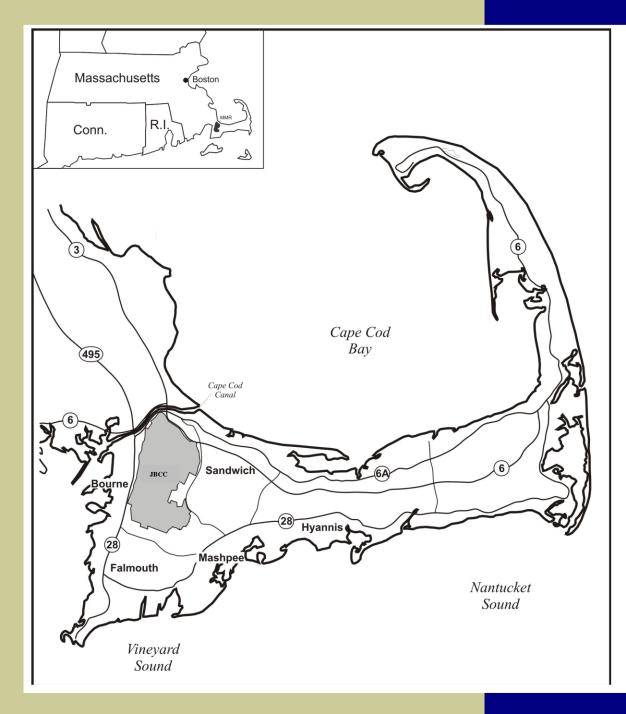
# Air Force Civil Engineer Center Wind Energy Projects for Groundwater Treatment Systems at Joint Base Cape Cod



Rose Forbes, P.E., Air Force Civil Engineer Center
28 May 2014
Mass Wind Working Group



The Installation
Restoration
Program at
Joint Base
Cape Cod
(JBCC)



#### **MULTI-USE FACILITY**

- Veterans Administration National Cemetery
- Barnstable County Sheriff's Office / Correctional Facility
- 6th Space Warning Squadron PAVE PAWS
- U.S. Department of Agriculture
- Massachusetts Environmental & Readiness Center
- U.S. Army Environmental Center Impact Area Groundwater Study Program
- Air Force Center for Engineering and the Environment/ Installation Restoration Program
- 253rd Combat Communications Group
- 267th Combat Communications Squadron
- U.S. Coast Guard Air Station Cape Cod
  - Exchange/Commissary
  - •Golf Course
  - •MWR
  - •Family Housing
  - •Storage for ships in Boston
- Massachusetts Army National Guard Army Aviation Support Facility #1
- Massachusetts Army National Guard Regional Training Institute
- Environmental Management Commission
- Senior Environmental Corps
- Massachusetts Disaster Preparedness Safe Haven Facility

- US. Air Force Auxiliary (Civil Air Patrol)
- Massachusetts Maritime Academy
- Federal Aviation Administration, North Atlantic Region
- Bourne School System
- Coast Guard Communications Station, Boston
- Coast Guard Electronic Systems Support Detachment
- Coast Guard Marine Safety Field Office
- Coast Guard Northeast Regional Fisheries Training Center
- Coast Guard LANT Area Armory
- Coast Guard Port Security Unit
- Police Motorcycle & Canine Training Areas
- Upper Cape Trash Transfer Station / Bay Colony Railroad
- U.S. Geological Survey
- Volpe Test Center
- Buzzards Bay Project
- FAA Cape Approach
- Crane Wildlife Management Area

#### Where did the contamination come from?





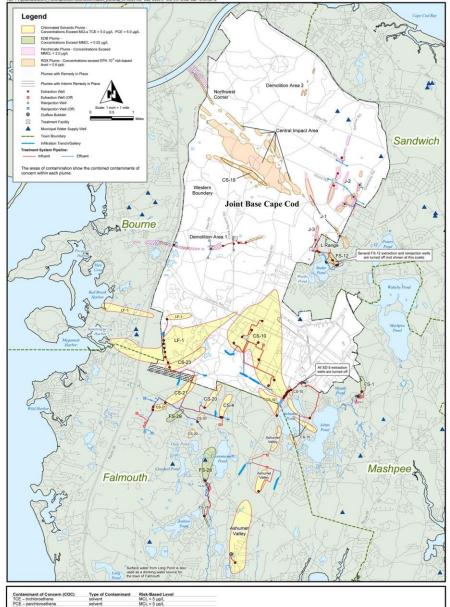
Primarily PCE, TCE, and EDB

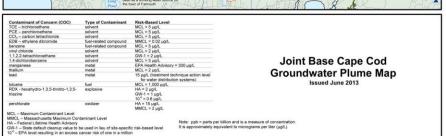
Concentrations < 1 mg/L (up to 4 mg/L)

Plumes are typically deep (>100 ft) and thick (>100 ft)

9 treatment plants treating 12 MGD

- > 27 miles of pipeline
- > 100 extraction and reinjection wells
- > 4,000 monitoring wells







