**The Art of Wind**
**IIT IPRO 314**
**Architectural Integration Group**
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# Wind Power and the Built Environment

Integrating wind power generation capabilities in a mixed-income residential development in Chicago.

## Summary

This project is an examination of the potential of wind power generation to be integrated into the architectural forms that make up the city of Chicago. We approached this project at two scales:

- **At an urban planning level:** *What strategies can be applied to the design of the city to allow for maximum harvest of wind energy?*
- **At the level of individual buildings:** *What types of turbines are most appropriate to application to individual buildings and how can they be applied? How can architecture enhance their ability to generate power?*

We anchored our project around a set of specific proposals for a specific site: The Lake Park Crescent Development. Proposals for two building designs were tested in a wind tunnel to validate design decisions and evaluate energy generation capacity.

## Design Program & Requirements

### Design Goals

- **Maximize production of wind power through site orientation and building design**
- **Integrate aspect of wind power generation with aspect of appealing community appearance. In other words, develop designs with a sense of context**
- **Test design hypotheses with actual analytical data**
- **Develop models for sharing/disposition of generated energy**
- **Back up final design proposals with projected data sets**

### Elements of Program

- **Site:** Building placement & orientation, streets, parking areas. Consider access to transportation, community context, prevalent wind directions, relationship to park
- **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 sq ft of living space, mixture of market rate and affordable units*
  - 12 "Row Homes": *Single family homes, approximately 3000 sq ft each*
  - 24 "City Homes": *Mixture affordable and market, approx 2500 sq ft each*
  - 1 Tower: *70 units public and affordable housing (approximately 1000 sq ft each*

### Parameters

*The following elements served as constraints for the design:*

- **Borders of site as noted by Phase II of Draper & Kramer development**
- **Number of units/total square footage to be accommodated by design**
- **Design timeline = next 10 years (technology, materials, energy costs)**

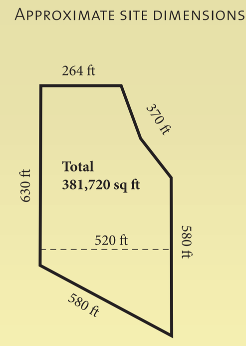
### Areas of Exploration/Definition

Areas the design team explored and defined during the course of the project:

- **Aesthetics:** Incorporation of neighborhood vernacular architecture vs. futurism/innovation
- **Building groupings:** Groupings of units were allowed to deviate from developer's plans to maximize wind.
- **Budget:** Budget of construction costs was not be factored into designs.

Developer's plans for Phase I of Lake Park crescent. Our program was modeled on a similar breakdown of unit totals and square footage.


Approximate site dimensions

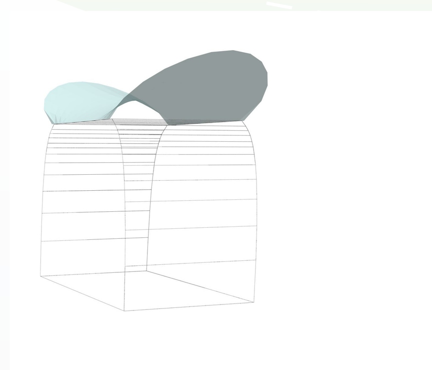



## Building Designs

The scale of the residential buildings on the site was defined according to each building program. Row homes, single-family homes and eight flats were treated as one building type and the two mid-rise towers were treated as a separate building type. An important aspect of design development was to maintain a stylistic and functional relationship between these two building types.

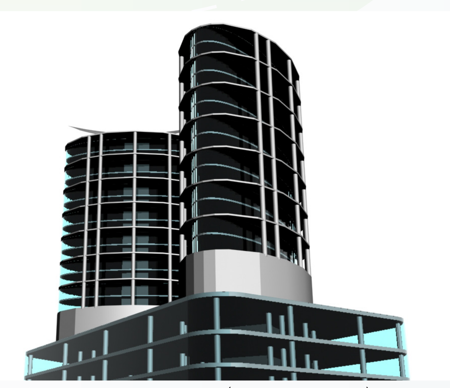
Initial sketches were refined to two typologies to be tested: a funnel system combined with horizontal axis turbines applied to a four story building and an array of turbines applied around the floor plates of a tower.

