DESIGNING FOR RESILIENCY WITH THE B3 GUIDELINES

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Becky Alexander AIA, Architect and Researcher, LHB
WHAT IS RESILIENCE?

Weeks after Tesla founder Elon Musk and Gov. Ricardo Rossello spoke about the tech company aiding Puerto Rico, Tesla says it has restored electricity to a children's hospital, using solar energy and batteries.

*Tesla*
WHAT IS RESILIENCE?

An aerial photo of burned buildings at the intersection of Lake St. and Chicago Ave. in Minneapolis on Tuesday, June 9, 2020. (John Autey / Pioneer Press)
WHAT IS RESILIENCE?

We're beginning to understand the biology of the covid-19 virus

Scientists are working around the clock to understand the biology of the covid-19 virus and how it infects human cells, which will help us design treatments to stop it.

Anatomy of a virus
The covid-19 virus has several features we may be able to target with drugs to break it down and stop it entering cells.

- RNA enclosed in protein
- Spike protein
- Lipid membranes
WHAT IS RESILIENCE?

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Photo by: Justin Sullivan
WHAT IS RESILIENCE?

**Resilience** is the capacity to deal with change and continue to develop.

**Social-ecological systems** are linked systems of people and nature. The term emphasizes that humans must be seen as a part of, not apart from, nature — that the delineation between social and ecological systems is artificial and arbitrary. Scholars have also used concepts like ‘coupled human-environment systems’, ‘ecosocial systems´ and ‘socioecological systems´ to illustrate the interplay between social and ecological systems. The term social-ecological system was coined by Fikret Berkes and Carl Folke in 1998 because they did not want to treat the social or ecological dimension as a prefix, but rather give the two same weight during their analysis.

**Ecosystem resilience** is a measure of how much disturbance (like storms, fire or pollutants) an ecosystem can handle without shifting into a qualitatively different state. It is the capacity of a system to both withstand shocks and surprises and to rebuild itself if damaged.

**Social resilience** is the ability of human communities to withstand and recover from stresses, such as environmental change or social, economic or political upheaval. Resilience in societies and their life-supporting ecosystems is crucial in maintaining options for future human development.
WHAT IS RESILIENCE?

**Vulnerability** refers to the propensity of social and ecological systems to suffer harm from exposure to external stresses and shocks. Research on vulnerability can, for example, assess how large the risk is that people and ecosystems will be affected by climate changes and how sensitive they will be to such changes. Vulnerability is often denoted the antonym of resilience.

**Anthropocene** is a term coined in 2000 by the Nobel Prize winning scientist Paul Crutzen. It describes the most recent period in the Earth's history, starting in the 18th century, when the activities of humans first began to have a significant global impact on the Earth's climate and ecosystems.
MINNESOTA SUSTAINABLE BUILDING 2030

CASE STUDY METRICS – www.casestudies.b3mn.org

Bear Head Lake State Park
Hennepin County 911 Facility
BSU Decker Hall Renovation
MnSCU Mankato Clinical Sciences Building
Hamline Station
Tettegouche Visitor Center and Rest Area

Western U Plaza
Kendall's Payne Avenue Hardware
Big Bog State Recreation Area
Minnesota National Guard Winona Armory Renovation
MSU Science Education Building
NHCC Biosciences and Health Careers Center

NCC Academic Partnership Center
SCC Classroom Renovation and Addition
UMM Green Living and Learning Community
BSU Memorial Hall Renovation
Camp Ripley COE Training Facility
Duluth Armory

Maplewood Mall Parking Structure
PTC Entrepreneurship Center and Business Incubator
Washburn Center for Children
STCC Medium Heavy Truck and Auto Body
Duluth Entertainment and Convention Center
Silver Creek Corner
System Design

Existing

- Efficiency as end goal
- Degenerative linear flows

Regenerative

- Effectiveness as end goal
- Within renewal capacity
- Integrate with natural processes
- Symbiosis
- Closed-loop system
- Multiple pathways

John Tillman Lyle, Regenerative Design for Sustainable Development, 1994
Vulnerability Assessment Framework

1. Establish assessment team
2. Gather information and set priorities
3. Obtain climate information
4. Estimate/model impacts
5. Consider consequences and adaptations

Apply, document, and learn
Future Weather Files

- Morphed weather files for the Minneapolis / Saint Paul Area
- Future performance analyzed using RCP 8.5, 50th percentile

*Intergovernmental Panel on Climate Change, Fifth Assessment Report. 2014*
Prototype: Multi-Family Residential: “Shelter in Place”

ENERGY SYSTEMS

1. GATHER: Solar Panels
2. STORAGE: DC Battery Storage and Inverter
3. REDUCE DEMAND: Use collected energy to power building
4. EFFICIENCY: Air exchanger and heat recovery
Prototype: Library: “Resilience Hub”

ENERGY SYSTEMS

1. GATHER: Solar Panels
2. STORAGE: DC Battery Storage and Inverter
3. EFFICIENCY: Air Exchanger with Heat Recovery
4. EFFICIENCY: Condensor
5. EFFICIENCY: In-Floor Ventilation and Evaporator
6. REDUCE DEMAND: Light Tubes
7. REDUCE DEMAND: Sunshades / Light Shelves
Prototype: Library