**Explosives, perchlorate** 

Concentrations < 1 mg/L

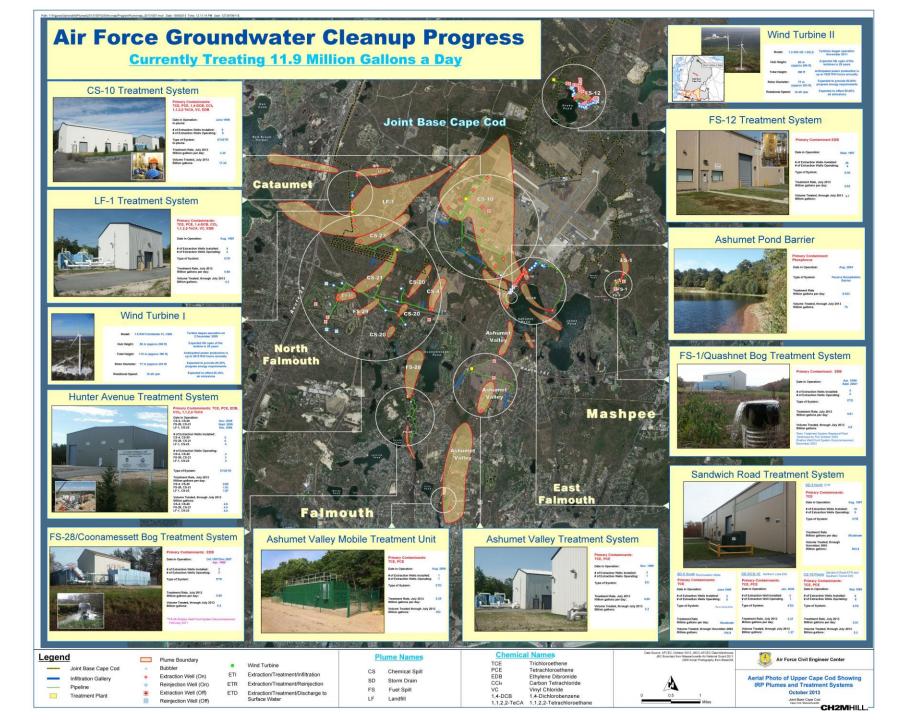
Plumes are typically deep (up to 100 ft deep) and thick (40-50 ft)

