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Built-Environment Report Summary for WINDExchange

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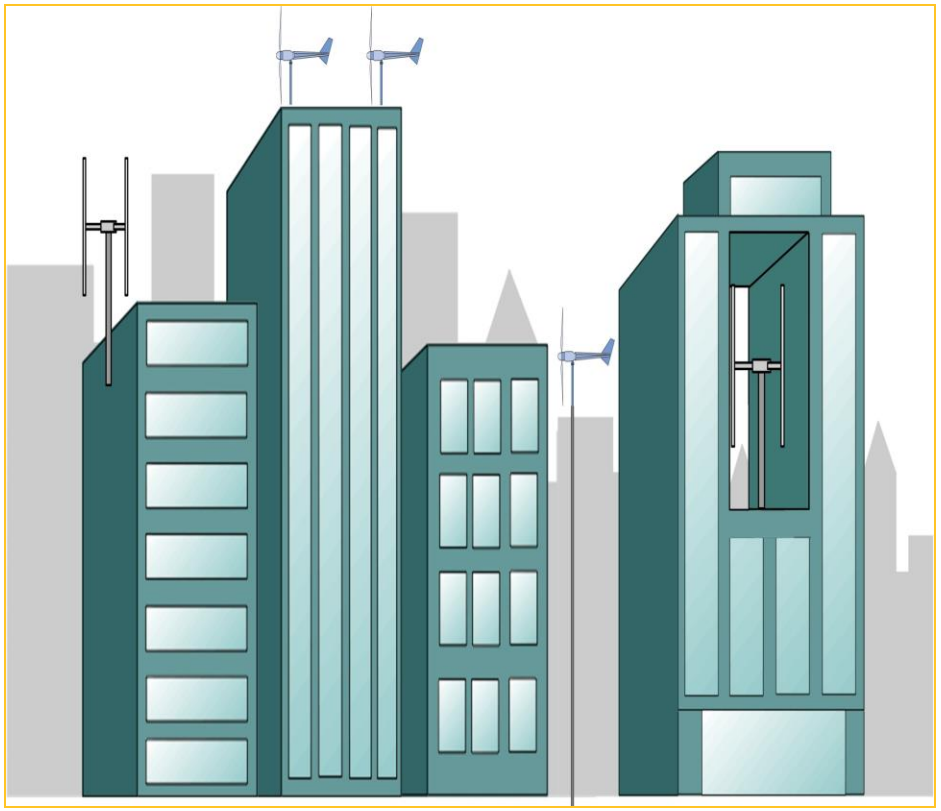
What Is the Built Environment?

- **Wind turbines installed in the urban environment can be:**
  - Building mounted
  - Building integrated
  - Surface mounted near buildings.
- **Unique considerations:**
  - Existing design standards are not intended for urban environments.
  - Existing test protocols are not designed for urban environments.

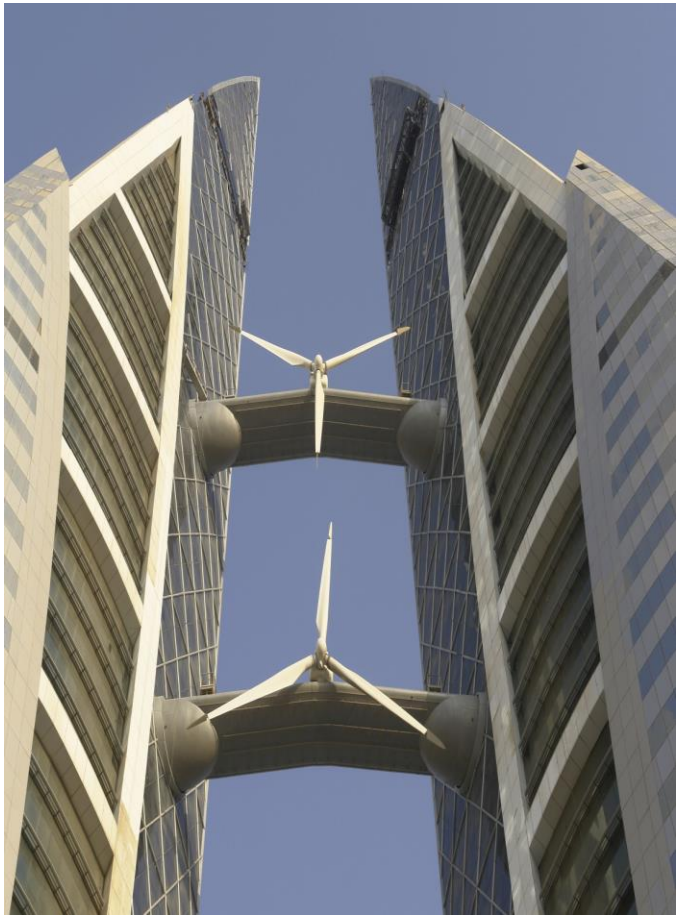


Built-environment deployments. *Illustration from Joe Smith, National Renewable Energy Laboratory*

