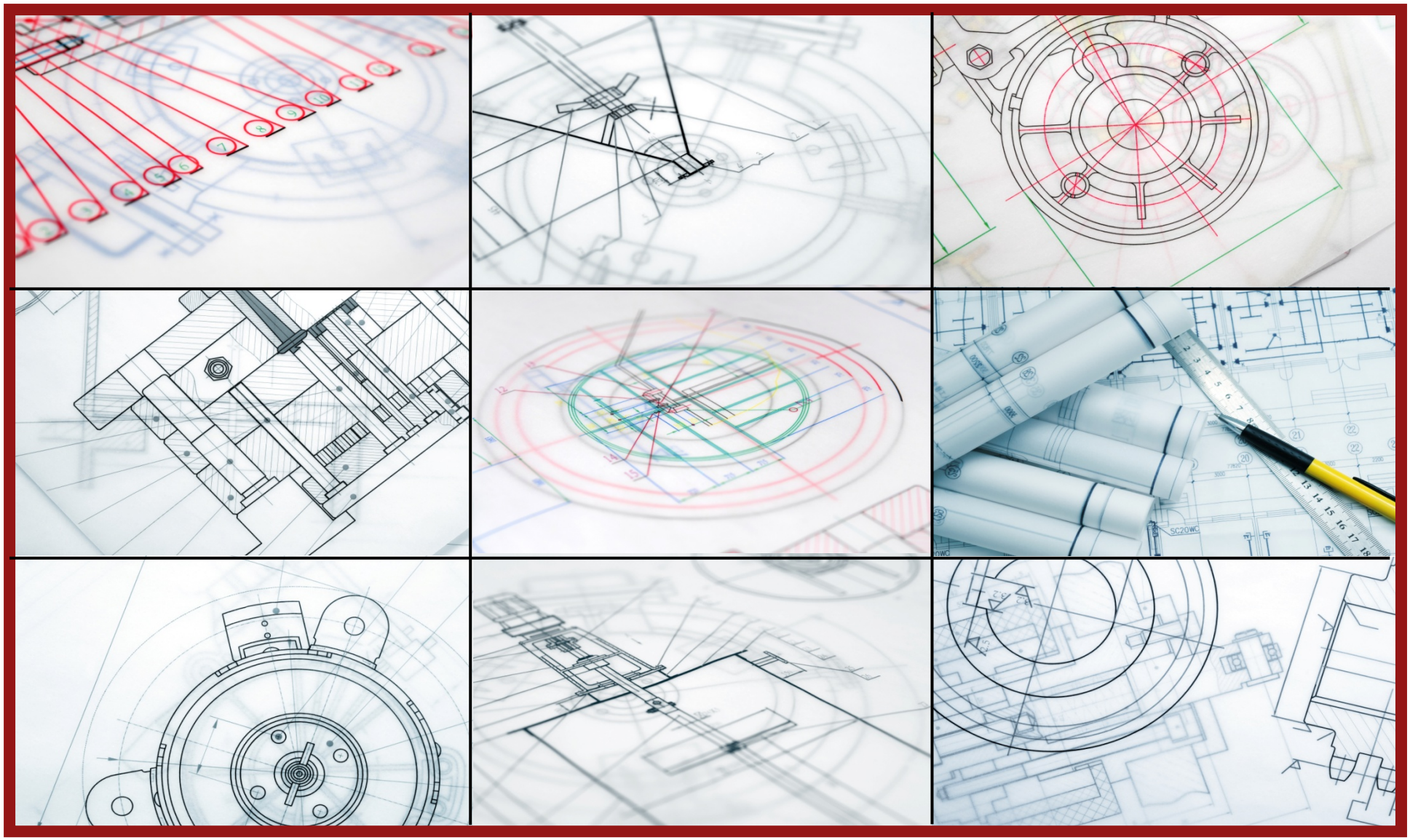

SEPTEMBER 2012

NATIONAL ENERGY EFFICIENCY TECHNOLOGY ROADMAP PORTFOLIO

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Special Thanks

While the Bonneville Power Administration has funded and managed the overall development and maturation of the *National* (formerly *Northwest*) *Energy Efficiency Technology Roadmap Portfolio*, the effort would not have been possible without the active engagement of nearly seventy representatives from nearly forty organizations. In particular, the members of the newly formed 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 Extension Energy Program, Energy Trust of Oregon, Puget Sound Energy, Snohomish Public Utility District, Seattle City Light, Idaho Power, and Avista.

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

Finally, a special thanks to our partners at the Electric Power Research Institute, who brought their collective experience to bear in helping us evaluate the current status of R&D projects and programs for this latest version.

There is still much work to be done to collectively improve our understanding of the current research landscape, but we are making strides in the right direction.

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

Joshua Binus
jdbinus@bpa.gov, 503.230.5298

Foreword

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. In order 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.

Beginning in December 2009, thirty-five experts from twenty organizations pooled their efforts to develop an energy efficiency technology roadmap portfolio 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 drafts of the *National* (formerly *Northwest*) *Energy Efficiency Technology Roadmap Portfolio* have been released in March and July 2010, March 2011, and March, August, and September 2012. The portfolio will always be a draft; it is intended as a living document, continuously refined as we move forward.

There are two notable additions to the *Roadmap* Portfolio commencing with the March 2012 version. We have expanded the roadmaps into two important industrial product and service areas: food processing and combined heat and power (CHP) technologies. We have also created a new appendix of existing R&D projects (Appendix B) to provide expanded and updated information previously contained in the individual "R&D Project Summaries" pages.

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, Joshua Binus (jdbinus@bpa.gov, 503.230.5298).

Sincerely,

Terry Oliver
Chief Technology Innovation Officer
Bonneville Power Administration

Table of Contents

Introduction

Technology roadmaps are created to develop tactical research and development (R&D) plans to meet the strategic goals of a wide array of industries and organizations. The National Energy Efficiency Technology Roadmap Portfolio provides a snapshot of stakeholders' current perspectives in regard to a shared research agenda for the next twenty years. This Portfolio provides clarity on:

1. Key drivers (environmental/global, market, policy and regulatory, and technology innovation) affecting the nation in regard to energy efficiency;
2. Products/services needed to address identified drivers;
3. Technologies needing developed in order to bring non-existing products to market;
4. Gaps in existing R&D programs designed to address identified technology needs; and
5. Regional and national priorities in regard to the treatment of R&D gaps.

Ultimately, the goal of identifying and prioritizing 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.

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 typically reopens every year in March; proposals not linked to technology needs identified in the roadmap are not eligible for awards. Because these roadmap 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.

In the process of identifying gaps in existing energy efficiency R&D programs, roadmapping participants 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. While treating this group of products and services was not the primary purpose of the roadmapping endeavor, some effort was dedicated 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.

To avoid confusion, the findings articulated by participants in these latter efforts are located in Appendix A.

By creating a regional technology roadmap portfolio that has now expanded to a national 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.

Using the Roadmap Portfolio

The National Energy Efficiency Technology Roadmap Portfolio 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 technology development research agendas in relation to specific energy efficiency products and services.

The content herein is organized into eight sections, with multiple product/service-level roadmaps within each section. The eight sections are:

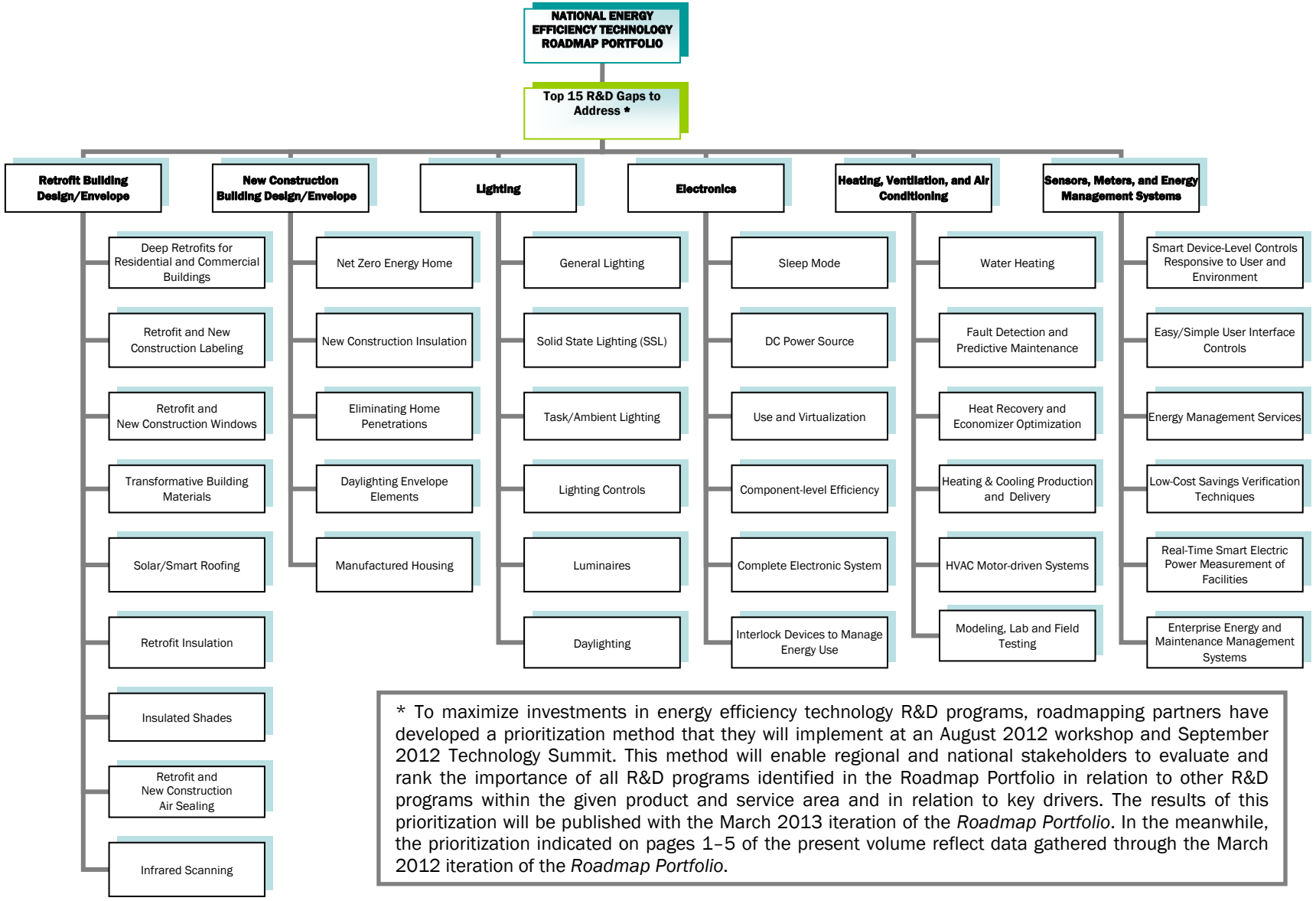
1. Retrofit Building Design/Envelope
2. New Construction Building Design/Envelope
3. Lighting
4. Electronics
5. Heating, Ventilation, and Air Conditioning
6. Sensors, Meters, and Energy Management Systems
7. Food Processing Industry
8. Combined Heat & Power

Additionally, one cross-cutting roadmap conveys the top-15 regional priorities in regard to the treatment of R&D gaps identified in all eight sections listed above. (See the organizational chart below.) All other supporting documents are in the appendices.

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.

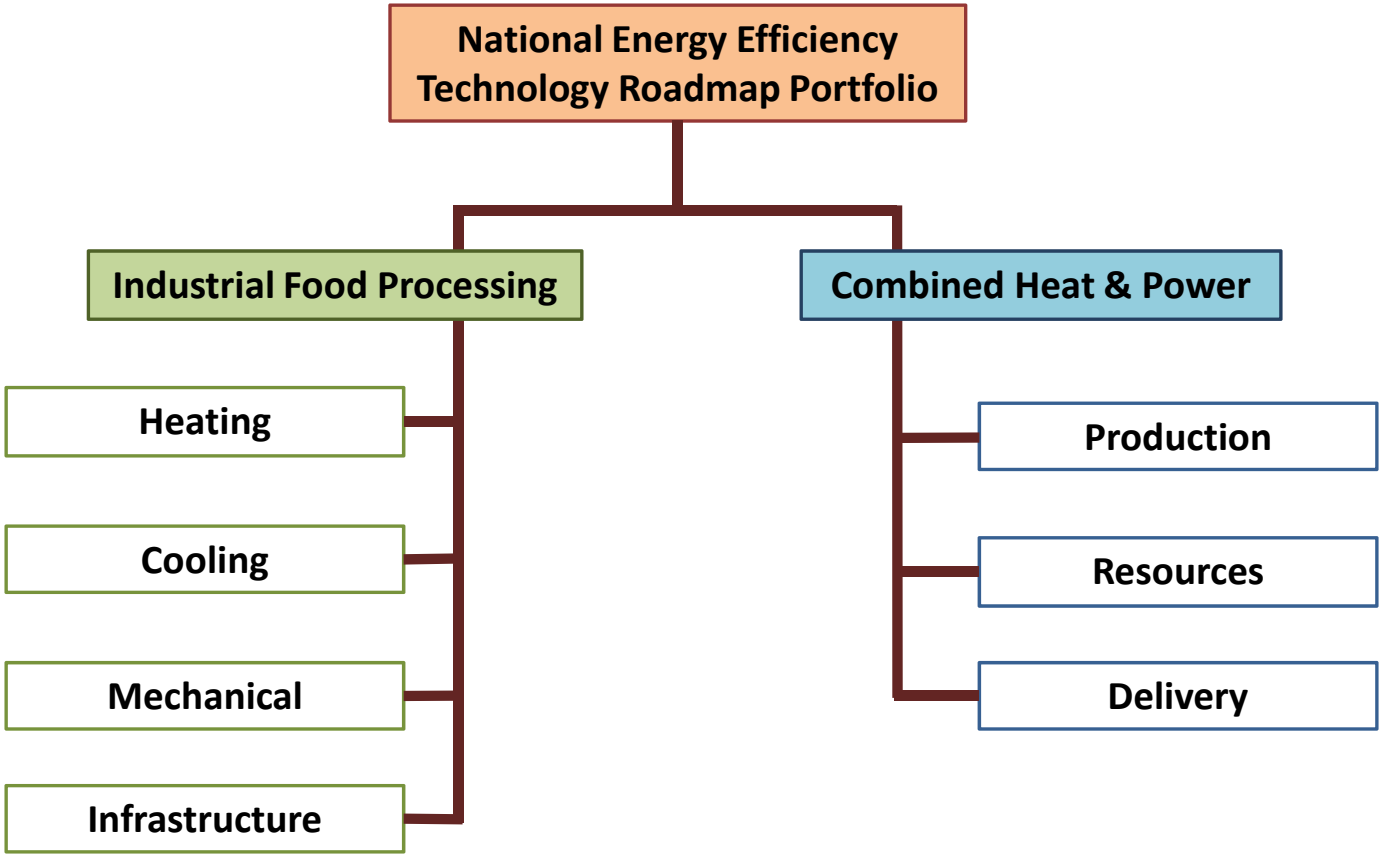
Roadmap Portfolio Organizational Chart:
Residential & Commercial Roadmaps



* To maximize investments in energy efficiency technology R&D programs, roadmapping partners have developed a prioritization method that they will implement at an August 2012 workshop and September 2012 Technology Summit. This method will enable regional and national stakeholders to evaluate and rank the importance of all R&D programs identified in the Roadmap Portfolio in relation to other R&D programs within the given product and service area and in relation to key drivers. The results of this prioritization will be published with the March 2013 iteration of the *Roadmap Portfolio*. In the meanwhile, the prioritization indicated on pages 1–5 of the present volume reflect data gathered through the March 2012 iteration of the *Roadmap Portfolio*.

Roadmap Portfolio Organizational Chart:

Industrial Roadmaps



Roadmap Definitions

Retrofit 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.

Retrofit and New Construction Windows

Increasing the energy efficiency of windows in existing and new buildings.

Transformative Building Materials

Innovative building materials with outstanding insulation and/or energy storage characteristics and are ideally also cheap and easy to use.

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.

Insulated Shades

Using operable insulating materials (such as window quilts and roman shades) to cover windows to reduce heating and cooling losses and block light.

Retrofit and New Construction Air Sealing

Minimizing (and ideally eliminating) air leakage through penetrations and gaps in the building envelope.

Infrared Scanning

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 Building Design / Envelope

Net Zero Energy Homes

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

New Construction Insulation

Roof, wall, and floor insulation in new construction.

Eliminating Home Penetrations

Minimizing and ideally eliminating penetrations of the building envelope for wiring, plumbing, ductwork, etc.

Daylighting Envelope Elements

Windows, translucent walls, and mirrored tubes to bring daylight more deeply into occupied spaces.

Manufactured Housing

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.

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.

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

Sleep Mode

Reducing energy use by minimizing standby losses of consumer electronics while not interfering with the user experience.

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.

Interlock Devices to Manage Energy Use

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)

Water Heating

Technologies to heat water for residential and commercial applications.

Fault Detection and Predictive Maintenance

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.

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.

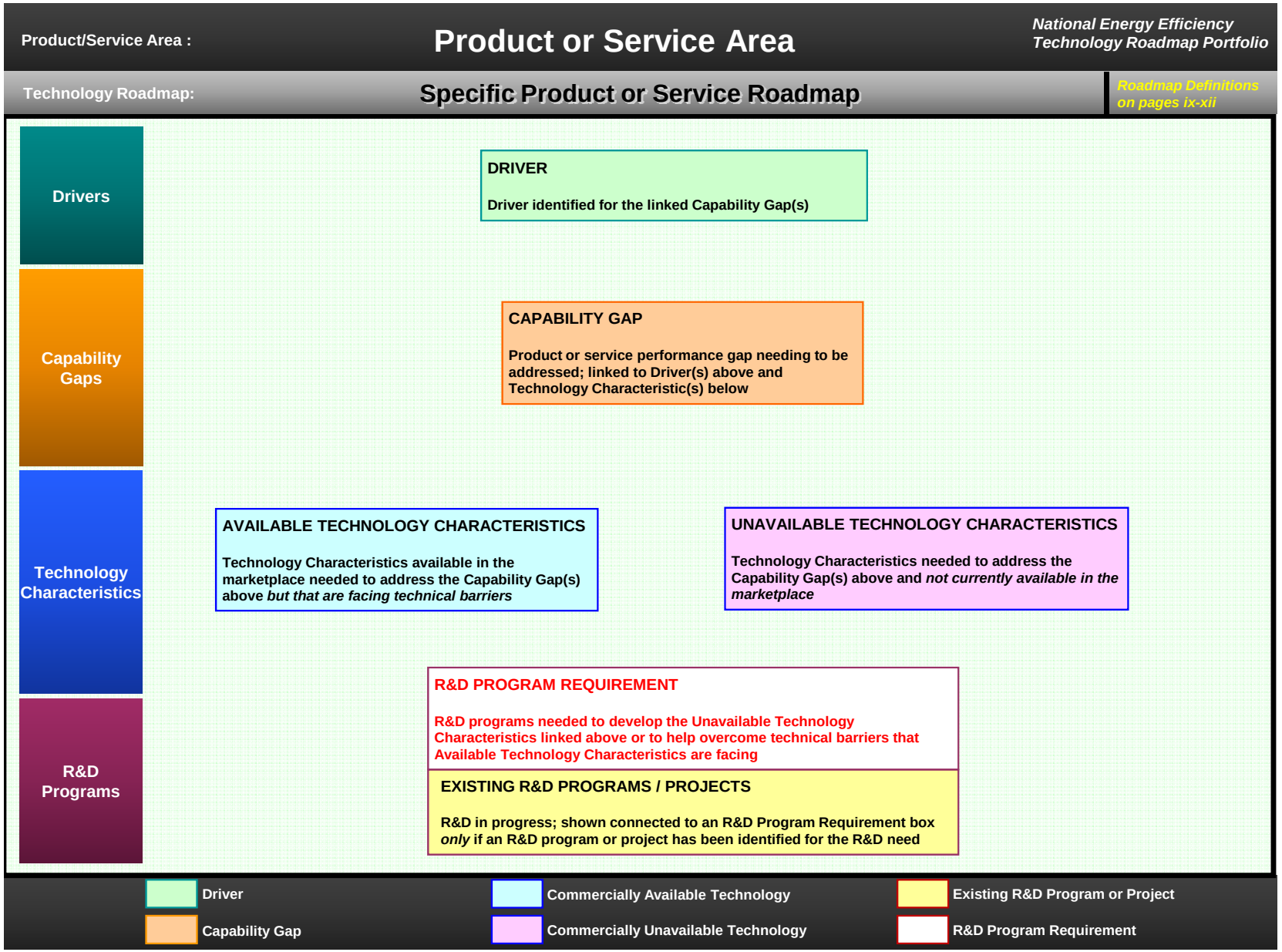
Resources

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.

Roadmap Key


Product/Service Area :
Product or Service Area
National Energy Efficiency Technology Roadmap Portfolio
Technology Roadmap:
Specific Product or Service Roadmap
Roadmap Definitions on pages ix-xii
Drivers
Capability Gaps
Technology Characteristics
R&D Programs
DRIVER
Driver identified for the linked Capability Gap(s)
CAPABILITY GAP
Product or service performance gap needing to be addressed; linked to Driver(s) above and Technology Characteristic(s) below
AVAILABLE TECHNOLOGY CHARACTERISTICS
Technology Characteristics available in the marketplace needed to address the Capability Gap(s) above but that are facing technical barriers
UNAVAILABLE TECHNOLOGY CHARACTERISTICS
Technology Characteristics needed to address the Capability Gap(s) above and not currently available in the marketplace
R&D PROGRAM REQUIREMENT
R&D programs needed to develop the Unavailable Technology Characteristics linked above or to help overcome technical barriers that Available Technology Characteristics are facing
EXISTING R&D PROGRAMS / PROJECTS
R&D in progress; shown connected to an R&D Program Requirement box only if an R&D program or project has been identified for the R&D need
Driver
Capability Gap
Commercially Available Technology
Commercially Unavailable Technology
Existing R&D Program or Project
R&D Program Requirement

High Priority R&D Roadmap

NOTE: To maximize investments in energy efficiency technology R&D programs, roadmapping partners have developed a prioritization method they will implement at an August 2012 workshop and September 2012 Technology Summit. This method will enable regional and national stakeholders to evaluate and rank the importance of all R&D programs identified in the *Roadmap Portfolio* in relation to other R&D programs within the given product and service area and in relation to key drivers. The results of this prioritization will be published with the March 2013 iteration of the *Roadmap Portfolio*. In the meanwhile, the prioritization indicated on pages 1–5 of the present volume reflect data gathered through the March 2012 iteration of the Roadmap Portfolio.

High Priority R&D Programs

Product & Service Area	RETROFIT BUILDING DESIGN/ENVELOPE	NEW CONSTRUCTION BUILDING DESIGN/ENVELOPE	LIGHTING	HVAC	SENSORS, METERS, & EMS

Driver

Environmental & Global Drivers: 1. Climate change; 2. Peak oil; 3. Energy security; 4. Water scarcity and cost, related health concerns; 5. Increasing cost and decreasing availability of raw materials; 6. Environmental impact of centralized power generation; 7. Fuel switching from combustion to electric

Market Drivers: 1. Increasing and uncertain future cost of electricity and gas; 2. Proliferation of consumer electronics (increased plug loads); 3. More and cheaper products due to globalization of manufacturing; 4. Increase in available funding for EE; 5. Increased adoption of LEED; 6. Changes in types of industries in the Northwest; 7. Market awareness (e.g., BPA E3T, utility demos and outreach); 8. Increased interest in and availability of plug-in hybrid and electric vehicles; 9. Energy efficiency promoted through mainstream media

Behavior / Social Drivers: 1. Employer pressure to increase productivity; 2. Consumer desire to be "green" and reduce embedded & used energy; 3. Consumer desire for comfort and aesthetics; 4. Changing demographics impacting purchasing choices and behavior; 5. Personal energy independence/interest in living off the grid; 6. Increased awareness of impact of behavior on energy usage; 7. Aging workforce, lack of trained workforce; 8. Pushback against over-regulation; 9. People like cool, new technologies; 10. People more "plugged in" electronically, digital information, social networking

Policy & Regulatory Drivers: 1. Carbon emissions penalties and/or incentives; 2. Use of codes to lock in efficiency gains; 3. Increasing budgets for emerging technology R&D; 4. American Clean Energy and Security Act of 2009; 5. Integrated resource planning; 6. Increased interest among legislators in efficiency and renewables; 7. Limits to existing transmission and generation capacity; 8. Smart grid technology development

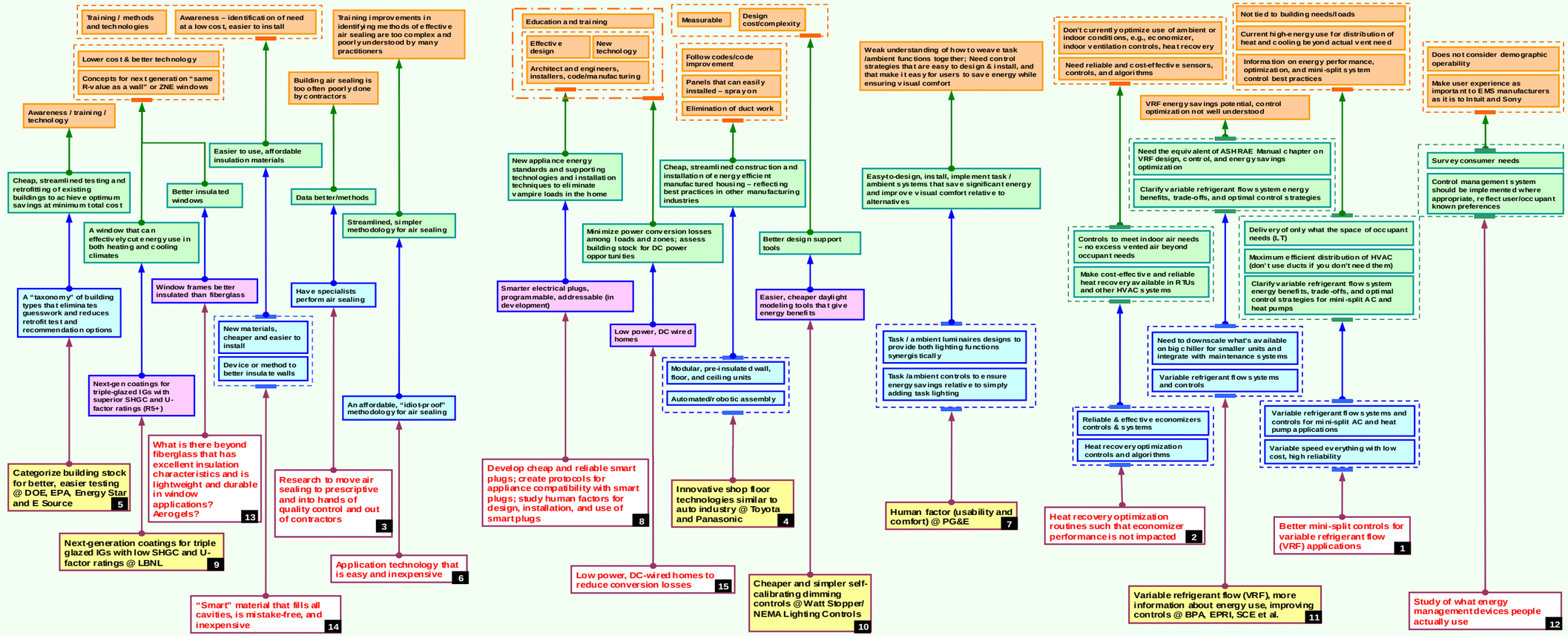
Technology Innovation Drivers: 1. Diffusion of common communication protocols into energy-consuming devices; 2. Integration of info, communication & entertainment devices; 3. Availability of new technologies such as solid state lighting; 4. Availability of cross-cutting, low-cost technology building blocks (i.e. wireless, ultra compact heat exchangers, advanced controls, ASDs)

Product/Service Performance GAP

Product/Service Performance GOAL

Technology

R&D Program



Product and Service Performance Gap
Product and Service Performance Goal
Current Technology
Current R&D (R&D underway)
Technology Gap (R&D need)
R&D Gap (No known R&D)
**Priority Ranking** (1 to 15)

High Priority R&D Programs

1. Better mini-split controls for variable refrigerant flow (VRF) applications: VRF and mini-splits, particularly with improved controls, can more efficiently respond to space conditioning needs than conventional HVAC systems with air ducts. To successfully realize the opportunity associated with broad interest and increasing application of variable refrigerant flow systems, more R&D is needed to optimize controls for mini-split system energy savings.

2. Heat recovery optimization routines such that economizer performance is not impacted: Make better use of exhaust air heat recovery and economizers. Develop algorithms that would most efficiently optimize the use of both systems.

3. Research to move air sealing to prescriptive and into hands of quality control and out of contractors: Building air sealing is too often poorly done by contractors. By having highly trained specialists perform air sealing, average infiltration rates will drop.

4. Innovative shop floor technologies similar to auto industry: Manufactured housing is generally overlooked. It can generate big energy and financial benefits with some optimization and lessons from other industries. Apparently, most of the work being done, to date, has been happening in Japan under the leadership of Toyota and Panasonic (http://www.joplinglobe.com/dailybusiness/x1383437018/Toyota-Panasonic-sally-into-nascent-green-housing-sector). *(NOTE: The score in this box reflects the fact that Roadmap drafts prior to the March 2011 identified this research area as an R&D gap.)*

5. Categorize building stock for better, easier testing: If a wide range of building stock is sorted into categories, energy assessments can be performed more expeditiously. DOE and EPA have collaborated on a national Commercial Buildings Energy Consumption Survey that collects information on the stock of U.S. commercial buildings, their energy-related building characteristics, and their energy consumption and expenditures (http://www.eia.doe.gov/emeu/cbecs/). The EPA has designed an Energy Star portfolio manager tool to help facility managers track and benchmark energy and water consumption across an entire portfolio of buildings (http://www.energystar.gov/index.cfm?c=evaluate_performance.bus_portfoliomanager). DOE's Residential Energy Consumption Survey characterizes U.S. homes through such data as structural features, fuels used, heating and cooling equipment, appliances, and energy usage patterns (http://www.eia.doe.gov/emeu/recs/). E Source's EnFocus system integrates geographic information system (GIS) data with utility billing records and could be used to categorize building stock and identify individual buildings (contact Michael Shepard at 303.345.9129). *(NOTE: The score in this box reflects the fact that Roadmap drafts prior to the March 2011 identified this research area as an R&D gap.)*

6. Application technology that is easy and inexpensive: If a common methodology for air sealing common building envelope types could be developed, a wider range of builders could implement it more effectively and consistently.

7. Human factor (usability and comfort): The elements for broad application are present - need human factors R&D on design and control approaches to realize the potential. This work could potentially be informed by researchers such as Joan Roberts, of Fordham, and Jennifer Veitch at the National Research Council of Canada, who are both working on designing healthy workplaces. PG&E also completed a study of how occupants respond to task-ambient lighting systems in 2009 (http://www.etcc-ca.com/component/content/article/21/2892-high-efficiency-office-low-ambienttask-lighting-large-office-). There is still much to be explored in this R&D space. *(NOTE: The score in this box reflects the fact that Roadmap drafts prior to the March 2011 identified this research area as an R&D gap.)*

8. Develop cheap and reliable smart plugs. Create protocols for appliance compatibility with smart plugs; study human factors for design, installation, and use of smart plugs: Make smart outlets a standard feature in new construction requires innovation in technology and building industry practices. Research is needed primarily to develop the ability of plugs to turn off equipment when not in use; secondarily, to enable participation in demand response events. The University of Florida at Gainesville has conducted some limited research on smart plugs and smart environments that addresses the design of the plugs, their capabilities, and their installation. In this research, the ability of the home operating system is explored, but their integration with the smart grid for demand response is not addressed.

9. Develop next-generation coatings for triple-glazed windows with low SHGC and R-value over 5: Develop a glazing product with high R-value and low SHGC that performs well in all seasons and climates. LBNL (High Performance Building Façade Solutions) is engaged in ongoing research into new coatings and highly insulated window technologies for both commercial and residential applications. *(NOTE: The score in this box reflects the fact*

that Roadmap drafts prior to the March 2011 identified this research area as an R&D gap.)

10. Cheaper and simpler self-calibrating dimming controls: Making daylighting cost-effective continues to be a challenge. Cheaper, easier to use, and self-calibrating controls can help to make daylighting more attractive. Dorene Maniccia of Watt Stopper (and chair of the NEMA Lighting Controls) is researching dual-loop daylight control systems that self commission and offer continual calibration. *(NOTE: The score in this box reflects the fact that Roadmap drafts prior to the March 2011 identified this research area as an R&D gap.)*

11. Variable refrigerant flow (VRF), more information about energy use, improving controls: Develop reliable engineering and technical information on how to optimize VRF energy savings while assuring comfort and reliability. BPA, EPRI, Southern California Edison, and others met in February 2011 to develop a short-term (2 – 3 year) roadmap for variable capacity heat pumps. This roadmap will be integrated into the Northwest Energy Efficiency Technology Roadmap as early as the end of March 2011. Other projects being carried out by BPA and EPRI are conducting VRF assessments and demos and analyzing the market position of VRF systems in the U.S. *(NOTE: The score in this box reflects the fact that Roadmap drafts prior to the March 2011 identified this research area as an R&D gap.)*

12. Study of what energy management devices people actually use: Creating standard, easy-to-use EMS interfaces can move them from fairly clunky software that is only occasionally accessed to being regularly used by maintenance personnel along with other duties. Human factors and usability studies will allow for optimization of device design, interface design, and communication protocols for the end user.

13. What is there beyond fiberglass that has excellent insulation characteristics and is lightweight and durable in window applications?: Other materials may be available to allow a more effectively insulated frame. E Source has identified aerogels as being among the lightest materials made, with great potential for a variety of building applications, ranging from insulating building studs (to reduce thermal bridging) to use in skylights and other daylighting applications.

14. "Smart" material that fills all cavities, is mistake-free, and inexpensive: Overall, the cost of sprayed insulation is still around twice that of installing fiberglass batting (http://www.toolbase.org/pdf/techinv/insulationalternatives_techspec.pdf).

15. Low power, DC-wired homes to reduce conversion losses: Design homes with both AC and DC outlets so that DC-ready electronic appliances can use the DC directly, eliminating conversion losses.

