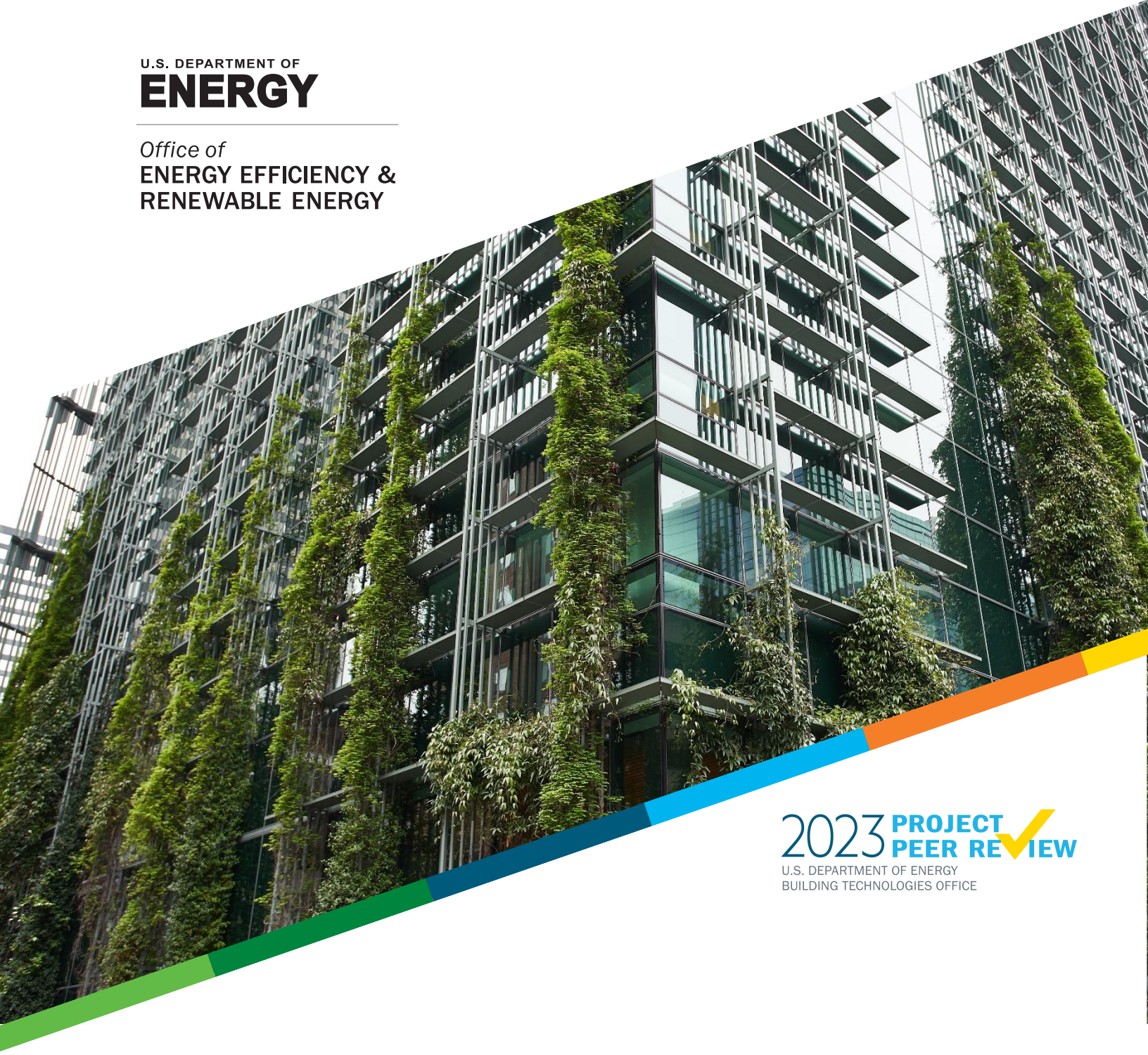
U.S. DEPARTMENT OF
ENERGY

Office of
ENERGY EFFICIENCY &
RENEWABLE ENERGY



2023 PROJECT PEER REVIEW
U.S. DEPARTMENT OF ENERGY
BUILDING TECHNOLOGIES OFFICE

Building Technologies Office

2023 Peer Review Report

Published January 2025

Disclaimer

Letter from the Director

In April 2023, the U.S. Department of Energy (DOE) Office of Energy Efficiency and Renewable Energy (EERE) Building Technologies Office (BTO) confirmed its long-standing commitment to transparency by hosting its 10th annual review of its research, development, and demonstration portfolio. Conducted in accordance with EERE Peer Review guidelines, the Peer Review provides an external assessment of the projects in BTO's portfolio and offers recommendations on BTO's overall technology focus and strategic direction. Peer Review results are considered during programmatic and funding opportunity decision-making.

The Peer Review is an essential tool for BTO's efforts to accelerate the adoption of technologies and techniques that enable high-performing, affordable buildings that meet Americans' need for resiliency and health while also supporting a reliable energy system. To ensure we are using our budget to achieve as great an impact as possible, the Peer Review offers a chance for us to receive rigorous evaluations from independent reviewers—including feedback on alignment with DOE goals, approaches, progress, and future work. The Peer Review also allows external stakeholders a unique chance to hear about achievements from every division of our portfolio.

The 2023 Peer Review included plenary sessions, a poster session, and special sessions on topics such as advanced construction for buildings. Research team members delivered over 150 project presentations. Peer reviewers, experts across a range of relevant disciplines, listened to project presentations and provided scores and comments. This report provides score and narrative summaries of peer reviewer evaluations for Emerging Technologies, Commercial Buildings Integration, and Residential Buildings Integration Programs.

BTO would like to thank all the reviewers who participated, as well as the more than 500 stakeholders from the federal government, national laboratories, industry, academia, and nongovernmental organizations who attended the event. Our reviewers include some of the top experts in the building technology and energy communities, and we are grateful for their feedback. By funding and rigorously reviewing projects that advance key technologies, we will support more affordable, reliable, secure American energy.

Hayes Jones
Acting Director, Building Technologies Office

Executive Summary

The Building Technologies Office (BTO) conducts research, development, and demonstration (RD&D) activities to accelerate the adoption of technologies and techniques that enable high-performing, affordable buildings that meet Americans' need for resiliency and health while also supporting a reliable energy system. BTO systematically prioritizes RD&D into technology opportunities across a range of emerging scientific breakthroughs and seeks cutting-edge solutions for energy efficiency in the subprogram areas listed below. This approach supports a diverse portfolio of projects that in turn support the U.S. Department of Energy's energy goals, developing the most promising and widely applicable technologies, testing technologies as integrated processes, and demonstrating processes to support scale-up. These technologies will use a broad variety of energy-saving materials, techniques, and applications to increase grid resilience and reduce energy expenditure.

