration in order to acknowledge, address, and ultimately resolve the question of “non-standard” (now commonly called “Outer-Range”) inflow conditions on wind turbine power curves; see www.pcwg.org

4.3 Estimate Project Costs and Conduct a Cost-Benefit Analysis

Project economics are often important criteria among many that project stakeholders will use to evaluate the feasibility of a BEWT project. We recommend that the project stakeholders evaluate the total project costs and expected energy output. That information can then be compared with onsite electric loads and power costs in light of other potential renewable energy or energy efficiency solutions. Additional value streams such as marketing, education, or carbon reduction should be considered and quantified to evaluate the viability of a BEWT project. The evaluation of the energy production capability and associated value will have high uncertainty. No projects assessed for this report have met their energy projection estimates. Guidance presented here should improve the accuracy of energy estimates.

BEWT projects can have higher costs due to:

- More complex and difficult wind resource evaluation requiring advanced modeling and/or extensive on site measurements
- Structural integration with the building
  - Specialized engineering and materials to understand, design, and implement building strengthening
  - Special mounting to isolate turbine vibrations from the building.
- Complex installation and maintenance logistics
- A non-optimal operating environment leading to premature turbine wear or failure
- Increased liability and insurance costs.

Once you have an energy projection, calculating the value of the energy is relatively straightforward (this topic is discussed in the *Small Wind Site Assessment Guidelines*). For a BEWT project, much of the project value may come from meeting other goals. The value of each of those goals may be difficult to quantify, and they may exceed the value of the energy generated.

5 Summary and Conclusions

BEWT projects are wind energy projects that are constructed on, in, or near buildings. These projects can be attractive because they present an opportunity for distributed, carbon-free generation. However, there are distinct challenges with this emerging application. In order to mitigate performance risk and manage expectations, NREL recommends that the following key steps be incorporated when planning a BEWT project:

- Establish baselines and develop project goals
- Perform a technical evaluation:
  - Project siting
  - Safety/liability
  - Wind resource
  - Energy production/turbine specification
  - Energy value and incentives.
- Estimate project costs
- Conduct a cost/benefit analysis

The built environment adds new dimensions, costs, and challenges to these planning process phases. Although relevant to the installation of all small wind turbines, the following parameters must be considered more carefully when siting BEWT projects:

- Wind resource
- Building characteristics and geometry
- Turbine technology
- Installation and maintenance
- Building occupant comfort and safety.

It should also be noted that based on several key factors (i.e., wind speeds are typically lower and costs for implementing projects in built environments are typically higher), projects in the built environment can be difficult to justify on a cost of energy or energy-offset basis. Understanding the expected production of a wind turbine in the built environment is a very complex undertaking; the use of onsite resource measurements combined with high-fidelity models is likely the only way to truly understand the expected turbine production.

5.1 Case Studies and Lessons Learned

In general, developers of BEWT projects we examined as part of our case studies and in external studies such as the Warwick wind trials[14] have had mixed results. Energy predictions rarely meet pre-construction expectations, and the turbines are often shut down or removed early due to vibration, noise, or reliability concerns. The Warwick wind trials consisted of 26 BEWT deployments, which had a variety of challenges. Although there was some variability in the performance and reliability of machines, the general results were quite poor. Overall capacity factor was reported at 0.85% and is noted as being indicative of BEWT projects, including real losses and use problems. In addition to the low performance, it was also noted that wind speeds at 16 out of the 26 sites were ~40% lower than the model predictions. Additionally, even when measurements were available and used to predict power, the

[14] http://www.warwickwindtrials.org.uk/2.html

turbines produced less energy than seemed apparent. This speaks to the importance of having not only robust models and measurements but also a good energy prediction model that can account for physical losses.

The NREL case studies contain examples of successful BEWT projects from a stakeholder perspective; however, it should be noted that these projects include goals for public relations or educational values in addition to energy production goals that are rarely met.

The case studies also demonstrate that BEWT projects with clear goals and informed planning were the most likely to be deemed successful by the stakeholders. In order to maximize the chances of success for a BEWT project, considerable effort and upfront planning are required, including evaluating the wind resource's strength and quality (TI, inflow angle, extreme direction change). The tools for estimating the wind resource on the top of a building are expensive and not well validated, so onsite data collection is advised. Special care must also be used to assess the TI at perspective sites since the impact of high TI on performance and reliability is not well understood. In addition, operation in high-TI environments can increase maintenance costs and shorten turbine life. No standards exist for testing turbines for the BEWT environment, so such installations result in a wind generator operating in an environment for which it was not designed or tested.

Siting the turbine in a built environment can also lead to additional costs not typically associated with the deployment of small wind generators. Unless the building has been designed to allow for the mounting of a specific wind generator, costly structural work may be required. The cost of engineering and building upgrade efforts may exceed the cost of the wind generators. Unless the installation is designed to provide easy access for service and maintenance, including removal and replacement of the entire turbine if necessary, then maintenance may also be more expensive than standard projects. Depending on the cash value of the energy produced, a poorly planned installation can end up not generating enough revenue to cover the turbine maintenance expense. A turbine that falls into disrepair is more likely to suffer a catastrophic failure which, in the built environment, may have increased liability associated with potential injury or other collateral damage.

Because installations in the built environment are currently not common, it is important to establish with the manufacturer that they are willing to warranty and support the wind generator in the environment where it will be installed. Current wind turbine design standards and certifications are designed around more conventional turbine installation environments, so even a certified turbine may be operating outside of its design envelope. Although not just confined to turbine suppliers providing technology to the built-environment market, a wind turbine manufacturer's ability to meet long-term warranties or even supply replacement parts is dependent on its overall financial health and should not be assumed.

This document defined BEWT projects, discussed the current state of the industry, laid out a recommended practice, and demonstrated real projects through a variety of case studies. The motivations for the implementation of these projects are varied, and depending on those overriding goals, not all of the projects were reported as being successful by their owners. None of the case study projects met their energy production estimates, largely due to the complexity of conducting accurate resource and production assessments in complex built environments. Additionally, although there may be some initial considerations that the installation of the turbine on top of a building may offset the cost of towers, the costs of deploying turbines in the built environment are typically more expensive than originally estimated. In the eyes of the project owners, some of the case study projects have been successful based on all of the goals set forth for the projects, such as raising awareness of sustainability. The experiences of some of the case study project developers left them skeptical about wind energy in general.

In conclusion, based on the findings associated with the case studies analyzed (especially the NASA Building 12 work funded by the U.S. Department of Energy), NREL recommends a thoughtful and thorough evaluation of any BEWT project to ensure the ultimate results match with pre-determined goals. Developers considering BEWT projects should understand that, based on the limited number of case studies that could be assessed as part of this report, projects in the built environment are likely to have lower power production values and higher related costs than would normally be assessed based on experience with turbine installations outside of the built environment.

Glossary

Built environment	An urban or suburban setting, characterized by buildings and other structures that typically result in lower wind speeds, higher turbulence, and the potential for significant off-axis flow, such as vertical wind velocities.
Built-environment wind turbine (BEWT)	Wind turbines that are typically 100 kW and smaller, located in an urban or suburban environment (built environment). They may be mounted on buildings or among buildings.
Computational fluid dynamics (CFD)	A branch of fluid mechanics that uses numerical analysis and algorithms to solve and analyze problems that involve fluid flows.
Extreme direction change	A measure of how variable the wind direction at a particular site might be.
Frequency distribution	Distribution of wind speeds that may be a modeled distribution using a statistical function or a table of a recorded history of hours of wind at each wind speed for a site.
Horizontal-axis wind turbine (HAWT)	A wind turbine designed with the axis of rotation around a horizontal shaft, typically with a propeller-like configuration.
Large eddy simulation (LES)	Mathematical model for turbulence used in computational fluid dynamics.
Levelized cost of energy (LCOE)	The total cost of installing and operating a project, expressed in dollars per kilowatt-hour of electricity generated by the system over its life.
Micrositing	The process of selecting a wind turbine location and determining the likely wind resource (speed and turbulence) available after considering all possible impacts, such as topography, ground cover, and obstacles, and their location relative to the tower's location. Part of selecting a location includes all of the other factors besides wind, such as construction access, land-use restrictions, aesthetics, access to a power system, etc.
Permitting	The process of obtaining legal permission to build a project, potentially from a number of government agencies, but primarily from the local building department (i.e., the city, county, or state). During this process, a set of project plans is submitted for review to assure that the project meets local requirements for safety, sound, aesthetics, setbacks, engineering, and completeness. The permitting agency typically inspects the project at various milestones for adherence to the plans and building safety standards.

Site assessment	The act of evaluating a site to determine a favorable location for a wind turbine, which includes assessing the expected wind resource and potential turbine performance at that location.
Small wind turbine	A wind turbine that has a rating of up to 100 kilowatts, typically installed near the point of electric usage such as near homes, businesses, remote villages, and buildings.
Turbulence intensity (TI)	A basic measure of turbulence that is defined by the ratio of the standard deviation of the wind speed to the mean wind speed. For wind energy applications, this is typically defined as a 10-minute average wind speed and standard deviation based on 1-second samples. Turbulence intensity is important for wind energy applications because it has implications for power performance and turbine loading.
Vertical-axis wind turbine (VAWT)	A turbine designed with the axis of rotation around a vertical shaft and two prevalent configurations: Darrieus, which is an egg-beater style with primarily lift aerodynamics, and Savonius, a split-barrel style with primarily drag-based aerodynamics.
Wind shear	The difference in wind speed and direction over a relatively short distance in the atmosphere. Wind shear can be broken down into vertical and horizontal components, with horizontal wind shear seen across storm fronts and near the coast, and vertical shear seen typically near the surface (although also at higher levels in the atmosphere near upper-level jets and frontal zones aloft).

References

Blackmore, P. (2010). Building-Mounted Micro-Wind Turbines on High-Rise and Commercial Buildings. IHS BRE Press. United Kingdom.