Retrofit Building Design/Envelope Roadmaps

Product/Service Area :

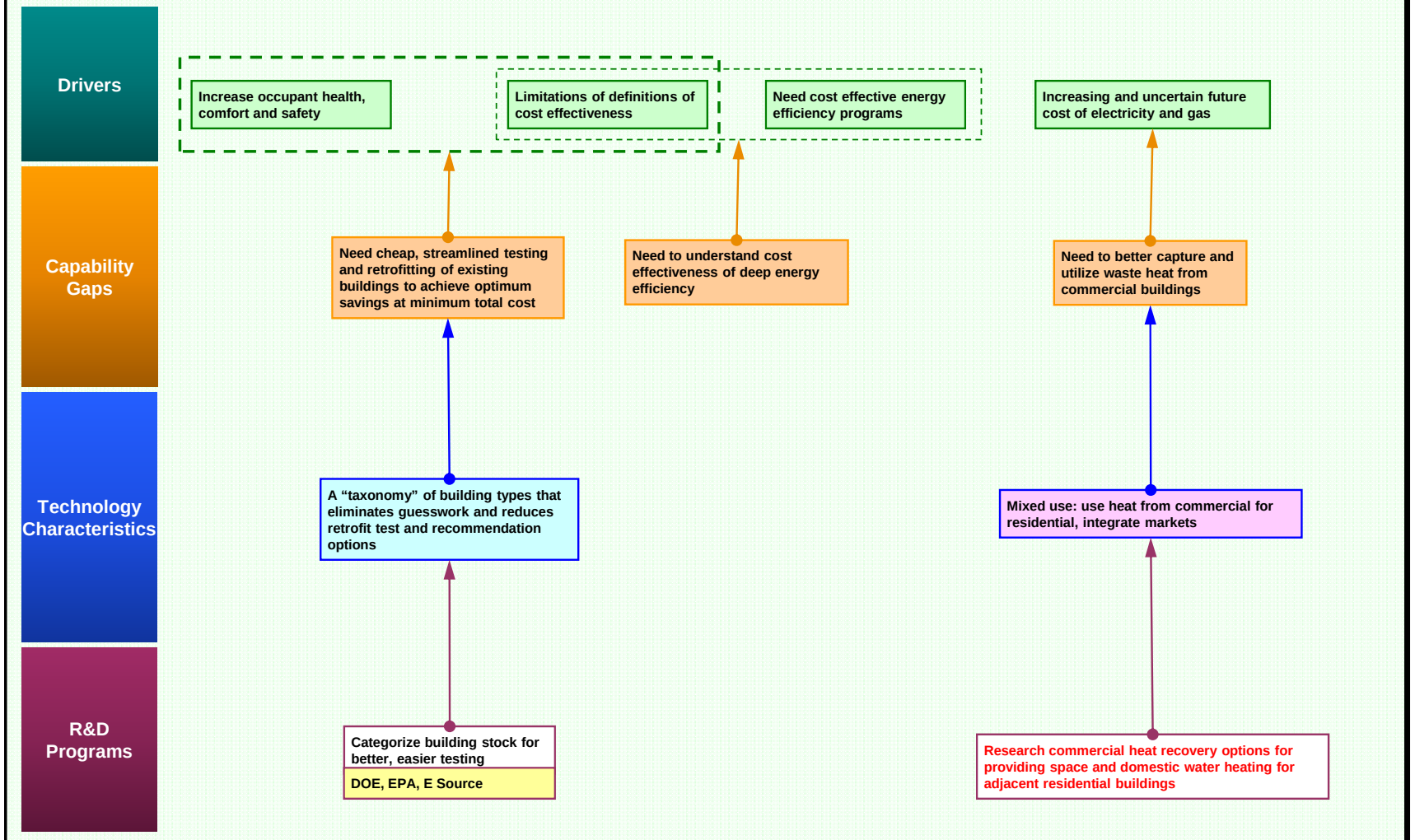
RETROFIT BUILDING DESIGN/ENVELOPE

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap:

Deep Retrofits for Residential & Commercial

Roadmap Definitions on pages ix-xii



Driver
Capability Gap
Commercially Available Technology
Commercially Unavailable Technology
Existing R&D Program or Project
R&D Program Requirement

R&D Project Summaries

Categorize building stock for better, easier testing: If a wide range of building stock is sorted into categories, energy assessments can be performed more expeditiously. There are four regularly-updated tools available for this purpose, one tool in beta testing, and one longstanding data source that is no longer kept current. (*NOTE: The score in this box reflects the fact that Roadmap drafts prior to the March 2011 identified this research area as an R&D gap.*)

- The U.S. Environmental Protection Agency (EPA) has designed an ENERGY STAR portfolio manager tool to help facility managers track and benchmark energy and water consumption across an entire portfolio of buildings (http://www.energystar.gov/index.cfm?c=evaluate_performance.bus_portfoliomanager).
- The U.S. Department of Energy's (DOE) Residential Energy Consumption Survey characterizes U.S. homes through such data as structural features, fuels used, heating and cooling equipment, appliances, and energy usage patterns (http://www.eia.doe.gov/emeu/recs/).
- E Source's EnFocus system integrates geographic information system (GIS) data with utility billing records and could be used to categorize building stock and identify individual buildings (http://www.esource.com/esource/preview_list/27113?highlight=allsubs&plain=no).
- E Source also provides clients a Residential Energy Use Study that they update annually with comparative data (http://www.esource.com/Residential_Energy-Use_2011).
- Specifically for lighting, the DOE's Commercial Lighting Solutions website provides facility-specific information on best practices and allows users to compare and contrast different lighting strategies easily. As of January 2012, this tool is available and in beta testing (https://www.lightingsolutions.energy.gov/comlighting/login.htm).
- The DOE and the EPA collaborated on a national Commercial Buildings Energy Consumption Survey (CBECS) from 1979 through fiscal year 2010 (September 2010). This survey collected information on the stock of U.S. commercial buildings, their energy-related building characteristics, and their energy consumption and expenditures. Survey data is no longer kept current because Congress de-funded the project beginning fiscal year 2011 (http://www.eia.doe.gov/emeu/cbecs/).

Research commercial heat recovery options for providing space and domestic water heating for adjacent residential buildings: With co-located commercial and residential buildings, commercial waste heat recovery can be more cost effective by utilizing it for adjacent residential use.

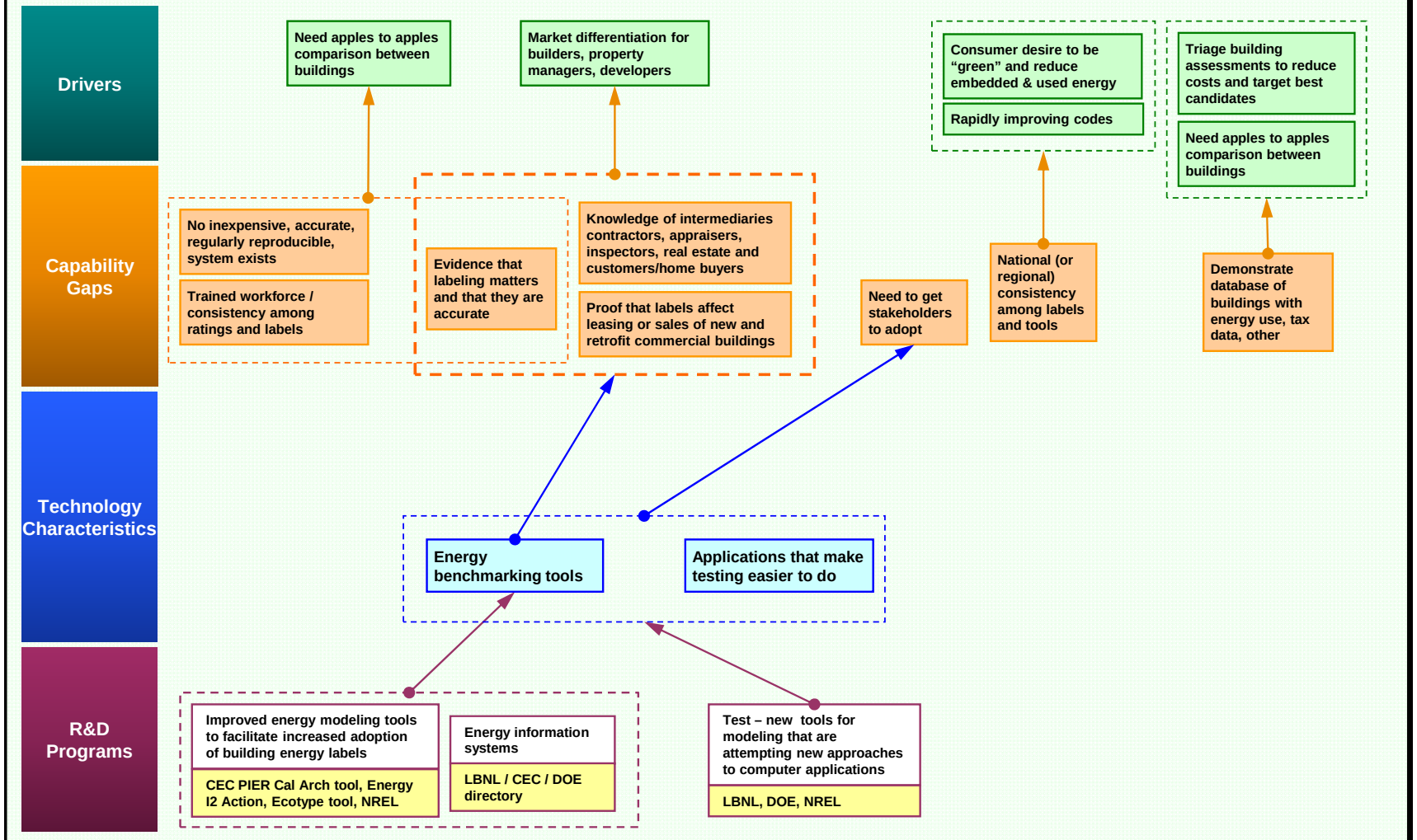
- As of January 2011, E Source reported that factors such as distribution losses and the need for customized engineering on both the commercial and residential side may pose obstacles to making this a cost-effective efficiency strategy and, while this is an interesting approach, they were not aware of any current research being done in this area.

Product/Service Area : **RETROFIT BUILDING DESIGN/ENVELOPE**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Retrofit and New Construction Labeling**

Roadmap Definitions on pages ix-xii



R&D Project Summaries

New modeling tools attempting new approaches to computer applications: In order to achieve wide-spread adoption of a consistent energy labeling program, better modeling tools are needed.

- The U.S. Department of Energy (DOE) maintains a Building Energy Software Tools Directory that provides a comprehensive list of currently available software tools. As of December 2011, the directory contained 405 internationally-produced modeling software tools developed for the PC, Mac, and UNIX platforms and the Internet. The tools are grouped in a variety of subject areas, including Whole Building Analysis; Codes, Standards, Materials, Components, Equipment, & Systems; and others (http://apps1.eere.energy.gov/buildings/tools_directory/).
- The Lawrence Berkeley National Laboratory (LBNL) is working with the California Energy Commission and the Department of Energy to evaluate and improve tools for tracking and monitoring energy use in commercial buildings. More information on these tools can be found at http://eis.lbl.gov/ and in Appendix B.
- Stellar Processes, Inc., has developed the EZ Sim Billing Analysis Tool, available for purchase at http://www.ezsim.com/. The tool's spreadsheet template makes possible sophisticated engineering analysis and simulation modeling within an easy-to-use interface to provide reliable and realistic conservation savings estimates. Howard Reichmuth, Senior Engineer at the New Buildings Institute, was co-developer of this tool (http://newbuildings.org/about-us/staff/howdy-reichmuth).

Improved energy modeling tools to facilitate the increased adoption of building energy labels: The broad adoption of building energy labels requires better energy modeling tools. Stakeholders recommended the Cal Arch, Energy I2 Action, Ecotype tools.

- The California Energy Commission's Public Interest Energy Research (PIER) program (http://www.energy.ca.gov/research/) sponsored the development of Cal-Arch, a web-based tool for energy use benchmarking (http://buildings.lbl.gov/hpcbs/Element_2/02_E2_P2_1_1.html). Cal-Arch uses data from both the U.S. Department of Energy's Commercial Buildings Energy Consumption Survey (CBECS) and California's Commercial End Use Survey (CEUS) (http://poet.lbl.gov/cal-arch/ceus.html). The CBECS is no longer funded as of Fiscal Year 2012, and the CEUS was last conducted in 2008. The most recent version of the tool (2008) is available at http://poet.lbl.gov/cal-arch/.
- The U.S. Department of Energy (DOE) Office of Energy Efficiency and Renewable Energy (EERE, http://www.eere.energy.gov/) maintains a periodically-updated Building Energy Software Tools Directory. As of December 2011, this directory contained 405 software tools used to track and evaluate energy efficiency, renewable energy, and sustainability (http://apps1.eere.energy.gov/buildings/tools_directory/).
- As of Feb. 2012, no further information could be found about the Energy I2 Action and Ecotype energy modeling tools or their respective development teams; research to uncover this information is ongoing.

Energy information systems: Energy information and systems to collect and make data available to building designers and facility management staff are key to achieving carbon-neutrality by 2030, which requires buildings, which contribute almost 50 percent of greenhouse gas emissions, to be designed to 50 percent of current average energy use for the building type and region. The establishment of building energy labeling requires sharing building energy performance data to establish performance benchmarks and ratings.

- The Lawrence Berkeley National Laboratory (LBNL) has been working with the California Energy Commission and the Department of Energy for fifteen years to test and track emerging and in-use energy information systems. This directory can be found at http://eis.lbl.gov/, and more information can be found in Appendix B.

Product/Service Area :

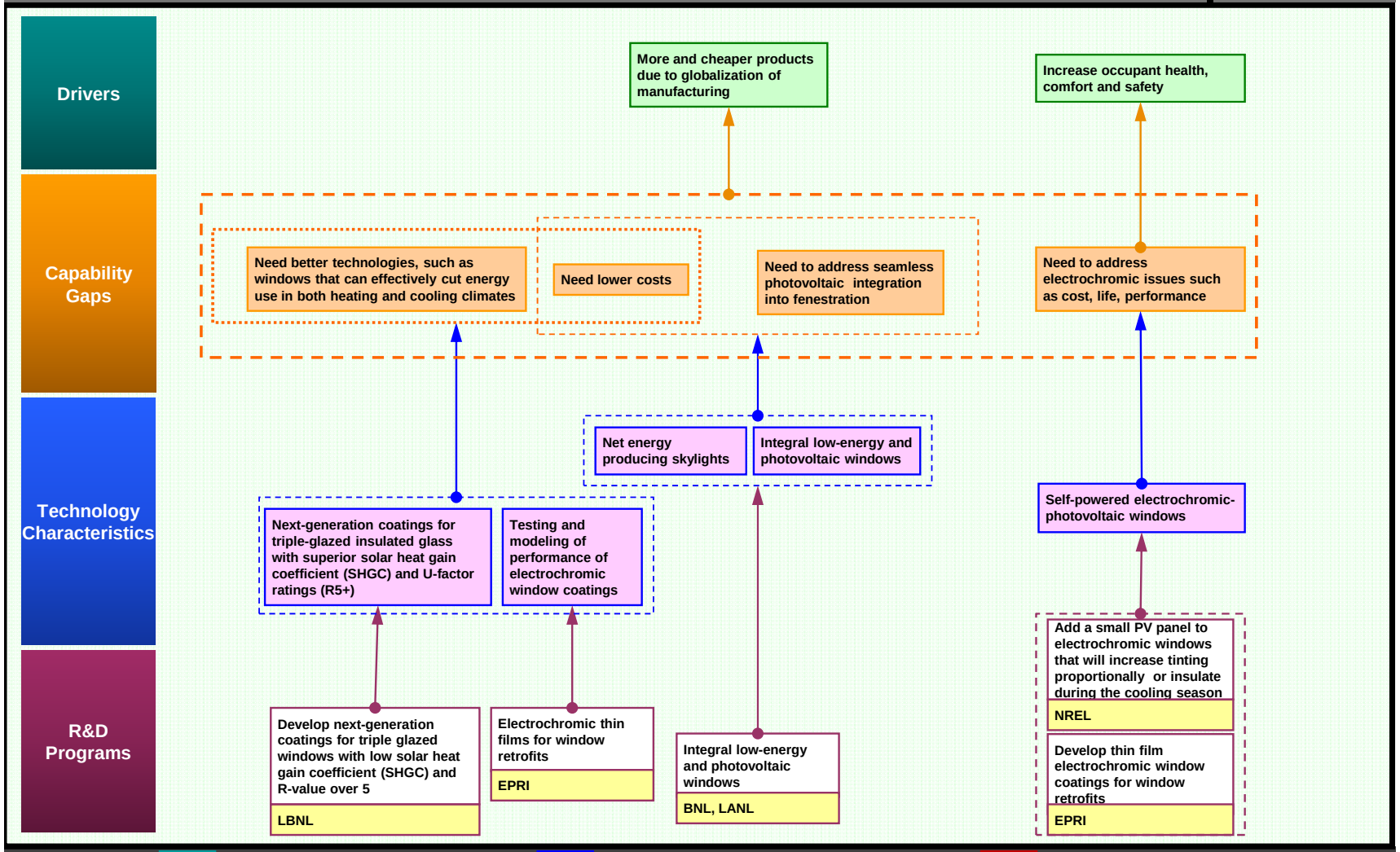
RETROFIT BUILDING DESIGN/ENVELOPE

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap:

Retrofit and New Construction Windows (1 of 2)

Roadmap Definitions on pages ix-xii



Driver
Capability Gap
Commercially Available Technology
Commercially Unavailable Technology
Existing R&D Program or Project
R&D Program Requirement

R&D Project Summaries

See next Page.

Product/Service Area :

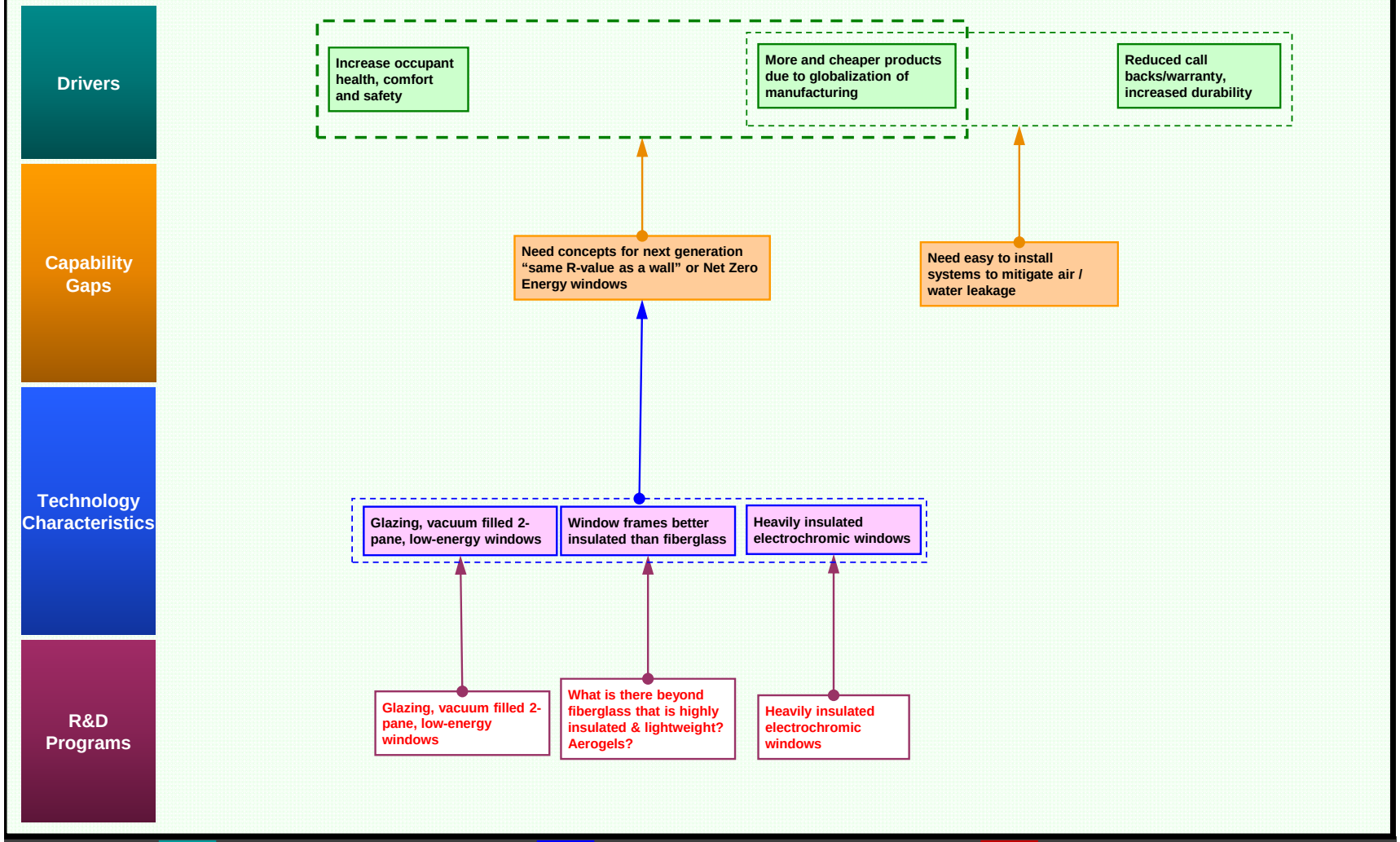
RETROFIT BUILDING DESIGN/ENVELOPE

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap:

Retrofit and New Construction Windows (2 of 2)

Roadmap Definitions on pages ix-xii



R&D Project Summaries

Add a small PV panel to electrochromic windows that will increase tinting proportionally or insulate during the cooling season: An electrochromic window powered by a small photovoltaic (PV) panel can vary tint with solar heat during the cooling system without low-voltage power distribution. (*NOTE: The score in this box reflects the fact that Roadmap drafts prior to the March 2011 identified this research area as an R&D gap.*)

- The National Renewable Energy Laboratory (NREL) is developing a prototype window with an integrated PV panel used to control and power the windows; more information on this project can be found in Appendix B.

Develop next-generation coatings for triple-glazed windows with low SHGC and R-value over 5: Develop a glazing product with high R-value and low Solar Heat Gain Coefficient (SHGC) that performs well in all seasons and climates. (*NOTE: The score in this box reflects the fact that Roadmap drafts prior to the March 2011 identified this research area as an R&D gap.*)

- The Lawrence Berkeley National Laboratory's (LBNL) High Performance Building Façade Solutions team is engaged in ongoing research into new coatings and highly insulated window technologies for both commercial and residential applications; more information on these projects can be found in Appendix B.

Integral low-energy and photovoltaic windows: By applying a thin, clear photovoltaic (PV) film on windows, power can be generated to help buildings achieve Net Zero Energy status. (*NOTE: The score in this box reflects the fact that Roadmap drafts prior to the March 2011 identified this research area as an R&D gap.*)

- Brookhaven National Laboratory (BNL) and Los Alamos National Laboratory (LANL) are collaborating to develop large area polymer honeycomb thin film, which is a transparent thin-film photovoltaic (PV) material. See Appendix B for more information on this project.
- As of January 2011, there were several Chinese and Japanese companies selling these types of products (for example, Suntech's Photovol Glass product, http://www.solarpowersolutions.nl/cms/support/get.file.php?file_id=683). However, high costs are still a barrier to widespread market penetration.

What is there beyond fiberglass that is highly insulated and lightweight?: Other materials may be available to allow a more effectively insulated frame.

- E Source reported in March 2010 about the status of research and market penetration of aerogels. These materials are clear and have significant insulative properties (R-value of about 10 per inch of thickness), and can be used in a variety of building applications, including windows, skylights, and daylighting applications (http://www.esource.com/members/TAS-AskES-15/Ask_ESource/Aerogels). Though aerogel products are available in the marketplace, high manufacturing costs are have thus far precluded more wide-spread adoption. Three companies current producing aerogel products:
  - Aspen Aerogels (http://www.aerogel.com/)
  - Cabot (http://www.cabot-corp.com/Aerogel)
  - ThermaBlok (http://www.thermablok.com/)

Glazing, vacuum-filled 2-pane, low-E windows: Combining the insulating property of vacuum between panes and low-emissivity (low-E) coatings results in a higher R-value glazing.

- Guardian Industries has developed different coatings for commercial and residential applications to achieve balance between capturing and reflecting solar heat in different climate zones. See http://www.guardian.com/GuardianGlass/GlassSolutions/Energy-EfficientLow-EGlass/index.htm.

Heavily insulated electrochromic windows: Adding electrochromic tinting to a high R-value glazing allows a window to block heat transfer and selectively block solar radiation. E Source reported that, as of January 2011, they were not aware of any current research in this area.

Product/Service Area : **RETROFIT BUILDING DESIGN/ENVELOPE**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Transformative Building Materials**

Roadmap Definitions on pages ix-xii

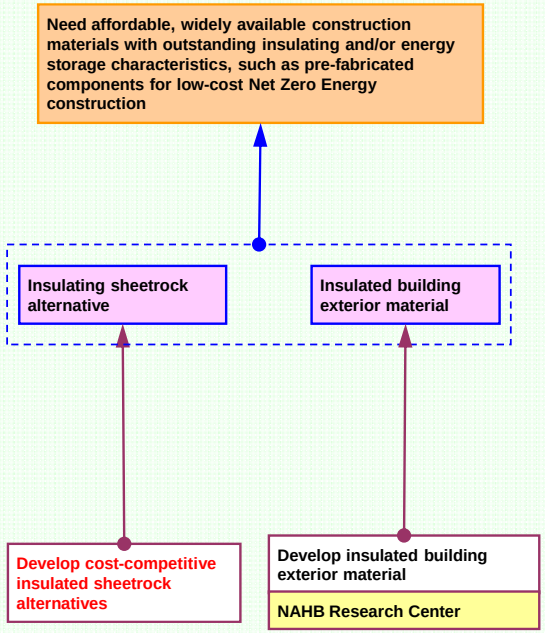
Drivers

Capability Gaps

Technology Characteristics

R&D Programs

Aug. 8 2012 workshop participants indicated that this roadmap was "Too broad-capability gaps fall under more specific roadmaps"



Driver
Capability Gap
Commercially Available Technology
Commercially Unavailable Technology
Existing R&D Program or Project
R&D Program Requirement

R&D Project Summaries

Develop insulated building exterior material: A cost-effective insulating material that can be applied to building exteriors would help achieve Net Zero Energy retrofits in buildings for which interior insulation is impractical. These materials are also referred to as Exterior Insulation Finishing Systems (EIFS). (*NOTE: The score in this box reflects the fact that Roadmap drafts prior to the March 2011 identified this research area as an R&D gap.*)

- The National Association of Home Builders (NAHB) Research Center's Technology Inventory, last updated in 2008, provides a centralized listing of more than 160 products and systems developed to increase the efficiency of housing units, including an exterior insulation finishing system and insulated vinyl siding products (http://www.toolbase.org/TechInventory/ViewAll.aspx).
- The National Institute of Building Sciences' Whole Building Design Guide published a guide specifically EIFS in June 2010 (http://www.wbdg.org/design/env_wall_eifs.php).

Develop cost-competitive insulated sheetrock alternatives: A cost-effective, insulated alternative to sheetrock would help achieve Net Zero Energy retrofits in buildings where wall cavities are shallow.

- E Source reported in January 2011 that they were not aware of any current R&D in this area, but in April 2010 E Source's Mary Horsey wrote an article identifying "phase change materials" as a potential area for exploration. These materials are designed to absorb and release energy into the surrounding environment, thereby saving energy and shifting HVAC loads to off-peak times (http://www.esource.com/members/TAS-AskES-16/Ask_ESource/PhaseChangeMatls).

Product/Service Area :

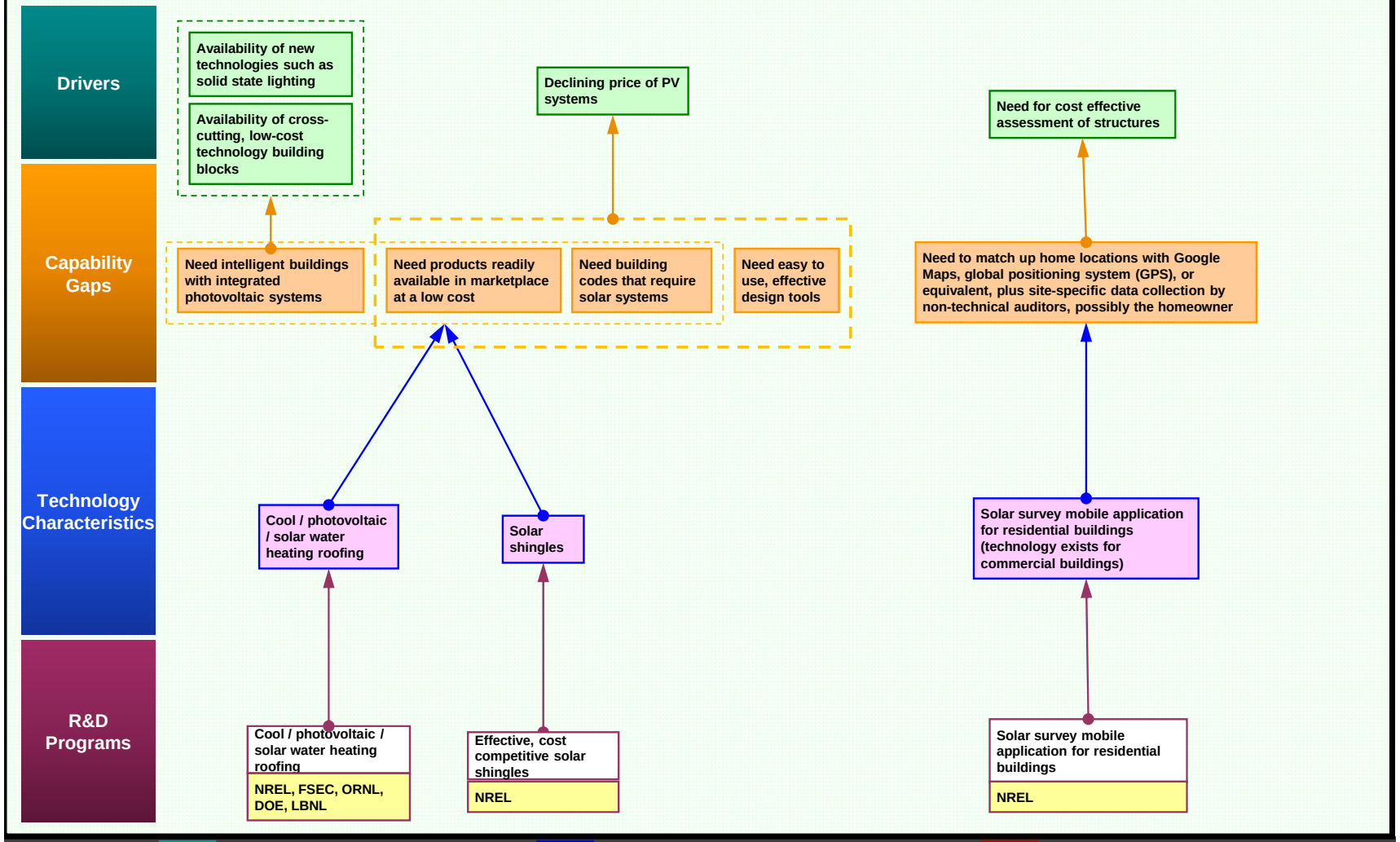
RETROFIT BUILDING DESIGN/ENVELOPE

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap:

Solar / Smart Roofing (1 of 2)

Roadmap Definitions on pages ix-xii



R&D Project Summaries

See next Page.

Product/Service Area :

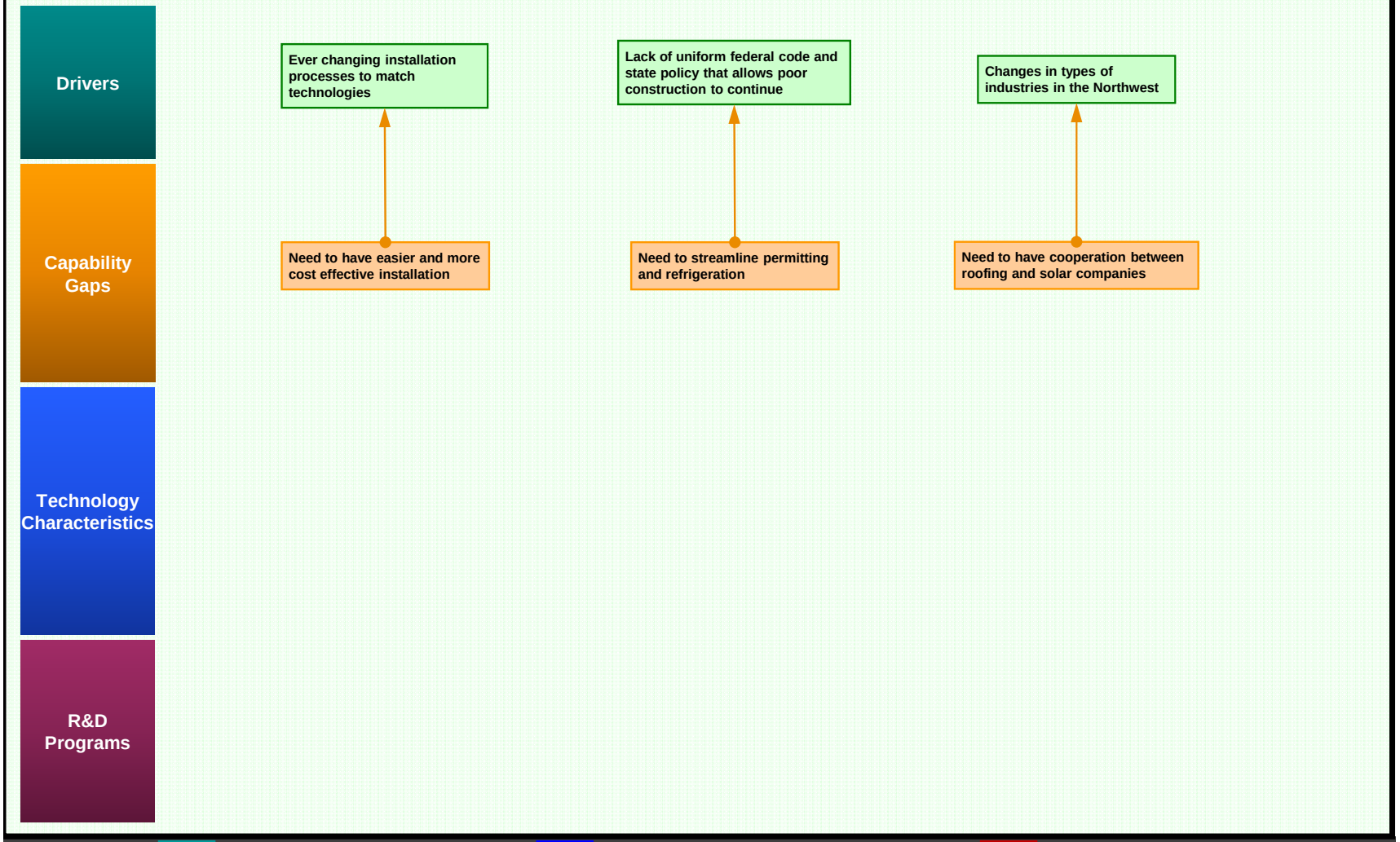
RETROFIT BUILDING DESIGN/ENVELOPE

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap:

Solar / Smart Roofing (2 of 2)

Roadmap Definitions on pages ix-xii



R&D Project Summaries

Cool / photovoltaic / solar water heating roofing: Develop affordable roofing systems with integrated solar photovoltaic (PV) and solar collectors for domestic hot water (DHW) while shading the building. Institutions engaged in current R&D into building-integrated PV and solar thermal systems include the U.S. Department of Energy (DOE) Office of Energy Efficiency and Renewable Energy (EERE), the Florida Solar Energy Center (FSEC), the National Renewable Energy Laboratory (NREL), and the Oak Ridge National Laboratory (ORNL).

- More information about the U.S. DOE EERE's Sunshot Initiative can be found in Appendix B.
- FSEC's work in this area is likely being done by their Photovoltaics & Distributed Generation Division, but information pertaining to this research was not available as of Feb. 2012 (http://www.fsec.ucf.edu/en/research/photovoltaics/index.htm).
- NREL's research in this area can be found in Appendix B.
- ORNL's research in this area can be found in Appendix B.

Solar survey mobile application for residential: A simple, inexpensive, accurate approach to surveying residential buildings' solar potential will assist in owners' decision-making and reduce overhead costs for installers. (*NOTE: The score in this box reflects the fact that Roadmap drafts prior to the March 2011 identified this research area as an R&D gap.*)

- The National Renewable Energy Laboratory's (NREL) In My Backyard (IMBY) system estimates photovoltaic (PV) electricity production based on location, system size, and other factors. By using a Google Maps interface, the IMBY system easily allows one to choose an accurate PV system location, and then the IMBY tool draws applicable data from one of NREL's databases to estimate potential electricity production (http://www.nrel.gov/eis/imby/).

Effective, cost-competitive solar shingles: Building-integrated photovoltaic (PV) technologies helps make solar power more affordable and easier to incorporate into a building. Although there are currently solar shingle products in the market (i.e., DOW POWERHOUSEtm solar shingles, http://www.dowsolar.com/), these products tend to have relatively low efficiencies and higher costs when compared with standard small PV systems.

