# IPRO 323 Spring 2002

**Sponsor:** Skidmore Owings & Merrill LLP  
Dr. Mahjoub Elnimeiri, Raymond Clark, Peter Ellis

<table>
<thead>
<tr>
<th>Team 1: Office Zone</th>
<th>Team 2: Residential Zone</th>
<th>Team 3: Residential Zone</th>
<th>Team 4: Office Zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAHAR ABBASZADEH FARD</td>
<td>EMERALD CRUZ</td>
<td>ALLAN CHUNG</td>
<td>CHING CHAN</td>
</tr>
<tr>
<td>MAGDY IBRAHIM</td>
<td>RUSSELL KELLY</td>
<td>ALICJA MORZYC</td>
<td>MEGHAN PECAUT</td>
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<tr>
<td>SANG MIN PARK</td>
<td>KELBY PHILLIPS</td>
<td>KATHERINE PANNEK</td>
<td>LINDSEY PHILLIPS</td>
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<tr>
<td>GORAN VESELINOVIC</td>
<td>ERIKA LAU</td>
<td>RAFAL TROJNIAK</td>
<td>SHANE STALEY</td>
</tr>
<tr>
<td>MICHAEL GEROUlis</td>
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### Climatic Data and Related Building Design Considerations

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>°Latitude</td>
<td>41°</td>
</tr>
<tr>
<td>Shading Needed – Period</td>
<td>June – August</td>
</tr>
<tr>
<td>Shadow Angles – South Side</td>
<td>65°</td>
</tr>
<tr>
<td>Prevailing Winds – Winter</td>
<td>SW – 12.0 MPH</td>
</tr>
<tr>
<td>Prevailing Winds – Summer</td>
<td>NE – 10.0 MPH</td>
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</table>
CHICAGO:
Climatic Data and Related Building Design Considerations

AVERAGE DAILY SOLAR RADIATION

kWh/m²/day
- 10 to 14
- 8 to 10
- 7 to 8
- 6 to 7
- 5 to 6
- 4 to 5
- 3 to 4
- 2 to 3
- 0 to 2
- none

DECEMBER
CHICAGO: Climatic Data and Related Building Design Considerations

AVERAGE DAILY SOLAR RADIATION

JUNE

kWh/m²/day

- 10 to 14
- 8 to 10
- 7 to 8
- 6 to 7
- 5 to 6
- 4 to 5
- 3 to 4
- 2 to 3
- 0 to 2
- none
Basic Area of Concern

Trump Tower Project, Chicago, IL

- Residential
- Residential
- Offices
- Offices

Zone 1
Task Group #1

Zone 2
Task Group #4

Zone 3
Task Group #2

Zone 4
Task Group #3
Group 1 Proposals

Solar Chimney

Modular window-wall systems with PV

Sky Garden
First Concept: SOLAR CHIMNEY
First Concept: **SOLAR CHIMNEY**

**Location:** South-East impractical acute-angled corner.

This chimney will funnel air from ground level through a wind turbine located at the very top.

**Materials:** Includes a steel structure, supported from floor slabs at each level, and a glass or plastic tube-like chimney.
At the base of this construction would be a giant umbrella-type structure:

i) scoop fresh air up into the chimney

ii) to shield a plaza located at the southwest corner of the building

At the top, a turbine would be installed, to convert this wind into a form of energy.

Some sort of shielding device would have to be constructed here as well, to protect the turbine from particles and debris.
Second Concept: Modular window-wall systems with PV
Second Concept: Modular window-wall systems with PV

The panel is designed as a one modular piece with everything installed: the blinds have the PV on the outer surface before the inner skin which consists of double low-E clear glass.

The chamber between two skins insures that PV cells do not get hot by means of natural ventilation.
Second Concept: Modular window-wall systems with PV
Questions and Concerns

- How do we ventilate the Panels?
- How do we clean the interior of the module?
- What is the best angle of the blinds?
- How do the modules connect with each other?
- How do the blinds work?
Second Concept: Modular window-wall systems with PV

- Vents to allow air escape from inside of the panel:
  - 0' - 6"

- Vents to allow air intake into the panel:
  - 5' - 0"

- Photovoltaic cells mounted on the glass:
  - 5' - 0"
Second Concept: **Modular window-wall systems with PV**

Detail showing the double skin window module
Second Concept: **Modular window-wall systems with PV**

Window-wall system incorporating PV modules
Two general possibilities for installing photovoltaic cells in high-rise building are building facades and roof. In this project, the sky garden with PV roof is another possibility as an architectural element of the building or the system.