Blodau, T. (May 2013). *Review of Inner/Outer Range Proposal*. PCWG Meeting #3, Repower HQ, Hamburg, Germany. http://www.pcwg.org/proceedings/2013-05-30/01-Introduction-06-Review-of-Outer-Range-Proposal-Tomas-Blodau-REPower.pdf

Boston Museum of Science Wind Lab. (2015). *Energized! Exploring Renewable Energy*. http://legacy.mos.org/energized/museum-wind.php

Detroit Metro Airport. (April 22, 2010). "Earth Day Breezes into Detroit Metro Airport -- Airport Authority Begins Testing New Wind Energy Technology." News release. http://www.wcaa.us/Portals/WCAACorp/WCAA%20Documents/PDFs/NR_Windspire_Event_22APR2010_POST.pdf

Dopp, T. "NYC Opens 1st Building-Mounted Wind Turbines at Brooklyn Yard." Bloomberg, April 9, 2009. http://www.bloomberg.com/apps/news?pid=newsarchive&sid=aOiCpp9Xi1pk

Encraft. (2009). Warwick Wind Trials Final Report. http://www.warwickwindtrials.org.uk/resources/Warwick+Wind+Trials+Final+Report+.pdf

Galbraith, K. "Assessing the Value of Small Wind Turbines." New York Times, September 3, 2008. http://www.nytimes.com/2008/09/04/business/04wind.html?pagewanted=all&_r=2

Greeson, E. (October 8, 2010). "RNP Visits ZGF Architects for Rooftop Renewables Tour." Renewable Northwest. http://www.rnp.org/node/rnp-visits-zgf-architects-rooftop-renewables-tour

Kono, T.; Kogaki, T. *Numerical Simulation Analysis of Wind Conditions over a Rectangular Prism-Shaped Building for Mounting Small Wind Turbines*. IEA Wind Task 27 Meeting, Dundalk, Ireland, September 25-27, 2012.

NASA. (August 26, 2015). *Our Planet Is Changing. We're On It!* https://www.codegreenhouston.org/dmdocuments/resources/gbrc_panel_jsc_8_26_15.pdf

Olsen, T.; Preus, R. (2015). *Small Wind Site Assessment Guidelines*. National Renewable Energy Laboratory, NREL/TP-5000-63696. http://www.nrel.gov/docs/fy15osti/63696.pdf

Rabkin, D.; Tomusiak, M. (September 2014). *Museum of Science Wind Turbine Lab Project History and Three-Year Performance Report*. Boston Museum of Science. http://www.mos.org/sites/dev-elvis.mos.org/files/docs/about-us/Three-Year-Performance-Report.pdf

Smith, J.; Forsyth, T.; Sinclair, K.; Oteri, F. (2012). *Built-Environment Wind Turbine Roadmap*. National Renewable Energy Laboratory, NREL/TP-5000-50499. http://www.nrel.gov/docs/fy13osti/50499.pdf

Tabrizi, B.; Whale, J.; Lyons, T.; Urmee, T. (2014). *Suitability of the von Karman and Kaimal spectrum for the structure of the turbulence in the built environment in terms of rooftop small wind turbine applications.* Submitted to *Journal of Wind Engineering and Industrial Aerodynamics*.

Tokuyama, H. (March 2011). *Analysis of Field Data Regarding Extreme Wind Direction Changes on an Urban Rooftop Site*. IEA Wind Task 27 meeting, Madrid, Spain, March 3-4, 2011.

Toja Silva, F. (April 2015). *CFD Simulation of the Wind Flow around Buildings: Case Study in Soria (Spain) – Computational Issues*. IEA Wind Task 27 Meeting, University of Applied Sciences Technikum Wien, Vienna, Austria.

Tomusiak, M. (July 26, 2011). "Museum of Science Analyzes Rooftop Turbines." Interstate Renewable Energy Council. http://www.irecusa.org/2011/07/19769/

Whale, J.; Ruin, S.; Tokuyama, H. (April 2012). Turbulence Intensity Values at Potential SWT Sites in Non-open Terrain. International Energy Agency Task 27 Meeting, Ithaca, New York, USA.

Wilson, D. (1979). "Flow patterns over flat-roofed buildings and application to exhaust stack design." ASHRAE Transactions 1979: 85 (2): 284-295.

Zemke, J. "Metro Airport Installs First Wind Turbines." Metromode, April 29, 2010. http://www.secondwavemedia.com/metromode/devnews/metroairportwindturbines0161.aspx

Bibliography

International Energy Agency, Wind Task 27, Small Wind Turbines in High Turbulence Sites, http://www.ieawind.org/task_27_home_page.html, accessed December 24, 2015.

Tabrizi, A.; Whale, J.; Lyons, T.; Urmee, T. (2014). Performance and safety of rooftop wind turbines: use of CFD to gain insight into inflow conditions. Renewable Energy, 67, pp. 242-251.

Toja-Silva, F.; Colmenar-Santos, A.; Castro-Gil, M. (August 2013). Urban wind energy exploitation systems: Behaviour under multidirectional flow conditions – Opportunities and challenges**.** Renewable and Sustainable Energy Reviews, Volume 24, pages 364-378.

Toja-Silva, F.; Peralta, C.; López, O.; Navarro, J.; Cruz, I. Roof region dependent wind potential assessment with different RANS turbulence models**.** Renewable Energy, under review.

Whale, J. *Designing and Installing Small Wind Turbines for the Built Environment*. IEA Wind RD&D Task 27 Extension, National Wind Technology Center, Louisville, CO, May 2014.

Appendix A: Case Studies

Twelve West

Location: Portland, OR

Turbine type: Skystream 3.7

Number of turbines: 4

Installation date: 2009

Building integrated: Roof mounted (23-story building, mounted on 45-foot poles, blades at an elevation of 82 meters)

Estimated production: ~9,000 kWh yearly, or ~1% of the building's electricity

Actual production: ~5,500 kWh per year

Cost: $20K per turbine; $240,000 for entire installation (mounting pads, engineering, etc.)

Incentives: 30% federal Investment Tax Credit in cash at project completion

Payback: ~40 years

Figure 8. Twelve West wind turbine installation in Portland, OR. ***Photo from Flickr 4852149002***

Maintenance record: Have had issues with Turbine #3 (does not spin on occasion and must be restarted). This is under control with building management.

What was the primary project objective? Raise awareness about renewable energy. Elevate the visibility of the building. Underscore the building's sustainability commitment.

Did the installation meet those goals? Rooftop wind in urban environments is challenging and has not evolved as much as we had hoped; however, all other objectives were met, and we consider this installation a success.

Given your experience and the lessons you've learned, what suggestions would you give to another organization determined to develop a similar project? Take advantage of and leverage as many resources as you can. Make sure the turbine project is a good fit for your site; a token array that never spins will be detrimental when it comes to public opinion. Pay careful attention to turbine siting. A prominent wind specialist from the Netherlands advised us on turbine placement based on the wind patterns in the area. Research the products well, and get comfortable with the fact that the manufacturer may go out of business (many of these companies are start-ups), which makes replacement/repair and warranty enforcement difficult.

Additional Notes

Turbine choice: Due to the limited data regarding built environment wind installations, project developers didn't know what to anticipate in terms of turbine selection. None of the turbines researched had long track records for this type of installation, so the group conducted a significant investigation to identify what turbines would be best to use. Project developers conducted in-depth research during their turbine selection process, visiting multiple vendors and installations prior to selecting Southwest Windpower Inc. as the turbine supplier. One factor that influenced the selection was the company's compliance with European certification standards (Greeson 2010).

Development process: The wind turbines were part of a larger project: the design and construction of a 23-story LEED Platinum-certified mixed-use apartment and office building. Project developers decided to utilize solar and wind energy to help reach their LEED goal. The turbines were integrated into the building design early in the process, allowing the building's developers time to consult with experienced wind energy professionals to properly assess the site prior to installation. During this period, the developers conducted a thorough site assessment that included flow pattern simulations conducted at the Oregon State University's Aero Engineering Lab.

The project developers also had to engage in discussions to address Federal Aviation Administration concerns related to the combined height of the building and project.

Public interest: Project developers believe the installation's visibility and the attention it has created for renewable energy and sustainability have been phenomenal. The installation has helped the building become a unique and recognizable feature in the city of Portland.

Sound impacts: Since the project is located directly above the building's penthouse units, special consideration had to be given to reducing the potential sound impacts of the installation. This increased costs but was essential to overall project success.

Detroit Metro Airport

Location: Detroit, MI

Turbine type: Windspire 1.2

Number of turbines: 6

Installation date: 2010

Operational status: As of July 2015, one turbine had a broken inverter and was not operational. Airport officials have relocated two turbines from the original location and will be moving forward with the goal of keeping at least three generating electricity by borrowing parts from the remaining turbines.

Building integrated: No

Estimated production: ~2,000 kWh per year

Actual production: Project was never tracked. When operating, contribution has been minimal.

Cost: $75,000 (Zemke 2010)

Incentives: No incentives provided

Payback: Production is not being recorded, so it's not feasible to estimate simple payback.

Figure 9. Detroit Metro Airport Windspire installation. ***Photo from Wayne County Airport Authority***

Maintenance record: Issues (inverters, bearings) from the beginning of the project until now. Manufacturer is bankrupt. It's difficult to find and maintain parts.

What was the primary project objective? Did the installation meet that (those) goal(s)? The project was a pilot program to determine whether the technology should be further deployed at the airport (Detroit Metro 2010). In terms of energy production, the project did not meet expectations. This is primarily due to maintenance issues, as well as lower-than-advertised production (developers were told that the turbines were not as efficient as other models and that they should not anticipate much production due to the site, but they are doubtful of efficient production even with a good resource). The project was installed during Earth Day 2010 and was featured in multiple articles and news stories. Airport officials say there is continued interest in the project from a visitor perspective and that they continue to be contacted about the project from those interested in installing similar projects.

Given your experience and the lessons you've learned, what suggestions would you offer to another organization determined to develop a similar project?

- Try to get guarantees of energy generation rates, not just anticipated estimates based on computer modeling.

- Make sure the manufacturer-approved sales/installation vendor is experienced and capable of doing the work.
- Work with established manufacturers so as not to run into repair/replacement part issues if the company folds.

