Defining Sustainable Power

Leveraging a Microgrid Approach
DEFINING SUSTAINABLE POWER

Sustainable design and assessment systems like LEED and PEER™ transform industries and stimulate innovation:

- Sustainable performance and design criteria and language
- Make the business case
- Recognition
- Uncover hidden value
- Feasibility & sensitivity
- Performance specification
- Verify results and benefits
WHERE TO START?
MICROGRID APPROACH

Buildings ➔ Microgrids ➔ Utility ➔ ISO

- Cities/Utilities
- Private – campus, developments, network of buildings
Microgrids connect buildings to provide sustainable power, as well as, key customer and grid services.

**Capabilities**
- Islanding
- Renewable generation
- Demand reduction
- District energy
- Load shifting
- Auto-restoration

**Performance Outcomes**
- 50% Outages
- 50% Capital waste
- 50% Energy waste
- 25% Peak demand
- 50% Emissions
DEFINING SUSTAINABLE/SECURE POWER

Performance Excellence in Electricity Renewal™

**ENERGY EFFICIENCY AND ENVIRONMENT**
Promote energy efficiency and environmental responsibility

**ENABLING CUSTOMER ACTION**
Engage customers as partners and investors in sustainable power

**SECURITY**
Ensure the reliability, power quality and safety of electricity

**RELIABILITY, POWER QUALITY, AND SAFETY**

**OPERATIONAL EFFECTIVENESS**
Identify and eliminate waste to get more value out of investments

**PEER**
# Sustainable Power Building Blocks

<table>
<thead>
<tr>
<th>Programs &amp; Processes</th>
<th>Metrics</th>
<th>Capabilities</th>
<th>Prerequisites</th>
<th>Customer Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Financing</td>
<td>DR Capability</td>
<td>Islanding</td>
<td>Dyn. Price</td>
<td>C</td>
</tr>
<tr>
<td>Aggregation</td>
<td>Value/Gap</td>
<td>Black Start</td>
<td>Data Privacy</td>
<td>O</td>
</tr>
<tr>
<td>Identify &amp; Eliminate Waste</td>
<td>MAIFI</td>
<td>Solar</td>
<td>Improvement Plan</td>
<td>R</td>
</tr>
<tr>
<td>Risks Analysis</td>
<td>PQ</td>
<td>Looping</td>
<td>Cyber Security</td>
<td>E</td>
</tr>
<tr>
<td>Procurement</td>
<td>CO₂/NOₓ/SOₓ</td>
<td>Dist. Energy</td>
<td>Safety</td>
<td></td>
</tr>
<tr>
<td>Financing</td>
<td></td>
<td>CHP</td>
<td>Local Air Permit</td>
<td></td>
</tr>
</tbody>
</table>

- **Prerequisites**: Safety, Cyber Security, AMI/SCADA, Procurement, Financing
- **Capabilities**: Net Metering, Supply Choice, Load Shift, Ancillary Services, Black Start, Islanding, Solar
- **Metrics**: DR Capability, Value/Gap, MAIFI, PQ, % Ren. & CHP, Load Curve, SAIDI/SAIFI, SEI
- **Customer Requirements**: C, O, R, E
Value and Gap

Quantify value of service that project microgrid provides for the bulk grid.

Quantify the gap in performance, provide justification for investment and path for improvement.

**Baseline**
PERFORMANCE

**Upper Limits**
OF PERFORMANCE

**Definition for upper limits of grid performance**

The ultimate measure of perfection is that our electric system does no harm – economic, social or environmental.

- Paul O’Neill

**Value**

**GAP**

**Improved**
PERFORMANCE

**Baseline Performance**

Definition for upper limits of grid performance

The ultimate measure of perfection is that our electric system does no harm – economic, social or environmental.

