Energy Efficiency Technology Roadmap

Volume 1: Introduction & Background

March 2015

Enhanced PDF Functionality

Functionality of the PDF version of this document has been enhanced in the following ways:

- **Embedded Table of Contents Links:** The Table of Contents has been linked to the appropriate sections of the document.
- **Internal links embedded within the document** to facilitate navigation between sections and "Back to Table of Contents."
- **Control + F:** As always, one can navigate through the document by searching for specific words or phrases by pressing the "Control" and "F" keys simultaneously.

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Back to Table of Contents

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Back to Table of Contents

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Special Thanks

While the Bonneville Power Administration has funded and managed the overall development and maturation of this Energy Efficiency Technology Roadmap, the effort would not have been possible without the active engagement of a diverse array of subject matter experts from organizations and institutions throughout North America. Since the beginning of this roadmapping project in late 2009, more than 200 participants representing 119 organizations have contributed approximately 5,120 hours and $1,100,000 worth of voluntary input. Their expertise is essential to this project.

Members of the Regional Emerging Technology Advisory Committee (RETAC) played a key role the roadmap's creation. Those members include representatives from Bonneville Power Administration, Northwest Power and Conservation Council, Northwest Energy Efficiency Alliance, Electric Power Research Institute, Pacific Northwest National Laboratory, Washington State University Energy Program, Energy Trust of Oregon, Puget Sound Energy, Snohomish Public Utility District, Seattle City Light, Idaho Power, and Avista. RETAC member input was critical in laying the groundwork for the Roadmap Portfolio and has been as important as the project has matured.

Thanks as well to the project team, who worked behind the scenes to plan, coordinate, analyze, evaluate, revise, and prepare everything needed to continue fine-tuning this portfolio. Without the help of contractors from the Engineering and Technology Management Department at Portland State University, the Washington State University Energy Program, and Livingston Energy Innovations, this roadmap would be much less robust than it is today.

Finally, a special thanks to our partners at the Electric Power Research Institute who brought their collective expertise to bear in 2012 to evaluate the current status of R&D projects and programs for this latest version. EPRI expertise and support was also essential in convening the National Energy Efficiency Technology Roadmapping Summit in Portland (Aug. 8 and Sep. 24–27, 2012). Since this event, EPRI and BPA have continued to work together to communicate the value of this resource and begin to build a broader collaboration for EE technology roadmapping and R&D tracking.

There is still much collaborative work to be done to improve our understanding of the current energy efficiency technology research landscape but we are making strides in the right direction and we truly appreciate the dedication and contributions of all who have been a part of this important endeavor.

For more information about the Energy Efficiency Technology Roadmap, contact:

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Back to Table of Contents

FORWARD

Technology has played a central role in the Northwest's development, from the Federal Columbia River Power System to technology giants like Boeing, Microsoft and Intel to thousands of businesses, universities and laboratories. In the Northwest, irrigation is high tech.

This savvy has allowed the region to meet half of its load growth through cost-effective investments in energy efficiency for more than thirty years. Through the leadership of the region's utilities, labs, universities, energy organizations and private businesses, the Northwest has been able to successfully deliver energy efficiency as a reliable resource.

The Northwest Power and Conservation Council's *Sixth Power Plan* calls for roughly 85 percent of the region's load growth to be met with energy efficiency by 2030. To meet these goals, we must find ways to increase the adoption rates of existing products and services. At the same time, we must also strategically target the region's research and development resources into efforts that will produce the technologies needed to enable the products of tomorrow.

In December 2009 thirty-five experts from twenty organizations pooled their efforts to develop a set of energy efficiency technology roadmaps for the residential and commercial sectors that would define a research agenda for the Northwest. The results of the intensive ten-week effort have been expanded and refined through additional workshops and the integration of critical comments from experts beyond the region. Revised versions of the Energy Efficiency Technology Roadmap have been released in March and July 2010; March 2011; March, August, and September 2012; January and March 2013; and March 2014. These roadmaps will always be a draft; it is intended as a living document, continuously refined as we move forward.

There were two notable additions to these roadmaps commencing with the March 2012 version. We expanded into two important industrial product and service areas: Industrial Food Processing and Combined Heat and Power (CHP). We also created a new appendix of existing R&D programs (Appendix B) to provide expanded and updated information previously contained in the individual "R&D Program Summaries" pages. Beginning with the March 2013 version, the residential and commercial sector R&D program summary pages identify key research questions for most R&D programs.

Far more minds are needed to contribute; hence the document is public, freely available for use by others in process, form, and content. As always, we are distributing this draft with a request: Please evaluate these findings with a critical mind and send us your comments. We are especially interested in filling in any holes in regard to existing research and development programs. We are not interested in duplicating efforts already underway elsewhere.

We will be collecting feedback on this draft on an ongoing basis. Any and all comments can be sent directly to our project manager, James V. Hillegas-Elting (jvhillegas@bpa.gov, 503.230.5327).

Sincerely,

Terry Oliver
Chief Technology Innovation Officer
Bonneville Power Administration

TABLE OF CONTENTS

Introduction

Special Introduction: March 2015

Reflecting its function as a live, working document to aid in strategic R&D planning, the title of this version of the roadmap has been changed to "Energy Efficiency Technology Roadmap" (hereafter EE Roadmap). Its constituent chapters have also been broken-out into separate volumes.

From 2009-2012, this resource was titled the Northwest Energy Efficiency Technology Roadmap; from 2012-2014 it was titled the National Energy Efficiency Technology Roadmap Portfolio. These titles reflect its evolution from a roadmap with largely regional subject matter expert contributors to one drawing from a more extensive range of experts from across North America. One reason for this change is to simplify its title. Another is to prepare for future iterations likely to involve more explicit alignment with BPA's newest demand-side roadmap resource, the Demand Response Technology Roadmap.[1]

Roadmap chapters have been arranged in stand-alone documents. These "volumes" correlate to chapters in earlier versions addressing residential and commercial sector topics (Building Design & Envelope; Lighting; Electronics; Heating, Ventilation, and Air Conditioning; Sensors, Meters, and Energy Management Systems) and industrial topics (Industrial Food Processing; Combined Heat and Power). Content within these volumes remains unchanged from the March 2014 version.

Since 2009, more than 200 experts representing nearly 120 research institutions, utilities, and vendors have contributed approximately 5,120 hours and $1,100,000 worth of voluntary input to develop and refine this resource. The EE Roadmap includes forty-one technology roadmaps in seven product and service areas in the commercial, residential, and industrial sectors, as Figure 1 identifies.

[1] BPA managed a project in 2014 to produce the agency's first Demand Response Technology Roadmap. The first draft was published in November 2014 and in March 2015 a revised version was included as part of the agency's annual funding opportunity announcement. See www.bpa.gov/ti for a link to this and the agency's other technology roadmaps.

Product & Service Area	Roadmaps	Capability Gaps	Technology Characteristics	R&D Program Descriptions
Building Design / Envelope	9	65	65	82
Lighting	6	68	52	69
Electronics	5	43	49	64
Heating, Ventilation, Air Conditioning	8	112	100	130
Sensors, Meters, EMS	6	46	51	46
Industrial Food Processing	4	49	82	56
Combined Heat and Power	3	52	77	75
Totals	*41*	*435*	*476*	*522*

Figure 1. Content of the EE Roadmap.

Purpose

Technology roadmapping is a tool that enables organizations to manage time and resource investments more thoroughly and accurately in response to increasing complexity and the accelerated pace of change. The defining elements of the roadmapping process are:

1. Solicit stakeholder expertise in a structured manner;
2. Distill this expertise within an easy-to-navigate deliverable, such as a diagram, document or website; and
3. Use the resultant deliverable to help guide planning.

The roadmapping approach is defined by some core elements but there is wide variation in how a given organization applies them. The result is that technology

Back to Table of Contents

roadmaps come in an array of formats and are created for a range of purposes. These variations reflect the different missions, cultures, and strategic goals of the organization(s) developing a given roadmap. As long as the roadmap fulfills the purposes that stakeholders intended, it can be considered a useful tool.

The EE Roadmap exists to define (and refine) a technology research agenda for the medium and long-term (three to twenty years) to guide institutional and regional investment strategies. It does so by identifying the landscape of energy efficiency R&D programs linked directly to desired technology characteristics and by tracking research needs that are already being addressed. This latter function provides confidence to BPA and other stakeholders that R&D project funding is not redundant and that resources are optimized within a strategic plan. In 2013 the United Nations Framework Convention on Climate Change deemed this approach a best practice in the way it clearly connects key organizational drivers with technology needs.

The EE Roadmap provides a snapshot of stakeholders' current perspectives on:

1. Key drivers (environmental/global, market, policy and regulatory, and technology innovation) affecting the agency in regard to energy efficiency;
2. Products/services needed to address identified drivers;
3. Technologies needing development to bring non-existing products and services to the marketplace; and
4. Gaps in existing R&D programs designed to address identified technology needs.

Ultimately, the goal of identifying and prioritizing technology R&D gaps allows for a more rational allocation of limited funding and resources by organizations such as the BPA, national labs, research universities, private businesses, and venture capitalists.

Technology R&D and Emerging Technologies Research

With its focus on R&D programs that seek to address business challenges and opportunities in the three-to-twenty-year time horizon, the EE Roadmap fulfills another important need. It is distinct from—but complementary to—the efforts of teams at BPA, the Northwest Energy Efficiency Alliance (NEEA), and elsewhere whose work involves "emerging technologies." This work tends to be focused more on the nearer-term time horizon (up to thirty-six months) than the R&D programs identified in the EE Roadmap.