15 treatment plants treating 3.7 MGD

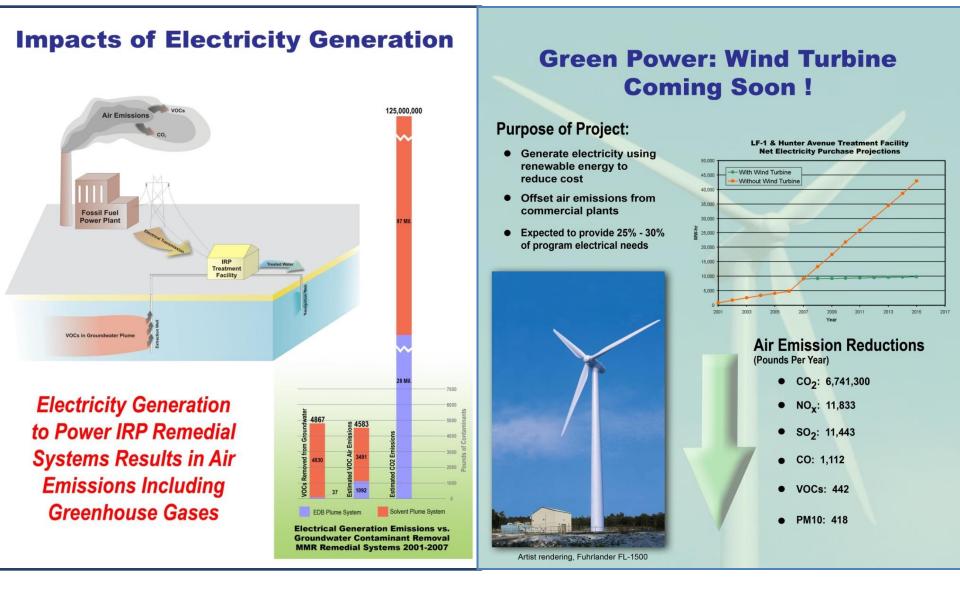
Several miles of pipeline

> 20 extraction wells, 3 reinjection wells, 11 infiltration trenches

~1200 monitoring wells

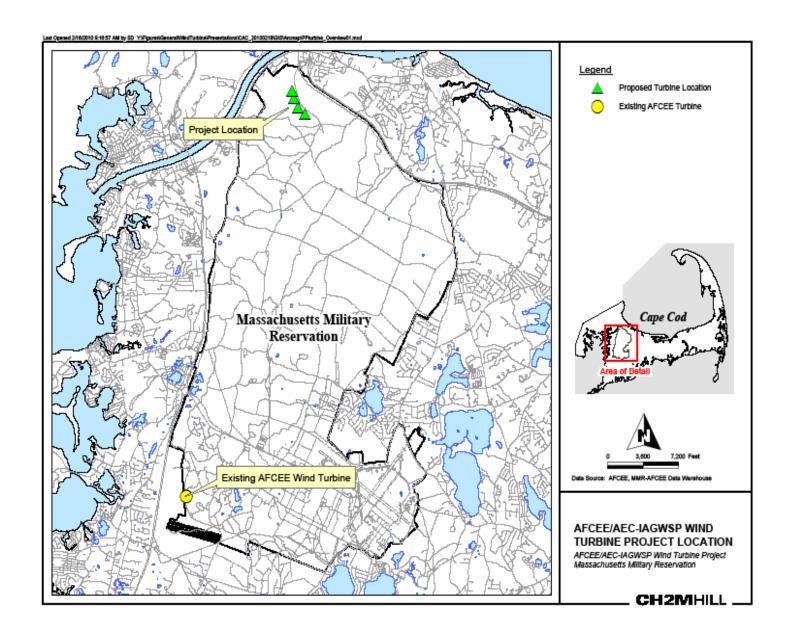






## Sustainability Evaluation

## Wind I and II



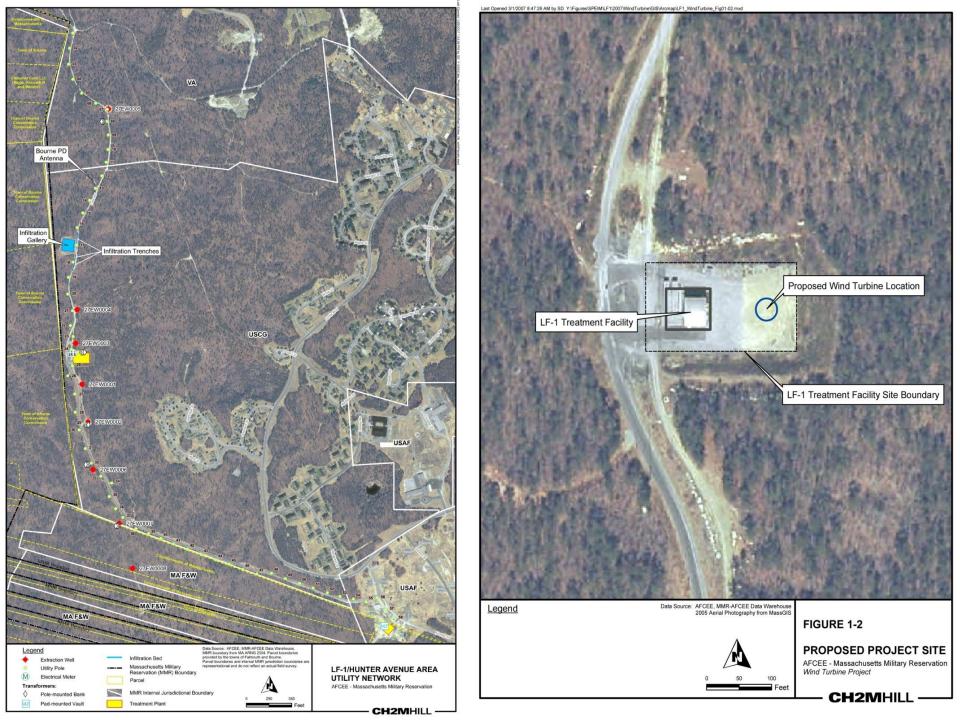
## Fuhrlander FL-1500

- Rating: 1.5 MW
- 80 m (~260 ft) hub height
- ~ 118 m (~390 ft) high from ground to tip of rotor blade
- 77 m (~253 ft) rotor diameter
- Speeds:
  - Rotational speed: 9.7-19 rpm
  - Avg site wind speed  $\sim 6.5-7.0$  m/s (14.5 15.7 mph) at 80 m hub height
  - Rated output @ 11 m/s (~25 mph)
  - Start wind @ 3 m/s (6.7 mph)
  - Stop wind @ 20 m/s (~45 mph)
  - Survival speed @ 59.5 m/s (134 mph)



- Fuhrlaender 1.5 MW, 80 m hub, 77 m rotor
- Five year project; date of operation 2 Dec 09
- Expectations:
  - produce ~ 3,810 MWh annually based on 29% capacity factor (P50); ~ 3,377 MWh annually based on 25.7% (P90)
  - generate 25-30% of AFCEE's total electrical requirement (>\$2M in 2009; \$1.7M in 2011)
  - •reduce ~25-30% air emissions
- •Actual production: 12,587 MWhr from startup (Dec 2009) through 30 Apr 2014; credit of \$1,793,772 through 25 Apr 2014
- Comparison of energy production to program energy use: see charts in presentation
- ROI showing ~10 years (does not account for pending gearbox exchange)





## Start Up Issues

- Startup at 50% power production
  - maximum output 750 kW for 50 hours
  - did not increase to 100% after 50 hours
  - reprogramming fixed problem now at 100%
- Autorestart not working properly
  - would not restart after shutting down for high wind, low wind or power outage
  - reprogramming fixed problem
- Turbine not responding well to gusts
  - shutdown on gusts less than cutout speed
  - reprogramming required along with replacement of encoder model

# Start Up Issues (cont)

#### Nacelle lighting not adequate

- reports of red flashing light at night too dim
- airfield ops concerns with visual identification during daytime
- light replaced white flash during the day and red flash at night

#### Remote monitoring not ready

- software not available at startup
- license agreement not finalized



## Operational Issues

Encoder – improper make/model

 Backup batteries – short life; possibly older when installed

 Generator brushes – short life; wore earlier than anticipated; possibly installed improperly