### Eight Flat



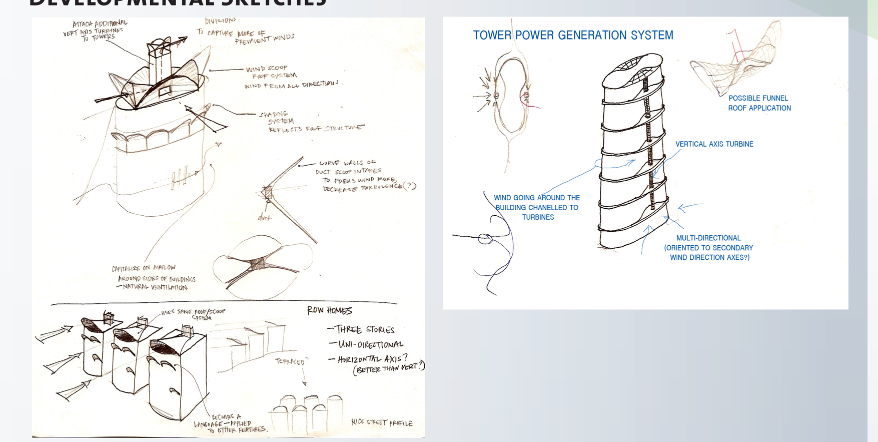
Four horizontal-axis turbines would be housed inside a funneling roof system to generate power

### Tower

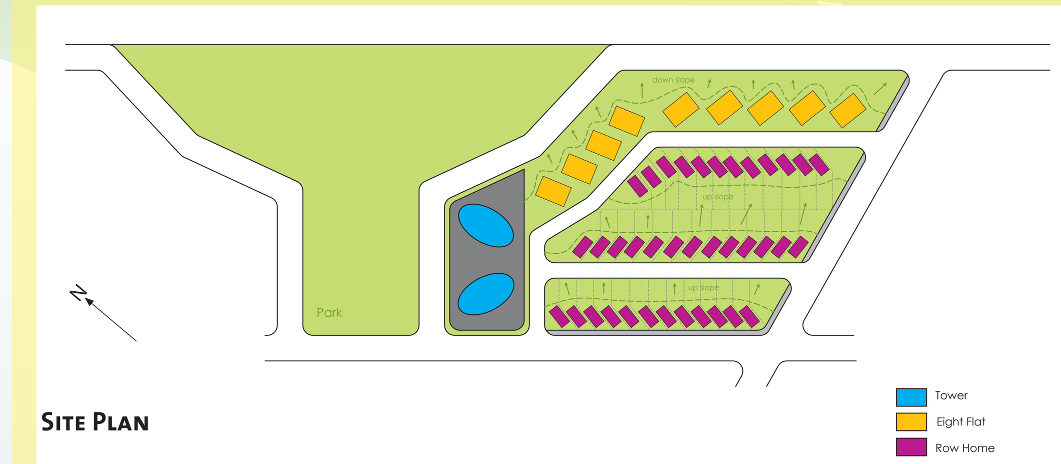


An array of vertical axis (omnidirectional) turbines would be spaced along outcropping floor plates to generate power

### Developmental Sketches

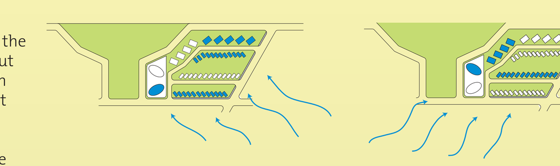



## Site Plans



Site Plan

We utilized a terraced grading system on the site to place the buildings at increasing elevations so that the wind turbines on the roofs would be able to catch wind from different heights without interfering with one another. The site slopes upward from south to north as well as upward from west to east. The two towers sit atop a single base, the south wall of which acts as a retaining wall to support the newly elevated earth. The plan also utilizes multiple building orientations. This enables some portion of the site to remain active, no matter which direction the wind is coming from at the time. The terraced approach also increases building façade exposure to sunlight that allows greater opportunities for photovoltaic applications on the façades.



