KUWAIT NEIGHBORHOOD PROPOSAL

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4.433 Urban Energy Modeling
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Team Introduction

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B.S. Biology and Environmental Studies | Bowdoin College
Guiding Principles

1. Minimize Energy Intensity
   *Focus on reducing the energy consumption per floor area*

2. Create Comfortable, Healthy Spaces
   *Improving access to daylight and outdoor thermal comfort*

3. Improve Resource-efficiency
   *Decrease water consumption*
**Methodology**

Completed several studies to determine the relationship between several variables and EUI and average daylight autonomy.

<table>
<thead>
<tr>
<th>Parametric Studies</th>
<th>Energy Supply</th>
<th>Thermal Comfort Analyses</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. WWR</td>
<td>1. Single cycle natural gas turbine</td>
<td>• Conducted initial evaluation of outdoor thermal comfort</td>
</tr>
<tr>
<td>2. Dimming</td>
<td>2. Combined Cycle Gas Turbine with a Secondary Steam Turbine</td>
<td>• Attempted to model photovoltaic panels and trees for use as shading materials</td>
</tr>
<tr>
<td>3. Building Height</td>
<td>3. Combined Cooling, Heat, and Power Plant with a natural gas turbine</td>
<td>• Lack of time allowed full investigation</td>
</tr>
<tr>
<td>4. Building Spacing</td>
<td></td>
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<tr>
<td>5. Internal Mass</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Infiltration Rate</td>
<td></td>
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<tr>
<td>7. Cooling CoP</td>
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</tbody>
</table>
NEIGHBORHOOD DEVELOPMENT
PROTOBLOCK GRID
STREET GRID
OFFICE SPACES
WALKING PATHS
RETAIL SPACES
OFFICE + RETAIL STACK
APARTMENT BLOCKS
INDEPENDENT VILLAS
RECLAIM GREEN
SOLAR FARM
NEIGHBORHOOD DENSITY

High Density: Mixed Use

Low Density: Singular Use
PROPOSED NEIGHBORHOOD
INSIDE THE CANYONS
INSIDE THE CANYONS
Kuwait City

- Land area (m²): 188,178
- Building area (m²): 312,536
- Residents (pp/m² land): 0.032
- Workers (pp/m² land): 0.056

**OPERATION ENERGY**
- 141 kWh/m²y

**EMBODIED ENERGY (50y)**
- 2,100 kWh/m²

**BUILDING GHG EMISSIONS (50y)**
- 8,500 kgCO₂/m²

**DAYLIGHT AREA**
- 72 % DA

**WALKABILITY SCORE**
- 74 % WS

**FINANCIAL RETURN (1y)**
- 16 % ROI
Energy Usage Color Map
Energy Consumption Details

ENERGY USE BY TYPE

Cooling, 31%
Hot Water, 9%
Equipment, 30%
Lighting, 29%

11 MW Peak Demand

Peak Demand by Type

- Cooling: 4,716 kW
- Hot Water: 1,813 kW
- Equipment: 2,508 kW
- Heating: 318 kW
- Lighting: 3,470 kW
## Energy Supply Strategies

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<tr>
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<tbody>
<tr>
<td>NG Input Therms</td>
<td>5.3M</td>
<td>2.9M</td>
<td>3.0M</td>
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<tr>
<td>Fuel Cost</td>
<td>$9.0M</td>
<td>$4.9M</td>
<td>$5.1M</td>
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<tr>
<td>CO2 Metric Tons</td>
<td>28.1k</td>
<td>15.3k</td>
<td>15.9k</td>
</tr>
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</table>
Combined Cycle and CCHP plants’ predicted energy consumption are ~45% of a standard, single cycle natural gas turbine plant.
72% Daylight Autonomy

Primary drivers of high access to daylight were (1) large 80% WWRs and (2) use of short residential villas.
Next Steps

1. Include financial analysis of power plant options

2. Determine feasibility of using a Rankine power cycle in Kuwait

3. Combine photovoltaic potential analysis with the previously shown power plant models

4. Apply power plant models to larger areas
URBAN RULE | PERFORMATIVE

DESIGN SIDE: Maximum EUI

- RETAIL: 175 kWh / sq.m.
- OFFICE: 75 kWh / sq.m.
- RESIDENTIAL: 115 kWh / sq.m.

