Connected Communities Examples: Spotlight on Reynolds Landing

May 4, 2020
DOE Intends to Invest $42 Million into “Connected Communities”

Connected Community:
A group of grid-interactive efficient buildings (GEBs) with diverse, flexible end use equipment that collectively work to maximize building and grid efficiency without compromising occupant needs and comfort.

Funding opportunity would enable regional GEB communities to share research results and lessons learned on projects that increase grid reliability, resilience, security and energy integration well into the future.

Demonstrate and evaluate the capacity of buildings as grid assets by flexing load in both new developments and existing communities across diverse climates, geography, building types and grid/regulatory structures.

Share research results and lessons-learned on projects that improve energy affordability, increase grid reliability, resilience, security and energy integration.
Webinar Agenda

• Welcome & Introductions
• Overview of Relevant Field Testing Projects
• Alabama Power Smart Neighborhoods
• Q&A
One note before we get started....

Your screen should look something like this.

Connected Communities
DOE Investment in Efficient, Smart, Flexible Buildings of the Future

Click here to open chat window

Select All Panelists to send a chat
Current BTO Field Testing Projects

• Smart Neighborhoods: Birmingham, AL & Atlanta, GA
• Post House: Evansville, IN
• AI-Driven Smart Community: Basalt, CO
• Grid-interactive Water Heaters: Pacific Northwest
• Transactive Campus: Richland & Spokane, WA; Toledo, OH
• Economic Dispatch: New York
• GT-Flex: Atlanta, GA
Post House: Evansville, IN

Demand Flexibility Strategies
• Apartment units aggregated for load-shed DR program
• Response is optimized using HVAC, connected lighting, water heating, and smart appliance loads

52 multifamily units in two mixed-use buildings (2nd building is control)

EE measures: Cold-climate heat pumps, Advanced air sealing, Connected water heater and appliances, LED lighting

DERs: Rooftop solar, EV chargers

Goals and Metrics
• Energy: Savings per unit and by measure type
• Load: Average and peak load reduction, DR snapback
• Occupant experience: Comfort, opt-out rate, satisfaction, and experience with smart home devices
• DER: PV.smart inverter performance
• Cost-effectiveness
AI-Driven Smart Community: Basalt, CO

Demand Flexibility Strategies
- Home energy management system uses model-predictive control of home load, responds to aggregator signals
- Community Aggregator module coordinates all the homes collectively; interacts with utility to get requests such as demand response

Goals and Metrics
- Energy: 35% better than code
- Load: Distribution feeder over-voltage reduction, 10% peak demand reduction, daily load shift
- Resilience: Days of operation with no net grid exchange
- Occupant comfort and experience: Indoor temperatures, satisfaction survey

27 new-construction townhomes

EE measures: High-efficiency homes, Cold-climate heat pumps, Heat pump water heater, Connected thermostats

DERs: Rooftop PV, Battery storage, EV chargers, Virtual microgrid

Source: NREL
Transactive Campus: Richland, Spokane WA; Toledo, OH

4-8 existing commercial buildings on 3 campuses; Pilot: tens of buildings in new EcoDistrict in Spokane, WA

*EE measures*: Agent-based transactive controls for existing HVAC, lighting

*DERs*: PV, battery and thermal storage, EV chargers

**Demand Flexibility Strategies**
- Efficiency optimization and fault diagnostics at individual building
- Transactive controls respond to grid prices and signals at campus or feeder level

**Goals and Metrics**
- Energy: Consumption and bill savings, per building and for campus
- Load: Coincident and non-coincident peak load reduction, distribution feeder congestion reduction
- Indoor environmental quality: indoor temperature and illuminance
- Occupant satisfaction survey
- Scalability: Deployment and integration time and effort
GT-FLEX: Atlanta, GA

12-18 existing education buildings on Georgia Tech campus

EE measures: Optimized controls for existing HVAC system, central plant upgrade (future)

DERs: Battery and thermal energy storage (future)

**Demand Flexibility Strategies**

- Efficiency optimization for individual buildings and central plant
- Pre-programmed strategies for optimal response for grid services (real-time pricing or demand response)

**Goals and Metrics**

- Energy: Utility bill savings, greenhouse gas reductions
- Load: Peak load reduction, load shift energy, for individual buildings and campus, DR program incentives
- Cost-effectiveness: return on investment

