ET Staff: Technology Managers

Jim Brodrick
(Solid-State Lighting)

Tony Bouza
(HVAC/WH/Appliances)

Karma Sawyer & Marc LaFrance
(Windows/Envelope)

Marina Sofos
(Sensors/Controls)

Amir Roth
(Building Energy Modeling)

Karma Sawyer
(Technology Analysis & Commercialization)

Sven Mumme
(Technology Commercialization)
ET Staff: Technical Project Officers, Fellows, & Admin

Jim Payne
(technical project officer)

Mohammed Khan
(technical project officer & SBIR manager)

Mike Atsbaha
(senior management analyst)

Carla Dunlap
(program support specialist)

Jared Langevin
(bto post-doctoral fellow)

Stephanie Johnson
(bto post-doctoral fellow)

Chioke Harris
(aaas fellow)

Brent Nelson
(aaas fellow)
Who Supports Energy Efficiency R&D (Federal)?

Fundamental Research

First Commercialization

Market Penetration

Building Technologies Office

Emerging Technologies

Commercial Buildings Integration
Residential Buildings Integration

Codes & Standards

ARPA-E

FEMP

ESTCP

ONR

GSA Green Proving Grounds

NSF

DOE Office of Science
BTO’s Emerging Technologies (ET) Program

- HVAC, Water Heating, & Appliances
- Windows & Building Envelope
- Lighting
- Building Energy Modeling
- Sensors & Controls
- Buildings to Grid

http://energy.gov/eere/buildings/emerging-technologies
As a result of ET-sponsored research, cost-effective technologies will be introduced into the marketplace by 2020 that will be capable of reducing a building’s energy use by 30% relative to 2010 cost effective technologies, and 45% by 2030.

2020 energy savings by end use, relative to 2010 stock and Energy Star efficiency levels:

<table>
<thead>
<tr>
<th>End Use</th>
<th>2010 Buildings Sector Energy Use (Quads)</th>
<th>Energy Use if 2010 Cost-Effective Technologies All Adopted (Quads)*</th>
<th>Energy Use if 2020 ET R&amp;D Targets Achieved and Technologies All Adopted (Quads)*</th>
<th>% of End-Use Energy Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lighting</td>
<td>4.8</td>
<td>3.5</td>
<td>0.7</td>
<td>80%</td>
</tr>
<tr>
<td>HVAC: Envelope</td>
<td>7.7</td>
<td>4.2</td>
<td>1.7</td>
<td>59%</td>
</tr>
<tr>
<td>HVAC: Equipment</td>
<td>5.6</td>
<td>3.1</td>
<td>1.3</td>
<td>59%</td>
</tr>
<tr>
<td>Water Heating</td>
<td>2.7</td>
<td>2.0</td>
<td>1.5</td>
<td>27%</td>
</tr>
<tr>
<td>Appliances</td>
<td>3.8</td>
<td>2.8</td>
<td>2.3</td>
<td>18%</td>
</tr>
<tr>
<td>Other (MELs, multi-family, mobile houses, etc.)</td>
<td>13.0</td>
<td>13.0</td>
<td>13.0</td>
<td>0%</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td>37.5</td>
<td><strong>28.6</strong></td>
<td><strong>20.2</strong></td>
<td><strong>29%</strong></td>
</tr>
</tbody>
</table>

*2010 Cost Effective Technologies and 2020 ET R&D Target Energy Consumption numbers show the technical potential of these technologies under a shared set of assumptions.
Emerging Technologies Program supports R&D of technologies and systems that are capable of substantially reducing building primary energy use, and accelerates their introduction into the marketplace.