 Lightning strike damaged bearings and isolation disc in the generator

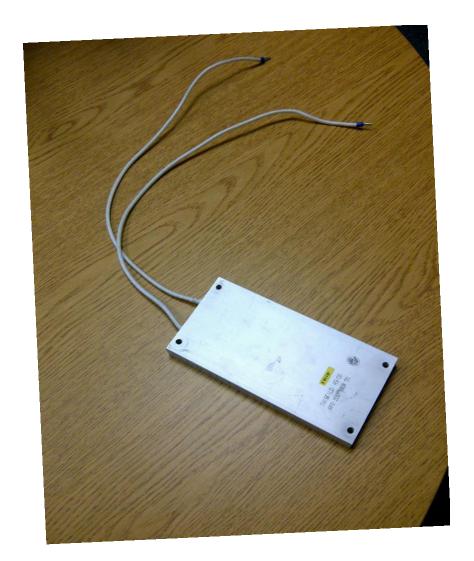
 Gearbox failed after 4.5 years of operation –borescope inspection identified bad bearing



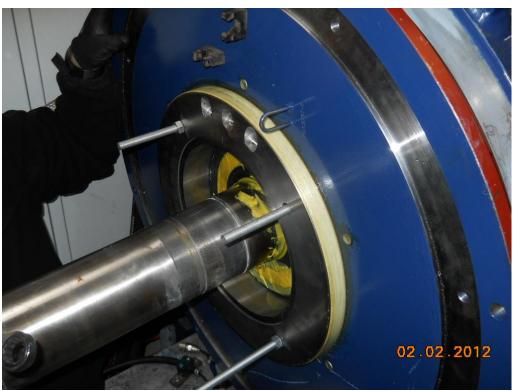
- Blade edge guard
  - Factory installed on edge of blades
  - Lighting strike caused material to bubble
  - Removed during blade inspection
- Bridge rectifier
  - monitors grid power
  - caused a grid loss error



- Chopping resistor
  - Bleeds off excess
     electricity produced and
     helps to stabilize power
     output
  - Faulty part resulted in a yaw converter error that lasted about 1.5 years.



Lightning damage to main bearing



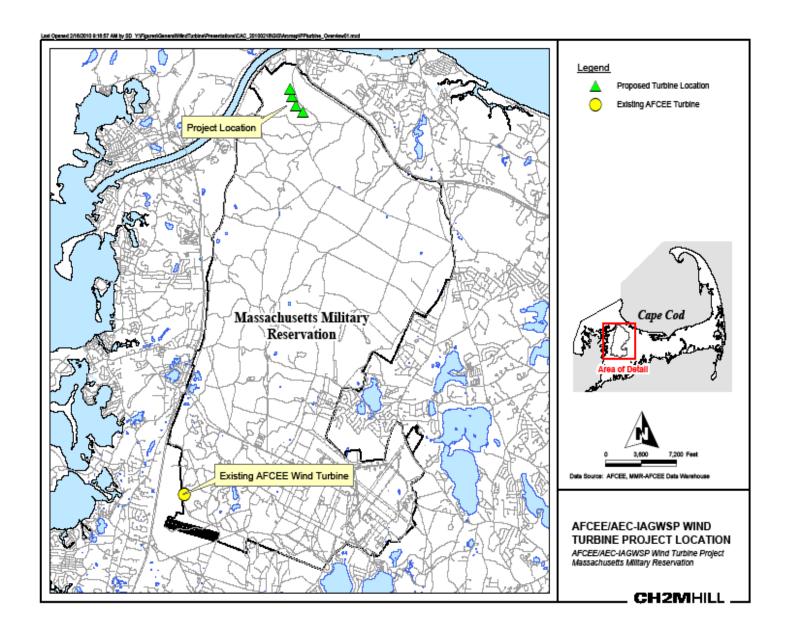


## Administrative Issues

#### Service issues:

- slow response to problems (delayed service), no written service agreement or warranty; foreign country
- some issues were eventually resolved i.e. availability guarantee; warranty
- issues with subcontracts; inexperienced technicians; travel delays from Germany
- No end of warranty inspection conducted
- Fuhrlaender closed North American office in Sep 2012 and subsequently filed for bankruptcy

## Wind II



- Two GE 1.5 MW, 80 m hub, 77 m rotor
- Two year project; date of operation 8
   Nov 11
- Expectations:
  - produce ~ 7,620 MWh annually based on 29% capacity factor (P50)
  - generate 50-60% of AFCEE's total electrical requirement (>\$2M in 2009; \$1.7M in 2011)
  - reduce ~25-30% air emissions
- Actual production: 18,812 MWh from 08
  Nov 2011 to 30 Apr 2014; credit of
  \$2,459,865 through 25 Apr 2014
- ROI showing ~10 years



### Construction Issue

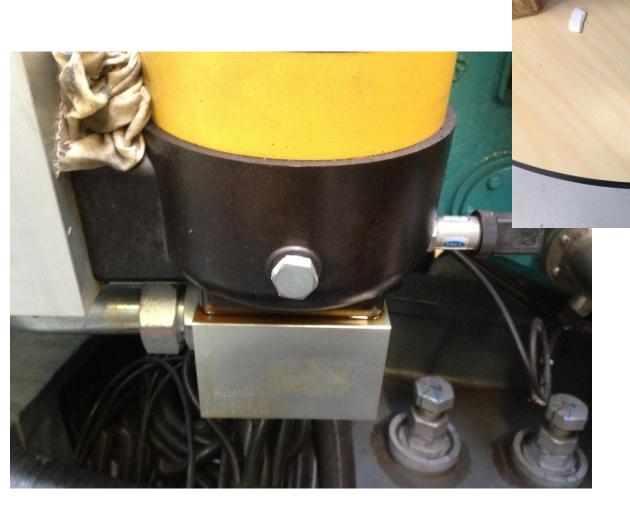
- Metric/English conversion for bolts and poor quality milling resulted in bolts being too large for tower flange opening
- GE milled flange openings on site to accommodate bolts