Source: GA Tech
Common Project Characteristics

- Multiple buildings (20-50 residential buildings/units, 5-10 commercial buildings)
- Energy efficiency features (controls upgrade at minimum)
- Distributed energy resources (one or more)
- Coordinated optimization for grid services
- Metrics: Annual energy consumption, Non-coincident peak load reduction
- Data collected: Interval meter readings, smart tstat & appliance data, weather, DER generation/usage, customer/occupant perceptions
Differing Project Characteristics

- Building sector (residential/commercial/mixed)
- EE measure mix (controls and/or hardware)
- DER type and scale (e.g., individual vs. shared)
- Optimization algorithms & coordination methods
- Grid services provided (peak reduction for DR, load shift, distribution voltage support, etc.)
- Resiliency (presence of microgrid)
- Business model (which entities develop, own, and operate different parts of the project)
- Metrics: Customer energy bills, Ease of deployment, Cost-effectiveness, IEQ
- Data collected: Building end-use, Feeder load, Cost
What DOE is Looking For

✓ Teams of strategic stakeholders
✓ Sets of multiple buildings
✓ Multiple DER integration
✓ Ability and willingness to share data
✓ Diversity of projects (geography, building type, climate, vintage, regulatory)

What We Hope to Achieve

• Measured impact of building as grid assets
• Solutions that address diverse grid needs that can be scaled in size and in other communities
• Input from occupants on impact and comfort level
• Demonstrated new business models for demand flexibility and DER coordination and optimization
• Online solutions center on best practices

Request for Information on Connected Communities

Visit eere-exchange.energy.gov or Scan the QR Code for the Request for Information:
“DE-FOA-0002291: Request for Information: Funding Opportunity Announcement 2206: “Connected Communities”

Send RFI responses to: CCPilotsRFI@ee.doe.gov
Alabama Power
Smart Neighborhood®

**Research & Development**

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Greg Sewell
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Distributed Energy Resources

Reynolds Landing
Objective
Design and build a first-of-a-kind connected community to understand and prepare for evolving customer expectations and future grid needs.

Scope
Demonstrate distributed energy resource (DER) use cases optimizing cost, reliability, and environmental impact with a community-scale microgrid.

Demonstrate 62 high-performance homes with connected home technologies providing an improved customer experience.

Demonstrate buildings-to-grid integration with real-time utility-to-customer interaction.
### Opportunity space

<table>
<thead>
<tr>
<th>Facilities or large critical loads require microgrids to cost-effectively meet continuity of operations and resilience requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing electric grid lack methods for managing on-site generation low voltage (building), medium voltage (distribution), and high voltage (transmission) systems</td>
</tr>
<tr>
<td>Buildings have the potential to reduce their consumption by 20%-30% through advanced sensors and controls</td>
</tr>
<tr>
<td>Significant advantages in co-optimizing microgrid generation &amp; neighborhood-scale consumption/residential loads</td>
</tr>
<tr>
<td>Significant need in scalable control and automation techniques for improving resilience and situational awareness</td>
</tr>
</tbody>
</table>

5.5 million commercial, 118 million residential, projected to be 80% of load growth through 2040
Overview (Centralized Theme, Alabama Power)

62 Residential Buildings

Alabama Power: Microgrid

- **PV System**: 420kW
- **Energy Storage System**: 250kW, 681kWh
- **Generator**: 400kW

Alabama Power: Neighborhood

- October 2017: Construction began
- December 2017: Entire Microgrid Completed
- May 2018: Entire Neighborhood Completed
- August 2018: Deployment of Full Neighborhood Water Heater Control
- October 2018: Deployment of Full Neighborhood HVAC Control
- November 2018: Integration of CSEISMIC Price Signal as Driver
- February 2019: Started running alternating on and off weekly against different study use cases.
Technical Approach

- Quantify the value to the grid of operating microgrid with controllable loads.
- Develop and demonstrate control algorithms for generating macroscopic load shapes.
- Evaluate price/incentive signal design with a microgrid and controllable loads.
- Develop scalable system-level architecture for performing control at scale.