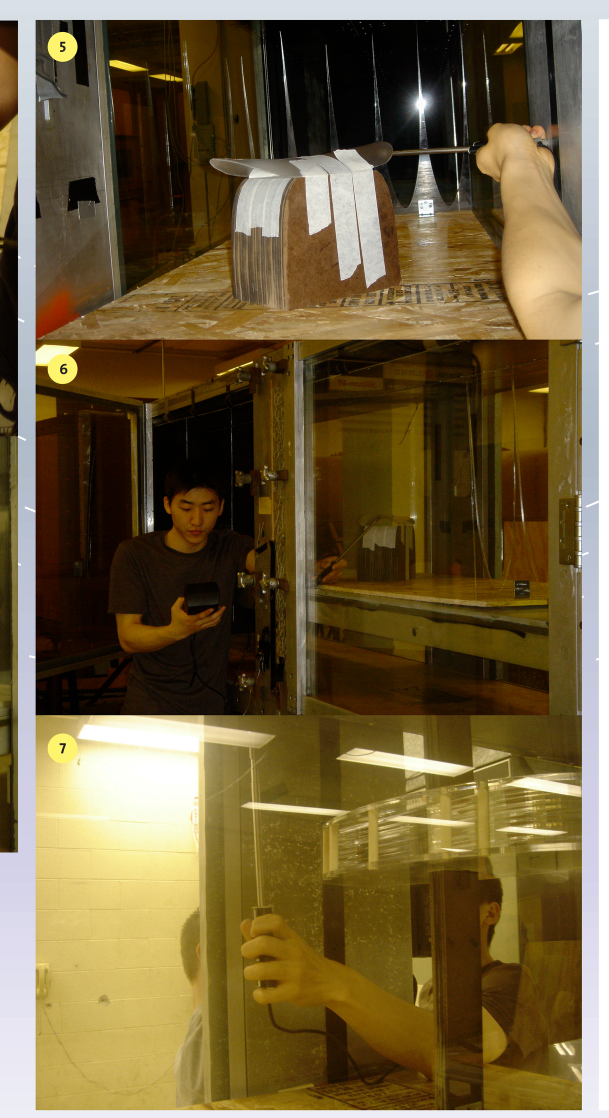
All buildings are oriented on site to take advantage of multiple wind directions