- Paul O’Neill
CLOSING THE GAP = COST SAVINGS

**OPERATIONAL EFFECTIVENESS CATEGORY**

**Estimated Gap**

**Baseline**
- Load duration curve
- Dynamic Pricing

**Load Response**
- Thermal Storage
- Load Automation

**Energy Efficiency**
- CHP
- Solar PV

**Improved Rate**
- Improved
- Estimated Gap

**Upper Limits**
- Achieved Value
## Value (50,000 MWh/10MW)

<table>
<thead>
<tr>
<th>Performance Criteria</th>
<th>Baseline</th>
<th>Current</th>
<th>Factors</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price, $/MWh</td>
<td>45</td>
<td>30</td>
<td>Real-Time</td>
<td>$750,000</td>
</tr>
<tr>
<td>Demand Charge</td>
<td>10</td>
<td>7</td>
<td>$14/kW/mo</td>
<td>$504,000</td>
</tr>
<tr>
<td>Source Energy, MMBtu/MWh</td>
<td>9.2</td>
<td>5.3</td>
<td>$4/ MMBtu</td>
<td>$780,000</td>
</tr>
</tbody>
</table>

$2,034,000
RELIABILITY PERFORMANCE CRITERIA

Capabilities

• Islanding
• Redundant Supply
• Redundant Distribution
U.S. Interruption Minutes by Utility

**Legend**
- NW
- MW
- SW
- South
- Mid-Atlantic
- NE
- SE
- Other

**Data source:** IEEE 2011, http://grouper.ieee.org/groups/td/dist/sd/doc/

- Average = 310
- UT Austin = 9.7
- 3rd Quartile
- 4th Quartile

1 day = 1,440 minutes
Microgrid Capabilities - Reliability

0. Baseline
1. Undergrounding
2. Distribution Redundancy
3. Alternative Sources of Supply
4. Islanding
Islanding Capability

- Life Safety Gen
- Chilled Water Storage
  - 4 Million Gallons
- 56 MW of Steam Turbines
- Base-load Tri-generation and district energy (in lieu of boiler)
- One 34 MW and one 43 MW gas turbine with inlet cooling

Number of operating hours at the demand level

8760
Power Oases Certification

• Life-safety diesels is not sufficient (i.e. immediate response – hours, egress emergency lights)

• Power Oases will be recognized for providing critical community and grid service

• Receive credit for powering entire building or campus for weeks to assist with recovery services

• Receive credit for providing grid service during normal grid operation (e.g. price/demand response, power quality)

• Demonstrate protection from threats

• Police/Fire
• Medical Center
• Assisted Living
• Schools
• Communications
• Shelters
• Hotels
• Fuel Stations
• Water, Waste Water, Flood Protection
• Residential Towers
## Power Quality Measurements

### CRITERIA DEFINITION

Metrics that describe the electric power that drives an electric load and the load’s ability to function properly.

<table>
<thead>
<tr>
<th>Event Type</th>
<th>Cause</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transients</td>
<td>discharge, load or capacitor switching</td>
<td>filters, isolation transformers</td>
</tr>
<tr>
<td>Oscillatory Transients</td>
<td>line/cable switching, capacitor or load switching</td>
<td>Surge Arrestors, filters, isolation transformers</td>
</tr>
<tr>
<td>Sags / Swells</td>
<td>Remote systems, faults</td>
<td>Ferroresonant transformers, energy storage</td>
</tr>
<tr>
<td>Undervoltage/Overvoltage</td>
<td>Motor starting, load variations, load dropping</td>
<td>Voltage regulators, Ferroresonant transformers</td>
</tr>
<tr>
<td>Harmonic Distortions</td>
<td>Nonlinear loads, system resonance</td>
<td>Active or passive filters, transformers with cancellation</td>
</tr>
<tr>
<td>Voltage Flicker</td>
<td>Intermittent loads, motor starting, arc furnaces</td>
<td>Static VAR compensator</td>
</tr>
</tbody>
</table>

### Rule of Thumb

Keep Impact Loads $\Delta \text{VAR} < 15\% \text{ VA}_{\text{short_circuit}}$

- Critical to digital processes
- Delicate manufacturing equipment
- Sensitive testing and industrial processes
RISK MITIGATION CRITERIA

Failure Modes and Effects Analysis (FMEA)