The purpose of this annual report is to (1) transparently demonstrate how BTO-funded projects align with its mission and goals, (2) enable the improvement of funded projects through the expertise of peer reviewers, and (3) advance building technology innovation.

The Peer Review process is a practical way to evaluate the responsible use of taxpayer funding. This report provides a general overview of the 2023 BTO Peer Review meeting and summaries of reviewer scores and input.

Table of Contents

List of Figures

List of Tables

Introduction

Today's U.S. building stock consists of nearly 130 million commercial and residential buildings. Collectively, these buildings consume about 75% of U.S. electricity and cost American households and businesses over $500 billion annually in energy bills.[1, 2, 3]

The U.S. Department of Energy (DOE) Building Technologies Office (BTO) seeks to improve the energy reliability, cost, and performance of the nation's building stock. To that end, BTO, in partnership with DOE's national laboratories, engages with universities, small businesses, and other private-sector entities to develop cutting-edge, affordable solutions that increase energy efficiency and improve performance.

BTO also leads initiatives to advance technological developments that will increase building energy efficiency, resulting in benefits throughout the economy. For example, the Grid-Interactive Efficient Buildings Initiative combines energy efficiency and demand flexibility with smart technologies and communications to improve building performance and help buildings respond dynamically to electric grid conditions, decreasing strain on grid infrastructure and the need for new electricity generation and transmission infrastructure.[4] As another example, the Advanced Building Construction Initiative integrates energy efficiency solutions into U.S. construction practices for new buildings and deep energy retrofits, addressing issues in areas such as envelope, heating, cooling, water heating, and ventilation.[5]

BTO conducts an annual peer review of its projects to ensure that they are relevant to program goals and objectives, are employing innovative and effective approaches, and are making strong progress to clearly defined goals. This peer review is a formal, documented evaluation process in which independent reviewers use objective criteria to judge the BTO-funded projects in terms of technical, scientific, or business merit; actual or anticipated results; and productivity. This evaluation provides BTO with essential knowledge on the quality and impact of its projects and programs, allowing for crucial project feedback as well as data that will inform future efforts. To make information about BTO's projects and initiatives accessible to the public and to promote collaborations and partnerships for new projects, BTO makes the Peer Review event free and open to the public.

Mission and Goals

BTO's mission is to develop, demonstrate, and accelerate the adoption of cost-effective technologies, techniques, tools, and services that enable high-performing, energy-efficient, and demand-flexible residential and commercial buildings. To this end, BTO leverages innovative R&D, development of technology validation tools, and information sharing. With coordination and engagement with industry and other key stakeholders, BTO gains a better understanding of user needs and can better direct technological research that will create innovative energy-saving solutions for U.S. homes and buildings. BTO technologies are also making energy more affordable, upgrading the energy systems in existing buildings, and creating more cost-effective options for energy storage.

DOE announced multiple new programs for the advancement of energy efficiency in three major BTO focus areas: heating and cooling, smart building technologies, and windows.

BTO is the only U.S. entity with responsibility and authority for building energy efficiency R&D, technology validation, and regulation. As such, BTO employs a strategy that includes:

- R&D of innovative building technologies and integration of such technologies into efficient, grid-connected, and secure building systems.
- Validation, verification, and integration of solutions that help reduce energy waste by improving building and homeowner understanding of efficient building operational practices and technologies as well as their costs and benefits.

Using this strategy, BTO has the potential to help Americans save over $200 billion annually in energy costs, in part through its goal of reducing building energy-use intensity by 30% by 2030.[7] To achieve these lofty goals, BTO organizes its activities under five different program areas:

- Emerging Technologies (ET) supports R&D and commercialization of high-impact building technologies with substantial potential for reducing primary energy consumption and energy-related costs.
- Commercial Buildings Integration (CBI) aims to improve existing and new commercial buildings through demonstration of cost-saving technologies that enhance building performance and operations. CBI partners with market leaders to increase technology adoption, providing design and management tools as well as performance data to reduce perceived risks and address market barriers that have inhibited widespread uptake.
- Residential Buildings Integration (RBI) encourages increased energy efficiency and improved comfort and affordability in existing and new residential buildings through technology R&D and field validation, development, and dissemination of

best practices, tools, and partnerships with public- and private-sector stakeholders.

This document offers overviews of these programs and component subprograms in later sections, including information on their activities, summaries, scores and descriptions of peer-reviewed projects, and overviews of reviewer comments on projects.

Also discussed are the BTO Peer Review objectives, processes, and scoring criteria, including the evaluation criteria for individual projects.

2023 BTO Peer Review Event

The 2023 BTO Peer Review was held in person April 24–28, 2023, at the DoubleTree Crystal City in Arlington, Virginia. More than 650 participants attended the event that included nearly 400 posters and presentations representing three of BTO's five technology programs. Of these projects, 174 were formally evaluated and broken down into the programs as shown below.