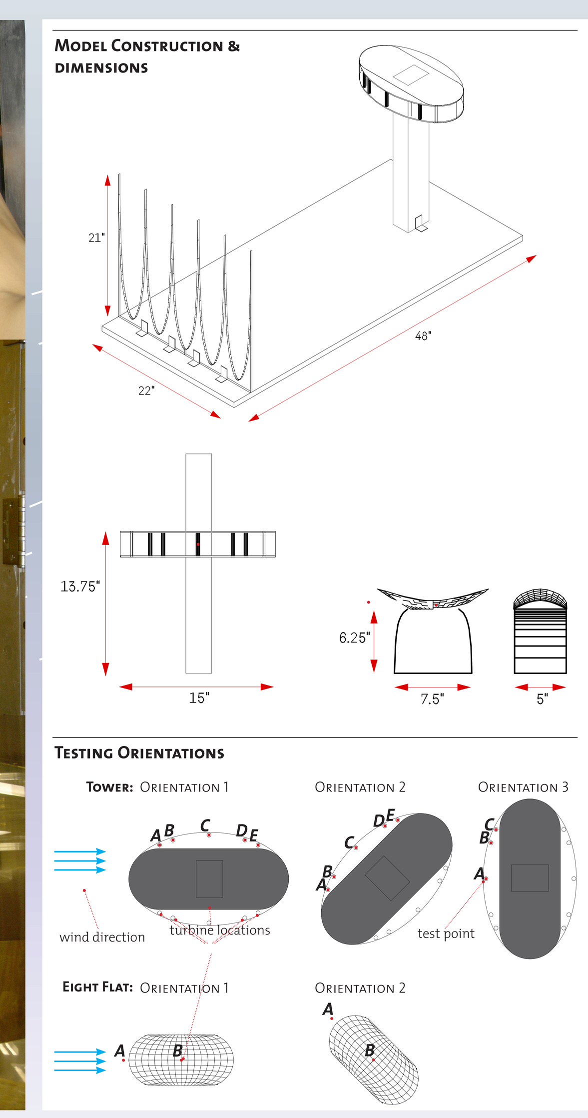
## Wind Tunnel Testing

### Testing Set-up and Equipment

1. High speed wind tunnel test section
2. Hot wire probe used to determine wind velocity at test point locations
3. Wind tunnel calibrated to simulate winds at 3 meters per second and 10 meters per second
4. Profile curves attached to test model simulate the effects of the boundary layer: wind velocity increases with height
5. Eight flat test model at orientation 2
6. Taking readings of eight flat at orientation 2
7. Calibrating wind tunnel for tower testing at orientation 3

### Test Models and Orientations



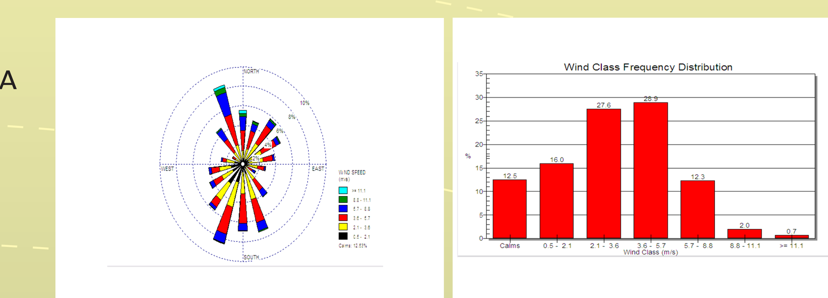



## Wind Data

The wind data from the Offshore Chicago, northern part of Chicago (Waukegan Harbor), and southern part of Chicago (Calumet) was analyzed. The selection of these sample sites from such a wide area is to obtain a better picture of how the wind actually behaves in Chicago. This data was used to plot Wind Rose Diagrams, which were created using a program called WRPlot. This program is specifically designed to plot the Wind Roses and the Wind Class Frequency Distribution Graphs, and it is also capable of performing frequency counts.