Potential Areas Served by Disaster Hubs

Minneapolis

Saint Paul
Prototype: Library

Library can support approximately 550 people in ‘hub mode’
• Roughly 10% of population living within ½ mile
• Statistically will include:
  • 64 people with a disability
  • 125 people living within 150% of poverty line
  • 42 children under age 5
  • 52 people over age 65

Potential Population Served by Disaster Hubs
American Community Survey, 2015
<table>
<thead>
<tr>
<th>Strategy</th>
<th>Hours: Actual and Percentage</th>
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<tr>
<td></td>
<td>Now</td>
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<tr>
<td>Comfort</td>
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<td>Sun Shading of Windows</td>
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<td>High Thermal Mass</td>
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<td>High Thermal Mass Nightflushed</td>
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<td>Direct Evaporative Cooling</td>
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<td>Two-Stage Evaporative Cooling</td>
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<td>Natural Ventilation Cooling</td>
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<td>Fan-Forced Ventilation Cooling</td>
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<td>Wind Protection of Outdoor Spaces</td>
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<td>Dehumidification Only</td>
<td>491</td>
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<td>Cooling, add dehumidification if needed</td>
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<tr>
<td>Heating, add humidification if needed</td>
<td>4791</td>
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</table>

*Predicted Effectiveness of Comfort Strategies for Minneapolis / Saint Paul – Climate Consultant, UCLA Energy Design Tools Group*
Future Weather Files

- Energy use in code buildings decreases over time
- Increase in cooling load is outweighed by decrease in heating loads
- Energy use in high performing buildings stable over time
Future Weather Files

- Energy use in code buildings decreases over time
- Increase in cooling load is outweighed by decrease in heating loads
- Energy use in high performing buildings stable over time
Prototype: Multi-Family Residential

Prototype: Multi-Family Residential

Predicted PV Production and Predicted Energy Use. Energy Modeled in IES-VE 2015, PV data from NREL PVWatts

Max PV = 789 kWh
Standard = 835 kWh
Shelter in Place = 358 kWh
Min PV = 237 kWh
Prototype: Library

Prototype: Library

Predicted PV Production and Predicted Energy Use. Energy Modeled in IES-VE 2015, PV data from NREL PVWatts

Max PV = 1513 kWh
Hub = 2100 kWh
Standard = 894 kWh
Min PV = 454 kWh
Regenerative and Resilient Design Strategies

**Regenerative Goal + Resilient Goal**

- **Renewable and Islandable Energy Source**
  - Maintain Habitable Temperature
  - Operate Building in Low Power Mode
  - Store Energy
  - Rainwater Capture + Use
  - Greywater Capture + Use
  - Potable Water Distribution
  - Provide Refuge

- **Continuity of Power**
- **Closed Water System**
- **Continuity of Water and Sanitation**
- **Shelter**

**Macro Strategies**

- Design for passive ventilation
- Design for passive heating and cooling
- Design for daylight
- Utilize shading devices
- Provide hook-ups for temporary power
- Enhance envelope insulation and thermal mass
- Elevate HVAC / electrical equipment
- Battery storage
- Program building automation system for dual mode operation (typical and emergency)
- Emergency lighting circuit
- Collect, store, treat rainwater from roof
- Oversize roof drains
- Plumb for greywater separation
- Store and treat greywater
- Distribute potable water without electricity
- Store emergency provisions
- Build sheltered spaces (large enough to shelter other members of community)
- Insulate water system
- Ensure sinks and toilets operate without power
B3 RESILIENCE GUIDELINES

Liz Kutschke, Center for Sustainable Building Research
NEW B3 GUIDELINE

• New guideline added to Performance Management section
• Project teams will complete a vulnerability and capacity assessment using the B3 Resilience Tool
• Project teams will implement at least one resilient design strategy based on vulnerability and capacity assessment
B3 RESILIENCE TOOL

• Excel worksheet tool

• County level data, sourced from Minnesota State Hazard Mitigation Plan, 2019

• Natural hazards and human-made hazards

• System assessment and goal setting

• Resilient design strategy bank
# B3 Resilience Tool – Vulnerability Assessment

**Step 1:**
- Project Address:
- Project County (select from dropdown)
- Hazard Mitigation / Management Plan Status: (Approved, Draft, Pending, or Expired)
- PDF Available?