Data

Situational Awareness

Analytics
Understanding homes are not primarily a grid asset

It is a balancing act to effectively manage resource efficiency and homeowner comfort

- **Changing philosophy on what supplies our generation**
  - Generation is moving from centralized plants to distributed
  - Integrating resources and coordinating resources is becoming more important (interoperability is a challenge)
  - Increased renewable generation

- **Increasing need for resilience of electrical system**
  - Establishing and utilizing residential building flexibility to support the grid.
  - Ensuring that customer privacy is maintained while supporting grid needs.
  - Improving system resiliency under threats of systems outages.
Multi-level of Optimization

Grid Level
- Alabama Power Interval Pricing Signal

CSEISMIC
- New Optimization Signal, Sent to Home Level Optimizer

Individual Home Level
- External Data Inputs
  - Weather
  - Pricing Signal
- Learned/Built Inputs
  - Simple Thermal model
  - Comfort Constraints
  - Equipment Performance

Implement Control Strategy
- Create Schedules & Setpoints
Models drive optimization

Residential-Level Optimization

- Equipment Models
- Home Model
- Energy Optimization
- Home Energy Management
- Weather
- Sub-Metering
- Selfpoints

Neighborhood-Microgrid Optimization

- 24 Hour Price Curve
- Iteration #
- Acceptance
- Optimize Price Signal
- Micro-Grid
- Residential
- 24 Hour Load Curve
- Iteration #
- Optimize Predict Load

- Capacity Management
- Adaptive Load Shape
- Reliability response
- Regulation response
Load Side Optimization

- Requires different data sources in near real-time:
  - Device measured data
  - Weather forecasting
  - Predicted behavior
- Optimization uses model predictive formulations for HVAC and water heater
- Comfort bands based on user input thermostat schedules and deadband.
- Driven by price signal from microgrid controller.
- Utilizes learning and predictions to assess future operations.
Optimization and Control

\[
\text{Objective} = \min \left\{ WP \sum_{t=0}^{T} Pelec(t) \cdot Price(t) + WD \sum_{t=0}^{T} Discomfort(t) \right\} \\
\quad \text{subject to : } \sum_{t=0}^{T} T_{\text{water}}(t) - T_{\text{max}}(t) \geq 0 \\
\quad \sum_{t=0}^{T} T_{\text{min}}(t) - T_{\text{water}}(t) \geq 0 \\
\quad \sum_{t=0}^{T} T_{\text{indoor}}(t) - T_{\text{max}}(t) \geq 0 \\
\quad \sum_{t=0}^{T} T_{\text{min}}(t) - T_{\text{indoor}}(t) \geq 0 \\
\quad WD = 80 \\
\quad WP = 1
\]
Water Heater Example in Detail

Objective Function:

\[
\min \sum_{t=0}^{T} W_P + \sum_{t=0}^{T} D_{WH}^P + W_{HP} \sum_{t=0}^{T} D_{HP}^P + W_{EL} \sum_{t=0}^{T} D_{EL}^P + W_{UP} \sum_{t=0}^{T} D_{UP}^P
\]

Constraints:

Heat Pump:

\[
Q_{t}^{HP} = \left\{ \begin{array}{l}
\leq 1500 - 8.0 \cdot T_{t}^{W} \\
\leq 3500 \cdot b_{t}^{HP} \\
\geq 0 \\
\end{array} \right.
\]

Electric:

\[
Q_{t}^{EL} = 5000 \cdot b_{t}^{E}
\]

Total:

\[
Q_{t}^{T} = Q_{t}^{HP} + Q_{t}^{E}
\]

Mode (On/Off) Options:

\[
1 \geq b_{t}^{E} + b_{t}^{HP} + b_{t}^{OFF}
\]

Tank Model:

\[
T_{t}^{W} = \frac{T_{t}^{W} \sum_{i=0}^{i=T} T_{i}^{W} + Q_{t}^{W} \sum_{i=0}^{i=T} Q_{i}^{W} \Delta t}{C_{W} \sum_{i=0}^{i=T} R_{W}} + T_{t}^{W}
\]

Comfort Model:

\[
\left\{ \begin{array}{l}
D_{t}^{HP} \geq T_{t}^{minHP} - T_{t}^{W} \\
D_{t}^{EL} \geq T_{t}^{minE} - T_{t}^{W} \\
D_{t}^{UP} \geq 0, \text{ heat pump} \\
D_{t}^{UP} \geq 0, \text{ electric} \\
D_{t}^{UP} \geq 0, \text{ turn off}
\end{array} \right.
\]

Output:

Mode Setpoint
Agent Framework

Agent based framework to support autonomous integration and negotiation of load resources with a microgrid controller.