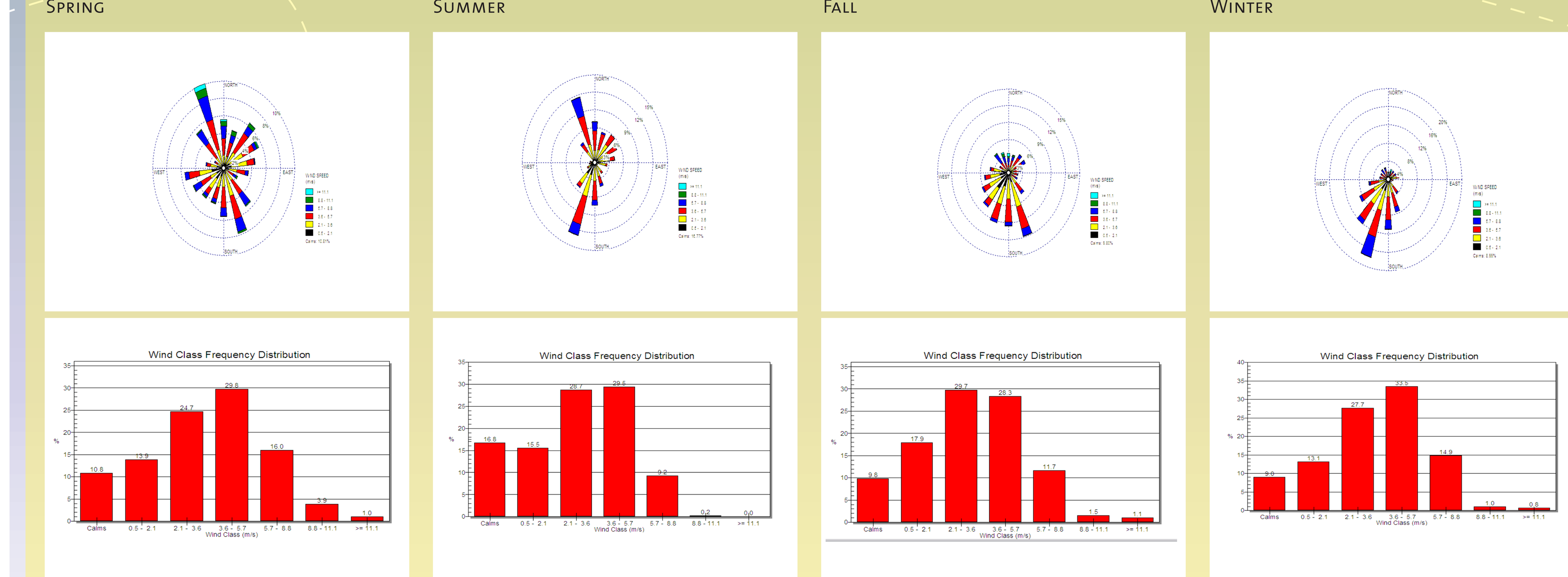
The Calumet data was most complete and reliable and therefore became the basis for the wind activity calculations for our site.

### Combined Annual Data
Calumet
2006




### Seasonal Data
Calumet
2006

Spring — Summer — Fall — Winter




## Site Context

The selected site is part of the Lake Park Crescent development. The development is bordered on the North by E. 40th Street, on the south by E. 42nd Place, on the West by Lake Park Avenue, and on the East by the Metra Tracks. Within this development the project site consists of the area designated for Phase 2 development on the Southern portion of the site.

Benefits to selecting this site:

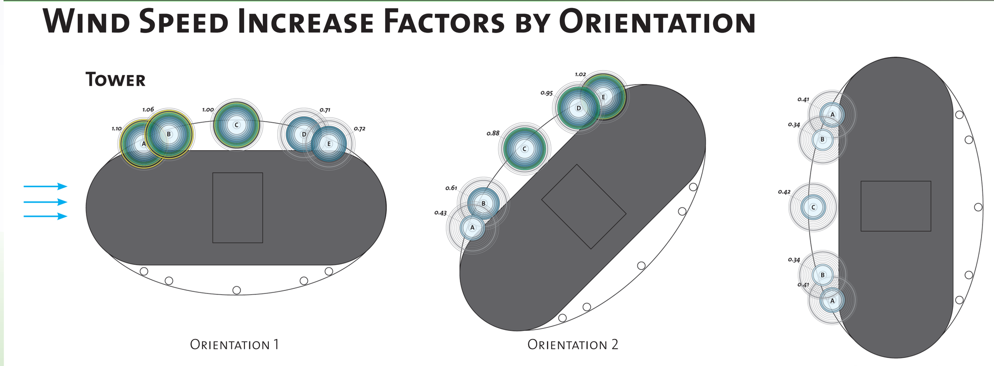
- **The site exemplifies prominent Chicago characteristics**
- **The site is supported by long-term investors**
- **The site has access to wind**


1. Site in Context
2-3. Developer renderings of Phase 1 Lake Park Crescent development and planned lakefront park.
3-7. Current conditions and buildings in Phase 1 development.

