Art of Wind Power IIT_IPRO 314: InterProfessional Project SAIC SC4012: Future Green: Strategies for City Living

Midterm Report

March 22, 2007

The report is divided into 3 sections

- Wind Farms
- Wind and Architecture
- Wind and Urban Open Space

Industrial Corridor Windfarm Proposal

Project Objective

Prototype design for windfarm-scale power production for local and grid use using an industrial corridor that includes Lake Michigan, the Calumet River, and brownfields within a portion of the proposed Calumet Heritage Corridor.

Project Analysis

Wind power in the Chicago region has not been adopted due to many reasons. Our project attempts to address four primary ones including:

- 1) Local wind resources have not been collected in a manner such that adaptation has seemed possible or profitable. Our project attempts to identify wind resources in the region then design accordingly and appropriately.
- 2) Aesthetic and ecological concerns have not been adequately addressed in the past. Our team has selected an industrial corridor for its site that includes low aesthetic and ecological impact opportunities. We have also researched vertical axis, and other bird-friendly turbines that will assuage ecological concerns, while at the same time providing ample power for local and grid use.
- 3) Siting issues continue to challenge the development of wind power due to the abstraction of grid-based power and lack of immediate connection between power generation and use. Our project proposes several local and immediate uses of the power, including water pumping and filtration, power generation for industrial use, and brownfield remediation.
- 4) Wind power on a the scale of a windfarm has not considered the opportunities inherent in an industrial setting, including existing infrastructure, buildings, vacant lands and the need for power.

Project Area

The Project Area is Corridor D of the proposed Calumet Heritage Corridor, an industrial corridor that links heavy industry, brownfields and a river that is a Superfund site with an offshore water intake facility and filtration plant where drinking water is collected and treated for consumption on the south side of Chicago. Besides this disturbing water problem, Corridor D has been chosen for several other reasons as well.

- 1) The site contains several brownfields, including the USX/Southworks Steel Plant, the Acme Coke Plant, and the Calumet River, a federal Superfund site.
- 2) The industrial corridor lies adjacent to Lake Michigan, which provides additional windfarm-scale development opportunities.
- 3) The industrial corridor consumes a significant amount of power within a relatively small area.
- 4) The corridor is surrounded by residential communities, which include public and private schools, community centers, and an environmental center, all of which become potential opportunities for collaboration and education.
- 5) The Heritage corridor overall contains over 2,000 acres of vacant land, much of which is zoned industrial, and thus opportunity site for future wind development.
- 6) The corridor intersects several TIFF districts and Empowerment Zones and Enterprise Communities, all of which are potential ties for funding.

7) Corridor D could easily become a prototype for windfarm-scale development throughout the Calumet Heritage Corridor, which is also a mixed, industrial-residential region.

Project Designs

Design opportunities exist on various levels and in three key locations within our Project Area. The three key locations for site-specific windfarm design application include:

- 1) Acme Coke Plant our chosen interior, brownfield site. Currently, we are considering horizontal and vertical cooling chimneys, wind turbines and phytoremediation as design applications to this site. We are also looking at educational tie-ins to the Calumet Environmental Education Center, which lies adjacent to this site.
- 2) USX/Southworks Site our selected lakefront, brownfield site. This site lies at the mouth of the Calumet River (Superfund site). Currently we are considering vertical axis wind turbines along the lakefront and within the site. We are currently researching the potential for wind-powered remediation of the water in the River as it enters the lake. We are also researching educational opportunities with one adjacent elementary school and a high school that has been proposed to be constructed on the site.
- 3) Chicago Water Department's 68th Street Crib our Lake Michigan site. This site has direct ties to the South Water Filtration Plant, where water from the crib is filtered and treated for drinking. The Filtration Plant lies directly north of the USX/Southworks site. Currently, we are considering horizontal axis turbines for the Filtration Plant, and both horizontal and vertical axis turbines for the crib.

For our project, we propose to address each site as part of a continuum, each one at a different level of remediation and occupiability. We intend to provide solutions that are specific, adaptable, and 'plug and play', responding to the changing conditions and opportunities in the Calumet Industrial Corridor.