Product/Service Area :

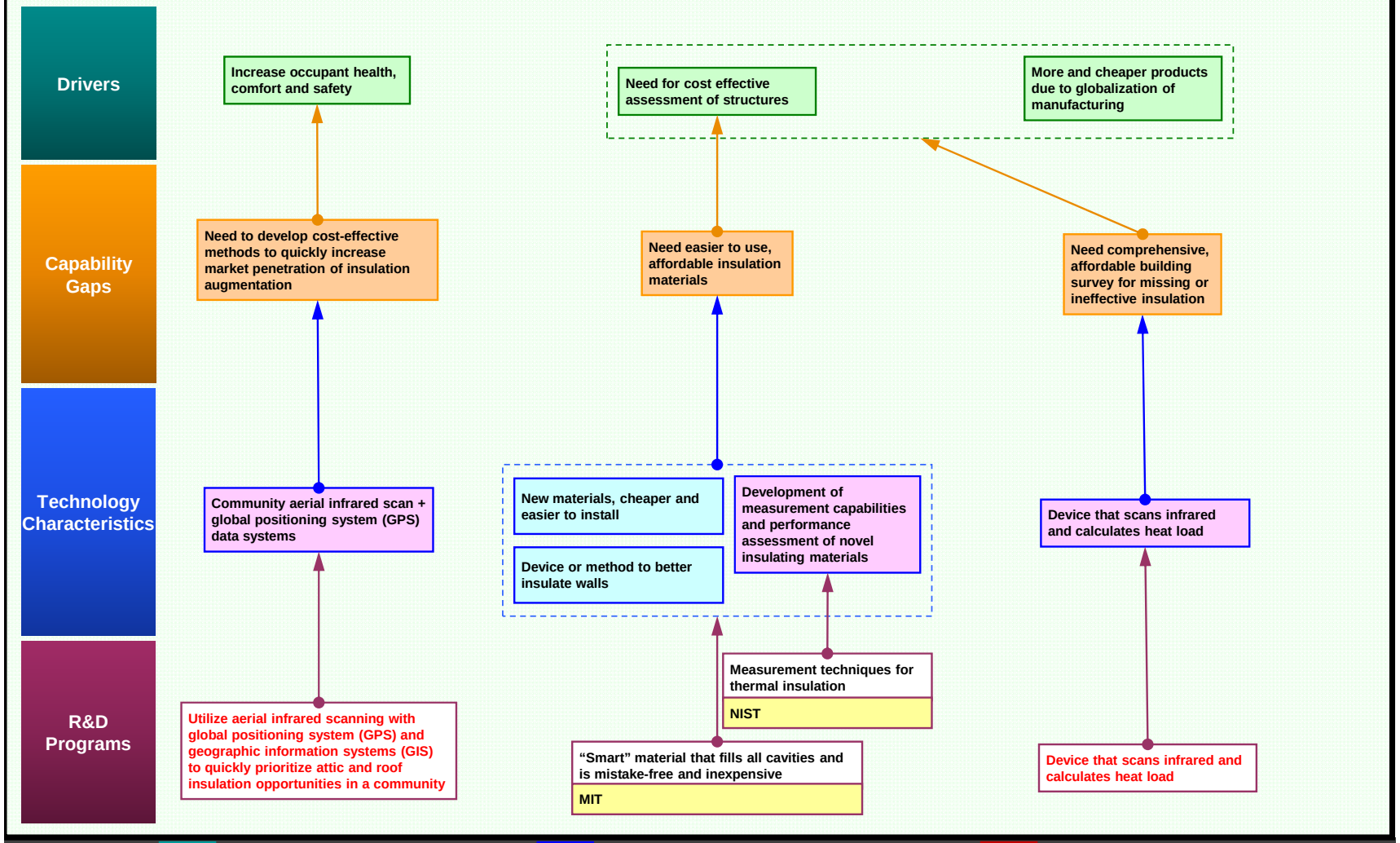
RETROFIT BUILDING DESIGN/ENVELOPE

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap:

Retrofit Insulation (1 of 2)

Roadmap Definitions on pages ix-xii



R&D Project Summaries

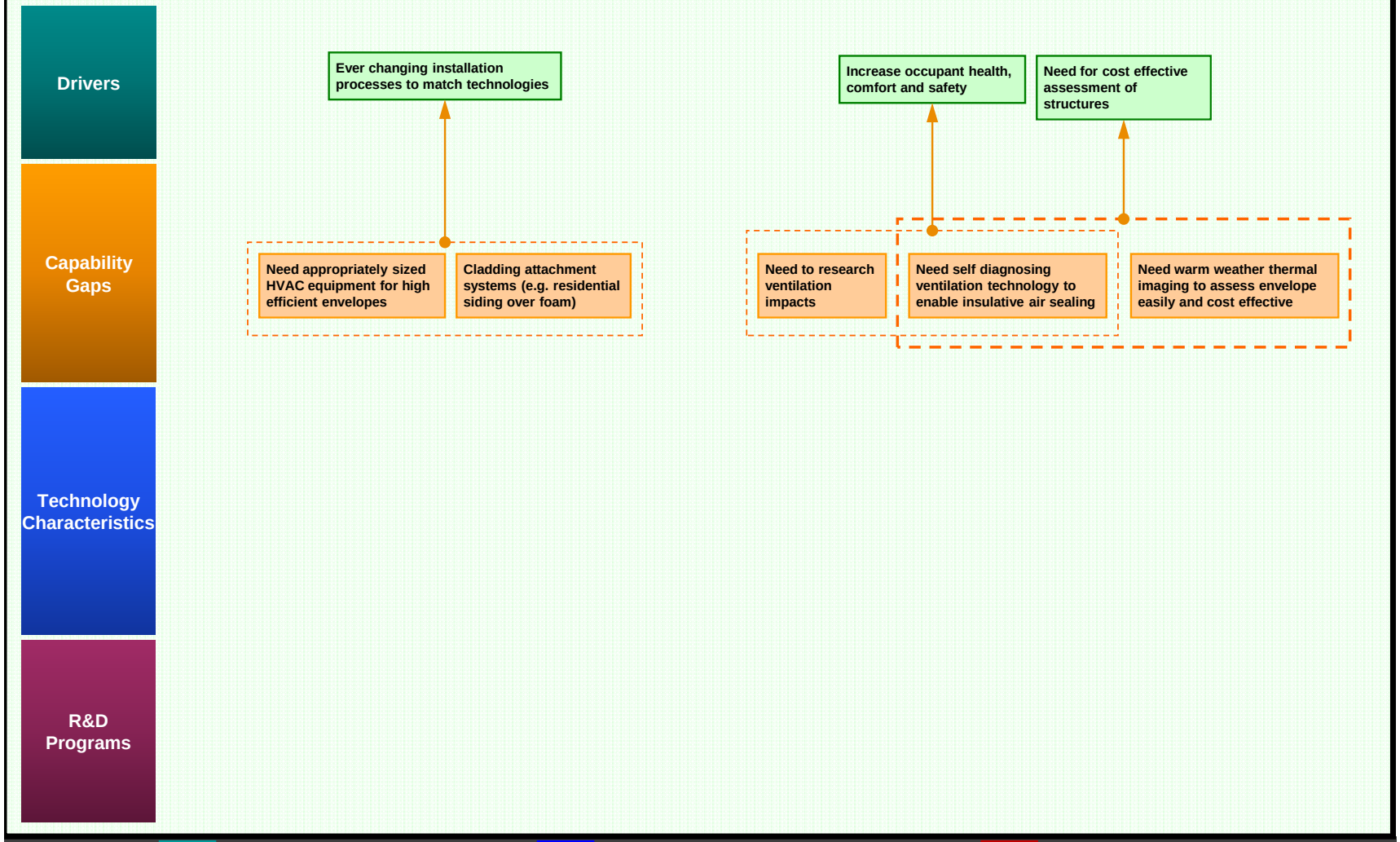
See next Page.

Product/Service Area : **RETROFIT BUILDING DESIGN/ENVELOPE**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Retrofit Insulation (2 of 2)**

Roadmap Definitions on pages ix-xii



R&D Project Summaries

"Smart" material that fills all cavities and is mistake-free and inexpensive: Sprayed fiber or foam insulation are notable contenders for addressing this gap. Sprayed insulation application costs are about twice the amount of fiberglass batting, indicating the need for R&D to drive down costs. The Massachusetts Institute of Technology's (MIT) Building Technology Research Program is working on related projects, and the National Association of Home Builders (NAHB) Research Center has one potential tool available.

- More information about MIT's research can be found in Appendix B.
- The NAHB's Research Center provides cost data, possible contingencies, and case studies for both sprayed fiber and foam insulation. According to this research, published circa 2002, the cost of sprayed insulation is still around twice that of installing fiberglass batting (http://www.toolbase.org/pdf/techinv/insulationalternatives_techspec.pdf).

Device that scans infrared and calculates heat load: With a bit more data input and programming capability, an infrared camera could translate surface temperature into heat load. As of January 2011, E Source was not aware of any current R&D in this area.

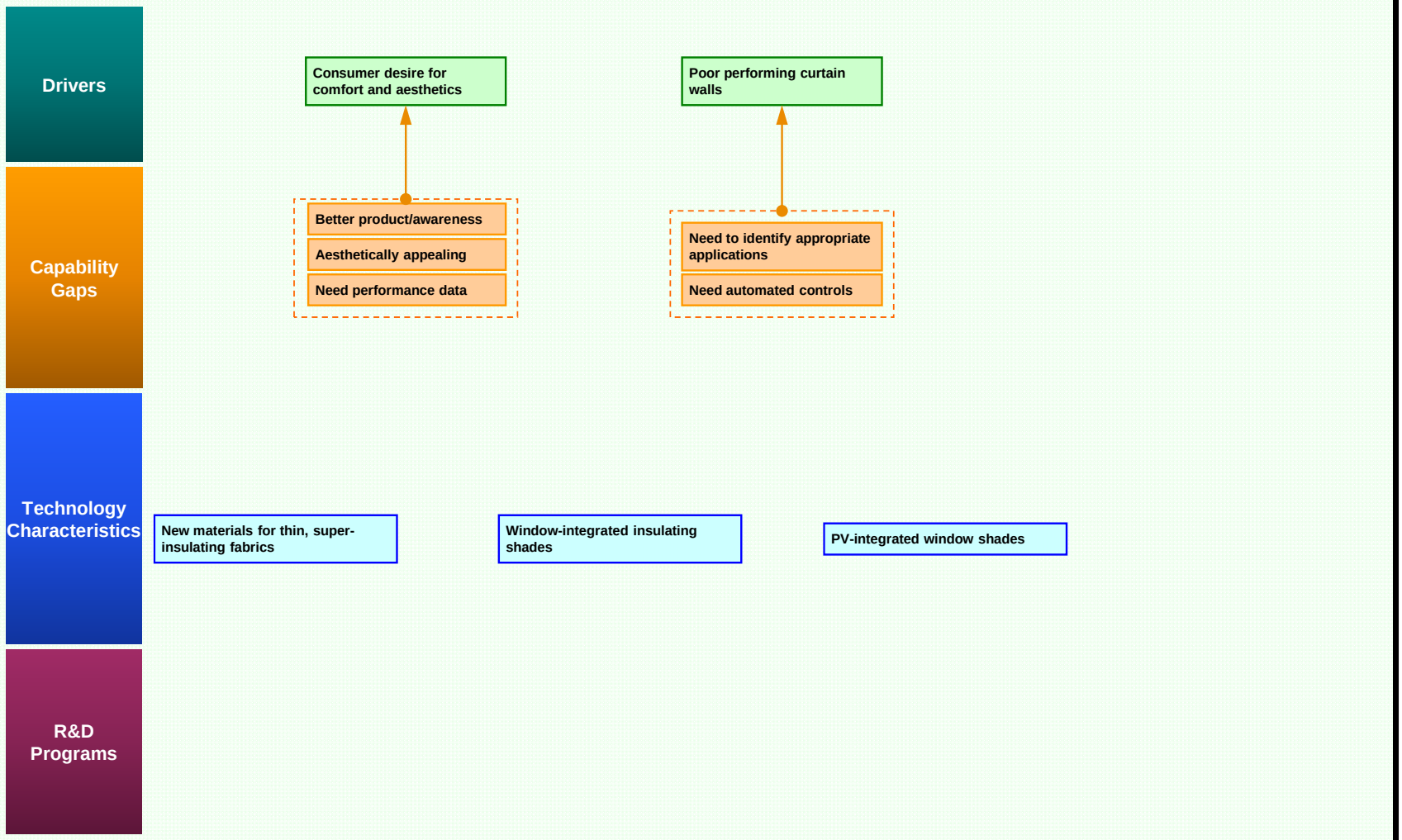
Utilize aerial infrared scanning with global positioning system (GPS) and geographic information systems (GIS) to prioritize attic and roof insulation opportunities quickly within in a community: Implementation costs of weatherization programs may be reduced and impacts greatly improved by integrating aerial infrared scanning with global positioning system (GPS) locating technologies and geographic information systems (GIS) mapping tools to aid in project identification and prioritization. As of January 2011, E Source was not aware of any current R&D in this area.

Product/Service Area : **RETROFIT BUILDING DESIGN/ENVELOPE**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Insulated Shades**

Roadmap Definitions on pages ix-xii



R&D Project Summaries

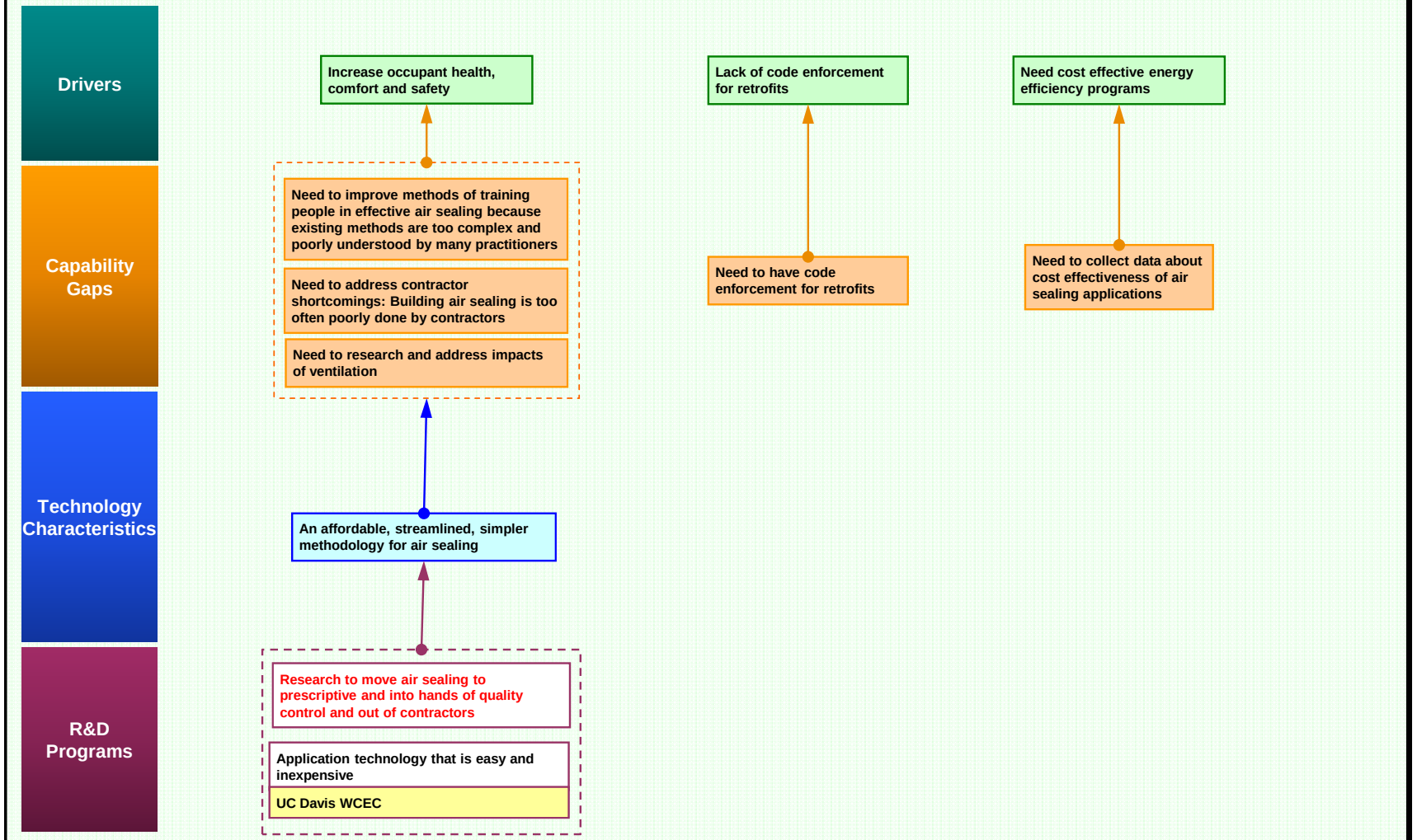
No current or prospective R&D projects identified for this Roadmap as of August 2012. However, the Technology Inventory list identified by the National Association of Home Builders (NAHB) Research Center provides some links to insulation technologies that are not yet widely used but that show potential energy efficiency benefits (http://www.toolbase.org/TechInventory/ViewAll.aspx).

Product/Service Area : **RETROFIT BUILDING DESIGN/ENVELOPE**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Retrofit & New Construction Air Sealing**

Roadmap Definitions on pages ix-xii



Driver | Capability Gap | Commercially Available Technology | Commercially Unavailable Technology | Existing R&D Program or Project | R&D Program Requirement

R&D Project Summaries

No current R&D projects identified for this Roadmap as of August 2012. However, the Technology Inventory list identified by the National Association of Home Builders (NAHB) Research Center provides some links to insulation technologies that are not yet widely used but that show potential energy efficiency benefits (http://www.toolbase.org/TechInventory/ViewAll.aspx).

- **Research to move air sealing to prescriptive and into hands of quality control and out of contractors:** Building air sealing is too often poorly done by contractors.

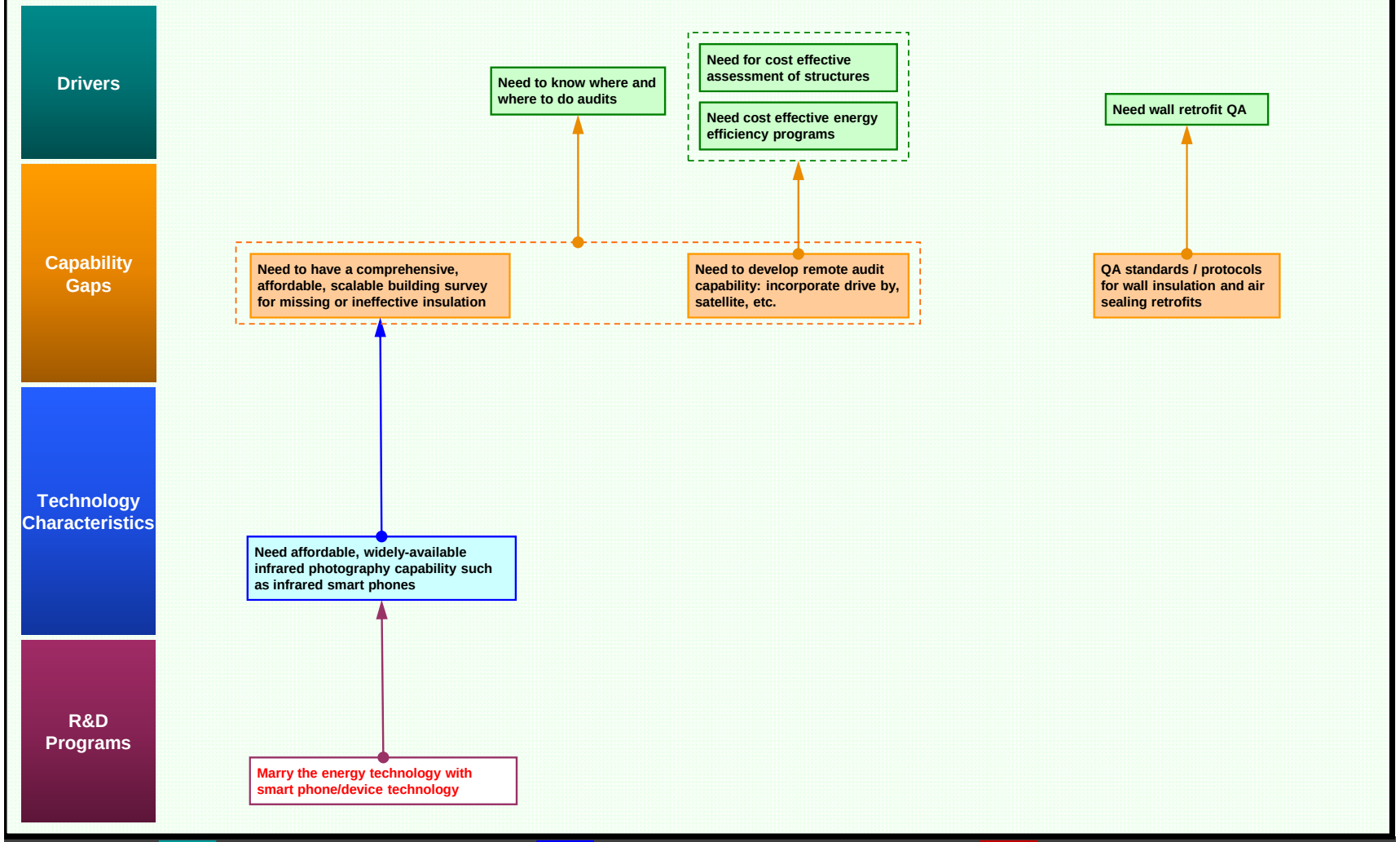
- **Application technology that is easy and inexpensive:** If a common methodology for air sealing common building envelope types could be developed, a wider range of builders could implement it more effectively and consistently.

Product/Service Area : **RETROFIT BUILDING DESIGN/ENVELOPE**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Infrared Scanning**

Roadmap Definitions on pages ix-xii



R&D Project Summaries

- **Marry the energy technology with smart phone/device technology:** To make infrared scanners more effective, find a way to link them to smart phones or devices, or develop a cell phone application that would allow the cell phone to function as an infrared (IR) camera.

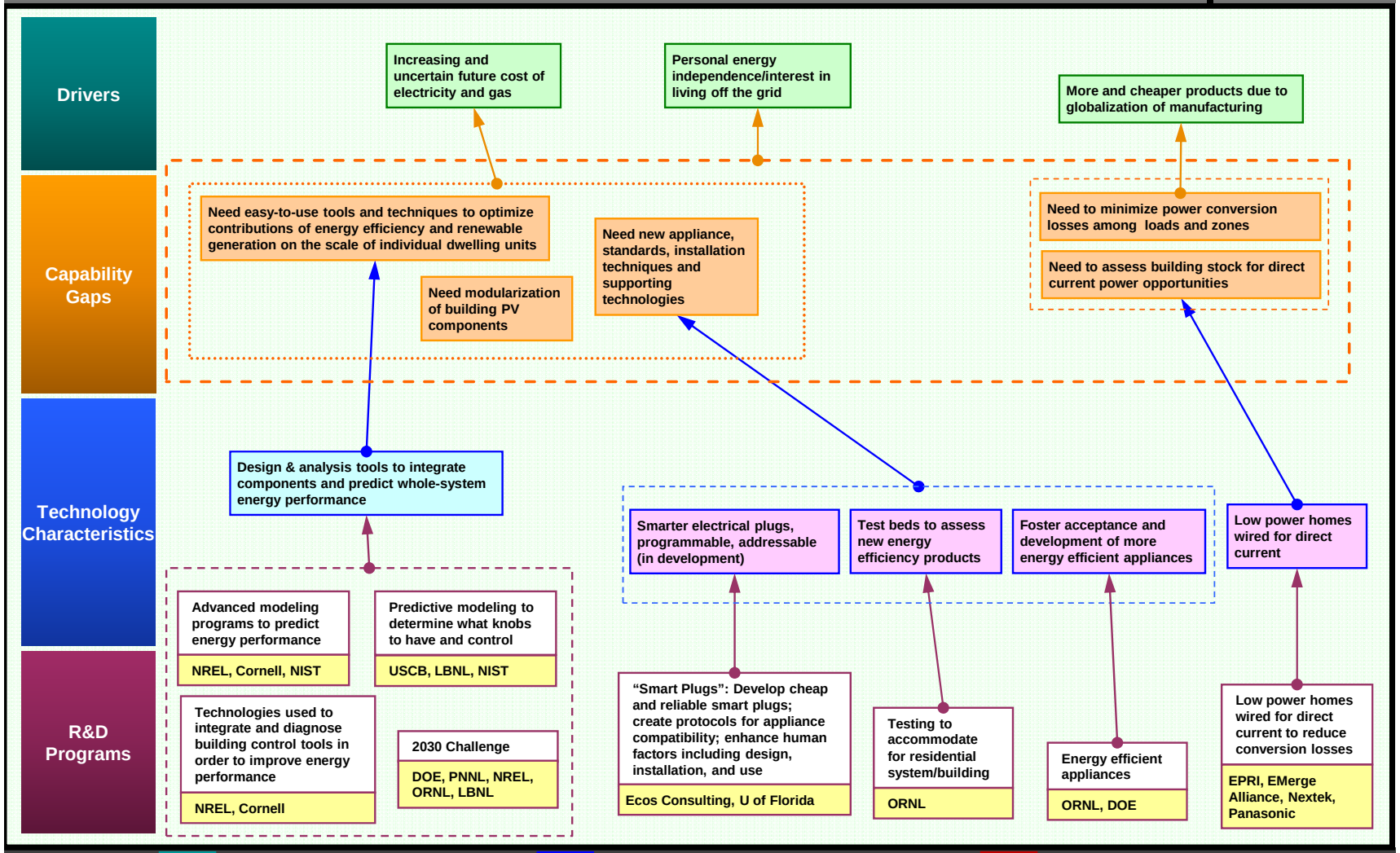
New Construction Building Design/Envelope

Product/Service Area : **NEW CONSTRUCTION BUILDING DESIGN/ENVELOPE**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Net Zero Energy Home (1 of 2)**

Roadmap Definitions on pages ix-xii



R&D Project Summaries

See next Page.

Product/Service Area : **NEW CONSTRUCTION BUILDING DESIGN/ENVELOPE**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Net Zero Energy Home (2 of 2)**

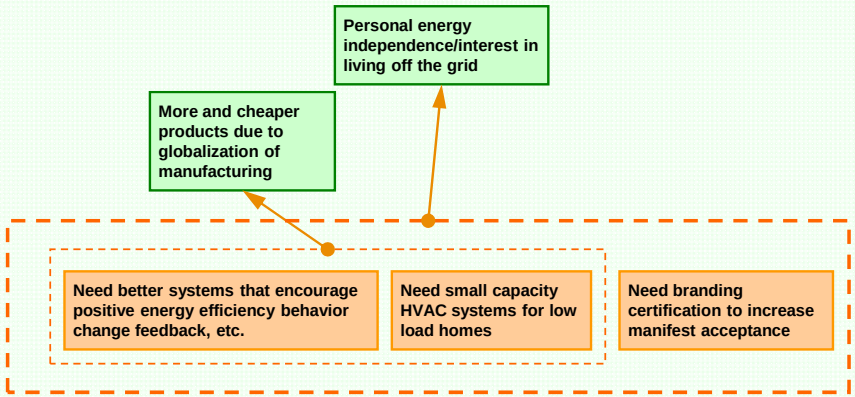
Roadmap Definitions on pages ix-xii

Drivers

Capability Gaps

Technology Characteristics

R&D Programs



Driver

Capability Gap

Commercially Available Technology

Commercially Unavailable Technology

Existing R&D Program or Project

R&D Program Requirement

R&D Project Summaries

General note on Net Zero Energy R&D: In late 2011, The California Public Utilities Commission (CPUC) and the California Energy Commission (CEC) held a workshop to develop a Research and Technology Action Plan as an integral element of the process of implementing the California Energy Efficiency Strategic Plan (http://www.cpuc.ca.gov/PUC/energy/Energy+Efficiency/eesp/). This Strategic Plan includes a section focused on Net Zero Energy (NZE) technologies for residential and commercial buildings (http://www.cpuc.ca.gov/NR/rdonlyres/6C2310FE-AFE0-48E4-AF03-530A99D28FCE/0/ZNEActionPlanFINAL83110.pdf). As of Feb. 8 2012, Edward Vine, Program Director for Planning and Analysis at the California Institute for Energy and Environment (http://uc-ciee.org/technical-experts/15/dpeople), had revised a Research and Technology Gap Analysis on NZE buildings that he originally compiled in June 2011.

"Smart plugs": Develop cheap and reliable smart plugs; create protocols for appliance compatibility with smart plugs; enhance human factors R&D for design, installation, and use: Make smart outlets a standard feature in new construction requires innovation in technology and building industry practices. "Smart plugs" or "smart strips" can refer to the ability of the outlet to turn-off devices when they are not being used, and to interactivity with smart grid systems for demand response and load control. Research is needed primarily to develop the ability of plugs to turn off equipment when not in use; secondarily, to enable participation in demand response events. Ecova (formerly Ecos Consulting) and Florida's Computer and Information Science and Engineering Department have conducted two preliminary studies in this area. (*NOTE: The score in this box reflects the fact that Roadmap drafts prior to the March 2011 identified this research area as an R&D gap.*)

- Ecos Consulting (http://www.ecova.com/) has done research on the energy savings potential of plugs that turn off devices when that are not being used. Their efforts have led them to identify the same technology gap that Pacific Northwest regional stakeholders have: further research is needed on the linkage of smart strips to building control interfaces (such as ZigBee, http://www.zigbee.org/). Research in this area would incorporate the functionality of both types of "smart plugs" (see Ecos Consulting, "Smart Plug Strips: Draft Report," July 22, 2009, http://www.efficientproducts.org//reports/smartplugstrip/Ecos-Smart-Plug-Strips-DRAFT-Jul2009-v2x.pdf).
- Researchers in the University of Florida's Computer and Information Science and Engineering Department (http://www.cise.ufl.edu/) have conducted some research on smart plugs and smart environments that addresses plug design, capabilities, and installation. This research explores the ability of the home operating system, but does not address smart grid integration for demand response purposes (see Hicham Elzabadani, Abdelsalam (Sumi) Helal, Bessam Abdulrazak, and Erwin Jansen, "Self-Sensing Spaces: Smart Plugs For Smart Environments," 2005, http://www.icta.ufl.edu/projects/publications/2005-ICOST-Selfsensingspaces.pdf).

Low power homes wired for direct current to reduce conversion losses: Design homes with both alternating current (AC) and direct current (DC) outlets so that DC-ready electronic appliances can use the DC directly, eliminating conversion losses. E Source reported that, as of January 2011, most research in this area in the United States is focused on commercial applications and DC-wired data centers; therefore, there is an R&D gap for DC-wired residential buildings. Some of the findings from this research may cross-over into the residential sector, and there is work being done in Japan. (*NOTE: The score in this box reflects the fact that Roadmap drafts prior to the March 2011 identified this research area as an R&D gap.*)

- The Electric Power Research Institute (EPRI) is conducting research on DC power for data centers and high voltage direct current (HVDC) systems that may have that results that can cross-over into commercial and/or residential applications; see Appendix B for more information.
- EMerge Alliance developed their "EMerge Standard" in 2009 to supplement ASHRAE building standards for DC low-voltage power distribution within commercial building interiors. See Appendix B for more information.
- Nextek Power Systems (http://www.nextekpower.com/) and Redwood Systems (www.redwoodsystems.com) are developing different DC power systems for commercial and industrial buildings.
- In Japan, Panasonic Electric Works is doing research on what they are calling "hybrid housing"—homes supplied with both AC and DC power (http://panasonic.net/pew/).

Predictive modeling to determine what knobs to have and control: Integrating and operating the variety of energy technologies required to achieve Net Zero Energy requires advanced modeling and controls. Research is ongoing at Cornell University, the Lawrence Berkeley National Laboratory (LBNL), the UC Santa Barbara (UCSB) Institute for Energy Efficiency (IEEE), and the National Institute for Standards and Technology (NIST).

- Researchers at Cornell University are currently working on a Green Building Design Computer Simulation Software project; see Appendix B for more information.
- LBNL's work in this area is identified in Appendix B.
- The Buildings & Design Solutions Group of UCSB's Institute for Energy Efficiency is doing research into economically viable Zero Net Energy building systems; see Appendix B for more information.
- NIST's work in this area is identified in Appendix B.
- A team within the Cornell University Program of Computer Graphics is working on a three-year grant funded by the Department of Energy (using American Recovery and Reinvestment Act (ARRA) funds) to use computer building simulations to streamline green design; see Appendix B for more information.

(continued on following page . . .)

2030 Challenge: To achieve carbon-neutrality by 2030 requires buildings, which contribute almost 50 percent of greenhouse gas emissions, to be designed to 50 percent of current average energy use for the building type and region. The U.S. Department of Energy (DOE), Pacific Northwest National Laboratory (LBNL), National Renewable Energy Laboratory (NREL), Oak Ridge National Laboratory, and the Lawrence Berkeley National Laboratory (LBNL) are doing work in this area.

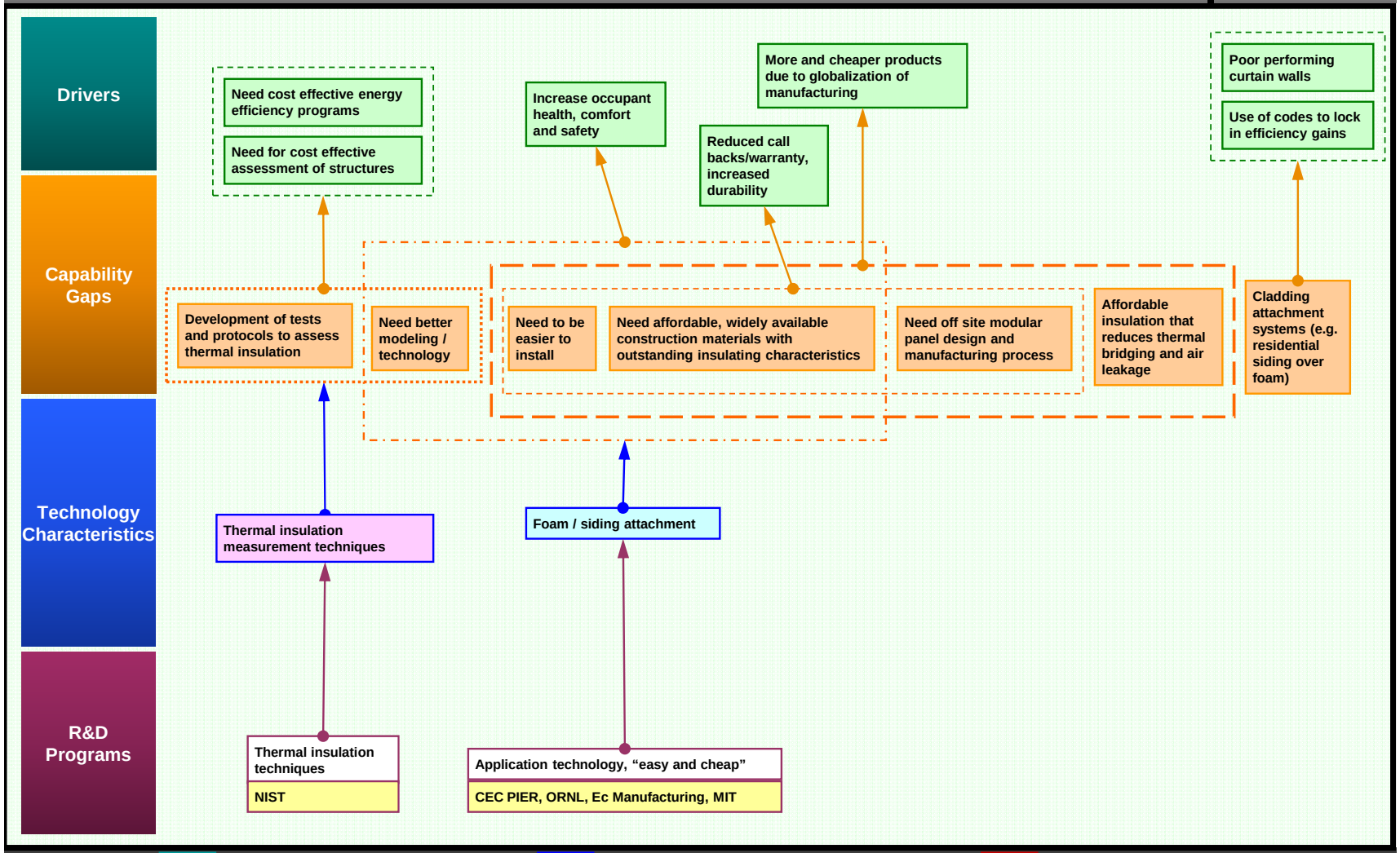
- For DOE research in this area, see Appendix B.
- PNNL research in this area is likely being done through the lab's Electricity Infrastructure & Buildings Division; as of Feb. 2012, specific projects had not been identified. See http://energyenvironment.pnnl.gov/ie_b_div.asp for more information.
- NREL has developed two tools to facilitate building design and analysis to help reach these goals:
  - In My Backyard (IMBY) system estimates PV electricity production based on such factors as location and system size. The IMBY system uses a Google Maps interface to allow users to easily choose a system location with pinpoint accuracy (http://www.nrel.gov/eis/imby/).
  - The HOMER computer model simplifies design option evaluations for both off-grid and grid-connected remote, standalone, or distributed generation (DG) power systems (https://analysis.nrel.gov/homer/, http://www.homerenergy.com/).
- In addition to the ongoing research & development projects at LBNL outlined in more detail in Appendix B, the LBNL is also working with the California Energy Commission and the Department of Energy to evaluate and improve tools for tracking and monitoring energy use in commercial buildings; see available tools at http://eis.lbl.gov/.
- For ORNL research in this area, see Appendix B.