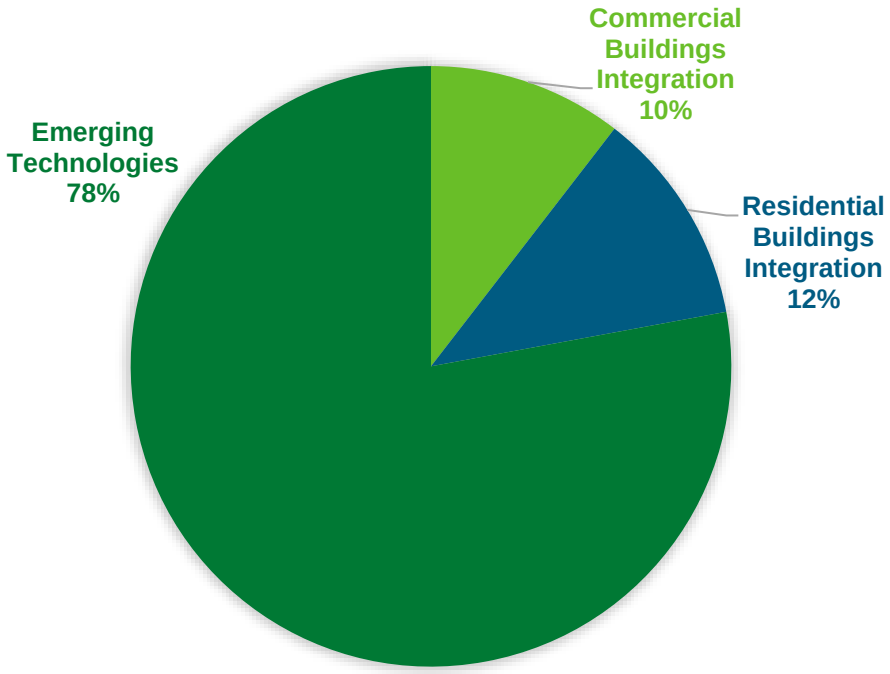


Figure 1. Summary of peer-reviewed projects by BTO program

The Appliance and Equipment Standards Program and Building Energy Codes Program are typically excluded from the peer review process, as the majority of their work and stakeholder input processes are statutorily mandated.

The objectives of the 2023 BTO Peer Review were to:

1. Conduct an independent evaluation of current BTO projects and performers, their efforts over the past year toward BTO goals, and their future plans.

2. Provide a forum to promote collaboration and partnerships among project performers and other stakeholders.

3. Demonstrate DOE's role in energy efficiency.

Independent reviewers were drawn from a variety of building-related backgrounds and included experts from industry, academia, national laboratories, government, and other stakeholder groups. Reviewers were screened for conflicts of interest and were assigned to projects based on their interests and areas of expertise. Reviewers evaluated each assigned project according to alignment, impact, approach, progress, future work, strengths, weaknesses, and recommendations, providing a numerical score for each criterion and then substantiating these scores with additional comments.

This report summarizes the scores and comments submitted by reviewers for the 175 projects that were formally evaluated at the 2023 BTO Peer Review. The following sections present an overview of the feedback on BTO-funded projects that advance program areas, with a summary of project scores provided.

Projects Supporting BTO Programs and Subprograms

The following are summaries of the projects reviewed for each technology track, including raw scores.

The chart below illustrates the number of projects for each technology track.

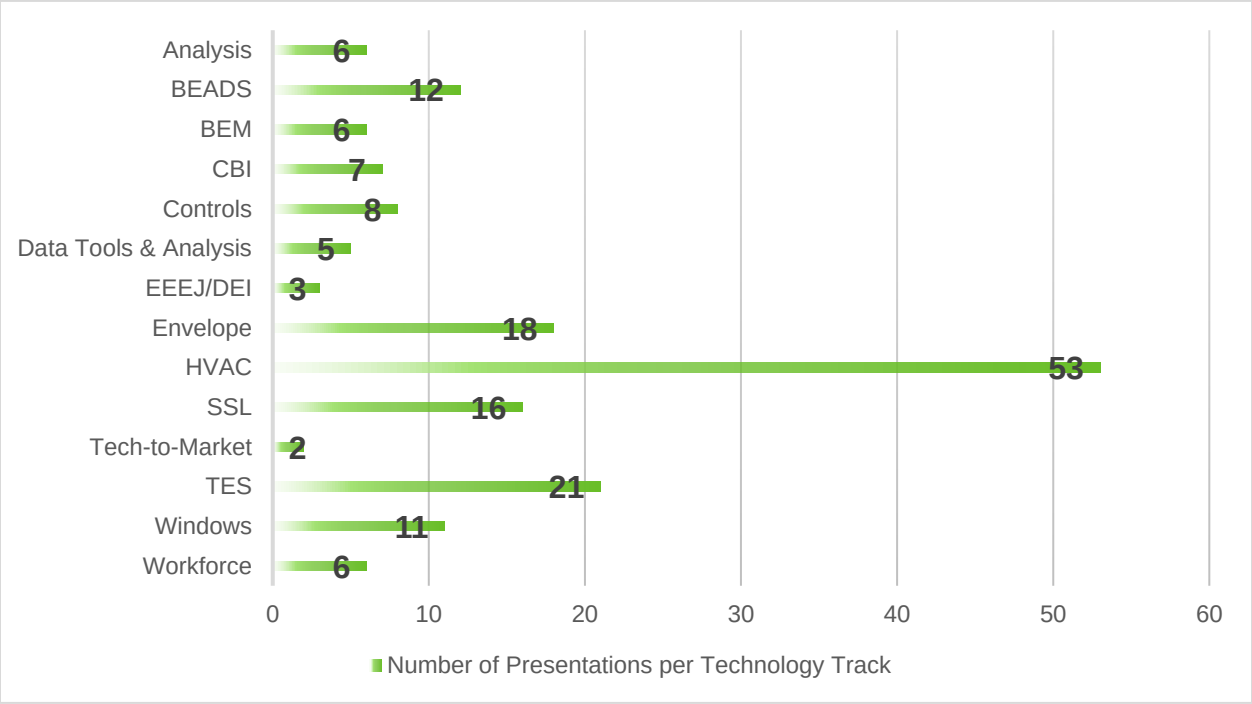


Figure 2. BTO 2023 Peer Review presentations per technology track

Emerging Technologies

The Emerging Technologies (ET) program aims to advance affordable, energy-saving technologies and strategies through research, development, and integration efforts. By supporting industry, national laboratories, and academia, the program facilitates the widespread adoption of energy-efficient building technologies, fostering job creation and cutting building energy use, all while promoting an innovative energy future.

Table 1. Scoring Summary of ET Projects

Technology Track	Project Count	Average Score Out of 4	Low Score Out of 4	High Score Out of 4
	Note: The following figures summarize *all* projects in an identified technology track.			
Analysis	6	3.65	3.20	3.93
Building Electric Appliances, Devices, and Systems	12	3.29	2.95	3.70
Building Energy Modeling	6	3.69	3.40	3.87
Controls	8	3.29	2.80	3.76
Data Tools and Analysis	5	3.18	2.76	3.48
Envelope	18	3.25	2.80	3.64
Heating, Ventilation, and Air Conditioning (HVAC)	53	3.25	2.27	3.93
Solid-State Lighting	16	3.34	2.93	3.67
Technology-to-Market	2	3.65	3.65	3.65
Thermal Energy Storage (TES)	21	2.83	2.15	3.40
Windows	11	3.00	2.40	3.43

Analysis

For the 2023 Peer Review, six total Analysis projects were formally reviewed—two of those projects related most specifically to ET. A summary of the reviewers' scores is provided below.

