Integrated Energy Systems Research at ORNL

Presented by
Roderick Jackson, Ph.D.
Group Leader, Building Envelope Systems Research

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ORNL is DOE’s largest science and energy laboratory

- $1.65B budget
- 4,400 employees
- 3,000 research guests annually
- $500 million invested in modernization
- 179 R&D 100 Awards

- Nation’s largest concentration of open source materials research
- World’s most intense pulsed neutron source and a world-class research reactor

- World’s most powerful open scientific computing facility
- Nation’s most diverse energy portfolio
- Managing the billion-dollar U.S. ITER project
ORNL’s mission
Deliver scientific discoveries and technical breakthroughs that will accelerate the development and deployment of solutions in clean energy and global security, and in doing so create economic opportunity for the nation.

Signature strengths
- Energy and environmental sciences
- Computational science and engineering
- Materials science and engineering
- Neutron science and technology
- Nuclear science and technology
Over 60% of our energy is wasted — innovative science is needed to solve this problem

Source: LLNL. 2013. Data is based on DOE/EIA-0035(2013–05), May, 2013. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports consumption of renewable resources (i.e., hydro, wind, geothermal and solar) for electricity in BTU-equivalent values by assuming a typical fossil fuel plant "heat rate." The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 65% for the residential and commercial sectors, 80% for the industrial sector, and 21% for the transportation sector. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527
Maximize ORNL’s impact

- Enhance technology transfer
- Invigorate science through graduate research and education
Close coupling of basic and applied R&D can accelerate new energy technologies

This coupling is a defining characteristic of Oak Ridge National Laboratory
High Performance Scientific Computing

- Titan is the world-leading scientific computing facility
- Operating at 20 petaflops (fastest non-classified system in world)
- Focus on computationally intensive projects of large scale and high scientific impact
- Enabling scientific discovery
Energy and Environmental Sciences: Solving problems at the nexus of energy, climate, and security
The Energy and Transportation Science Division provides solutions to pressing energy challenges

Sustainable transportation

Energy efficiency in buildings

Advanced manufacturing
**R&D focus areas**

**Envelope:** Develop component technologies that are more resistant to heat flow, airtight, and moisture-durable than existing technologies

**Equipment:** Develop component technologies that deliver the same amenities while using significantly less energy than existing technologies

**System/building integration:** Verify that advanced component technologies deliver what they promise and are durable and reliable in real buildings
We Stand at a Key Point In Time

• Buildings are more efficient than ever
Maximizing Energy Efficiency in Homes

The Houses

- A public/private partnership to maximize cost effective energy efficient practices and technologies needed for zero energy buildings

- Four houses that demonstrate different strategies to achieving 50 to 60% energy savings relative to traditional new construction

- The four houses are unoccupied for the duration of a two-year field study. Occupancy for an average 3 bedroom home is simulated in the homes.
We Stand at a Key Point In Time

• Buildings are more efficient than ever

<table>
<thead>
<tr>
<th>Year</th>
<th>Residential Building Energy Code</th>
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<tbody>
<tr>
<td>1986</td>
<td>Baseline</td>
</tr>
<tr>
<td>2006</td>
<td>2006 IECC</td>
</tr>
<tr>
<td>2009</td>
<td>2009</td>
</tr>
<tr>
<td>2012</td>
<td>2012</td>
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</tbody>
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Energy Efficiency Level

- 20% in 1986
- 10% in 1994
- 0% in 1998
- 10% in 2004
- 15% in 2006
- 30% in 2009
- 15% in 2012

% Energy Savings

- 0%
- 10%
- 20%
- 30%
- 40%
- 50%
- 60%
We Stand at a Key Point In Time

- Buildings are more efficient than ever
- Cost of distributed generation is lower than ever

U.S. Distributed PV Installations (Actual and Projected)

Historical PV Prices
We Stand at a Key Point In Time

• Buildings are more efficient than ever
• Cost of distributed generation is lower than ever

ZERO non-renewable energy buildings could be a near term reality
Envision a Future...

where communities have full access to sustainable power where they need it, when they need it.

By integrating “scientific discoveries and technical breakthroughs” in energy systems through key ORNL strengths, we have the opportunity to improve the lives of people all over the globe for generations.
Buildings with Sustainable Power: Where They Need It, When They Need It

Cost effective, energy efficient buildings are required
Matching load to generation is a primary science and engineering challenge

- <15% of energy consumption occurs during peak PV generation
- Uncertainty increases complexity
- Weather and occupancy patterns
- Additional generation, storage, and building energy management solutions are needed
Matching load to generation is a primary science and engineering challenge.
Science and engineering advances: Many opportunities exist

- Building load flexibility
- Building load factor
- Building peak load
- Storage energy density
- Storage power density
- Generation variability
- Generation power capacity

Theoretical limit
State of the art
System optimization is required for cost-effective integrated energy systems
Task 1: Advanced Heat Engine Generators

Demonstrate the potential of advanced heat engine generator (HEG) systems to generate power for vehicles and buildings.

Task 1: Advanced Heat Engine Generators

Building/transportation sized HEG

Vehicle demonstration

HEG system design: Sensitivity analysis

Additive manufacturing
Task 2: Ground-Level Integrated Diverse Energy Storage (GLIDES)

Develop a unique, low-cost, high round trip efficiency storage technology for building applications

<table>
<thead>
<tr>
<th>Key advantages</th>
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<tbody>
<tr>
<td>Simple, low cost (&lt;$80/kWh-e)</td>
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<tr>
<td>Accepts different energy sources</td>
</tr>
<tr>
<td>Round-trip efficiency: 82% (modeled)</td>
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</tbody>
</table>
Task 3: Flexible and Scalable Integrated Energy Systems Control (IESC)

Demonstrate integrated energy systems control of Flexible Research Platform (FRP1), HEG, and GLIDES.
Task 4: Demonstration of Use-Inspired Basic Research

![Graph comparing energy density to power density for different storage methods: Capacitors, Electrochemical Capacitors (Supercapacitors), Batteries, Fuel Cells.](presentation_image)
Demonstration of Use-Inspired Research: 2D Capacitors

<table>
<thead>
<tr>
<th>Quest for fundamental understanding</th>
<th>Basic research</th>
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</thead>
<tbody>
<tr>
<td>Consideration of use</td>
<td>Applied research</td>
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Graphene
BN
Graphene
Let's Talk