## Start Up Issues

- Generator cooling fans failed
  - One fan failed within first week of operation the day of the ribbon cutting ceremony
  - Second fan failed a few weeks later
  - Known problem with the installed turbine model
  - Why wait until after turbine is up to replace?
- Nacelle lighting did not switch from white strobe to red strobe at night
  - Received complaint from concerned resident living 5 miles away

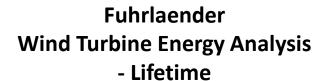
Oil leak at filter housing



# **Details**

	Wind I	Wind II
Machines	One Fuhrlaender 1.5 MW	Two GE 1.5 MW
Hub height/rotor diameter	80 m/77 m	80 m/77 m
Total height	~390 ft	~390 ft
Startup Date (witness test)	2 Dec 2009	8 Nov 2011
Project Timeframe	~5 years	~2 years
Distance from homes	1140 ft (on base residents)	3000 ft (off base residents)
Foundation	Spread form – 57' diameter, 600 yds 5000 psi concrete	Spread form – 47' diameter, 470 yds 5000 psi concrete
Blades	ND: 122 ft, 13,600 lbs each	TX: 121.4 ft, 13,900 lbs each
Tower Sections	MN: 4; 41'-79'; 65,000-106,000 lbs	IA: 3; 72'-97' long; 62,700-114,000 lbs
Machine Head	GE: 12.8' high, 26.6' long, 143,200 lbs	FL: 12.5' high, 29' long, 126,000 lbs
Crane	Manitowoc 16000; 440 ton; 315' mast	Manitowoc 16000; 440 ton; 315' mast
Funding Type	Environmental Restoration Account	Environmental Restoration Account
Constructability Assessment	\$400,000	\$462,284
Construction	\$4.87M (plus two years O&M)	\$9.43M (plus substation and one year O&M)
Utility Interconnection	\$53,858 (to existing 23 kV distribution)	\$272,000 (to new 23 kV distribution line through new substation and then to existing 115 kV transmission line)
Title II Oversight	\$150,000	\$341,000 (and environmental surveys)
Energy Production (startup to date)	12,587 MWhr (02 Dec 09 – 30 Apr 14)	18812 MWhrs (8 Nov 11 – 30 Apr 14)
ROI	~10 years	~10 years

Weekly Energy Production



Weekly Electricity Production [MWh]

Weekly Electricity Production

────Wind Turbine Estimated Cumulative Energy Production (based on capacity factor of 25.4%) [MWh]



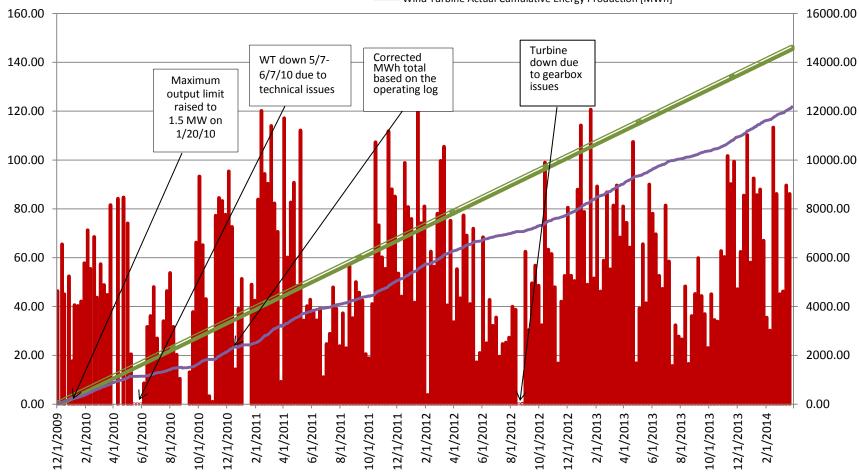
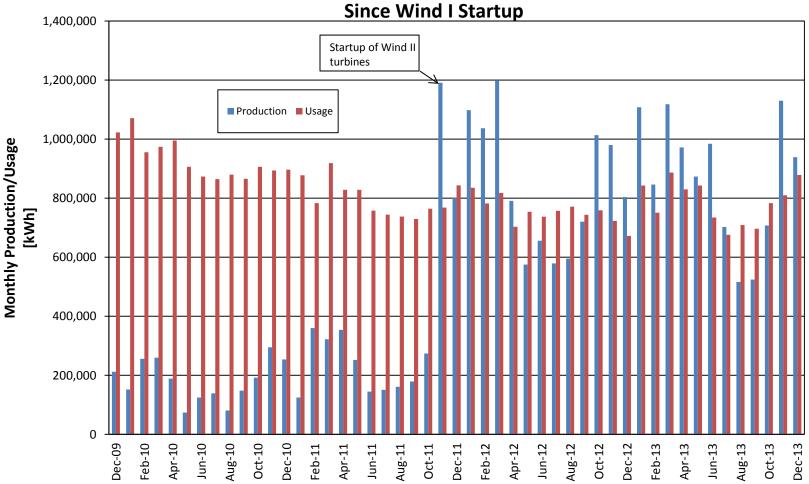