Table 2. Scoring Summary of ET Analysis Projects

Project	Weighted Average	Number of Reviewers	Alignment and Impact	Approach	Progress and Future Work
Scout	3.73	6	4.00	3.67	3.67
Future Weather	3.63	6	3.50	3.67	3.67

Building Electric Appliances, Devices, and Systems

The 12 Building Electric Appliances, Devices, and Systems (BEADS) projects seek to advance energy efficiency and cost savings. All 12 projects were grouped under the ET program. A summary of the 2023 Peer Review scores is provided below.

Table 3. Scoring Summary of ET BEADS Projects

Project	Weighted Average	Number of Reviewers	Alignment and Impact	Approach	Progress and Future Work
A Behind-the-Wall DC Bus to Power Low Voltage DC Products	2.95	5	2.75	3.25	2.75
BE-SATED: Building Energy Storage at the Edges of Demand	3.55	4	3.25	3.75	3.50
ISO: Next-Generation Domestic Refrigerator with Unprecedented Performance Using Isobutane as Refrigerant	3.13	3	3.00	3.00	3.33
TEDW	3.33	3	3.33	3.33	3.33
CWD: Next-Gen Combined Washer and Dryer Platform for Higher Efficiency and Fast Operation	3.33	3	3.33	3.33	3.33
HERES: High-Efficiency Refrigerator with Cold Energy Storage Enabling Demand Flexibility	3.35	4	3.25	3.25	3.50
RCO: Domestic Electric Oven Reimagined: Eco-Friendly Cooking Oven at Scale Using Recycled Reinforced Composites	3.27	3	3.00	3.33	3.33
TER: Dual-Evaporator, Variable-Capacity Refrigerator, Coupled with Thermo-Electric Freezer	3.13	3	3.00	3.00	3.33
Grid-Interactive, Resilient Lighting and Plug Load Management System Using DC Power	3.15	4	3.25	3.25	3.00
Affordable and Equitable Residential Electrification Under Electrical Panel and Service Constraints	3.50	4	3.50	3.50	3.50
Smart Electrical-Panel-Based HEMS	3.70	4	3.50	3.75	3.75
High-Fidelity Self-Learning Tool for Residential Load and Load Flexibility Forecasting	3.10	3	3.33	3.33	2.67

Building Energy Modeling

All six of the Building Energy Modeling (BEM) projects fall under the ET designation, and a summary of the 2023 reviewer scores is provided below.

Table 4. Scoring Summary of ET BEM Projects

Project	Weighted Average	Number of Reviewers	Alignment and Impact	Approach	Progress and Future Work
URBANopt	3.73	6	3.67	3.83	3.67
ASHRAE Standard 229P	3.77	6	3.5	3.83	3.83
ASHRAE Standard 205	3.73	6	3.83	3.67	3.67
OpenStudio	3.87	6	4.00	3.83	3.83
ASHRAE Standard 140	3.68	5	3.60	3.80	3.60
Simplified PRM	3.40	6	3.33	3.33	3.50

Controls

The eight Controls projects are all contained within the ET program, and a summary of the 2023 reviewer scores is provided below.

Table 5. Scoring Summary of ET Controls Projects

Project	Weighted Average	Number of Reviewers	Alignment and Impact	Approach	Progress and Future Work
Spawn and Modelica Buildings Library	3.36	5	3.60	3.20	3.39
Low-Cost Open Platform for Monitoring and Control of Buildings (VOLTTRON)	3.00	4	3.00	3.00	3.00
Semantic Modeling and Interoperability	3.60	5	3.60	3.60	3.60
A Scalable Hardware-and-Human-in-the-Loop (HwHuIL) GEB Building Equipment Performance Dataset	3.55	4	3.25	3.75	3.50
Open Building Control II	3.76	5	4.00	3.80	3.60
Benchmarking Smart Thermostats	3.04	5	2.79	3.39	2.79
A Data-Driven Control Verification Framework	2.79	4	3.20	2.60	2.79
Building Optimization Testing Framework (BOPTest)	3.24	5	3.00	3.40	3.20

Data Tools and Analysis

Out of the five Data Tools projects, one is classified under ET and summarized below, and the four others are listed under the CBI technology track.

Table 6. Scoring Summary of ET Data Tools and Analysis Project

Project	Weighted Average	Number of Reviewers	Alignment and Impact	Approach	Progress and Future Work
Advancing Residential Building Decarbonization: Understanding Home Occupant Decision-Making Dynamics	3.05	4	3.25	3.25	2.75

Envelope

A full 16 of the 18 Envelope projects fall under ET, finding innovative new ways to advance building insulation and durability. These projects are summarized below.

Table 7. Scoring Summary of ET Envelope Projects

Project	Weighted Average	Number of Reviewers	Alignment and Impact	Approach	Progress and Future Work
Multi-Scale Simulations and Machine Learning-Guided Design and Synthesis of High-Performance Thermal Insulation Materials	3.16	5	3.40	3.20	3.00
Real-Time Evaluator to Optimize Prefab Retrofit Panel Installation	3.28	5	3.20	3.20	3.39
Development of Low-Cost VIP Core Materials Through Coupling Effect	3.08	5	3.40	2.80	3.20
Robotically and Autonomously Installed Wall Interior Spray Foam	3.20	5	2.79	3.39	3.20
Locating and Measuring Air Leakage Using Refractive Fluid Flow Imaging	3.64	5	3.40	3.80	3.60
Self-Healing Films to Improve Durability of VIPs by In-Situ Remediation of Film Defects	3.44	5	3.60	3.40	3.40
Cool Surfaces Manhattan Project	2.80	5	3.20	2.60	2.80
Nondestructive Microwave Reflection-Based Moisture Detector for Durable Building Envelope Retrofits	3.28	5	2.80	3.40	3.40
Low-Carbon, Recyclable, Biobased Foam Insulation	3.28	5	3.60	3.20	3.20

Project	Weighted Average	Number of Reviewers	Alignment and Impact	Approach	Progress and Future Work
High Performance Insulated Cladding	3.36	5	3.60	3.60	3.00
Aerogel Production for Low-Cost and High-R Insulation	3.32	5	3.80	3.20	3.20
Preinstalled Sealant for Prefab Components	3.52	5	3.60	3.60	3.40
Insulated Siding for Residential Retrofits	3.28	5	3.60	3.20	3.20
Nanoporous Wood Chips Based Sizable, Robust, and Low-Cost Honeycomb Vacuum Insulation Panels	3.50	4	3.50	3.75	3.25
High-Performance (R-10/inch) Clay-Cellulose-Silica Nanopore Insulation Board for New and Retrofit Buildings	2.90	4	3.50	2.75	2.75
Scale-Up Manufacturing of TABE Panels	3.20	5	2.80	3.20	3.40

HVAC

The largest of the peer-reviewed technology tracks, Heating, Ventilation, and Air Conditioning (HVAC), covers 44 projects within the ET program, and 53 projects total. Below is a summary of the ET HVAC projects.