### External Influences
- DOE budget
- Spin-off products
- Legislation
- Market incentives
- Private sector R&D
- Energy prices
- Legislation / Regulation

<table>
<thead>
<tr>
<th>Sub-Programs</th>
<th>Objectives</th>
<th>Activities / Partners</th>
<th>Key Outputs</th>
<th>Short Term Outcome</th>
<th>Mid-Term Outcome</th>
<th>Long Term Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid State Lighting</td>
<td>Support R&amp;D of high efficiency next-generation technologies &amp; components</td>
<td>Competitive &amp; shared R&amp;D funding focused on energy efficiency performance by researchers in lab &amp; test facilities</td>
<td>Technical pathway &amp; research reports</td>
<td>Private sector has access to validated solutions to develop or improve technologies &amp; reduce cost</td>
<td>Private sector engages in targeted R&amp;D &amp; develops advanced, more cost-effective tech.</td>
<td></td>
</tr>
<tr>
<td>HVAC, Water Heating &amp; Appliances</td>
<td>Improve performance &amp; cost of near term technologies &amp; reduce manufacturing costs</td>
<td>Competitive &amp; shared funding of field testing, modeling &amp; validation</td>
<td>Prototypes that fill technical gaps</td>
<td>Manufacturers aware of advanced tech. &amp; available reduced cost production solutions</td>
<td>Manufacturers produce highly energy efficient equipment &amp; push in the market</td>
<td></td>
</tr>
<tr>
<td>Windows &amp; Building Envelope</td>
<td>Accelerate market entry &amp; availability of technologies &amp; processes</td>
<td>Manufacturing R&amp;D with emphasis on cost reduction with industry</td>
<td>Prototypes or packaged solutions that reduce cost</td>
<td>Manufacturing advanced, reduced cost solutions</td>
<td>Manufacturers &amp; retailers understand product benefits</td>
<td></td>
</tr>
<tr>
<td>Sensors &amp; Controls</td>
<td>Improve energy modeling tools &amp; capabilities &amp; testing techniques</td>
<td>Pre-commercial technology demos with industry</td>
<td>Open-source sensor &amp; control platforms &amp; standardized communication protocols</td>
<td>Tech. cost &amp; performance data &amp; demo reports</td>
<td>Building industry have solutions to install &amp; integrate products in buildings</td>
<td></td>
</tr>
<tr>
<td>Building Energy Modeling (BEM)</td>
<td>Develop energy modeling tools</td>
<td>Development of installation &amp; verification techniques with industry</td>
<td>Manufacturing R&amp;D with emphasis on cost reduction with industry</td>
<td>Installation &amp; verification techniques</td>
<td>Industry competitions, workshops &amp; recognition</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Outreach to stakeholders with cost &amp; performance data analysis</td>
<td>Pre-commercial technology demos with industry</td>
<td>Industry competitions, workshops &amp; recognition</td>
<td>Industry competitions, workshops &amp; recognition</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Competitive &amp; shared funding to develop, improve &amp; test modeling tools</td>
<td>Manufacturing R&amp;D with emphasis on cost reduction with industry</td>
<td>Tech. &amp; market assessments</td>
<td>Industry competitions, workshops &amp; recognition</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Development of test &amp; simulation protocols by researchers to support industry standards</td>
<td>Manufacturing R&amp;D with emphasis on cost reduction with industry</td>
<td>Comprehensive, accurate, easy to use modeling tools &amp; approaches</td>
<td>Industry competitions, workshops &amp; recognition</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Standardized simulation &amp; test protocols</td>
<td>Manufacturing R&amp;D with emphasis on cost reduction with industry</td>
<td>Standardized simulation &amp; test protocols</td>
<td>Industry competitions, workshops &amp; recognition</td>
<td></td>
</tr>
</tbody>
</table>

*Researchers are national labs, universities & research institutions

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**Advanced energy efficient technologies** are regularly innovated, widely available in the market, & have similar or better life-cycle costs relative to conventional technologies.

**Energy Efficient Buildings** are designed or upgraded with communicative, energy efficient technologies & controlled to optimize system operations & grid integration, while minimizing energy use & costs.