One design issue that impacts each of the sites is intermittency. Wind farms in other countries address this issue by typically using fossil fuels as a backup for the when the turbines are not rotating. We are considering other, non-carbon-releasing options, including fuel cells for power storage, geothermal and solar.

Plug and Play Wind Farms in Industrial Chicago

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why grid-scale wind power generation in chicago?

- Nuclear, coal-derived, and natural gas are not sustainable energy sources
- Wind power is clean and renewable
- Wind power is local
- Wind in Chicago, just 3 miles off the lakeshore, blows at an annual average speed of 15 to 16 mph
- Wind can become the backbone of a sustainable approach to electrical power production in the Chicago region.

what are the impediments to adoption of wind power in chicago?

Not In My BackYard

Variability

Flyway

Not widely accessible to end-users

Not cost-effective for utility companies

how can we get around these?

Must be widely accessible and cost-effective

Integrated into the grid and 'farmed'

Address variability issues

Situated in an industrial context

concept

To embed wind farms into industrial corridors and brownfield sites throughout Chicago, producing large amounts of power for local and grid use. The farms would also be tied to a remediatory function (environmental and economic).



The Calumet Industrial Corridor is the ideal site for prototyping an approach to urban/industrial wind farms in general.



Why the Calumet Industrial Corridor?

Contains several brownfield sites (USX/Southworks Steel Plant, the Acme Coke Plant, and the Calumet River)

Adjacent to Lake Michigan

Consumes a significant amount of power

Surrounded by residential communities (opportunities for collaboration and education)

Heritage corridor contains 2000 acres of vacant land which is zoned industrial.

The corridor intersects several TIF districts, Empowerment Zones, and Enterprise communities (opportunities for funding)

Corridor D can extend into the rest of the larger Calumet Heritage Corridor, which extend into Indiana (including Gary)

The Calumet Industrial Corridor is part of the larger Calumet Heritage Corridor



Potential sites in the Calumet Corridor range from dangerously contaminated (superfund sites) to usable, all of which are viable sites for wind farming.





Calumet River



Central river running through the entire calumet corridor area

EPA superfund site

River contaminated with hazardous fill (steel mill slag etc.)

River and property connections to Indiana

Intermodal transportation hub

USX Southworks Steel site



In the initial stages of development.

Lakefront property

Wide, open space without elaborate infrastructure to work with

High potential for industrial development.

Relatively low contamination.

South water filtration plant site:

The water filtration plant sits just north of and adjacent to the USX/Southworks site.

The crib (water intake) for the plant sits approximately 3 miles off the lakeshore east and slightly west of the water plant.

'usable' site in the corridor

in the lake - high wind generation



proposal

To address the different conditions in the Calumet industrial corridor as part of a continuum.

To provide solutions that are specific, adaptable, and 'plug and play'











Conclusion

collects local wind resources so that adoption is profitable

industrial corridor preesents low aesthetic and ecological impact opportunities

local and immediate uses of the power (industrial energy consumption, remediation, water filatration)

to consider the wind farm as a system that adapts to the changing conditions of an industrial and urban setting over time

Can we live with wind?

WIND POWER AND THE BUILT ENVIRONMENT

MIDTERM PRESENTATION

RESEARCH GOALS & PROCESS

- 1) Choose an appropriate site that displays qualities unique to Chicago, has a relationship with long-term investors and has potential wind activity.
- 2) Gather macro wind data from surrounding locations and analyze this data to approximate the prevailing micro wind conditions of the specific site.
- 3) Evaluate the energy needs of the site.
- 4) Research and evaluate existing turbine technologies that would be most appropriate for the scope and scale of the site.
- 5) Explore alternative material choices for existing turbine technologies that may increase efficiency and aesthetic appeal.
- 6) Propose several design hypotheses at the scale of the site and individual buildings and test these designs with a wind tunnel smoke test.
- 7) Modify and refine existing models in an iterative process with the previous goals that will result in a series of design guidelines for future neighborhood design projects that desire to take advantage of wind power.