- Rest and refugee area with green.
- Dynamic overall shape.
Third Concept: **Sky Garden**
### Total Energy Consumption

Using E-Quest for calculating Electric Consumption (kWh x000)

<table>
<thead>
<tr>
<th></th>
<th>Zone 1</th>
<th>Zone 2</th>
<th>Zone 3</th>
<th>Zone 4</th>
<th>Total</th>
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<tbody>
<tr>
<td>Space Cool</td>
<td>1,083.20</td>
<td>785.80</td>
<td>668.10</td>
<td>1,800.00</td>
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<td>Heat Reject.</td>
<td>28.00</td>
<td>20.50</td>
<td>17.50</td>
<td>-</td>
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<tr>
<td>Refrigeration</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Space Heat</td>
<td>674.30</td>
<td>519.50</td>
<td>489.40</td>
<td>1,050.00</td>
<td>2,733.20</td>
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<tr>
<td>HP Supp.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>810.00</td>
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<tr>
<td>Hot Water</td>
<td>277.20</td>
<td>198.60</td>
<td>165.70</td>
<td>620.00</td>
<td>1,261.50</td>
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<tr>
<td>Vent. Fans</td>
<td>581.00</td>
<td>422.00</td>
<td>360.00</td>
<td>750.00</td>
<td>2,113.00</td>
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<tr>
<td>Pumps &amp; Aux.</td>
<td>457.50</td>
<td>330.30</td>
<td>277.90</td>
<td>-</td>
<td>1,065.70</td>
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<tr>
<td>Ext. Usage</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Misc. Equip.</td>
<td>2,670.30</td>
<td>1,916.90</td>
<td>1,597.90</td>
<td>1,920.00</td>
<td>8,105.10</td>
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<tr>
<td>Task Lights</td>
<td>235.20</td>
<td>168.50</td>
<td>140.60</td>
<td>-</td>
<td>544.30</td>
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<tr>
<td>Area Lights</td>
<td>1,471.30</td>
<td>1,025.70</td>
<td>818.90</td>
<td>2,480.00</td>
<td>5,795.90</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>7,478.00</strong></td>
<td><strong>5,387.90</strong></td>
<td><strong>4,535.90</strong></td>
<td><strong>9,430.00</strong></td>
<td><strong>26,831.80</strong></td>
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</tbody>
</table>
Annual Energy Consumption by End-use.

- **Misc. Equip.** 31%
- **Area Lights** 22%
- **Task Lights** 2%
- **Space Cool** 17%
- **Space Heat** 11%
- **Hot Water** 5%
- **Vent. Fans** 8%
- **Pumps & Aux.** 4%
Number of PV Panels

Zone 0 (Health Center) | Zone 1 (Office) | Zone 2 (Office) | Zone 3 (Office) | Zone 4 (Residential)
---|---|---|---|---
East | South | West
180 | 360 | 468 | 504 | 1,116
325 | 650 | 689 | 574 | 899
200 | 360 | 468 | 504 | 1,116
400 | 360 | 468 | 504 | 1,116
600 | 689 | 574 | 504 | 1,116
800 | 650 | 689 | 574 | 899
1,000 | 360 | 468 | 504 | 1,116
1,200 | 360 | 468 | 504 | 1,116
## Energy Saving Calculation for the proposed scheme