**Step 2:**

<table>
<thead>
<tr>
<th>Natural Hazards</th>
<th>Scale / Metric</th>
<th>Scale / Metric Explanation or Source</th>
<th>Risk</th>
<th>Primary Service Impact</th>
<th>Secondary Service Impact (Optional)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flooding</td>
<td>FEMA Flood Zone Types - High, Moderate, Minimal Risk</td>
<td>FEMA/NIST Wind Zone, Max Windspeed in Extreme Events</td>
<td>Minimum Design Load Wind Speed for 100-year Mean Recurrence Interval (MRI) from ASCE 7-16 (2016)</td>
<td>Wind Zone (NIST)</td>
<td>Wind Speed for 100 Year Event (ATC)</td>
<td>FEMA Flood Zone (FEMA)</td>
</tr>
<tr>
<td>High Wind</td>
<td>Windsstorm Vulnerability Ranking (1 = most vulnerable, red, 87 = least vulnerable, green)</td>
<td>Average Windsstorm Events per Year</td>
<td>Expected Windsstorm Events per Year (highlighted if expected increase)</td>
<td>2019 Minnesota Hazard Mitigation Plan - County Rankings</td>
<td>2019 Minnesota Hazard Mitigation Plan - County Rankings</td>
<td></td>
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<tr>
<td>Tornado</td>
<td>Design Load Windspeed for Tornado, if a certain type of project requires a shelter</td>
<td>FEMA Tornado Risk by Tornado Count and Wind Zone</td>
<td>Tornado Vulnerability Ranking (1 = most vulnerable, red, 87 = least vulnerable, green)</td>
<td>Expected Storm Count per Year (highlighted if expected increase)</td>
<td>2010 Minnesota Hazard Mitigation Plan - County Rankings</td>
<td>2010 Minnesota Hazard Mitigation Plan - County Rankings</td>
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<td>Wildfire</td>
<td>USDA/USDA Wildfire Hazard Potential - average rating within 5 miles</td>
<td></td>
<td></td>
<td></td>
<td>USDA/USDA Wildfire Hazard Potential</td>
<td>USDA/USDA Wildfire Hazard Potential</td>
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<tr>
<td>Drought</td>
<td>% of Time from 2000-2018 in Moderate Drought or Worse</td>
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<td>2019 Minnesota Hazard Mitigation Plan</td>
<td>2019 Minnesota Hazard Mitigation Plan</td>
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<td>Hall</td>
<td>Hall Storm Vulnerability Ranking (1 = most vulnerable, red, 87 = least vulnerable, green)</td>
<td>Average Hall Storm Events per Year</td>
<td>Expected Hall Storm Events per Year (highlighted if expected increase)</td>
<td>2019 Minnesota Hazard Mitigation Plan - County Rankings</td>
<td>2019 Minnesota Hazard Mitigation Plan - County Rankings</td>
<td></td>
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<td>Winter Storm</td>
<td>Perceived Risk - Minnesota Hazard Mitigation Plan</td>
<td></td>
<td></td>
<td></td>
<td>2019 Minnesota Hazard Mitigation Plan</td>
<td>2019 Minnesota Hazard Mitigation Plan</td>
</tr>
</tbody>
</table>

**DIRECTIONS:**
1. Vulnerability Assessment
2. Project Assessment
3. ASCE 7 - Table 1604.5
4. Design Strategies
5. References
### B3 Resilience Tool – Vulnerability Assessment

#### Key:
- Blue highlighted areas show constants or outputs calculated by the spreadsheet.
- Yellow highlighted areas show required inputs.
- Dark yellow highlighted areas show required inputs with a drop-down selection.
- Grey highlighted areas will remain blank.

#### Step 1: Project Address

- **Project County (select from dropdown):** Ramsey County

#### Step 2: Hazard Mitigation / Management Plan Status

- **Draft** (Approved, Draft, Pending, or Expired)

#### Step 3: Natural Hazards

<table>
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<th>Natural Hazards</th>
<th>Scale / Metric</th>
<th>Scale / Metric Explanation or Source</th>
<th>Risk</th>
<th>Primary Service Impact</th>
<th>Secondary Service Impact (Optional)</th>
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<tbody>
<tr>
<td>Flooding</td>
<td>FEMA Flood Zone Type - High, Moderate, Minimal Risk</td>
<td>FEMA/NST Wind Zone, Max Wind Speed in Extreme Events</td>
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<td></td>
<td></td>
<td>Flood Zone (FEMA)</td>
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<td></td>
<td>FEMA/NST Wind Zone, Max Wind Speed in Extreme Events</td>
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<td></td>
<td></td>
<td></td>
<td>Wind Zone (NST)</td>
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<td>High Wind</td>
<td>19</td>
<td>Windstorm Vulnerability Ranking (1 = most vulnerable, 8 = least vulnerable, green)</td>
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<td>2019 Minnesota Hazard Mitigation Plan - County Rankings</td>
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<td>1.48</td>
<td>Average Windstorms per Year</td>
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<td>2019 Minnesota Hazard Mitigation Plan - County Rankings</td>
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<td>0.49</td>
<td>Expected Windstorms per Year (highlighted if expected increase)</td>
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<td>2019 Minnesota Hazard Mitigation Plan - County Rankings</td>
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<td>Tornado</td>
<td>8</td>
<td>Tornado Vulnerability Ranking (1 = most vulnerable, 8 = least vulnerable, green)</td>
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<td>Tornado Risk Level (FEMA)</td>
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<td>2019 Minnesota Hazard Mitigation Plan - County Rankings</td>
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<td>2019 Minnesota Hazard Mitigation Plan - County Rankings</td>
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<td>Wildfire</td>
<td>25.1–27.5%</td>
<td>% of Time from 2000-2018 in Moderate Drought or Worse</td>
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<td></td>
<td>USDA/USDA Wildfire Hazard Potential</td>
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<td>Storm Hazard Ranking (1 = most vulnerable, 8 = least vulnerable, green)</td>
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<td>2019 Minnesota Hazard Mitigation Plan</td>
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<td>1.18</td>
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<td>2019 Minnesota Hazard Mitigation Plan - County Rankings</td>
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<td>Winter Storm</td>
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<td>Perceived Risk - Minnesota Hazard Mitigation Plan</td>
<td></td>
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<td></td>
<td>2019 Minnesota Hazard Mitigation Plan</td>
</tr>
</tbody>
</table>

### DIRECTIONS
1. Vulnerability Assessment
2. Project Assessment
3. ASCE 7 - Table 1604.5
4. Design Strategies
5. References