WIND POWER AND THE BUILT ENVIRONMENT MIDTERM PRESENTATION

SITE: LAKE PARK CRESCENT DEVELOPMENT









SITE: LAKE PARK CRESCENT DEVELOPMENT









WIND POWER AND THE BUILT ENVIRONMENT

MIDTERM PRESENTATION

QUALIFYING CRITERIA

- Unique to Chicago
- Rich in history
- Actual client
- Long-term investment potential
- Mix of building typologies
- Proximity to lake and open space = potential for wind exposure

WIND POWER AND THE BUILT ENVIRONMENT MIDTERM PRESENTATION

DESIGN GOALS

- Maximize production of wind power through the comprehensive orientation of the site and the individual building design.
- 2) Integrate wind power generation with an appealing community appearance.
- 3) Treat wind as an integrated component of a comprehensive alternative energy system

WIND POWER AND THE BUILT ENVIRONMENT MIDTERM PRESENTATION

PROGRAM: ELEMENTS

1) **Site:**

Building placement & orientation, streets, parking areas. Consider access to transportation, community context, prevalent wind directions, relationship to park

2) Buildings:

Design of actual residence buildings with integrated turbines. Breakdown of units required as follows (developed based on CHA projections and developer plans):

- 10 "Six Flats": Approx 10,000 ft2 of living space, mixture market and affordable
- 12 "Row Homes": Single family homes, approximately 3000ft2 each
- 24 "City Homes": Mixture affordable and market, approx 2500 ft2 each
- 2 Towers: 70 units public and affordable housing, (square footage TBD).

WIND POWER AND THE BUILT ENVIRONMENT

MIDTERM PRESENTATION



PROGRAM: PARAMETERS

1) **Design constraints:**

- Borders of site
- Number of units/total square footage to be accommodated by design
- Design timeline = next 10 years (technology, materials, energy costs)

2) Areas of exploration:

- Aesthetics: Incorporation of neighborhood vernacular architecture vs. futurism/ innovation
- **Building groupings:** Groupings of units may deviate from developer's plans to maximize wind. Sensitivity to community and history of high-rise tenements is important in considering this question.
- **Budget:** Budget of construction costs will not be factored into designs. ROI will be calculated based on turbine costs vs. energy outputs

WIND POWER AND THE BUILT ENVIRONMENT MIDTERM PRESENTATION

SITE PROPOSAL 1: TERRACED ROOFS

Roof slopes designed in increasing heights to channel wind upward from one turbine to the next.





SITE PROPOSAL 2: CURVED FAÇADES

Directing wind along the exterior of the building to recessed turbines



WIND POWER AND THE BUILT ENVIRONMENT

MIDTERM PRESENTATION

SITE PROPOSAL 3: FUNNELS

Funnelling wind along curvilinear skins to horizontal axis turbines mounted in buildings or interstitial spaces

GRID ORIENTED SW - NE TO CAPITALIZE ON PREVALENT WIND DIRECTIONS

FUNNELING "SKINS" CHANNEL WIND TO TURBINES MOUNTED IN TOWERS

PEDESTRIAN-ONLY GREEN STRIP LINKS TO LAKEFRONT

SMALLER BUILDING FUNNELS CHANNEL WIND TO EMBEDDED TURBINES

Tower Six Flat Row House City House Covered Parking

The Art of Wind IIT IPRO 314 Architectural Integration Group

WIND POWER AND THE BUILT ENVIRONMENT

MIDTERM PRESENTATION

SITE PROPOSAL 4: TOWER - LAKE - AXIS



WIND POWER AND THE BUILT ENVIRONMENT MIDTERM PRESENTATION

TURBINE COMPARISON: VERTICAL AXIS VS. HORIZONTAL AXIS

Түре	Strengths	Limitations
Helical Blade (Vertical Axis)	 Limitless use Design flexibility: Can be integrated into buildings or can stand by itself Least affected by turbulence, wind speed & direction Starts to operate at low wind speed 	 Power generation is low compared to the horizontal axis type. (small sweep area) High turbine cost for its power generation
Propeller (Horizontal Axis)	 Limitless use Higher power generation. (large sweep area) Reasonable turbine cost for its power generation 	 Turbulence & change in wind direction usually decreases power production. Starts to operate at relatively high wind speed (3~4 m/s) Aesthetic issues