Table 8. Scoring Summary of ET HVAC Projects

Project	Weighted Average	Number of Reviewers	Alignment and Impact	Approach	Progress and Future Work
Dalrada Commercial Heat Pump Validations (Lab and GSA buildings)	3.10	3	3.33	3.00	3.00
High Efficiency Air-Source Multi-Stage Cold Climate Integrated Heat Pump (CRADA Nortek Global HVAC, LLC)	3.20	2	3.00	3.50	3.00
International HVAC&R Research Collaboration Through IEA & IIR	3.16	5	3.40	3.00	3.20
Multi-Functional Equipment for Direct Decarbonization with Improved Indoor Air Quality	3.28	5	3.20	3.40	3.20
Next Generation Low Cost Direct-Expansion Heat Pumps Using Refrigerant Mixtures with GWPÂ <Â 150 (CRADA with Emerson Helix Center)	3.55	4	3.75	3.50	3.50

Project	Weighted Average	Number of Reviewers	Alignment and Impact	Approach	Progress and Future Work
Wrap Tank Heat Pump Water Heater with Wrap-tank Microchannel Condenser and Submerged Condenser Options (CRADA - Rheem)	2.93	3	2.67	3.00	3.00
Separate Sensible and Latent AC System	3.30	2	3.50	3.50	3.00
Reconfigure System Architecture for Low GWP Refrigerants (CRADA - Emerson)	3.00	5	3.00	3.00	3.00
Flexible HP WH with Embedded Energy Storage	3.20	3	3.33	3.33	3.00
120 V Heat Pump Water Heater Replacement Solution for 30- to 40-Gallon Gas Water Heaters	3.13	3	3.67	3.00	3.00
High Temperature Heat Pump for Commercial Space and Water Heating	3.47	3	4.00	3.67	3.00
Novel Compact Flooded Evaporators for Commercial Refrigeration	3.53	3	3.67	3.67	3.33
Analysis of Frost Formation and Novel Defrost Techniques for Commercial Refrigeration Applications (CRADA - Hillphoenix/Dover Food Retail)	2.67	3	2.67	2.67	2.67
Compressor Technology Development for Refrigerants <150 Global Warming Potential	2.67	3	3.33	2.33	2.67
Energy Efficient Refrigerated Food Processing and Dispensing Machines for Quick Service Restaurants and Food Retail (CRADA - Taylor Company)	3.30	6	3.17	3.17	3.50
Evaluation of a Micro-Cascade System for Supermarket Refrigeration Using Low GWP Refrigerants (CRADA - Honeywell)	3.16	9	3.56	3.33	2.78
FlowHT150 - Heat Transfer and Pressure Drop Characterization of Global Warming Potential <150 Refrigerants	3.33	3	3.33	3.33	3.33

Project	Weighted Average	Number of Reviewers	Alignment and Impact	Approach	Progress and Future Work
PoolHT150 – Pool Boiling Heat Transfer for Refrigerants with GWP <150	3.33	3	3.33	3.33	3.33
Ultra-Low GWP Refrigerants to Reduce Carbon Footprint in Data Centers (CRADA - Chemours)	3.47	6	3.33	3.50	3.50
Low Charge Heat Pump Water Heater Using Propane (CRADA - Rheem)	3.12	5	3.20	3.20	3.00
Grid-Interactive Efficient Buildings by Modular Design of Plug-and-Play Equipment	3.00	3	3.00	2.67	3.33
Development of a CO_2 Chiller Heat Pump for Multiple North American Applications	3.53	3	3.67	3.33	3.67
Ice Storage for Efficient and Flexible Decarbonization of Hydronic Space Heating	3.33	6	3.33	3.50	3.17
Predictive Device-level Control and Optimal Sizing of Integrated Heat Pump Systems for Energy Resilience	3.33	3	3.33	3.00	3.67
Virtual Sensor-Based Fault Detection and Diagnosis (FDD) and Control Suite for Widespread Adoption of Residential Embedded-FDD Heat Pumps	2.67	3	2.67	2.67	2.67
Cost Compression for Multifamily Heat Pump Water Heaters	2.88	5	3.20	2.80	2.80
High-Temperature Combination Heat Pumps for Low-Cost Electrification	3.47	6	3.67	3.50	3.33
Heat Pump Space- and Water-Heating in Cold Climates	3.53	6	4.00	3.50	3.33
Low-Global Warming Potential Refrigerant Leak-Sensing Methods for Commercial Refrigeration	2.95	4	3.25	2.75	3.00
Al-Ce Alloy Based Compact Heat Exchanger for Refrigerant Charge Reduction and Unprecedented Durability (CRADA – Eck)	3.28	5	3.60	3.60	2.80

Project	Weighted Average	Number of Reviewers	Alignment and Impact	Approach	Progress and Future Work
Compressor Is a Sensor (CRADA – Emerson)	3.25	4	2.75	3.50	3.25
A Grid-Interactive Modulating Air Distribution Manifold	3.70	4	3.50	3.75	3.75
Higher-Performance Lower-Cost Plastic Heat Exchangers	2.65	4	2.75	2.50	2.75
Retrofittable Efficiency Technology for Resilient Refrigeration with AI-Based Controls	3.60	4	3.50	3.75	3.50
Separating Sensible and Latent Cooling with Electrically Charged Rotating Vortexes and Vapor Capturing Air Handler Technology	3.80	6	4.00	3.83	3.67
Cold Climate Heat Pump Using Vapor Compression Cycle Cascaded with a Thermoelectric Heat Pump	3.80	6	4.00	4.00	3.50
Enabling CO_2 Isothermal Compression Using Liquid Piston Within Integrated Gas Cooler	3.73	6	4.00	3.67	3.67
Grid Interactive Micro-Distributed Refrigerated Display Case	3.93	6	4.00	4.00	3.83
Hybrid Manufacturing for High Performance Air-to-Refrigerant Heat Exchangers	3.13	3	3.00	3.33	3.00
Super-Efficient Air Conditioning Unit	2.27	3	2.67	2.67	1.67
Development of Sustainable Heat Pump Systems for Electrified Transitions in Winter Markets	3.37	6	3.50	3.50	3.17
Cold Climate Heat Pump Water Heater Using Environment-Friendly Refrigerants (CRADA - Rheem)	3.80	3	3.67	3.67	4.00
Development of Next Generation Heat Pump Water Heater Deploying Newly Emerging Refrigerants (CRADA A.O. Smith)	3.75	4	3.75	3.75	3.75