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[PDF Available? Yes](https://www.ramseycounty.us/sites/default/files/ Emergency%20Response)
B3 RESILIENCE TOOL – VULNERABILITY ASSESSMENT
# B3 Resilience Tool – Vulnerability Assessment

**Step 1:**
- **Project Address:** 2200 Larpenteur Ave, Saint Paul, MN 55109
- **Project County (Select from dropdown):** Ramsey County

**Step 2:**
- **Hazard Mitigation / Management Plan Status:** Draft

**Step 3:**
- **PDF Available?:** Yes

**Natural Hazards**

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<th>Natural Hazards</th>
<th>Scale / Metric</th>
<th>Scale / Metric Explanation or Source</th>
<th>Risk</th>
<th>Primary Service Impact</th>
<th>Secondary Service Impact (Optional)</th>
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<td>Flooding</td>
<td>Minimal Risk (Zone X, Unshaded)</td>
<td>FEMA Flood Zone Types - High, Moderate, Minimal Risk</td>
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<td>Potable Water</td>
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<td>Flood Zone (FEMA)</td>
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<td>Zone IV (250 mph)</td>
<td>FEMA/NIET Wind Zone, Max Windspeed in Extreme Events</td>
<td>Medium</td>
<td>Electricity</td>
<td>Structure</td>
<td>Wind Zone (NIET)</td>
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<td>Minimum Design Load Wind Speed for 100-year Mean Recurrence Interval (M1) from ASCE 7-16 (2016)</td>
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<td>Wind Speed for 100 Year Event (ATC)</td>
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<td>Windstorm Vulnerability Ranking (1 = most vulnerable, red, 87+ least vulnerable, green)</td>
<td>Medium</td>
<td>Electricity</td>
<td>Structure</td>
<td>2019 Minnesota Hazard Mitigation Plan - County Ranking</td>
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<td>2019 Minnesota Hazard Mitigation Plan - County Ranking</td>
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<td>USDA/USFA Wildfire Hazard Potential</td>
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<td>0.05</td>
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<td>USDA/USDA Wildfire Hazard Potential</td>
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<td>% of Time from 2000-2018 in Moderate Drought or Worse</td>
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<td>Potable Water</td>
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<td>2019 Minnesota Hazard Mitigation Plan</td>
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<td>Half Storm Vulnerability Ranking (1 = most vulnerable, red, 87+ least vulnerable, green)</td>
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<td>Winter Storm</td>
<td>High</td>
<td>Perceived Risk - Minnesota Hazard Mitigation Plan</td>
<td>High</td>
<td>Transportation</td>
<td>Electricity</td>
<td>2019 Minnesota Hazard Mitigation Plan</td>
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</tbody>
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**DIRECTIONS:**
1 - Vulnerability Assessment
2 - Project Assessment
3 - ASCE 7 - Table 1604.5
4 - Design Strategies
5 - References
### B3 RESILIENCE TOOL – VULNERABILITY ASSESSMENT

<table>
<thead>
<tr>
<th>Human-Made Hazards</th>
<th>Scale / Metric</th>
<th>Scale / Metric Explanation or Source</th>
<th>Risk</th>
<th>Primary Service Impact</th>
<th>Secondary Service Impact (Optional)</th>
<th>Reference</th>
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<tbody>
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<td>Civil Unrest</td>
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<td>Cyber Attack</td>
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<td>Infrastructure Failure</td>
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<td>Air or Water Pollution</td>
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#### Step 4

**Service(s) Most Likely to be Disrupted:**

- (Required)
- (Optional)

#### Step 5

**Highest Priority Hazard(s):**

- (Required)
- (Optional)
B3 RESILIENCE TOOL – VULNERABILITY ASSESSMENT

**Human-Made Hazards**

<table>
<thead>
<tr>
<th>Human-Made Hazards</th>
<th>Scale / Metric</th>
<th>Scale / Metric Explanation or Source</th>
<th>Risk</th>
<th>Primary Service Impact</th>
<th>Secondary Service Impact (Optional)</th>
<th>Reference</th>
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<td>Epidemic / Pandemic</td>
<td>200 sq/ft/person</td>
<td>Occupant density of designed use</td>
<td>Low</td>
<td>Safety</td>
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</tr>
<tr>
<td>Civil Unrest</td>
<td>Minimal</td>
<td>Proximity to commercial district</td>
<td>Low</td>
<td>Structure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cyber Attack</td>
<td>Minimal</td>
<td>Reliance on internet/digital systems</td>
<td>Low</td>
<td>Communication</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Infrastructure Failure</td>
<td>Moderate</td>
<td>Proximity to major infrastructure</td>
<td>Low</td>
<td>Safety</td>
<td>Active heavy rail line</td>
<td></td>
</tr>
<tr>
<td>Fire</td>
<td>Minimal</td>
<td>Flammable materials stored on site</td>
<td>Low</td>
<td>Safety</td>
<td>Structure</td>
<td></td>
</tr>
<tr>
<td>Explosion</td>
<td>Minimal</td>
<td>Combustibles stored on site</td>
<td>Low</td>
<td>Safety</td>
<td>Structure</td>
<td></td>
</tr>
<tr>
<td>Major Accident</td>
<td>Moderate</td>
<td>Proximity to hazardous processes or sites</td>
<td>Low</td>
<td>Structure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Air or Water Pollution</td>
<td>Minimal</td>
<td>Air quality concern level</td>
<td>Low</td>
<td>Potable Water</td>
<td>Safety</td>
<td></td>
</tr>
</tbody>
</table>