Figure 11

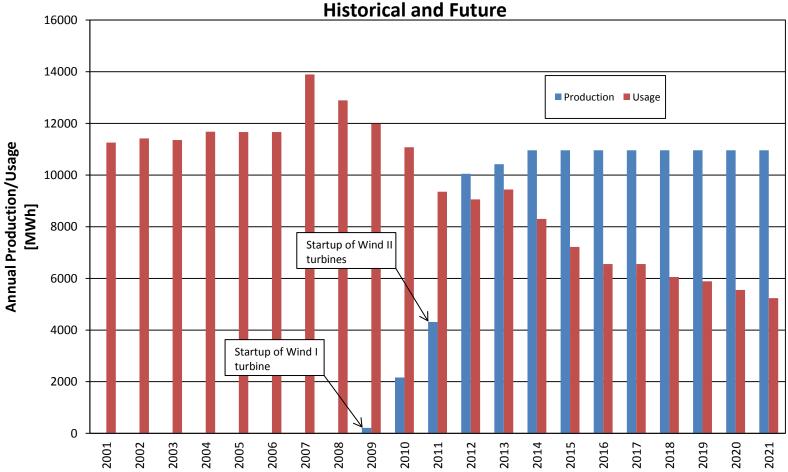
JBCC Wind Turbine Production vs. Remediation Project Usage
Since Wind I Startup



kWh = kilowatt-hours

Figure 10

JBCC Wind Turbine Production vs. Remediation Project Usage
Historical and Future



#### Notes:

- 1. 2014-2021 data figures are estimated.
- 2. Future wind turbine performance estimates are based net capacity factors (NCF) of 25.4% for the Wind I turbine (NCF for 2013 computed from production reported by NSTAR) and 28.3% for the Wind II turbines turbine (NCF for 2012 computed from production reported by NSTAR).
- 3. Future electricity usage figures are based on AFCEC estimates of electricity consumption as plumes are remediated and flow rates are reduced.

- Communicate early and often with stakeholders
- Understand net-metering, RECs, and state rules
- Utility Interconnection build in time and plan for costs and changes
- Logistics room to haul and build (bridges, road width, corners, permits, bad drivers, Military Cargo Preference Act of 1904, etc)
- Explore additional grants can AF/DoD accept them?
- Inspect the manufacturing facilities if possible
- Make sure the turbine components suppliers and transportation companies are insured.
- Evaluate modes of transportation (roadway, rail, barge)
- Contracting: Firm Fixed Price or Cost (Best Value or Lowest Price); own/operate or lease with power purchase agreement

- Do spare parts come with the wind turbine purchase? If not,
   plan for funding of a spare parts package
- Just because spare parts are new doesn't necessarily mean they will work
- Plan for technical and safety training involve local emergency response personnel
- An FAA ruling of presumed hazard is not the end of a project, it's the beginning of negotiations
- Ensure manufacturers are reputable and there are working wind turbine models in the US for several years
- Select contractors who have experience with wind turbine planning and construction projects
- Are anchor bolts sized correctly? Metric vs english conversions can cause problems
- Provide site signage/directions to transportation companies and police details

- Long lead time on turbines explore interest from manufacturers (important on Wind I, not so much on Wind II)
- Evaluate use of direct drive turbines no gearboxes
- Some manufacturers have specific setback requirements
- Plan on a schedule and hold contractors to it include liquidated damages in contracts
- Evaluate warranties and O&M/service contracts in advance; build in availability guarantee if possible
- Conduct end of warranty inspections
- Contracting officers may not want to mix construction and O&M; use warranty as justification for O&M; specify manufacturer's standard warranty in contract package (typically 2 years)

- Construct foundation in cool weather and allow time to achieve strength
- Use existing wind resource data and other studies if available and applicable
- Consult experts (i.e. DOE, AFCESA) on funding mechanisms (DERA, ECIP, EULs, ESPCs, tax credits)
- Don't plan a ribbon cutting ceremony until the turbine is up and operational
- Long Haul Project need a dedicated champion

## Other Energy Projects at JBCC

- PAVE PAWS installed two GE 1.68 MW wind turbines; operational in Jan 2014
- The Air National Guard is planning the installation of multi
   MW solar panel arrays on the MMR landfill developer PPA
- The VA cemetery installed a smaller wind turbine (50 kW) on their property
- USCG uses a geothermal heating/cooling system at two of its hangars and is exploring the possibility of a solar array
- JBCC agencies are actively making improvements in energy efficiency including programs offered by Cape Light Compact
- New buildings are LEED silver at a minimum

# Solar PV Array on Landfill

- EPA-funded Feasibility Study (FS) to evaluate potential for solar photovoltaic (PV) on landfill
- FS conducted by NREL
- Otis ANG (102 IW) is the proponent
- Defense Logistics Agency is the contracting office
- Proposals have been evaluated
- Awaiting selection of contractor