Project	Weighted Average	Number of Reviewers	Alignment and Impact	Approach	Progress and Future Work
Ultra-Clear Aerogels for Insulated Glass in Refrigeration Doors (CRADA - AeroShield Materials)	3.13	3	3.00	3.33	3.00

Solid-State Lighting

The 16 projects within Solid State Lighting (SSL) aim to expand use of energy-efficient light sources by investing in innovative design, increasing sustainability and combatting barriers to broad manufacturing and consumer adoption. All the SSL projects relate to the ET program, and those 2023 reviewer scores are summarized below.

Table 9. Scoring Summary of ET SSL Projects

Project	Weighted Average	Number of Reviewers	Alignment and Impact	Approach	Progress and Future Work
SSL Human Factors Research	3.60	3	4.00	3.33	3.67
PNNL - Germicidal Ultraviolet (GUV) Disinfection for Energy Savings and Healthier Buildings	3.55	3	3.66	3.33	3.66
Lossless Beam-Width Adjustment with Low-Cost Mechanics	3.20	3	3.33	3.00	3.33
Sustainability and Life Cycle Analysis	3.13	3	3.66	3.00	3.00
Automated Luminaire Design and Local Manufacturing for Highly Efficient, Customized Lighting Solutions	2.93	3	3.33	2.67	3.00
Development and Commercialization of Design Tools for Predicting Occupant and Energy Impacts of Building Lighting Systems	3.67	3	3.67	3.67	3.67
Microprinting Waveguides for Ultra-Thin and Flexible LED Lighting Panels	3.26	3	3.00	3.00	3.66
Cd-Free QD Building Blocks for Human-Centric Lighting	3.00	3	3.67	2.67	3.00
Optimizing Tunable Lighting for Human Health	3.49	4	3.50	3.25	3.50
Development of Lighting Application Efficacy Measurement Framework	3.15	4	3.25	3.00	3.25
High Aspect Ratio OLEDs	3.60	3	3.33	4.00	3.33
Scalable Thin LED Light Sheet Platform	3.07	3	3.33	3.00	3.00

Project	Weighted Average	Number of Reviewers	Alignment and Impact	Approach	Progress and Future Work
Solutions to Droop and the Green Gap by Novel Carrier Injection	3.39	3	3.67	3.33	3.33
SSL Field Research	3.60	4	4.00	3.50	3.50
Increasing the Radiative Rates of Triplet Emitters to Achieve Long-Lived and Efficient White-Emitting Organic Light Emitting Diodes (OLEDs)	3.60	3	3.33	3.67	3.67
PNNL - Data-Driven Electrical Systems (DDES)	3.44	3	4.00	3.00	3.33

Technology to Market

The Technology-to-Market (T2M) projects aim to springboard real-world adoption of energy efficiency initiatives. The two T2M projects are summarized below.

Table 10. Scoring Summary of ET T2M Projects

Project	Weighted Average	Number of Reviewers	Alignment and Impact	Approach	Progress and Future Work
Energy Program for Innovation Clusters (EPIC)	3.65	4	3.75	3.50	3.75
Generating Decarbonization Impact Through the JUMP Into STEM Student Competition	3.65	4	3.75	3.50	3.75

Thermal Energy Storage

The 20 Thermal Energy Storage (TES) projects within ET focus on modifying existing energy storage systems to increase efficiency and lower costs. These projects are summarized below.

Table 11. Scoring Summary of ET TES Projects

Project	Weighted Average	Number of Reviewers	Alignment and Impact	Approach	Progress and Future Work
Development of a Novel, Thermochemical, Nanocellulose-Based Material for Thermal Energy Storage	3.35	4	3.25	3.5	3.25
Model-Based Predictive Control and Sensor Technology for Phase-Change Thermal Energy Storage Systems	2.95	4	3.25	2.75	3.00

Project	Weighted Average	Number of Reviewers	Alignment and Impact	Approach	Progress and Future Work
Energy Storing Efficient HVAC	2.70	2	2.50	3.00	2.50
Dual-Purpose Heating & Cooling Thermal Battery for Flexible and Energy Efficient Heat Pump Systems	2.15	4	1.75	2.00	2.50
A New Approach to Encapsulate Salt Hydrate PCM	3.40	4	3.50	3.25	3.50
High Energy Density Hydrogel Thermo-Adsorptive Storage	3.00	4	3.00	3.25	2.75
Wall Embedded Multi-Functional Heat pump with Energy Storage Systems for Grid-Responsive and Weather-Transactive Controls	2.65	4	2.75	2.50	2.75
High-Density, Low-Hysteresis Thermal Storage Using Hydrated Salts in Surface-Functionalized Hydrogels	2.75	4	2.75	2.75	2.75
Multipurpose Latent Heat Storage System for Building Applications - Development of Low-Cost, High-Performance, Easy-to-Apply, Non-Flammable, Inorganic Phase Change Material (PCM) Technology	3.00	4	3.00	3.25	2.75
Salt Hydrate Eutectic Thermal Energy Storage for Building Thermal Regulation	3.25	4	3.25	3.25	3.25
Developing a Software Tool for Discovery, Sizing and Sales of Thermal Energy Storage Systems	2.70	4	3.00	2.75	2.50
Thermal Energy Storage for Smart Building Envelopes	2.67	3	2.67	2.67	2.67
Low Cost PCM Integration into Heat Pumps	2.85	4	2.75	3.00	2.75
Demonstration of Active Insulation Systems	2.33	3	2.33	2.00	2.67
Packaged Integrated Heat Pump Coupled with a Two-Stream Liquid Desiccant System for Sensible and Latent Energy Storage in Building (CRADA with Emerson)	2.50	4	3.00	2.25	2.50

Project	Weighted Average	Number of Reviewers	Alignment and Impact	Approach	Progress and Future Work
Development of TES Systems with Thermally Anisotropic Building Envelopes	2.95	4	3.25	3.00	2.75
Additive Manufacturing to Enable High Performance Salt-Hydrate Based Thermal Energy Storage Products	2.80	3	2.67	3.00	2.67
Icephobic Heat Exchange for Efficient, Resilient Building Cooling	2.60	3	3.00	2.67	2.33
Stable Thermochemical Salt Hydrates for Energy Storage in Buildings	2.90	4	3.00	3.00	2.75
Behind the Meter (BTM) Thermal Energy Storage in Buildings	3.13	3	3.00	3.33	3.00
THERMAplus, TES Optimized for Integration with Chillers and Heat Pumps	2.87	3	3.00	2.67	3.00

Windows

The nine Windows projects within ET are summarized below. Note that Core Window Performance covers a series of three subprojects.