### Calculation of Savings for the Designed module & Sky Garden

**IPRO 323 - Spring 2002**

**Task Group I**

**Façade**

<table>
<thead>
<tr>
<th>Zone</th>
<th>Number of modules</th>
<th>East</th>
<th>South</th>
<th>West</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Zone 0</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Health Center</td>
<td>5 floors @ 16' fl2fl</td>
<td>36</td>
<td>65</td>
<td>36</td>
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<tr>
<td>Area of PV at 41' (Blind area)</td>
<td>46.2</td>
<td>83.16</td>
<td>10015</td>
<td>83.16</td>
</tr>
<tr>
<td>Area of PV at 90' (Spandrel area)</td>
<td>18.1</td>
<td>33.66</td>
<td>6077.5</td>
<td>33.66</td>
</tr>
<tr>
<td><strong>Zone 1</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Office</td>
<td>10 floors @ 13' fl2fl</td>
<td>36</td>
<td>65</td>
<td>36</td>
</tr>
<tr>
<td>Area of PV at 41' (Blind area)</td>
<td>33.2</td>
<td>11952</td>
<td>21580</td>
<td>11952</td>
</tr>
<tr>
<td>Area of PV at 90' (Spandrel area)</td>
<td>18.7</td>
<td>6732</td>
<td>12150</td>
<td>6732</td>
</tr>
<tr>
<td><strong>Zone 2</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Office</td>
<td>13 floors @ 13' fl2fl</td>
<td>36</td>
<td>53</td>
<td>36</td>
</tr>
<tr>
<td>Area of PV at 41' (Blind area)</td>
<td>33.2</td>
<td>15537.6</td>
<td>21584.8</td>
<td>15537.6</td>
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<tr>
<td>Area of PV at 90' (Spandrel area)</td>
<td>18.7</td>
<td>6751.6</td>
<td>12843.3</td>
<td>6751.6</td>
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<tr>
<td><strong>Zone 3</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Office</td>
<td>14 floors @ 13' fl2fl</td>
<td>36</td>
<td>47</td>
<td>36</td>
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<tr>
<td>Area of PV at 41' (Blind area)</td>
<td>33.2</td>
<td>10732.8</td>
<td>19056.8</td>
<td>10732.8</td>
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<tr>
<td>Area of PV at 90' (Spandrel area)</td>
<td>18.7</td>
<td>3424.8</td>
<td>10733.9</td>
<td>3424.8</td>
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<tr>
<td><strong>Zone 4</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Health Center</td>
<td>31 floors @ 11' fl2fl</td>
<td>36</td>
<td>29</td>
<td>36</td>
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<tr>
<td>Area of PV at 41' (Blind area)</td>
<td>24.5</td>
<td>27542</td>
<td>22025.5</td>
<td>27342</td>
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<tr>
<td>Area of PV at 90' (Spandrel area)</td>
<td>18.7</td>
<td>20869.2</td>
<td>16811.3</td>
<td>20869.2</td>
</tr>
</tbody>
</table>

**Total Area of PV at 41'**

- East: 100% 79880.4
- South: 100% 100552
- West: 100% 79880

**Total Area of PV at 90'**

- East: 70% 49144
- South: 70% 58661.9
- West: 70% 49144

**Total PV Area with tilt factor**

- 114281 sqft
- 141615 sqft
- 114281 sqft

**Total PV Area with tilt & orientation factor on the façade**

- 316751 sqft

**Sky Gardens**

<table>
<thead>
<tr>
<th>Roof 1</th>
<th>Area at 45' (80%)</th>
<th>7204</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area at 30' (-100%)</td>
<td>80%</td>
<td>5761.2</td>
</tr>
<tr>
<td>The ratio of PV to vision glass</td>
<td>70%</td>
<td>10274.2</td>
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</table>

<table>
<thead>
<tr>
<th>Roof 2</th>
<th>Area at 45' (80%)</th>
<th>7204</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area at 30' (-100%)</td>
<td>80%</td>
<td>5761.2</td>
</tr>
<tr>
<td>The ratio of PV to vision glass</td>
<td>70%</td>
<td>10274.2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Roof 3</th>
<th>Area at 45' (80%)</th>
<th>7204</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area at 30' (-100%)</td>
<td>80%</td>
<td>5761.2</td>
</tr>
<tr>
<td>The ratio of PV to vision glass</td>
<td>70%</td>
<td>10274.2</td>
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</table>

**Rooftop**

<table>
<thead>
<tr>
<th>Area at 30' (80%)</th>
<th>12139</th>
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</thead>
<tbody>
<tr>
<td>Area at 30% (-100%)</td>
<td>90%</td>
</tr>
<tr>
<td>The ratio of PV to vision glass</td>
<td>100%</td>
</tr>
</tbody>
</table>

**Total PV Area with Orientation factor & Tilt factor on the roofgardens**

- 44030.92 sqft

**Total PV- Crystalline Area on façade & roof gardens**

- 44031 sqft + 310838.2 sqft = 362781.8 sqft

**Net output of Crystalline Panels at 100% (41') = 15 kWh/sqft/yr**

- Reduction Factor = 90% 90%
- Shading Factor = 95% 95%

**Total output**

- 4652676 kWh/yr

**Annual Energy Consumption from EQuest**

- 26831800 kWh/yr

**Percentage of Energy savings per year**

- 17.34%
Group 2 Proposals

Double window-wall with PV

Wind Turbines
First Concept: DOUBLE WINDOW-WALL WITH PV

Plan view of the curtain wall

Elevation

Section
First Concept:

DOUBLE WINDOW-WALL WITH PV

Detail of the Enclosure System
Second Concept: WIND TURBINES

Elevation of the tower with incorporation of wind turbines located on various mechanical floors.
Second Concept: **WIND TURBINIES**