# QUESTIONS/COMMENTS?



rose.forbes@us.af.mil www.mmr.org **NEW ENGLAND'S GENERAL EXCELLENCE WINNER** 

# CAPE COD TIMES

capecodONLINE.com

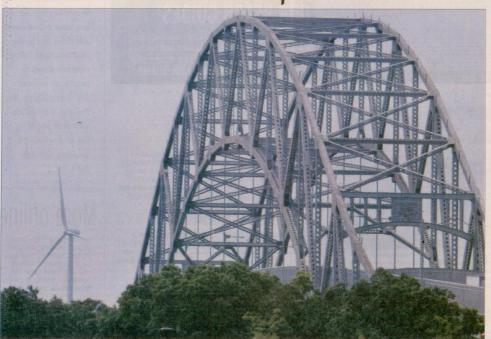
Health: Greek drama prescribed C1

Business: Carpenters picket work site C4

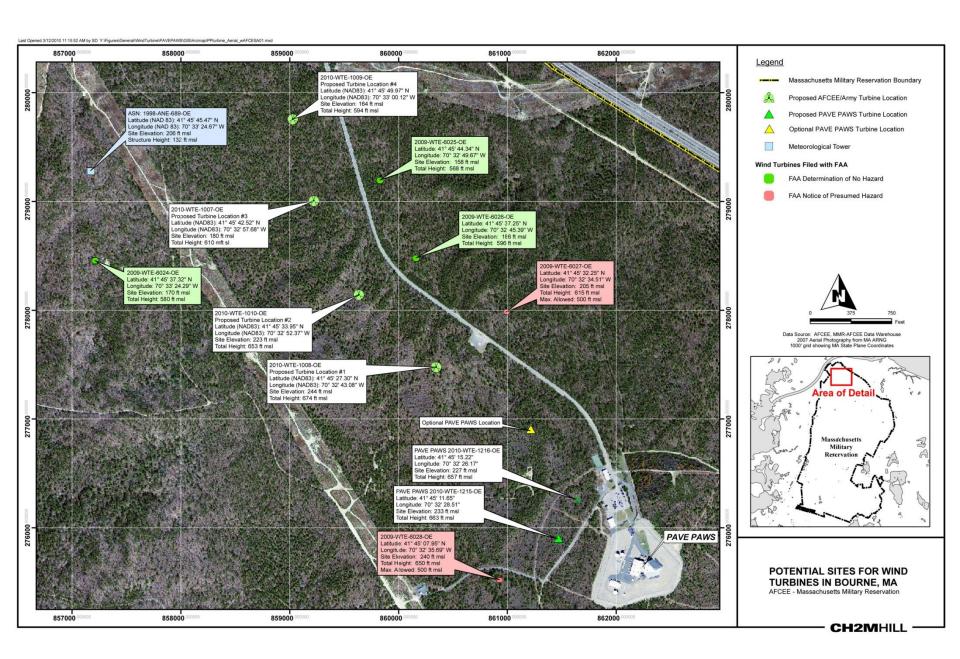
Vol. 75, No. 167



# Tower of power



Travelers heading onto the Cape over the Sagamore Bridge will see a new landmark towering over the trees with the addition of a 390-foot wind turbine on the Massachusetts Military Reservation, the first of two 1.5-megawatt turbines planned for the location. Combined with a turbine already in operation near Route 151 in Falmouth, the three turbines are expected to someday generate all the electricity needed for the Air Force Center for Engineering and the Environment to operate the groundwater treatment plants needed for the ongoing pollution cleanup at the base.



### **Capacity Factor**

- A percentage measurement of the actual output of a turbine as compared to the theoretical maximum output if the turbine were to run at full power 24 hours a day for a year.
  - Gross capacity factor represents the output estimated using only wind statistics
  - Net capacity factor considers wind statistics and efficiency losses such as availability, utility outages, and electrical losses.

# **Availability**

- the amount of time the turbine is ready for operation
- usually included in the turbine supply agreement provided by the manufacturer
- is typically 95%-98%

### Wind Shear

- the change in the wind speed with height
- wind speeds generally increase with height through the lower part of the atmosphere
- usually assigned a value of 0.143
  - site wind shear is 0.27

### Power Law

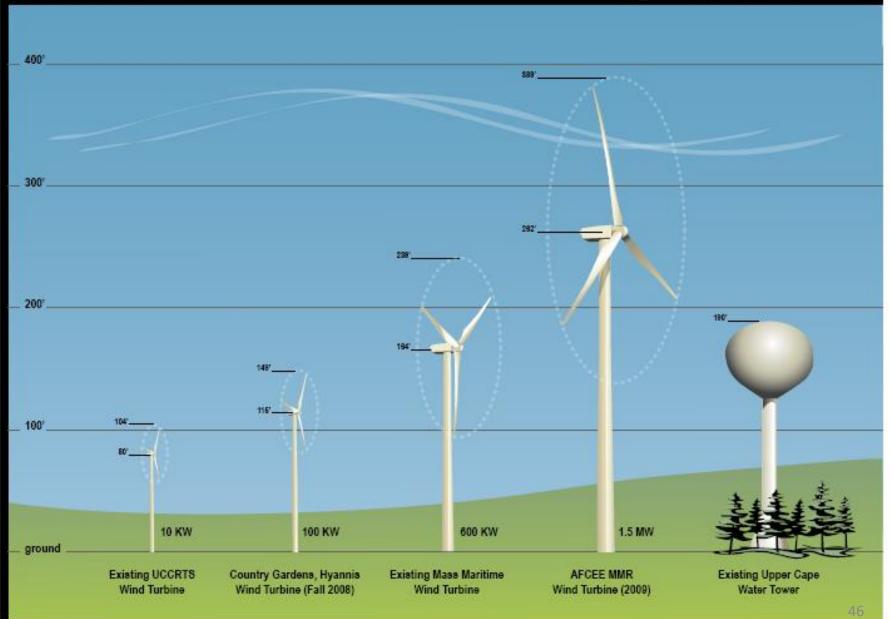
- The power available in the wind is proportional to the cube of its speed
- doubling the wind speed increases the available power by a factor of eight

