Wind Turbines Case Study

Workplace Hazards of Green Industries

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Outline

- Background
- Before you can install a wind turbine: Community Buy-in
- Manufacturing Processes
- Installation
- Use
- Maintenance & Disposal
- Research recommendations

Introduction

- Increasingly abundant energy source in the US
- Alternative to coal & petroleum
- Largest wind energy projects are in CA and TX
  – Capable of generating 585.3-981.0 MW of power
- Wind farms in Southern Illinois produce an increasingly larger share of energy consumed in the US every year
- Most of the electricity consumed in Chicago is not produced in Illinois
- Illinois state renewable portfolio standard (RPS), 2007:
  – Requires all investor-owned and alternative retail electric suppliers to generate 25% of 2025 electricity from renewable sources

Energy Consumption Estimates Illinois 2011

Fuel type	Amount consumed over entire year (in trillion BTUs)	Percent of total
Coal	1,052	23.6%
Natural gas	986.4	22.1%
Motor gasoline excluding ethanol	540.8	12.1%
Distillate fuel oil	270.7	6.1%
Jet fuel	144.3	3.2%
Liquified petroleum gas	71.5	1.6%
Residual fuel	0.2	0.0045%
Other petroleum	173.7	3.9%
Nuclear	1002.7	22.5%
Hydroelectric	1.4	0.031%
Biomass	145.4	3.3%
Other renewables	**65.4**	**1.5%**
Total	4454.5	99.9% (rounding)

www.eia.gov/state/?sid=IL

Community Buy-in

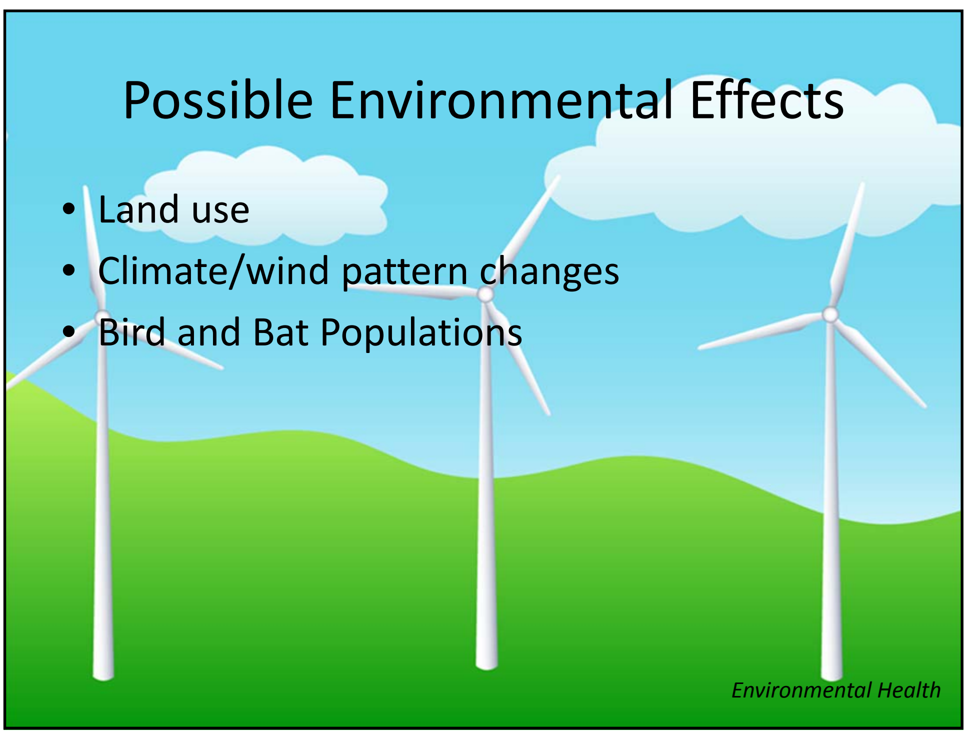
- Who gets financial or other benefits?
- Residents vs Local government
- Assumptions- Are these true?
  - The majority of the public supports wind power.
  - Opposition to wind power is therefore deviant.
  - Opponents are ignorant or misinformed.
  - The reason for understanding opposition is to overcome it.
  - Trust is key.