Product/Service Area : **NEW CONSTRUCTION BUILDING DESIGN/ENVELOPE**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **New Construction Insulation**

Roadmap Definitions on pages ix-xii



R&D Project Summaries

Application technology, "easy and cheap": To achieve widespread use of more efficient building insulation, develop new materials that are cost-competitive with existing materials and that are easy to install. The Oak Ridge National Laboratory (ORNL) and Ec Manufacturing have recently developed insulation products, and research in this area is ongoing at the California Energy Commission's Public Interest Energy Research (PIER) program and at the Massachusetts Institute of Technology (MIT). (*NOTE: The score in this box reflects the fact that Roadmap drafts prior to the March 2011 identified this research area as an R&D gap.*)

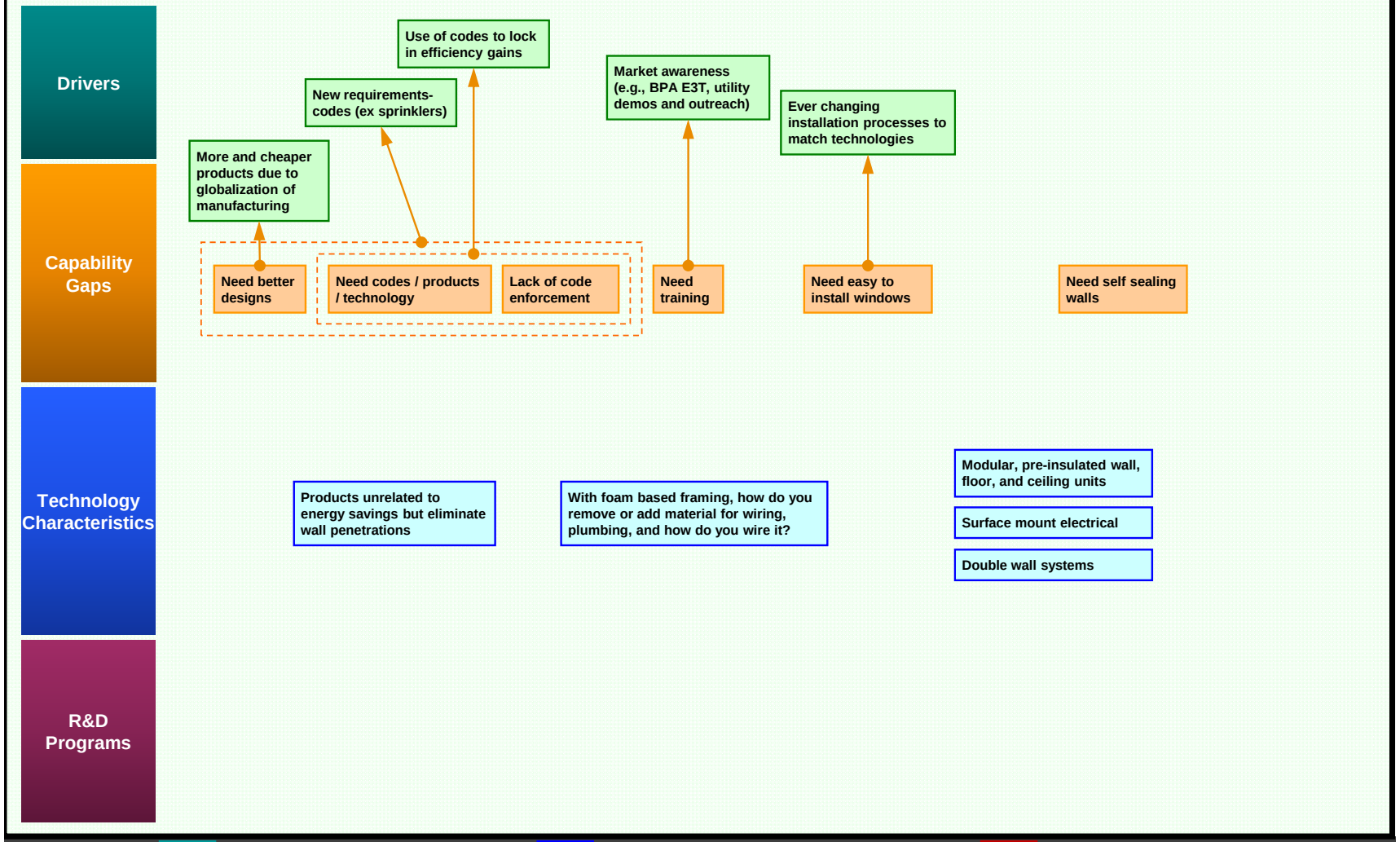
- ORNL developed a panelized wall system in 2010 with foam core insulation that can be easily assembled, is airtight, and is extremely energy efficient (http://www.ornl.gov/adm/partnerships/factsheets/10-G01077_ID1581.pdf).
- In 2010, Ec Manufacturing, LLC, of Colorado introduced to the market its rSTUD line of insulated, thermally-broken dimensional lumber products (http://rstud.com/, http://www.jetsongreen.com/2010/10/new-thermally-broken-rstud-lumber.html#).
- As of 2008, PIER researchers are exploring the feasibility of using a low-cost, perlite-based ceramic insulator material for buildings (http://www.energy.ca.gov/pier/portfolio/Content/06/EISG/Improved%20Insulation%20for%20Buildings.htm).
- MIT has been researching insulated concrete forms to determine the advantages over conventional wood-framed construction. See Appendix B for more information.

Product/Service Area : **NEW CONSTRUCTION BUILDING DESIGN/ENVELOPE**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Eliminating Home Penetrations**

Roadmap Definitions on pages ix-xii



Driver
Capability Gap
Commercially Available Technology
Commercially Unavailable Technology
Existing R&D Program or Project
R&D Program Requirement

R&D Project Summaries

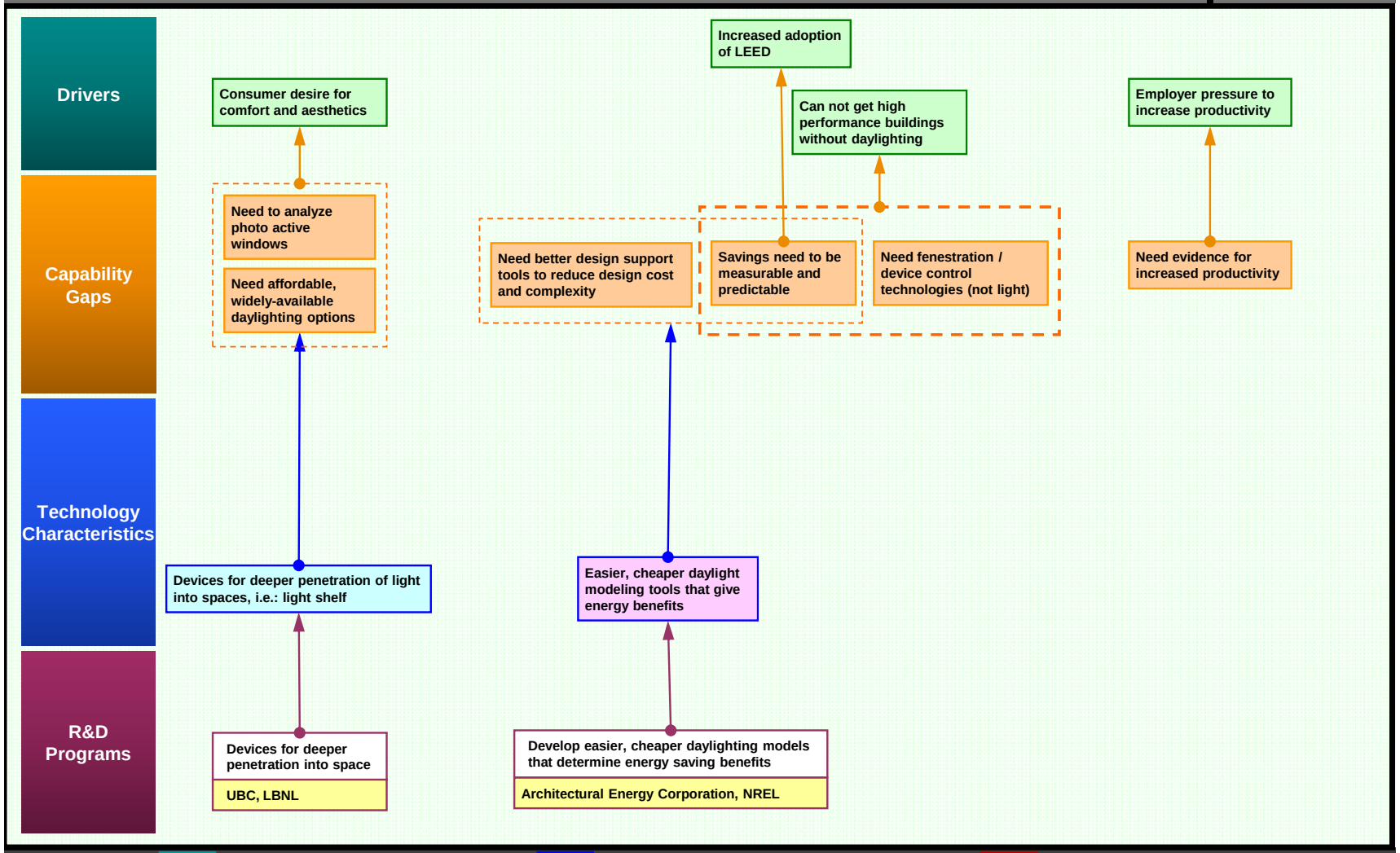
No current or prospective R&D projects identified for this Roadmap as of August 2012.

Product/Service Area : **NEW CONSTRUCTION BUILDING DESIGN/ENVELOPE**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Daylighting Envelope Elements**

Roadmap Definitions on pages ix-xii



Develop easier, cheaper daylighting models that determine energy savings benefits: Affordable daylighting design and commissioning software with intuitive design features for ease of usability will assist in optimum placement of sensors and optimum daylight harvesting, promoting successful and long-lasting applications. Stakeholders identified research in this areas at the Architectural Energy Corporation (AEC); there is also ongoing R&D at the Daylighting Collaborative and at the National Renewable Energy Laboratory (NREL). (*NOTE: The score in this box reflects the fact that Roadmap drafts prior to the March 2011 identified this research area as an R&D gap.*)

- The AEC (http://www.archenergy.com/) released the first version of its Sensor Placement and Optimization Software (SPOT™) in 2005, with the support from the California Energy Commission's Public Interest Energy Research (PIER) Lighting Research Program (http://www.energy.ca.gov/research/index.html). AEC has released periodic updates to the software with the support of the Northwest Energy Efficiency Alliance (NEEA, http://neea.org/) and other organizations. SPOT™ is a free tool using uses a Microsoft® Excel platform with a RADIANCE engine, and was developed to help designers quantify existing and desired lighting characteristics and establish optimal sensor placement for user controls. AEC released the most recent version (4.2) in July 2010 (http://www.archenergy.com/SPOT/). E Source reported in Jan. 2011 that the New Buildings Institute (http://newbuildings.org/) was also involved in this project.
- The Daylighting Collaborative (http://www.daylighting.org/) maintains a list of currently available daylighting modeling software (http://www.daylighting.org/designaids.php#computer). As of Feb. 2012, this list numbered twelve free and for-cost modeling tools.
- NREL is working on a project funded by the Bonneville Power Administration (BPA) Technology Innovation (TI) office to study the feasibility of integrating building energy models for new and existing buildings that evaluates daylighting as a viable energy efficiency strategy and that can be analyzed using emerging building energy efficiency metrics such as the Energy Utilization Index (EUI). This is BPA TI Project #252,"Integrated Daylighting and Energy Analysis Toolkit (IDEAKit)"; See Appendix B for more information.

Devices for deeper penetration into space: For more effective daylighting, develop devices to transfer daylight deeper into building spaces. Ongoing research in this area includes work at the University of British Columbia (UBC), California Lighting Technology Center (CLTC) at the University of California Davis, and the Lawrence Berkeley National Laboratory (LBNL).

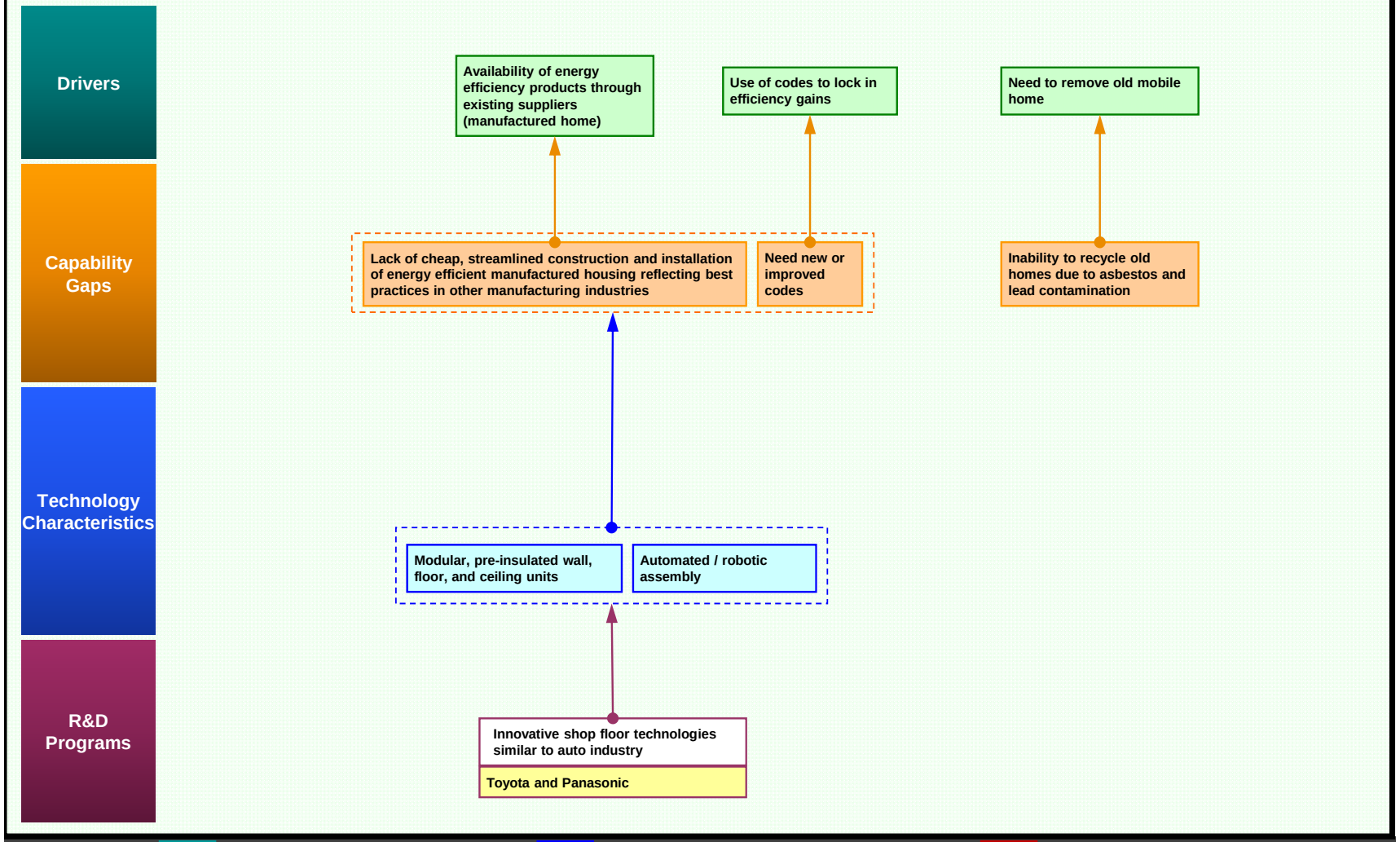
- UBC Structured Surface Physics Department (http://www.phas.ubc.ca/ssp/index.html) developed and extensively evaluated their Core Sunlighting System (http://www.phas.ubc.ca/ssp/CoreSun_index.html), a cost-effective, architecturally-integrated approach that they call "the first core daylighting system with potential for widespread adoption." The system is composed of sunlight concentration panels and dual-function prism light guides to replace conventional light fixtures and incorporate lighting fixture dimming technologies to distribute collected sunlight. As of early 2012, SunCentral Inc. (http://www.suncentralinc.com/) is developing this technology for commercial applications, with a projected market availability date of 2013.
- The CLTC is currently working on an R&D project to evaluate the application of UBC's Core Sunlighting System to the climate and topography of California's Central Valley. See Appendix B for more information on this effort.
- LBNL's Windows & Daylighting team in the Buildings Energy Efficiency research group has developed some daylighting technologies and strategies over the past two decades, including lightshelves / lightpipes, tools for daylighting predictions, and daylighting controls. (http://windows.lbl.gov/daylighting/Default.htm). As of Feb. 2012, it is not clear what specific R&D projects in these areas are ongoing at LBNL.

Product/Service Area : **NEW CONSTRUCTION BUILDING DESIGN/ENVELOPE**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Manufactured Housing**

Roadmap Definitions on pages ix-xii



R&D Project Summaries

Innovative shop floor technologies similar to auto industry: Manufactured housing is generally overlooked. It can generate significant energy efficiency and financial benefits with some optimization and lessons from other industries. Most of the work done to date in this area has been in Japan under the leadership of Panasonic and Toyota. Based upon available data, while Panasonic and Toyota do appear to be producing advanced manufactured housing that deliver significant energy efficiency results, it is not clear the extent to which the work in Japan involves innovative shop floor technologies. Further, it does not appear that much is being done to bring these technologies to the U.S. housing industry. Therefore, further domestic research in this area seems warranted. (*NOTE: The score in this box reflects the fact that Roadmap drafts prior to the March 2011 identified this research area as an R&D gap.*)

- Panasonic: http://www.panahome.jp/english/.
- Toyota: http://www.toyota-global.com/company/profile/non_automotive_business/housing.html; see also Appendix B.

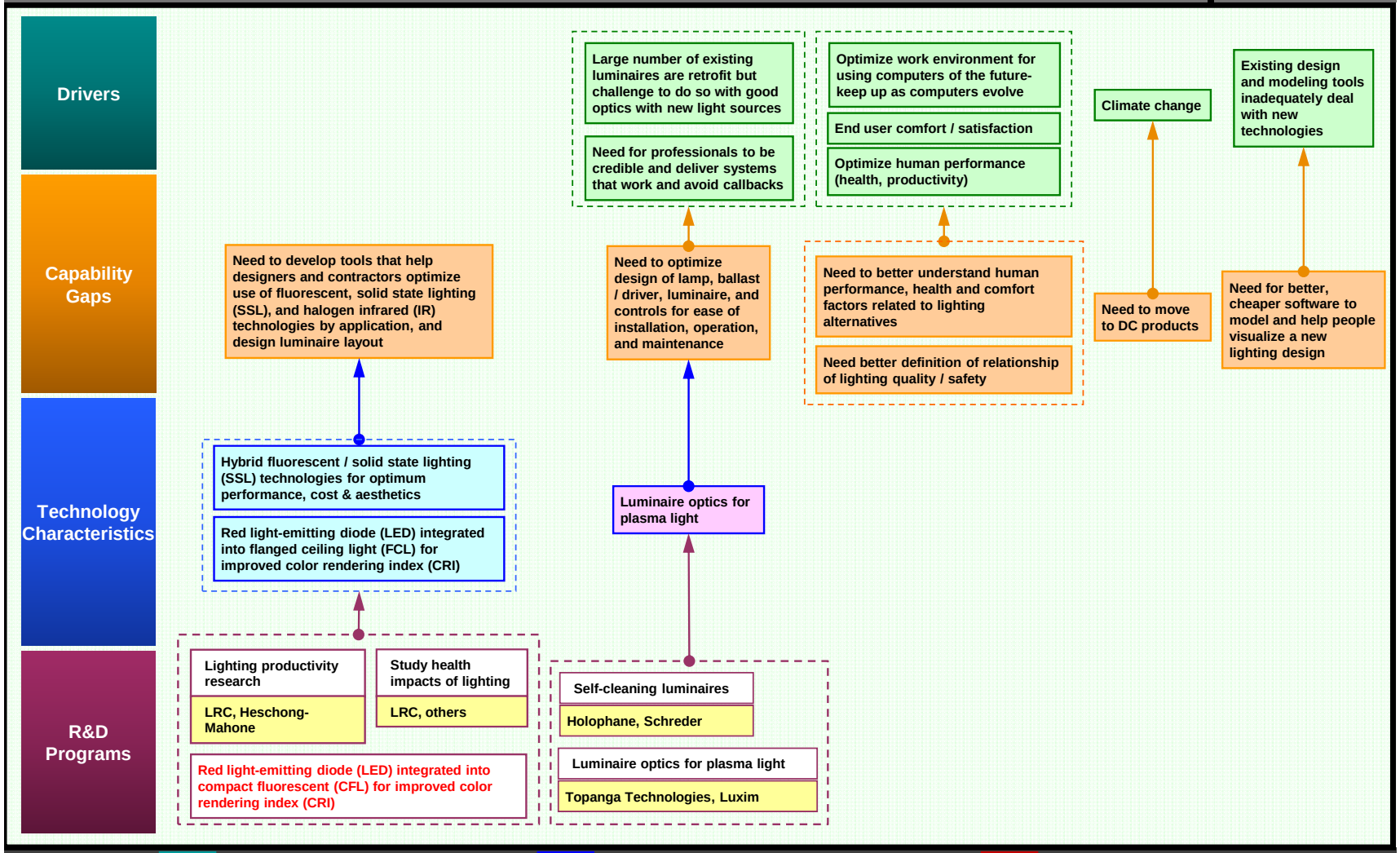
Lighting Roadmaps

Product/Service Area : **LIGHTING**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **General Lighting**

Roadmap Definitions on pages ix-xii



R&D Project Summaries

Lighting productivity research: To expand the use of some efficient lighting techniques, research is needed to better document positive impacts on productivity, building on work by the Heschong-Mahone Group (http://www.h-m-g.com/) and the Lighting Resource Center (LRC, http://www.lrc.rpi.edu/).

- For Heschong-Mahone Group's completed projects in this area, see http://www.h-m-g.com/Projects/daylighting/projects-PIER.htm.
- For some specific current LRC projects in this area, see Appendix B; for LRC's work in this area generally, see http://www.lrc.rpi.edu/researchAreas/healthVision.asp.

Luminaire optics for plasma light: Plasma lighting claims 120 lumens per watt and 30,000 hour life. Research on luminaire optics is needed to take better advantage of this new lamp technology. California Lighting Technology Center (CLTC) affiliates Luxim Corporation and Topanga Technologies are two of the leading Light-emitting Plasma (LEP) companies. (*NOTE: The score in this box reflects the fact that Roadmap drafts prior to the March 2011 identified this research area as an R&D gap.*)

- Luminaires using the Luxim LEP lamp were shown at LightFair International conferences 2010 and 2011 (http://www.luxim.com/).
- Topanga Technologies (http://topangatech.com/).

Self-cleaning luminaires: Explore surface films and treatments to reduce reductions in luminaire reflectivity and transmittance due to surface deterioration and contamination. Both Holophane (http://www.holophane.co.uk/) and The Schréder Group GIE (http://www.schreder.com/Pages/default.aspx) have developed self-cleaning luminaries. (*NOTE: The score in this box reflects the fact that Roadmap drafts prior to the March 2011 identified this research area as an R&D gap.*)

- Holophane's Prismpack applies the company's self-cleaning reflector technology in a line of energy efficient lighting options for high bay industrial and commercial applications (http://www.holophane.co.uk/downloads/Prismpack_UK.pdf).
- The Schréder Group's Furyo lights make use of a hydrophilic coating on the exterior of the glass that causes raindrops to spread over the glass and wash away any residue (http://www.schreder.com/272-1-259-520/product/print_fiche.aspx).

Study health impacts of lighting: To expand the utilization of some efficient lighting techniques, research is needed to better document positive impacts on human health, building on work that stakeholders indicated was ongoing at the Rensselaer Polytechnic Institute's Lighting Resource Center (LRC) and other institutions. This work could potentially be informed by researchers such as Joan Roberts of Fordham University and Jennifer Veitch at the National Research Council of Canada, who are both working on designing healthy workplaces.

- For LRC work in this area, see Appendix B.
- Bonneville Power Administration staff sent queries to Professors Roberts (http://www.dsm.fordham.edu/ns/roberts.html) and Veitch (http://www.nrc-cnrc.gc.ca/eng/projects/irc/office-lighting.html) in Feb. 2012, still awaiting reply.

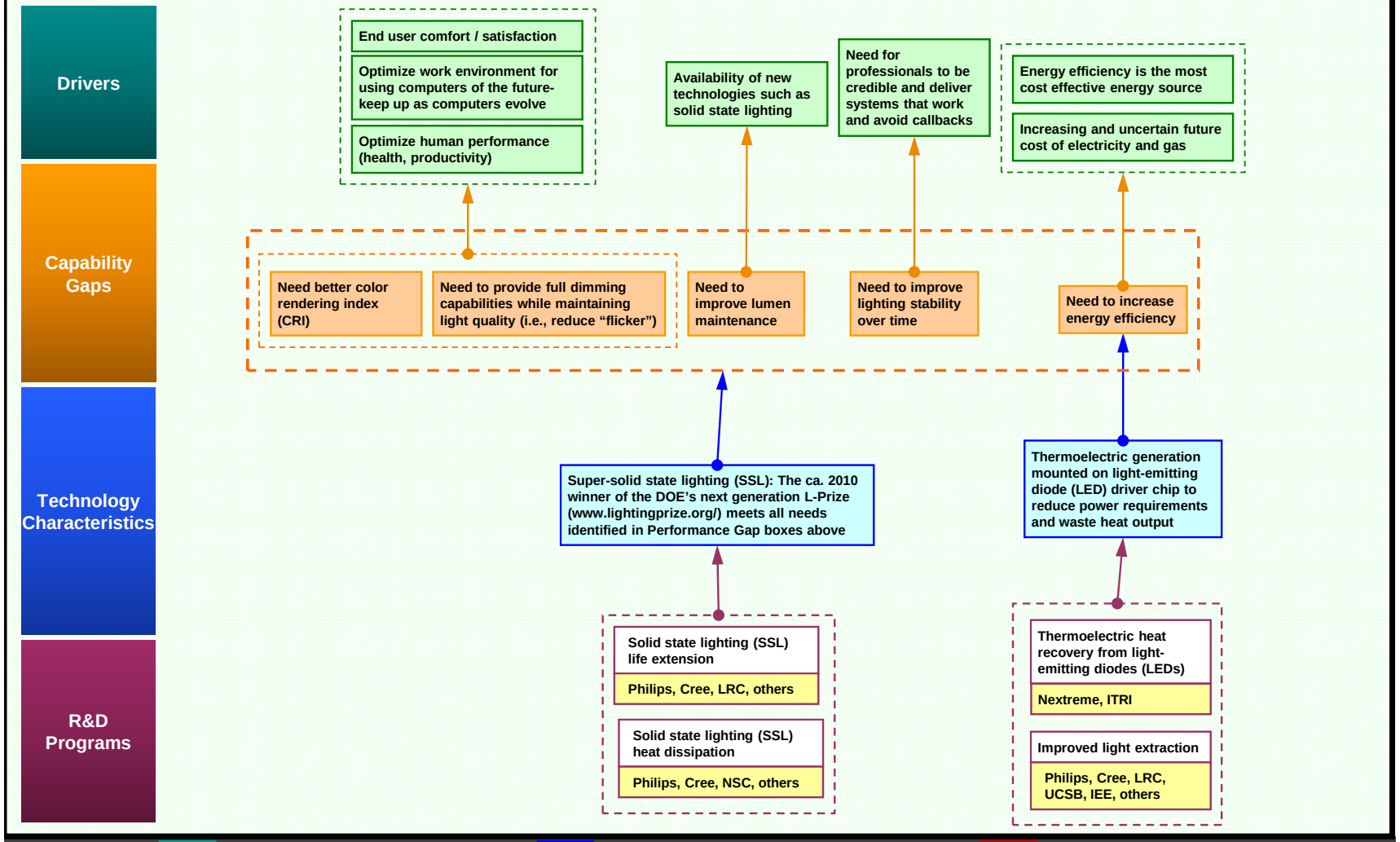
Red light-emitting diode (LED) integrated into compact fluorescent (CFL) for improved color rendering index (CRI): Research the combination of red light-emitting diodes (LEDs) into compact fluorescent lights (CFLs) to raise Color Rendering Index (CRI), making it closer to that of incandescent, which is still the current favorite for residential applications.

Product/Service Area : **LIGHTING**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Solid State Lighting (SSL) (1 of 2)**

Roadmap Definitions on pages ix-xii



R&D Project Summaries

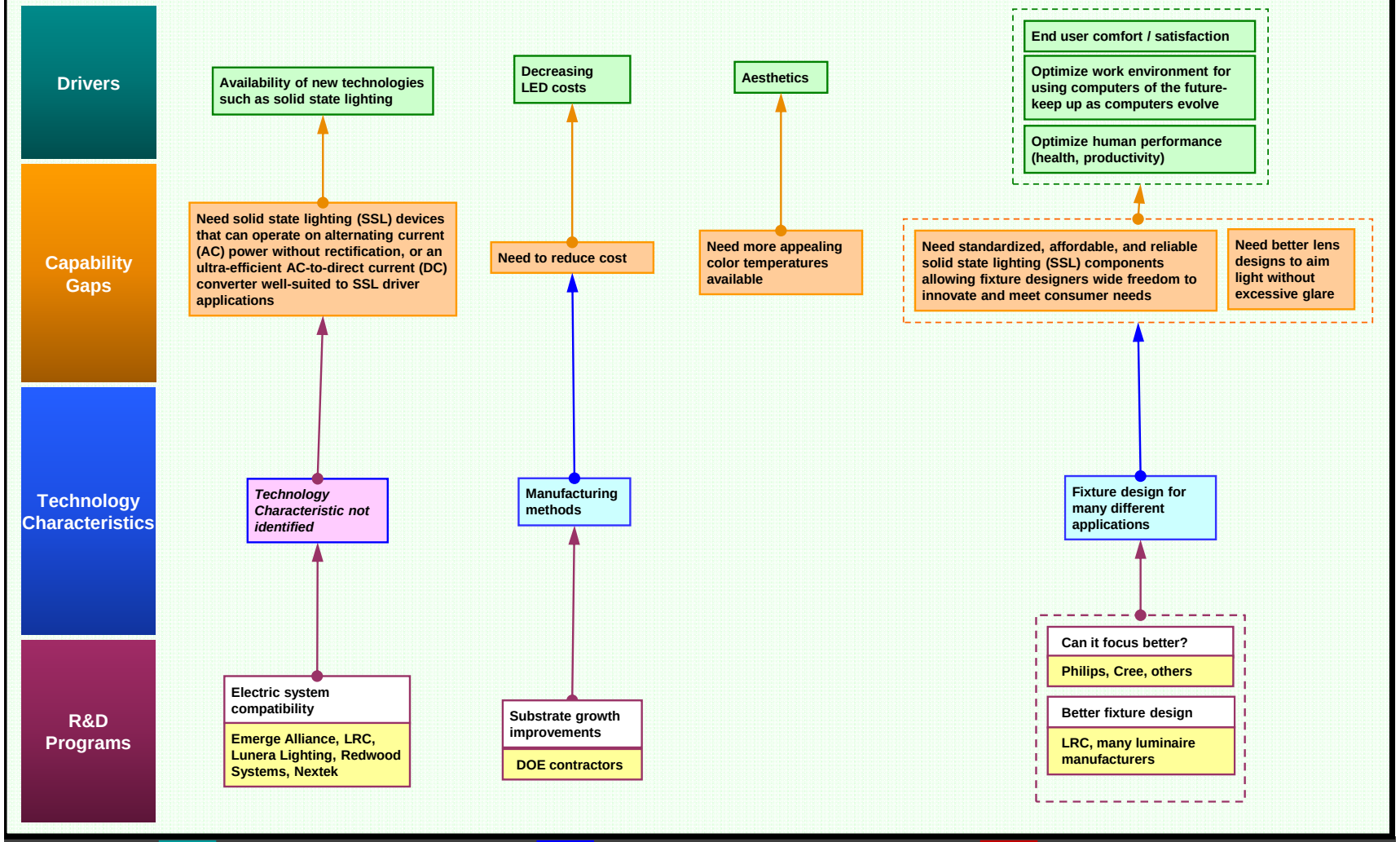
See next Page.

Product/Service Area : **LIGHTING**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Solid State Lighting (SSL) (2 of 2)**

Roadmap Definitions on pages ix-xii



Driver
Capability Gap
Commercially Available Technology
Commercially Unavailable Technology
Existing R&D Program or Project
R&D Program Requirement

R&D Project Summaries

Better fixture design: Designing luminaires that take best advantage of solid state lighting (SSL) characteristics rather than look like traditional fixtures leads to the best performance. Dealing with replacement parts for premature failure is an issue. Lack of interchangeability will hamper the market. Many luminaire manufacturers are researching this issue, as is the Department of Energy (DOE) Office of Energy Efficiency and Renewable Energy (EERE) and the Lighting Research Center (LRC).

- DOE EERE sponsors two design competitions: The "L Prize" to accelerate SSL lighting development to replace incandescent bulbs, and the "Next Generation Luminaires" competition to foster advanced commercial luminaire design and commercialization (for both competitions, see http://www1.eere.energy.gov/buildings/ssl/competitions.html).
- LRC's ongoing research in this area is identified in Appendix B.

Can it focus better?: Designing luminaires that take best advantage of solid state lighting (SSL) characteristics to deliver luminous flux on the task rather attempting to mimic traditional fixtures leads to the best performance. Research is ongoing at the Department of Energy (DOE) Office of Energy Efficiency and Renewable Energy (EERE) as well as Royal Philips Electronics, Cree, Inc., and other manufacturers; ongoing research from private firms tends largely to be proprietary and, therefore, not thoroughly or consistently reported through companies' web pages.

- Cree, Inc.: http://cree.com/.
- Philips Research conducts lighting R&D for Royal Philips Electronics; see http://www.research.philips.com/index.html.
- DOE EERE sponsors two design competitions: The "L Prize" to accelerate SSL lighting development to replace incandescent bulbs, and the "Next Generation Luminaires" competition to foster advanced commercial luminaire design and commercialization (for both competitions, see http://www1.eere.energy.gov/buildings/ssl/competitions.html).

Electric system compatibility: Unlike most other light sources, most light-emitting diode (LED) products require conversion of alternating current (AC) to direct current (DC) power, which introduces system inefficiencies. Multiple parties are researching this issue, including Emerge Alliance and the Lighting Research Center (LRC) and the private firms Lunera Lighting, Inc., Redwood Systems, Inc., and Nextek, Inc.. Ongoing research from private firms tends largely to be proprietary and, therefore, not thoroughly or consistently reported through companies' web pages. (*NOTE: The score in this box reflects the fact that Roadmap drafts prior to the March 2011 identified this research area as an R&D gap.*)

- Emerge Alliance is developing standards for DC power for commercial buildings, which would provide an environment where LEDs could be used directly. See Appendix B.
- LRC is researching electronic walls and ceilings that are compatible with LEDs. See Appendix B for more information.
- In addition to the above, to help educate lighting designers, architects, and engineers on the applications of quickly-evolving LED lighting technologies, the LRC has been conducting bi-annual LED Lighting Institute workshops in Troy, New York. These workshops include hands-on training in system integration, design, and evaluation (http://www.lrc.rpi.edu/programs/solidstate/SSLeducation.asp).

Improved light extraction: Constant development of higher efficacy light-emitting diode (LED) / driver packages is ongoing with the goal of more lumens per watt without sacrificing lamp life. Research is ongoing at the Lighting Research Center (LRC) and the University of Santa Barbara's Institute for Energy Efficiency (IEE) as well as Royal Philips Electronics, Cree, Inc., and other manufacturers; ongoing research from private firms tends largely to be proprietary and, therefore, not thoroughly or consistently reported through companies' web pages.

- Cree, Inc.: http://cree.com/.
- Philips Research conducts lighting R&D for Royal Philips Electronics; see http://www.research.philips.com/index.html.
- LRC's ongoing research in this area is identified in Appendix B.
- IEE's ongoing research in this area can be found in Appendix B.

(continued on following page . . .)

Solid state lighting (SSL) heat dissipation: Excess heat directly affects both short-term and long-term light-emitting diode (LED) performance. The short-term (reversible) effects are color shift and reduced light output, while the long-term effect is accelerated lumen depreciation and thus shortened useful life. Research is ongoing at Royal Philips Electronics, Cree, Inc., and National Semiconductor Corporation (NSC); ongoing research from private firms tends largely to be proprietary and, therefore, not thoroughly or consistently reported through companies' web pages.

- Cree, Inc.: http://cree.com/.
- Philips Research conducts lighting R&D for Royal Philips Electronics; see http://www.research.philips.com/index.html.
- NSC offers a variety of LED thermal management solutions for exterior and interior applications in commercial and residential buildings (http://www.national.com/en/led/tempsensors.html).

Solid state lighting (SSL) life extension: Electrical and thermal design of the light-emitting diode (LED) system or fixture determine how long LEDs will last and how much light they will provide. Driving the LED at higher than rated current will increase relative light output but decrease useful life. Operating the LED at higher than design temperature will also decrease useful life significantly. Research is ongoing at the Lighting Research Center (LRC) as well as Royal Philips Electronics, Cree, Inc., and other manufacturers; ongoing research from private firms tends largely to be proprietary and, therefore, not thoroughly or consistently reported through companies' web pages.

- Cree, Inc.: http://cree.com/.
- The LRC's ongoing research in this area is identified in Appendix B.