Table 12. Scoring Summary of ET Windows Projects

Project	Weighted Average	Number of Reviewers	Alignment and Impact	Approach	Progress and Future Work
Low-Cost, High-Performance Electrochromic Devices	2.40	6	2.67	2.33	2.33
Dynamic Reflective Metals	2.87	6	2.67	2.67	3.17
Dynamic Highly Insulating Windows	3.13	6	3.33	2.83	3.33
Core Window Durability	3.40	6	3.33	3.5	3.33
Vacuum Glazing	3.36	5	3.60	3.40	3.20
Aerogel Highly Insulating Materials	2.93	6	3.00	3.00	2.83
Core Window Performance	3.43	6	3.50	3.17	3.67

Commercial Buildings Integration

BTO's Commercial Buildings Integration (CBI) program aims to advance innovative building technologies for significant energy savings and lowered costs for businesses. Through partnerships with stakeholders, CBI develops practical resources and tools to simplify energy efficiency improvements in commercial buildings. By conducting

research, forming alliances with industry leaders, and leveraging laboratories, CBI accelerates the adoption of energy-efficient technologies to benefit U.S. businesses across various sectors.

Table 13. Scoring Summary of CBI Projects

Technology Track	Project Count	Average Score Out of 4	Low Score Out of 4	High Score Out of 4
	Note: The following figures summarize *all* projects in an identified technology track.			
Analysis	6	3.65	3.20	3.93
Commercial Buildings Integration	7	3.28	3.05	3.53
Data Tools and Analysis	5	3.18	2.76	3.48
Energy Affordability	3	3.37	3.37	3.37
HVAC	53	3.25	2.27	3.93
TES	21	2.83	2.15	3.40

Analysis

Two of the Analysis projects focus specifically on commercial-building energy usage. These projects are summarized below.

Table 14. Scoring Summary of CBI Analysis Projects

Project	Weighted Average	Number of Reviewers	Alignment and Impact	Approach	Progress and Future Work
ComStock	3.90	6	3.83	4.00	3.83
Exploring Equity in Benefit Flows in Commercial Buildings	3.50	4	3.83	3.50	3.33

Commercial Buildings Integration

Six CBI projects are listed in their own CBI-specific technology track. These projects are summarized in the below table.

Table 15. Scoring Summary of CBI-Specific Projects

Project	Weighted Average	Number of Reviewers	Alignment and Impact	Approach	Progress and Future Work
Plug Process Loads	3.53	3	3.67	3.33	3.67
Efficient and Healthy Schools Campaign (22296)	3.27	3	3.67	3.33	3.00
Efficient and Healthy Schools Campaign (22291d)	3.33	6	3.67	3.17	3.33

Project	Weighted Average	Number of Reviewers	Alignment and Impact	Approach	Progress and Future Work
Building Envelope Campaign	3.27	3	3.67	3.00	3.33
Integrated Lighting Campaign	3.30	4	3.50	3.25	3.25
Technology Analysis and Validation of Integrating Connected Grid-Interactive Flexible Building Loads, Lighting, Automated Shades, and Intelligent Energy Storage to Provide Grid-Interactive Flexible Building Loads	3.05	3	3.25	3.25	2.75
Space Conditioning BBA Technology Research Team: Energy, Health, and Environmental Performance in All Communities	3.20	4	4.00	3.00	3.00

Data Tools and Analysis

Four of the Data Tools and Analysis projects are designed to better assess commercial structures and offer tools for solutions-oriented communication. These projects are summarized in the below chart.

Table 16. Scoring Summary of CBI Data Tools and Analysis Projects

Project	Weighted Average	Number of Reviewers	Alignment and Impact	Approach	Progress and Future Work
Building Energy Asset Score	2.76	5	2.60	2.80	2.80
SEED Platform	3.28	5	3.60	3.20	3.20
Building Efficiency Targeting Tool for Energy Retrofits (BETTER)	3.48	5	3.80	3.40	3.40
Audit Template	3.32	5	3.40	3.20	3.40

Under-Resourced Communities

The two Under-Resourced Communities projects aim to prioritize energy solutions for under-Resourced communities. These projects are summarized below.

Table 17. Scoring Summary of CBI Under-Resourced Communities Projects

Project	Weighted Average	Number of Reviewers	Alignment and Impact	Approach	Progress and Future Work
Driving Equitable Access to Energy Efficient, Zero Energy, and Zero Carbon Buildings in Underserved Communities	3.37	6	3.50	3.50	3.17
Systems Technology Energy Equity and Justice (ST-EEJ) Engagement	3.37	6	3.50	3.67	3.00

HVAC

The one HVAC project within CBI is summarized below.

Table 18. Scoring Summary of CBI HVAC Project

Project	Weighted Average	Number of Reviewers	Alignment and Impact	Approach	Progress and Future Work
No Vapor-Compression, Electrochemical-Looping Heat Pump (NOVEL HP)	3.00	4	3.50	3.00	2.75

Thermal Energy Storage

The one TES project within CBI is summarized below.

Table 19. Scoring Summary of CBI TES Project

Project	Weighted Average	Number of Reviewers	Alignment and Impact	Approach	Progress and Future Work
Wall Embedded Multi-Functional Heat Pump with Energy Storage Systems for Grid-Responsive and Weather-Transactive Controls	2.65	4	2.75	2.50	2.75

Residential Buildings Integration

RBI works closely with diverse stakeholders, including home builders, energy professionals, and government agencies to enhance energy efficiency across new and existing homes. Through research, partnerships, and scalable technology development, RBI aims to make residential buildings more affordable, comfortable, and resilient, significantly reducing their energy consumption.