OCCUPANT SIDE: pricing

- Building owners pay 4 fils (0.01 USD) per kWh for all energy consumed under the threshold.
- Building owners pay 60 fils (0.15 USD) per kWh for all energy consumed above the threshold.

icons by: Dennis Nicolai Andersen, Ralf Schmitzer, chiccabubble
<table>
<thead>
<tr>
<th>URBAN RULE</th>
<th>PRESCRIPTIVE</th>
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<tbody>
<tr>
<td><strong>MINIMUM COOLING CoP</strong></td>
<td><strong>DIMMING REQUIREMENTS</strong></td>
</tr>
<tr>
<td>RETAIL</td>
<td>6</td>
</tr>
<tr>
<td>OFFICE</td>
<td>6</td>
</tr>
<tr>
<td>RESIDENTIAL</td>
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</table>

Icons by: Dennis Nicolai Andersen, Ralf Schmitzer, chicabubble
PARAMETRIC ANALYSES | cooling CoP

EUI as a Function of Cooling CoP
### PARAMETRIC ANALYSES | Cooling CoP percent change in EUI

#### Residential

<table>
<thead>
<tr>
<th></th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
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</thead>
<tbody>
<tr>
<td>Cooling COP</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
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<tr>
<td>EUI</td>
<td>125</td>
<td>115</td>
<td>109</td>
<td>105</td>
<td>102</td>
<td>100</td>
<td>98</td>
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<tr>
<td>% Change</td>
<td>-8.0%</td>
<td>-5.2%</td>
<td>-3.7%</td>
<td>-2.9%</td>
<td>-2.0%</td>
<td>-2.0%</td>
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</table>

#### Office

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<th>7</th>
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<tbody>
<tr>
<td>Cooling COP</td>
<td>3</td>
<td>4</td>
<td>5</td>
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<td>7</td>
<td>8</td>
<td>9</td>
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<tr>
<td>EUI</td>
<td>78</td>
<td>72</td>
<td>69</td>
<td>66</td>
<td>64</td>
<td>63</td>
<td>62</td>
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<tr>
<td>% Change</td>
<td>-7.7%</td>
<td>-4.2%</td>
<td>-4.3%</td>
<td>-3.0%</td>
<td>-1.6%</td>
<td>-1.6%</td>
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</table>

#### Retail

<table>
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<tr>
<th></th>
<th>3</th>
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<th>7</th>
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<tbody>
<tr>
<td>Cooling COP</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
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<tr>
<td>EUI</td>
<td>199</td>
<td>178</td>
<td>166</td>
<td>158</td>
<td>153</td>
<td>149</td>
<td>145</td>
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<tr>
<td>% Change</td>
<td>-10.6%</td>
<td>-6.7%</td>
<td>-4.8%</td>
<td>-3.2%</td>
<td>-2.6%</td>
<td>-2.7%</td>
<td></td>
</tr>
</tbody>
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Financial Results

**Inputs**
- Annual Rent Rates
  - Adjust the annual rent based on local market values.

- Daylighting (sDA) Premium
  - The added premium to rent rates based on building sDA values.

**Construction Costs**
- Residential
  - {0}
  - $598,051,419
- Office
  - {0}
  - $76,033,253
- Retail
  - {0}
  - $68,423,208

**Operational Expenses**
- Annual Maintenance Costs
  - (assumes 20% of rent revenue)
  - Residential: $30,878,659
  - Office: $26,575,530
  - Retail: $28,968,660

**Revenue from Rent**
- w/o Daylight Premium
  - Residential: $98,849,106
  - Office: $36,959,509
  - Retail: $39,915,724

- w/ Daylight Premium
  - Residential: $165,904,344
  - Office: $74,044,171
  - Retail: $50,939,881

**Results**
- Cash Flow from Operations (CFO)
  - [Revenue - (Maintenance + Energy Costs)]
  - Also known as the Net Operating Income (NOI)
  - Residential: $116,924,171
  - Office: $50,939,881
  - Retail: $50,939,881

- CFO/Construction Cost (i.e. investment yield)
  - Most developers would aim to build new to a ratio (i.e. yield) of about 10%.
  - Residential: 15.75%
  - Office: 27.65%
Embodied Energy Falsecolor
Energy Parametric Studies

Approach: We used the simplified blocks below to determine the impact of 6 different parameters on EUI.