Built-Environment Wind Turbines (BEWTs)

- **Benefits**
  - Clean and renewable
  - Visible
  - Distributed generation.
- **Challenges**
  - Safety
  - Reliability
  - Performance and economics.

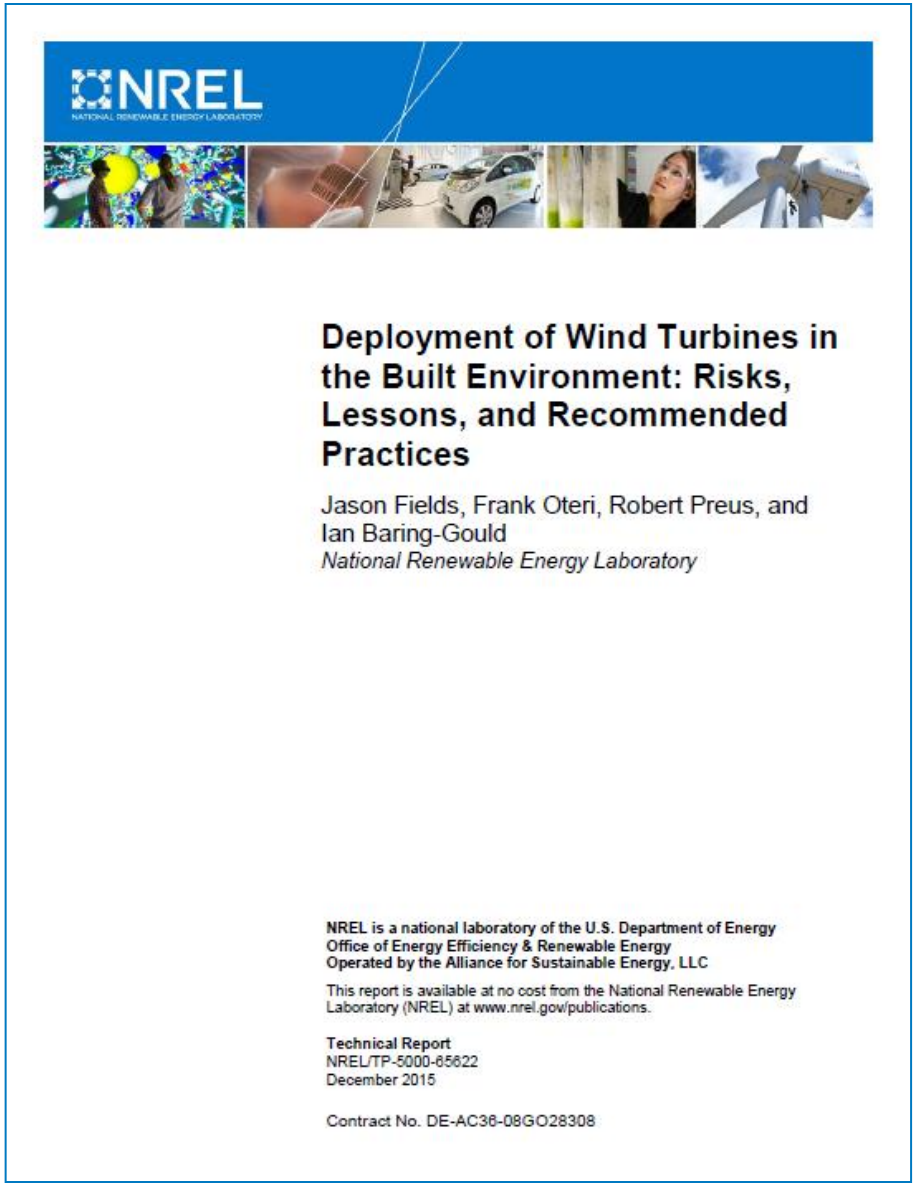
Reliable information on wind turbines in the urban environment is needed!