Another way to describe the sometimes subtle differences between these areas of research is in relation to the following categories:

Breakthrough: High-risk projects to deliver significant improvements in efficiency, effectiveness, and/or usability but that take longer to bring out of the R&D realm and into full market implementation.

Incremental: Lower-risk projects offering step-by-step improvements in efficiency, effectiveness, and/or usability in new applications and likely to be ready for full market implantation in no more than three years.

Confirmational: Lower-risk projects to ratify or corroborate efficiency, effectiveness, and/or usability in new applications, within different climate conditions, or by proving something not yet used at BPA and likely to be ready for full market implementation in no more than three years.

Just as the BPA Technology Innovation Office seeks to balance risks and project duration across the agency's R&D portfolio, the EE Roadmap project team seeks to build roadmap content that balances breakthrough-type research needs with the shorter-duration incremental and confirmational projects that are generally considered emerging technologies research.

BPA's Energy Efficiency Emerging Technology (E3T) team and NEEA lead the Pacific Northwest's efforts to coordinate regional emerging technology research. This collaboration was a recommendation of the Northwest Energy Efficiency Taskforce in 2009 (more information below) and is also done in collaboration with national organizations such as the Consortium for Energy Efficiency and the California Emerging Technologies Coordinating Council. These groups research and analyze products and services with the potential to deliver significant energy savings but that may be facing market, behavioral, regulatory, or other barriers to large-scale introduction. Thus, *emerging technology* is defined as as any technology that is already available in the marketplace but that is facing one or more barriers to widespread adoption.

Both the EE Roadmap and emerging technologies work strives to bridge "chasms" that exist between an idea and its implementation within utility programs as a proven energy-efficient product or service. Tracking R&D programs through the EE Roadmap aids the efforts of emerging technologies teams by enabling the more rapid identification of technologies with energy savings potential; in turn, emerging technologies teams contribute to the work of utility programs staff by validating this potential and providing the necessary quantitative data to determine if a given product or service delivers energy savings.

Figure 2 on the following page illustrates how the EE Roadmap project and emerging technology research are both necessary to help "fill the pipeline" of energy-efficient products and services for utility programs implementation. This diagram also correlates this process with the Department of Energy's Technology Readiness Levels (TRLs) and identifies two potential "chasms" that can be barriers to implementing energy-efficient technologies.

[continued on p. xii]

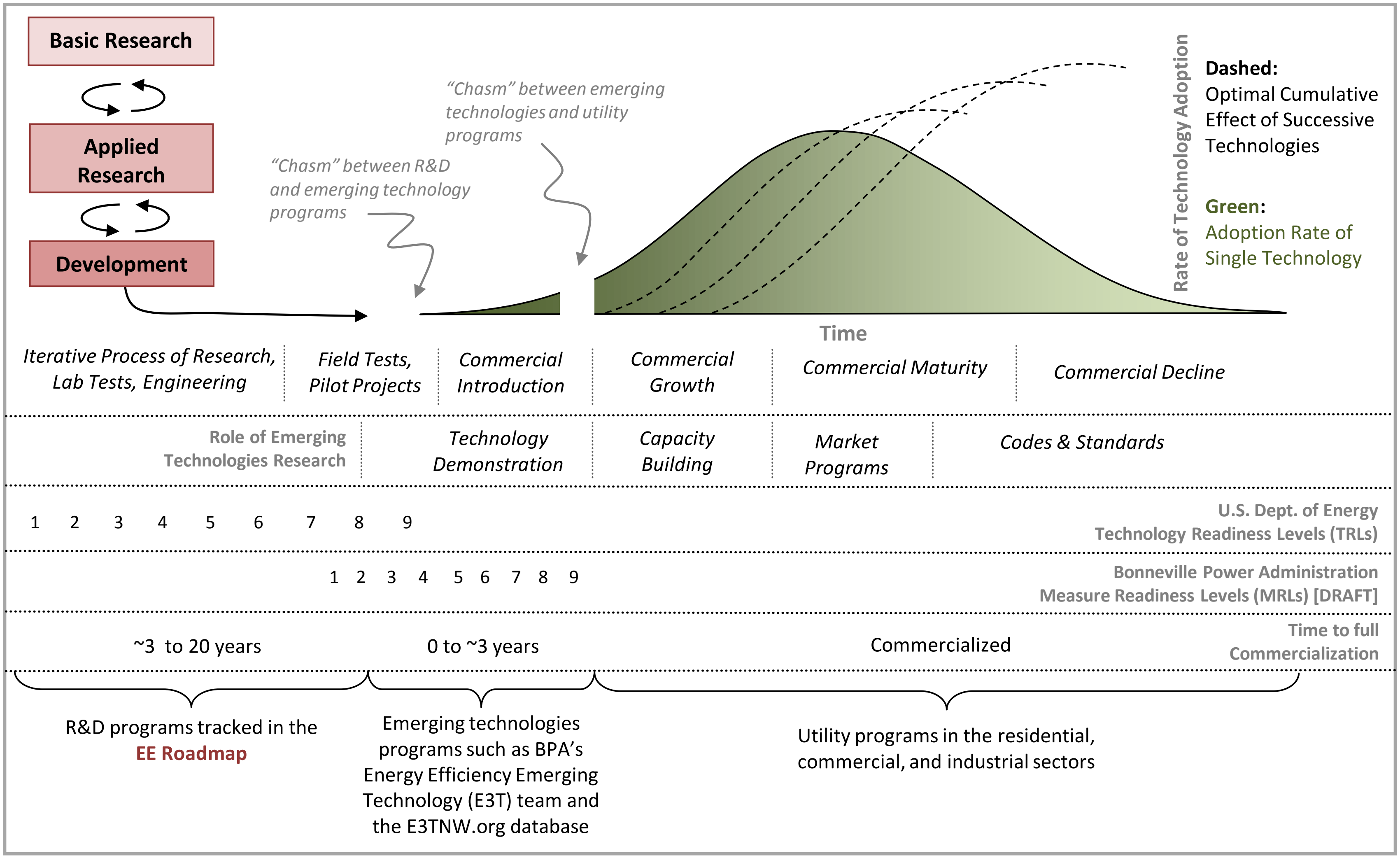


Figure 2. Energy Efficient Technology Commercialization Process. Simplified schematic illustrating a broadly representative example of the process of bringing an idea for an energy-efficient product or service through the phases of research, development, design, testing, evaluation, pilot-scale implementation, and commercial introduction and maturity. For comparative purposes, this general process is roughly correlated with the phases of emerging technologies initiatives, the U.S. Department of Energy's Technology Readiness Levels, and an ongoing effort at the Bonneville Power Administration to define a system of Measure Readiness Levels to guide the process of transferring products and services into full-scale utility programs implementation .

(Adapted from a number of sources including: Institute for Building Efficiency, "Advancing Energy Efficiency Technology: California Helps Blaze the Trail: Insights from the Emerging Technologies Coordinating Council 2010 Summit," n.d. (ca. Nov. 2010), http://www.institutebe.com/Building-Efficiency-Events/ettc-summit-2010.aspx; BPA Measure Readiness Levels currently under development; BC Hydro "Shaping the ET Future: Innovation in ET Programs," n.d.; U.S. Department of Energy Office of Energy Efficiency and Renewable Energy, "Technology Readiness Levels (TRLS)," http://www1.eere.energy.gov/manufacturing/financial/trls.html.)

Back to Table of Contents

Another important purpose of the EE Roadmap is that it is focused on *technology* R&D programs. There are many other important considerations that propel or hinder the widespread adoption of energy efficiency products and services, such as market conditions, human behavior, regulations, policies, standards, and education/training. Readers will find these non-technology-related considerations in the EE Roadmap primarily within the Driver or Capability Gap categories, but they generally do not fall within the purview of *technology* R&D programs. Other institutions have developed or are developing roadmaps that focus specifically on these other considerations. The EE Roadmap will include citations to and updates about these other roadmaps as information becomes available. Examples include the American National Standards Institute (ANSI) Energy Efficiency Standardization Coordination Collaborative (EESCC) roadmapping project and the Alliance to Save Energy's energy efficiency policy recommendations of February 2013 listed below.

Background

From the beginning, development of the EE Roadmap has been a needs-driven, collaborative effort that reflects the input and expertise of a diverse range of stakeholders. In 2008 and 2009 a group of executives representing regional utilities and stakeholders convened as the Northwest Energy Efficiency Taskforce (NEET) to explore how to deliver electricity conservation savings more effectively and efficiently. Among NEET's recommendations was that BPA and NEEA improve coordination and collaboration on energy efficiency emerging technology research.

As an initial step, stakeholders formed a representative group of subject matter experts as the Regional Emerging Technology Advisory Committee (RETAC). One of the RETAC's first projects was to initiate the development of an updateable energy efficiency technology roadmap that would describe the present landscape of research programs needed to enable technology characteristics that fill capability gaps and, thereby, address key economic, social, environmental, regulatory, and other drivers.

BPA staff had created an agency-specific energy efficiency roadmap in the mid-2000s, but the RETAC's charge was for BPA to broaden the scope of this effort. This work helped inform the initial stages of the creation of the Northwest Energy Efficiency Technology Roadmap which, as its title indicates, was motivated by a scope that expressly incorporated the breadth of regional business challenges and opportunities.