Additional Notes

Although Bryan Wagoner, Wayne County Airport Authority's Environmental Program Administrator, was not in charge at the time, he believes that Small Wind Certification Council certification would have been influential in terms of technology selection if it had been available.

Wagoner also believes that additional research prior to installation could have benefitted the overall project. "If we had to do it over again, we would do a more planned project where metering and that kind of stuff were included in the initial design; where we did some studies beforehand and maximized the wind. I think with that we'd get a much better result."

Museum of Science

Location: Boston, MA

Number of turbines: 9

Turbine type: Windspire 1.2-kW, Skystream 3.7, Swift, Proven 6, AeroVironment AVX1000 (bank of 5)

Installation date: 2009

Building integrated: roof mounted

Estimated production: 20,498 kWh per year (15% installed capacity)

Actual production: Cumulatively, the wind turbines average 4,229 kWh of electricity per year (Rabkin and Tomusiak 2014) (~20% of what was originally estimated)

Cost: ~$350,000 (Tomusiak 2011)

Incentives: Massachusetts Clean Energy Center (formerly known as the Renewable Energy Trust) provided a $300,000 grant for purchase and installation. Site and resource assessment were funded through a $50,000 grant from the Kresge Foundation (Tomusiak 2011).

Figure 10. Skystream installation at the Boston Museum of Science. ***Photo from Boston Museum of Science, NREL 18006***

Payback: Assessment showed that wind profile and site assessment would not yield monetary payback within 20 years. The project went forward as a test lab.

Maintenance record:

- Skystream: Out of service last 3 months of 2012. Periodically stops and restarts for months at a time. Currently operational
- Windspire: Initial inverter issues. Standard model replaced by extreme wind model in 2011. In 2014, the mounting connection failed in high wind. Currently non-operational
- Proven 6: Wiring adjustment in 2013. Currently operational
- AVX1000: Recurring inverter and hardware issues during first year of operation (Rabkin and Tomusiak 2014). Currently operational
- Swift: Brake adjustment 3 months after installation. Currently operational.

What was the primary project objective? Did the installation meet those goals?
The primary objectives of the Museum of Science Wind Lab included:

- Creating a roof-top location where a variety of commercially available small wind turbines could be tested in the built environment
- Providing data and experience for the general public and industry professionals

- Constructing an exhibit that would become a landmark for both the city and region
- Generating clean energy while making a statement on its importance (Rabkin and Tomusiak 2014).

Years of project experience, wind data, and performance data have been shared with more than 1,300 people so far (Boston Museum of Science 2015). These include the general public; industry professionals; and university classes from Massachusetts Institute of Technology, Worcester Polytechnic Institute, Boston University, Northeastern, and Emerson. Of all the energy-saving and sustainable practices the museum employs, the turbines are the most visible to the public. The project has been producing clean energy that is used onsite with only two confirmed bird strikes since 2009 and none of the other problems people often fear (sound, vibration, ice-throw, safety, aesthetics, wildlife issues, etc.).

Given your experience and the lessons you've learned, what suggestions would you give to another entity determined to develop a similar project?

- Establish well-defined project goals.
- Communicate with stakeholders early and often to gain their support.
- Measure the wind resource as close to hub height as practical in order to better understand the energy potential of your wind regime and any possible restrictions due to structural factors of the building or the surrounding environment.
- Installation sites may need to be a compromise between wind, building structures, and perceived public safety.
- Roof-mounting turbines is expensive compared to conventional installations, primarily due to higher costs of engineering and structural steel supports (Rabkin and Tomusiak 2014).
- Maintenance can be a more complex issue than originally anticipated. Roof access and access to skilled technicians is a major long-term concern. Consider how quickly and affordably you can reproduce installation circumstances prior to establishing a project.

Additional Notes

During the permitting of the project, developers had to engage in discussions to address Federal Aviation Administration concerns related to the combined height of the building and project and proximity to Logan International Airport. Other concerns, all resolved before installation, included permitting by Cambridge and Boston, location in a historical district, location in a wetland, views from neighboring residential high-rises, different roof structures built over decades, and the perception of public safety.

Project developers said that the installation has not received any complaints related to sound or vibration, even though the largest turbine is located above the museum's Omni Theatre.

Brooklyn Navy Yard

Location: Brooklyn, NY

Number of turbines: 6

Turbine type: AeroVironment AVX 1000 (1 kW)

Installation date: 2008

Building integrated: Roof mounted

Estimated production: 14,400 kWh (estimates based on a sustained wind speed of 29 mph)

Actual production: Over the first 192 days of the project: 126.92 kWh. Estimated production for that time period was 6,269 kWh.

Figure 11. Brooklyn Navy Yard wind turbine installation. ***Photo from Flickr 2874788682***

Cost: $6,500/turbine (Galbraith 2008)

Incentives: N/A

Payback: N/A

Maintenance record: N/A

What was the primary project objective? Did the installation meet that (those) goal(s)? I believe the goals were primarily to promote the emerging wind technology, create a highly visible indication of the building's emphasis on sustainable design, and hopefully cover the costs of the installation over a reasonable amount of time based on energy savings. The first two goals were met but the third fell short.

Given your experience and the lessons you've learned, what suggestions would you offer to another airport or municipality determined to develop a similar project? Personally, before I consider wind technology on a future project, I would want to gather real-world data on wind speeds in the project location over an extended period. Mockups of the building geometry would be useful as well. I believe wind speed was the primary reason why our third goal (cover the costs of the installation over a reasonable amount of time based on energy savings) was not met.

The balance between visibility and strongest resource also has to be considered. During the development of this project, a choice had to be made between siting the turbine installation where it would be most visible or where the resource was strongest. In this case, visibility was given priority, which could have contributed to the overall underperformance of the project.

Additional Notes

The wind turbine was part of a larger project: the design and construction of the three-story, 89,000-square-foot Perry Avenue building. The development was the first multi-story structure in the nation to be classified as a "green industrial facility" by the U.S. Green Building Council (Dopp 2009).

The location did not provide the necessary wind speeds, with the exception of a few minutes each day. This resulted in an insignificant amount of power production.

Due to high maintenance costs and poor system performance, the owners have not kept the installation in working order or continued to track data.

Pearson Court Square

Location: Long Island City**,** New York

Turbine type: VisionAIR5 (Urban Green Energy)

Number of turbines: 3

Installation date: Spring 2014. Fully operational as of summer 2015

Building integrated: Roof mounted

Estimated production: ~6,000 kWh annually, depending on wind conditions and nearby site obstructions

Actual production: Too early to determine; system recently began generating

Cost: ~$185,000 total project cost, including installation of additional significant steel structural support

Incentives: New York State Energy Research and Development Authority; project also qualified for the Investment Tax Credit

Payback: Will not know until after a year or more of operation

Maintenance record: System needed to be adjusted to resolve vibration and noise issues. These need to be monitored as the turbines were installed on the roof of a multi-family building with many residents.

What was the primary project objective? Did the installation meet that (those) goal(s)? Project objectives included: Furthering the building's sustainable practices, marketing, and onsite energy generation. It is still too early in the process to determine how well the installation generates energy, but the other project objectives were met. In terms of marketing, during the project's initial launch and leasing phase, it was highlighted in numerous domestic publications (10-15, including the New York Times) and three local television news reports. The project also gained international attention via a German radio station's reporter who visited the site and conducted an interview with Pearson Court Square representatives.

Given your experience and the lessons you've learned, what suggestions would you give to another entity determined to develop a similar project?
The delay between installation and being fully operational was due in part to the interconnection approval process with the local electric utility company. Speak with local utility companies regarding interconnection early in the development process. Determine whether the local utility has requirements that must be met prior to interconnection in order to ensure timely operation.

Project intent should be more than generation. With a project that consists of three small wind turbines, the amount of generation under the best circumstances is limited. The project's additional objectives of furthering the building's overall sustainability and the increased visibility via the project's marketing value allowed the installation to be considered successful even if generation proves to be limited.

Additional Notes

Project developers utilized the company Pfister Energy to install the turbines. Pfister was the recommended installer by Urban Green Energy, manufacturers of the turbine selected for the project. While the installers had significant experience constructing other sustainability installations, they did not have experience installing these Urban Green Energy turbines. The developers found it interesting that no one had really done these projects before; it was difficult to find experienced installers.

NASA Building 12

The NASA Building 12 project is unique among the case studies as it involved detailed pre-construction and post-construction measurements. NREL researchers initiated a measurement campaign consisting of multiple rooftop anemometers and other atmospheric instrumentation located on the prospective turbine pad mounts and in the immediate rooftop vicinity. The Building 12 measurement program consisted of two phases: Phase 1[15] is the pre-construction measurement campaign, and Phase 2 is the post-construction measurement campaign. The full installation and commissioning documentation and datasets are available.[16] The power data for Phase 2 was measured by the NASA enterprise Supervisory Control and Data Acquisition system and contains inputs directly from the turbine inverters. As of the writing of this document, Phase 2 data collection is ongoing, so this report contains a subset of the total data.

Location: Houston, TX

Turbine type: Eddy GT (Urban Green Energy) 1 kW

Number of turbines: 4

Installation date: December 2014

Building integrated: roof mounted

Estimated production: ~1,250 kWh annually (NASA 2015)

Actual production: In March 2015, the turbines produced 0.11692 kWh. Additional time and data are needed to determine the total production for the first year.

Cost: ~$100,000 (not including electrical infrastructure)

Incentives: N/A

Payback: Project developers believe the installation will not yield any monetary payback.

Maintenance record: Software update required. NASA is currently waiting on the installer and equipment manufacture to provide the update.

[15] Phase 1 data are available at http://en.openei.org/doe-opendata/dataset/nasa-building-12-wind-turbines-phase-1-data
[16] http://en.openei.org/wiki/NASA_Building_12_Wind_Turbines

Figure 12. NASA Building 12 wind turbine installations. ***Photo by Dave Jager, NREL***

What was the primary project objective(s)? Did the installation meet that (those) goal(s)? The primary objectives of the Building 12 installation include:

- Construct a high-visibility continuation of the facility's sustainability efforts
- Provide an educational and demonstration project that utilizes a new form of renewable technology
- Produce onsite generation
- Comply with mandates regarding renewable energy production at federal buildings.