Policy/Education

Advantages/Disadvantages

Advantages	Disadvantages
Uses a free, renewable source	Noise concerns, Visual impacts
Produces no air pollutants/greenhouse gas	Higher initial setup cost
Less environmental impact than other alternative energy sources	Generation cannot be controlled to meet demand
No fuel purchase required (dependent on storage method)	Requires large areas of land
Minimal operating expenses	Transport issues (wind farms generally rural)

Possible Community Health Effects
• Low frequency noise
– Annoyance/Psychological distress
– Sleep disturbance
• Flying objects
• Stress
• Visual disturbances
• Mitigated by
– Surrounding noises
– Expectation
– Visibility
Medicine/IH



Possible Environmental Effects
• Land use
• Climate/wind pattern changes
• Bird and Bat Populations
Environmental Health

Structure of Wind Turbine

1. **Foundation**: Ensure structure's stability
2. **Tower**:
   – Helps absorb varying wind powers
   – Carries the weight of the rotor blades and nacelle
3. **Nacelle**: Houses machinery
4. **Rotor & Blades**:
   – Wind energy → mechanical movement
5. **Hub**: Rotor blades bolted into the hub

http://www.wwindea.org/technology/ch01/en/1_2.html

Manufacturing: VARTM System

- VARTM: Vacuum-Assisted Resin Transfer Molding
- Multistep Process
  – Gel coating: pigmented polyester resin (styrene)
  – Glue wiping: glue (34% styrene) applied to blade edges and then wiped off
  – Installing the safety platform: styrene resin
- Closed modeling system
  – Reduces environmental emissions & worker exposure

IH

Exposures during VARTM Manufacturing

- Colorless liquid with a foul odor in high concentrations
  - Sweet aromatic odor at low concentrations
- Inhalation and dermal routes of exposure
- Health effects
  - CNS effects, Eye & Respiratory irritation
- Exposure Limits
  - OSHA PEL: 100 ppm TWA, 200 ppm Ceiling
  - NIOSH REL: 50 ppm 10h TWA, 100 ppm STEL, 700 ppm IDLH
  - ACGIH TLV: 20 ppm TWA, 40 ppm STEL

IH

Manufacturing: Epoxy-Based System

- Resin formulation
  - Mixture of epoxy resin, reactive dilutant, curing agents, & other ingredients
- Prepregging
  - Application of formulated resin product in solution or molten form to a reinforcement such as carbon, fiberglass, aramid fiber, or cloth
- Cutting prepreg
- Construction of blade shells, beams, assembly fittings
  - **Making a mold:** glass fiber sheets impregnated with an epoxy resin based on tetraglycidyl-4,4’-methylenedianiline
  - **Making rotor blades:** glass fiber impregnated with epoxy resin based on diglycidyl ether of bisphenol A (DGEBA)
- Finishing

IH

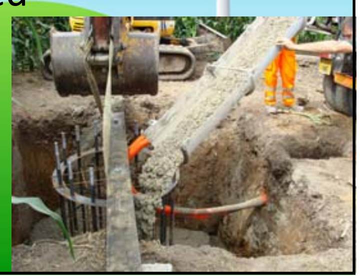
Exposures during Epoxy Manufacturing

Exposure	Exposure Limits	Health Hazards
Epoxy Resin	NA	Allergic Reactions, Skin Irritation, Rashes, & Dermatitis
Diglycidyl Ether	OSHA PEL: 0.5 ppm Ceiling NIOSH REL: 0.1 ppm TWA ACGIH TLV: 0.1 ppm TWA	Eye, Respiratory System Irritation, Skin Burns (carcinogenic), Cumulative Systemic Toxicity
4,4’ Methylenedianiline (MDA)	OSHA PEL: 10 ppb TWA, 100 ppb STEL NIOSH REL: Lowest Feasible Concentration (LFC) due to being potentially carcinogenic ACGIH TLV: 0.1 ppm TWA, 0.5 ppm STEL	Hepatitis