<table>
<thead>
<tr>
<th>Item</th>
<th>Failure</th>
<th>Cause</th>
<th>Local Effect</th>
<th>System Effect</th>
<th>Probability</th>
<th>Severity</th>
<th>Detection</th>
<th>Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Substation #2 Overcurrent protection device opens on high load</td>
<td>Overcurrent protection device opens on high load</td>
<td>High loads on Circuit 9 due to recent additional loads added</td>
<td>Circuit #9 automatically switches to supply from Substation #4</td>
<td>Added load on Substation #4 exceeds capacity and trips regional protection device for area-wide black-out</td>
<td>Moderate</td>
<td>Recent load additions have increased this probability</td>
<td>HIGH Commercial customers value their operations at $15 million per outage.</td>
<td>Power readings at Substation #2 for Circuit #9.</td>
</tr>
</tbody>
</table>

- Identify ALL possible failures in every component, assembly and sub system of the system.
- Determine how to Mitigate the failure
- Prioritize list and take action

Power System Reliability Engineering References:
- IEEE 3006 Series  Power System Reliability (formerly IEEE gold Book)
- IEC 60812 Analysis techniques for system reliability - Procedures for FMEA
## Reliability Summary and Score

### UT Austin Results

### Reliability, Power Quality and Safety

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Max Points</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sustained Interruptions</td>
<td>25</td>
<td>23.0</td>
</tr>
<tr>
<td>Momentary and Other Interruption Indices (bonus criteria)</td>
<td>10</td>
<td>0.0</td>
</tr>
<tr>
<td>Capabilities for Reliability</td>
<td>55</td>
<td>43.0</td>
</tr>
<tr>
<td>Power Quality Improvement (bonus criteria)</td>
<td>10</td>
<td>5.0</td>
</tr>
<tr>
<td>Risk Mitigation</td>
<td>20</td>
<td>14.0</td>
</tr>
<tr>
<td>Innovations (bonus criteria)</td>
<td>5</td>
<td>4.5</td>
</tr>
<tr>
<td><strong>Core Points</strong></td>
<td><strong>100</strong></td>
<td><strong>80.0</strong></td>
</tr>
<tr>
<td><strong>Bonus Points</strong> (Limited to 15 points)</td>
<td><strong>15</strong></td>
<td><strong>9.5</strong></td>
</tr>
<tr>
<td><strong>Subtotal (Limited to 100 points)</strong></td>
<td><strong>89.5</strong></td>
<td></td>
</tr>
</tbody>
</table>

### Highlights:
- 3 year average ASAI of 0.999982
- Distribution Looping and Alternative Feeds
- Islanding Capability
- Power Resiliency for Essential Services
- Risk Mitigation – Moved critical pumps above flood plain
Reliability Benefits – Ice Calculator

UT Austin:

- 50,000 residential customers
- 155 commercial customers
- SAIDI and SAIFI based on three year average

<table>
<thead>
<tr>
<th>Reliability Savings</th>
<th>Baseline</th>
<th>UT Austin</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAIDI</td>
<td>310.0</td>
<td>9.7</td>
</tr>
<tr>
<td>SAIFI</td>
<td>1.600</td>
<td>0.040</td>
</tr>
<tr>
<td>LBNL Reliability Cost ($)</td>
<td>$ 1,523,538</td>
<td>$ 48,278</td>
</tr>
<tr>
<td>Reliability Savings ($)</td>
<td>$ 1,475,260</td>
<td>$ 1,475,260</td>
</tr>
</tbody>
</table>
ENERGY EFFICIENCY AND ENVIRONMENTAL Performance Criteria

• Efficiency (SEI) \( \text{MMBtu/MWh} \)

• Emissions
  \(- \text{CO}_2\text{e, NOx, SO}_2 \) \( \text{lb./MWh} \)

• Water \( \text{gal/MWh} \)

• Solid Waste \( \% \text{ Recycled} \)

Capabilities:

• Local clean power (e.g. solar, cogeneration)

• Renewable energy credits, REC’s

• Environment improvements (e.g. aesthetics)
Energy Efficiency

Source Energy Intensity (MMBtu/MWh) by State

UT Austin = 5.5

Texas = 9.2
## Environmental Metrics and Benefits

<table>
<thead>
<tr>
<th></th>
<th>United States</th>
<th>Texas (benchmark)</th>
<th>UT Austin</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CO₂ Intensity</strong></td>
<td>1391</td>
<td>1565</td>
<td>775</td>
</tr>
<tr>
<td>(lb/MWh)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>NOₓ Intensity</strong></td>
<td>1.37</td>
<td>1.12</td>
<td>1.29</td>
</tr>
<tr>
<td>(lb/MWh)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>SO₂ Intensity</strong></td>
<td>2.77</td>
<td>2.18</td>
<td>0.02</td>
</tr>
<tr>
<td>(lb/MWh)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Water Usage</strong></td>
<td>487</td>
<td>332</td>
<td>106</td>
</tr>
<tr>
<td>(gal/MWh)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Waste</strong></td>
<td>55.3</td>
<td>69.9</td>
<td>100</td>
</tr>
<tr>
<td>(% Recycle)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Benefits