Project developers feel that the installation did not meet all of its goals primarily due to the location's low wind resource, which led to an overall underperformance of the installation.

Given your experience and the lessons you've learned, what suggestions would you offer to another entity determined to develop a similar project?
If you are serious about the amount of energy your project will produce, you should conduct a thorough assessment of the location's resource prior to moving forward with equipment purchase and installation.

- **Project location is key to project having access to resource.** Alternative siting options were extremely limited due to the multitude of historical buildings at Johnson Space Center and the funding being tied directly to Building 12 renovations. Building 12 is located in the middle of an industrial building and office park. The building is approximately two stories (30') and is surrounded by several taller multi-story buildings (up to 111') at most orientations. Due to the surrounding structures and their influence on the local wind resource, the location is not optimal for this type of installation. The following image shows the elevation of Building 12 and its surrounding buildings.

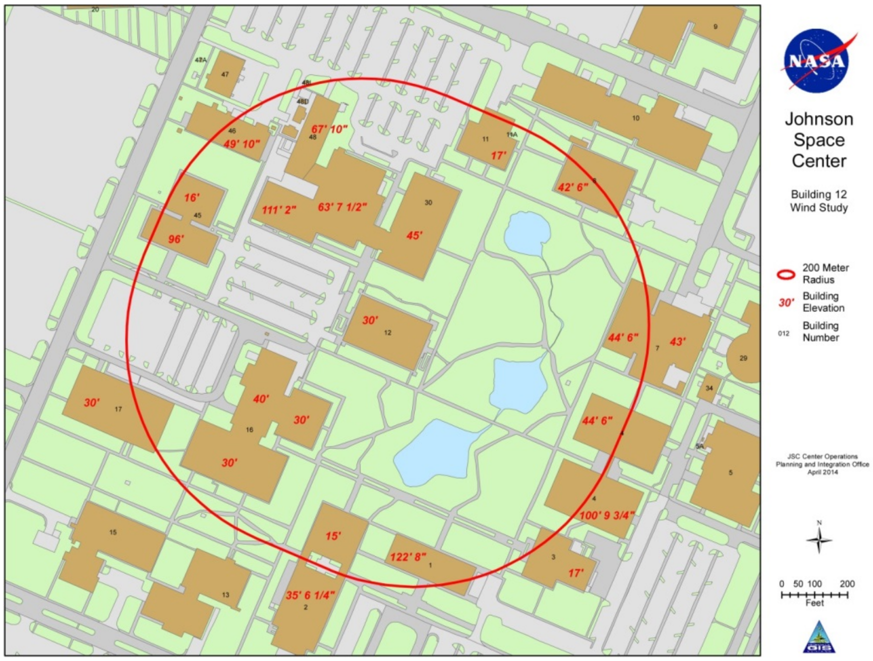


Figure 13. A part of the NASA Building 12 project assessment, this elevation map shows the height of surrounding structures.

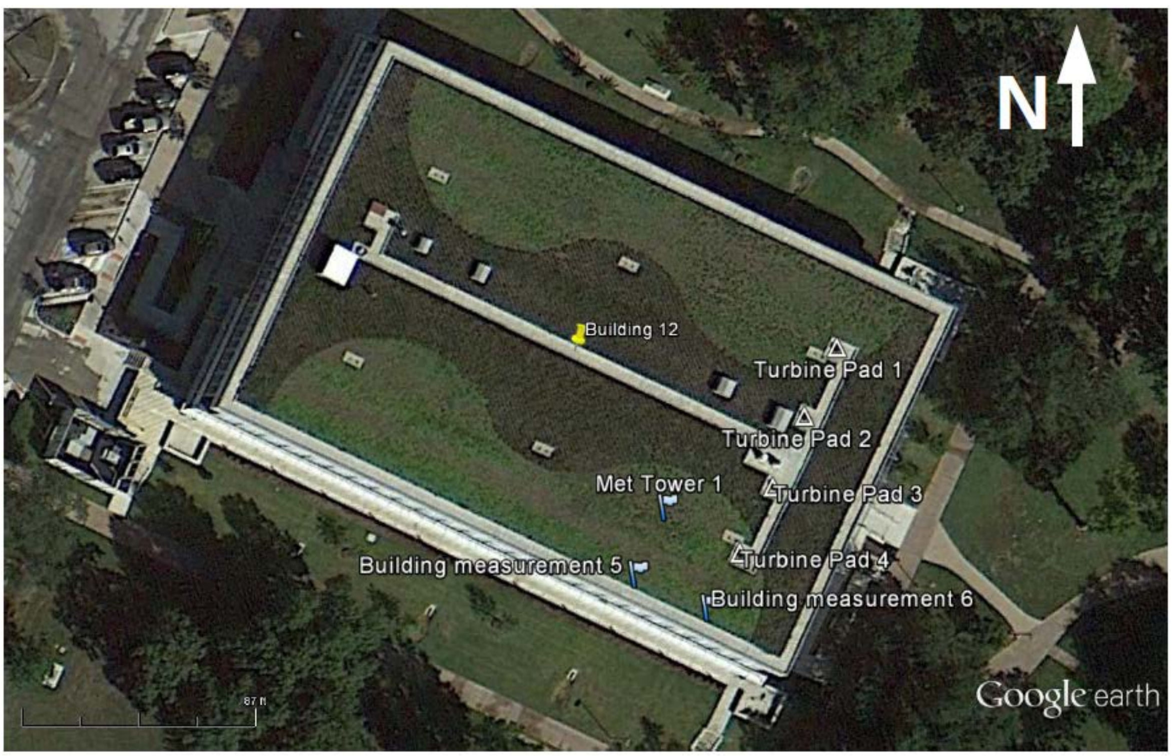


Figure 14. Aerial satellite photo showing the layout of the NASA Building 12 project

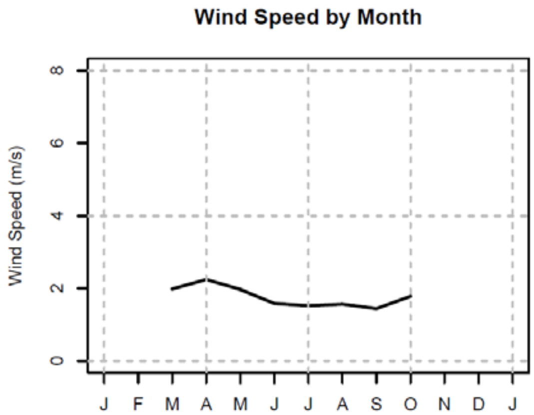


Figure 15. NASA Building 12 monthly average wind speeds

- **The resource and technology must match.** During Phase 1 of the NASA-NREL/Department of Energy collaboration, the project developers conducted an 8-month onsite resource assessment prior to construction but after committing to the installation. The assessment included anemometer measurements at sites that have since become turbine locations (Figure 15). Although the assessment revealed that the site has a low wind resource (<2 m/s), the project moved forward with Phase 2, which included the installation of four Eddy GT turbines.

Since installation, the project has been hindered by low production. This can be attributed to the resource not matching the required cut-in speed for the technology to begin generating power (~3.5 m/s). Additionally, the turbines have not produced as much power as even the low winds would predict using a simple convolution of the wind speed frequency distribution with the wind turbine power curve. It is currently believed that the inverters represent the discrepancy in the expected power from wind speed measurements versus actual turbine power measurements. The inverters require a sustained minimum wind speed in order to function. This minimum duration is often not achieved, and the energy produced from the turbine is converted into heat energy for system protection. This setup is sometimes known as a dump load. The low wind speeds combined with the inverter setup mean that the NASA Building 12 turbines are performing well below their anticipated generation and even the potential as measured with wind speed. This demonstrates the critical link not only between anticipated generation and onsite measurements but also the need to account for losses as part of the energy estimation process.

Figure 16 demonstrates the marked difference between expected power and actual power. The figure represents the measured wind speed as WS (mps), the predicted energy as UGE PWR, and the actual measured turbine energy as Watts1-4. UGE PWR is created by convolving the measured wind speed with the manufacturer's turbine power curve. The difference between the UGE PWR and Watts1-4 is dramatic, with the turbines only producing power in rare higher-wind events. The actual energy production values for March 2015 are shown in Table 4. The last column also demonstrates how long in hours a typical 60-watt light bulb could be powered with the energy generated from the turbines over the course of the month.