IH

Initial Set-Up

- Site excavation and prep
- Build foundation & turbine base
  - Metal and concrete grid
- Network grid is set
- Day for installation determined
  - Minimize wind



Engineering/IH

Supplies

- Disassembled parts transported to site
  - Large flat bed trucks
  - Tower is 3-4 parts with stairs inside
- Large cranes used to lift heavy poles/equipment
- Huge team of people & safety equipment

Engineering/IH

Assembly

- Base section of tower set in cement foundation
  - Bolted down
- Subsequent tower sections are set and fixed atop each other
  - Cranes used to lift parts, People inside tower bolts down

Engineering/IH

Rotor Flying

- Nacelle is fixed to top section of tower or rotor
  - Workers inside top of tower to assemble
- Rotor is flown up and fixed to turbine body
- Electronic parts connected
- Final connection to network grid and turbine turned on

http://www.siemens.com/press/pool/de/pressebilder/photonews/PN200818/PN200818_04_300dpi.jpg

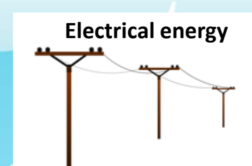
Electrical Energy Generation

- Convert kinetic energy of wind to electrical energy
- Most explanations of wind turbines SKIP electricity generation
  - https://www1.eere.energy.gov/wind/wind_how.html
- Missing step: STORAGE

Mechanical (kinetic) energy

http://www.opdi-technologies.com/Projects.2.aspx

Electrical energy



http://cliparts101.com/free_clipart/24116/Electric_tower

Potential energy (storage)

http://www.teachengineering.org/view_lesson.php?url=collection/cub_/lessons/cub_energy/cub_energy_lesson01.xml

EE Storage

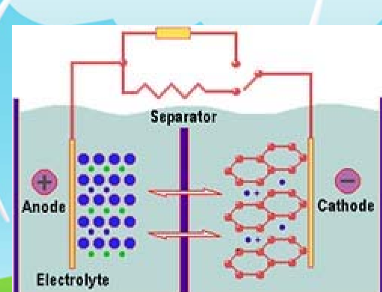
- Why is this important?
  - Wind turbine use is not reliable
    - Peak times of day and year
    - Above times not necessarily correlated to peak usage times
    - Difficult to use wind power effectively without coupling with a natural gas plant as back-up
    - Complicated to run any power plant because of energy usage variability

Engineering/IH

Methods of Storage-1

Conventional Methods

- Batteries
  - Potential energy stored in the form of an electrolyte gradient



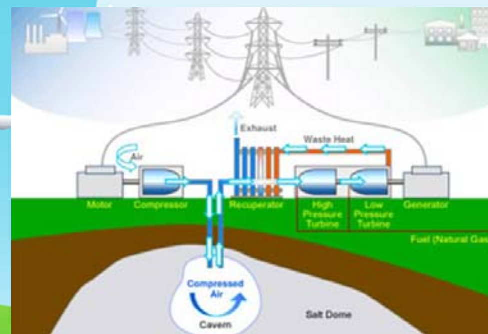
http://www.csanyigroup.com/wind-power-storage

- Capacitor
  - Potential energy stored in form of electrostatic charge

Engineering/IH

Methods of Storage-2

- Compressed air underground
  - PE stored as compressed air
  - Storage usually occurs in already present underground "containers"
  - Compression takes place during off-peak hours of the day
  - Use natural gas combustion to heat air into turbine, move turbine, and generates electricity



