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

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

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.

Advantages/Disadvantages

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

- Low frequency noise
  - Annoyance/Psychological distress
  - Sleep disturbance
- Flying objects
- Stress
- Visual disturbances
- Mitigated by
  - Surrounding noises
  - Expectation
  - Visibility

Possible Environmental Effects

- Land use
- Climate/wind pattern changes
- Bird and Bat Populations
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 $\rightarrow$ mechanical movement
5. **Hub**: Rotor blades bolted into the hub

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
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

Manufacturing: Epoxy-Based System

- Resin formulation
  - Mixture of epoxy resin, reactive diluant, 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
### Exposures during Epoxy Manufacturing

<table>
<thead>
<tr>
<th>Exposure</th>
<th>Exposure Limits</th>
<th>Health Hazards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Epoxy Resin</td>
<td>NA</td>
<td>Allergic Reactions, Skin Irritation, Rashes, &amp; Dermatitis</td>
</tr>
<tr>
<td>Diglycidyl Ether</td>
<td>OSHA PEL: 0.5 ppm Ceiling NIOSH REL: 0.1 ppm TWA ACGIH TLV: 0.1 ppm TWA</td>
<td>Eye, Respiratory System Irritation, Skin Burns (carcinogenic), Cumulative Systemic Toxicity</td>
</tr>
<tr>
<td>4,4’ Methyleneedianiline (MDA)</td>
<td>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</td>
<td>Hepatitis</td>
</tr>
</tbody>
</table>

### 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
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

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
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

Electrical Energy Generation

• Convert kinetic energy of wind to electrical energy
• Most explanations of wind turbines SKIP electricity generation
• Missing step: STORAGE
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

Methods of Storage-1
  Conventional Methods

• Batteries
  – Potential energy stored in the form of an electrolyte gradient

• Capacitor
  – Potential energy stored in form of electrostatic charge
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

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

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

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
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)

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
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

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?
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
References


References

References

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  - Mid section Install: http://www.youtube.com/watch?v=7xkD7Pv0I
  - Nacelle Install: http://www.youtube.com/watch?v=12dlOHeOyU
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- Epoxy-based manufacturing

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