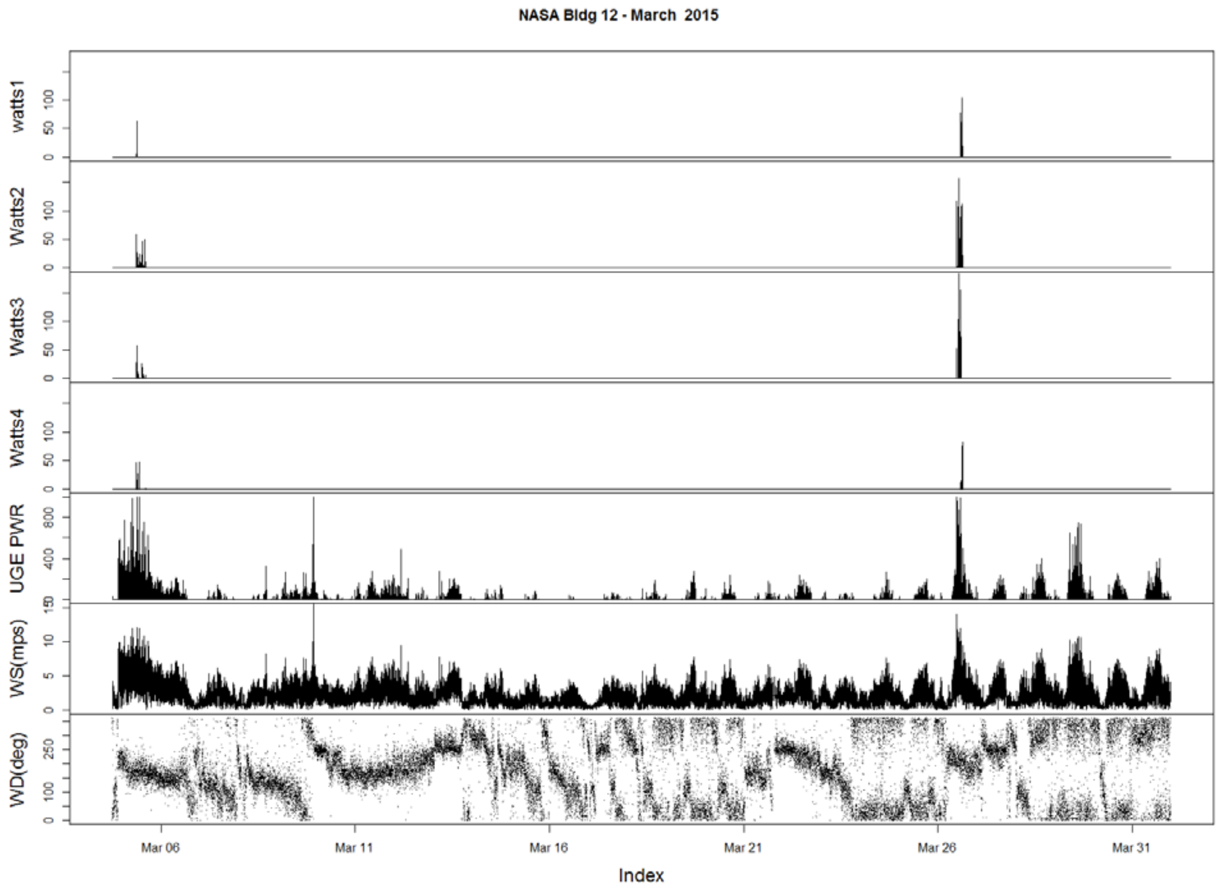


Figure 16. Monitoring data from the NASA Building 12 for March 2015 including wind direction (WD), wind speed (WS), expected power (UGE PWR), and actual power in watts for the four installed turbines

Table 4. NASA Building 12 Predicted vs. Actual Energy (March 2015)

Turbine	Energy (Wh)	Capacity Factor (%)	60-W Light Bulb Duration (Hours)
1	16.54	0.0022%	0.28
2	59.10	0.0079%	0.99
3	33.12	0.0045%	0.55
4	8.16	0.0011%	0.14
UGE PWR*	7810.0	1.05%	130.17

*predicted energy from concurrent wind speed measurements and UGE power curve

The measurement program also yields some unique data with which to evaluate BEWT projects. The following image is an analysis of the TI for the four pad-mounted instruments during the pre-construction measurement campaign. This is plotted against the IEC 61400-2 turbulence curve, which represents the class A turbulence level. The plot shows a large cluster of TI values below the recommended IEC design criteria. However, upon closer inspection, one can see that all turbine locations exhibit instances of extremely high TI values, which would lead to both power and reliability concerns.

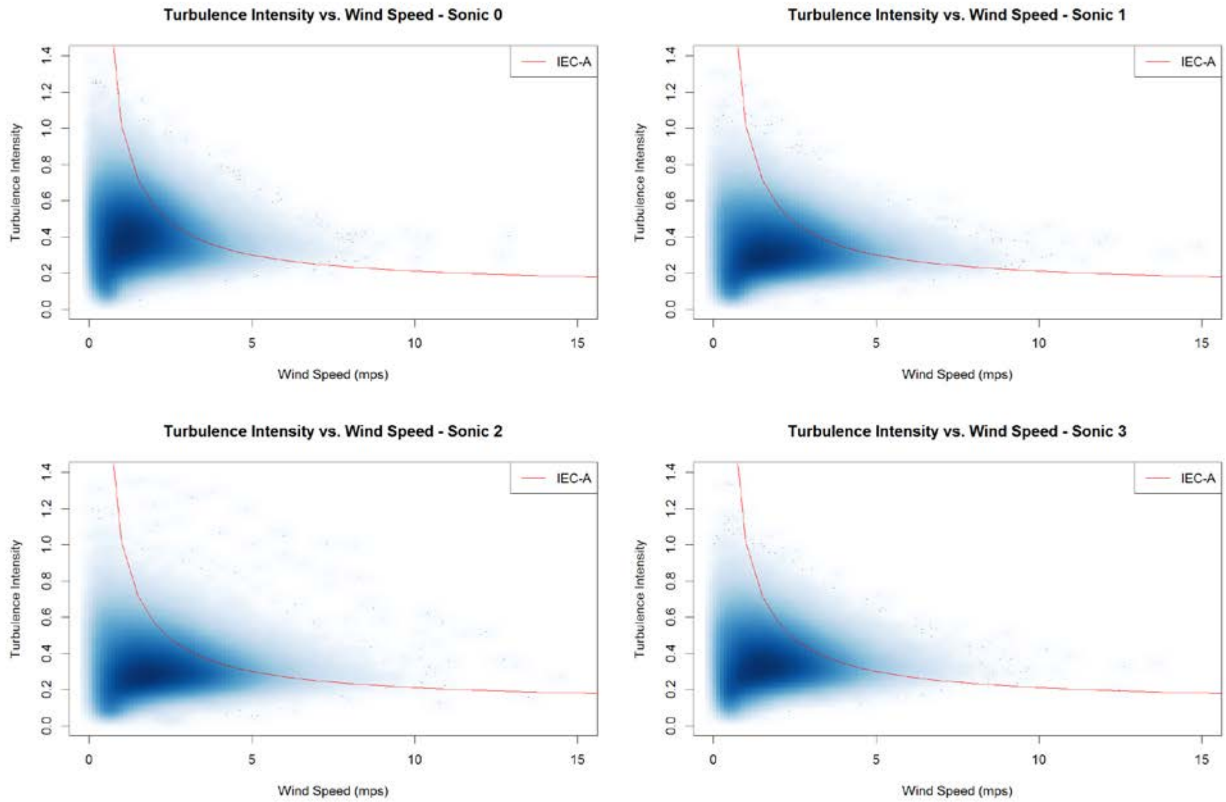


Figure 17. NASA Building 12 TI vs. wind speed

Additional Notes

According to project developers, turbine selection was influenced by two factors: wildlife impacts and wind speed requirements. In terms of wildlife, NASA's Environmental Office preferred that the turbine be a vertical-axis machine as opposed to a horizontal-axis machine in order to reduce potential avian impacts. The wind speed requirements impacted turbine selection by limiting tower height of the installation, thus limiting the turbine models that could be utilized in the project.

Project developers intended to install Tangarie GALE 5-kW vertical-axis wind turbines, but the manufacturer went out of business after the order was placed. Since the wind turbine installation was part of a larger renovation of Building 12, the subsequent delay caused NASA officials to reduce the scope of work for the general contractors that were hired to construct the entire renovation project, including the wind turbine installation. Once the new turbine model was selected, NASA onsite maintenance contractors completed the installation.

Johnson Space Center has a previous wind turbine installation at its Child Care Center. The project is located in an area with fewer surrounding structures that could impact the wind resource. The Skystream turbines utilized for this project have been generating in line with production estimates.

WATERFRONT ALLIANCE

217 Water Street
Suite 300
New York, NY 10038

Tel: 212.935.9831
waterfrontalliance.org

Public Testimony
New York City Council, Committee on Environmental Protection
Re: Oversight - Facilitating the Use of Wind Power in New York City

February 26, 2018

Roland Lewis, President and CEO
Waterfront Alliance

The Waterfront Alliance is a non-profit civic organization and coalition of more than 1,000 community and recreational groups, educational institutions, businesses, and other stakeholders committed to restoring and revitalizing New York Harbor and the surrounding waterways. Our waters have been revitalized with education, recreation, and transportation, and the harbor has long been a vital conduit for commerce.

Waterfront Alliance strongly supports Resolution 0176-2018 in support of the State of New York's "commitment to and facilitation of the development of large-scale offshore wind projects by 2030," which is sponsored by Council Members Donovan Richards and Helen Rosenthal. In March 2017, the Bureau of Ocean Energy Management entered into a lease for nearly 80,000 acres approximately 30 miles off the coast of New York for exploration of offshore wind development. Although power generation is not expected to begin until approximately 2027, New York City must take this once-in-a-generation opportunity—to provide renewable energy to New York City and simultaneously create new, good-paying jobs in the maritime sector—as the kind of bold action we need to combat the threat of climate change-related storms and sea level rise. As other states along the Atlantic coast have taken the initiative to prepare ports and staging areas for this emerging industry, New York risks losing out on capturing the enormous economic potential of offshore wind.

Offshore wind power generation presents opportunities for simultaneous economic and environmental benefits for New York City and its residents. Its growth would contribute toward the goals of the Clean Energy Standard, which requires 50 percent of New York State's electricity to come from renewable energy by 2030. This would continue to reduce our dependence on greenhouse gas-emitting fossil fuels and reduce our region's impact to global climate change. It would also position New York City as the hub for thousands of new jobs and maritime support services this growth industry will require. Our waterfront has the capability to support new, high-wage industrial and logistics jobs that can create new career pathways in clean energy for New Yorkers living with the risks posed by climate change.

We must preserve and build upon the expertise we have right here in New York's maritime sector to fully capture the benefits of offshore wind power generation. While the port industry has expanded over the past generation to bring much of the region's container and terminal operations to New Jersey, many of the maritime support services, including tugs, barges, and ship repair services, which make our ports run smoothly, are located in New York City. In particular, we can utilize the industrial maritime infrastructure along the Brooklyn waterfront as the nexus for a vital new industry with vast regional and global potential. One such example is the South Brooklyn Marine Terminal (SBMT), where the City has invested more than $100 million in infrastructure improvements to reactivate the facility with maritime-dependent uses.

New York's proximity to proposed offshore wind development sites along the East Coast positions us as a good candidate for a centralized port for the industry. To become a first mover, and catalyze investment that could serve additional markets beyond New York, we must commit to fully utilizing our port infrastructure and invest in workforce development, skills training, and job placement. Building the training facilities, developing a skilled workforce, and utilizing our working waterfront will embed labor and supply chains within our region, and new attract manufacturers and logistics companies to serve the offshore wind sector.