<table>
<thead>
<tr>
<th>Agent</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Home Interface</td>
<td>Data Pass through and collector of optimization and electrical consumption projections for Aggregator agent</td>
</tr>
<tr>
<td>HVAC Interface</td>
<td>Translates HVAC decisions and status to vendor API</td>
</tr>
<tr>
<td>Water Heater Interface</td>
<td>Translates Water Heater decisions and status to vendor API</td>
</tr>
<tr>
<td>HVAC Optimizer</td>
<td>Utilizes building specifications, forecasted weather data, building parameter data, price forecast, and HVAC status data to optimally schedule HVAC and provide expected electrical consumption.</td>
</tr>
<tr>
<td>Water Heater Optimizer</td>
<td>Utilizes predicted water consumption, price forecast, and Water Heater status data to optimally schedule Water Heater and provide expected electrical consumption.</td>
</tr>
<tr>
<td>SoCo Interface</td>
<td>Pulls data from Southern Company API which includes weather, building specifications, historical load measurements by circuit, device credentials, and historical data.</td>
</tr>
<tr>
<td>Learning</td>
<td>Utilizes data collected from SoCo stored data to perform predictions on hot water usage, internal heat loads, building parameters, etc.</td>
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</tbody>
</table>
Enterprise-scale Deployment

• An integrated system interacting with vendor API, SoCo API, and VOLTTRON Agents

• VOLTTRON allocates price signals to resources (loads) which optimize and provide total load projection

• This process iterates until Microgrid controller meets minimum convergence criteria.

• Real-time optimization driven by measurements and forecasts

• Optimizing and dispatching WH and HVAC units 62 homes
Integration with RES API

- API Managed by central gateway
- Several individually managed backend resources
- Gateway provisioned to handle 1M Requests/day
- RES Processes ~3M messages per 24hr. Period
- 14 API sets for REST based communications
- 4 Categories of functions to manage various backend activities
  - Security Management
  - Data capture
  - Data provisioning
  - Configuration management
- All external interactions managed through centralized API Gateway
Phased Testing Approach

**Laboratory**
- Simulation-based Testing
- Software as Deployed

**ORNL Yarnell Station**
- Unoccupied Research Home in West Knoxville
- Development Testing

**Southern Company Idea Home**
- Southern Company Development Environment
- Unoccupied Research Home at Reynold's Landing
<table>
<thead>
<tr>
<th>High Performance Homes</th>
<th>Managing Behind the Meter Assets</th>
<th>Identifying Revenue &amp; Rate Design Impacts</th>
<th>Understanding Renewable Energy Grid Integration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Changing Load Shapes</td>
<td>Energy Use Optimization</td>
<td>Informed Load Forecasting</td>
<td>Help meet 2050 Low-to-No Carbon Goal</td>
</tr>
<tr>
<td>Tighter envelope</td>
<td>Buildings as a resource</td>
<td>New building codes &amp; standards</td>
<td>New infrastructure needs</td>
</tr>
<tr>
<td>Advanced Building Energy Systems</td>
<td>Create load shapes</td>
<td>How to price energy in IoT future</td>
<td>Balance grid &amp; customer benefits</td>
</tr>
</tbody>
</table>
Smart Neighborhoods Are Energy Efficient
(reduce annual energy usage (kwh))

- Homes have been measured against the HERS Index:
  - AL Code Minimum Homes (e.g., 2015 IECC) achieve a HERS 70
  - Neighborhood Homes achieved HERS 45
  - Therefore, the Smart Neighborhood Homes are ~35% More Energy Efficient Than AL’s Code Minimum Homes.

- The conversion of the entire AL Residential Sector into Efficient Smart Construction will achieve significant energy and carbon savings.