WIND POWER AND THE BUILT ENVIRONMENT

MIDTERM PRESENTATION

TURBINE COMPARISON: SMALL SIZE VS. UTILITY SIZE

Түре	Strengths	Limitations
Small Turbine	 No emissions No fuel cost Design is highly reliable. Can be integrated into building or other architectural designs to minimize visibility. 	 High capital cost means only competitive where peaking power is expensive or in remote locations. Is an intermittent resource. Cannot be used as primary power source without backup or storage system.
Utility-Size Turbine	 No emissions No fuel cost Design is highly reliable. Can deploy multiple sets to create "farms." Manufacturing costs are becoming competitive with central station generation. 	 Moderate capital cost means that tax credits are still required to justify installations. Some complain of visual impacts. Wind farms are dependent on grid infrastructure, and can contribute to congestion bottlenecks.

WIND POWER AND THE BUILT ENVIRONMENT

MIDTERM PRESENTATION

WIND ROSES



EAST



Waukegan Harbor, IL (2006)



Offshore Chicago, IL (2006)

Calumet, IL (2006)

WES

WIND POWER AND THE BUILT ENVIRONMENT

MIDTERM PRESENTATION

WIND ROSES: ANNUAL COMPARISON

Offshore Chicago Wind Data





2005

2006

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MIDTERM PRESENTATION



WIND CLASS FREQUENCY DISTRIBUTION

Offshore Chicago



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MIDTERM PRESENTATION

ARCHITECTURAL INTEGRATION GROUP

IIT IPRO 314

WIND CLASS FREQUENCY DISTRIBUTION



Waukegan Harbor, IL (2006)

WIND POWER AND THE BUILT ENVIRONMENT

MIDTERM PRESENTATION

WIND CLASS FREQUENCY DISTRIBUTION



Calumet, IL (2006)

WIND POWER AND THE BUILT ENVIRONMENT

MIDTERM PRESENTATION

ENERGY NEEDS: METHODOLOGY

- Energy need (electrical) per square footage.
- Energy need based each unit (appliance) household usage.
- Energy need based on household income.
- End-Use Estimation was used to calculate and project future energy usage.

WIND POWER AND THE BUILT ENVIRONMENT

MIDTERM PRESENTATION

ENERGY NEEDS: RESIDENTIAL ENERGY USE



Total Energy Consumption: 21.07 Quadrillion Btu

2004 Residential building energy end usage

WIND POWER AND THE BUILT ENVIRONMENT

MIDTERM PRESENTATION

SITE ENERGY NEEDS ESTIMATION

24 City Homes	12 Row Homes	10 Six Flats	2 Towers
2700000000	1080000000	45000000	? BTU
2700	1080	450	? MBTU
790861.1599	316344.464	131810.1933	? KWH

1 KWH = 3414 BTU

WIND POWER AND THE BUILT ENVIRONMENT

MIDTERM PRESENTATION

POTENTIAL ENGINEERING MATERIALS FOR TURBINES

- Presented with the problem of needing materials that meet the desired engineering properties while remaining aesthetically pleasing
- Many traditional metals and alloys such as steels and aluminum alloys must be used in the manufacture of wind turbines and can be designed in a way that is aesthetically pleasing
- However, newer composite materials can provide an appeal that alloys alone cannot

WIND POWER AND THE BUILT ENVIRONMENT MIDTERM PRESENTATION

POTENTIAL MATERIALS: LITRACON

Litracon: translucent concrete

- 4% optical fibers in a matrix of fine concrete
- Glass fibers act as aggregate in the concrete, making it as strong as traditional concrete
- Glass fibers can be arranged to form different patterns, such as wood grain
- Examples of use can be for turbine tower, base, housing
- Very expensive
- Only available in pre-fab blocks and panels



WIND POWER AND THE BUILT ENVIRONMENT

MIDTERM PRESENTATION

POTENTIAL MATERIALS: POLYMER MATRIX COMPOSITES

POLYMER MATRIX COMPOSITES: fiberglass, carbon fiber in polymer matrix, etc.