New York City must be a world leader as we rise to meet the challenges we face together. We must once again look to the water's edge to meet new challenges—the port that helped New York grow into a global capital for commerce and culture must be called into service to help protect our planet and preserve our livelihood. We urge the New York City Council to take the steps necessary to support the development of offshore wind energy in New York, to support new job growth and combat the threats posed by global climate change. We thank you for the opportunity to present this testimony, and welcome any questions you may have.

Swanston, Samara

From: Roger Fortune <RFortune@StahlRE.com>
Sent: Monday, February 26, 2018 1:54 PM
To: sswansto@pratt.edu
Subject: Testimony for Hearing: "Oversight: Facilitating the Use of Wind Power in New York City"

Samara:

Hello. I received an invitation to testify at the Hearing "Oversight: Facilitating the Use of Wind Power in New York City." I was unable to attend today, but I wanted to submit a written statement. I was unable to find any other email for you, but this one at Pratt. My statement is as follows:

The Stahl Organization is fully supportive of Int. No. 48 and Int. No. 50, bills that support improving the sustainability of New York City. In 2014, Stahl installed two wind turbines at the top of 388 Bridge Street in Downtown Brooklyn, at a height of 600 feet. Unfortunately, our experience with wind turbines has not met expectations. The installation costs for the wind turbines have not been off-set by the energy generated by them – which powers exterior lighting at the crown of the building. In addition, the cost of their annual servicing and the difficulties we've experienced integrating the electrical circuits of the wind turbines, battery packs and lighting have been significant. Finally, the irregularity of the wind patterns at our location mean that there are significant periods with insufficient wind to power the turbines.

Stahl wholeheartedly supports all efforts to improve energy efficiently and encourage sustainability, however our overall conclusion is that only a limited number of turbines can be installed on tall buildings, it is likely not the best use for valuable roof space, and the quantity of power produced is not material to the overall consumption in the building.

The Stahl Organization is a privately held, New York City-based real estate investment and development company founded by the late Stanley Stahl in 1949. Stahl owns over 3,00 residential units and 5 million square feet of commercial space. Thank you.

Roger Fortune
The Stahl Organization
277 Park Avenue
New York NY 10172
Office: (212) 826-7060
Direct: (212) 826-5506
Fax: (212) 223-4609

WIND·e20®

Small Wind Testimony

February 26, 2018

CGE Energy

Power to make a difference™

Introducing WIND•e20®

WIND·e20®

The World's Most INNOVATIVE Wind Turbine

TECHNOLOGY INNOVATIONS

$0 FINANCIAL INNOVATIONS

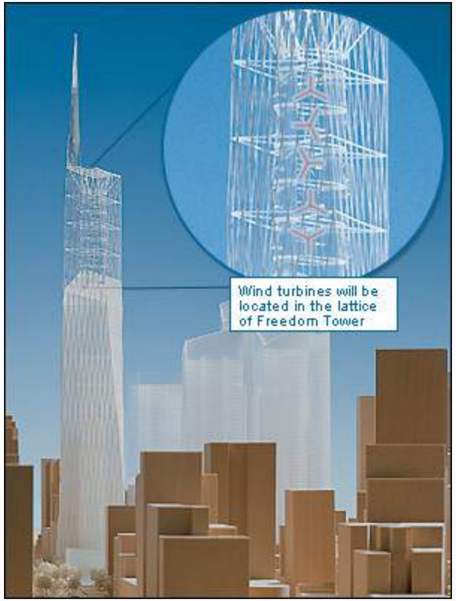
COMMUNITY INNOVATIONS

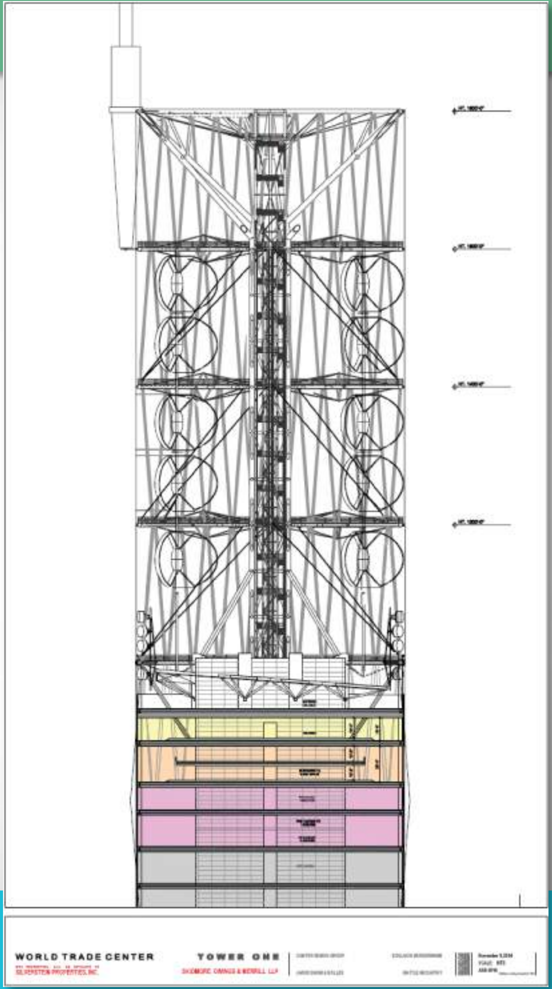
WIND•e20 History: Prototypes

- Two Successful Prototypes
- Proven design
- 5 U.S. Patents, more pending

WIND•e20 History: Freedom Tower

- Freedom Tower originally specified wind turbines
- Heavily vetted and selected as preferred technology
- Tower redesign abandoned original turbine plans





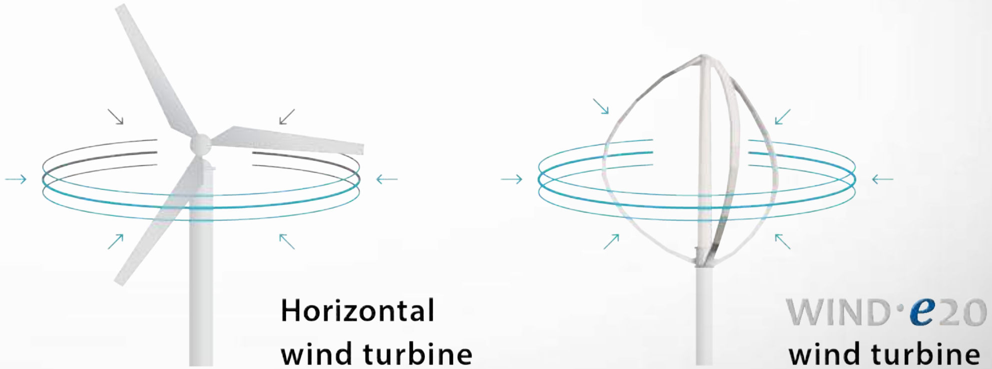
CGE Energy

Power to make a difference™

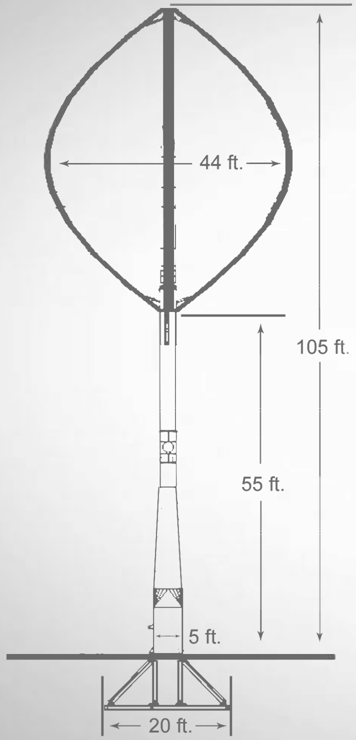
Vertical Axis Technology

WIND·e20®

- For business, non profit and government applications
- 20, 50, and 65 KW
- Omnidirectional power generation



WIND•e20 Size Comparison



Height: 105-Foot

WIND•e20:
105 ft.

Water Tower:
130 ft.

Statue of Liberty:
305 ft.

Horizontal Turbine:
450 ft. (w/ blades)

Innovative Installation and Maintenance

- Turbine delivered on a flatbed truck
- WIND•e20 hydraulically raises/lowers
- Installed within days
- Small crew needed

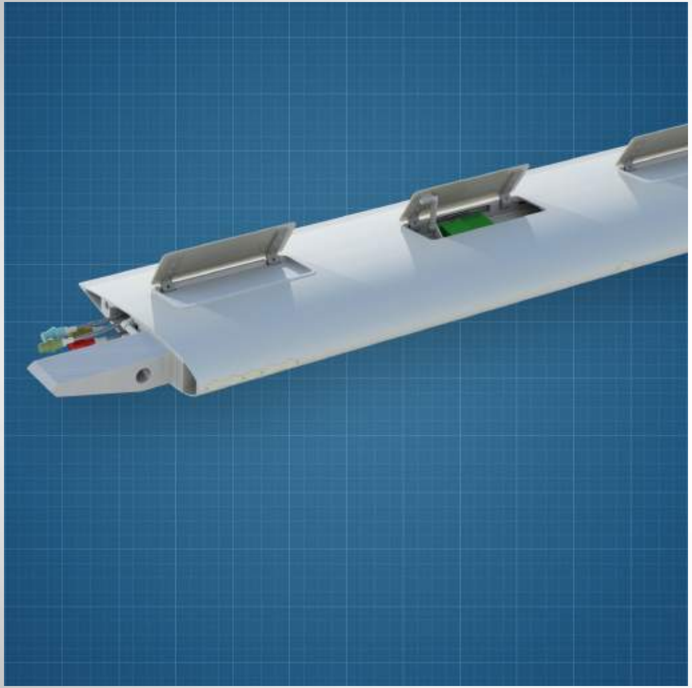
CGE Energy

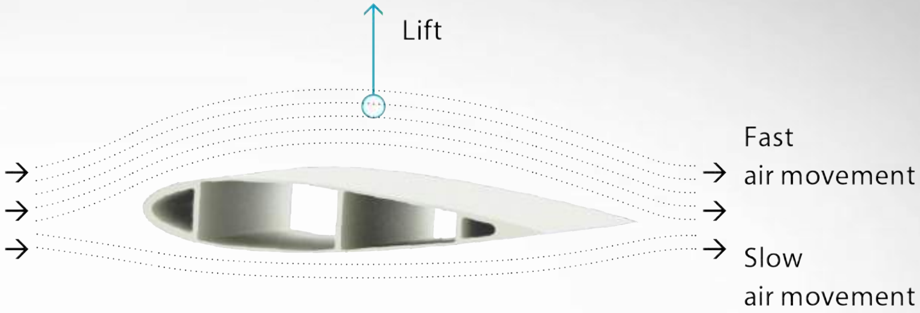
Power to make a difference™

Eco-Friendly Footing

- **Pre-cast** (No concrete poured onsite)
- **20 x 20 foot** (5 x 5 foot above ground)
- **Excavated with common backhoe**
- **Removable** (can be relocated)

