Measuring the Sustainability of Infrastructure Systems:
*Information Requirements and Desiderata*

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Overview

- Three measurement approaches for CIS
- Comparative utility for various purposes
- Lessons learned from vertical construction
- CIS measurement as an innovation
Prescriptive Measurement

- Set of heuristic or theory-based “shoulds”
- Either a few overdesigned or many situation-specific items
- Based on current technology
- Measurement = did you do it or not?

“Use pervious pavement for parking”
Performance-based Measurement

- Minimum threshold on a performance continuum
- The how is up to the designer. Framing is key!

“Reduce runoff from paved areas to predevelopment equivalent.”

(http://newmedia.kvcc.edu/)
Systems-based Measurement

• Whole solution performance-based measurement

• Captures synergies and opportunities bigger than individual project features

“Allow no stormwater runoff to cross site boundaries.”

(AFRC/Homestead ARB/Cadle)
Purposes of Measurement

- Baselining
- Benchmarking
- Prioritization, decision support, and selection
- Documentation
## Approach vs. Purpose

<table>
<thead>
<tr>
<th></th>
<th>Prescriptive</th>
<th>Performance-based</th>
<th>Systems-based</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baselining</td>
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<td>Benchmarking</td>
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<td>Prioritization</td>
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<td>Documentation</td>
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<tr>
<td><strong>Useful whenÉ</strong></td>
<td><strong>Coarse resolution is enough</strong></td>
<td><strong>Good performance simulation models exist</strong></td>
<td><strong>Facilities are perceived within larger context</strong></td>
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<td></td>
<td><strong>Best practices are well-established and do not change</strong></td>
<td><strong>System behavior is predictable</strong></td>
<td><strong>Ongoing changes to the system are possible to optimize performance</strong></td>
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# Scales of Assessment

<table>
<thead>
<tr>
<th>Scale</th>
<th>Threshold Systems</th>
<th>Profile Systems</th>
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<tbody>
<tr>
<td>Raw Material</td>
<td>• Forest Stewardship Council Certification</td>
<td>• BEES</td>
</tr>
<tr>
<td>Product or Assembly</td>
<td>• GreenSeal</td>
<td>• Athena</td>
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<tr>
<td></td>
<td>• GreenLabel Plus</td>
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<tr>
<td>Building</td>
<td>• LEED</td>
<td>• GBTool</td>
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<tr>
<td></td>
<td>• GreenGlobes</td>
<td></td>
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<tr>
<td>Development, City, or Region</td>
<td>• LEED-ND</td>
<td>• ICLEI Profile</td>
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<td></td>
<td>• Ecological Footprint</td>
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<tr>
<td></td>
<td>• Carbon Footprint</td>
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<tr>
<td>Enterprise</td>
<td>• Ranking in Dow Jones Sustainability Index</td>
<td>• GRI’s Triple Bottom Line</td>
</tr>
<tr>
<td></td>
<td>• Carbon Footprint</td>
<td>• SAM Corporate Sustainability Assessment</td>
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## Carbon Facts

**Product Size**: 1 Cheeseburger (130g)

### Amount Per Serving

<table>
<thead>
<tr>
<th>Kilograms CO₂ Equivalent</th>
<th>Kilograms CO₂</th>
<th>Kilograms CH₄</th>
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<tbody>
<tr>
<td>3.08</td>
<td>243</td>
<td>123</td>
</tr>
</tbody>
</table>

### Total C: Energy Sources

- **Transportation**: 120g
- **Fossil Fuel (Diesel)**: 120g
- **Fossil Fuel (Gasoline)**: 48g
- **Electricity Production**: 75g
- **Fossil Fuel (Natural Gas)**: 75g
- **Fossil Fuel (Coal)**: 0g
- **Other**: 0g

### Total C: Non-Energy Sources

- **Enteric Fermentation**: 81.0g (1854CO₂E)
- **Manure**: 25.8g (650gCO₂E)
- **Other**: 5.2g (120gCO₂E)

### Carbon/Product Ratio

- 23.7

### Localism Rating

- C

### Sustainable Production Rating

- D

### Overall Carbon Code

- Orange

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**Energy Star**

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**Virginia Tech**

*Invent the Future*
Lessons from Vertical Construction

- Scope and boundary of analysis
- Amalgamation and scale validity
- Context specificity
- Mutual exclusivity and collective exhaustiveness
- Utility to target audiences
Lessons from Vertical Construction

- Meaningful results vs. level of effort
- Distinction among alternatives
- Projected vs. actual performance
- Obtaining uniform data
Attributes of Innovations Affecting their Adoption

- Relative advantage vs. competitors/status quo
- Compatibility/fit with context
- Complexity/prior knowledge required
- Trialability/level of commitment
- Observability of results
Prescriptive Measurement

- Required info:
  - Presence/absence of design features

- Validation:
  - Direct inspection
  - Observation/documentation

- Outcomes:
  - Problems can be corrected as you go
  - Potential overdesign

- **Relative Advantage:** Low precision, low investment
- **Compatibility:** Good fit with practice
- **Complexity:** Limited training required
- **Trialability:** Low initial commitment by owners
- **Observability:** Features are observable, but real performance may not correlate
Performance-based Measurement

- **Required info:**
  - Ability of sub-systems to meet performance thresholds

- **Validation:**
  - Performance testing
  - Simulation models
  - Design heuristics

- **Outcomes:**
  - May be too late to fix problems after the fact
  - Design to fit

- **Relative Advantage:** Better precision, medium investment
- **Compatibility:** May require new services/tools
- **Complexity:** May require modeling expertise
- **Trialability:** Medium owner commitment; large design/const commitment
- **Observabiliy:** Correlates well with performance indicators
Systems-based Measurement

• Required info:
  – Inputs and outputs
  – Sources and sinks

• Validation:
  – Simulation models
  – Real-time tracking

• Outcomes:
  – Isolating and fixing problems can be tough
  – Subsystem synergies can improve overall performance

• Relative Advantage: High utility for custom systems/variable investment

• Compatibility: Requires additional tracking

• Complexity: May require new data sources

• Trialability: High commitment and cooperation required

• Observability: May or may not correlate well with public indicators
Conclusions

• Simpler approaches can ultimately be counterproductive
• Measurement approach should be matched to desired use of results
• More complex approaches can be customized to fit client needs
• Future work:
  – Human/organizational context of decisions
  – Defining new types of failure modes for CIS
Questions?

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