From its inception the project team has envisioned the portfolio as a live, working document to be continually refined and revised to reflect stakeholder needs and the ever-evolving technology landscape. Northwest-focused editions of the portfolio were published in 2010, 2011, and early 2012. The March 2012 version included food processing and combined heat and power roadmaps and a new appendix ("Appendix B") to track existing R&D projects identified in the roadmap pages. With the success of the project and increased interest from colleagues outside of the region, in 2012 the project team expanded the scope by convening the National Energy Efficiency Technology Roadmapping Summit (more information on this event below).

In the process of identifying gaps in existing energy efficiency R&D programs, roadmapping participants in 2010 also identified a list of products and services that were already available in the marketplace but not widely adopted due to various technical and/or market barriers—the "emerging technologies" described above. While addressing this group of products and services was not the primary purpose of the roadmapping endeavor, a workshop was held to articulate:

1. Barriers to the wider adoption of existing products/services; and
2. Necessary components to future market intervention programs and other initiatives to increase adoption rates for these targeted products/services.

The findings articulated by participants in this workshop can be found in Appendix A, specifically Appendix A4, "Workshop 3 (Market Interventions, Programs, Other Initiatives)."

BPA has served in a leadership role in the development and continued refinement of the EE Roadmap because of the important role the agency plays in conservation, marketing, transmission, and environmental stewardship; however, the agency does not "own" the process or the product. The portfolio would be of significantly less value if it were not for the input, support, and critical feedback at every stage of the process from each of the individuals and institutions identified in the "Support Staff" and "Workshop Participants" pages above. Since the beginning of this roadmapping project in late 2009, more than 200 participants representing 119 organizations have contributed approximately 5,120 hours and an estimated $1,100,000 worth of voluntary input.

BPA's Office of Technology Innovation uses these roadmaps to guide its annual solicitation for proposals for energy efficiency R&D projects. This annual solicitation occurs in March; proposals not linked to technology needs identified in the roadmap are not eligible for awards. Because these roadmaps are shared public resources, any organization can also use them to guide their own research efforts with some confidence that their work fits into a larger research agenda crafted and vetted by technical experts from across the country.

By creating a regional technology roadmap that has expanded to be national in scope, the Northwest has taken an important step toward the goal of creating continuity between its R&D efforts to bring non-existing technologies to market, ongoing work in emerging technologies, and present and future market intervention strategies.

Both the EE Roadmap and the work of emerging technology organizations are critically important in realizing energy savings: As recent studies from the Energy Trust of Oregon and the Northwest Power and Conservation Council's NW Resource Adequacy Forum conclude, regional energy efficiency targets will fall short before 2020 without robust efforts to identify and bring to market a steady stream of increasingly more efficient technologies.

At the national level, the Alliance to Save Energy's February 2013 report *Energy 2030: Doubling U.S. Energy Productivity by 2030* recognizes the critical role that government plays in complementing private sector energy productivity and market adoption of energy-efficient technologies. Because "private R&D budgets are small in many sectors related to energy productivity in part due to the fragmented markets and industry structures and to the spillover of knowledge," this report notes,

> *government support both for R&D and for a wide range of deployment programs has been critical to advances in energy productivity. Often these programs have been most effective in concert: R&D support helps develop technologies, technical assistance and incentives assist early market introduction, information programs spur broad commercialization, and standards ensure that all consumers benefit and push markets forward toward further innovation (p. 22).*

National Energy Efficiency Technology Roadmapping Summit (2012)

The National Energy Efficiency Technology Roadmapping Summit convened in Portland, Oregon, September 24–27, 2012, with a preparatory workshop held August 8. Planning and implementing this event involved close collaboration among BPA, the Electric Power Research Institute (EPRI), Portland State University Engineering and Technology Management Department, Washington State University Energy Program, and NEEA. Summit participants included government entities, national laboratories, academic and other research institutions, public and investor-owned utilities, vendors, non-profit organizations, and others. (Names of Summit workshop participants have been integrated into the list on the preceding pages.)

Subject matter experts volunteered their time to update and expand energy efficiency technology roadmaps within the residential and commercial sectors. They further strengthened the roadmaps by articulating key research questions for most R&D programs listed in the EE Roadmap. In so doing, workshop participants helped refine a resource used to optimize research and development investments by limiting redundant spending and identifying opportunities for inter-organizational collaboration.

In conjunction with the roadmapping workshops, EPRI organized four full days of expert panel presentations on cutting-edge technologies. The two-fold purpose of these presentations was: 1) to convene a group of expert speakers to provide brief and informative highlights and overviews of noteworthy research and development efforts; and 2) to provide a venue in which national experts could network with one another, share ideas and achievements, and gain inspiration and insights that could be applied in the corresponding roadmapping workshop.

See Appendix A for Roadmapping Summit schedules, agendas, and workshop minutes. For Summit presentations and videos, see http://online.etm.pdx.edu/bpa_summit/home.html.

While this roadmapping initiative commenced in the Pacific Northwest, expanding the collaboration beyond the region during 2012 was the first step in developing a resource to benefit many other institutions and constituencies. Including the pre-Summit workshop held August 8, 2012, the Summit brought together about 180 experts representing 101 organizations from across the United States and British Columbia. Collectively, these participants voluntary provided approximately 4,200 hours and $950,000 of in-kind contributions to the EE technology roadmapping effort.

Integrated Systems

Many participants this roadmapping initiative have stressed the importance of pursuing energy efficiency with an integrated systems approach rather than as a series of discrete "widgets." A systems approach can foster synergistic innovation among a suite of technologies, while the discrete approach can counteract efficiency gains if technologies work at cross-purposes. A simple example of the latter case would be a building daylighting system not linked with lighting controls so that even though the building interior received more natural light, the electric lights remained at full power. Conversely, addressing this need using the integrated systems approach would entail coupling the daylighting system with lighting controls to increase or decrease the amount of electric light provided based on the amount of daylight available.

The March 2013 version of the EE Roadmap documented the expertise contributed during the Roadmapping Summit. This version was the first to identify cross-cutting integrated systems. These were within the "Commercial Integrated Buildings" pages of the HVAC roadmaps section.

The March 2014 version expanded upon this by identifying technology R&D programs that explicitly address integrated systems (see the "Using the Roadmap" section below to learn about how these systems are signified in the diagrams). A critical first step in designating integrated systems as such was to develop an operational definition of this concept applicable to the EE Roadmap:

> An **integrated system** is a product or service composed of technology characteristics developed with the express intention of optimizing the functionality, compatibility, and efficiency of two or more formerly distinct features. The integrated systems approach:
>
> 1. can apply at the component, equipment, building, facility, or campus scales;
> 2. can pertain both to design tools and processes and/or to specific products and services; and
> 3. only applies to products and services that use electricity (including, however, integration of renewables into electrical systems).

There are two broad and not exclusive categories considered in this definition. Applying the integrated systems approach to design means optimizing sub-systems that are potentially complementary or in conflict, such as developing

Back to Table of Contents

daylighting solutions to decrease the need for electric lighting or designing HVAC systems with operable windows in mind. Integrated systems at the level of specific products and services can refer to two general categories. The first is the aggregation of two or more features, such as multi-service chilled beams. The second are energy management software and communications systems that track and optimize energy flows and applications within a building, facility, or campus.

For the technology areas covered in the EE Roadmap, non-electrical products and services are generally to be considered outside of this definition. Integrating building- or campus-scale renewable energy sources (solar, wind, etc.) into the electrical system is considered an integrated system within the EE Roadmap, but power generated from fuel sources that is *not* to be connected to an electrical system is not. Thus, technologies involving fuel switching are not integrated systems, but a combined photovoltaic and battery storage array connected to a building's electrical system is.

As with all EE Roadmap content, this operational definition is provisional pending additional research and further refinement from subject matter experts and project stakeholders. It is intended as a working definition to help frame the content that follows and provide a starting point for further collaboration.

Selected Sources

The list below identifies sources for additional details on some of the background information provided above.

American National Standards Institute Energy Efficiency Standards Coordinating Collaborative, "Standardization Roadmap: Energy Efficiency in the Built Environment," Version 1.0, Jan. 2014, available at http://www.ansi.org/standards_activities/standards_boards_panels/eescc/overview.aspx?menuid=3.

Alliance to Save Energy, Alliance Commission on National Energy Efficiency Policy, *Energy 2030: Doubling U.S. Energy Productivity by 2030*, Feb. 7, 2013, http://ase.org/sites/default/files/full_commission_report.pdf.

Cambridge University Institute for Manufacturing, "Roadmapping for Strategy and Innovation" website, http://www.ifm.eng.cam.ac.uk/resources/techmanworkbooks/roadmapping-for-strategy-and-innovation/.

"E3T: Energy Efficiency Emerging Technologies," http://e3tnw.org/.

Energy Trust of Oregon, "Briefing Paper: Energy Efficiency Programs," June 8, 2012, http://energytrust.org/library/meetings/board/120608_Board_Strategic_Planning_Workshop.pdf.

Ryan Fedie, Gregg Ander, Jorge Marques, and Jonathan Livingston, "The View from Here: A Utility Perspective on North American Emerging Technology Alignment," 2012 ACEEE Summer Study on Energy Efficiency in Buildings, http://www.aceee.org/files/proceedings/2012/data/papers/0193-000183.pdf.

Ben Kroposki, Bobi Garrett, Stuart Macmillan, Brent Rice, Connie Komumua, Mark O'Malley, and Dan Zimmerle, "Energy Systems Integration: A Convergence of Ideas," National Renewable Energy Laboratory Technical Paper TP-6A00-55649, July 2012, http://www.nrel.gov/esi/pdfs/55649.pdf.