### Confidence Level

- P(50) indicates the representative number (i.e. wind speeds) has a 50% chance of being exceeded over the timeframe of analysis [6.8 m/s].
- P(90) indicates the wind speed has a 90% chance of being exceeded of the timeframe of analyses [5.5 m/s]
  - A one year P90 confidence level indicates the wind speed that will be exceeded in 9 of 10 years

#### **Height Comparison**





# Economics (the simple version)

- Estimated installation cost is \$4.5 million per 1.5 MW turbine
- O&M cost is \$25,000 per turbine per year
- Predict annual production is 3.5 million kWh
- Assume that each kWh has an average value of \$0.20
- Yearly revenue is equal to the value of energy produced minus
   O&M or \$675,000
- In this simplified model, it will take 6.7 years to recoup the investment, after that the energy is almost free
- The turbine is expected to last for 25 years
- A more complex version of this analysis that accounts for inflation and other factors is being completed

# Net Metering:

- Electricity added to the grid behind a customer's meter displaces electricity bought from the grid that would have gone through the meter. It's like adding water from your own well behind the city's water meter.
- If extra electricity is produced on a windy day, the meter simply "spins backwards" providing credit for the excess.
- When the wind doesn't produce enough electricity to meet the demand, the meter spins forward with grid supplied electricity, but the credits from when the meter spun backward are used first.
- If more energy is bought than is produced, you pay based on how much the meter spun forward.
- Through Massachusetts' "virtual net metering", other meters at other loads can use the excess credits generated by a turbine behind a meter. The meter at the turbine counts as a "load".
- Virtual net metering allows us to power several treatment plants with a turbine using the utility company's grid to distribute the electricity. The turbine does not have to be metered behind the treatment plant.
- Massachusetts' new rules allow net metering up to 2 MW per turbine but there is no limit on the number of turbines.

Net Metering is not applicable to commercial wind farms. Commercial wind farms are not "behind the meter" and they have to compete on the open market to sell their electricity.

### **NSTAR Net Metering Cap**

- NSTAR's Highest Historical Peak Load = 4,958 megawatts (2 Aug 2006)
- Net Metering Cap: 49.58 megawatts (1% of highest historical peak load)
- Net Metering Totals (Through end of July 2010)
  - Projects Online: 16.9 megawatts
  - Projects with Applications Submitted: 33.1 megawatts
  - Total (both above): 50 megawatts
- http://www.nstaronline.com/business/rates\_tariffs/i nterconnections/other.asp

### Noise and Health

- Dr. Robert McCunney's presentation (July 2010) focused on results from a review of wind turbine noise and health studies published in the peer-reviewed literature.
- Generally, these results may be summarized as follows:
  - Audible and sub-audible noise produced by wind turbines does not have direct physiological effects on human health or on hearing, balance, and other systems.
  - "Wind turbine syndrome" has not been documented in the peer-reviewed literature and is not a recognized medical diagnosis, and all reports are based on "case series" - a valid method for presenting cause-effect hypotheses but not a scientifically rigorous epidemiological approach.
  - Individuals respond differently to wind turbine noise, and some people particularly those already opposed to turbine installation - may experience annoyance, leading to stress responses with potentially serious health consequences.
- <a href="http://awea.org/newsroom/releases/AWEA CanWEA SoundWhitePaper 12-11-09.pdf">http://awea.org/newsroom/releases/AWEA CanWEA SoundWhitePaper 12-11-09.pdf</a>

### **Property Values**

- Not well studied for wind facilities
- Some evidence of property values dropping at time of wind project announcement but recovering after construction

## Calculate the capacity factor

- From 02 Dec 2009- 20 Jan 2011, the wind turbine generated 2430 MWhr (414 days)
- From 21 Jan 2011 31 Mar 2011, the wind turbine generated 762 MWhr (69 days)
- Calculate the capacity factor for both timeframes

## **Capacity Factor**

- A percentage measurement of the actual output of a turbine as compared to the theoretical maximum output if the turbine were to run at full power 24 hours a day for a year.
  - Gross capacity factor represents the output estimated using only wind statistics
  - Net capacity factor considers wind statistics and efficiency losses such as availability, utility outages, and electrical losses.

## Calculate the capacity factor

- From 02 Dec 2009-01 Dec 2010 (one year operation), the wind turbine generated 2,157 MWhr
- From 28 Feb 2012 27 Feb 2013 (one year),
   the wind turbine generated 2766 MWhr
- Calculate the capacity factor for both timeframes

### **Answers**

1500 kW \* 365 days \* 24 hr/day\* cf = 2,157,000 kWhr

$$- cf = 16.4\%$$

- 1500 kW \* 365 days \* 24 hr/day \* cf = 2,766,000 kWhr
  - cf = 21%