Substrate growth improvements: Light-emitting diodes (LEDs) are grown on substrates and there is ongoing research to improve the process for such things as: higher external quantum efficiency performance, better electrostatic discharge durability, simple low-cost fabrication, high product yield with high brightness, and better heat management. The U.S. Department of Energy (DOE) sponsors research in this area at various contractors.

- DOE's ongoing research and development in this area can be found in Appendix B.

Thermoelectronic heat recovery from light-emitting diodes (LEDs): Heat dissipation is essential to good performance of light-emitting diode (LED) lighting. One approach suggested for dissipating the heat is to actually generate electricity from the generated heat using thermoelectric (or thermoelectronic) devices (similar to photovoltaic (PV), but they operate on heat, not light), increasing the effective efficiency of the system. Nextreme Thermal Solutions and the Industrial Technology Research Institute (ITRI) in Taiwan are among the institutions researching this area. (*NOTE: The score in this box reflects the fact that Roadmap drafts prior to the March 2011 identified this research area as an R&D gap.*)

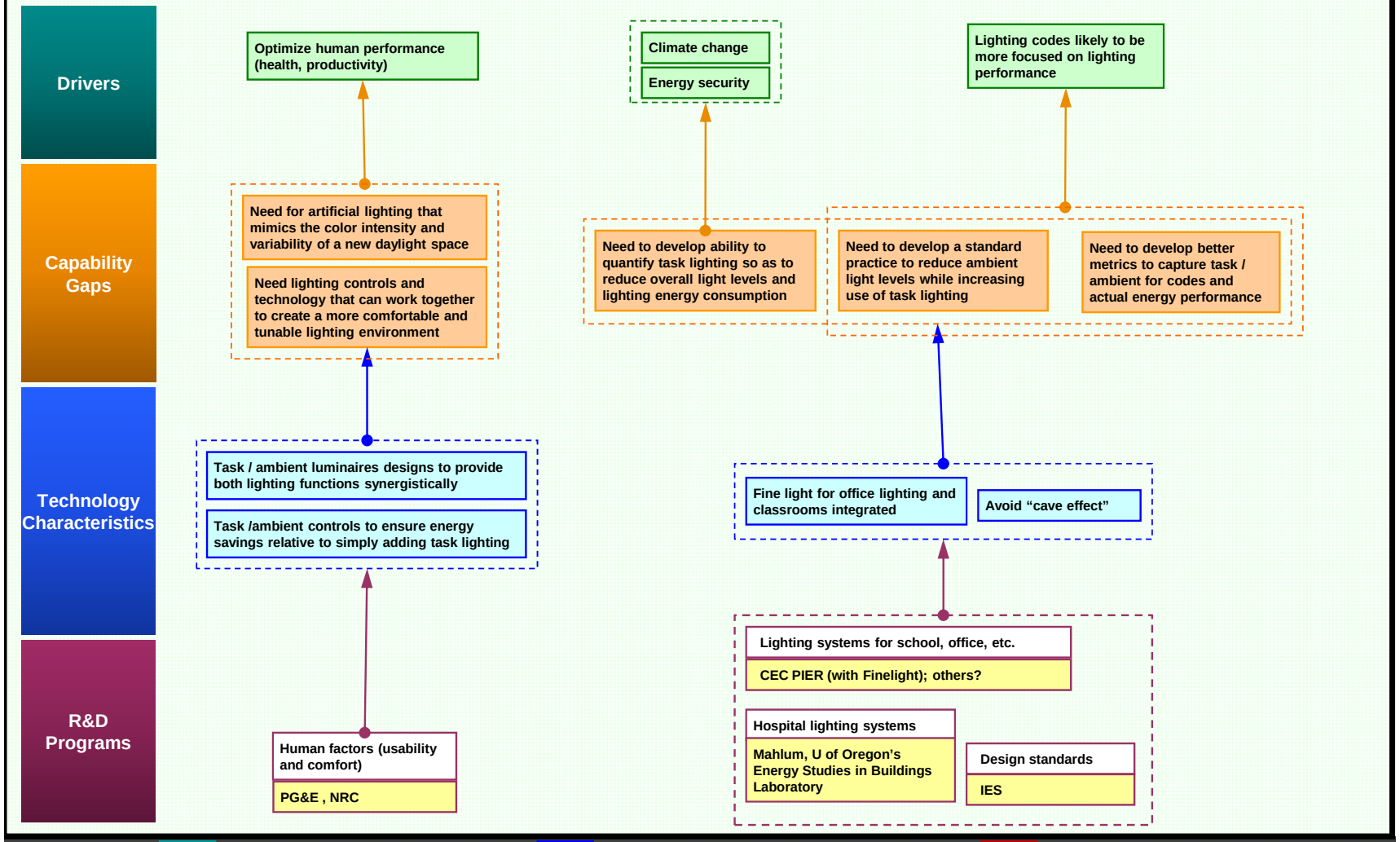
- Nextreme Thermal Solutions has developed a number of technologies to generate power from waste heat. These technologies include their Thermobility™ system that converts heat into electricity for low-power wireless applications (http://www.nextreme.com/pages/power_gen/apps/thermobility.shtml), and thin film thermoelectric materials (http://www.nextreme.com/pages/power_gen/power_gen.shtml).
- ITRI reported in 2005 on a project involving the cooling performance of a silicon-based thermoelectric device on high power LEDs; see Appendix B for more information.

Product/Service Area : **LIGHTING**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Task/Ambient Lighting (SSL) (1 of 2)**

Roadmap Definitions on pages ix-xii



R&D Project Summaries

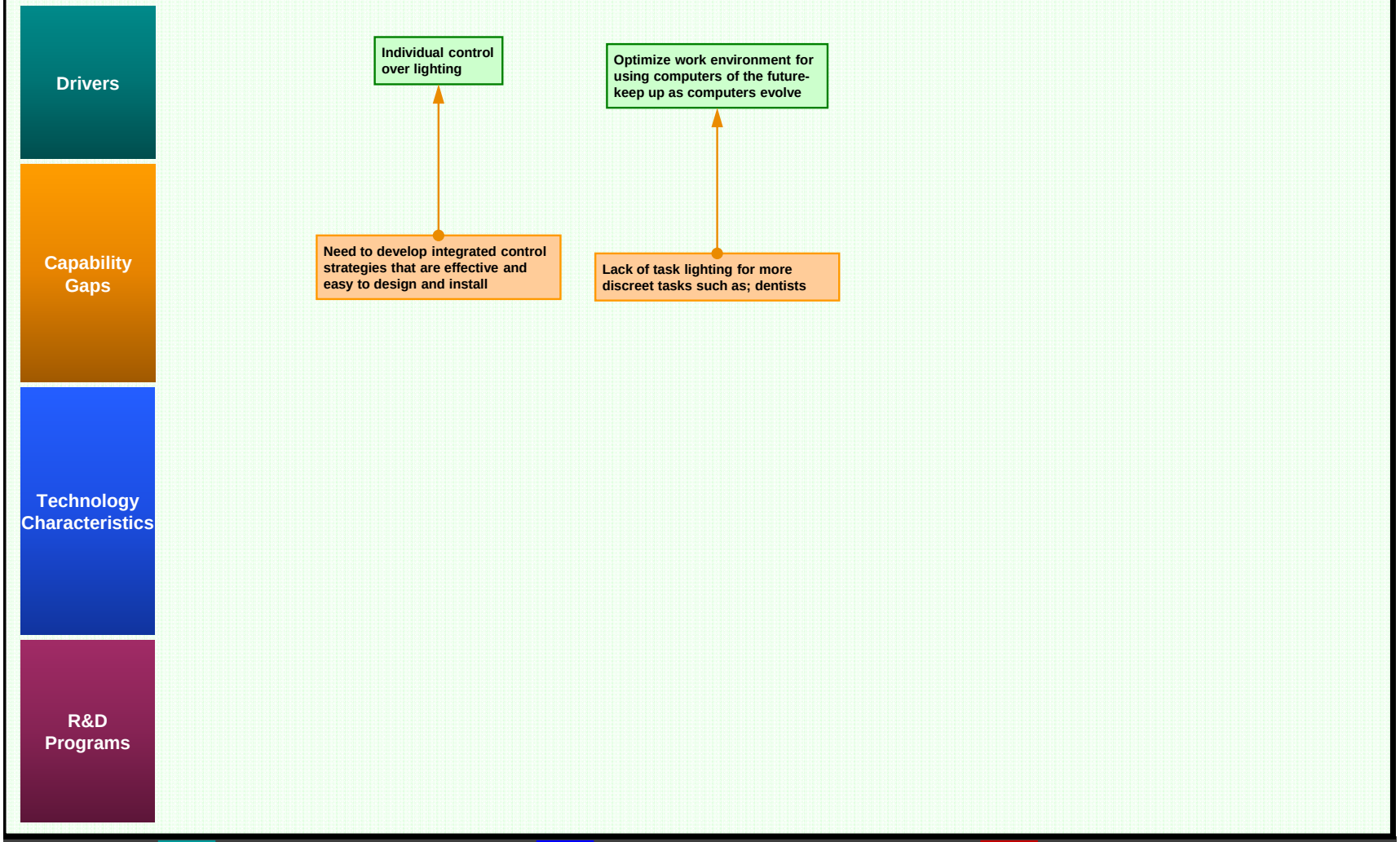
See next Page.

Product/Service Area : **LIGHTING**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Task/Ambient Lighting (2 of 2)**

Roadmap Definitions on pages ix-xii



R&D Project Summaries

Design standards: The Illuminating Engineering Society (IES) is currently developing design for task and ambient lighting applications; apply these standards as they become available.

- IES: http://www.iesna.org/.

Hospital lighting systems: Optimize lighting in hospitals by reducing ambient lighting and instituting effective task lighting. (*NOTE: The score in this box reflects the fact that Roadmap drafts prior to the March 2011 identified this research area as an R&D gap.*)

- Seattle design firm Mahlum (http://www.mahlum.com/) dedicated the inaugural issue of their Healthcare Design Insights periodical in Autumn 2009 to daylighting in hospitals, including providing basic guidelines and brief descriptions of some current research in this area (http://www.mahlum.com/pdf/MahlumHDIAutumn2009Issue01.pdf).
- The University of Oregon's Energy Studies in Buildings Laboratory (http://aaa.uoregon.edu/esbl/) partnered with Zimmer Gunsul Frasca Architects (http://www.zgf.com/) in 2005 on a joint research study, "Daylighting Hospital Patient Rooms" (http://www.betterbricks.com/graphics/assets/documents/Daylighting_Patient_Rooms_brochure_final.pdf).

Human factor (usability and comfort): The elements for broad application are present, but need human factors R&D on design and control approaches to realize the potential. Some work has been done in this area, but there is still much to be explored in this R&D space. Pacific Gas & Electric (PG&E) has done some work in this area. This research could potentially be informed by Professors Joan Roberts of Fordham University and Jennifer Veitch at the National Research Council (NRC) of Canada, who are both working on designing healthy workplaces.

- PG&E in 2009 completed a study of how occupants respond to task-ambient lighting systems (http://www.etcc-ca.com/component/content/article/21/2892-high-efficiency-office-low-ambienttask-lighting-large-office-).
- Professor Veitch, Senior Research Officer of the NRC's Indoor Environment Research Program (http://www.nrc-cnrc.gc.ca/eng/projects/irc/office-lighting.html) reported in late February 2012 that there are some relevant findings from the NRC's work in this area, and details at http://www.nrc-cnrc.gc.ca/eng/programs/irc/ie.html.
- Bonneville Power Administration staff sent query to Professor Roberts (http://www.dsm.fordham.edu/ns/roberts.html) in Feb. 2012, still awaiting reply.

Lighting systems for school, office, etc.: Review research from existing programs that adopt Finelight's Integrated Classroom Lighting System (http://www.finelite.com/about-us/news/icls-integrated-classroom-lighting-system.html) or Personal Lighting System (http://finelite.pinnaclecart.com/), and/or related systems, to maximize lighting effectiveness in offices and reduce the need for over-lighting:

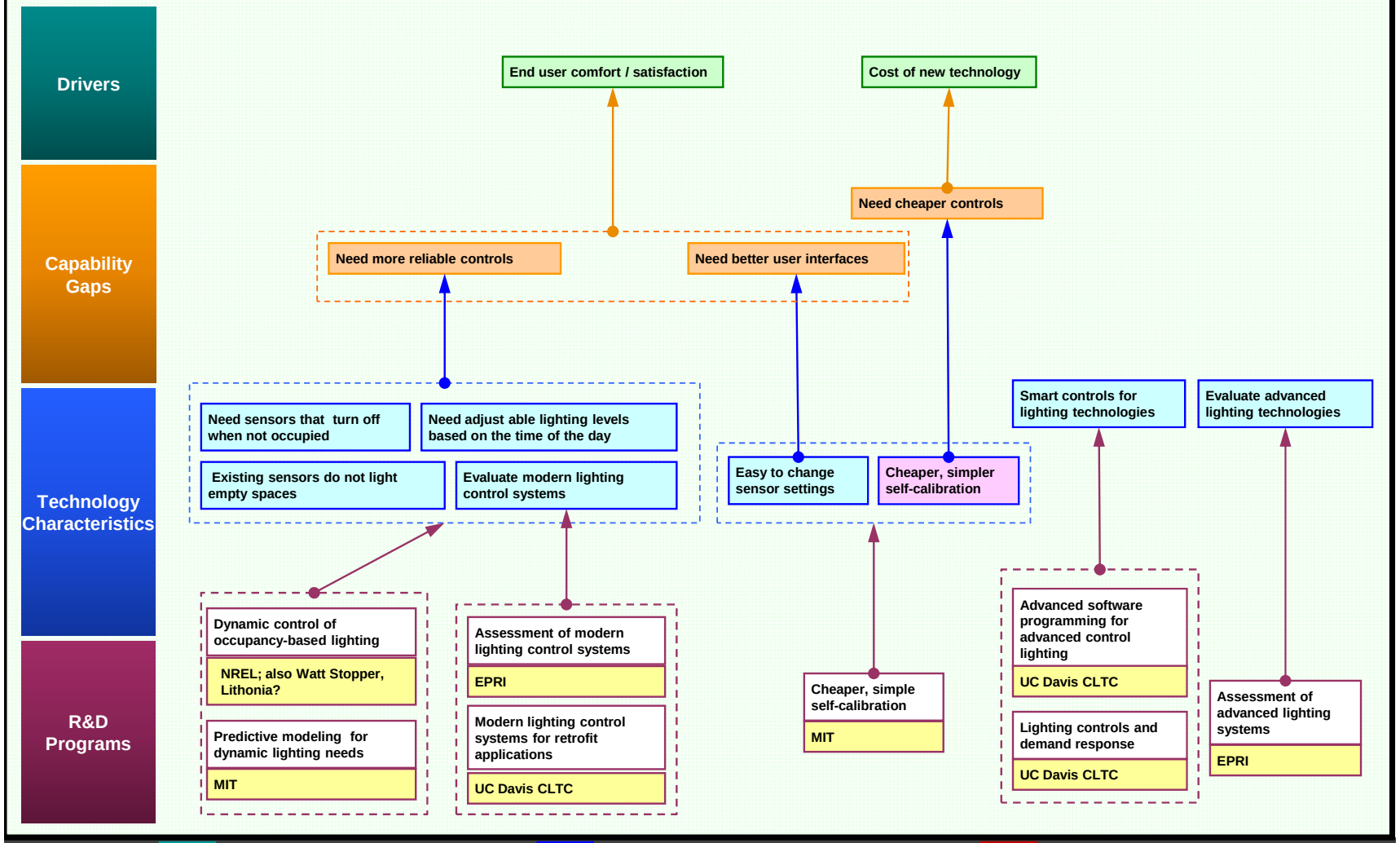
- In May 2007, Finelite, Inc., completed the California Energy Commission (CEC) Public Interest Energy Research (PIER) study "Integrated Classroom Lighting System Final Report (CEC-500-2005-141-A14)" outlining the development and testing of an integrated classroom lighting system (ICLS) for K-12 classrooms (available at http://www.energy.ca.gov/pier/project_reports/CEC-500-2005-141-A14.html).

Product/Service Area : **LIGHTING**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Lighting Controls (1 of 3)**

Roadmap Definitions on pages ix-xii



Driver
Capability Gap
Commercially Available Technology
Commercially Unavailable Technology
Existing R&D Program or Project
R&D Program Requirement

R&D Project Summaries

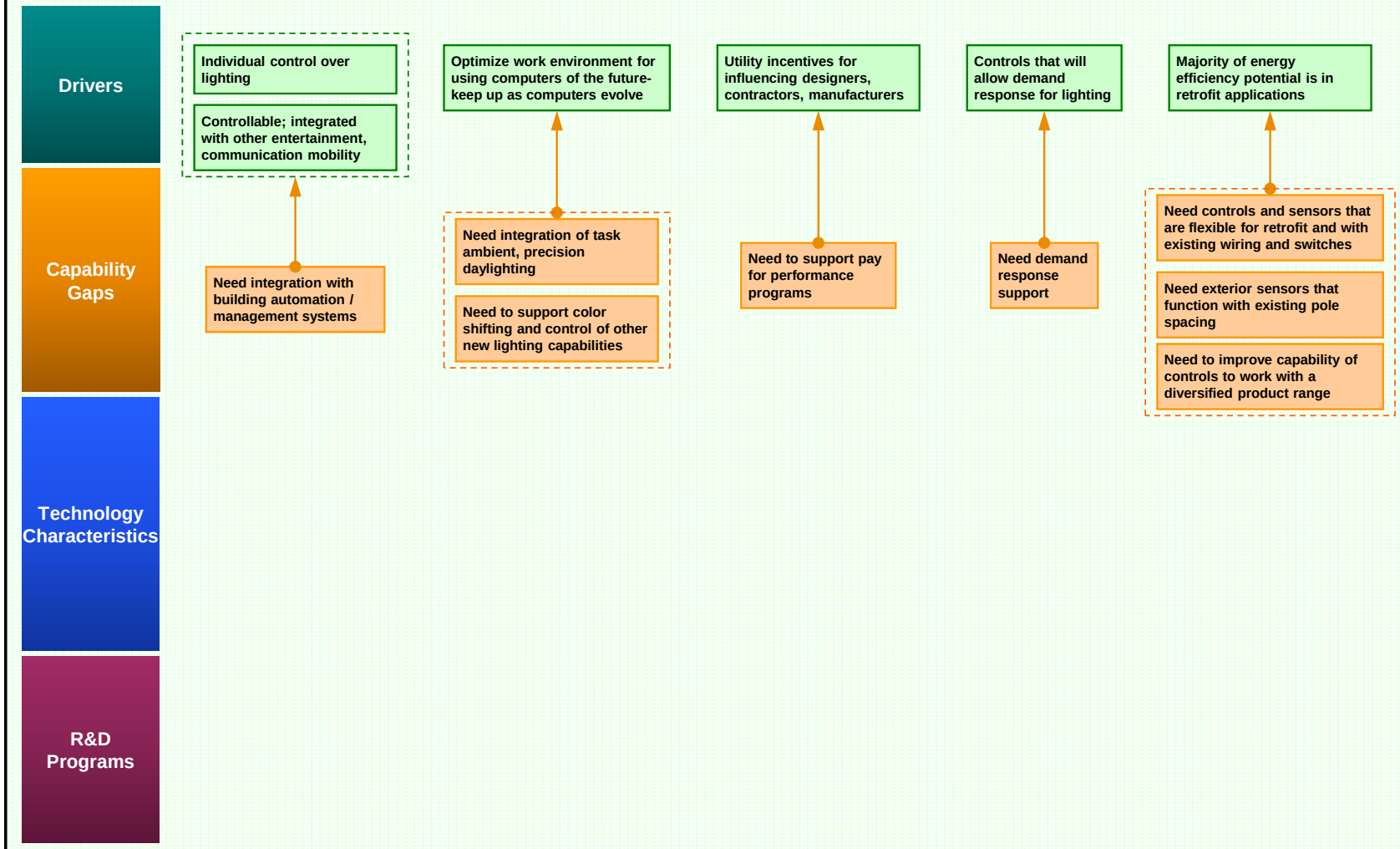
See next Page.

Product/Service Area : **LIGHTING**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Lighting Controls (2 of 3)**

Roadmap Definitions on pages ix-xii



Driver
Capability Gap
Commercially Available Technology
Commercially Unavailable Technology
Existing R&D Program or Project
R&D Program Requirement

R&D Project Summaries

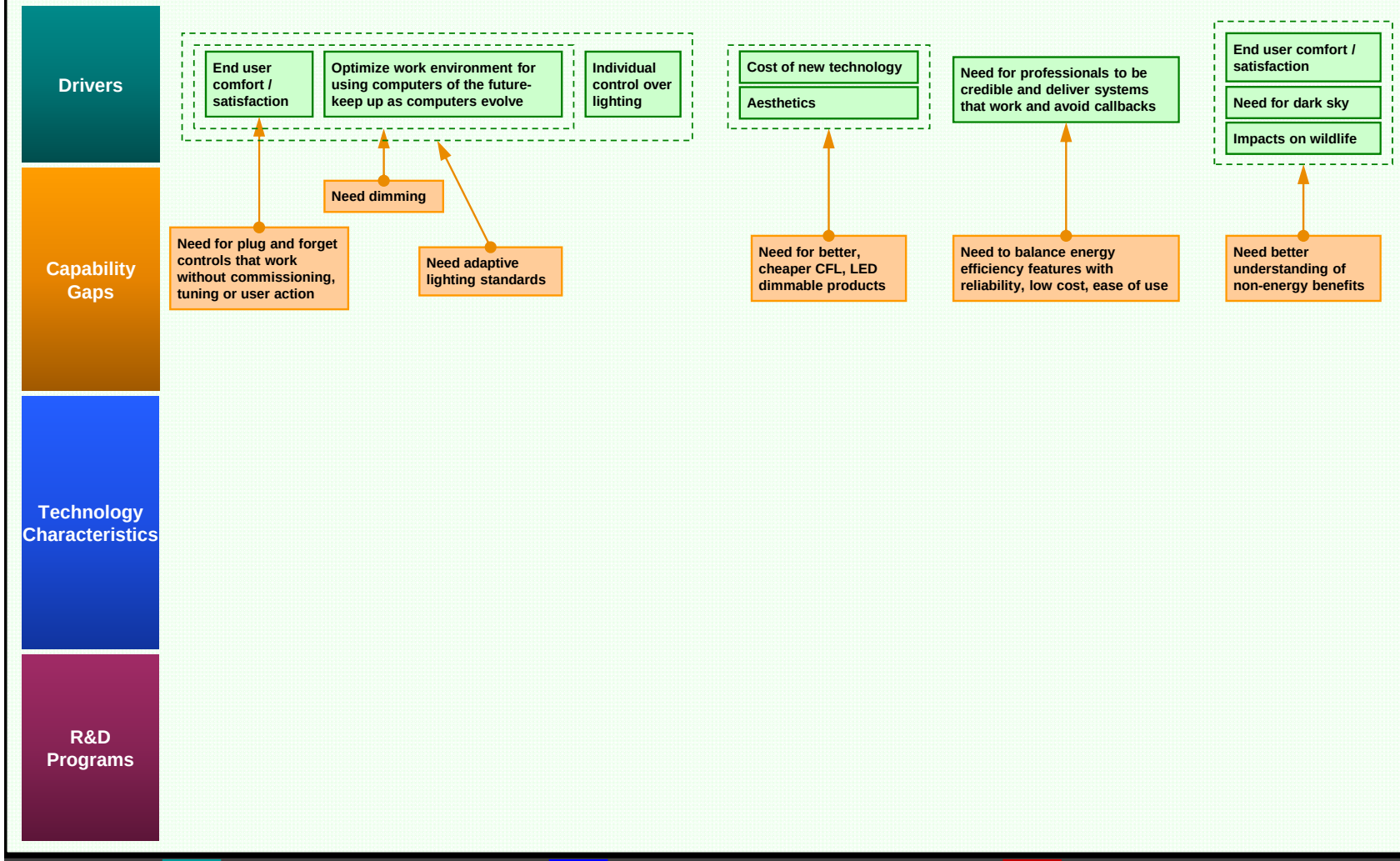
See next Page.

Product/Service Area : **LIGHTING**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Lighting Controls (3 of 3)**

Roadmap Definitions on pages ix-xii



Driver
Capability Gap
Commercially Available Technology
Commercially Unavailable Technology
Existing R&D Program or Project
R&D Program Requirement

R&D Project Summaries

Cheaper, simpler self-calibration: Some controls try to adjust settings according to the habits of the user. Cheaper, simpler, and more effective ways of doing this will be helpful. This will likely take advantage of better predictive modeling. (*NOTE: The score in this box reflects the fact that Roadmap drafts prior to the March 2011 identified this research area as an R&D gap.*)

- The Massachusetts Institute of Technology's (MIT) Media Lab is currently researching feedback controlled solid state lighting, with a specific focus on low-cost solutions that sense and respond to human factors including user context, circadian rhythms, and productivity, and integrating these responses with atypical environmental factors. See Appendix B for more information.
- The National Renewable Energy Laboratory (NREL) is working on a project funded by the BPA Technology Innovation (TI) office to develop an enhanced Image Processing Occupancy Sensor (IPOS) prototype. This is BPA TI Project #247, "Image Processing Occupancy Sensor (IPOS) Prototype Enhancement and Testing"; see Appendix B for more information.

Dynamic control of occupancy-based lighting: Likely using predictive modeling developed from research being done at Massachusetts Institute of Technology's (MIT) Media Lab and possibly other institutions, integrate controls that predict lighting needs dynamically by taking into account the time of day and day of the week for the user will make lighting controls more useful and more acceptable to users. Stakeholders have indicated that R&D in this area may be ongoing at Watt Stopper and/or Lithonia Lighting.

- Bonneville Power Administration staff sent query to Dorene Maniccia of Watt Stopper in Feb. 2012, still awaiting reply; (Maniccia is also Chair of the Lighting Controls Section of the Association of Electrical Equipment and Medical Imaging Manufacturers (NEMA), see http://cltc.ucdavis.edu/content/view/142/164/).
- Lithonia Lighting: http://www.lithonia.com/.

Predictive modeling for dynamic lighting needs: Research on modeling that will better predict lighting needs by taking into account the time of day and day of the week will make lighting controls more useful and more acceptable to users. Researchers at Massachusetts Institute of Technology's (MIT) Media Lab are among those doing work in this area. (*NOTE: The score in this box reflects the fact that Roadmap drafts prior to the March 2011 identified this research area as an R&D gap.*)

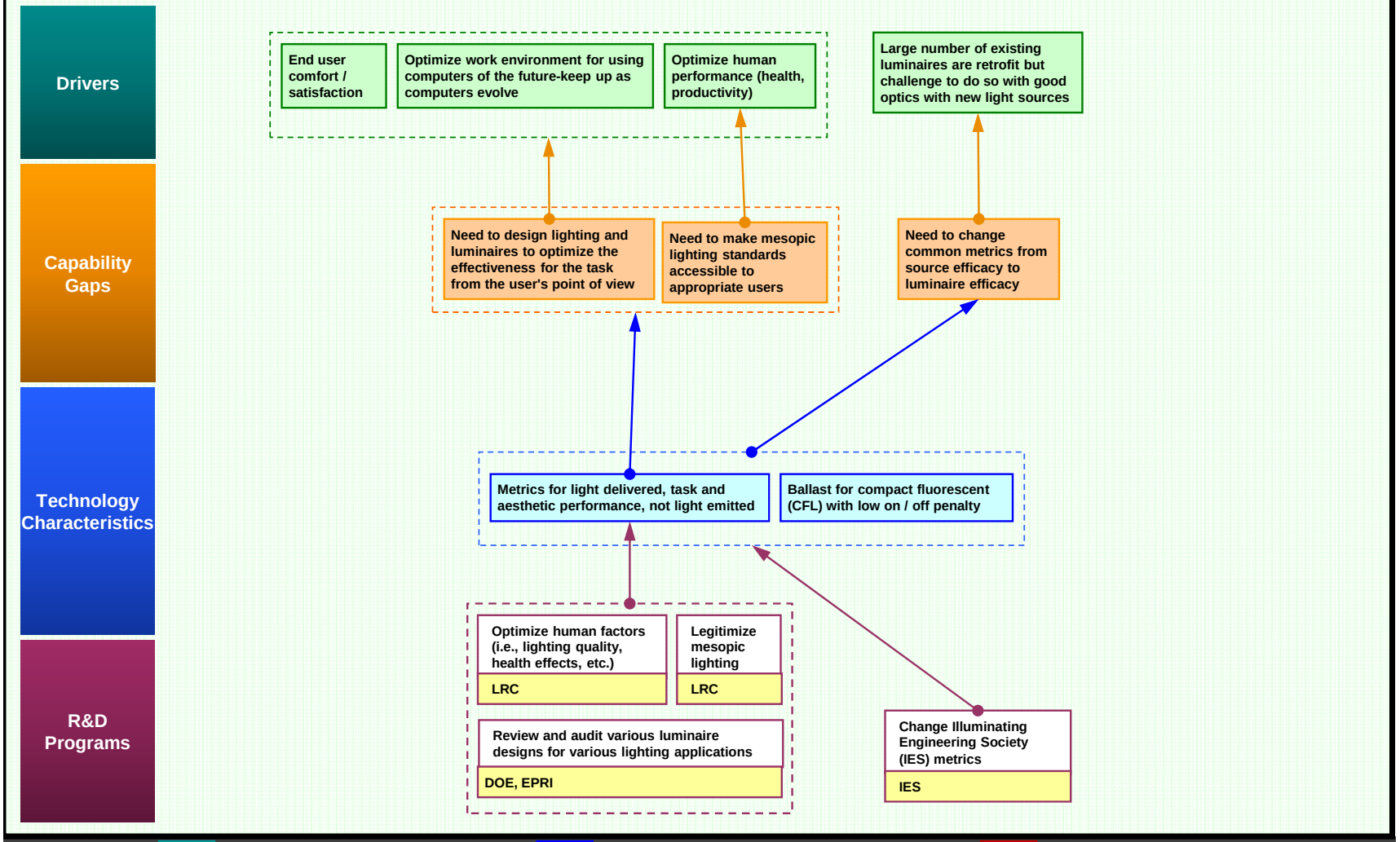
- The MIT Media Lab is currently researching feedback controlled solid state lighting, with a specific focus on low-cost solutions that sense and respond to human factors including user context, circadian rhythms, and productivity, and integrating these responses with atypical environmental factors. See Appendix B for more information.

Product/Service Area : **LIGHTING**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Luminaires (1 of 2)**

Roadmap Definitions on pages ix-xii



R&D Project Summaries

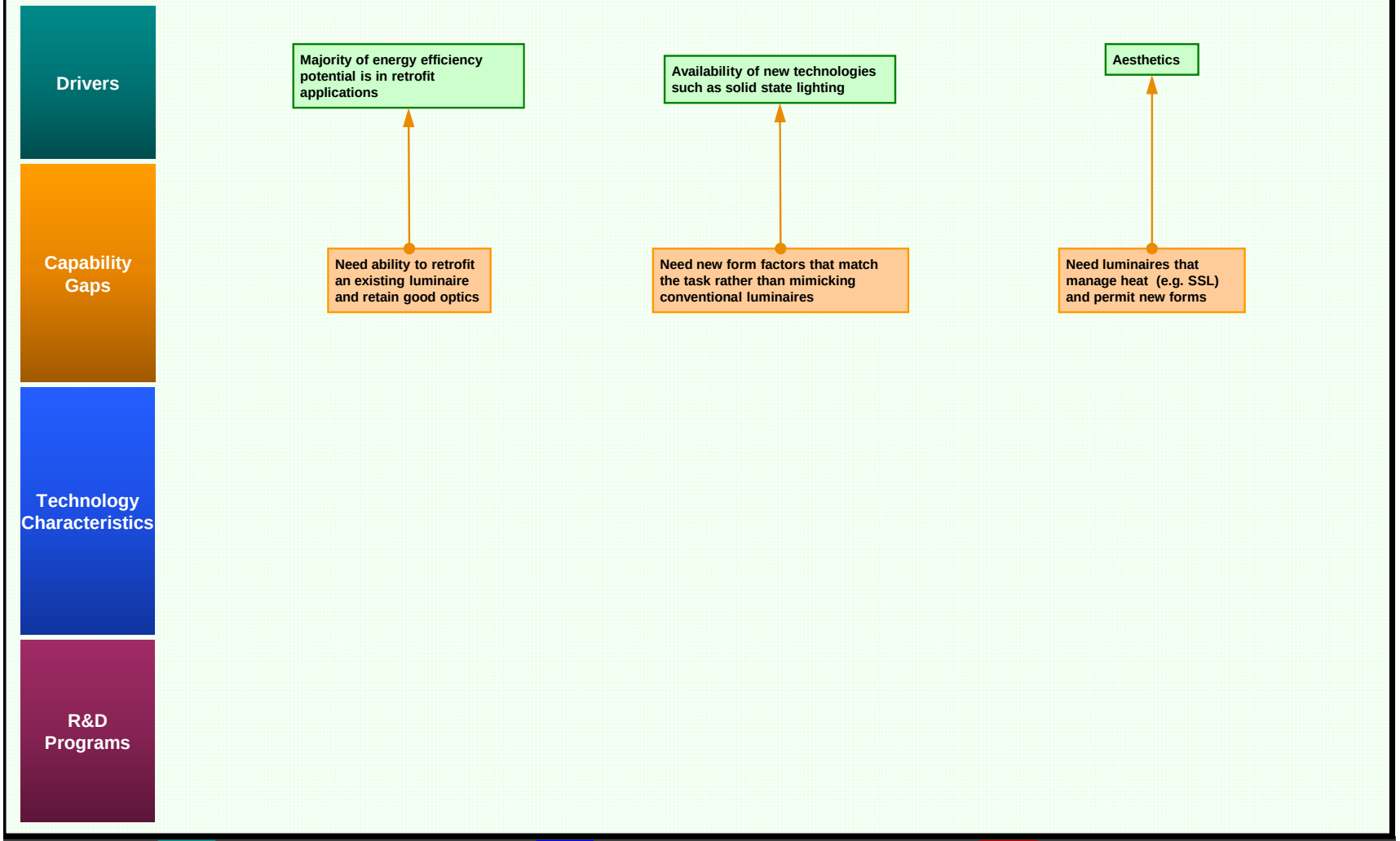
See next Page.

Product/Service Area : **LIGHTING**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Luminaires (2 of 2)**

Roadmap Definitions on pages ix-xii



R&D Project Summaries

Change Illuminating Engineering Society (IES) metrics: Metrics and standards have evolved as we learn more about how humans use light most effectively. More work needs to be done to continue to improve Illuminating Engineering Society (IES) metrics.

- IES: http://www.iesna.org/.

Optimize human factors (i.e., lighting quality, health effects, etc.): Regardless of how efficient lighting is, it's only useful if it actually helps humans. Research on the relevant human factors is important and may apply to luminaires. Rensselaer Polytechnic Institute's Lighting Research Center (LRC) is doing much in this area.

- Appendix B provides an overview of LRC's research in this area. The LRC has upwards of sixty ongoing R&D projects at any given time, and a public list of R&D progress and final reports can be found at http://www.lrc.rpi.edu/resources/newsroom/projectsheets.asp.
- In addition to the projects identified above, the LRC also manages and updates the National Lighting Product Information Program (NLPIP, http://www.lrc.rpi.edu/programs/NLPIP/index.asp). This resource aids contractors, designers, building managers, homeowners, and others in identifying and using correctly the energy-efficient lighting solution that best fits their needs.

Legitimize mesopic lighting: Mesopic lighting, to be fully accepted by the market, needs to have standards changed to legitimize it. Provide data to support IES standards modifications. The Lighting Research Center (LRC) is working in this area.

- An overview of LRC's mesopic lighting research can be found in Appendix B.

Review and audit of various luminaire designs for various lighting applications: The importance of luminaires has often been overlooked in specifications and codes. Need to rate luminaires so better data are available, then educate architects and designers on which luminaires to use for which applications to improve efficiency and effective lighting. The U.S. Department of Energy (DOE) has done work in this area.