<table>
<thead>
<tr>
<th>Projected Savings for AL Residential Conversion</th>
<th>EE Savings</th>
<th>CO2 Tons/Yr/Home Avoided</th>
<th>CO2 Tons/Yr Avoided</th>
<th>Equivalent cars removed from the road</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predicted from homes at HERS 45</td>
<td>35%</td>
<td>0.65tn</td>
<td>~820,000tn</td>
<td>~164,000 cars</td>
</tr>
<tr>
<td>Actual, measured home usage (from AMI Meter)</td>
<td>44%</td>
<td>0.79tn</td>
<td>~1,000,000tn</td>
<td>~200,000 cars</td>
</tr>
</tbody>
</table>

This data is derived from using EPA’s AVERT.
HVAC Peak Analysis

- With only 2°F flexibility of indoor temperature, **the optimization of HVAC can’t pre-cool to ride through a 6-hr peak.**
  - We are exploring shorter peak pricing events for increased grid benefits from HVAC peak reduction.
  - Water heaters may be better suited for longer duration events.

- Additional Observations:
  - Homeowners interact with their HVAC thermostat more frequently than WHs resulting in optimization being disabled more frequently.
  - ~50% of homeowners operate their smart thermostat in manual mode instead of using a programmed schedule.

- Observed 75-140W per HVAC peak power reduction (~15% reduction)

- HVAC Precooling before peak pricing

- Price Signal
WH Peak Analysis – Summer 2019

- Water heaters are better suited for longer duration events.

Additional Observations:
- **Water draw forecast is based on generalized, conservative patterns that vary significantly from actual usage** (see notes for more information).
- We observed that the water heaters ran in hybrid mode (e.g., electric resistant mode) more frequently than the simulations.
- Water heater energy consumption is higher due to maintaining higher water temperature and more aggressive heating to ensure occupants did not run out of hot water.
Price Driven Control

Quantify Grid Service Capability

Determine the additional value of continuous optimization vs. event driven DR

Ability to predict Homeowner Comfort/Convenience/Productivity

Forecasting Day-Ahead Cost is like predicting the weather

Planning tools use average data, which removes value

Device Capabilities enabled in APIs
Alabama – Significant Lessons Learned

• Significant load flexibility is available from residential loads
  – A coordinated control framework and customer education key to success
  – Reducing computational footprint is needed for seamless deployment
  – Potential exists for improvement – Current control settings are conservative

• Design of control-related application identified new requirements
  – Clouds-in-the-loop
  – Latency and Reliability
  – Data security and authentication
  – Format or content changes of the data from manufacturers’ APIs can cause disruption in operation.

• Training is required to educate homeowners on how to interact with their thermostat to achieve the best results (i.e., adjust the programmed schedule instead of setting a manual hold on the temperature) - Many users do not utilize schedules (HVAC) and as a result optimization is difficult

• Simultaneous Development, Deployment, and Data Analysis

• Energy and demand savings are not the same – shifting demand often requires using additional energy in the form of pre-heating or pre-cooling

• Shorter and/or more specific peaks allow for more significant demand impacts
Alabama – Significant Lessons Learned (Cont’d)

• Need for developing innovative rates or price structures to align customers and utilities
  • Dual-benefit for homeowners and utility
• Opportunities to scale these systems across utility for large-scale, aggregate impacts
  • A rich understanding of requirements - design, automation, deployment
• Differences in how these results translate into the existing housing stock with very different thermal and equipment characteristics
  • Automatic commissioning and learning of the energy usage
• What frequency of control is optimal to minimize impacts to the customer while providing grid benefits? (hourly, daily, etc)
  • Understanding customer adoption
Southern Company Smart Neighborhood Initiatives
Understanding tomorrow’s home today

Two first of a kind smart home communities at the intersection of energy efficiency, distributed energy resources & buildings to grid integration and the traditional utility model

- 46 townhomes
- Atlanta, Georgia
- Homeowner owned solar + storage
- Grid integration of solar, storage, HVAC, water heating & EV charging

- 62 single-family homes
- Birmingham, Alabama
- Utility owned, grid-connected microgrid
  - 330 kW solar
  - 680 kWh storage
  - 400 kW NG generator
- Grid integration of microgrid, water heating & HVAC

Major Research Partners
Electric Power Research Institute and U.S. Department of Energy’s Oak Ridge National Laboratory

Key Vendor Partners
LG Chem, Delta, Carrier, ecobee, Rheem, SkyCentrics, Flair, Vivint, Pulte Homes, Signature Homes

Key Results
Homes are 30-40% more efficient
EV makes up 15-20% of total usage
Successful microgrid islanding
New business opportunities deployed
Discussion