Aerodynamic Blade Design





- Carbon fiber, aerodynamic blades
- Trim flaps for air braking
- Blades fold down prior to storms
- Also features disk braking system

Quiet and Safe for Birds

SAFE FOR BIRDS

- Vertical blades increase visibility
- Support from the Audubon Society

LOW NOISE

- No pulsating noise of HAWT turbines
- Approximately 40 dB at 20 feet
- *Compare: Quiet residential area is 40 dB*

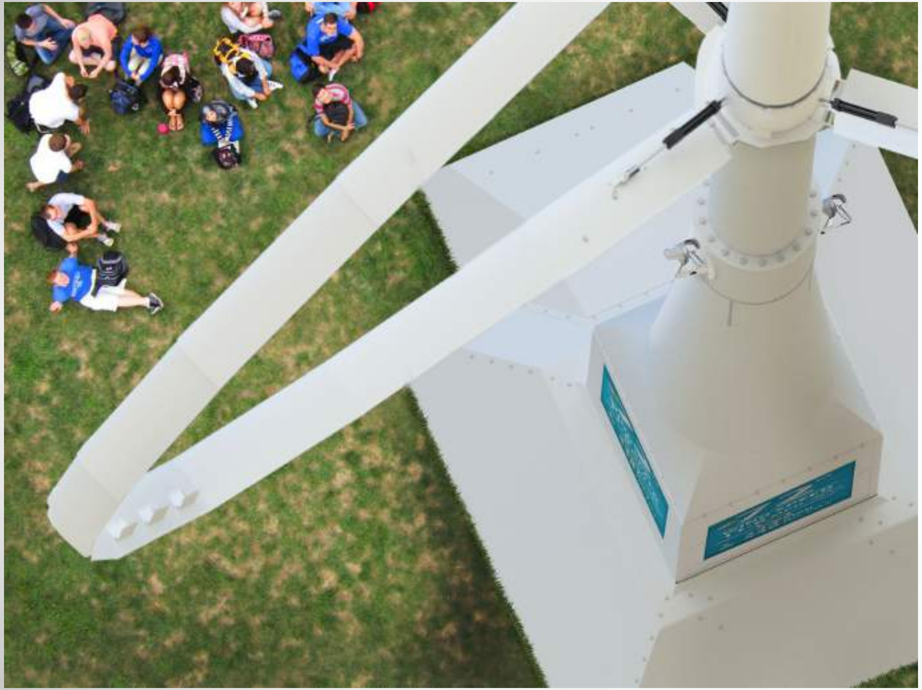
Manufacturing Partner: ROUSH Industries

WIND·e20® ROUSH®

- Strategic Manufacturing Partner
- Optimizing for manufacturing
- Known for performance and delivery
- 1/10th Scale Units Built

CGE Energy

Power to make a difference™



INTEGRAL TO COMMUNITY

- Sustainability
- Communications
- Life Safety
- Emergency Response

CGE Energy

Power to make a difference™

Our Solution

CGE Sustain

$0

NO UPFRONT COST

100% MAINTAINED

SAVINGS GUARANTEE

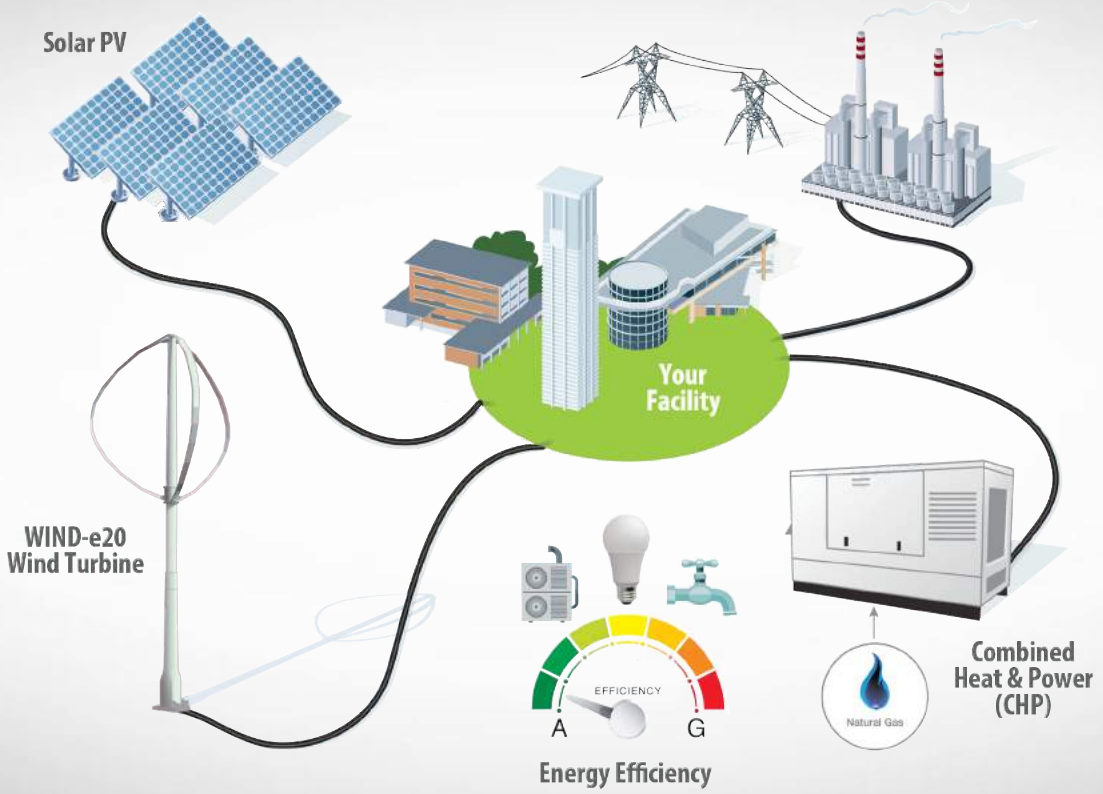
ONGOING TRACKING

PROMOTION

WIND·e

ONSITE WIND

Integrated Solution



No Upfront Cost

Monthly Expenses:

Power to make a difference ™

Thank you.

Contact: Paul Schneider
pschneider@cgeenergy.com
248-446-1344

Bergey Windpower Co.
2200 Industrial Blvd.
Norman, OK 73069
Tel: 405-364-4212
Fax: 405-364-2078

Committee on Environmental Protection
New York City Council

February 25, 2018

RE: Oversight Hearing on "Facilitating the Use of Wind Power in New York City", February 26th, 1:00 PM

Dear Council Members and Staff,

Thank you for inviting me to attend and provide testimony at tomorrow's hearing. I regret that I can not attend due to a prior commitment in Washington DC and I apologize for late response. I do believe facilitating wind energy development in New York City is an important and timely issue. I applaud Council Member Constantinides for his leadership on the issue. I hope you will accept my comments on the general topic and the two proposed laws.

I have been in the small wind turbine industry for 40 years and Bergey Windpower is the world's leading supplier of small wind turbines from 1 kW to 10 kW for residential, farm and remote power applications. Our turbines are installed in all 50 states and over 100 countries. I have served as president of the American Wind Energy Association twice and have recently stepped down after four terms as president of the Distributed Wind Energy Association. I am a mechanical engineer and I have been deeply involved in the development of national and international standards for small wind turbines.

Small wind turbines are an underdeveloped "behind the meter" renewable energy technology that has some attractive attributes:

- The equipment is primarily made in America
- Wind resources are strongest in the winter, complementing solar on a seasonal basis
- Wind turbines are typically producing power 80-95% of the time, including at night
- Wind turbine towers have a small footprint
- Costs at the 10 kW scale are currently higher than solar. At 100 kW the costs are less. At both sizes the industry has been able to aggressively drive down costs with new technology. Costs are expected to come down by 40-50% in the next few years, to costs below imported solar.
- Hybrid wind/solar microgrids hold great promise for cost-effective resiliency
- Small turbines are visible and can serve as a symbol of environmental stewardship

But, small wind systems move, make noise, some people don't like them, and the industry has suffered from a number of hucksters that have made unsupported claims and allowed turbines to be placed where they should not have been.

I reside in Oklahoma, but I travel to New York City several times a year because our children live there. So, I am at least somewhat familiar with your urban landscape. The density of buildings makes much of the City inappropriate for small wind systems, but there are nonetheless, many, many areas with the space and the wind exposure to make small wind feasible. I appreciate the current focus on "waterfront" areas because this is the largest opportunity I foresee. I am not at all enthusiastic about the opportunity on buildings. We have declined to place our turbines on quite a number of buildings in NYC because the high turbulence operating environment, difficult structural engineering challenges and liability issues makes such projects too risky. In most cases the energy production would have been a de minimis fraction of the buildings energy demand and the primary purpose of the installation was "green washing".

I think the wind mapping mandated in Int. No. 48 would be worthwhile investment, but I would limit the scope to the freestanding wind turbines in waterfront areas. The National Renewable Energy Laboratory published a report on turbines for the "built environment" in 2016 that showed building-mounted turbines to be hugely ineffective (capacity factors in the 2-4% range) and that the only customers satisfied with the projects were those that did it for the image, not the energy. I am attaching a copy of the NREL report with this letter. I would recommend a lower cost, lower resolution map that would give people a sense of the possible. And I think setting the bar at an annual average wind speed of 11 mph at 100 ft in elevation would be a good indicator.