- Fiberglass already being used in blades of small turbines
- Ability of fiberglass to be formed into different shapes allows for more creativity in designs
- Fiberglass could be used to create a wind funnel to direct the wind through a passage
- •Different plastic pellets such as those on the right allow for wide range of colors

WIND POWER AND THE BUILT ENVIRONMENT MIDTERM PRESENTATION



POTENTIAL MATERIALS: WOOD COMPOSITES

WOOD PLASTIC COMPOSITES

- made up of up to 70% cellulose in plastic
- Able to be molded
- Can be colored to look like wood and have grain design
- Resistant to moisture and rot
- •Behave similarly to wood
- Not as rigid as wood and may warp in high temperatures
- Wood epoxy composites: wood laminated or coated with epoxy
- Good fatigue resistance
- Have been used in past in turbine blades, usage has decreased



WIND POWER AND THE BUILT ENVIRONMENT MIDTERM PRESENTATION

POTENTIAL MATERIALS: WOOD COMPOSITES cont'd

WOOD EPOXY COMPOSITES

- wood laminated or coated with epoxy
- Good fatigue resistance
- Have been used in past in turbine blades, usage has decreased



WIND POWER AND THE BUILT ENVIRONMENT

MIDTERM PRESENTATION

REMAINING PROCESS

- Test site models in wind tunnel
- Refine site and building designs
- Select appropriate turbines for designs
- Develop model for energy distribution and grid connection
- Calculate and analyze wind and energy data from site and buildings
- Develop wind design guidelines for future projects and sites

WIND POWER AND THE BUILT ENVIRONMENT MIDTERM PRESENTATION

URBAN WIND POWER:

CHICAGO CASE STUDY

IPRO -314 Spring 2007

GROUP 3 Cara Ellis, Brendan Hudson, Jae Min Lee, Rob Fleming, Tor Kyaagba, Michael Krauss

URBAN CRITERIA

ENERGY PRODUCTION SERVES A FUNCTION THAT DOES NOT REQUIRE CONVENTIONAL POWER BACK UP, AND CONTINUES TO FUNCTION AROUND SEASONAL/DIURNAL VARIATION.

INSTALLATION CLEARLY DEMONSTRATES HOW WIND POWER WORKS TO A LARGE PUBLIC AUDIENCE.

ENERGY PRODUCED SHOULD BE LINKED TO A POSITIVE FUNCTION THAT AMELIORATES THE URBAN ENVIRONMENT AND THEREFORE EXPRESSES THE ECOLOGICAL BENEFIT OF RENEWABLE ENERGY.

CONTEXT OF APPROACH

AN IMPORTANT SUSTAINABILITY ISSUE IN ADDITION TO THE NEED FOR CLEAN ENERGY IS THE NEED FOR CLEAN WATER.

THOUGH LAKE MICHIGAN IS CONSIDERED RELATIVELY CLEAN BODY OF WATER, THE NEAR SHORE WATER WITHIN AND AROUND THE MARINAS IS COMPROMISED BY URBAN DENSITY, LACK OF CIRCULATION, AND WATERCRAFT POLLUTION.

BURNHAM HARBOR & NORTHERLY ISLAND

PUMP MARINA AND STORM WATER FOR TREATMENT THROUGH A WETLAND/ OXYGENATION SYSTEM ON NORTHERLY ISLAND MODEL FOR FUTURE DEVELOPMENT IN OTHER MARINAS ALONG THE LAKE

LANDSCAPING AND ARCHITECTURAL DESIGN AROUND WATER TREATMENT STRATEGIES TO MAXIMIZE PUBLIC INTERACTION

ENCOURAGE ECOLOGICAL DIVERSITY IN THE CITY AND ESTABLISH A RICH AND BEAUTIFUL BUFFER ZONE BETWEEN CITY AND LAKE







LAKEFRONT IS AN APPROPRIATE CHOICE OF SITE FOR WIND ENERGY

TURBINES ARE SCALED FOR THE URBAN ENVIRONMENT AND DESIGNED FOR CLOSE PUBLIC INTERACTION

THE AESTHETICS OF TURBINES AND THE WAY THEY ARE INSTALLED PROVIDE AN OPPORTUNITY FOR PUBLIC AWARENESS AND UNDERSTANDING OF RENEWABLE ENERGIES THAT CAN LEAD TO WIDESPREAD ACCEPTANCE