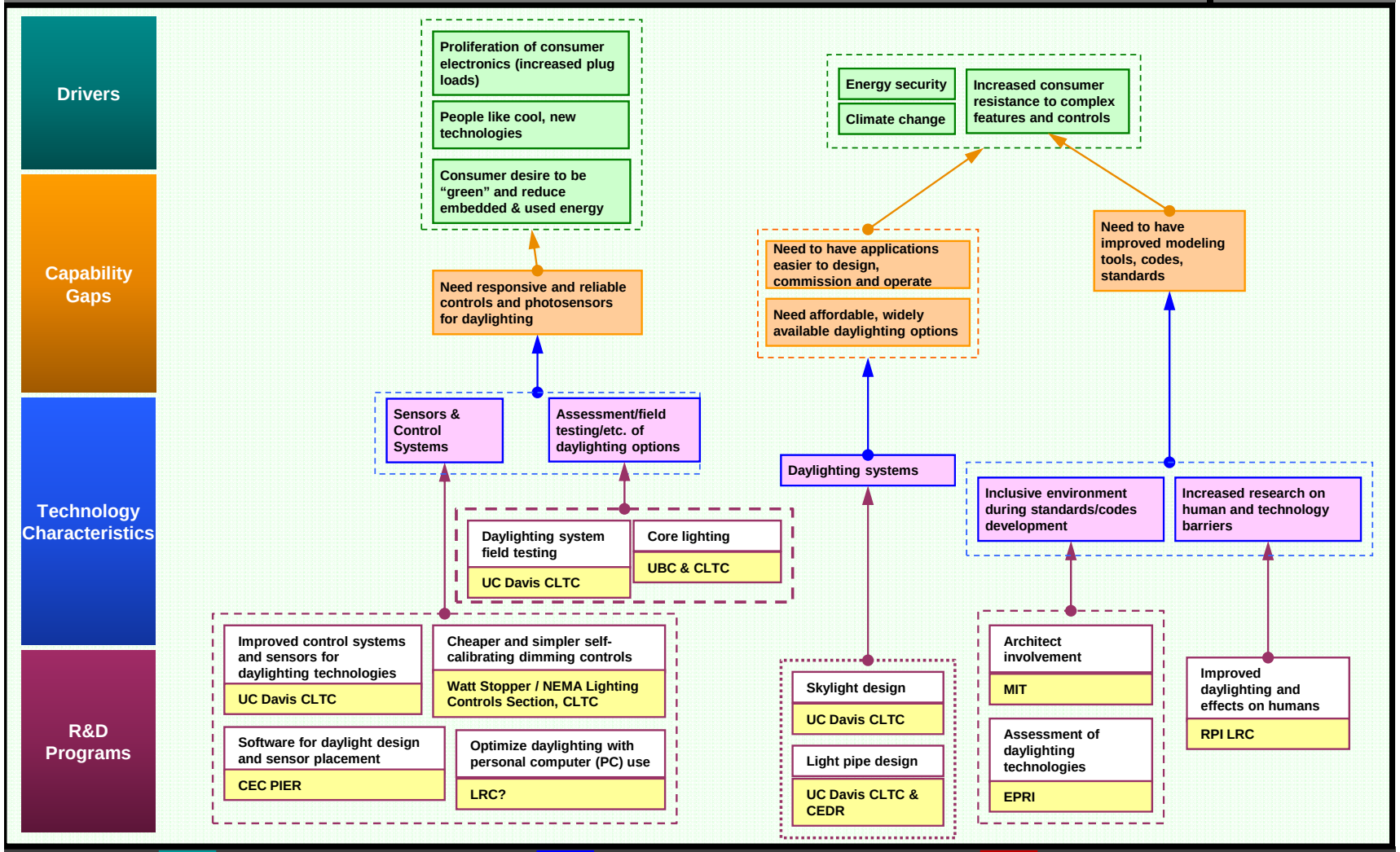
- The DOE's Commercial Lighting Solutions provides tools in this area (https://www.lightingsolutions.energy.gov/comlighting/login.htm).

Product/Service Area : **LIGHTING**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Daylighting (1 of 2)**

Roadmap Definitions on pages ix-xii



R&D Project Summaries

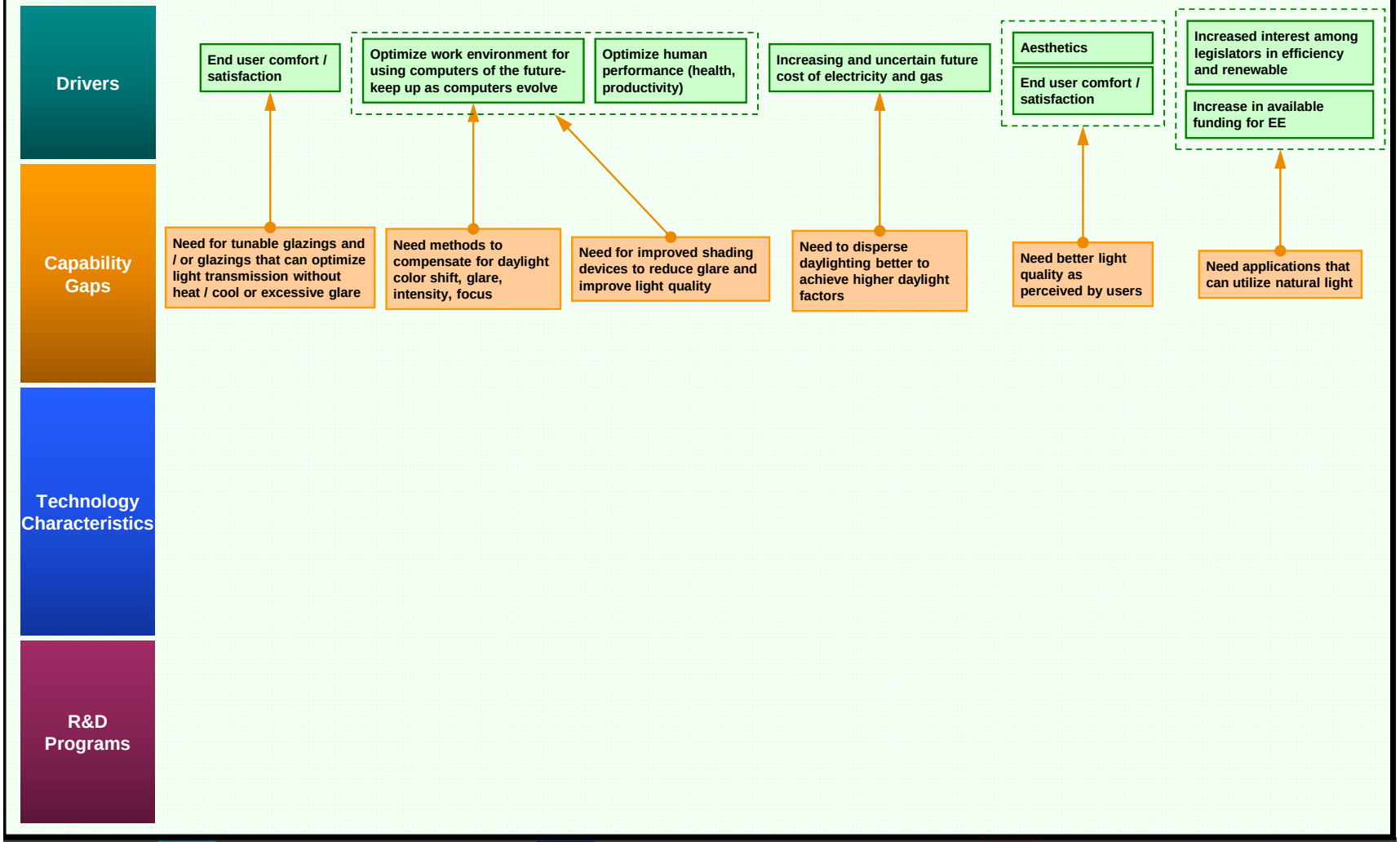
See next Page.

Product/Service Area : **LIGHTING**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Daylighting (2 of 2)**

Roadmap Definitions on pages ix-xii



R&D Project Summaries

Cheaper and simpler self-calibrating dimming controls: Making daylighting cost-effective continues to be a challenge. Cheaper, easier to use, and self-calibrating controls can help to make daylighting more attractive. Stakeholders indicated that research was ongoing at the Lighting Research Center (LRC), and possibly at Watt Stopper and under the aegis of the Lighting Controls Section of the Association of Electrical Equipment and Medical Imaging Manufacturers (NEMA); R&D is also ongoing at the California Lighting Technology Center (CLTC). (*NOTE: The score in this box reflects the fact that Roadmap drafts prior to the March 2011 identified this research area as an R&D gap.*)

- Dorene Maniccia of Watt Stopper (and chair of the NEMA Lighting Controls Section) is researching dual-loop daylight control systems that self commission and offer continual calibration (http://cltc.ucdavis.edu/content/view/142/164/). Bonneville Power Administration staff sent query to Ms. Maniccia in Feb. 2012, still awaiting reply.
- The Lighting Research Center's (LRC) Capturing the Daylight Dividend program has completed R&D on daylighting systems and controls, and has also worked on a number of case studies. (http://www.lrc.rpi.edu/researchAreas/daylighting.asp).
- Information about CLTC research in this area can be found in Appendix B.

Core lighting: Daylighting has traditionally concentrated on perimeter zones (near windows). There is an ongoing research partnership between the University of British Columbia (UBC) and the California Lighting Technology Center (CLTC) to provide daylighting in core zones, but more research is needed to find more affordable and effective ways of doing this.

- The CLTC is currently working on an R&D project to evaluate the application of UBC's Core Sunlighting System to the climate and topography of California's Central Valley. See Appendix B for more information on this effort.

Optimize daylighting with personal computer (PC) use: Research on how to effectively use personal computers to monitor and control daylighting. Stakeholders have indicated that Rensselaer Polytechnic Institute's Lighting Research Center (LRC) is working in this area.

- Appendix B provides an overview of research at LRC, which has upwards of sixty ongoing R&D projects at any given time. A public list of R&D progress and final reports can be found at http://www.lrc.rpi.edu/resources/newsroom/projectsheets.asp, and some additional information about LRC's research can be found in Appendix B.

Overcome human and technology barriers: Investigate both human factors and technical barriers to adopting daylighting. Stakeholders have indicated that Rensselaer Polytechnic Institute's Lighting Research Center (LRC) is working in this area.

- Appendix B provides an overview of research at LRC, which has upwards of sixty ongoing R&D projects at any given time. A public list of R&D progress and final reports can be found at http://www.lrc.rpi.edu/resources/newsroom/projectsheets.asp, and some additional information about LRC's research can be found in Appendix B.
- In addition to the projects identified above, the LRC also manages and updates the National Lighting Product Information Program (NLPIP, http://www.lrc.rpi.edu/programs/NLPIP/index.asp). This resource aids contractors, designers, building managers, homeowners, and others in identifying and using correctly the energy-efficient lighting solution that best fits their needs.

Skylight design: Making daylighting cost-effective continues to be a challenge. Effective, affordable, leak-resistant skylight design could help make daylighting easier and more affordable to adopt. The California Lighting Technology Center (CLTC) is engaged in ongoing R&D in this area, and California Energy Design Resources (CEDR) website provides a list of skylight and daylighting resources. (*NOTE: The score in this box reflects the fact that Roadmap drafts prior to the March 2011 identified this research area as an R&D gap.*)

- Information about CLTC's ongoing research into sunlighting and solatube skylight systems can be found in Appendix B.
- California's utility ratepayers fund the state's EDR program; Southern California Edison administers the program under the auspices of the California Public Utilities Commission (CPUC). The EDR website serves as a portal for architects, engineers, lighting designers, and developers to access energy design tools and resources that will foster energy-efficient commercial and industrial building design. EDR resources include daylighting and sky light design (http://www.energydesignresources.com/technology/daylighting-design.aspx, http://www.energydesignresources.com/resources/publications/design-briefs/design-brief-skylights-with-suspended-ceilings.aspx).

Software for daylight design and sensor placement: Develop good, affordable software for designing daylighting systems, including determining optimum placement of sensors. Stakeholders have indicated that there is ongoing research in this area at the California Energy Commission's (CEC) Public Interest Energy Research (PIER) program.

- Some PIER research in this general area can be found in Appendix B; as of Feb. 2012, Bonneville Power Administration staff has queried PIER researchers for more specific information.

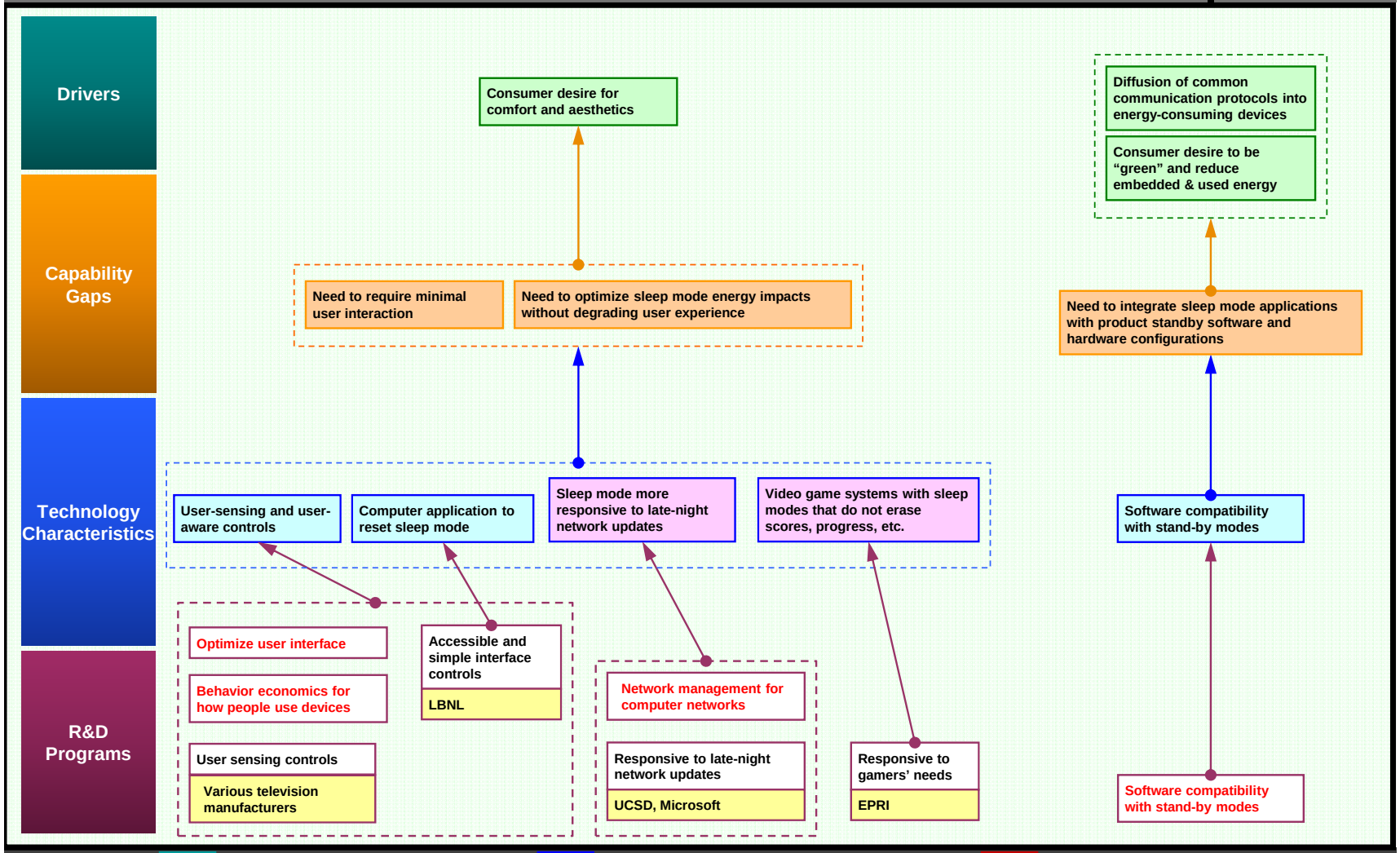
Electronics Roadmaps

Product/Service Area : **ELECTRONICS**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Sleep Mode**

Roadmap Definitions on pages ix-xii



R&D Project Summaries

Accessible and simple interface controls: To facilitate widespread adoption of sleep mode technology, develop controls that are as simple or accessible as possible. If they're complicated or a hassle, they won't get used. (*NOTE: The score in this box reflects the fact that Roadmap drafts prior to the March 2011 identified this research area as an R&D gap.*)

- In December 2004, the Lawrence Berkeley National Laboratory (LBNL) developed Institute of Electrical and Electronics Engineers (IEEE) Standard #1621, "Standard for User Interface Elements in Power Control of Electronic Devices Employed in Office/Consumer Environments." The purpose of the standard is "to accomplish a similarity of experience of power controls across all electronic devices so that users will find them easier to use and be more likely to utilize power management features that save energy" (http://eetd.lbl.gov/Controls/1621/).

Responsive to gamers' needs: Video games with sleep mode are losing scores. The Electric Power Research Institute (EPRI) completed a preliminary study of this in 2010 and is currently doing some work in this area. (*NOTE: The score in this box reflects the fact that Roadmap drafts prior to the March 2011 identified this research area as an R&D gap.*)

- In 2010, EPRI completed a preliminary study on the power consumption of various gaming consoles. The deliverable for this study was a press release, but ongoing related work in this and other areas of electronics components and systems is part of EPRI's End Use Energy Efficiency and Demand Response research (Program 170) and can be found in Appendix B.

Responsive to late-night network updates: Sleep mode must become more responsive to late-night network administrative updates. Researchers at U.C. San Diego (UCSD) and at Microsoft are working in this area. (*NOTE: The score in this box reflects the fact that Roadmap drafts prior to the March 2011 identified this research area as an R&D gap.*)

- Researchers at UCSD developed their "SleepServer" software in 2009 to reduce personal computer energy consumption within enterprise environments by hosting a light-weight image of each PC on the server that can allow the individual PCs to remain in sleep mode longer, but still remain accessible for waking. This product is currently being refined for wider applicability and commercialization. More information about this project in Appendix B.
- Microsoft's "sleep proxy" allows PCs to remain in sleep mode, on average, about 50% more of the time without sacrificing employee or IT accessibility. More information about this project in Appendix B.

Behavior economics for how people use devices: To facilitate widespread adoption of sleep-mode technology, study the way the most common user groups interact with electronic devices so the sleep-mode technology will be compatible with their behavior.

Network management for computer networks: To facilitate widespread adoption of sleep mode technology, it's not enough that it works well with end users. Sleep mode also needs to meet the needs of network administrators; otherwise, they will not support (or will even disallow) its use.

Optimize user interface: Facilitate widespread adoption of sleep mode technology by developing optimized, intuitive, and tailored user interface and control capabilities.

- As with the "accessible and simple interface controls" R&D project within this Roadmap, the Lawrence Berkeley National Laboratory (LBNL) has developed the Institute of Electrical and Electronics Engineers (IEEE) Standard #1621, "Standard for User Interface Elements in Power Control of Electronic Devices Employed in Office/Consumer Environments" (http://eetd.lbl.gov/Controls/1621/). There is still much research needed in this area.

User sensing controls: Stakeholders indicate that research in this area is underway at a variety of television manufacturers, but this R&D is not accessible for collaboration. To facilitate widespread adoption of sleep mode technology, study the way the most common user groups use electronic devices so the sleep mode technology will be compatible with their behavior and not cause user inconveniences.

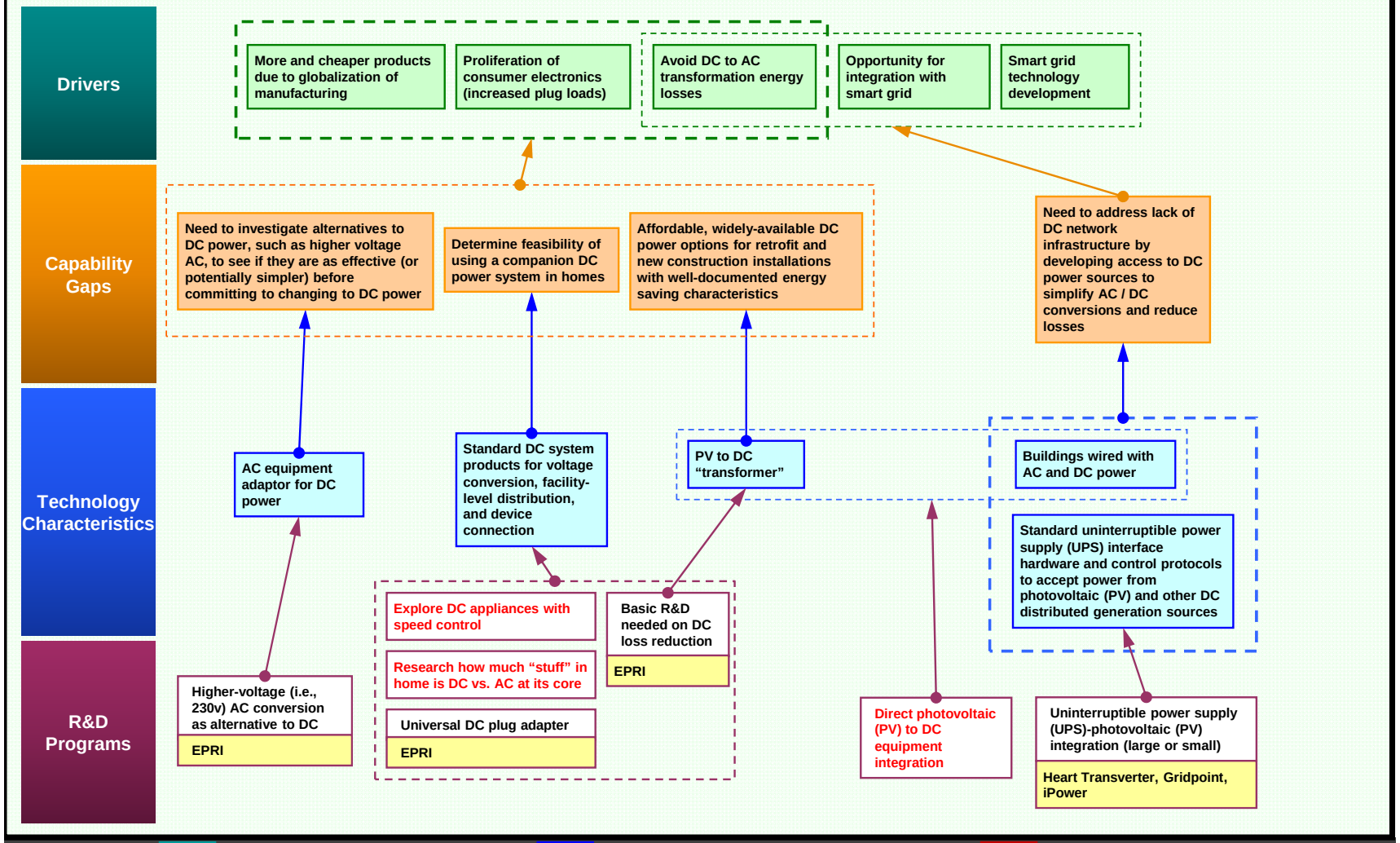
Software compatibility with stand-by modes: To facilitate widespread adoption of sleep mode technology, it is essential that the technology serves the needs of end users and network administrators and is also compatible with all commonly used software applications and video games. According to E Source, ongoing work in this area seems to be primarily occurring within the software and hardware developers (e.g. Microsoft, Dell, etc.); open demonstrations of research are unknown at this time.

Product/Service Area : **ELECTRONICS**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Direct Current (DC) Power Source (1 of 2)**

Roadmap Definitions on pages ix-xii



R&D Project Summaries

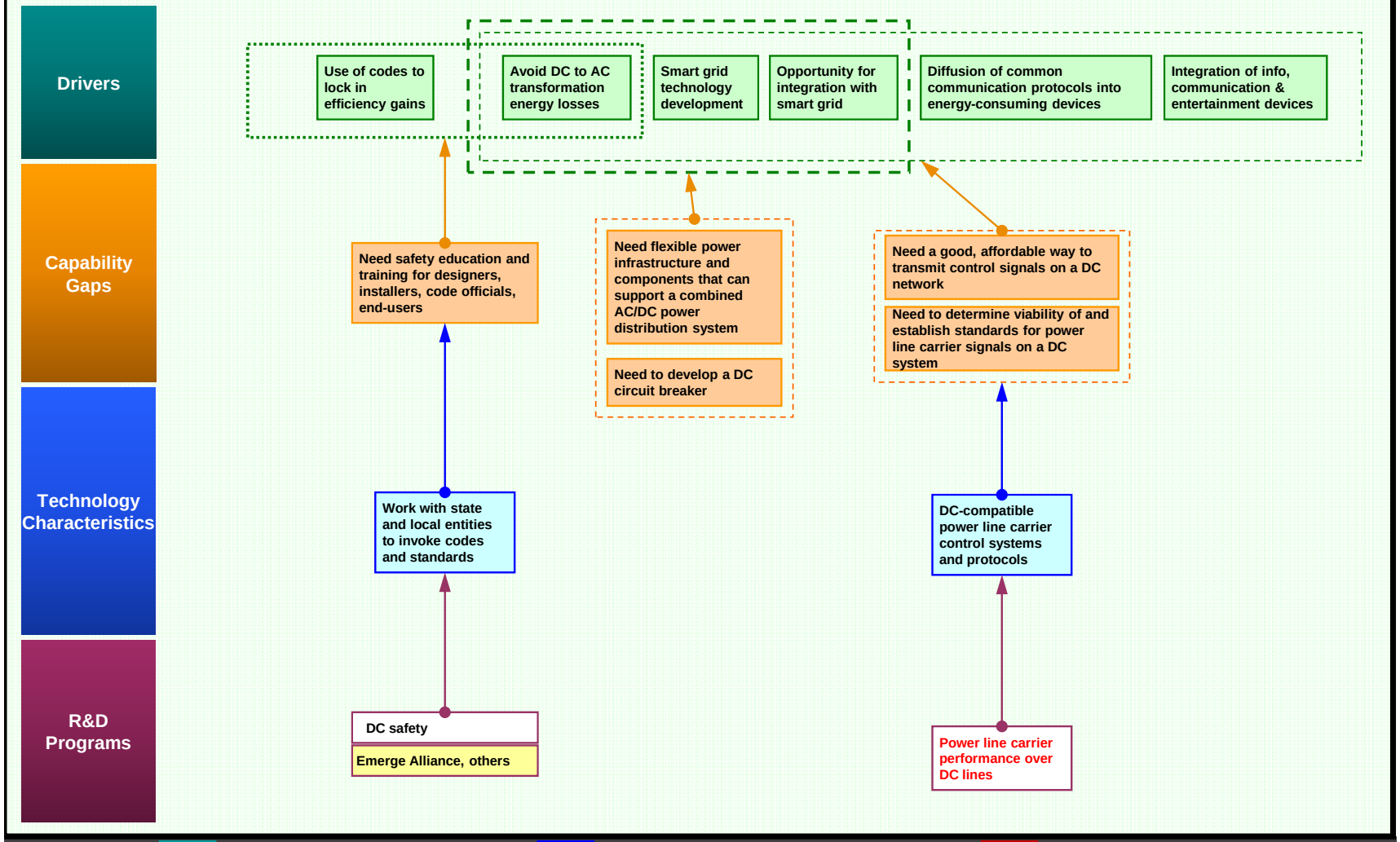
See next Page.

Product/Service Area : **ELECTRONICS**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Direct Current (DC) Power Source (2 of 2)**

Roadmap Definitions on pages ix-xii



R&D Project Summaries

Universal DC plug adapter: One of the issues with converting to direct current (DC) is that it is totally non-standard. The development of a universal plug for DC will greatly aid adoption.

- The Electric Power Research Institute (EPRI) is conducting research in this area, see Appendix B for more information.

Basic R&D needed on DC loss reduction: The concept of using direct current (DC) power supply in a data center makes intuitive sense, but it is not well tested, especially in comparison to other approaches such as using higher alternating current (AC) supply voltage (230V.). Basic proof-of-concept and maybe some small trials are needed before expanding further. (*NOTE: The score in this box reflects the fact that Roadmap drafts prior to the March 2011 identified this research area as an R&D gap.*)

- The Electric Power Research Institute (EPRI) is assessing efficiency and loss-reduction potential for distribution technologies in general, including for DC power. See Appendix B for more information.

DC Safety: Direct current (DC) acts very differently from alternating current (AC), so we need a whole new set of safety standards, education, and training so that people understand and implement DC safely. Emerge Alliance and the Electric Power Research Institute (EPRI) are working to develop DC power standards for commercial buildings that address safety concerns. (*NOTE: The score in this box reflects the fact that Roadmap drafts prior to the March 2011 identified this research area as an R&D gap.*)

- For EPRI's and Emerge Alliance's work in this area, see Appendix B.

Higher voltage conversion AC as an alternative to DC (230v): As an alternative to converting data centers to direct current (DC), some researchers have suggested that we could save more energy by simply converting data centers to 230V. The change would be simple and would require no equipment changes, since computer equipment is typically provided with a 115V/230V switch. Evaluate this thoroughly before committing to DC data centers.

- The Electric Power Research Institute (EPRI) is conducting research in this area, see Appendix B for more information.

UPS-PV integration (large or small): One of the things that could change with providing direct current (DC) to data centers is the uninterruptible power system (UPS). It is likely that many data centers will convert to DC UPS. Solar photovoltaic (PV) systems, too, may supply DC directly rather than converting to alternating current (AC) and back again. Research is needed to determine how most effectively to do this. Heart Transverter, Gridpoint , and iPower are working in this area. (*NOTE: The score in this box reflects the fact that Roadmap drafts prior to the March 2011 identified this research area as an R&D gap.*)

- Heart Transverter developed a 2 kW power management device and control hardware for integrating PV, electric vehicles, battery banks, and some other combinations of AC or DC within its power range. See Appendix B for more information.
- Gridpoint seems to have designed a product that is specifically meant to integrate with PV. See Appendix B for more information.
- iPower's offering promises to tailor its UPS to specific distributed generation systems for an added cost. See Appendix B for more information.

Direct photovoltaic (PV) to DC equipment integration: Solar photovoltaic (PV) systems may supply direct current (DC) directly rather than converting to alternating current (AC) and back again. This will be most effective if the voltage of the PV system is matched with the most common voltage needed by the DC equipment. Research is needed to determine how to do this most effectively.

Explore DC appliances with speed control: Since variable speed is easy to do with direct current (DC) motors, having DC in the building may allow the possibility of using many more DC motors for variable-speed applications. The economic advantages are greatest when there is a large number of DC motors or DC electronic loads that can all operate, or be easily adapted to operate, on the same DC voltage.

Power line carrier performance over DC lines: Power line carrier solutions for controls are attractive. Do some basic research to see if this is viable on direct current (DC) systems; would likely need to avoid jumping alternating current (AC)-DC or DC-AC converters.

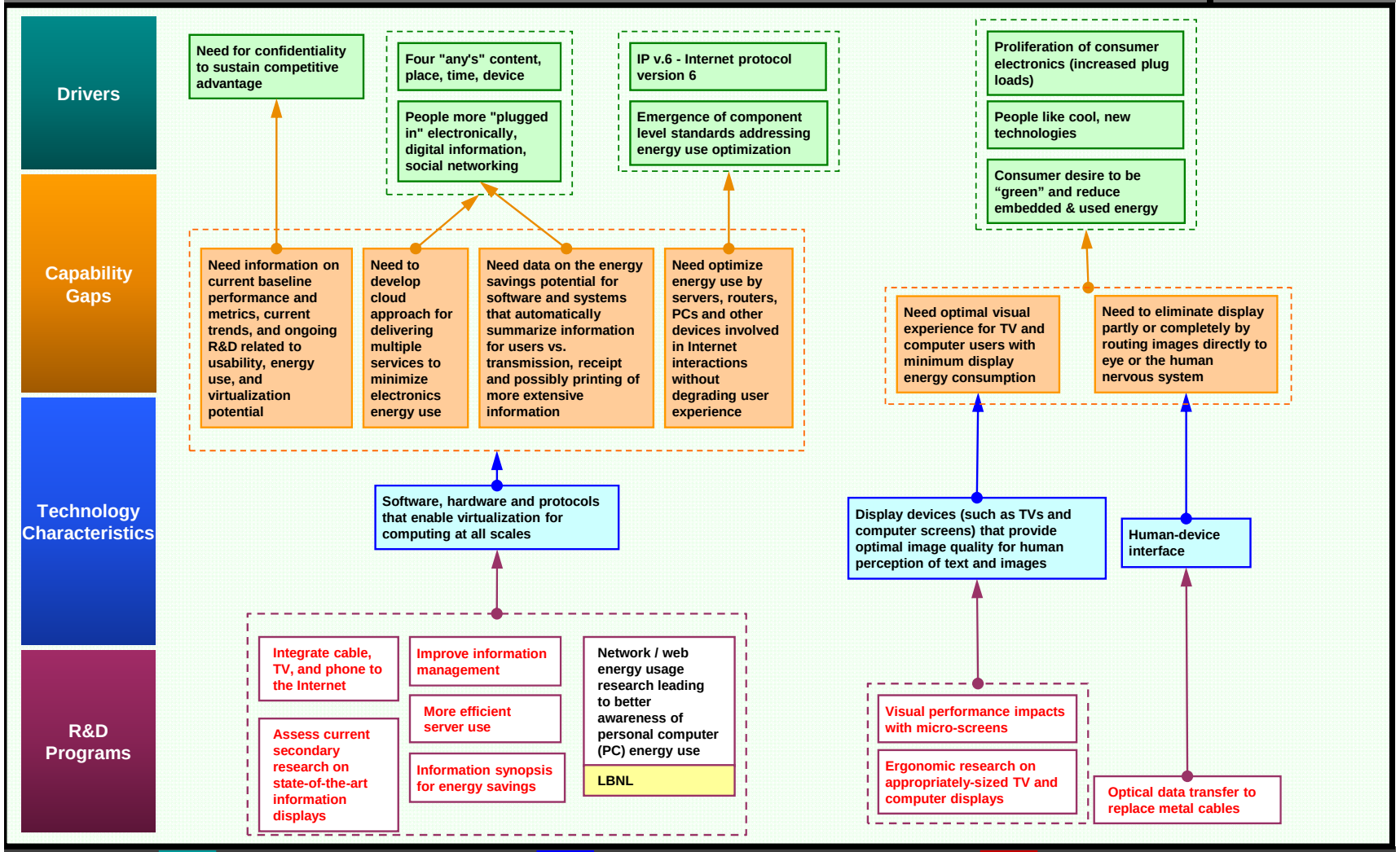
Research how much "stuff" in home is DC vs. AC at the core: Conduct basis analysis to see if there is enough direct current (DC) equipment in a typical home to justify having a DC supply in homes. It is unlikely that the load of DC in a home is enough to justify supplying DC.

Product/Service Area : **ELECTRONICS**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Use and Virtualization (1 of 2)**

Roadmap Definitions on pages ix-xii



R&D Project Summaries

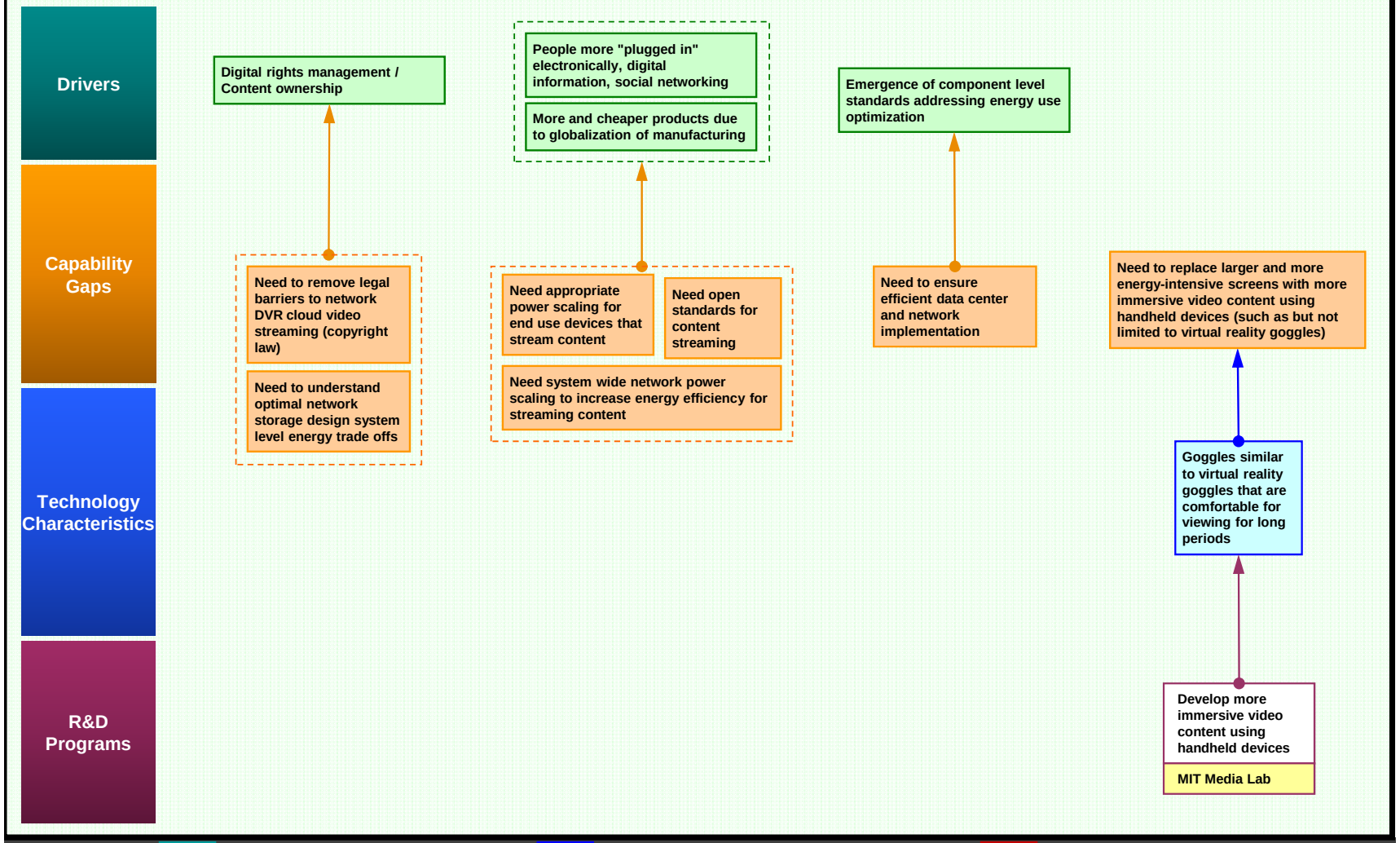
See next Page.

