IPRO 302: Alternative Metropolitan Power Strategy

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• Interdisciplinary

• Topic Focused
  – Service
  – Sustainability
  – Energy
  – Business
Diverse IPRO Group

- ECE
- ChE
- PSYC
- ARCH
- CAE
- BUS
Outline

• Background
• Research process
• Design Costs
• Solution Design
• Cost Benefit Analysis
• The Future
Current Problem

Energy Source

- Nuclear Power: 59%
- Coal-Fired: 33%
- Natural Gas-Fired: 5%
- Biomass Power: 1%
- Wind Power: 1%
- Hydro Power: 1%
Current Problem

Current
- Renewable: 3%
- Non Renewable: 97%

Future
- Renewable: 20%
- Non Renewable: 80%
Outline

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Power Supply in Chicago
Energy Demand

Annual Power Consumption

Weekly Graph

Daily Graph
Energy Demand

Non Renewable 80%

Renewable 20%

= 3,143 GWHr Annually
Environmental Data
Environmental Data
Renewable Technologies

Wind

Solar

Photovoltaic

Solar Thermal
CT

- 2 simple cycle turbines (85MW and 279 MW)
- Relatively low installation cost
- Low emissions
- Starts up quickly
- High heat recovery
CT Power Plant
Outline

• Background
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• The Future
Design Calculations

• Capital Cost
• Operating & Maintenance
• Insurance and Legal Fees
• Fuel
• Land
• Transmission Costs
System Capital Costs

<table>
<thead>
<tr>
<th>Technology</th>
<th>Capital Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar PV</td>
<td>10.3</td>
</tr>
<tr>
<td>Solar Thermal</td>
<td>5.8</td>
</tr>
<tr>
<td>Wind</td>
<td>2.3</td>
</tr>
<tr>
<td>Coal</td>
<td>0.85</td>
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</tbody>
</table>
Solar is Too Expensive

- Solar would require a $5 to $10 billion capital investment
- It’s too expensive to consider further
Outline

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Wind

General Electric 2.5 MW wind turbine
Rotor Diameter: 100 Meters
Tower Height: 100 Meters
Footprint < 1 Acre
Land Use Requirements

Fixed Turbine

Rotating Turbine
Wind Strategy

• 500 Turbines

• 5 Farms
  – 100 Turbines Each

• 1,250 MW Combined Generation
  – 30% Assumed capacity factor
  – 375 MW Average output
Location of Facilities
Location of Facilities
Location of Facilities
Outline

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Cost-Benefit Assumptions

• 5 year Depreciation Schedule
• 40% Tax Rate
• 3% Inflation
• 20 Year Evaluation period
• 1 year for capital development
Cost-Benefit Analysis

• Accounts for
  – Initial Investment (Capital)
  – Sales (Cost per kWh)
  – Cost of Sales (O&M)
  – Depreciation
  – Taxes
  – Inflation
Internal Rate of Return (IRR)

• Based on bond investment ratings based on risk
• Typical Rates
  – Coal investment 7% IRR
  – Wind 8-10%
  – Solar PV and Thermal (12-25%)
Cost of Energy

- Solar PV: $0.52/kWhr
- Solar Thermal: $0.30/kWhr
- Wind: $0.075/kWhr
- Coal: $0.03/kWhr
Conclusion: Final System Design

500, 2.5MW Wind Turbines + 2 Combustion Turbines

3143 GWHr/year (360MW dispatchable)

$2.3B in capital
Internal Return Rate: 8%

$0.075/ kWHr
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Future Work

• Investigate alternative back-up sources
  – CT with Renewable Back-up

• Compare the cost of wind with...
  – carbon sequestration
  – other carbon removal processes
What we’re doing to help IPRO302.F10

• Research Summary Document
  – Explain all assumptions made
  – Explain sources and their importance in industry

• Easy way to pass along research
QUESTIONS?
We need to account for 20% of Chicago’s power use.
### Illinois - Wind Resource Potential

#### Cumulative Rated Capacity vs. Gross Capacity Factor (CF)

The estimates show the potential megawatts of rated capacity that could be installed on land above a given gross capacity factor (without losses) at 80-m and 100-m heights above ground. Areas greater than 30% at 80 m are generally considered to have suitable wind resource for potential wind development with today's advanced wind turbine technology. AWS Truewind, LLC developed the wind resource data for windNavigator® (http://navigator.awstruewind.com) with a spatial resolution of 200 m. NREL filtered the wind potential estimates to exclude areas unlikely to be developed, such as wilderness areas, parks, urban areas, and water features (see Wind Resource Exclusion Table for more detail).

#### Table

<table>
<thead>
<tr>
<th>State</th>
<th>Total (km²)</th>
<th>Excluded² (km²)</th>
<th>Available (km²)</th>
<th>Available % of State</th>
<th>% of Total Windy Land Excluded</th>
<th>Installed Capacity³ (MW)</th>
<th>Annual Generation (GWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Illinois</td>
<td>70,763.6</td>
<td>20,787.1</td>
<td>49,976.4</td>
<td>34.25%</td>
<td>29.4%</td>
<td>249,882.1</td>
<td>763,529</td>
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</table>
# Turbine Analysis

<table>
<thead>
<tr>
<th>Wind Turbines</th>
<th>Turbine Power Output (MW)</th>
<th>Annual Electrical Consumption (MWh)</th>
<th>Avg. Demand (MWh/ hours per year= MW)</th>
<th>Capacity Factor</th>
<th>Adjusted Supply (MW)</th>
<th>Number of Units</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2.5</td>
<td>3,143,000</td>
<td>358.7899543</td>
<td>0.3</td>
<td>1195.97</td>
<td>478.39</td>
</tr>
</tbody>
</table>

479 Turbines adjusted to **500 Total turbines** for Transmission and Transformation losses.

![Graph showing Total GWh 500 Turbines and 20% of Chicago ComEd Power Consumption (GWh)](image-url)
Offshore Wind

• Issues
  - Shipping Lanes
  - It is currently Illegal
  - Aesthetic opposition and Ecological concerns

• Benefits
  - Increased Capacity Factor of 5 – 10%
  - Increased consistency and direction of wind
  - Substantial decrease in transmission distance