Jonathan Livingston, Jack Callahan, Ryan Fedie, Robert Penney, and Jack Zeiger, "The E3T Framework: Fast-Tracking Emerging Technology Development in the Pacific Northwest," 2010 ACEEE Summer Study on Energy Efficiency in Buildings, http://www.aceee.org/files/proceedings/2010/data/papers/2041.pdf.

"National Energy Efficiency Technology Roadmapping Summit, September 24-27, 2012, DoubleTree Hotel, Portland, Oregon," http://online.etm.pdx.edu/bpa_summit/home.html.

National Renewable Energy Laboratory, "Energy Systems Integration" website, http://www.nrel.gov/esi/.

"NEET Report: Northwest Energy Efficiency Taskforce Report, Recommendations, Action Plan," Oct. 2009, http://www.nwcouncil.org/energy/neet/NEET%20 Report%20October%202009.pdf.

"Northwest Energy Efficiency Taskforce," http://www.nwcouncil.org/energy/neet/.

NW Adequacy Forum, "Pacific Northwest Power Supply Adequacy Assessment for 2017, Final Report," Nov. 21, 2012, http://www.nwcouncil.org/news/2012/12/4.pdf.

"Regional Emerging Technology Advisory Committee," https://conduitnw.org/Pages/Group.aspx?rid=29.

Technology Executive Committee of the United Nations Framework Convention on Climate Change, "Background paper on Technology Roadmaps," April, 2013, available through http://unfccc.int/ttclear/pages/home.html.

University of California Berkeley Center for the Built Environment, “Advanced Integrated Systems” website, http://www.cbe.berkeley.edu/research/ais.htm.

U.S. Department of Energy Advanced Manufacturing Office, “Technology Readiness Levels (TRLSs),” Dec. 2011, http://www1.eere.energy.gov/manufacturing/financial/trls.html.

Back to Table of Contents

Energy Efficiency Roadmaps & Strategy Documents

The lists below are intended to be broadly representative rather than exhaustive and will be updated as new information becomes available.

Energy Efficiency Technology Roadmapping

Electric Power Research Institute (EPRI)

Power Delivery and Utilization Sector Roadmaps, April 2012, http://mydocs.epri.com/docs/ CorporateDocuments/Roadmaps/PDU%20Roadmap_2012-04.pdf.

Oak Ridge National Laboratory (ORNL)

Research and Development Roadmap for Water Heating Technologies, prepared by Navigant Consulting, Inc., Sep. 30, 2011, http://www.ornl.gov/ci/ees/etsd/btric/pdfs/ WaterHeatingTechnologiesRoadmap_9-30-2011_FINAL.pdf.

Lawrence Berkeley National Laboratory (LBNL)

High-Performance Data Centers: A Research Roadmap, July 2003, http://hightech.lbl.gov/ documents/ datacenters_roadmap_final.pdf.

U.S. Department of Energy Office of Energy (DOE) Efficiency and Renewable Energy (EERE)

Building Technologies Office Strategic Plans, http://www1.eere.energy.gov/buildings/residential/ba_strategic_plan.html.

Solid-State Lighting Research and Development: Multi-Year Program Plan, prepared by Bardsley Consulting (and others), April 2012, http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/ssl_mypp2012_web.pdf.

Buildings R&D Breakthroughs: Technologies and Products Supported by the Building Technologies Program, April 2012, http://apps1.eere.energy.gov/buildings/publications/pdfs/corporate/rd_breakthroughs.pdf.

Summary of Gaps and Barriers for Implementing Residential Building Energy Efficiency Strategies, Aug. 2012, http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/49162.pdf.

Windows and opaque building envelope roadmaps (as of November 2012, these roadmaps were soon to be published at http://www.eereblogs.energy.gov/buildingenvelope/).

Energy Efficiency Standards Roadmapping

American National Standards Institute (ANSI) Energy Efficiency Standardization Coordination Collaborative (EESCC)

Through 2013 the ANSI EESCC worked with stakeholders to develop an energy efficiency standardization roadmap. This roadmap provides an overview of the energy efficiency standardization landscape (including existing and in-development standards, codes, guidelines, and conformance programs) and identifies perceived gaps in energy efficiency standardization and conformance activities. In January 2014 the project team made available the first draft of this document for public comment.

"Standardization Roadmap: Energy Efficiency in the Built Environment," Version 1.0, Jan. 2014, available at http://www.ansi.org/standards_activities/standards_boards_panels/eescc/overview.aspx?menuid=3.

Other Energy Efficiency Roadmapping

International Energy Agency (IEA)

The IEA has produced a series of energy efficiency roadmaps to "accelerate the development of low-carbon energy technologies in order to address the global challenges of energy security, climate change and economic growth." These roadmaps represent "international consensus on milestones for technology development, legal/regulatory needs, investment requirements, public engagement/outreach and international collaboration." Included within them are recommendations for the development of standards, test protocols, performance certification ratings, and metrics in addition to the development of some particular technologies.

"Technology Roadmaps," http://www.iea.org/roadmaps/.

Oregon Built Environment & Sustainable Technologies Center (Oregon BEST)

Oregon BEST regularly convenes Agenda Development Forums of subject matter experts to develop prioritized research agendas to achieve energy efficiency and environmental performance goals. To date, Oregon BEST has published two reports in their Research Agenda Series.

"Deep Retrofits Research Agenda," Nov. 2012, http://oregonbest.org/sites/default/files/consortium/adf2012-09_deepretrofitsresearchagenda_lowresv2.pdf.

"Living Building Challenge Materials Research Agenda," Jan. 2013, http://oregonbest.org/sites/default/files/consortium/adf2012-11_lbcmaterialsresearchagenda.pdf.

Energy Efficiency Strategic Planning Documents

Alliance to Save Energy (ASE)

In February 2013, the ASE published energy efficiency policy recommendations written by its Alliance Commission on National Energy Efficiency Policy, *Energy 2030: Doubling U.S. Energy Productivity by 2030*. This reported concluded that "the U.S. can double its energy productivity by 2030 using cost-effective technologies and practices. Benefits to the nation from achieving this goal would be monumental . . . net benefits could be over $1,000 a year in average household savings in utility and transportation costs, over a million added jobs, a one-third reduction in carbon dioxide emissions, and a similar reduction in oil imports." To achieve these outcomes, the ASE "urges policy makers and the private sector to take immediate and concerted action" to "Unleash Investment in energy productivity throughout the economy, Modernize Regulations and Infrastructure to improve energy productivity, and Educate and Engage consumers, workers, business executives, and government leaders on ways to drive energy productivity gains."

The ASE believes that "these strategies can be implemented without burdensome *mandates* or massive government spending. To achieve this goal and its benefits, some public-private partnerships, and targeted government investments will be needed, and some rules will need to be reformed and strengthened."

Energy 2030: Doubling U.S. Energy Productivity by 2030, Feb. 7, 2013, http://ase.org/sites/default/files/full_commission_report.pdf.

Energy 2030 Recommendations, http://ase.org/resources/energy-2030-recommendations.

Energy 2030 Research Reports, http://ase.org/resources/ee-commission-report-summaries.

American Council for an Energy-Efficient Economy (ACEEE)

The ACEEE published a report in 2013 to analyze "several targeted policies that leverage market forces and address specific market failures and barriers to energy efficiency without requiring substantial spending or government mandates."

Shruti Vaidyanathan, Steve Nadel, Jennifer Amann, Casey J. Bell, Anna Chittum, Kate Farley, Sara Hayes, Michelle Vigen, and Rachel Young, "Overcoming Market Barriers and Using Market Forces to Advance Energy Efficiency," ACEEE, March 2013, available at http://www.aceee.org/research-report/e136.

California Public Utilities Commission (CPUC)

The CPUC launched a strategic effort in 2007 to achieve ambitious energy efficiency and greenhouse gas emission reductions by transforming the marketplace. The CPUC worked closely on this project with the state's regulated utilities—Pacific Gas and Electric Company, Southern California Edison Company, San Diego Gas & Electric Company, and Southern California Gas Company—and more than 500 individuals and organizations. The result was a roadmap for energy efficiency through and beyond 2020 that sets forth a long-term vision and goals for each economic sector and identification of near-term, mid-term and long-term strategies.

California Energy Efficiency Strategic Plan, http://www.cpuc.ca.gov/PUC/energy/Energy+Efficiency/eesp/.

California Energy Efficiency Strategic Plan, update Jan. 2011, http://www.energy.ca.gov/ab758/documents/CAEnergyEfficiencyStrategicPlan_Jan2011.pdf.

California Energy Efficiency Strategic Plan—HVAC Action Plan, http://www.cpuc.ca.gov/NR/rdonlyres/25B56CBE-7B79-41BC-B1C0-AE147F423B19/0/HVACActionPlan.pdf.

California Energy Efficiency Strategic Plan—Lighting Action Plan, http://www.cpuc.ca.gov/NR/rdonlyres/BE058656-3913-4DDD-92D5-60E82DD6AF0C/0/Lightingchapter_CAEnergyEfficiencyStrategicPlan_Jan2011.pdf.

California Energy Efficiency Strategic Plan—Zero Net Energy Commercial Building Action Plan, http://www.cpuc.ca.gov/NR/rdonlyres/6C2310FE-AFE0-48E4-AF03-530A99D28FCE/0/ZNEActionPlanFINAL83110.pdf.

Back to Table of Contents

National Action Plan for Energy Efficiency

The U.S. Environmental Protection Agency and Department of Energy co-facilitated the National Action Plan for Energy Efficiency from 2005 to 2010. It was "a private-public initiative to create a sustainable, aggressive national commitment to energy efficiency through the collaborative efforts of gas and electric utilities, utility regulators, and other partner organizations. Such a commitment can take advantage of large opportunities in U.S. homes, buildings, and schools to reduce energy use, save billions on customer energy bills, and reduce the need for new power supplies."