I have a number of comments on Int. No. 50:

1. In 28-319.2 Removal: I recommend removing the references to the manufacturer's suggested useful life. Not operating for 12 months is a better and a sufficient trigger. We designed our turbines to last 30 years, but now some have been in operation for 36 years. It would be unfortunate to require an operating wind turbine to be removed just because the manufacturer underestimated its useful life.

2. In 426.3 Design Standards: I recommend only referencing and requiring the two ANSI standards for small wind systems: AWEA 9.1-2009 and UL 6142. There is no reason to list research labs, energy commissions, certification agencies, international standards bodies and foreign trade associations. NYSERDA and the IRS require small wind turbines to certified to either AWEA 9.1-2009 (for turbines up to ~ 60 kW) or a subset of the IEC 61400 standards. I recommend using the NYSERDA language and would be happy to put the Council in contact with someone at NYSERDA who could help with that.

3. In 426.5 Brakes and locks: This is vague and will be difficult to implement on a case-by-case basis. If turbines are required to be certified in 426.3 then this section is unnecessary because the AWEA and IEC standards that AWEA references include requirements for failsafe overspeed protection systems and emergency shutdowns. These capabilities are certified by accredited certification bodies such as ICC-SWCC and Intertek. I can put you in touch with experts in either of those organizations who can verify that the standards cover this concern.

4. In 426.10 Shadow flicker: I would contend that this is unnecessary because there have been, as far as I know, no pattern of complaints about shadow flicker from small wind turbines. This is an issue with large turbines that at 4 times the height and 200 times the size of a small wind turbine. The shadows of a small turbines are much, much smaller and cover a much smaller distance. I can't think of a small wind turbine ordinance that has a shadow flicker clause.

5. In 426.11 Signal interference: I don't think this will be a problem, so I recommend rewording the section to say that small wind systems shall not cause signal interference that exceeds that caused by other structures in the vicinity. On the other hand, I would allow cell phone or other antennas on the turbine towers, which would benefit the owner and his/her neighbors.

In closing I appreciate the opportunity to comment and would be happy to assist the Council in any further work to perfect these proposed laws.

Sincerely,

Michael L S Bergey

Michael L.S. Bergey
President & CEO

THE COUNCIL
THE CITY OF NEW YORK

Appearance Card

I intend to appear and speak on Int. No. ________ Res. No. ________
☐ in favor ☐ in opposition

Date: 2/26/18

(PLEASE PRINT)

Name: Daniel Korpen
Address: 8 Harbor Hill Drive, Huntington
I represent: Professional Engineer
Address:

THE COUNCIL
THE CITY OF NEW YORK

Appearance Card

I intend to appear and speak on Int. No. 0598/2050 Res. No. 0176
☑ in favor ☐ in opposition

Date: 2/26/2018

(PLEASE PRINT)

Name: Kartik Amarnath
Address: 166A 22nd St. Brooklyn, NY 11232
I represent: NYC Environmental Justice Alliance
Address: 166A 22nd St. Brooklyn, NY 11232

THE COUNCIL
THE CITY OF NEW YORK

Appearance Card

I intend to appear and speak on Int. No. ________ Res. No. ________
☐ in favor ☐ in opposition

Date: ________

(PLEASE PRINT)

Name: John H. Lee; Alan Price; Anthony Fiore
Address: Administration
I represent:
Address:

Please complete this card and return to the Sergeant-at-Arms

THE COUNCIL
THE CITY OF NEW YORK

Appearance Card

I intend to appear and speak on Int. No. 48 + 50 Res. No. ______
☒ in favor ☐ in opposition

Date: 2-26-2018

(PLEASE PRINT)

Name: PAULA SPEER

Address: 138 71st ST. APT E5 BROOKLYN, NY 11209

I represent: MYSELF, ALSO MEMBER 350 BROOKLYN

Address: "

Please complete this card and return to the Sergeant-at-Arms

THE COUNCIL
THE CITY OF NEW YORK

Appearance Card

I intend to appear and speak on Int. No. ______ Res. No. ______
☐ in favor ☐ in opposition

Date: ______

(PLEASE PRINT)

Name: John Lee

Address: ______

I represent: Mayor's Office

Address: ______

Please complete this card and return to the Sergeant-at-Arms

THE COUNCIL
THE CITY OF NEW YORK

Appearance Card

I intend to appear and speak on Int. No. ______ Res. No. ______
☐ in favor ☐ in opposition

Date: ______

(PLEASE PRINT)

Name: Alan Price

Address: ______

I represent: Department of Buildings

Address: ______

Please complete this card and return to the Sergeant-at-Arms

THE COUNCIL
THE CITY OF NEW YORK

Appearance Card

I intend to appear and speak on Int. No. ______ Res. No. ______

☐ in favor ☐ in opposition

Date: ______

(PLEASE PRINT)

Name: Anthony Fiore

Address: ______

I represent: DCAS

Address: ______

THE COUNCIL
THE CITY OF NEW YORK

Appearance Card

I intend to appear and speak on Int. No. ______ Res. No. ______

☑ in favor ☐ in opposition

Date: ______

(PLEASE PRINT)

Name: Ling Tsou

Address: ______

I represent: United for Action

Address: ______

THE COUNCIL
THE CITY OF NEW YORK

Appearance Card

I intend to appear and speak on Int. No. ______ Res. No. ______

☑ in favor ☐ in opposition

Date: 2/26/18

(PLEASE PRINT)

Name: William Becchina

Address: 17 Buckingham Meadow Rd. 11733

I represent: Energy WALL, LLC

Address: 1001 New Holland Av. Lancaster PA.

Please complete this card and return to the Sergeant-at-Arms

THE COUNCIL
THE CITY OF NEW YORK

Appearance Card

I intend to appear and speak on Int. No. ________ Res. No. ________

☐ in favor ☐ in opposition

Date: ________

(PLEASE PRINT)

Name: Ian Brownstein

Address: ________

I represent: Standford . Edu

Address: ________

THE COUNCIL
THE CITY OF NEW YORK

Appearance Card

I intend to appear and speak on Int. No. ________ Res. No. ________

☐ in favor ☐ in opposition

Date: ________

(PLEASE PRINT)

Name: David Suroil

Address: ________

I represent: Vortex Bladeless

Address: Spain

THE COUNCIL
THE CITY OF NEW YORK

Appearance Card

I intend to appear and speak on Int. No. ________ Res. No. ________

☐ in favor ☐ in opposition

Date: ________

(PLEASE PRINT)

Name: Paul Schreider

Address: ________

I represent: CS E Energy

Address: Michigan

Please complete this card and return to the Sergeant-at-Arms

THE COUNCIL
THE CITY OF NEW YORK

Appearance Card

I intend to appear and speak on Int. No. ______ Res. No. ______

☐ in favor ☐ in opposition

Date: 2/26/78

(PLEASE PRINT)

Name: Claire Chandler

Address: 657 E. 26th St. 3V Brooklyn 11210

I represent: 350 Brooklyn

Address: ______

THE COUNCIL
THE CITY OF NEW YORK

Appearance Card

I intend to appear and speak on Int. No. 48 + 50 Res. No. ______

☑ in favor ☐ in opposition

Date: ______

(PLEASE PRINT)

Name: Bob Wyman

Address: 203 West 85th Apt PH2

I represent: Self

Address: ______

THE COUNCIL
THE CITY OF NEW YORK

Appearance Card

I intend to appear and speak on Int. No. 48 & 50 Res. No. 176

☒ in favor ☐ in opposition

Date: ______

(PLEASE PRINT)

Name: Lisa DeCapri

Address: 325 West 93rd Street, NY NY 10025

I represent: ______

Address: ______

Please complete this card and return to the Sergeant-at-Arms

THE COUNCIL
THE CITY OF NEW YORK

Appearance Card

I intend to appear and speak on Int. No. ______ Res. No. ______
☐ in favor ☐ in opposition

Date: 2-26-18

(PLEASE PRINT)

Name: CAPT. ERIC WIBERG
Address: MCALLISTER TOWING
I represent: 17 BATTERY PLACE #1200 NYC 10004
Address:

THE COUNCIL
THE CITY OF NEW YORK

Appearance Card

I intend to appear and speak on Int. No. 1726-2019 1729-2019 Res. No. Obsessed w/ Gov. Cuomo
☑ in favor ☐ in opposition

Date: Feb. 26, 2018

(PLEASE PRINT)

Name: Catherine Skopic
Address: 140 West Broadway, N.Y., N.Y. 10013
I represent: Myself; Shut Down Indian Point Now; Interfaith Moral Action on Climate
Address:

THE COUNCIL
THE CITY OF NEW YORK

Appearance Card

I intend to appear and speak on Int. No. ______ Res. No. ______
☐ in favor ☐ in opposition

Date: ______

(PLEASE PRINT)

Name: Roland Lewis
Address: 470 E. 7th St. Bklyn NY
I represent: Waterfront Alliance
Address: 217 Water St NY NY

Please complete this card and return to the Sergeant-at-Arms

THE COUNCIL
THE CITY OF NEW YORK

Appearance Card

I intend to appear and speak on Int. No. ______ Res. No. ______
☐ in favor ☐ in opposition

Date: 2/26/18

(PLEASE PRINT)

Name: M. DANIEL FARB

Address: LAWRENCE, NY

I represent: FLOWER TURBINES

Address: DFARB@FLOWERTURBINES.COM

Please complete this card and return to the Sergeant-at-Arms

THE COUNCIL
THE CITY OF NEW YORK

Appearance Card

I intend to appear and speak on Int. No. ______ Res. No. 0176-2018
☑ in favor ☐ in opposition

Date: 2/26/18

(PLEASE PRINT)

Name: Ryan Chavez

Address: 166A 22nd Street, Brooklyn

I represent: UPROSE

Address: ______

Please complete this card and return to the Sergeant-at-Arms