Tested Parameters

1. **WWR** Higher WWRs increased EUI
2. **Dimming** decreased EUI
3. **Internal Mass** had no impact
4. **Infiltration** Higher rates increased EUI
5. **Building Height** Taller buildings decreased EUI
6. **Building Spacing** Greater distance between buildings decreased EUI
Daylight Parametric Studies

Average sDA as a Function of EUI for Various FARs

- High FAR
- Base FAR
- Low FAR

EUI, kWh/square meter

Average sDA

D01 Dimmed
Average sDA as a Function of EUI for Various WWrs

- 20% at EUI 168
- 40% at EUI 174
- 60% at EUI 180
- 80% at EUI 188
Reference Block

Our proposed reference block consisted of two residential towers with three floors of retail space below.

Select Characteristics

- FAR: 3.4
- Floors: 8
- WWR: 20%
- EUI: 211
- Average sDA: 25%
simulation results: larger tower height decreased EUI
“deep street canyons in hot, dry climates experience a considerably lower daytime air temperature than shallow canyons” (Jamei et al., 2016)
“the small courtyard is an excellent thermal regulator... if the courtyard’s size is kept small enough to achieve shade during the day, it will allow more heat dissipation from surrounding indoor spaces” (Heidari, 2010)
“E–W oriented streets suffer from a prolonged period of solar exposure during the summer compared with N–S oriented streets.” (Jamei et al., 2016)
Current Block Design

Select Characteristics

- FAR: 4.1
- Floors: 14
- WWR: 80%
- EUI: 124 vs. 211
- Average sDA: 51% vs. 25%

- NV estimated to reduce cooling load by 7%
- Max PV supplies ~35% of annual electric needs
“green areas are usually cooler than their surrounding built up areas, leading to a temperature difference of up to 1 to 7 degrees C” (Jamei, 2016)
ADAPTIVE GREEN SPACE

• high water (and energy) intensity
• consumed 44.8 MM m³/yr (2002) (only 12 MM m³/yr was recycled)
• water table has risen 5m (2001)

• low water (and energy) intensity
• as population grows, so will wastewater quantities; as of 2002, 74 MM m³/yr wastewater was not being re-used

Greenspace Corridors
Courtyard
Streetview
Neighborhood
## Reference vs. Current Design Comparison

<table>
<thead>
<tr>
<th>METRIC</th>
<th>REFERENCE CASE</th>
<th>CURRENT DESIGN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block dimensions</td>
<td>75m x 65m</td>
<td>75m x 65m</td>
</tr>
<tr>
<td>Street width</td>
<td>8m</td>
<td>10m E/W 12m for N/S</td>
</tr>
<tr>
<td>FAR</td>
<td>3.4</td>
<td>4.1</td>
</tr>
<tr>
<td>OD/m² w/res.</td>
<td>0.06</td>
<td>0.06</td>
</tr>
<tr>
<td>OD/m² w/o res.</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td># of stories</td>
<td>8</td>
<td>14</td>
</tr>
<tr>
<td>WWR</td>
<td>20%</td>
<td>80%</td>
</tr>
<tr>
<td>PV area</td>
<td>3,225m</td>
<td>2,895m</td>
</tr>
<tr>
<td>PV/floor area</td>
<td>36.5 kWh/m²</td>
<td>47.3 kWh/m²</td>
</tr>
<tr>
<td>EUI</td>
<td>211</td>
<td>124</td>
</tr>
<tr>
<td>EUO</td>
<td>1,180 kWh per person/year</td>
<td>2,275 kWh per person/year</td>
</tr>
<tr>
<td>Average sDA</td>
<td>25%</td>
<td>51%</td>
</tr>
</tbody>
</table>
REFERENCES