Behavior, Energy and Climate Change:

How Building Design can

Change the Equation

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Bilbao Airport, Spain, Santiago Calatrava Architect
Buildings currently use a lot of energy

• 30% of all energy used in the county
• 67% of all the electricity used in the county

• We spend 95% of our lives inside of buildings!

• How Buildings are designed
  – determine behavioral choices
  – which either increase, or decrease, energy use

• To get to zero-net energy buildings
  – we need buildings that allow good behavioral choices
Buildings use so much energy, because:

- We want them to have
  - the same temperature
    - everywhere, immediately, at all times
  - uniform illumination
    - everywhere, at all times of day and night

- We insist on fast food, immediate comfort, one-size-fits-all building design

- Our performance standards strive for static uniformity
  - instead of dynamic responsiveness and variation
The summer iced-latte drive-through

- The highest kWh use for
  - small retail in SMUD territory
- The patrons want an iced latte during peak 103°F summer afternoon
  - while their car idles
  - in the middle of a hot parking lot
- The expresso machines are on 24/7
  - so they are ready at 6 am
- The refrigerator also dumps its heat into the little space
  - to provide ice to chill the drink
  - and fresh milk
  - which is then steamed
- The employee needs the roof-top package AC to stay comfortable
  - but the windows remain open
  - to serve the clients
When the power goes out....

- This classroom cannot be inhabited
A Classroom that can operate comfortably with no electricity

Oakridge High School, El Dorado Hills, California
Natch and Lewis Architects, circa 1980
Take the stairs

- When they are inviting…
- Have daylight
- And views
- And places to stop and talk
Buildings that can operate without electricity

- Narrow floor plates
  - Most people working near the perimeter
    - for views, ventilation, and daylight

- Lowrise
  - Stairs, instead of elevators or escalators
    - 5-floor walkups the standard of Paris and Washington DC
  - Skylights bring daylight into the top floors
    - Courtyards and atria in the center

- Oriented to solar path
  - For passive heating, cooling and daylighting
  - Places to be inside and out
    - choose shade or sun, warmth or coolth

- Fail gracefully without power
  - “like an escalator, a good building is never broken….”
Migrate to your comfort zone

- Sometimes dark and cozy
- Sometimes bright and airy
  - and a range of choices in between
Retail Sales: Where would you linger?
Competitive lighting wars: fighting for shoppers’ attention…
Window transparency

• How to balance the light
  – inside and outside
• Can daylight be used to
  – to direct shoppers attention?
  – highlight merchandise?
  – to create memorable shopping experiences?
Display windows that work

- Sunlight highlights product
- visible from the freeway!
Scandinavian Design, Roseville Calif
Designed to new 2005 Title 24 requirements for daylit stores

- Display walls are perpendicular to windows
  - creating a wash of daylight into space
Magical Day- Night Transformations

- Why design building lighting as if it is always nighttime?

- In the daytime
  - high ambient, with pervasive (bluish) daylight, electric light only to supplement

- In the nighttime
  - low ambient, with local pools of warm (reddish) illumination
A California Elementary School, circa 1960
Fresno, California
Pinwheel School – 1985, Fresno, Ca

- Minimal windows, with black “limousine” glass to reduce solar heat gain
- no shade for shelter or quiet play
- increased noise from playground
- dust from playground
- radiant temperatures outside, 20°F higher than ambient
- radiant temperatures inside, 5°F higher than ambient behind south walls
- during a power outage, teachers opened the door for minimal daylight
  - or took their class outside to read in the cold...
40% of all Classrooms in Fresno are Portables

and 200,000 children in California
attend school in portable classrooms!

(Teachers prefer portables
because they have their own thermostats)
“Evidence Based Design”

• Can we isolate the effects of design choices on human behavior or performance outcomes?

• Term borrowed from medical field
  – Research on what works
  – Step away from charisma and design fads

• “Epidemiological field studies”
  – large populations
  – multi-variate regressions, statistical probabilities
  – measured outcomes of interest to building owners
    • help quantify the value of good performance
HMG has completed 8 Daylight & Human Performance Studies:

- **Retail**
  - Two major chain stores
    - 108 and 74 stores each, outcome = $$ sales, # transactions

- **Schools**
  - Four school districts
    - 8-9000 students each, outcome = math and reading test scores

- **Offices**
  - “Call Center”
    - 100 subjects, 2 months, outcome = work speed
  - “Desk Top”
    - 200 subjects,
    - outcomes = cognitive & visual performance, health and satisfaction
**Examples of window effects for reading**