Overseeing the creation of the Action Plan was a group of more than sixty leading gas and electric utilities, state agencies, energy consumers, energy service providers, environmental groups, and energy efficiency organizations. The group "identified key barriers limiting greater investment in cost-effective energy efficiency, made five key policy recommendations to overcome the barriers, and documented policy and regulatory options for greater attention and investment in energy efficiency."

National Action Plan for Energy Efficiency (last updated Oct. 17, 2012), http://www.epa.gov/cleanenergy/energy-programs/suca/resources.html.

National Action Plan for Energy Efficiency, *Vision for 2025: A Framework for Change*, Nov. 2008, http://www.epa.gov/cleanenergy/documents/suca/vision.pdf.

Energy Efficiency Technology R&D Funding

The table below identifies energy efficiency technology R&D funding institutions and provides overviews of their request for proposal (RFP) processes and schedules. Though not exhaustive, this list is current at the time of publication based upon available information and is subject to change at any time.

As of the date of publication, BPA and EPRI staff continue to reach out to representatives of other R&D funding institutions with the complementary goals of:

- Identifying opportunities to use portfolio content to decrease the risk of redundant and unnecessary spending by coordinating R&D expenditures and efforts where feasible;
- Determining effective ways to expand and enhance portfolio content in efficient and mutually-beneficial ways; and
- Disseminating accurate and timely R&D RFP solicitation information and schedules to interested institutions, organizations, and firms.

Institution	Website	Scope	RFP Schedule
American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE)	https://www.ashrae.org/standards-research--technology/research	ASHRAE solicits annual research proposals that align with their five-year strategic research plans.	See https://www.ashrae.org/standards-research--technology/research
Bonneville Power Administration (BPA) Office of Technology Innovation	http://www.bpa.gov/Doing%20Business/TechnologyInnovation/Pages/default.aspx	"One key to BPA's success is making a firm connection with the business and technology challenges facing the utility industry. Technology roadmaps capture the logic and business framework for research and development. The roadmaps describe the specific BPA-related factors driving technology needs and identify the areas offering the greatest potential. BPA's Technology Innovation uses a cross agency Council of executives and technologists to guide its research and development efforts. BPA's Technology Innovation initiative has an annual cycle of portfolio funding based on strategic needs identified in the agency's technology roadmaps."	Annual RFP opens early March
California Energy Commission (CEC) Electric Program Investment Charge (EPIC)	http://www.energy.ca.gov/research/epic/	"The portion of the EPIC Program administered by the Energy Commission will provide funding for applied research and development, technology demonstration and deployment, and market facilitation for clean energy technologies and approaches for the benefit of ratepayers of Pacific Gas and Electric Company, San Diego Gas & Electric Company, and Southern California Edison Company."	See http://www.energy.ca.gov/research/upcoming_funding.html
California Energy Commission (CEC) Public Interest Energy Research (PIER) Program	http://www.energy.ca.gov/contracts/pier.html	Offers funding in the areas of Buildings End-Use Energy Efficiency; Energy Innovations Small Grant (EISG) Program; Energy Technology Systems Integration; and the Renewable Energy Research Area.	See http://www.energy.ca.gov/contracts/pier.html

Back to Table of Contents

INSTITUTION	WEBSITE	SCOPE	RFP SCHEDULE
State of Delaware Energy Efficiency Investment Fund	http://www.dnrec.delaware.gov/energy/information/otherinfo/Pages/EnergyEfficiencyInvestmentFund.aspx	The Energy Efficiency Investment Fund (EEIF) was created to help Delaware businesses make strategic investments in capital equipment and facility upgrades that will help decrease operating costs, reduce energy consumption, and improve environmental performance. The program offers funding for technical assistance, as well as competitively awarded grants and loans for implementation of energy efficiency projects."	"The EEIF program anticipates releasing solicitations on an annual basis"
National Science Foundation (NSF) Transformative Research	http://www.nsf.gov/about/transformative_research/	"As part of the larger Federal research and development effort, NSF has a comprehensive, overarching mandate to help keep all the fields and disciplines of science and engineering research healthy and strong. NSF accomplishes this through programs that support basic research proposed by individual investigators or collaborative groups of investigators. In addition to funding research through core disciplinary programs, NSF also provides support for facilities, equipment, instrumentation, centers of research, and activities such as workshops that help to advance fields of science."	See http://www.nsf.gov/about/transformative_research/
New York State Energy Research and Development Authority (NYSERDA) Energy Efficiency and Renewable Programs	http://www.nyserda.ny.gov/en/Energy-Efficiency-and-Renewable-Programs.aspx	"Conducting a multifaceted energy and environmental research and development program has been a central responsibility at NYSERDA since its inception in 1975. NYSERDA's R&D Program supports the development and commercialization of innovative energy and environmental products, technologies, and processes that improve the quality of life for New York's citizens and help New York businesses to compete and grow in the global economy." NYSERDA's Research and Development Program Areas include Energy Resources; Transportation and Power Systems; Energy and Environment Markets; Industry; Buildings; and Transmission and Distribution.	See http://www.nyserda.ny.gov/Energy-Innovation-and-Business-Development.aspx
Ontario Power Authority Industrial Accelerator Program	http://www.industrialaccelerator.ca/	"Industrial Accelerator is designed to assist eligible transmission-connected companies to fast track capital investment in major energy-efficiency projects. The five-year program will provide attractive financial incentives to encourage investment in innovative process changes and equipment retrofits so that the rate of return is competitive with other capital projects. In exchange, participants will contractually commit to delivering specific conservation targets within a set period of time and to maintaining them over the expected life of the project."	See http://www.industrialaccelerator.ca/
U.S. Department of Defense Environmental Security Technology Certification Program (ESTCP)	http://www.serdp.org/	"ESTCP releases at least one solicitation each fiscal year. Researchers from Federal organizations, universities, and private industry can apply for ESTCP funding. All proposals must respond to a Topic Area associated with the solicitation. ESTCP projects are formal demonstrations in which innovative technologies are rigorously evaluated. ESTCP demonstrations are conducted at DoD facilities and sites to document improved efficiency, reduced liability, improved environmental outcomes, and cost savings."	See http://www.serdp.org/Funding-Opportunities/ESTCP-Solicitations

INSTITUTION	WEBSITE	SCOPE	RFP SCHEDULE
U.S. Department of Defense Strategic Environmental Research and Development Program (SERDP)	http://www.serdp.org/	"SERDP issues two annual solicitations. The Core Solicitation seeks proposals for basic and applied research, and advanced technology development. Core projects vary in cost and duration, consistent with the scope of the work proposed. The SERDP Exploratory Development (SEED) program is designed to investigate innovative approaches that entail high technical risk or require supporting data to provide proof of concept. SEED projects are limited to not more than $150,000 and are approximately one year in duration. SEED projects that are successful are considered for additional follow-on funding. All submissions must be in response to a Statement of Need (SON) associated with the solicitation. Core and SEED solicitations have different SONs and different due dates."	See http://www.serdp.org/Funding-Opportunities/SERDP-Solicitations
U.S. Department of Energy	http://energy.gov	"The mission of the Energy Department is to ensure America's security and prosperity by addressing its energy, environmental and nuclear challenges through transformative science and technology solutions."	See http://energy.gov/public-services/funding-opportunities
U.S. Department of Energy Advanced Research Projects Agency–Energy (ARPA–E)	http://arpa-e.energy.gov	"ARPA-E funds technology-focused, applied research and development aimed at creating real-world solutions to important problems in energy creation, distribution, and use. . . . ARPA-E issues periodic Funding Opportunity Announcements (FOAs), which are focused on overcoming specific technical barriers around a specific energy area. ARPA-E also issues periodic OPEN FOAs to identify high-potential projects that address the full range of energy-related technologies, as well as funding solicitations aimed at supporting America's small business innovators."	See http://arpa-e.energy.gov/?q=programs/apply-for-funding
U.S. Department of Energy Office of Energy Efficiency & Renewable Energy (EERE)	http://www.eere.energy.gov/	"The Office of Energy Efficiency and Renewable Energy (EERE) works with business, industry, universities, and others to increase the use of renewable energy and energy efficiency technologies. One way EERE encourages the growth of these technologies is by offering financial assistance opportunities for their development and demonstration."	See http://www1.eere.energy.gov/financing/
U.S. Department of Energy Office of Energy Efficiency & Renewable Energy (EERE) Building America Program	http://www1.eere.energy.gov/buildings/residential/ba_index.html	"Since 1995, the U.S. Department of Energy's Building America program has provided research and development of building innovations to the residential construction and remodeling industry. As a national center for world class research, Building America develops market-ready solutions through partnerships with building and remodeling industry leaders, nationally recognized building scientists, and the national laboratories."	See http://www1.eere.energy.gov/financing/

Back to Table of Contents

Using the Roadmap

The EE Roadmap is a reference tool designed to be a living, working document. It was not crafted with any expectation that it would be read from beginning to end like a traditional report or narrative. Rather, its design allows for quick reference to technology development research agendas in relation to energy efficiency product and service areas in the residential, commercial, and industrial sectors.