Table 20. Scoring Summary of RBI Projects

Technology Track	Project Count	Average Score Out of 4	Low Score Out of 4	High Score Out of 4
	Note: The following figures summarize *all* projects in an identified technology track.			
Analysis	6	3.65	3.20	3.93
Envelope	18	3.25	2.80	3.64
HVAC	53	3.25	2.27	3.93
Windows	11	3.00	2.40	3.43
Workforce	6	3.16	2.55	3.70

Analysis

The two Analysis projects within RBI are summarized below.

Table 21. Scoring Summary of RBI Analysis Projects

Project	Weighted Average	Number of Reviewers	Alignment and Impact	Approach	Progress and Future Work
ResStock and End-Use Savings Shapes for the U.S. Housing Stock	3.93	6	4.00	4.00	3.83
Chicago Energy Efficiency Planning and Analysis, and Integrated Retrofit Strategy Validation in Single Family Homes	3.20	6	3.33	3.17	3.17

Envelope

The two Envelope projects within RBI are summarized below.

Table 22. Scoring Summary of RBI Envelope Projects

Project	Weighted Average	Number of Reviewers	Alignment and Impact	Approach	Progress and Future Work
Renew-Wall	3.00	4	3.00	3.00	3.00
Hygrothermal Performance of New and Retrofit Residential Building Envelopes	3.20	4	3.00	3.25	3.25

HVAC

The final eight HVAC projects within RBI are summarized below.

Table 23. Scoring Summary of RBI HVAC Projects

Project	Weighted Average	Number of Reviewers	Alignment and Impact	Approach	Progress and Future Work
Juneau Heat Pump Deployment	3.48	5	3.80	3.40	3.40
Field Validation in SE	3.32	5	3.40	3.40	3.20
Field Validation in Hot Climate	3.52	6	3.60	3.60	3.39
Combination HP and HPWH	3.16	5	3.40	3.00	3.20
Dual Fuel Controls	2.92	5	3.00	2.80	3.00
Load Shifting with Ductless Heat Pumps	3.20	5	3.20	3.40	3.00
Smart Tools for Efficient HVAC Performance (STEP) Campaign	3.20	4	3.00	3.25	3.25
Develop Field Test Methods and Analytical Techniques to Assess HVAC Fault Impacts and a Simplified Commissioning Method	2.85	4	2.75	3.25	2.50

Windows

The four Windows projects within RBI are summarized below.

Table 24. Scoring Summary of RBI Windows Projects

Project	Weighted Average	Number of Reviewers	Alignment and Impact	Approach	Progress and Future Work
R5 Window and Attachments	2.70	4	3.00	2.75	2.50
Storm Window and Insulating Panel (SWIP) Campaign	3.00	5	3.40	3.00	2.80
Adding Exterior Insulation Siding and Windows	2.68	5	3.00	2.80	2.40
Windows Deployment and Partnership for Advanced Window Solutions (PAWS)	3.08	5	3.40	3.00	3.00

Workforce

All six of the projects in the Workforce technology track are concerned with residential buildings. These projects are summarized below.

Table 25. Scoring Summary of RBI Workforce Projects

Project	Weighted Average	Number of Reviewers	Alignment and Impact	Approach	Progress and Future Work
Interstate Renewable Energy Council, Inc. - Dynamic and Responsive Distributed Energy Resource Education Solutions for Building, Fire, and Safety Department Officials	3.70	4	3.5	3.75	3.75
Western States Building Energy & Controls Apprenticeship (BECA) Program	2.90	4	3.00	2.75	3.00
Frontier Energy - PATHS: Career Pathways to Advance the Trades in HVAC Services	3.15	4	3.75	3.00	3.00
Construction Methodology Transformation for the Benefit of Workforce Development	3.50	4	3.50	3.50	3.50
Training the Next Generation of Heat Pump HVAC Technicians	3.15	4	3.25	3.00	3.25
City University of New York: City College - Remote Coaching with Performance Data for Enhanced Building Operations (Building Re-Tuning and On-Going Commissioning)	2.55	4	2.75	2.50	2.50

Recommendations

This final section recommends future steps and initiatives BTO can pursue to improve the performance of BTO-funded projects. BTO is committed to ongoing development of its projects to practically support energy efficiency and savings for buildings.

Nurture Dialogue About Technology Adoption

Efforts to increase efficiency in residential and commercial buildings are only as successful as a technology's affordability, accessibility, and adoptability. With that in mind, BTO aims to improve the performance of its projects by creating opportunities for BTO and project researchers to discuss commercialization and market transformation. BTO will create spaces for open discussion of technology adoption and will spotlight successful commercialization case studies with the intent of solidifying the entire research, development, and demonstration process.

Encourage Real-World Testing

Peer reviewers at the 2023 BTO event were asked to provide suggestions on how to improve projects. One recurring theme was the recommendation to test and evaluate a proposed technology in realistic settings. Real-world testing's value was emphasized for a variety of reasons, including the demonstration of a technology's scalability, discovery of effectiveness beyond lab conditions, and increased ability to test if relevant factors were accounted for in a model. With that feedback in mind, BTO will consider assigning additional weight to real-world testing in its development of funding opportunities and rubrics to encourage its prioritization in future projects.

Examples

The RBI team provided two specific examples of recommendations to pursue in the future.

First, Building Science Advisor (BSA) is a tool on the Building America Solution Center that helps teach building science principles and can inform residential building designers on how to specify energy-efficient, moisture-durable wall systems, without the need to learn how to use complex hygrothermal modeling software. At the 2023 Peer Review, RBI received feedback that the tool needed a better user interface and experience, including a wider range of wall assemblies in the database.

Second, the ResStock-EUSS project was one of the top-rated projects in the 2023 Peer Review. Reviewers gave two specific suggestions for improvement:

- One reviewer identified a need to model HVAC system types, especially in larger multifamily buildings with shared systems.
- One reviewer commented that outreach is essential for future work. The reviewer suggested using YouTube training sessions for all levels of interest.

RBI is implementing this feedback by updating the BSA tool, including HVAC system type capability in FY25 funding to support Building Performance Standards, and recording webinars to support Buildings Upgrade Prize participants.

In Summary

BTO is committed to funding projects that support buildings innovation, and the feedback gained by this process helps ensure that each project aligns with DOE goals and advances accessible solutions for real-world users. BTO is dedicated to identifying pragmatic ways to improve projects' performance, since these research projects are the essential energy-efficient, cost-saving technologies needed to improve the efficiency of residential and commercial buildings now and in the future.

Endnotes

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