**Step 4**

- Service(s) Most Likely to be Disrupted:
  - Structure (Required)
  - Safety (Optional)
  - Potable Water (Optional)

**Step 5**

- Highest Priority Hazard(s):
  - Winter Storm (Ice, snow, hail, etc.) (Required)
  - Extreme Wind (Including tornado) (Optional)
B3 RESILIENCE TOOL – PROJECT ASSESSMENT

Step 1: Initial Project Assessment
- Building Use
- ASCE Building Risk Category
- Intended Service Life

Step 2: Served Population Assessment
- Total Anticipated Occupants
- Anticipated % Elderly
- Anticipated % Youth
- Social Vulnerability

Step 3: Resilient Goal Setting
- Primary goal during and after a hazard event:

Step 4: Services Required for Resilient Goal:
- Required
- Optional

References:
- Social Vulnerability Index by census tract (CDC) - 2016
- Introduction to CDC’s Social Vulnerability Index (YouTube, 3:45)
# B3 RESILIENCE TOOL – PROJECT ASSESSMENT

### Step 1: Initial Project Assessment

<table>
<thead>
<tr>
<th>Building Use</th>
<th>Multifamily Residential</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASCE Building Risk Category</td>
<td>II</td>
</tr>
<tr>
<td>Intended Service Life</td>
<td>100 Years</td>
</tr>
</tbody>
</table>

*Reference: ASCE Table 1604.5*

### Step 2: Served Population Assessment

<table>
<thead>
<tr>
<th>Total Anticipated Occupants</th>
<th>187</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anticipated % Elderly</td>
<td>Unknown</td>
</tr>
<tr>
<td>Anticipated % Youth</td>
<td>Unknown</td>
</tr>
<tr>
<td>Social Vulnerability</td>
<td>Moderate-to-High</td>
</tr>
</tbody>
</table>

*Social Vulnerability Index by census tract (CDC) - 2016*  
*Introduction to CDC’s Social Vulnerability Index (YouTube, 3:45)*

### Step 3: Resilient Goal Setting

Primary goal during and after a hazard event: **Shelter In Place**

*Secure current occupants and support health, safety, and welfare for duration of outage or 4 days*

### Step 4: Services Required for Resilient Goal:

- Cooling / Heating  *(Required)*
- Restrooms  *(Optional)*
- Food Storage (Including Refrigeration)  *(Optional)*
- Device Charging  *(Optional)*
- Accessibility  *(Optional)*
Resilience Goals in the Event of an Emergency:

• Shelter-In-Place: Secure current occupants and support health, safety, and welfare for duration of 4 days during a system outage

• Resilience Hub: Secure occupants and accept others in need of shelter, and support health, safety, and welfare for duration of 4 days during a system outage

• Evacuate and Shut Down: Safely evacuate occupants and secure building systems against physical damage.
### B3 RESILIENCY TOOL – PROJECT ASSESSMENT

#### Step 5: Internal Systems

<table>
<thead>
<tr>
<th></th>
<th>Primary System</th>
<th>Secondary or Back-Up System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drinking water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wastewater and stormwater</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Circulation / Vertical Transportation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Information and Communications</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Food Storage and Preparation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heating</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cooling</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ventilation</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Step 6: Critical Load - Electricity

<table>
<thead>
<tr>
<th></th>
<th>NREL’s ReOpt Lite Tool</th>
<th>Project Data Needed for ReOpt Lite Tool:</th>
<th>Notes:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recommended PV size (kW)</td>
<td></td>
<td>Site Location</td>
<td>Chose 'Resilience' in Step 1</td>
</tr>
<tr>
<td>Recommended Battery Power (kW)</td>
<td></td>
<td>Critical Load Factor % (percent of typical load that must be met during outage)</td>
<td>Some building profiles built in, based on DOE reference buildings</td>
</tr>
<tr>
<td>Recommend Battery Capacity (kWh)</td>
<td></td>
<td>Required Inputs for this assessment:</td>
<td>Can build custom critical load profile with account registration</td>
</tr>
<tr>
<td>Percent of Possible Annual Outages Sustained by System (%)</td>
<td></td>
<td>Outage Duration - 4 days / 96 hours</td>
<td>Download results PDF to include in submission</td>
</tr>
</tbody>
</table>

- Outage Start Date - Select 'Autoselect using critical load profile' and select 'Start Outage on Peak'
- Type of Outage Event: Major Outage
B3 RESILIENCE TOOL – PROJECT ASSESSMENT
### B3 RESILIENCE TOOL – PROJECT ASSESSMENT

#### Step 5: Internal Systems

<table>
<thead>
<tr>
<th>System</th>
<th>Primary System</th>
<th>Secondary or Back-Up System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drinking water</td>
<td>Municipal water</td>
<td>Unknown</td>
</tr>
<tr>
<td>Wastewater and stormwater</td>
<td>Municipal sewer</td>
<td>Unknown</td>
</tr>
<tr>
<td>Circulation / Vertical Transport</td>
<td>Elevator</td>
<td>Stair</td>
</tr>
<tr>
<td>Information and Communications</td>
<td>Telephone and internet</td>
<td>Unknown</td>
</tr>
<tr>
<td>Food Storage and Preparation</td>
<td>n/a</td>
<td>Natural gas</td>
</tr>
<tr>
<td>Heating</td>
<td>Electric heating system</td>
<td>Natural ventilation</td>
</tr>
<tr>
<td>Cooling</td>
<td>Electric cooling system</td>
<td>Unknown</td>
</tr>
<tr>
<td>Ventilation</td>
<td>DOAS</td>
<td>Natural ventilation</td>
</tr>
</tbody>
</table>