- Energy Efficiency Savings Equivalent to 12,000 Net Zero Homes
- CO₂ Savings Equivalent to taking 26,500 automobiles off the road
LEVERAGING PROCUREMENT EXAMPLE

**Illinois Power Agency Default Electricity Mix**
- **NUCLEA**: 35%
- **COAL**: 43%
- **WIND**: 18%
- **HYDRO**: 1%
- **BIOMASS**: 2%
- **SIMPLE CYCLE NATURAL GAS**: 1%

**Chicago Electricity Mix**
- **WIND**: 5%
- **COMBINED CYCLE NATURAL GAS**: 95%

**Energy Efficiency and Environment Methodology**
Chicago CCA Energy Efficiency Benefit

ENERGY CONSUMED

BEFORE ~ 13,000,000 MWh_s (SEI 10.5)
AFTER ~ 9,200,000 MWh_s (SEI 7.5)
SAVINGS ~ 3,800,000 MWh_s

SEI Ratio = SEI / 3.4
MWh_{source} = SEI Ratio * MWh_{e}

SEI RATIO

3 : 1
2 : 1

units of input fuel to deliver one unit of electricity
OPERATIONAL EFFECTIVENESS
MAKING THE BUSINESS CASE

Capabilities

• Load Curve
• Demand Response
• Price Response
Load Duration % of Peak = \( \frac{\text{Total annual electricity purchased kWh}}{\text{Peak purchased kWh} \times 8760 \text{ hours}} \)

Baseline Calculation

Total Purchased: 200,000 MWh
Peak Purchased: 65 MW

Load Duration % of Peak:
\( \frac{200,000}{(65 \times 8760)} = 35\% \)
**CAPABILITIES FOR OPERATIONAL EFFICIENCY CRITERIA**

**Load Duration Curve – Improved**

**Improvement Calculation**

**GO TO: EXERCISE SHEET**

REDUCED Peak Purchase: 65 - 40 = 25 MW

New Energy Purchase: 118,000 MWh

Load Duration % of Peak:

\[
\frac{118,000}{(25 \times 8760)} = 54\%
\]

**NEW PEAK DEMAND**
Demand Response Capability

\[
\text{Demand Response Capability (\%) = \frac{\text{Total DR capacity MW}}{\text{Peak annual demand MW}}} \]

**Improvement Calculation**

Peak Annual Load Demand: 65 MW
Steam Turbine + Storage: 25+ MW
CHP Turbine Capacity: 25+ MW
Demand Response Capability: \((25 + 25) / 50 = 100\%\)
Operations Summary and Score

UT Austin Results

Operational Effectiveness

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Max Points</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operational Capability (Load Curve &amp; DR)</td>
<td>83</td>
<td>62.0</td>
</tr>
<tr>
<td>Actual Estimated Value</td>
<td>26</td>
<td>23.0</td>
</tr>
<tr>
<td>Estimated Gap (bonus criteria)</td>
<td>8</td>
<td>4.0</td>
</tr>
<tr>
<td>Innovations (bonus criteria)</td>
<td>5</td>
<td>4.3</td>
</tr>
<tr>
<td>Core Points</td>
<td>100</td>
<td>79.0</td>
</tr>
<tr>
<td>Bonus Points</td>
<td>22</td>
<td>14.3</td>
</tr>
<tr>
<td>Total (Limited to 100 points)</td>
<td></td>
<td>93.3</td>
</tr>
</tbody>
</table>

Highlights:
- 78% Load Duration Percent of Peak
- 88% System Energy Efficiency
- Substantial Value in Demand Charge savings and Reliability
- Primary Opportunity Cost is associated with increasing local renewables
Customer Capability = Grid Support