Product/Service Area : **ELECTRONICS**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Use and Virtualization (2 of 2)**

Roadmap Definitions on pages ix-xii



Driver
Capability Gap
Commercially Available Technology
Commercially Unavailable Technology
Existing R&D Program or Project
R&D Program Requirement

R&D Project Summaries

Network/web energy usage research leading to better awareness of energy use of Internet, email, and other computer uses: Many users consider it environmentally benign to transfer information electronically rather than with paper, but there is substantial energy use for this; research this and raise user awareness. As a subtopic, perform a literature search to identify the manufacturers, national labs, and other organizations involved with R&D on the broader use of optical data transfer, which is more energy efficient than metal cables.

- For more information on the Lawrence Berkeley National Laboratory research in this area, see Appendix B.

User comfort with virtual reality (VR) goggles: Virtual reality (VR) goggles can replace displays using much more energy, but research is needed on user comfort with VR goggles. Also examine the potential savings, comfort, and usability of miniaturized displays embedded in traditional eyeglass frames.

- The Massachusetts Institute of Technology (MIT) Media Lab is currently researching VR viewing technology; see Appendix B for more information.

Assess secondary research on state-of-the-art information displays: Perform a literature search to identify the manufacturers, national labs, and other organizations involved with R&D on information displays as a potential path to energy savings.

Ergonomic research on right-sized TV & computer displays: The trend in TV and computer displays seems to be "bigger is better," which increases energy use. Research "right-sized" displays.

Improve information management: Perform a literature search to identify the manufacturers, national labs, and other organizations involved with R&D on information displays.

Information synopsis for energy savings: Perform a literature search and primary research needed to identify potential energy savings by systems and software that automatically summarize lengthy documents for users.

Integrate cable, TV and phone to the Internet: Using one appliance to do computing, cable TV, and phone could conceivably save energy. Research to examine the extent that that full function is maintained or improved would be useful.

More efficient server use: To greatly cut energy use for data center servers and cooling, research "virtualization," which increases the sharing of servers so fewer servers and power supplies are needed.

Optical data transfer to replace metal cables: Perform a literature search to identify the manufacturers, national labs, and other organizations involved with R&D on the broader use of optical data transfer, which is more energy efficient than metal cables.

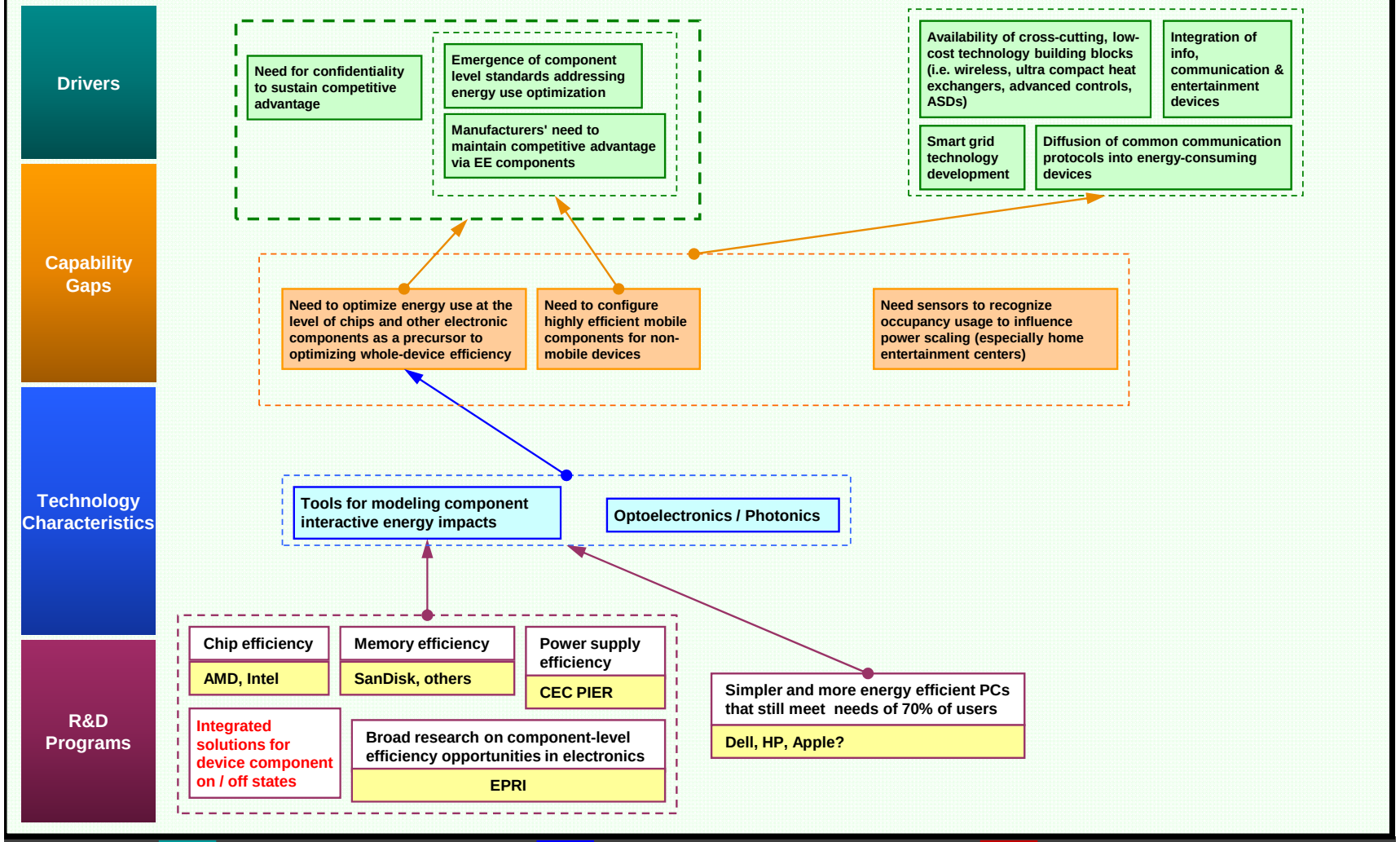
Visual performance impacts with micro-screens: Using smaller computer screens saves energy, but for some applications performance may be reduced such that this is not feasible. Research user feedback.

Product/Service Area : **ELECTRONICS**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Component-Level Efficiency**

Roadmap Definitions on pages ix-xii



R&D Project Summaries

Broad research on component-level efficiency opportunities in electronics: Explore a wide range of approaches to component efficiencies utilizing untapped and underutilized opportunities.

- The Electric Power Research Institute (EPRI) is conducting various electronics R&D projects for gaming consoles, network devices, computers, and related technologies under their Program 170; more information about this work in Appendix B.

Chip efficiency: Continue advancing R&D efforts that target microprocessor and other chip efficiencies. Stakeholders report that research is ongoing at Advanced Micro Devices, Inc. (AMD), Intel Corporation, and other manufacturers. Ongoing research from manufacturers tends largely to be proprietary and, therefore, not thoroughly or consistently reported through companies' web pages.

- Intel Corporation's research group–Intel Research—works on a variety of projects applicable to regional stakeholders' interests, including cloud computing, energy, microarchitecture, and personal energy systems. See http://techresearch.intel.com/index.aspx and http://techresearch.intel.com/ResearchAreaDetails.aspx?Id=2 for more information.
- Semiconductor design company AMD has a research division—AMD Research—with locations throughout the U.S. where work is done in a variety of areas related to semiconductors and information technology systems; see http://www.amd.com/us/aboutamd/corporate-information/research/Pages/research.aspx.

Memory efficiency: Continue advancing R&D efforts that target memory efficiency, including development of new, lower-power memory technologies. Stakeholders report that research is ongoing at SanDisk and other manufacturers. Ongoing research from manufacturers tends largely to be proprietary and, therefore, not thoroughly or consistently reported through companies' web pages.

- SanDisk: http://www.sandisk.com/.

Power supply efficiency: Continue advancing R&D efforts that target power supply efficiency. The Electric Power Research Institute (EPRI), Ecova, Inc., and the California Energy Commission's (CEC) Public Interest Energy Research (PIER) program are involved in this work.

- EPRI and Ecova, Inc., (http://www.ecova.com/), with funding from the CED PIER program, have collaborated to create and maintain a website to serve as a forum on current and recently completed R&D on energy efficient power supplies in the "active" or "on" mode (http://www.efficientpowersupplies.org/).
- Ecova, Inc., maintains the website EfficientProducts.org to provide a central location showcasing research on energy efficient consumer products (http://www.efficientproducts.org/index.php).
- An overview of CEC PIER-funded research in consumer and office electronics as of April 2010 can be found at http://www.calit2.uci.edu/uploads/Media/Text/Meister_CECPresentation_ConsumerandOfficeElectronics_Meister.pdf.

Simpler and more energy efficient PCs that still meet needs of 70% of users: Explore innovative approaches to reducing energy use by mass-market PCs. Stakeholders report that research is ongoing at Dell, Hewlett-Packard (HP), Apple, and other manufacturers. Ongoing research from manufacturers tends largely to be proprietary and, therefore, not thoroughly or consistently reported through companies' web pages.

- Apple, Inc., reports that every product they sell exceeds ENERGY STAR specifications, and that their goal is to reduce energy use with their laptop and desktop computers while not negatively impacting user experience. Their research includes both hardware and software products, and focuses on three areas: 1) using more efficient power supplies; 2) using components that require less power; 3) using power management software; see http://www.apple.com/environment/energy-efficiency/.
- The work of HP's worldwide research group—HP Labs—spans a range of technical applications and business areas, including cloud computing, security, information analytics, infrastructure, and networking. HP introduced their rp5700 Desktop PC in 2007 that achieved the highest performance rating of the Electronic Products Environmental Assessment Tool (EPEAT) (http://www.epeat.net/) registry and met ENERGY STAR® 4.0 requirements; in April 2010, HP introduced two space-saving and energy-efficient desktop PCs; see http://www.hpl.hp.com/ and http://www.hp.com/hpinfo/newsroom.

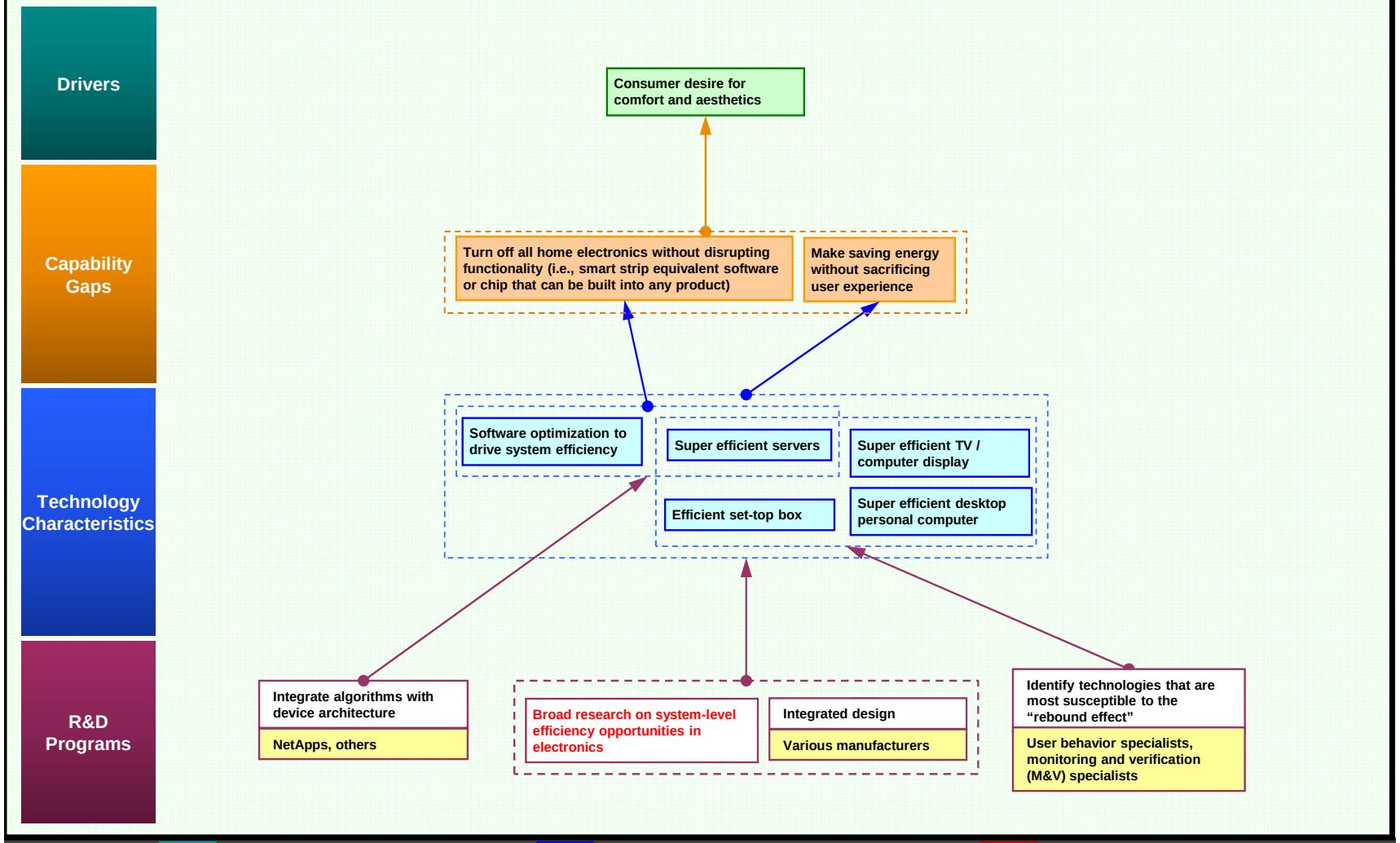
Integrated solutions for device component on/off states: Develop "whole-device" approaches and technologies that minimize or eliminate component standby losses in any operational state.

Product/Service Area : **ELECTRONICS**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Complete Electronic System**

Roadmap Definitions on pages ix-xii



Driver
Capability Gap
Commercially Available Technology
Commercially Unavailable Technology
Existing R&D Program or Project
R&D Program Requirement

R&D Project Summaries

Integrate algorithms with device architecture: Develop software-hardware hybrid approaches to minimize servers' and other electronic systems' energy use. Stakeholders indicate that research in this area is underway at NetApp, Inc. (http://www.netapp.com/us/), but this R&D is not always accessible for collaboration and tends largely to be proprietary and, therefore, not thoroughly or consistently reported through companies' web pages.

Integrated design: Develop tools and approaches to help manufacturers do whole-system designs that achieve ultra-low energy consumption. Stakeholders indicate that research in this area is underway at a variety of television manufacturers, but this R&D is not accessible for collaboration and tends largely to be proprietary and, therefore, not thoroughly or consistently reported through companies' web pages.

Identify which technologies are most susceptible to the "rebound effect": Perform human factors R&D to determine which combinations of products and users are most likely to cancel out intended energy savings. Stakeholders indicate that research in this area is underway at a institutions that specialize in measurement & verification (M&V) and behavior, but further information about this R&D is not known as of Feb. 2012.

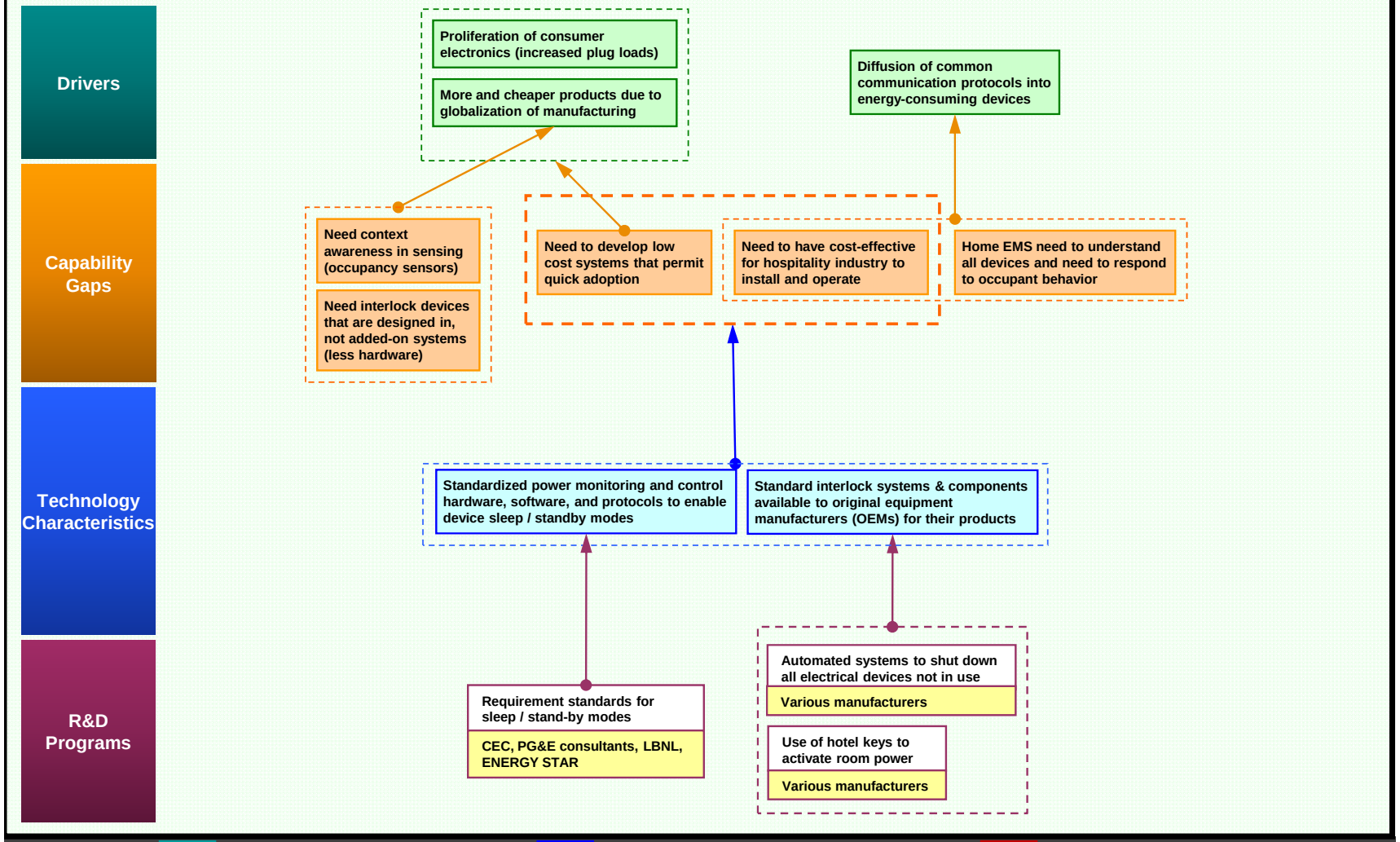
Broad research on system-level efficiency opportunities in electronics: Explore a wide range of approaches to product efficiencies utilizing untapped and underutilized opportunities.

Product/Service Area : **ELECTRONICS**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Interlock Devices to Manage Energy Use (1 of 2)**

Roadmap Definitions on pages ix-xii



R&D Project Summaries

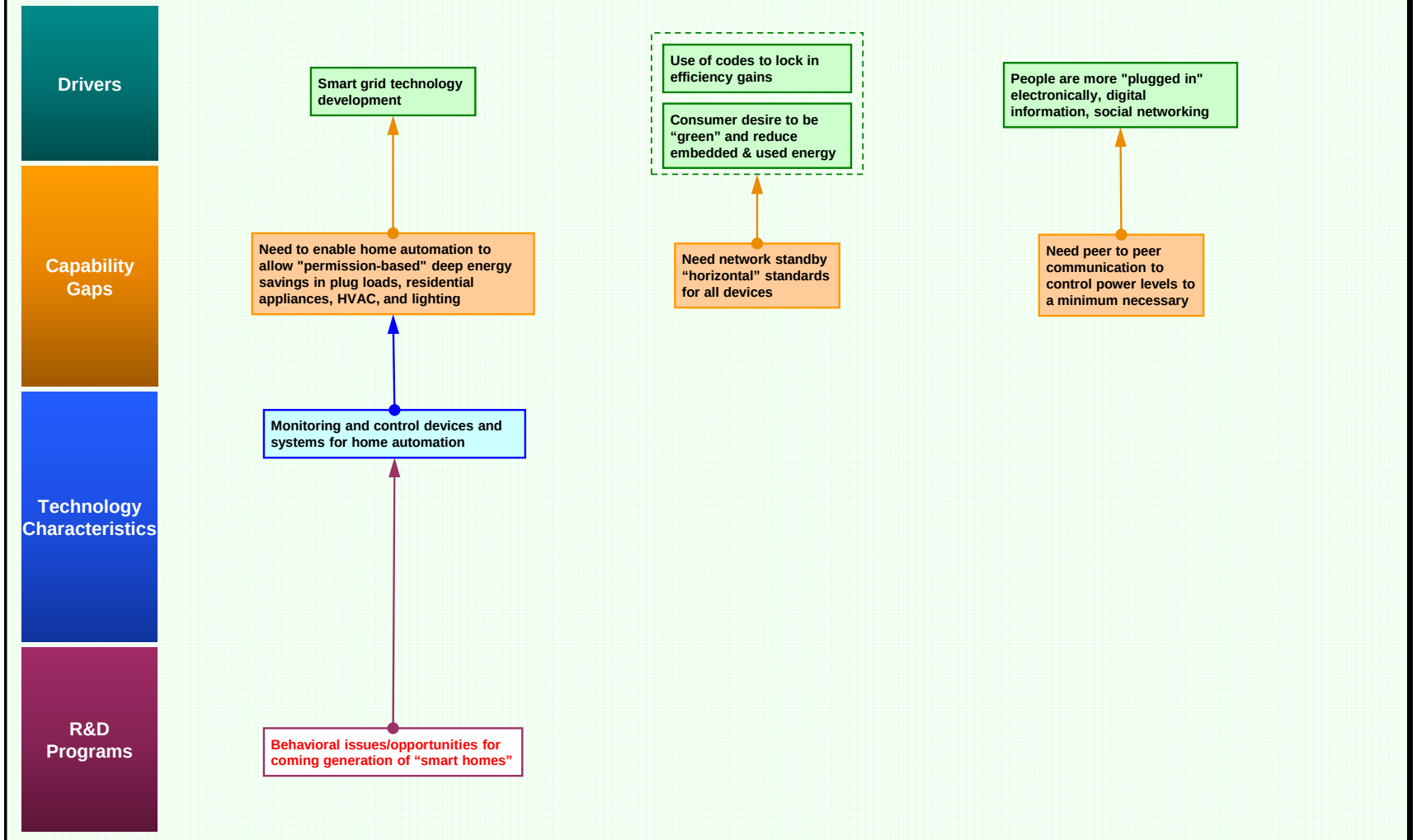
See next Page.

Product/Service Area : **ELECTRONICS**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Interlock Devices to Manage Energy Use (2 of 2)**

Roadmap Definitions on pages ix-xii



R&D Project Summaries

Automated systems to shut down all electrical devices not in use: Stakeholders indicate that various products are already equipped with this functionality, but that there is a need to advance current best practices for products that turn themselves off when not in use.

Requirement standards for sleep / stand-by modes: Develop equipment and code-based approaches to eliminating product energy consumption when not in use. Research is ongoing at the California Energy Commission (CEC), Pacific Gas & Electric (PG&E), the Lawrence Berkeley National Laboratory (LBNL), and ENERGY STAR.

- CEC research in this area has not yet been specified as of Feb. 2012.
- Stakeholders referenced PG&E research in this area, which is likely conducted by the PG&E Emerging Technologies Program. This program does not have its own website, and current contact information is not readily apparent; as of Feb. 2012, attempts continue to track-down this information.
- Ongoing work in this area at the LBNL can be found in Appendix B.
- ENERGY STAR sleep-mode/stand-by standards for computers and electronic equipment can be found at http://www.energystar.gov/index.cfm?c=products.pr_find_es_products.

Use of hotel keys to activate room power: Continue advancing key-based systems that disable lighting, HVAC and other energy uses in hotel rooms when not occupied.

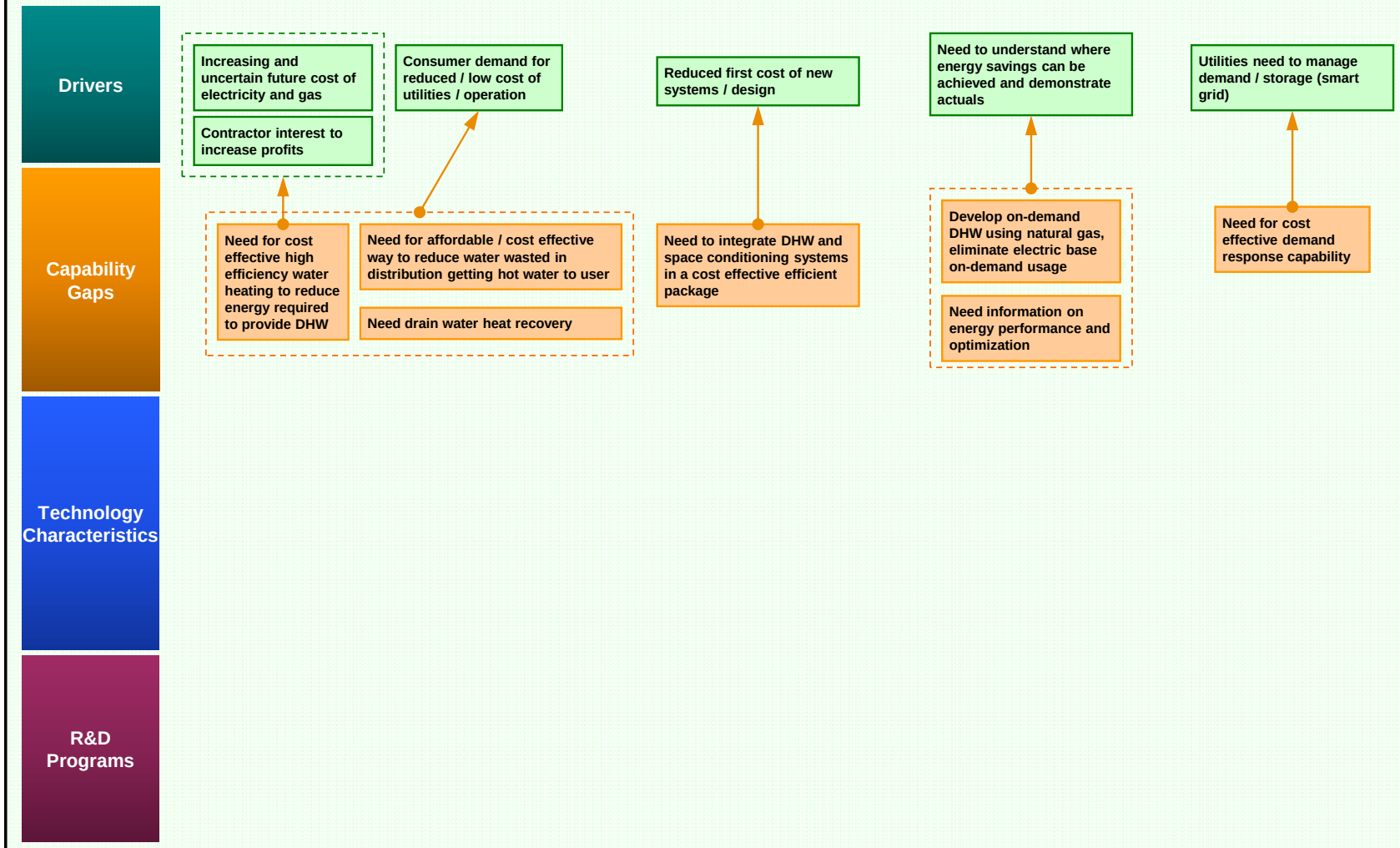
- Madison Gas and Electric of Wisconsin has compiled an overview of the potential benefits associated with hotel room automation systems: http://www.mge.com/business/saving/madison/PA_63.html. They have also collated links to nineteen automation controls manufacturers (http://www.mge.com/business/saving/madison/PA_manufacturers.html#PA63).

Behavioral issues / opportunities for coming generation of "smart homes": Perform human factors R&D to develop understanding of opportunities and barriers for energy reductions in home automation using current and emerging technologies.

Heating, Ventilation, and Air Conditioning Roadmaps

Technology Roadmap: **Water Heating**

Roadmap Definitions on pages ix-xii



Driver
Capability Gap
Commercially Available Technology
Commercially Unavailable Technology
Existing R&D Program or Project
R&D Program Requirement

R&D Project Summaries

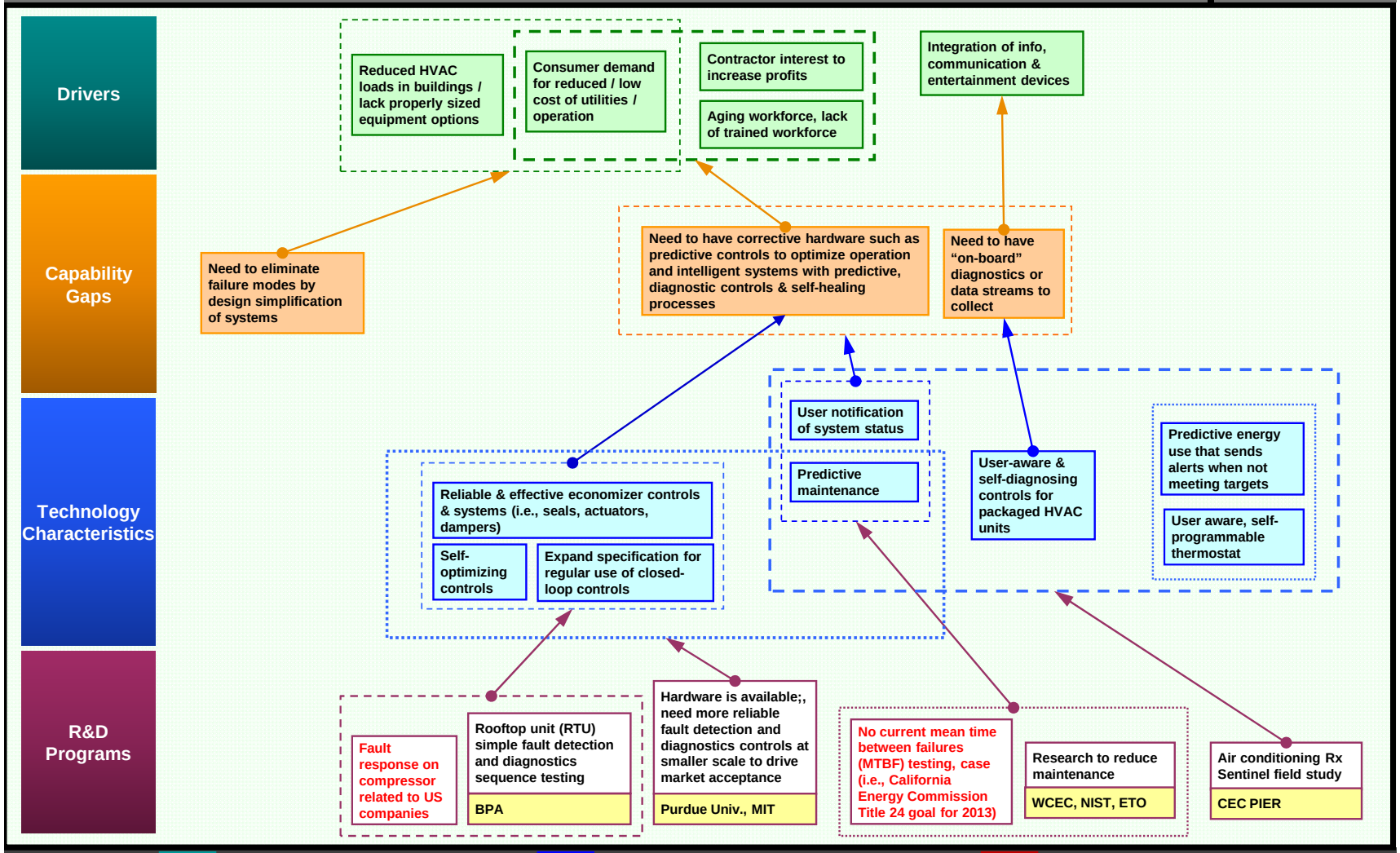
New roadmap in the portfolio as of August 2012, no R&D projects yet identified.

Product/Service Area : **HEATING, VENTILATION, AND AIR CONDITIONING (HVAC)**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Fault Detection and Predictive Maintenance (1 of 2)**

Roadmap Definitions on pages ix-xii



R&D Project Summaries

Hardware is available; need more reliable FDD controls at smaller scale to drive market acceptance: Though hardware is available for sophisticated controls, more work is needed on software and thoughtful design and application of sophisticated fault detection and diagnostics (FDD) controls.

- Engineering graduate student Siyu Wu is currently working on thesis research at the Applied Controls Laboratory of the University of California at Merced, under the guidance of Dr. Jian-Qiao Sun (http://faculty.ucmerced.edu/jqsun/index.html). They delivered a paper at the American Council for an Energy-Efficient Economy (ACEEE) 2010 conference, "Multilevel Fault Detection and Diagnosis on Office Building HVAC Systems." This paper presented a multilevel fault detection method that allowed for the uniform application of the FDD strategy to an entire building (http://eec.ucdavis.edu/ACEEE/2010/data/papers/1992.pdf).

Rooftop unit (RTU) simple fault detection and diagnostics sequence testing: Bonneville Power Administration conducted research in 2008-2009 on roof-top units (RTUs) with special attention paid to controls and fault detection and diagnostics; see http://www.bpa.gov/energy/n/emerging_technology/AirHandlerControls. cfm.

Hardware is available; software development is needed: Much of the hardware useful for implementing self-diagnoses of HVAC equipment controls is available. The biggest remaining need is good software and design.

- The Purdue University Energy Center's Smart Buildings Research group is working on fault detection and diagnostics software; as of Feb. 2012, specific R&D project information is not readily apparent through the research group's website, but general information can be found at http://www.purdue.edu/discoverypark/energy/research/efficiency/green_building.php.

Air Conditioning Rx Sentinel field study: Developing and testing self-diagnostic controls for air conditioning will help increase reliability and efficiency of HVAC systems. Stakeholders indicated that this study was underway through the California Energy Commission's (CEC) Public Interest Energy Research (PIER) program, but further details of this were not available as of Feb. 2012.

Research to reduce maintenance: Reducing maintenance on energy-efficient equipment can help expedite uptake of the equipment. Downtime in itself can be wasteful and reduces service. Replacing equipment prematurely likewise increases embedded energy of equipment and reduces service. Research is ongoing at the National Institute of Standards and Technology (NIST) and the Western Cooling Efficiency Center (WCEC) at the University of California Davis, and the Energy Trust of Oregon (ETO) is also involved in this work in some capacity.

- WCEC is working to commercialize fault detection and diagnostics tools. See Appendix B for more information.
- NIST's Energy and Environment Division has two ongoing fault detection and diagnostics projects. See Appendix B for more information.
- ETO staff reported in February 2012 that their projects and programs do not explicitly address maintenance reduction, though this is often an ancillary benefit of their work; they also do not work formally within a fault detection paradigm. However, they are engaged in a number of ongoing programs and pilot projects involving energy information systems for commercial buildings, a roof top unit tune-up program, and soliciting customer and contractor feedback on energy use and equipment operation to help them manage energy use. See Appendix B for more information.

No current mean time between failures (MTBF) testing: Need better information on the mean time between failures (MTBF) for different equipment in order to inform predictive maintenance programs and controls; for case study see California Energy Commission Title 24 goal for 2013.