Bahrain World Trade Center. *Photo from iStock 6924031*

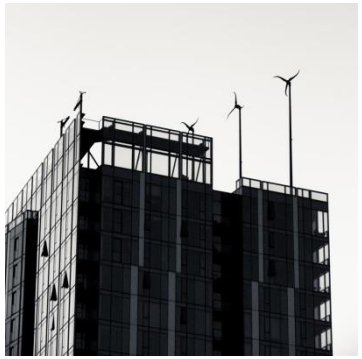
BEWTs Recommended Practice

- Report targeted to end users and decision makers
- **Key components:**
  - Case studies
  - Lessons learned
  - Recommended practice
  - Overview of BEWT standards.
- **Includes contributions from:**
  - IEA Task 27 and BEWT studies (Blackamore, Mertens, Tabrizi, Toja, etc.)
- Specific to United States but applicable to other markets
- Does not focus on building-integrated/flow-augmented turbines, but many of the principles apply.



Case Studies

Pearson Square Court (NY)
Photo from UGE



Twelve West (OR)
Photo from Flickr 4852149002

Boston Museum of Science (MA)
Photo from Boston Museum of Science, NREL 18006

Detroit Metro Airport (OH)
Photo from Wayne County Airport Authority

Brooklyn Navy Yard (NY)
Photo from Flickr 2874788682

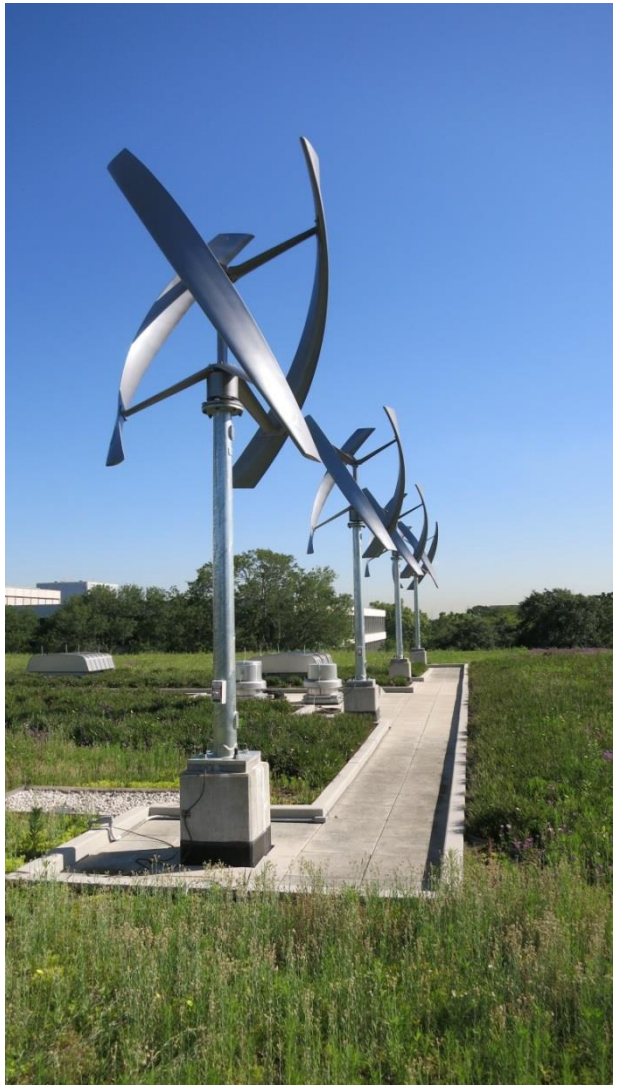
NASA Building 12 (TX)
Photo by Dave Jager, NREL