Microgrid Grid Services
- Real-time & day-ahead response
- Demand response
- Capacity
- Voltage support
- Reactive power
- Frequency
- Utility event support

Number of operating hours at the demand level: 8760
CUSTOMER ENGAGEMENT

- AMI - Access to data
- Dynamic pricing
- Interconnect
- Net metering
- Incentives

- Contribution
  - DR
  - Local Gen
  - Services
Managing Demand with Storage

Load Requirements for hot day in August

- **Load shifted to lower price**
- **Peak reduced**

Same amount of energy is sold while peak is reduced by 25%

- **Thermal Storage**
- **Baseline**
- **Time-of-Use**
Perfecting Power at University of Texas

87% System Efficiency

Combustion Turbine

Steam Turbine

Chillers

Chilled Storage

Electricity

Chilled Water

Campus

Natural Gas

Recovered Heat

Cleaner Fuel

Recovered Heat

Load Balancing

Steam

Image source: http://philosophy.commons.gc.cuny.edu/files/2012/12/austin.jpg

### Customer Summary and Score

#### UT Austin Results

**Enabling Customer Action**

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Max Points</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tools and Information</td>
<td>10</td>
<td>0.0</td>
</tr>
<tr>
<td>Standard Processes and Policies (N/A for campus)</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>Programs and Incentives</td>
<td>5</td>
<td>0.0</td>
</tr>
<tr>
<td>Customer Contribution</td>
<td>85</td>
<td>60.0</td>
</tr>
<tr>
<td>Innovations (bonus criteria)</td>
<td>20</td>
<td>19.0</td>
</tr>
</tbody>
</table>

**Core Points**

<table>
<thead>
<tr>
<th></th>
<th>Max Points</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100</td>
<td>60.0</td>
</tr>
</tbody>
</table>

**Bonus Points**

<table>
<thead>
<tr>
<th></th>
<th>Max Points</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20</td>
<td>19.0</td>
</tr>
</tbody>
</table>

**Subtotal** (Limited to 100 points)

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>79.0</td>
</tr>
</tbody>
</table>

### Highlights:

- Local Clean Generation from high efficiency CHP
- Local Demand Response Capability from excess local generation capacity
- Several innovations including lighting reduction program and software that maximizes chiller and generation efficiency
Overall UT Austin Score: 356 / 400

Energy Efficiency and Environmental

94

Reliability, Power Quality and Safety

90

Operational Effectiveness

93

Enabling Customer Action

79
LEVERAGING VALUE/GAP TO VERIFY/MAKE THE BUSINESS CASE

TOTAL GAP = $3,850,000
- Reliability OC $50,000
- Energy Waste OC $3,630,000
- Demand Charge OC $170,000
- Real Time Price OC $0

TOTAL VALUE = $13,400,000
- Reliability Value $1,500,000
- Energy Efficiency $6,500,000
- Local Generation Savings ($3,100,000)
- Demand Charge $8,500,000

**Site Characteristics**
- **Baseline**
  - Facility Demand: 51 MW
  - Facility Usage: 355,000 MWh
  - Electricity Supply/T&D: $75/MWh
  - Demand Charge: $14/kW/month

**Performance Indicators**

<table>
<thead>
<tr>
<th>Performance Indicators</th>
<th>Baseline</th>
<th>Current</th>
<th>Upper Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEI, MMBtu/MWh</td>
<td>9.2</td>
<td>5.3</td>
<td>3.0</td>
</tr>
<tr>
<td>Local Generation, MWh</td>
<td>0</td>
<td>348k</td>
<td>355k</td>
</tr>
<tr>
<td>Demand Charge/ MWh</td>
<td>$25</td>
<td>$0.50</td>
<td>$0</td>
</tr>
<tr>
<td>SAIDI, min</td>
<td>310</td>
<td>9.7</td>
<td>0</td>
</tr>
</tbody>
</table>
PEER USES

- Build a **common language** and shared vision
- Make the **business case** for investment
- **Promote** great performance **and reveal hidden value**
- **Benchmark** to an industry standard
- Create innovative **conceptual designs**
- Develop **performance based specification and policy**
- Measure and **verify benefits/financial projections**
- Establish a **competitive differentiation**