---

Impact:
- Meet cost and performance R&D targets for SSL, HVAC, water heating, appliances, windows, building envelope, sensors & controls and BEM
- Enable the development of cost-effective technologies that will be capable of reducing bldg. EUI 30% by 2020
- Reduce EUI in all bldgs. 30% by 2030

Dec. 2015
## Emerging Technologies Program Logic Model

**OBJECTIVE**  
Develop next-gen tech  
Improve near-term tech  
Provide modeling tools

<table>
<thead>
<tr>
<th>OBJECTIVE</th>
<th>ACTIVITIES</th>
<th>KEY OUTPUT</th>
<th>SHORT-TERM OUTCOME</th>
<th>MID-TERM OUTCOME</th>
<th>LONG-TERM OUTCOME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Develop next-gen tech</td>
<td>Next-gen tech &amp; component R&amp;D</td>
<td>Next-gen prototypes</td>
<td>Performance goals met</td>
<td>Private sector R&amp;D</td>
<td></td>
</tr>
<tr>
<td>Improve near-term tech</td>
<td>Cost reduction R&amp;D</td>
<td>Reduced cost prototypes</td>
<td>Validated products</td>
<td>Adopted products</td>
<td></td>
</tr>
<tr>
<td>Provide modeling tools</td>
<td>Demonstrate pre-commercial technologies</td>
<td>Validated demo results</td>
<td>Adopted tools</td>
<td>Wide use</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Update and validate key tools</td>
<td>Widely used modeling tools</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### External Influences
- DOE Budget
- Legislation / Regulation
- Spin-off Products
- Energy Prices
- Market Incentives
- Private R&D

**Updated Dec. 2015**
BTO Emerging Technologies Annual Spend FY13 – FY16

Fiscal Year

FY13
FY14
FY15
FY16

ET Annual Spend ($K)

Program Management
Technical Performers
Grid Modernization
Other ET FOAs
SSL FOA
Other Lab Funding (Direct)
Lab Core Funding (Direct)
ET Fiscal Year 2016 Budget ($79.912M)

FOAs ($33.1M)

- Grid Modernization ($18M)
- SSL Support (NETL & Conference)
- Direct Lab Support (Core + Other Projects)
- T2M ($1M)

ET Technical Program Support

Modeling

SSS

HVAC

Windows & Envelope

Sensors & Controls

Funding Opportunity Announcements (FOAs):
- Solid-State Lighting R&D ($10.1M)
- BENEFIT ($20.0M)
- General Service Lamps (GSL) R&D ($3.0M)
ET Funding Opportunities in FY16

- **BENEFIT (Building Energy Frontiers and Innovation Technologies)**
  - Rotates among non-SSL topics
  - Early stage and later stage R&D; often includes “open” topic
- **Solid State Lighting (SSL) Advanced Technology R&D**
- **General Service Lamps (GSL) R&D**
- **Catalyst (software solutions; joint with SunShot)**
- **ORNL JUMP (hardware)**
- **Small Business Vouchers (SBV)**

**Small Business Innovative Research:**
- 2 – 3 topics offered each year
2016 BENEFIT & SBIR FOA Topics

2016 BENEFIT

Topic 1 Open Topic for Energy Efficiency Solutions for Residential and Commercial Buildings

Topic 2 Human-in-the-Loop Sensor & Control Systems

Topic 3 Infiltration Diagnostic Technologies

Topic 4 Plug-and-Play Sensor Systems

Topic 5 Advanced Air-Sealing Technologies for Existing Buildings

BUILD (Buildings University Innovators and Leaders Development) Supplements

2016 BTO SBIR

High-Efficiency Materials for Solid-State Lighting

Energy-Efficiency Solid-State Luminaires, Products, and Systems

Technologies for Sensing and Managing Indoor Air Quality in Buildings
Organizations Supported by ET FOAs

<table>
<thead>
<tr>
<th>BTO/ET FOA Funding</th>
<th>FY12</th>
<th>FY13</th>
<th>FY14</th>
<th>FY15</th>
</tr>
</thead>
<tbody>
<tr>
<td>$-</td>
<td>$-</td>
<td>$-</td>
<td>$1,911,116</td>
<td>$-</td>
</tr>
<tr>
<td>Non-Profit</td>
<td>$1,317,976</td>
<td>$3,159,402</td>
<td>$4,629,063</td>
<td>$2,400,000</td>
</tr>
<tr>
<td>Lab</td>
<td>$1,572,000</td>
<td>$4,254,604</td>
<td>$4,899,911</td>
<td>$3,614,240</td>
</tr>
<tr>
<td>University</td>
<td>$10,169,675</td>
<td>$12,175,046</td>
<td>$14,226,504</td>
<td>$10,405,403</td>
</tr>
<tr>
<td>Company</td>
<td>$-</td>
<td>$-</td>
<td>$-</td>
<td>$-</td>
</tr>
</tbody>
</table>
Impact of Achieving ET 2020 R&D Goals