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

Lessons Learned: Overview

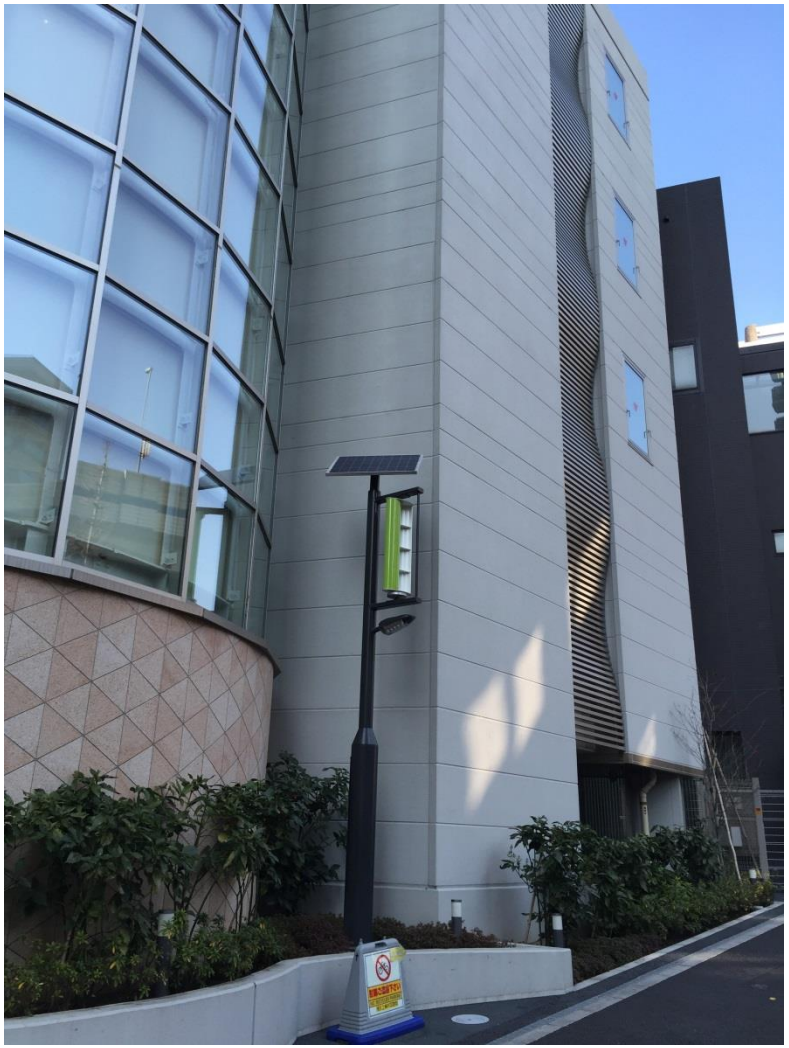
- Planning
- Costs
- Performance and Reliability.



NASA Building 12, Phase 2. *Photo from Mike Van Bavel*

Lessons Learned: 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 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.



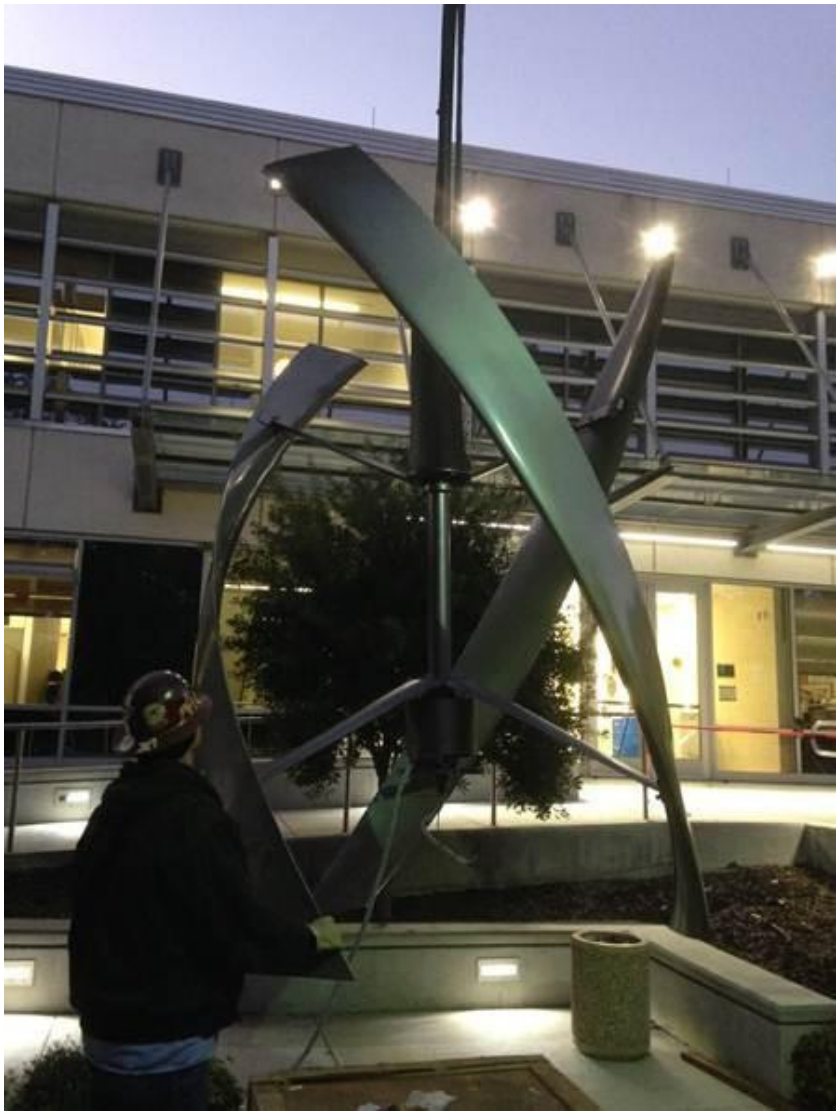
BEWT installation in Japan. *Photo from Breton Barker, U.S. Department of Energy*