#### Step 6: Critical Load - Electricity

<table>
<thead>
<tr>
<th>Parameter</th>
<th>NREL’s ReOpt Lite Tool</th>
<th>Project Data Needed for ReOpt Lite Tool</th>
<th>Notes:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recommended PV size (kW)</td>
<td>66</td>
<td>Site Location</td>
<td>Chose ‘Resilience’ in Step 1</td>
</tr>
<tr>
<td>Recommended Battery Power (kW)</td>
<td>36</td>
<td>Critical Load Factor % (percent of typical load that must be met during outage)</td>
<td>Some building profiles built in, based on DOE reference buildings</td>
</tr>
<tr>
<td>Recommended Battery Capacity (kWh)</td>
<td>173</td>
<td>Required Inputs for this assessment:</td>
<td>Can build custom critical load profile with account registration</td>
</tr>
<tr>
<td>Percent of Possible Annual Outages Sustained by System (%)</td>
<td>94</td>
<td>Outage Duration - 4 days / 96 hours</td>
<td>Download results PDF to include in submission</td>
</tr>
</tbody>
</table>

Outage Start Date - Select ‘Autoselect using critical load profile’ and select ‘Start Outage on Peak’
Type of Outage Event: Major Outage

User Guides and tutorial videos available here
## B3 RESILIENCE TOOL – DESIGN STRATEGIES

<table>
<thead>
<tr>
<th>Step 1</th>
<th>Highest Priority Hazard(s):</th>
<th>Winter Storm (ice, snow, hail, etc.)</th>
<th>Extreme Wind (including tornado)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Resilience Goal:</td>
<td>Shelter in Place</td>
<td></td>
</tr>
<tr>
<td>Step 2</td>
<td>Strategy Selected:</td>
<td>[Required]</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Strategy Selected:</td>
<td>Optional</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Strategy Selected:</td>
<td>Optional</td>
<td></td>
</tr>
</tbody>
</table>

### Table: Design Strategies

<table>
<thead>
<tr>
<th>Primary Hazard</th>
<th>Secondary Hazard</th>
<th>Category</th>
<th>Primary Impact</th>
<th>Secondary Impact</th>
<th>Tertiary Impact</th>
<th>Primary Service Supported</th>
<th>Secondary Service Supported</th>
<th>Metric(s) or Measured Effect(s)</th>
<th>Related B3 Guideline(s)</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extreme Temp.</td>
<td></td>
<td>Envelope</td>
<td>Temperature</td>
<td>Regulation</td>
<td>Passive Survivability</td>
<td>Electricity / Natural Gas</td>
<td></td>
<td>Impact on heat gain (°F)</td>
<td>E.1 - Energy Efficiency</td>
<td>Passive</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Impact on heat loss (°F)</td>
<td>E.4 - Thermal Comfort</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Peak electrical demand impact (kW)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Annual energy impact (kWh)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flooding</td>
<td>Extreme Temp.</td>
<td>Biowalls</td>
<td>Siting / Landscape</td>
<td>Site Water Management</td>
<td>Temperature Regulation</td>
<td>Structure/Safety</td>
<td>Volume of water captured from site (gal)</td>
<td>S.2 - Site Water Quality and Efficiency</td>
<td></td>
<td>Passive</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Volume of pollutants and solids captured from site (cu ft/gal)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Building Orientation</td>
<td>Siting / Landscape</td>
<td>Passive Survivability</td>
<td>Temperature Regulation</td>
<td>Electricity / Natural Gas</td>
<td>Reduction in electrical usage (kW)</td>
<td></td>
<td>E.1 - Energy Efficiency</td>
<td>Passive</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ceiling Fans</td>
<td>HVAC</td>
<td>Temperature</td>
<td>Regulation</td>
<td>Passive Survivability</td>
<td>Electricity / Natural Gas</td>
<td>Reduction in summertime peak demand (kW)</td>
<td></td>
<td>E.1 - Energy Efficiency</td>
<td>Passive</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Reduction in wintertime peak demand (kW)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Reduction in interior air temperature (degrees)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Reduction in peak electrical demand (kW)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Reduction in annual electrical energy (kWh)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
B3 RESILIENCE TOOL – DESIGN STRATEGIES
# B3 RESILIENCE TOOL – DESIGN STRATEGIES

## Step 3: Use dropdown arrow controls in ‘Primary Service Supported’ to select service(s) identified. Exclude services not included in building.

## Step 4: Assess resulting design solutions for appropriateness, feasibility for the project, and the established resilience goal and services.