Roadmap content is organized into eight volumes. Volume 1 provides an overall introduction and background, defines key terms and concepts, and guides readers in understanding how roadmap content is organized and interpreted. The remaining volumes contain multiple roadmaps within the respective area:

- Volume 1: Introduction & Background
- Volume 2: Building Design/Envelope
- Volume 3: Lighting
- Volume 4: Electronics
- Volume 5: Heating, Ventilation, and Air Conditioning
- Volume 6: Sensors, Meters, and Energy Management Systems
- Volume 7: Industrial Food Processing
- Volume 8: Combined Heat & Power

In addition to these volumes, there are two ancillary documents to the EE Roadmap:

- Appendix A contains process documents for all of the technology roadmapping workshops held to date, including minutes from each workshop.
- Appendix B contains more information, when available, about existing R&D programs identified in roadmap diagrams.

Disclaimer

Some roadmaps, project summaries, and appendix pages identify specific vendors, commercial products, or proprietary systems and technologies. BPA, its partner institutions, and other stakeholders make these references solely for context; these references do not constitute endorsement on the part of BPA, the Department of Energy, or any stakeholder involved in the creation and refinement of these roadmaps.

Roadmap "Swim Lane" Definitions

Roadmap diagrams are composed of the following four "swim lanes":

Drivers: Critical factors that constrain, enable, or otherwise influence organizational decisions, operations, and strategic plans. These factors can include: existing or pending regulations and standards; the environment; market conditions and projections; consumer behavior and preference; and organizational goals and culture, among others.

Capability Gaps: Barriers or shortcomings that stand in the way of meeting drivers.

Technology Characteristics: Specific technical attributes of a product or service necessary to overcome capability gaps.

R&D Programs: The iterative process undertaken at universities, national laboratories, some businesses, and related organizations to generate new ideas for products and services, develop models and prototypes, evaluate these in laboratory settings, and conduct engineering and production analyses with the goal of delivering the product or service to the marketplace. Within the *Roadmap Portfolio* the generic abbreviation "R&D" is to be understood as including, when appropriate, design, deployment, and demonstration in addition to research and development.

What is the difference between a "Technology Characteristic" and a "Capability Gap?"

A food processing company finds that the machine it currently uses to peel potatoes removes a significant amount of the flesh of the potato. Removing too much of the flesh reduces the yield of each processed potato and this reduced yield means that the company is not getting as much saleable product out of each unit of potatoes. The company must also pay increased costs to dispose of their wastes.

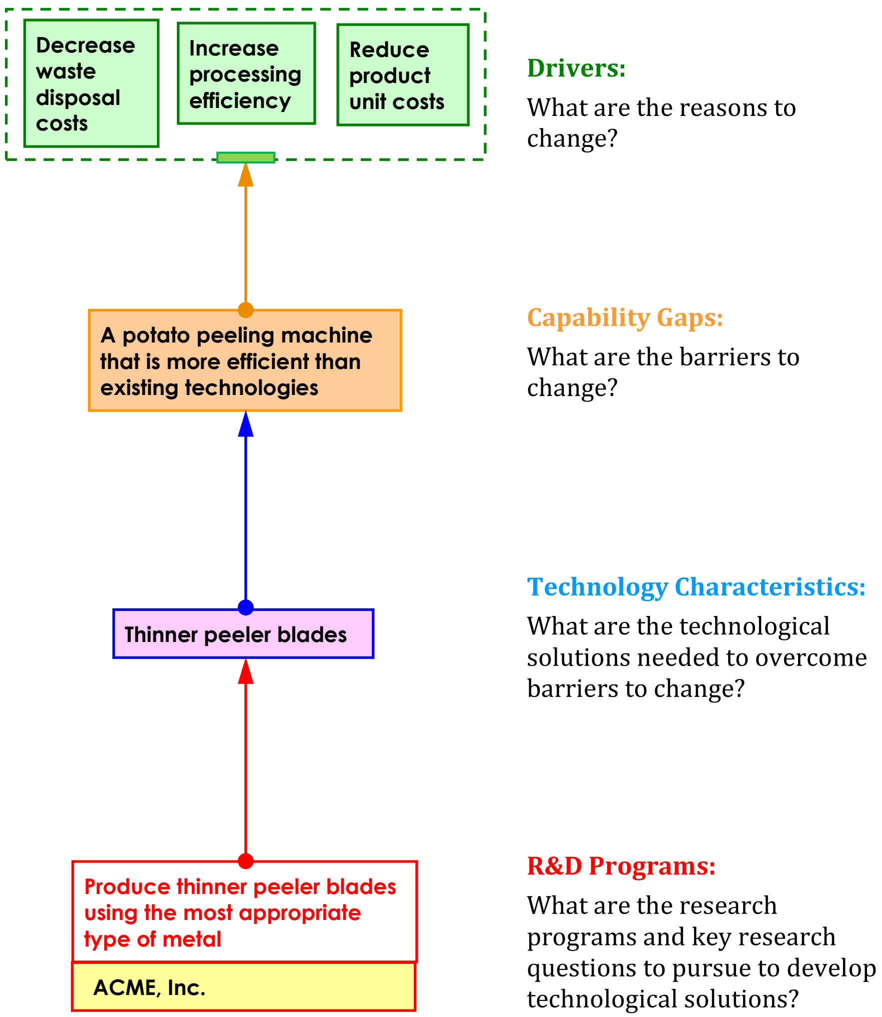
Faced with this situation, the company is facing three Drivers: 1) the desire to increase processing efficiency; 2) the desire to reduce product unit costs; and 3) the desire to reduce waste disposal costs.

Motivated by these drivers, company officials are seeking a solution that will improve the yield of their potato peeling machine. This is their Capability Gap: A peeling machine that is more efficient than existing technology.

Company officials take their request to their engineering team and ask them to develop a solution that will overcome the capability gap and, thereby, meet the three drivers. The engineering team applies their technical expertise to suggest that if they were to reduce the thickness of the peeler cutting blade they would be able to meet the requirements and overcome the capability gap. Thus the engineers have established a Technology Characteristic.

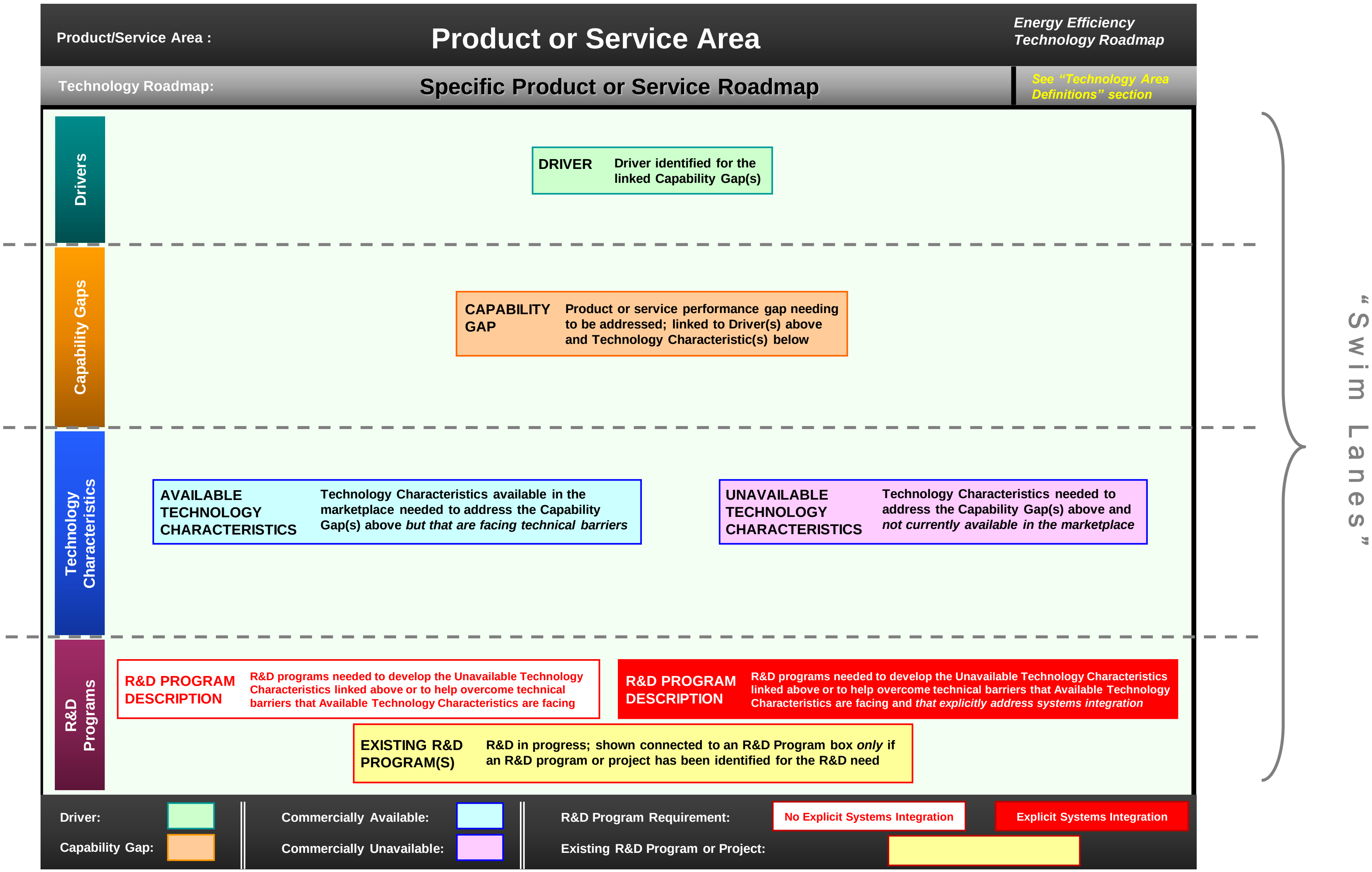
The engineers' next step is to commence an R&D Program in which they investigate the kinds of metal they could use to create thinner blades and then test these blades.