## Results

### Wind Speed Increase Factors by Orientation

Tower

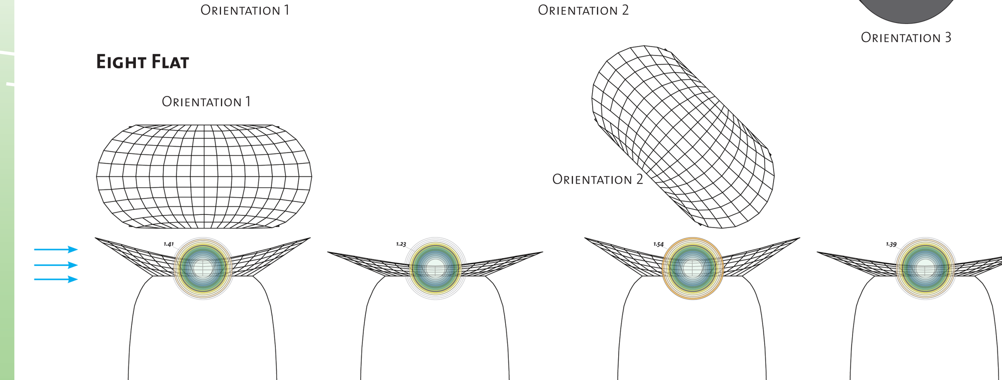



Wind Speed Increase Factor was determined by calculating the ratio of the wind velocity at the control point with the velocity at the turbine location.

The tower clearly demonstrates maximum efficiency when oriented with the long axis parallel to the wind direction.

An unexpected result is the increase factor of the rear turbines in the angled orientation.

Eight Flat




The application of a funnel has a clear impact on wind velocity, roughly proportional to the ratio of the cross section at entrance to the cross section at the narrowest point, where the turbine would be housed.

### Energy Production Capacity

To calculate energy production, optimum building orientations were cross referenced to wind roses by season to determine frequency of wind directions in various building orientations. The corresponding wind increase factors were applied to determine average power output per building per season.

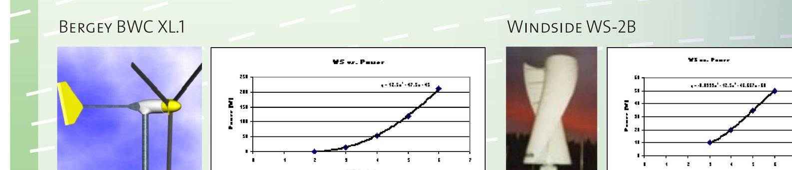
| | Number of Turbines | Type | x Output per turbine | = Annual output per building |
|---|---|---|---|---|
| Eight Flat | 4 | Horiz. | 454.01 KWH | 1816.04 KWH |
| Row Homes & City Homes | 1 | Horiz. | 454.01 KWH | 454.01 KWH |
| Tower | 170 | Vert. | *adjusted for orientation and season | 17470.475 KWH |

Site is designed to accommodate 2 towers, 10 eight flats, 24 City Homes and 12 Row Homes:

| Total for eight flats + | Total for RH & CH + | Total for Towers = | **GRAND TOTAL FOR SITE** |
|---|---|---|---|
| 18160.40 | 16344.36 | 34940.45 | **69445.71 KWH** |

#### Selected Turbines

Bergey BWC XL.1 — Windside WS-2B




## Conclusions

**Building forms can indeed increase the velocity of the wind and thereby improve the effectiveness of turbines** integrated into the architecture. The wind tunnel tests confirmed that the roof funnel forms were able to increase the velocity of the wind **by a factor greater than 1.5**. And the testing of the tower model illustrated just how much or little a building mass can negatively impact the effectiveness of wind turbines.

**We were able to take conceptual ideas and refine them using qualitative analysis through discussion and research, then test those designs in a controlled environment in order to calculate quantitative results.**

**Future classes will have the opportunity to build upon this** to consider in greater depth the intricate relationship between efficiency of design through additional testing and expressive design through greater analysis of the the social and political aspects of this site.