## Step 5: Select resilient design strategy / strategies to explore for full implementation.

### Table: Primary Hazard - Secondary Hazard - Strategy

<table>
<thead>
<tr>
<th>Primary Hazard</th>
<th>Secondary Hazard</th>
<th>Strategy</th>
<th>Category</th>
<th>Primary Impact</th>
<th>Secondary Impact</th>
<th>Related B3 Guideline(s)</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter Storm</td>
<td></td>
<td>Design for Increased Snow Load</td>
<td>Envelope</td>
<td>Structural Protection</td>
<td>Emergency Operation</td>
<td>Structure / Safety</td>
<td>Passive</td>
</tr>
<tr>
<td>Extreme Wind</td>
<td>Summertime</td>
<td>Design to FORTIFIED Commercial Gold Level Certification</td>
<td>Envelope</td>
<td>Structural Protection</td>
<td>Emergency Operation</td>
<td>Structure / Safety</td>
<td>Passive</td>
</tr>
<tr>
<td>Extreme Wind</td>
<td>Summertime</td>
<td>Design to FORTIFIED Commercial Roof Level Certification</td>
<td>Envelope</td>
<td>Structural Protection</td>
<td>Emergency Operation</td>
<td>Structure / Safety</td>
<td>Passive</td>
</tr>
<tr>
<td>Winter Storm</td>
<td></td>
<td>Ice Dam Resistant Construction</td>
<td>Temperature Regulation</td>
<td>Escape / Evacuation</td>
<td>Emergency Operation</td>
<td>Structure / Safety</td>
<td>Passive</td>
</tr>
</tbody>
</table>

## Secondary Service Supported

<table>
<thead>
<tr>
<th>Service Supported</th>
<th>Metric(s) or Measured Effect(s)</th>
<th>Related B3 Guideline(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety</td>
<td>Enhanced Structural Performance</td>
<td>Passive</td>
</tr>
<tr>
<td>Reliable Water</td>
<td>Roof related components and connections meet ASCE 7</td>
<td>Passive</td>
</tr>
<tr>
<td>Cooling / Heating</td>
<td>Roof related components and connections meet ASCE 7</td>
<td>Passive</td>
</tr>
<tr>
<td>Accessibility</td>
<td>Roof related components and connections meet ASCE 7</td>
<td>Passive</td>
</tr>
</tbody>
</table>

## Crosswalk

- [1 - Vulnerability Assessment](#)
- [2 - Project Assessment](#)
- [3 - ASCE 7 - Table 1604.5](#)
- [4 - Design Strategies](#)
- [5 - References](#)
### B3 RESILIENCE TOOL – DESIGN STRATEGIES

#### Step 1
- **Highest Priority Hazard(s):**
  - Winter Storm (e.g., snow, hail, etc.)
  - Extreme Wind (including tornado)
- **Resilience Goal:** Shelter In Place

#### Step 2
- **Strategy Selected:** Ice Dam Resistant Construction
- **Strategy Selected:** Design to FORTIFIED Commercial Roof Level Certification

#### Step 3
<table>
<thead>
<tr>
<th>Primary Hazard</th>
<th>Secondary Hazard</th>
<th>Strategy</th>
<th>Category</th>
<th>Primary Impact</th>
<th>Secondary Impact</th>
<th>Tertiary Impact</th>
<th>Primary Service Supported</th>
<th>Secondary Service Supported</th>
<th>Matrix(s) or Measured Effect(s)</th>
<th>Related B3 Guideline(s)</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter Storm</td>
<td></td>
<td>Design for Increased Snow Load</td>
<td>Envelope</td>
<td>Structural Protection</td>
<td>Passive Survivability</td>
<td>Structure/Safety</td>
<td>Reduced risk of damage due to increased intensity of storm events</td>
<td>Passive</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extreme Wind</td>
<td>Summer Storm</td>
<td>Design to FORTIFIED Commercial Gold Level Certification</td>
<td>Envelope</td>
<td>Structural Protection</td>
<td>Passive Survivability</td>
<td>Emergency Operation</td>
<td>Roof related components and connections meet ASCE 7</td>
<td>Passive</td>
<td>Enhanced Structural Performance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extreme Wind</td>
<td>Summer Storm</td>
<td>Design to FORTIFIED Commercial Roof Level Certification</td>
<td>Envelope</td>
<td>Structural Protection</td>
<td>Passive Survivability</td>
<td>Emergency Operation</td>
<td>Roof related components and connections meet ASCE 7</td>
<td>Passive</td>
<td>Enhanced Structural Performance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extreme Wind</td>
<td>Summer Storm</td>
<td>Design to FORTIFIED Commercial Silver Level Certification</td>
<td>Envelope</td>
<td>Structural Protection</td>
<td>Passive Survivability</td>
<td>Emergency Operation</td>
<td>Roof related components and connections meet ASCE 7</td>
<td>Passive</td>
<td>Enhanced Structural Performance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Winter Storm</td>
<td></td>
<td>Ice Dam Resistant Construction</td>
<td>Envelope</td>
<td>Temperature Regulation</td>
<td>Site Water Management</td>
<td>Storm Damage</td>
<td>Structure/Safety</td>
<td>Reduced risk of roof damage or failure due to moisture</td>
<td>E1 - Energy Efficiency</td>
<td>E2 - Moisture and Water</td>
<td></td>
</tr>
</tbody>
</table>

#### Step 5
- **Strategy Selected:** Ice Dam Resistant Construction (Required)
- **Strategy Selected:** Design to FORTIFIED Commercial Roof Level Certification (Optional)
DESIGN STRATEGY SOURCES
ADDITIONAL RESILIENCE GUIDELINES

• Energy Efficiency - Required
  o Perform energy model with future weather file to determine impacts on energy use and HVAC system sizing

• Thermal Comfort - Recommended
  o Demonstrate passive survivability in the event of a power outage lasting 4 days

  o Environmentally Preferred Materials - Recommended
    o Fire-resistant and non-combustible exterior materials
    o High impact and wind resistance ratings for glazing
    o Locally sourced materials
    o Insect resistant materials
EXISTING RESILIENCE IN B3