The diagram to the right illustrates this example:



Back to Table of Contents

ROADMAP DIAGRAM KEY



R&D Program Summaries Key

R&D Program Title. Brief summary of R&D program needed to develop the associated Unavailable Technology Characteristics or to help overcome technical barriers that Available Technology Characteristics are facing.

Existing research: Institution(s) listed where R&D program(s) are ongoing.

- Brief descriptive summaries of each institution's R&D program that may include, where applicable, hyperlinks to web pages and/or reference to further program details in Appendix B of the *National Energy Efficiency Technology Roadmap Portfolio*.

Key research questions:

1. One or more research questions that subject matter experts have identified as among the key questions and topic areas to pursue within the R&D program or project; numbers provided for identification only and do not imply prioritization.

R&D Program Title. Brief summary of R&D program needed to develop the associated Unavailable Technology Characteristics or to help overcome technical barriers that Available Technology Characteristics are facing.

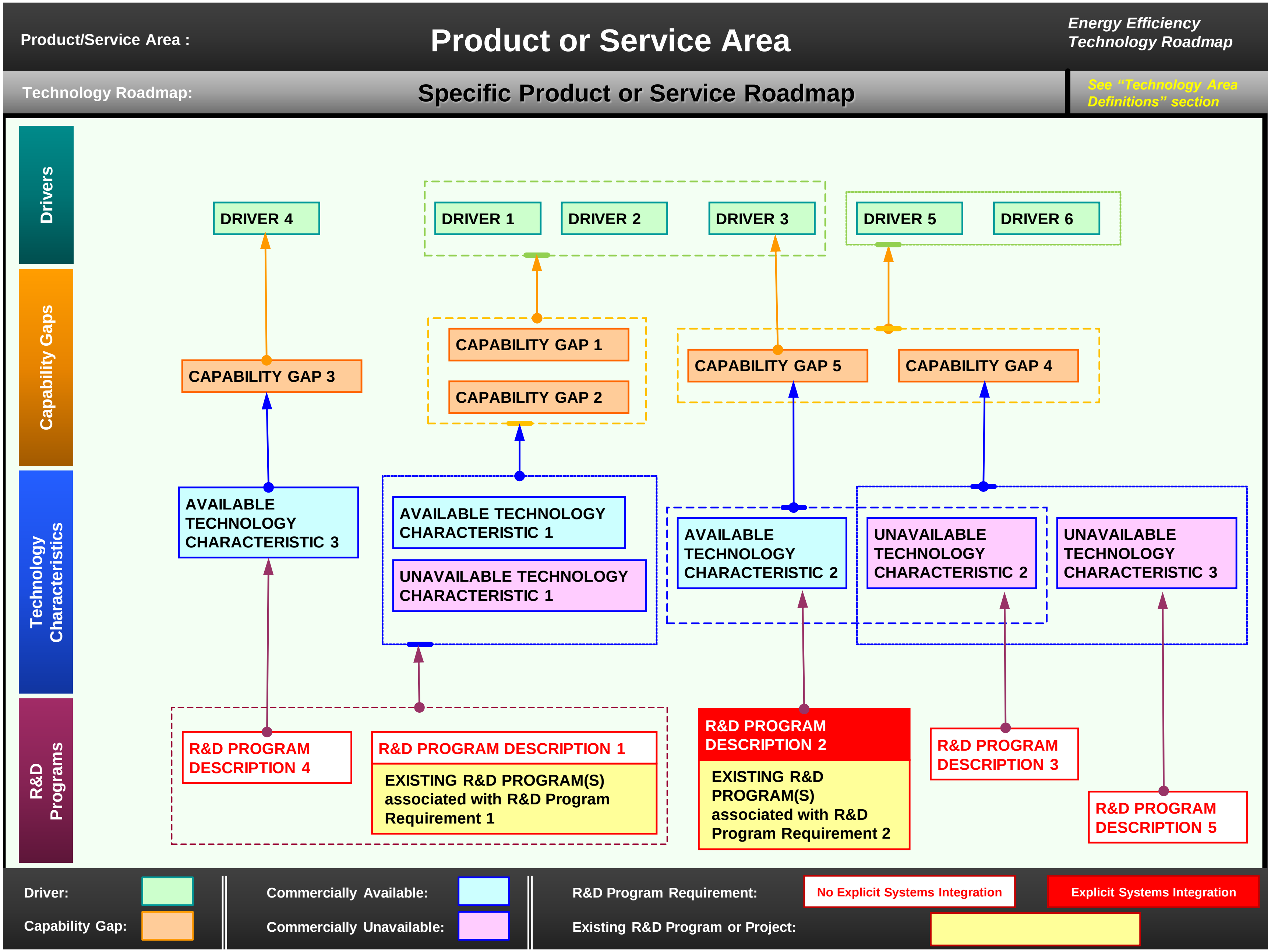
Existing research: None identified. *[R&D program titles that do not have an associated yellow box indicating "Existing R&D Program or Project," by definition, are not underway.]*

Key research questions:

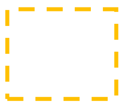
1. One or more research questions that subject matter experts have identified as among the key questions and topic areas to pursue within the R&D program or project; numbers provided for identification only and do not imply prioritization.

Back to Table of Contents

How to Interpret Roadmap Pages



The diagram above represents a typical EE Roadmap page. The most straightforward way to interpret portfolio pages is from the R&D Programs "swim lane" at the bottom up through the Technology Characteristics, Capability Gaps, and Drivers swim lanes.

	Arrows connect individual or groups of boxes in swim lanes to identify critical connections between them.
	Dotted and dashed lines indicate that two or more elements in a swim lane are associated and linked either to another element (or group of elements) in the swim lane above and/or below.
	Short, thick solid lines indicate that the arrow is connecting to the dotted or dashed line surrounding two or more boxes.

Thus, in the diagram on the preceding page, the red arrow connects R&D Program Description 4 (at bottom left) to Available Technology Characteristic 3; the blue arrow connects Available Technology Characteristic 3 to Capability Gap 3; and the orange arrow connects Capability Gap 3 to Driver 4. This means that R&D Program Description 4 helps meet Driver 4. Expressed in another way, meeting the requirements of Driver 4 is a rationale for engaging in R&D Program Description 4.

For purposes of illustration some of the other associations to be drawn from the diagram above are explained below. The following abbreviations are used in the examples:

- R&D = R&D Program Description
- ATC = Available Technology Characteristic
- UTC = Unavailable Technology Characteristic
- CG = Capability Gap
- D = Driver

R&D 1 and R&D 4 linked to D 1, D 2, and D 3

R&D 1 and R&D 4 are associated by the surrounding dashed box because they both contribute directly to UTC 1 and ATC 1. This is shown by the red arrow from R&D 1 and R&D 4 to the dotted blue box surrounding UTC 1 and ATC 1.

Both of these technology characteristics, in turn, are associated with CG 1 and CG 2, and both of these capability gaps are linked to D 1, D 2, and D 3.

R&D 3 linked to D 3, D 5, and D 6

R&D 3 is linked to UTC 2, as the red arrow indicates, but *not* to ATC 2 or UTC 3 because the red arrow links directly to the UTC 2 box and not the blue dashed or dotted lines.

UTC 2 is linked to both CG 4 and CG 5 in the following ways: first, the blue dotted box associates both UTC 2 and UTC 3 and these together are linked to CG 4 by a blue arrow; next, the blue dashed box associates both UTC 2 and ATC 2 and these are linked by a blue arrow to CG 5.

CG 4 and CG 5 are associated with one another as indicated by the dashed orange box surrounding them and an orange arrow links both capability gaps to D 5 and D 6.

Though CG 4 and CG 5 are associated in their linkage to D 5 and D 6, CG 5 independently is linked to D 3, as the orange arrow connecting CG 5 and D 3 indicates.