Residential Energy (Single Family, All Regions)

End Use
- Heating
- Secondary Heating
- Cooling
- Lighting
- Water Heating
- Refrigeration
- Drying
- Drying
- Other

*Energy Savings %

“ET 2020” represents the R&D goals for BTO for the year 2020 (ET = Emerging Technologies)

Source: 2015 DOE Quadrennial Technology Review (Chioke Harris, Jared Langevin, Jack Mayernik, & Brent Nelson)
### Representative ET 2020 R&D Goals

<table>
<thead>
<tr>
<th>Area</th>
<th>Current</th>
<th>2020 goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insulation</td>
<td>R-6/in and $1.1/ft²</td>
<td>R-8/in and $0.35/ft²</td>
</tr>
<tr>
<td>Windows (residential)</td>
<td>R-5.9/in and $63/ft²</td>
<td>R-10/in and $10/ft²</td>
</tr>
<tr>
<td>Vapor-compression heating, ventilation, and air conditioning (HVAC)</td>
<td>1.84 COP and 68.5 $/kBtu/hr cost premium</td>
<td>2.0 Primary COP and $23/kBtu/hr cost premium</td>
</tr>
<tr>
<td>Non-vapor compression HVAC</td>
<td>Not on market</td>
<td>2.3 Primary COP and $20/kBtu/hr cost premium</td>
</tr>
<tr>
<td>LEDs (cool white)</td>
<td>166 lm/W and $4/klm</td>
<td>231 lm/W and $0.7/klm</td>
</tr>
<tr>
<td>Daylighting and controls</td>
<td>16% reduction in lighting for $4/ft²</td>
<td>35% reduction in lighting for $13/ft²</td>
</tr>
<tr>
<td>Heat pump clothes dryers</td>
<td>Not on market</td>
<td>50% savings and $570 cost premium</td>
</tr>
</tbody>
</table>

**COP = Coefficient of Performance**

COP is based on primary energy input.

All goals include performance **AND** cost.

Source: 2015 DOE Quadrennial Technology Review
Setting Efficiency & Cost Targets: HVAC (example)

- Compares 2020 R&D targets for cold-climate heat pumps and advanced vapor compression air conditioners to Energy Star units.

  Analysis is conducted with the P Tool (soon Scout) to set cost and performance targets, vetted with stakeholders, to achieve desired energy savings.

Sources for Energy Star data:
Analysis indicates ET 2020 R&D targets for HVAC and windows & envelope lead to 60% space heating & cooling energy savings in 2020. The ET program is on track to meet this goal.
Tracking Progress on Efficiency & Cost: Water Heaters

Electric
- Non-CO₂ vapor compression
- CO₂ vapor compression
- Non-vapor compression

Gas-Fired
- Absorption/Adsorption

Moral: Both performance AND cost matter!
ET-Supported Commercialized Technologies

BTO Commercialized Products & 2030 Technical Potential

Number of Products (left axil) vs 2030 Technical Potential (right axil)
- Windows & Envelope
- HVAC
- Water Heating & Appliances
- Lighting

2030 Staged Technical Potential (TBTu)
- LUXEON Warm White LEDs (2030 TP = 516 TBTu)
- Dow LiquidArmor (2030 TP = 1731 TBTu)
- ClimateMaster Ground Source HP (2030 TP = 1246 TBTu)
- ORNL CO₂ HP Water Heater (2030 TP = 786 TBTu)

Highlights

U.S. DEPARTMENT OF ENERGY
Energy Efficiency & Renewable Energy
### Other ET Highlights