Lessons Learned: Project Costs

Additional expenses from:

- Development / engineering
- Installation
- Maintenance

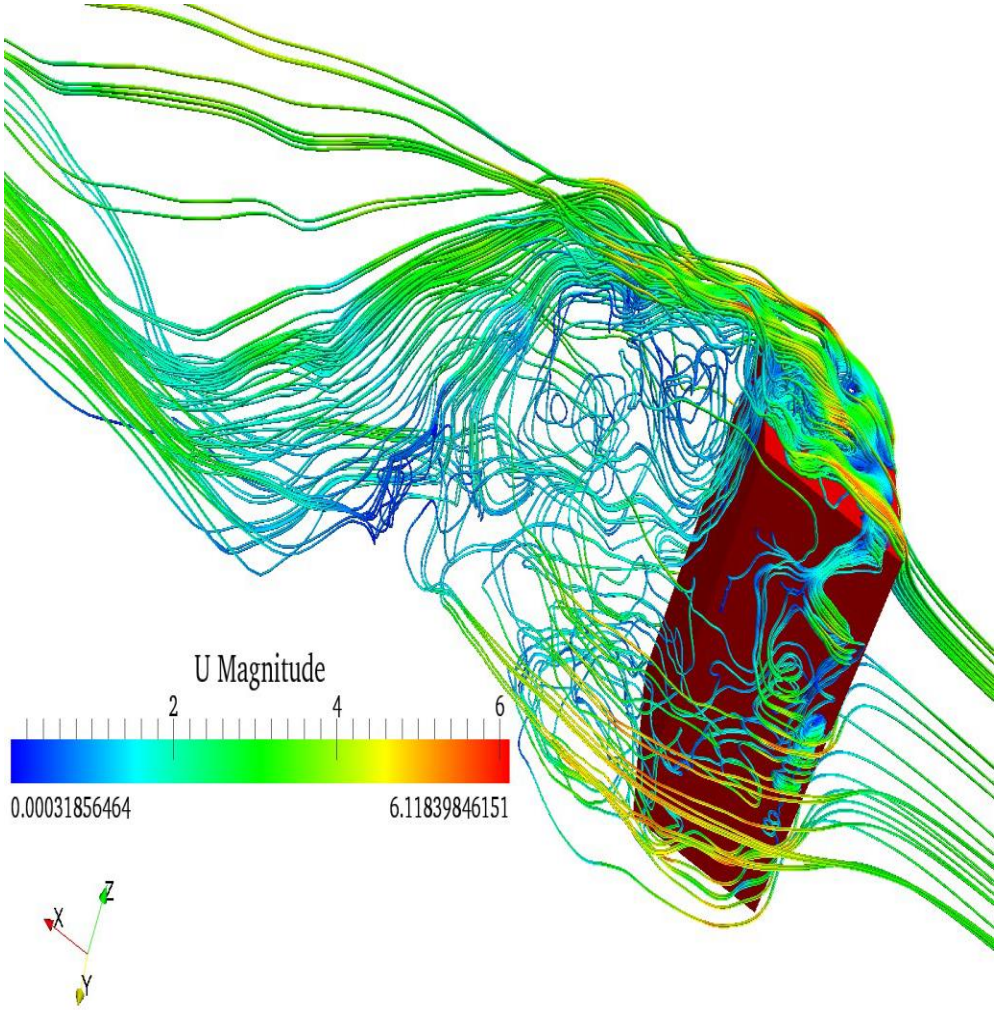
tend to result in higher project costs.