R&D 2 linked to D 3

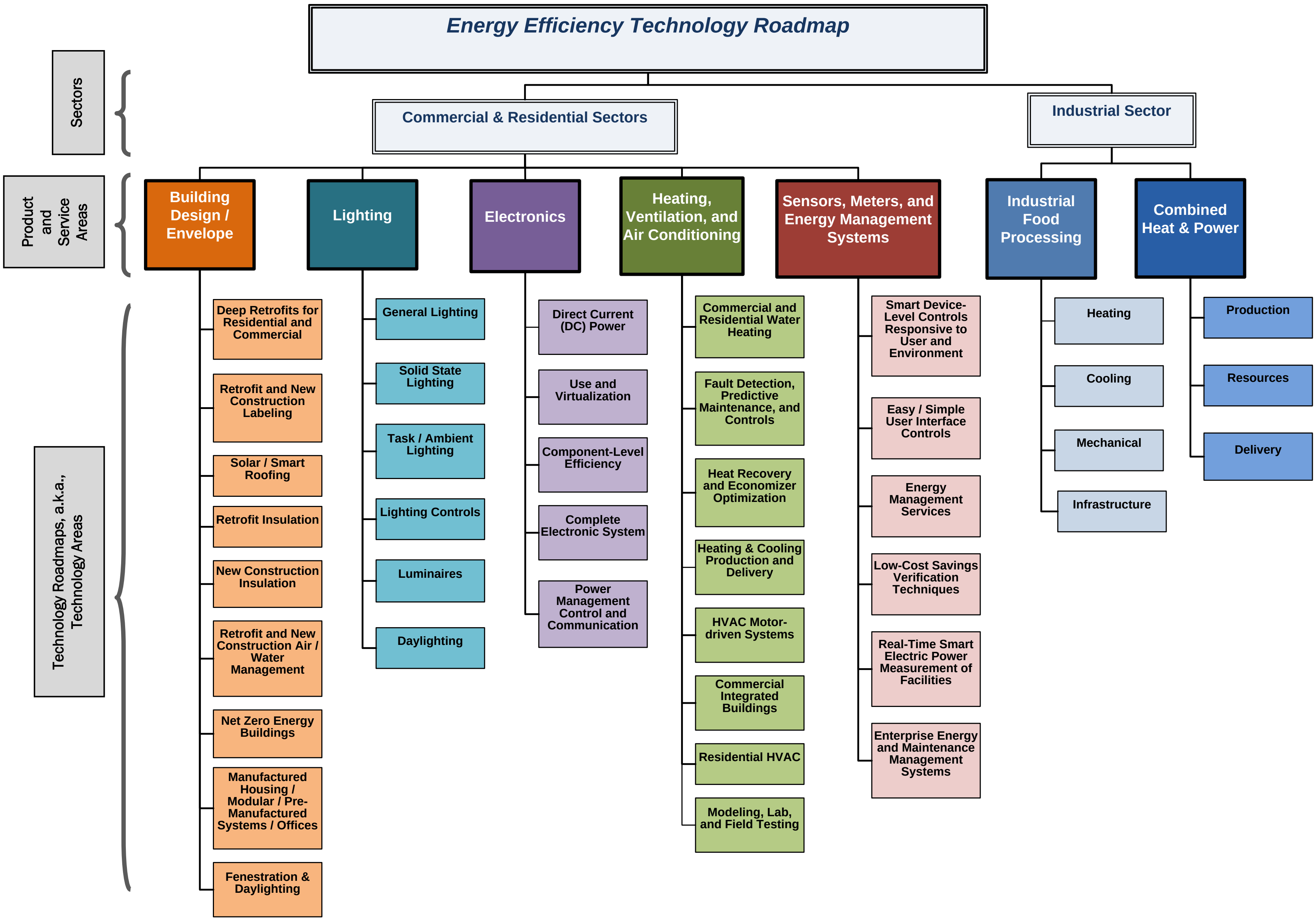
A red arrow links R&D 2 with ATC 2. R&D 2 is identified with a red-filled box, denoting that this research addresses a need for an integrated systems approach.

ATC 2 and UTC 2 are associated as is shown by the blue dashed box surrounding them. The blue arrow from this box connects to CG 5.

An orange arrow links CG 5 to D 3 but *not* to D 1 and D 2. These three drivers are associated with one another but only in terms of their linkage to CG 1 and CG 2, not in terms of their linkage to CG 5.

Back to Table of Contents

ROADMAP ORGANIZATIONAL CHART



Technology Area Definitions

Building Design / Envelope

Deep Retrofits for Residential and Commercial Buildings

A whole-building analysis and construction process that uses an integrative approach (rather than focusing on isolated energy systems) to achieve much larger energy savings than conventional energy retrofits.

Retrofit and New Construction Labeling

A program that provides the general public, building owners and tenants, potential owners and tenants, and building operations and maintenance staff an overview of the energy performance of a building so that they can make more informed decisions about purchasing, renting, leasing, and upgrading buildings.

Solar/Smart Roofing

Integrating solar thermal and solar electric (building-integrated photovoltaic) technologies into roofing materials.

Retrofit Insulation

Techniques and materials for adding insulation to the building envelope of an existing building. Also includes using infrared scanning technology to observe and analyze variations in heat flows in and through the envelope of a building to improve design and construction and minimize heating and cooling losses from air leaks and inadequate insulation.

New Construction Insulation

Roof, wall, and floor insulation in new construction.

Retrofit and New Construction Air / Water Management

Minimizing (and ideally eliminating) air leakage and water infiltration through penetrations and gaps in the building envelope for wiring, plumbing, ductwork, etc.

Net Zero Energy Buildings

Technologies and techniques used to design and construct buildings with greatly reduced needs for energy through very high efficiency such that the balance of energy needs are supplied with renewable technologies on-site.

Manufactured Housing / Modular / Pre-Manufactured Systems / Offices

Technologies and techniques used in a factory to produce pre-built homes delivered to a site in one or more pieces that, once assembled, provide a home ready for occupancy.

Fenestration & Daylighting

Fenestration, shades, and daylighting products and services that conserve energy. Includes: increasing the energy efficiency of windows in existing and new buildings; windows, translucent walls, and mirrored tubes to bring daylight more deeply into occupied spaces; and using operable insulating materials (such as window quilts and roman shades) to cover windows to reduce heating and cooling losses and block light.

Lighting

General Lighting

Technologies and strategies to optimize the use of lighting fixtures, components, and controls for general illumination (rather than decorative, traffic, signs, etc.).

Solid State Lighting

More affordable, efficacious, and reliable light emitting diode (LED) lighting system, using technologies and techniques that take full advantage of LED's characteristics, such as directionality, long life, and controllability while mitigating concerns such as heat management, lumen maintenance, color-shift, and component failure.

Task/Ambient Lighting

Products and systems design to minimize total lighting energy use by minimizing ambient lighting and providing effective and efficient task lighting.

Lighting Controls

Technologies and design approaches to improve the effectiveness and usability of lighting controls to minimize energy use while maintain good lighting quality.

Back to Table of Contents

Luminaires

Materials and designs to improve the optical efficiency of luminaires, which may consist of a body, ballasts, reflector, and lens.

Daylighting

Technologies and strategies to maximize the use of daylight and minimize the need for electric lighting while maintaining good quality lighting that promotes health and productivity.

ELECTRONICS

Direct Current (DC) Power Source

Providing direct current (DC) power in buildings to operate equipment while eliminating energy losses of transformers, improving motor speed control, and integrating more directly with photovoltaic systems.

Use and Virtualization

Techniques for using consumer electronics and computers to minimize energy use without sacrificing functionality, such as through integration and server virtualization.

Component-Level Efficiency

Producing components for consumer electronics, such as power supplies and chips, that are much more energy efficient than those in common use.

Complete Electronic System

Using integrated design to produce consumer electronics and computer servers than are significantly more energy efficient than those commonly in use while not sacrificing product functionality.

Power Management Control and Communication

Reducing energy use through “sleep modes” that minimize standby losses of consumer electronics while not interfering with the user experience. Also includes automated technologies to reduce energy use of plug loads according to occupants’ needs, preferably convenient to users and affordable to building owners.

HEATING, VENTILATION, AND AIR CONDITIONING (HVAC)

Commercial and Residential Water Heating

Technologies to heat water for residential and commercial applications.

Fault Detection, Predictive Maintenance, and Controls

Automated notification of changes in components, such as dampers, amp draw, filters, etc., that will allow maintenance to be addressed sooner, thereby improving the system efficiency and minimize premature and major equipment failures.

Heat Recovery and Economizer Optimization

Maximizing use of non-mechanical cooling with outside air and of heat from cooled spaces to reduce energy use.

Heating & Cooling Production and Delivery

Producing and delivering heating and cooling through large heating, ventilation, and air conditioning (HVAC) systems.

HVAC Motor-driven Systems

Energy efficient motors and drives, primarily adjustable speed drives, used in heating and cooling equipment, along their motor control systems.

Commercial Integrated Systems

Products and services developed from a holistic systems perspective to provide for complementary and integrated heating, ventilation, and air conditioning tailored to the requirements of commercial, multi-family residential, and high-rise office buildings.

Residential HVAC

Products and services developed from a holistic systems perspective to provide for complementary and integrated heating, ventilation, and air conditioning tailored to the requirements of residential buildings.

Modeling, Lab and Field Testing

Using a combination of computer modeling software and lab or field testing to predict the performance of heating and cooling systems in a variety of applications.

SENSORS, METERS, AND ENERGY MANAGEMENT SYSTEMS

Smart Device-level Controls Responsive to User and Environment

Automated energy management systems that responds effectively to input from users and the environmental conditions.

Easy/Simple User Interface Controls

An energy management system that is easy to use and understand.

Energy Management Services

Home energy management systems integrated with a service to help consumers understand and reduce their energy use.

Low-cost Savings Verification Techniques

Devices and software used to verify energy savings from implementation of measures without the significant time and expense of a conventional measurement and verification study.

Real-time Smart Electric Power Measurement of Facilities

Devices and systems to gather data on building operation schedules as well as energy use and demand in real time so users or an energy management system can respond effectively.

Enterprise Energy and Maintenance Management Systems

Energy management systems for large organizations with multiple buildings, such as a corporate or university campus.

INDUSTRIAL FOOD PROCESSING

Heating

Technologies used for heating food and industrial food processing equipment.

Cooling

Technologies used for cooling food and industrial food processing equipment.

Mechanical

Various mechanical and technical systems used within the industrial food processing facility outside of the realm of heating and cooling technologies, such as raw material storage, transportation, and equipment operation.

Infrastructure

Technical infrastructure to support industrial food processing operations such as lighting, HVAC systems, energy management systems, water treatment, data management, and others.

COMBINED HEAT AND POWER

Production

Technologies used to generate heat and power, such as fuel cells, turbines, generators, and heat recovery systems.

Resources

Identifying, sourcing, delivering, and storing fuel used within combined heat and power systems.

Delivery

Storing, moving, and optimizing both heat and energy generated from combined heat and power systems.

Back to Table of Contents