• Site and Water
  o S.1- Human System Connections
  o S.2- Site Water Quality and Efficiency
  o S.3- Soil
  o S.4- Sustainable Vegetation Design

• Energy and Atmosphere
  o E.1- Energy Efficiency
  o E.2- Renewable Energy
  o E.3-Efficient Equipment and Appliances
EXISTING RESILIENCE IN B3

• Indoor Environmental Quality
  o I.2- Moisture and Water Control
  o I.4- Thermal Comfort
  o I.5- Lighting and Daylighting
  o I.8- Ergonomics and Physical Activity
  o I.9- Wayfinding and Universal Access

• Materials and Waste
  o M.3- Waste Reduction and Management
  o M.4- Health
PEER PROGRAMS – OPTIONAL MEASURES

• LEED v4.1
  o Innovation Credit – Implement Pilot Credit, 1-5 pts
    • Pilot Credit 98 – Assessment and Planning for Resilience
    • Pilot Credit 99 – Design for Enhanced Resilience

• Enterprise Green Communities
  o Resilient Communities: Multi-Hazard / Vulnerability Assessment (10 pts)
  o Resilient Communities: Strengthening Cultural Resilience (8 pts)
  o Access to Potable Water During Emergencies (8 pts)
  o Resilient Energy Systems: Flood Proofing (8 pts)
  o Resilient Energy Systems: Critical Loads (8 pts)
RESILIENCE IN PRACTICE

Becky Alexander, LHB
WHAT IS THE ARCHITECT'S ROLE IN DESIGNING FOR RESILIENCE?

- Understand site hazards, vulnerability, and risks
- Analyze risks to building
- Discuss risks with the client
- Assist in setting resilience goals
- Recommend strategies
Inform site selection and programming
Leverage existing city or county plans for hazard mitigation, climate adaptation, and/or resilience planning.
CONDUCTING A VULNERABILITY ASSESSMENT

Use plans, maps, and data together.
CONDUCTING A VULNERABILITY ASSESSMENT

Use plans, maps, and data together.
CONDUCTING A VULNERABILITY ASSESSMENT

Note the age and source of the data referenced in plans and hazard maps. Consider future projections.
JUDGING THE RELATIVE RISKS

<table>
<thead>
<tr>
<th>Impact</th>
<th>Likelihood</th>
</tr>
</thead>
<tbody>
<tr>
<td>rare catastrophe</td>
<td>probable disaster</td>
</tr>
<tr>
<td>bad luck</td>
<td>management challenge</td>
</tr>
</tbody>
</table>
Resilience is a design challenge
Involves an integrated design team
Goals will vary by program and hazard type
### SETTING RESILIENCE GOALS

**DEGENERATIVE**
- loses critical functionality in response to short-term shocks; cannot accommodate social, economic, and environmental changes
- burdens the surrounding community during periods of disruption or stress

**SUSTAINABLE**
- maintains critical functionality in event of short-term shocks and predicted social, economic, and environmental changes
- neither supports nor burdens the surrounding community during periods of disruption or stress

**REGENERATIVE**
- dynamically adapts in order to thrive in event of short-term shocks and changing social, economic and environmental conditions
- serves as resource reservoir to replenish nearby stressed systems

LHB Thrive
## SETTING RESILIENCE GOALS

<table>
<thead>
<tr>
<th>Standard</th>
<th>Good</th>
<th>Better</th>
<th>Living Community Principles</th>
<th>Regenerative</th>
</tr>
</thead>
<tbody>
<tr>
<td>No emergency plan or risk assessment conducted.</td>
<td>Emergency plan created and/or risks assessed.</td>
<td>Emergency plan includes access to nearby amenities and facilities. All community facilities have backup generators in case of emergency.</td>
<td>RESILIENT COMMUNITY CONNECTIONS</td>
<td>All residents know and understand the emergency plan and their role in a response. Community is able to assist other communities in the event of an emergency.</td>
</tr>
</tbody>
</table>

RESILIENCE HUB

• Coordinates resource distribution and services before, during, or after a hazard event

• Provides shelter, electricity, water, food, ice, refrigeration, charging stations, and basic medical supplies

• Could provide: space for growing food, trees for shade, resilience education

• Comprehensive model: Community ownership of hub within a well-trusted community building, offering services throughout the year
SUSTAINABILITY SYNERGIES

• Site selection
• Alternative transportation support
• Stormwater management
• Sustainable vegetation design
• Water and energy efficiency
• Passive strategies for thermal comfort and daylighting
• Renewable energy
• Design for disassembly
• Universal access and wayfinding

Photo of National Eagle Center, LHB.
SUSTAINABILITY CONFLICTS

• Programming for infrequently used services may increase building size

• Oversized/undersized systems (e.g. structural, mechanical)

• Redundant systems (e.g. power supply)

• Extra systems (e.g. air conditioning)
KEY TAKEAWAYS

1. Value to client
2. Raise the topic
3. Consider the future
4. Envelope performance is critical
5. This is just another design problem to solve
   - Know your goal
   - Focus on the top hazard(s)
   - Synergize with other strategies
QUESTIONS?

SPEAKERS

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PROJECT TEAM

Footer graphic adapted from “Integrative Process” diagram by 7group and Bill Reed.