NASA Building 12 turbine installation. *Photo from Dave Jager, National Renewable Energy Laboratory*

Lessons Learned: Project Performance

- When compared with actual production, BEWT project performance is often over-estimated. ***None of the case study projects met their energy production estimates.***
- Consolidation of small turbine manufacturers is common and can lead to loss of warranty and difficulty in service parts availability.
- Current national and international standards do not reflect wind conditions often seen in the built environment.



CFD simulation of flow around building. *Image from Francisco Toja*

Twelve West: Estimated vs. Actual Energy

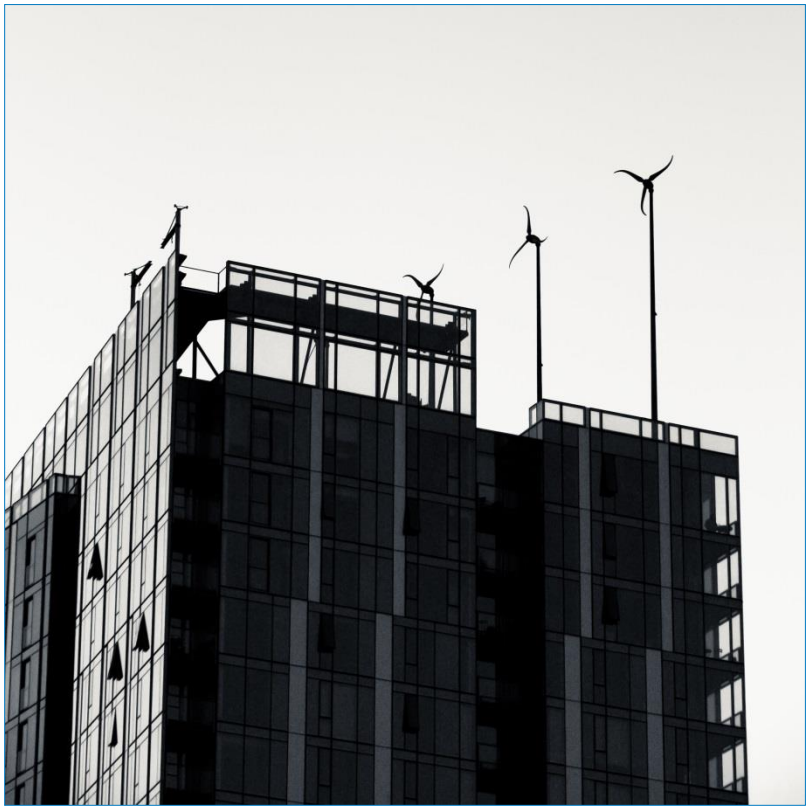
Estimated production:

- ~9,000 kWh/year
- 11% CF
- LCOE: $2.846/kWh

Actual production:

- ~5,500 kWh/year
- 7% CF
- LCOE: $4.657/kWh

Average Portland retail rate: $0.1256/kWh.
BEWT power is 37 times more expensive.



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

NASA B12: Estimated vs. Actual Energy

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

Key Conclusions - Outcomes/Risks

- The team could not find an example of a BEWT project for which the energy production met pre-construction estimates.
  Measured CF range: <1% to 7%
- BEWTs are often shut down or removed early due to vibration, noise, or reliability issues.
- BEWT OEMs often fail, voiding warranties and reducing spare parts supply.
- Project costs are often higher than expected.

NASA Building 12, Phase 1. *Photo from Jason Fields, National Renewable Energy Laboratory*

Other Conclusions

- Certified turbines are recommended, but BEWT operating conditions are not currently certifiable.
- Owners may consider projects successful if other drivers (in addition to economics) are prioritized.
- Project design and planning, including safety plans, are often insufficient.
- Education for interested stakeholders is sorely needed.

NASA Building 12, Phase 1. *Photo from Jason Fields, National Renewable Energy Laboratory*

Successful BEWT Project Attributes

- Thoughtful and diverse project goals
- Rigorous planning and due diligence, including an understanding of the risks associated with BEWTs
- Deployment on buildings taller than surroundings
- Use of certified horizontal-axis turbines.

NASA Building 12, Phase 1. *Photo from Jason Fields, National Renewable Energy Laboratory*

BEWT Research Next Steps

Current plans:

- Continue engagement with IEA Task 27.

For further information:

Latest report: http://www.nrel.gov/docs/fy16osti/65622.pdf

- http://en.openei.org/wiki/Built-Environment_Wind_Turbines
- http://en.openei.org/wiki/NASA_Building_12_Wind_Turbines

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

Thank you!

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