SITE ANALYSIS

WIND DATA FROM CRIBS

AVERAGE SPEED ~7MPH

Max Length of Wind below 5 mph ${\sim}7$ days Omnidirectional winds



WIND TURBINE

WINDSIDE

- · LOW CUT-IN SPED
- · NO CUT-OUT SPEED
- · BIRD FRIENDLY
- · LOW NOISE
- · URBAN AESTHETICS
- · OMNI DIRECTIONAL WIND



WIND POWER

	Shaft power production of wind turbines watts m/s					
	Starting of power production at m/s					
	4	3	2	2	2	2
Wind velocity m/s	Model WS-0,15 W	Model WS-0,30C W	Model WS-2 W	Model WS-4 W	Model WS-30 W	Model WS-75 W
3	1	2	10	20	150	375
4	2	4	20	40	300	750
5	3	7	35	70	527	1312
6	5	10	50	100	750	1875
7	7	15	75	150	1125	2812
8	10	21	105	210	1575	3937
9	15	30	150	300	2250	5625
10	20	40	200	400	3000	7500

WIND VARIABILITY

COMPENSATION FOR WIND VARIABILITY

STORAGE OF

ENERGY USING FLYWHEELS CAN COMPENSATE FOR WIND VARIABILITY AND PROVIDE ANDTHER OPPORTUNITY FOR DEMONSTRATIO Ν

APPLY EXCESS ENERGY TO CITY INFRASTRUCTUR E (I.E. LIGHTS)



PUMPING WATER

PUMPING WATER CAN BE ADJUSTED TO POWER GENERATION

APPROX. 1500W FOR 6000 GALLON OF WATER PER HOUR





URBAN WIND POWER:

CHICAGO CASE STUDY

GROUP 3

CARA ELLIS, BRENDAN HUDSON, JAE MIN LEE, ROB FLEMING, TOR KYAAGBA, MICHAEL KRAUSS

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SITE ANALYSIS

WIND DATA FROM

CRIBS

AVERAGE SPEED

~7мрн

MAX LENGTH OF

WIND BELOW 5

MPH \sim 7 days

OMNIDIRECTIONAL

WINDS



WIND TURBINE



WINDSIDE

- Low cut-in sped
- NO CUT-OUT SPEED
- BIRD FRIENDLY
- Low Noise
- URBAN AESTHETICS
- OMNI DIRECTIONAL WIND

Rated power	20A/12 V
Mast recommendation	wood
Cut-in wind speed	1,5 m/s
Rated wind speed	15 m/s
Cut-out wind speed	none
Swept area	4 m ²
Vane weight	40 kg
Total weight of turbine	700 kg
Rotor speed control	not required, electronic
Overspeed control	none required
Generator model	Windside
Generator construction	permanent magnet
Generator types	1-400 V/12,24,48 V
Gear box	without gear
Main brake system	electronic
Charging controller	Windside WGU-25/WGC-10
Measured sound emission	0 dB

WIND POWER

Shaft power production of wind turbines watts m/s

Starting of power production at m/s

	4	3	2	2	2	2
Wind	Model	Model	Model	Model	Model	Model
velocity	WS-0,15	WS-0,30C	WS-2	WS-4	WS-30	WS-75
m/s	W	W	W	W	W	W
3	1	2	10	20	150	375
4	2	4	20	40	300	750
5	3	7	35	70	527	1312
6	5	10	50	100	750	1875
7	7	15	75	150	1125	2812
8	10	21	105	210	1575	3937
9	15	30	150	300	2250	5625
10	20	40	200	400	3000	7500

WIND VARIABILITY

COMPENSATION FOR WIND VARIABILITY STORAGE OF ENERGY USING FLYWHEELS CAN COMPENSATE FOR WIND VARIABILITY AND **PROVIDE ANOTHER** OPPORTUNITY FOR DEMONSTRATION APPLY EXCESS ENERGY TO CITY INFRASTRUCTURE (I.E. LIGHTS)



PUMPING WATER

PUMPING WATER CAN BE ADJUSTED TO POWER GENERATION APPROX. 1500W FOR 6000 GALLON OF WATER PER HOUR