Detailed Elevation
Second Concept: **WIND TURBINES**

Location of wind turbines in plan
## Second Concept: WIND TURBINES

<table>
<thead>
<tr>
<th>Level</th>
<th>Height</th>
<th>Wind Speed</th>
<th>Power/ Turbine Area</th>
<th>Turbine Area</th>
<th>Total Power</th>
<th>Façade Area lost</th>
<th>Power/ Façade Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof</td>
<td>330 m</td>
<td>27 m/s</td>
<td>2,362 W/m²</td>
<td>42 m²</td>
<td>99,204 Watts</td>
<td>None</td>
<td>N/A</td>
</tr>
<tr>
<td>3</td>
<td>201 m</td>
<td>16 m/s</td>
<td>492 W/m²</td>
<td>63 m²</td>
<td>30,996 Watts</td>
<td>1,525 m²</td>
<td>20.3 W/m²</td>
</tr>
<tr>
<td>2</td>
<td>137 m</td>
<td>11 m/s</td>
<td>160 W/m²</td>
<td>63 m²</td>
<td>10,080 Watts</td>
<td>1,870 m²</td>
<td>5.4 W/m²</td>
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<tr>
<td>1</td>
<td>78 m</td>
<td>6 m/s</td>
<td>26 W/m²</td>
<td>84 m²</td>
<td>2,184 Watts</td>
<td>2,175 m²</td>
<td>1.0 W/m²</td>
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Group 3 Proposals

(South Side)

Curtain wall system

(West Side)
First Concept: **Parabolic Trough Collectors**

Flat Panel vs. Concentrators

Parabolic Trough Concentrators are the simplest parabolic concentrating systems.
Second Concept: **Sun Motor Tracking System**

One-axis vs. Two-axis Tracking systems.
This is how a sensored panel works.
## Station Identification

<table>
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<tr>
<th>City</th>
<th>Chicago</th>
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<tbody>
<tr>
<td>State:</td>
<td>IL</td>
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<tr>
<td>Latitude:</td>
<td>41.78 ° N</td>
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<tr>
<td>Longitude:</td>
<td>87.75 ° W</td>
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<tr>
<td>Elevation:</td>
<td>190 m</td>
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## PV System Specifications

<table>
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<th>AC Rating:</th>
<th>4.0 kW</th>
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<tr>
<td>Array Type:</td>
<td>1-Axis Tracking</td>
</tr>
<tr>
<td>Array Tilt:</td>
<td>41.8 °</td>
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<tr>
<td>Array Azimuth:</td>
<td>180.0 °</td>
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<tr>
<td>Cost of Electricity:</td>
<td>8.0 ¢/kWh</td>
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## Energy Production

<table>
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<tr>
<th>Month</th>
<th>Energy (kWh)</th>
<th>Energy Value ($)</th>
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<tr>
<td>1</td>
<td>440</td>
<td>35.20</td>
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<td>2</td>
<td>494</td>
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<td>3</td>
<td>642</td>
<td>51.36</td>
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<td>4</td>
<td>751</td>
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<td>5</td>
<td>861</td>
<td>68.88</td>
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<td>6</td>
<td>847</td>
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<td>12</td>
<td>312</td>
<td>24.96</td>
</tr>
<tr>
<td>Year</td>
<td>7625</td>
<td>610.00</td>
</tr>
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</table>
Design: Curtain Wall

-A flat panel system will be used over a concentrator. The concentrator is an efficient way of gathering sun, but due to overheating and an expensive cooling and tracking system, it is not economical.

-To protect the PV panels from the strong turbulence of Chicago winds, a double wall façade is used. The panels still remain effective and will be able to operate longer due to less stress being placed on the fragile panels. In addition, vents in the wall will allow for natural cooling and the use of the double wall gives residents access to a balcony year round.

-A tracking system will be used to make efficient use of the panels. The panels will be able to track the sun’s path through the sky during the solar window.

-As a result an effective design is created that allows the building to function with the use of PV panels.
South Side Curtain Wall
West Side Curtain Wall
Group 4 Proposals

Corners with Prefabricated Units

Prefabricated Units Applied to Facade
First Concept: **Corners with Prefabricated Units**

Utilizing South facade for maximum sun and wind power
First Concept: **Corners with Prefabricated Units**

PV & Turbine Unit
First Concept: **Corners with Prefabricated Units**

- Top floors (Residential)
- Middle floors (Office)
- Bottom floors (Office)

Floor Plans with Turbine Location
First Concept: **Corners with Prefabricated Units**

- **Proposed Form**
- **Proposed Lighting Scheme**
Second Concept: **Prefabricated Units Applied to Facade**

Units attached to slab, generator in spandrel
Second Concept: Prefabricated Units Applied to Facade

Wind direction
Prefabricated units allow for ease of installation, as well as maintenance.

Shaping the building can control and increase the energy produced by wind as well as create dynamic interior spaces.

During the day, the PV panels visually mark where the energy is being produced.

Using the units to power exterior lighting is a visual portrayal that the building is utilizing renewable energy and changing in response to fluctuating environmental conditions.

Conclusion