Engineering/IH

Methods of Storage-3

- Flywheel
  - Cylinder contains a rapidly spinning shaft
  - Cylinder is levitated by a magnet to limit friction and loss of energy
  - Potential energy is stored by increasing the speed of the flywheel's revolutions

http://green.blogs.nytimes.com/2010/01/25/advancing-the-flywheel-for-energy-storage-and-grid-regulation/?_r=0

Engineering/IH

Maintenance & Disposal

- Associated Hazards
  - Fall risk
    - Most wind turbines are over 100 feet tall
  - Electrical hazards
    - Arc flashes (including arc burn and blast hazards)
    - Electric shock
    - Fires
    - Thermal Burns
  - Can cause injury or death

Safety

Mortality from Maintenance/Disposal

- 80 wind related deaths between May 1980-2013
  - 27 of which in the US
  - 19 from maintenance
  - 2 from construction (installation and removal)
- 2011: Deadliest year (15 fatalities)
  - OSHA and AWEA alliance to focus on worker safety
- Numerous other deaths have come from suicides or factors not related to turbine operations

Epidemiology

OSHA Fall Protection

- Maintenance falls under OSHA's general industry requirements
- Workers exposed to falls of 4 feet or more must be protected by a standard railing or other PPE
  - Safety net
  - Personal fall arrest
- While climbing a fixed tower ladder (>20 ft)
  - Landing platform every 30 ft (fitted cage or well)
  - Landing platform every 20 ft (if not equipped)

Safety

OSHA Electric Generation Protection

- Protective grounding systems to reduce any stray voltage to a safe level
- Job briefings must include
  - Review of the particular sources and hazards or potential hazardous energy present
  - Methods to control the potential hazards
- Minimum Approach Distances for unqualified and qualified employees

Safety

Electric Power PPE

- Generally includes
  - Safety glasses
  - Face shields
  - Hard hats
  - Safety shoes
  - Insulating (rubber) gloves with leather protectors
  - Insulating sleeves
  - Flame-resistant (FR) clothing
- Electric power workers often use Insulating Protective Equipment (IPE)
  - Line hoses
  - Rubber hoods
  - Rubber blankets
  - Insulating live-line tools
    - Hotsticks
    - Switchsticks
    - Shotgun sticks

Safety

Research Approach for better characterization of health effects

From anecdotal to empirical: closing the knowledge gap

1. Identify appropriate study population
   - Occupational groups at risk
     - Production workers (e.g. epoxy resins and dermatitis)
     - Transporters/loaders
     - Maintenance workers (e.g. fire safety)
     - Disposal workers
   - Residents at risk
     - Those within *x* yards of a wind turbine?
     - Those identified at a health clinic?

Epidemiology

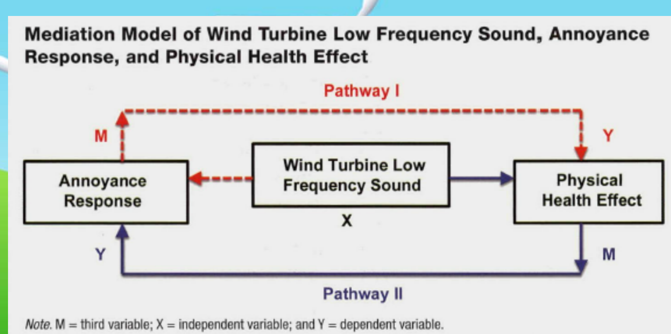
Research Approach

2. Carefully plan the study design
   - Considerations:
     - Randomization
     - Objective metrics (e.g. blood pressure or biomarkers)
     - Control group
     - Blinded data collection
     - N-size and statistical power
     - Choice of hazards and outcomes
3. Use results to design interventions and guide policy

Epidemiology

Research Approach

Sample Causal Model:



Source: Roberts and Roberts, 2013

Epidemiology

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  - Mid section Install: http://www.youtube.com/watch?v=-T3ksD7Pv0I
  - Nacelle Install: http://www.youtube.com/watch?v=12dIJOhHo0U
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