<table>
<thead>
<tr>
<th>Finger plan</th>
<th>Pinwheel</th>
<th>Portable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity view</td>
<td>Activity view</td>
<td>East window</td>
</tr>
<tr>
<td>160 sf view</td>
<td>15 sf view</td>
<td>No binds</td>
</tr>
<tr>
<td>DC 5</td>
<td>DC 1</td>
<td>DC 2</td>
</tr>
<tr>
<td>2 ext doors</td>
<td>South window</td>
<td>64 sf view</td>
</tr>
<tr>
<td>Total windows</td>
<td>Total windows</td>
<td>Total windows</td>
</tr>
<tr>
<td>= + 6%</td>
<td>= + 6%</td>
<td>= - 8%</td>
</tr>
<tr>
<td>= +14%</td>
<td>= - 7%</td>
<td>= - 5%</td>
</tr>
<tr>
<td>= - 14%</td>
<td>= + 6%</td>
<td>= + 0%</td>
</tr>
<tr>
<td>= + 10%</td>
<td>= - 9%</td>
<td>= + 0%</td>
</tr>
<tr>
<td>= + 16%</td>
<td>= - 10%</td>
<td>= - 13%</td>
</tr>
</tbody>
</table>
**Examples of window effects for math**

<table>
<thead>
<tr>
<th>Finger plan</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Vegetation view</td>
<td>0 sf high win</td>
<td>East window</td>
</tr>
<tr>
<td>150 sf high win</td>
<td>DC 1</td>
<td>No binds</td>
</tr>
<tr>
<td>DC 5</td>
<td>South window</td>
<td>DC 2</td>
</tr>
<tr>
<td>Total windows</td>
<td>Total windows</td>
<td>0 sf high win</td>
</tr>
</tbody>
</table>

- Vegetation view: + 10%
- 150 sf high win: + 8%
- DC 5: - 13%
- Total windows: + 5%
- 0 sf high win: - 2%
- DC 1: + 4%
- South window: - 9%
- Total windows: - 7%
- East window: - 12%
- No binds: - 5%
- DC 2: + 0%
- 0 sf high win: - 2%
- Total windows: - 19%
The newly discovered non-optic ganglion receptor

- There are non-visual light receptors in the retina
  - especially sensitive to blue light
  - similar to the blue sky
- That signal a separate neural and hormonal pathway
  - orchestrating circadian response
    - melatonin, dopamine, serotonin
- Thus, light at the eye effects:
  - alertness
  - mood
  - memory
  - health

Allow people to make choices

• Lighting and HVAC are currently designed for 80% comfort levels
  – that means 79% of people
    • would be comfortable with less
    • and 20% want more
  – Why not give them all the option?
    • And save lots of energy......
• “One Size Fits All” is always less efficient
People have wide ranging lighting preferences

- **A Win-Win**: Allowing them to exercise those preferences can result in
  - happier, more productive workers
  - and substantial energy savings
Occipant controls

(why is this revolutionary??)

• Lighting
  – Local switches
    • why only in California’s energy code ??
    • manual-on / auto-off occupancy sensors..
  – Task / ambient lighting systems
    • desk lamps for high level of light, but only where and when you want it
    • desk lamps are usually off
      – GSA study found workers occupy desks only 1/3 of time
      – current PG&E Emerging Technology study of 3 office spaces to document savings

• HVAC
  – Adaptive standards
    • different comfort levels with natural ventilation
    • higher temperatures expected in the summer, in warmer climates
  – Variable occupant preferences
    • under floor ventilation
    • individual workstation controls (we do it for cars!)
Daylight – disabled

- First comes the sunlight
- Then the shades…
- Then the glare…
- Then come the disabled controls…
• Warema – fully automated blinds
  – with local occupant over-rides

• Inverted to redirect daylight upwards
• Perforated for view
• Separate controls, for lower view versus upper daylight portions
• Specular for solar control
Partially Perforated Blinds –
Filtered View and Sun Projection
Lighting Energy Savings from Daylighting
per Dr. Christoph Reinhart, Harvard University

% Daylight Autonomy = % of hours per year without need for electric lighting
To rely on occupant behavior for energy savings….

- We need to understand it
  - and predict it
- Requires studies of preferences and trade-offs
  - and predictive probability of action

- Such as
  - use of task lights
  - blinds operation behavior
  - thermostat settings
    - manual versus programmable behavior
    - demand response choices (SMUD small commercial pilot)
That means teaching human behavior

- To building designers and engineers
  - they need human factors coursework in school
  - they need different goals and examples
  - they need defensible standards and references

- We need to change
  - ASHRAE and IESNA standards
    - based on research (which needs funding!)
    - statistical probability functions from large population studies
Embrace variation, in our built environment, and in responsive occupant controls…

Thank you for your interest!

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