<table>
<thead>
<tr>
<th>Subprogram</th>
<th>Journal Publications</th>
<th>IP</th>
<th>Licenses</th>
</tr>
</thead>
<tbody>
<tr>
<td>HVAC</td>
<td>3</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Lighting</td>
<td>1</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>Windows/Envelope</td>
<td>7</td>
<td>7</td>
<td>11</td>
</tr>
<tr>
<td>Sensors and Controls</td>
<td>0</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>Modeling</td>
<td>13</td>
<td>14</td>
<td>0</td>
</tr>
<tr>
<td><strong>Totals:</strong></td>
<td><strong>24</strong></td>
<td><strong>42</strong></td>
<td><strong>36</strong></td>
</tr>
</tbody>
</table>

As a result of ET-sponsored research, cost-effective technologies will be introduced into the marketplace by 2020 that will be capable of reducing a building’s energy use by 30% relative to 2010 cost effective technologies, and 45% by 2030. [BTO Multi Year Program Plan]
## Buildings RD&D Opportunities in the 2015 QTR

| **Building thermal comfort and appliances** | - Materials that facilitate deep retrofits (e.g., thin insulating materials)  
- Low/no-GWP heat pump systems  
- Improved tools for diagnosing heat flows over the lifetime of a building  
- Clear metrics for the performance of building shells for heat and air flows |
| **Lighting** | - Test procedures for reliably determining the expected lifetime of commercial LED and OLED products  
- Understanding why LED efficiency decreases at high power densities  
- High efficiency green LEDs  
- Efficient quantum dot materials  
- Advanced sensors and controls for lighting  
- Glazing with tunable optical properties  
- Efficient, durable, low-cost OLEDs  
- Lower cost retrofit solutions for lighting fixtures |
| **Electronics and miscellaneous building energy loads** | - More efficient circuitry (hardware and software)  
- More flexible power management (hardware and software)  
- Standardized communications protocols  
- Wide-band-gap semiconductors for power supplies |
| **Systems-level opportunities** | - Accurate, reliable, low installed cost sensors  
- Energy harvesting to power wireless sensors and controls  
- Improved control systems (cybersecurity, install/commissioning)  
- Control algorithms to automatically optimize building system performance  
- Open-source software modules supporting interoperability  
- Easy-to-use, fast, accurate software tools to design and operate buildings  
- Co-simulation modeling with a widely used interface standard  
- Decision science research incorporating personal information security  
- Components and systems that allow building devices to share waste heat |

Source: 2015 DOE Quadrennial Technology Review (QTR)
Fundamental Research Challenges in the 2015 QTR

- Materials with tunable optical properties (adjust transmissivity and absorptivity by wavelength)
- Materials for efficient LEDs
- Materials for efficient motors and controls (magnets, wide-band-gap semiconductors)
- Enthalpy exchange materials
- Materials for low-cost Krypton/Xenon replacement
- Materials for non-vapor-compression heat pumps (e.g. thermoelectric, magnetocaloric, electrocaloric)
- Big-data management for large networks of building controls and next-generation grid systems
- Ultra-efficient computation (neural networks)
- Decision science research

Source: 2015 DOE Quadrennial Technology Review (QTR)
FY17 ET Priorities

Proposed FOAs or FOA Topics

• Solid-State Lighting R&D

• BENEFIT FOA
  – Envelope & windows \( \Rightarrow \) Look for an upcoming workshop (June?)
  – Sensors & controls \( \Rightarrow \) Look for an upcoming roadmap
  – Open topic
  – BUILD supplements

• Low-Global-Warming-Potential (Low-GWP) HVAC&R
  – Two previous workshops, upcoming RFI

• Miscellaneous Electric Loads (MELs) R&D
  – Panel discussion at this Peer Review (Wednesday afternoon)

• Decision Science R&D for Buildings
  – Side meeting at this Peer Review (Thursday afternoon)
  – Workshop in San Francisco (early May)
How To Get Involved with BTO/ET

• Get on our email list
  (http://www1.eere.energy.gov/buildings/newsletter.html, and click on “Sign up to receive news and events from BTO”)

• Attend the annual BTO Peer Review

• Provide feedback on draft roadmaps; currently one available on Building Energy Modeling, and soon one on Sensors & Controls

• Volunteer to be a reviewer (send CV to BTOreviewer@ee.doe.gov)

  ▪ Apply to a FOA, postdoc, or other funding opportunity!
    (https://eere-exchange.energy.gov/)

patrick.phelan@ee.doe.gov