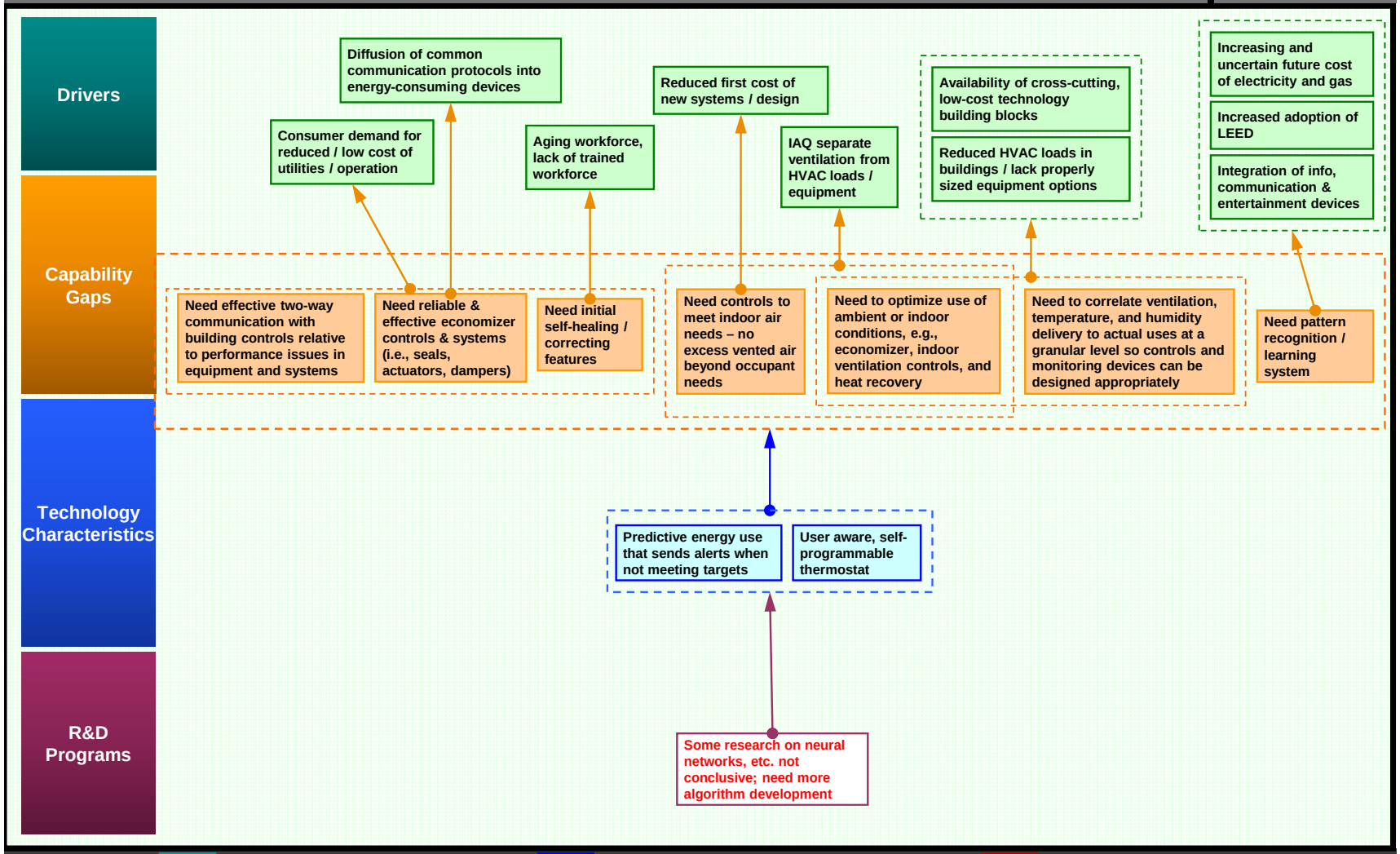
Fault response on compressors related to U.S. companies: One of the important areas to develop right now is self-diagnostic controls. An important aspect of that is to develop and implement fault response on compressors.

Product/Service Area : **HEATING, VENTILATION, AND AIR CONDITIONING (HVAC)**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Fault Detection and Predictive Maintenance (2 of 2)**

Roadmap Definitions on pages ix-xii



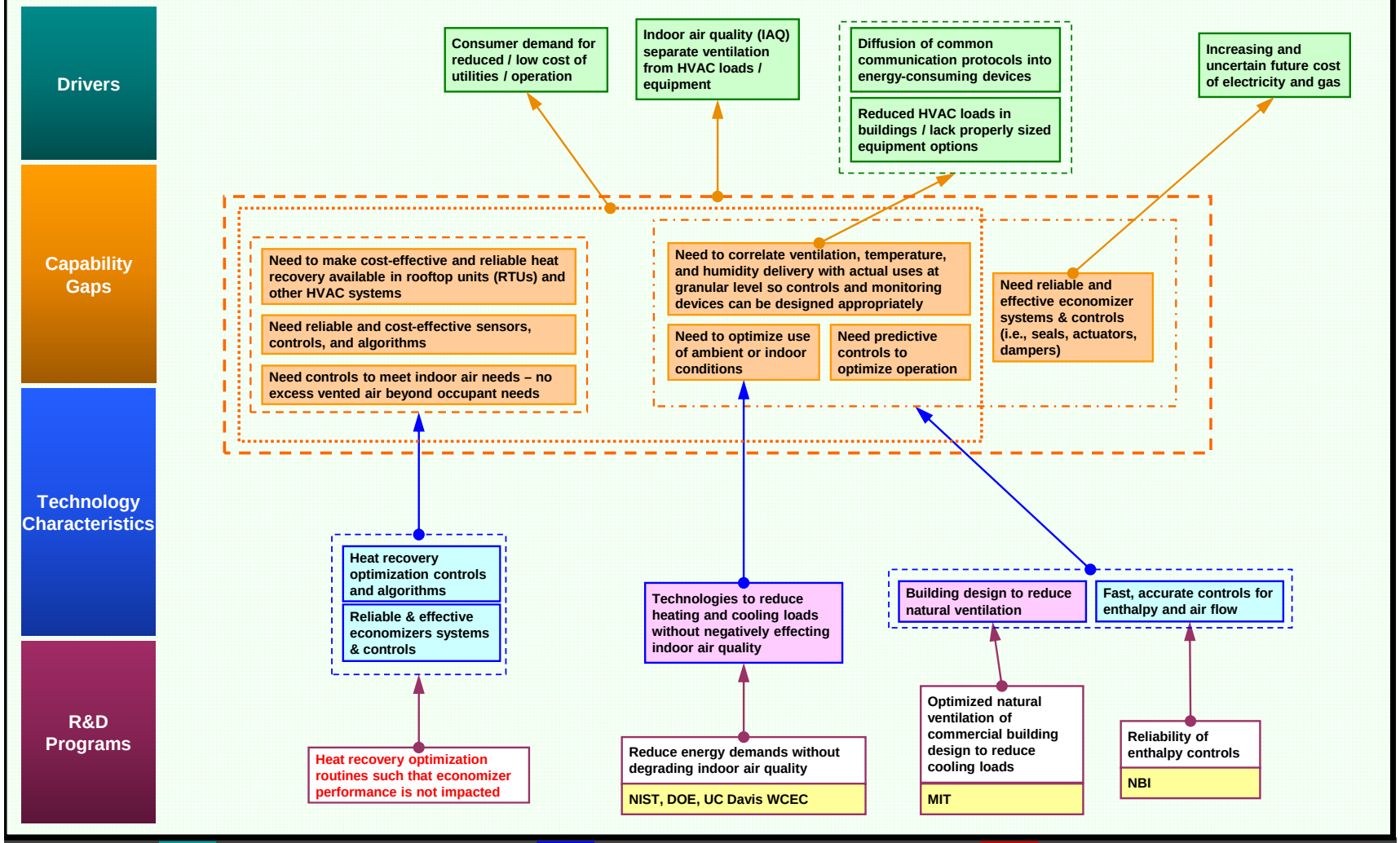
- **Some research on neural networks, etc., not conclusive; need more algorithm development:** More research on neural networks and artificial intelligence is needed to help inform design of self-healing and learning HVAC controls systems.

Product/Service Area : **HEATING, VENTILATION, AND AIR CONDITIONING (HVAC)**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Heat Recovery and Economizer Optimization (1 of 2)**

Roadmap Definitions on pages ix-xii

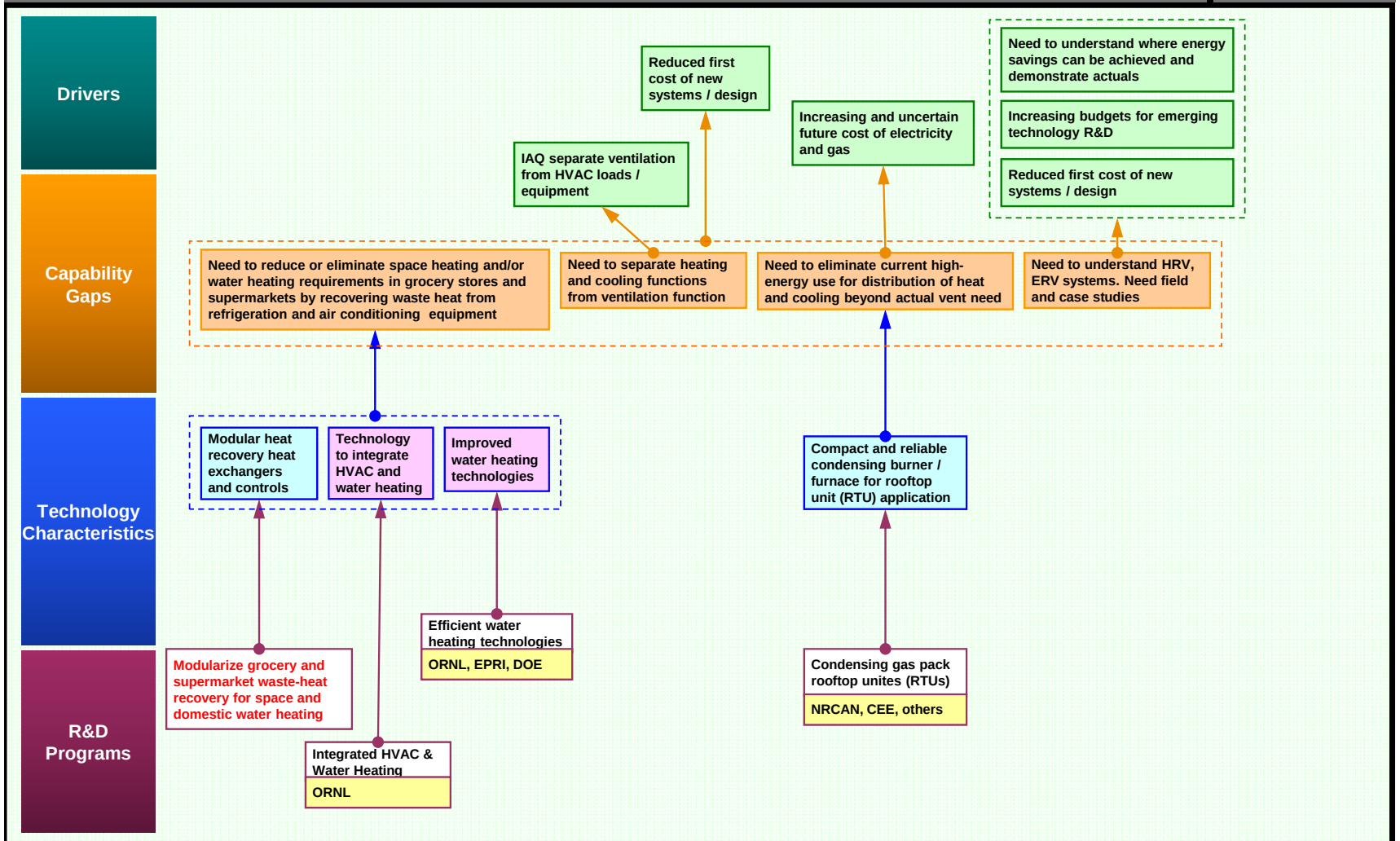


R&D Project Summaries

See next Page.

Technology Roadmap: Heat Recovery and Economizer Optimization (2 of 2)

Roadmap Definitions on pages ix-xii



R&D Project Summaries

Condensing gas pack rooftop units (RTUs): Roof-top units (RTUs) with condensing gas heat will be much more efficient than non-condensing. Field test as necessary and encourage implementation in the Northwest. Stakeholders indicated that work in this area is ongoing at the Consortium for Energy Efficiency (CEE) and Natural Resources Canada (NRCAN); CEE staff member Tony Gross has also indicated that Douglas Kosar at the Gas Technology Institute and Dick Lord at Carrier Corporation have expertise in ongoing research in this area, and BPA staff is in the process of following-up with these contacts.

- Martin Thomas oversees NRCAN (http://www.nrcan.gc.ca/home) research in this area; as of Feb. 2012, Bonneville Power Administration staff have queried Mr. Thomas for more information.
- CEE does not conduct its own technical research in this area, but does keep abreast of R&D and helps bring emerging technologies into the marketplace; see http://www.cee1.org/.
- Gas Technology Institute: http://www.gastechnology.org/webroot/app/xn/xd.aspx?it=enweb&xd=gtihome.xml.
- Carrier Corporation: http://carrier.com/Carrier+Corporate+Sites/Corporate

Reliability of enthalpy controls: Good enthalpy control is important for efficient control of economizers. To date, enthalpy controls have been found to have notorious reliability issues. Developing and testing a reliable enthalpy control could help save significant energy in the Northwest. Stakeholders have indicated that work is ongoing in this area at the New Buildings Institute (http://newbuildings.org/), but as of Feb. 2012, no further information on such efforts have been uncovered.

Heat recovery optimization routines such that economizer performance is not impacted: Developing controls and system designs to optimize heat recovery and use of outside air can reduce or eliminate HVAC compressor and burner operation for many hours per year.

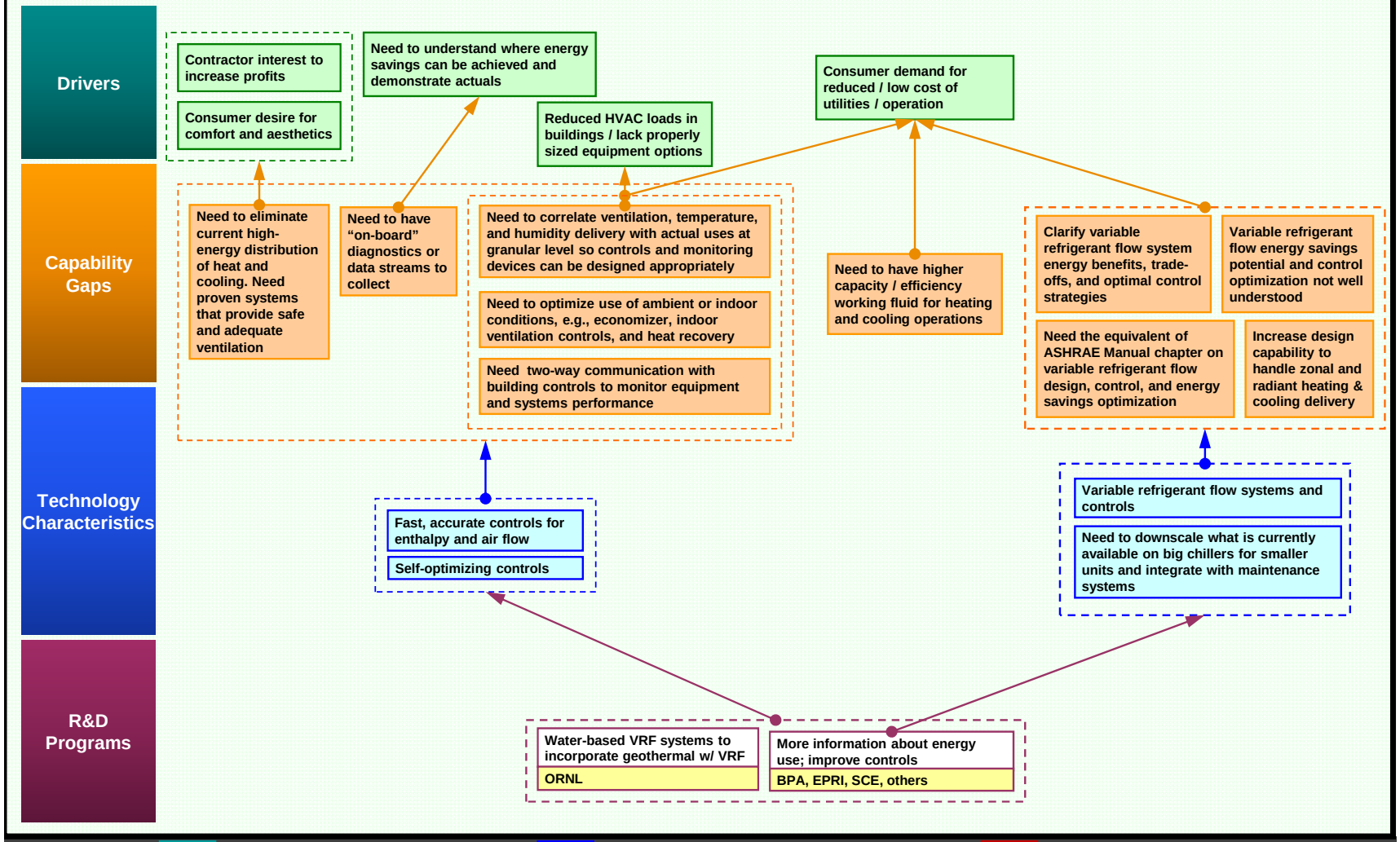
Modularize grocery and supermarket waste-heat recovery for space and domestic water heating: Do a field study of using heat recovery from grocery refrigeration or air conditioning to use for space heating in other areas or to pre-heat domestic hot water.

Product/Service Area : **HEATING, VENTILATION, AND AIR CONDITIONING (HVAC)**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Heating & Cooling Production and Delivery (1 of 2)**

Roadmap Definitions on pages ix-xii



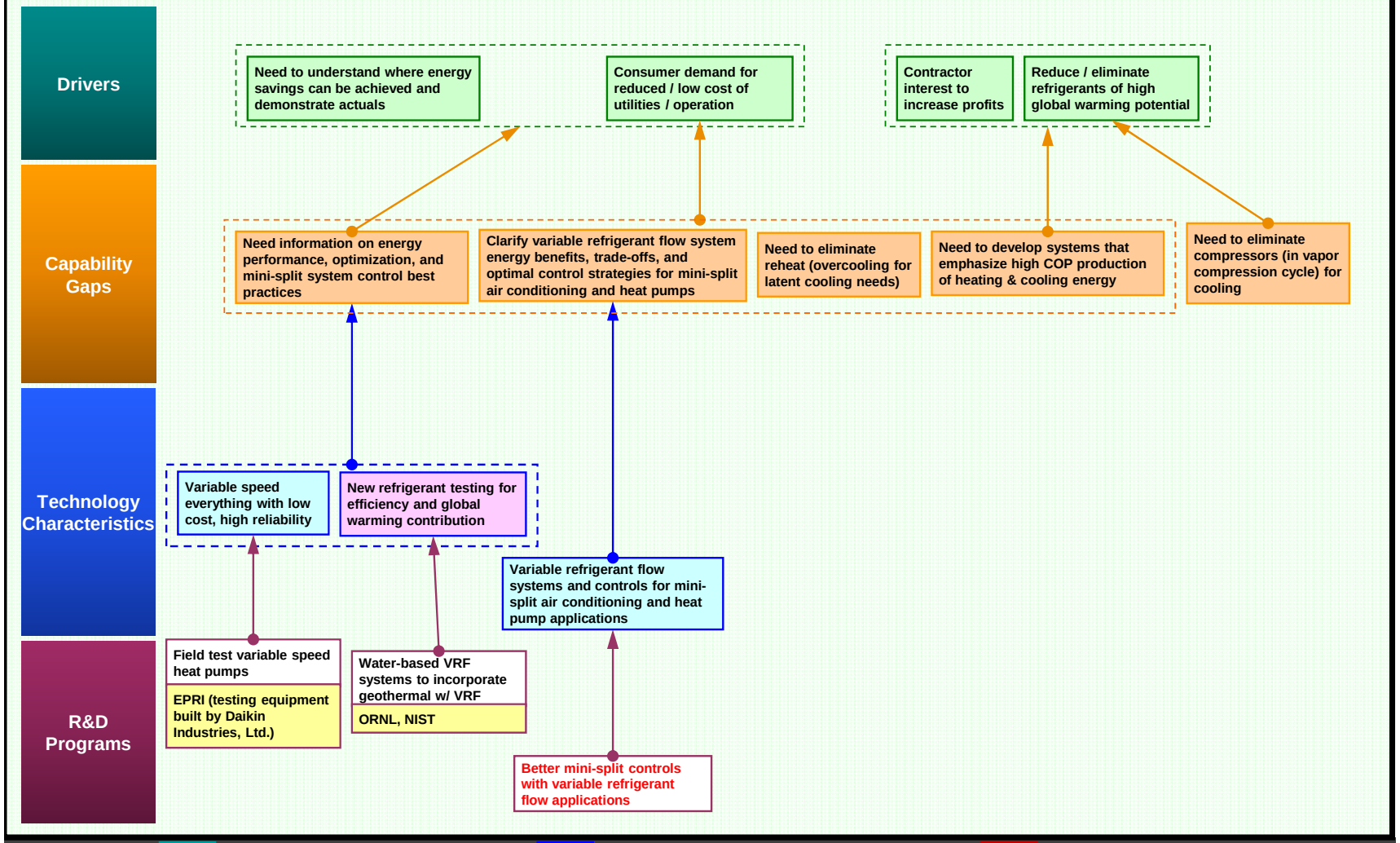
Driver
Capability Gap
Commercially Available Technology
Commercially Unavailable Technology
Existing R&D Program or Project
R&D Program Requirement

R&D Project Summaries

See next Page.

Technology Roadmap: **Heating & Cooling Production and Delivery (2 of 2)**

Roadmap Definitions on pages ix-xii



R&D Project Summaries

Field test variable speed heat pumps: One of the most promising heating and air conditioning technologies is variable refrigerant flow, or "multi-split" systems. However, good field testing is needed to verify that it can perform in the field as promised in theory. Stakeholders reported that the Electric Power Research Institute (EPRI) was conducting research in this area specifically with technologies developed by Daikin Industries; as of Feb. 2012, further information about this testing was not known.

More information about energy use; improve controls: Develop reliable engineering and technical information on how to optimize variable refrigerant flow (VRF) energy savings while assuring comfort and reliability.

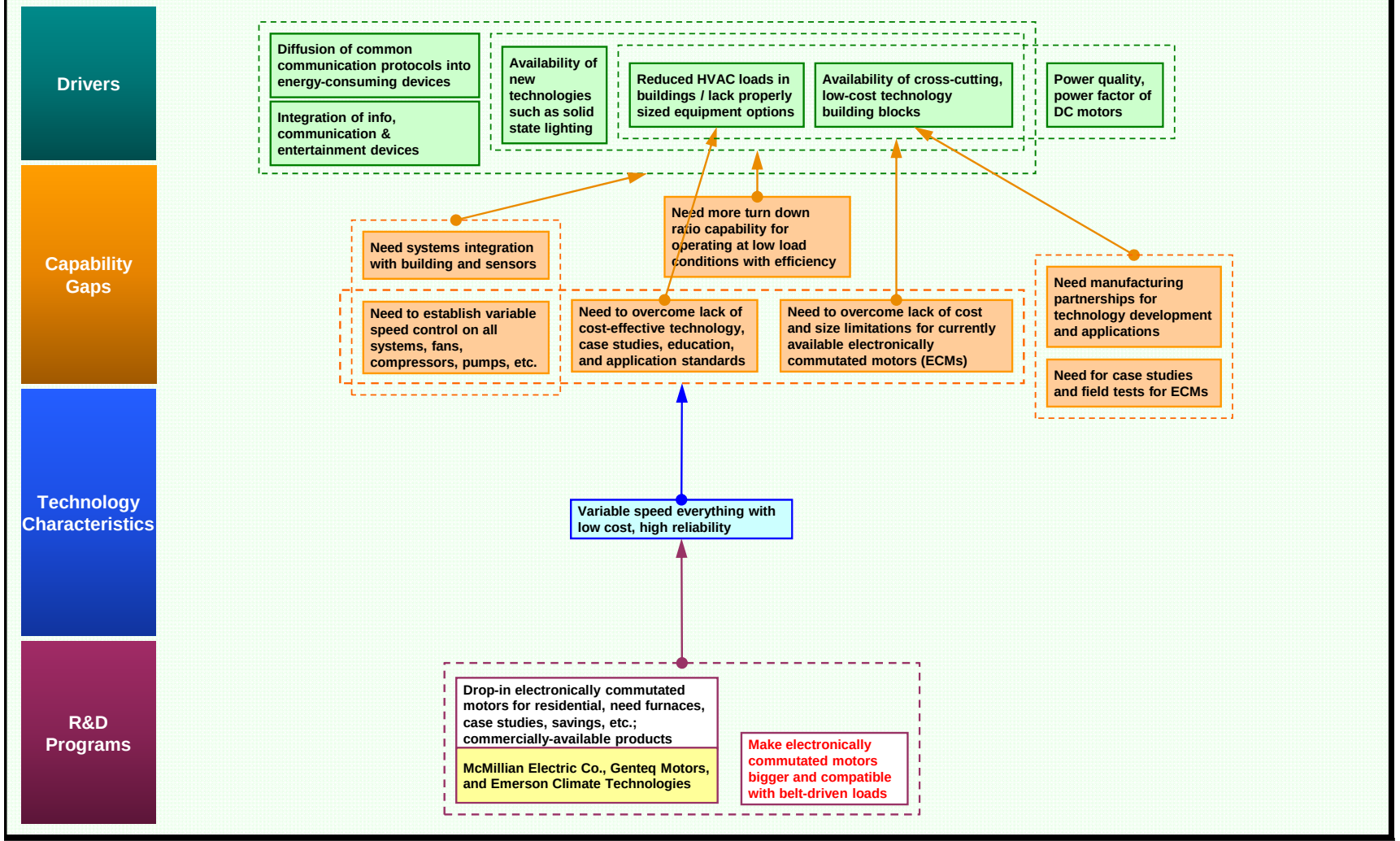
- Thirty-five subject matter experts representing Bonneville Power Administration (BPA), the Electrical Power Research Institute (EPRI), Southern California Edison (SCE), and seventeen other institutions collaborated from 2009-2011 to produce the Variable Capacity Heat Pump Measure Development Roadmap (http://www.bpa.gov/energy/n/emerging_technology/VCHPOverview.cfm). As part of this effort, BPA contracted EES Consulting of Kirkland, Washington, to perform secondary research and provide estimates of efficiency improvements in the Northwest by applying variable capacity heat pump technology; see "Measure Summary Report: Variable Refrigerant Flow," February 2011, http://www.bpa.gov/energy/n/emerging_technology/pdf/BPA_VRF_Measure_Report_Final_R1.pdf.
- EPRI continues to conduct laboratory testing and modeling of advanced variable refrigerant flow systems in partnership with SCE and the Florida Solar Energy Center (FSEC) and funding from BPA's Energy Efficiency Emerging Technology (E3T) team; more information in Appendix B.

Better mini-split controls with flow (VRF) applications: Variable refrigerant flow (VRF) and other control optimization can make mini-splits even better alternatives to conventional central air conditioning.

Technology Roadmap:

HVAC Motor-driven Systems

Roadmap Definitions on pages ix-xii



R&D Project Summaries

Drop-in electronically commutated motors for residential applications: Use of electronically commutated motors (ECMs) for small motors could decrease energy use and increase ease of speed control significantly. A line of ECMs that would drop-in easily for retrofits would make implementation easier and more widespread. *(NOTE: The score in this box reflects the fact that Roadmap drafts prior to the March 2011 identified this research area as an R&D gap.)*

- As of January 2011, E Source reported that there were at least three commercially-available options for drop-in replacement brushless permanent magnets (BPM, a.k.a., electronically commutated motors) for furnace and/or air conditioning motors (see http://www.esource.com/node/27096); these included
  - McMillian Electric Company (http://www.mcmillanelectric.com/) offers the high-efficiency Concept 3 motor with climate optimized controls for standard heating and air conditioning systems (http://www.proctoreng.com/c3motor.html).
  - Genteq Motors (http://genteqmotors.com/) offers the Evergreen IM high-efficiency ECM designed to replace HVAC system blower motors. (http://genteqmotors.com/products/genteq/evergreen-im/).
  - Emerson Climate Technologies (http://www.emersonclimate.com/en-US/Pages/Home.aspx) offers the Rescue Ecotech® is designed to drop-in to existing permanent split capacitor blower applications, and does not require complex wiring modifications or system control changes (http://www.emersonclimate.com/en-US/products/motors/variable_speed_ecm/rescue_ecotech/Pages/rescue_ecotech.aspx).

Make electronically commutated motors bigger and compatible with belt-driven loads: electronically commutated motors (ECMs) have been very effective for saving energy and simplifying speed control for small motors. Having them available in larger sizes could simplify many retrofits, increase efficiency, and simplify design of variable speed systems.

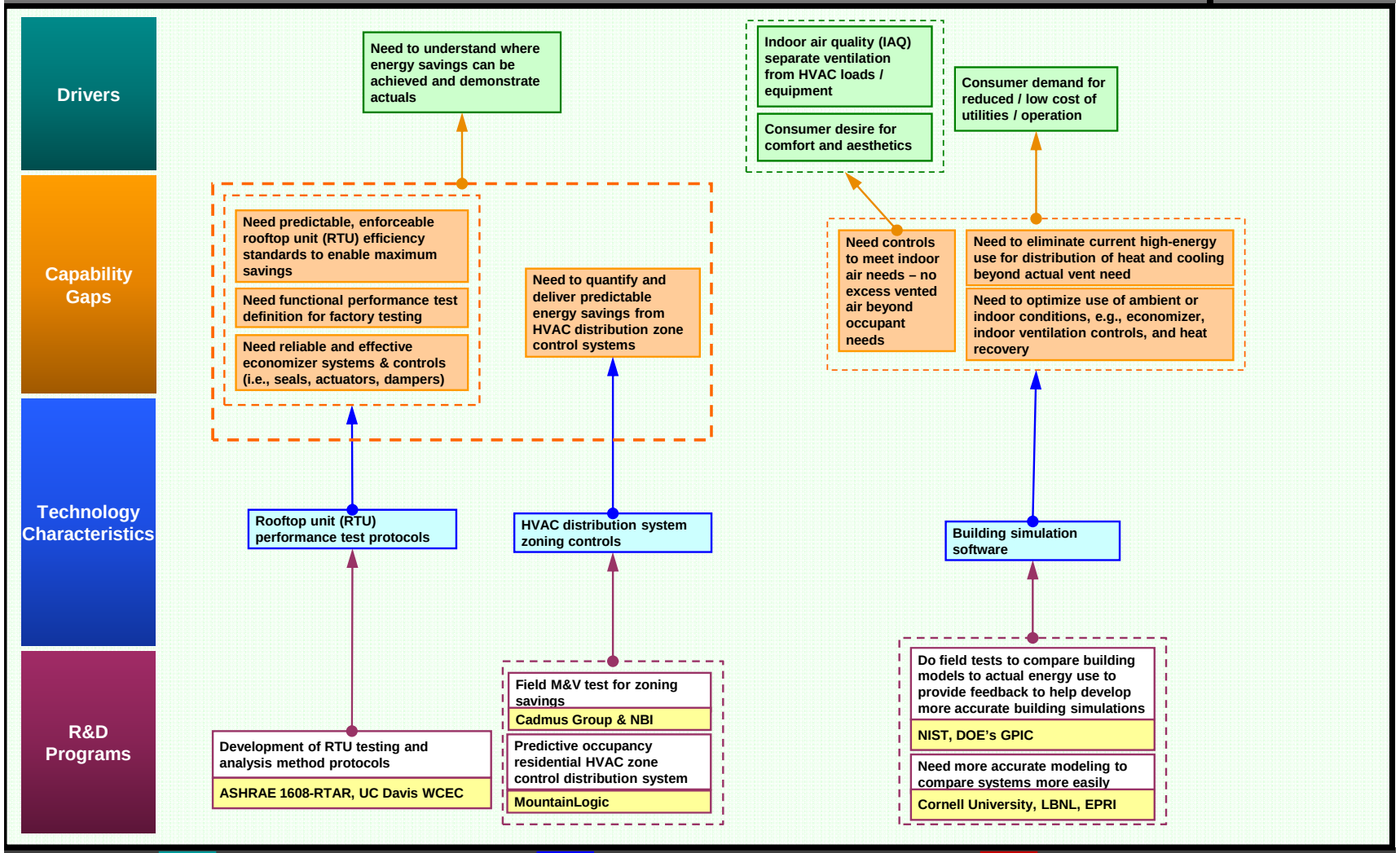
- E Source reported in January 2011 that they were not aware of any current research into very large ECMs, because as ECM motor size increases, the technology has to compete with highly efficient 3-phase motors. Research in electric vehicle technologies is illustrative. E Source Research Manager Bryan Jungers reported that his analysis of direct current-permanent magnet (DC-PM) motors in comparison to alternating current (AC) induction motors showed that the DC motors tended to be 10 to 20% more energy efficient on average in the 75kW range. For larger motors (~200+ kW), however, the AC induction motor is the preferred option, as it is usually smaller, lighter, and less expensive. For applications less than or equal to about 50 kW, the PM motors seem to have a size and weight advantage, partly due to their smaller and lighter motor controller. In the range of 50 to 150 kW, the market seems somewhat split on these two options: for heavy-duty vehicle applications, AC is the preferred technology, while for light-duty vehicles, PM seems to have an edge thus far. The 50 to 150 kW range is effectively where the cross-over might be for switching from one technology to the other.

Product/Service Area : **HEATING, VENTILATION, AND AIR CONDITIONING (HVAC)**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Modeling, Lab and Field Testing (1 of 2)**

Roadmap Definitions on pages ix-xii



Driver | Capability Gap | Commercially Available Technology | Commercially Unavailable Technology | Existing R&D Program or Project | R&D Program Requirement

R&D Project Summaries

Develop load-based lab testing for rooftop units (RTUs): The American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) is currently working on updating the testing standard for roof-top units; ASHRAE 1608-RTAR. Once that is completed, implement the standard in the Northwest. Information about this standard is not readily apparent through ASHRAE's website; Bonneville Power Administration staff queried ASHRAE as of Feb. 2012 and are still awaiting reply.

Do field tests to compare building models to actual energy use; provide feedback to help develop more accurate building simulations: Do field tests to compare building model to actual energy use when built. Provide feedback to building modeling developers to help them develop more accurate building simulations. Teams at the National Institute of Standards and Technology (NIST) and the U.S. Department of Energy (DOE) are working in this area.

- NIST's Energy and Environment Division is engaged in one facet of this research with their "Design and In-Situ Performance of Vapor Compression System" project. More information in Appendix B.
- E Source reported that as of early 2012, the DOE had established an "Energy Innovation Hub" in Pennsylvania called the Greater Philadelphia Innovation Center (GPIC). They plan to devote a significant part of their efforts to comparing measured performance to modeled performance, including computational tools that will enable robust and rapid design of integrated building systems (http://gpichub.org/activities/tools/tools).

Field M&V test for zoning savings: Do field monitoring and verification (M&V) tests to gather data for optimizing design choices for zoning with different heating and cooling systems.

- BPA's Energy Efficiency Emerging Technology (E3T) is currently working with the Cadmus Group and the New Buildings Institute (with guidance from the Northwest Power & Conservation Council's Regional Technical Forum) to build upon pilot tests in 2008-2009 to develop methods for measuring and verifying electricity savings from HVAC system retro-commissioning. Full description and project details at http://www.bpa.gov/energy/n/emerging_technology/RetroRTU.cfm.

Need more accurate modeling to compare systems more easily: Building modeling for design has been a great boon to designing energy-efficient buildings, but there's much room for improvement. We should make it much easier to try out alternative scenarios without having to do detailed re-designing of the building model. Researchers at the Lawrence Berkeley National Laboratory's (LBNL) and Cornell University are working on aspects of this.

- LBNL's Simulation Research Group is involved in research, development, and deployment of building design and operation software tools. Recent products that they've launched include EnergyPlus whole building simulation tool (http://apps1.eere.energy.gov/buildings/energyplus/), Building Controls Virtual Test Bed (http://simulationresearch.lbl.gov/bcvtb), and the GenOpt generic optimization program (http://simulationresearch.lbl.gov/GO/).
- The LBNL Simulation Research Group also manages the "Modelica Library for Building Energy and Control Systems," a free and expanding library of open-source dynamic simulation models for building energy and control systems (http://simulationresearch.lbl.gov/modelica). Administrators of this library seek contributions to the library's holdings, and are particularly interested, as of early 2012, in expanding the library; validating models currently in the library; enhancing documentation; and improving the numerical robustness of large system models.
- A team within the Cornell University Program of Computer Graphics is working on a three-year grant funded by the Department of Energy (using American Recovery and Reinvestment Act (ARRA) funds) to use computer building simulations to streamline green design; see Appendix B for more information.

Predictive occupancy residential HVAC zone control distribution system: Significant energy savings will result from refining and tailoring occupancy controls to improve upon existing control systems.

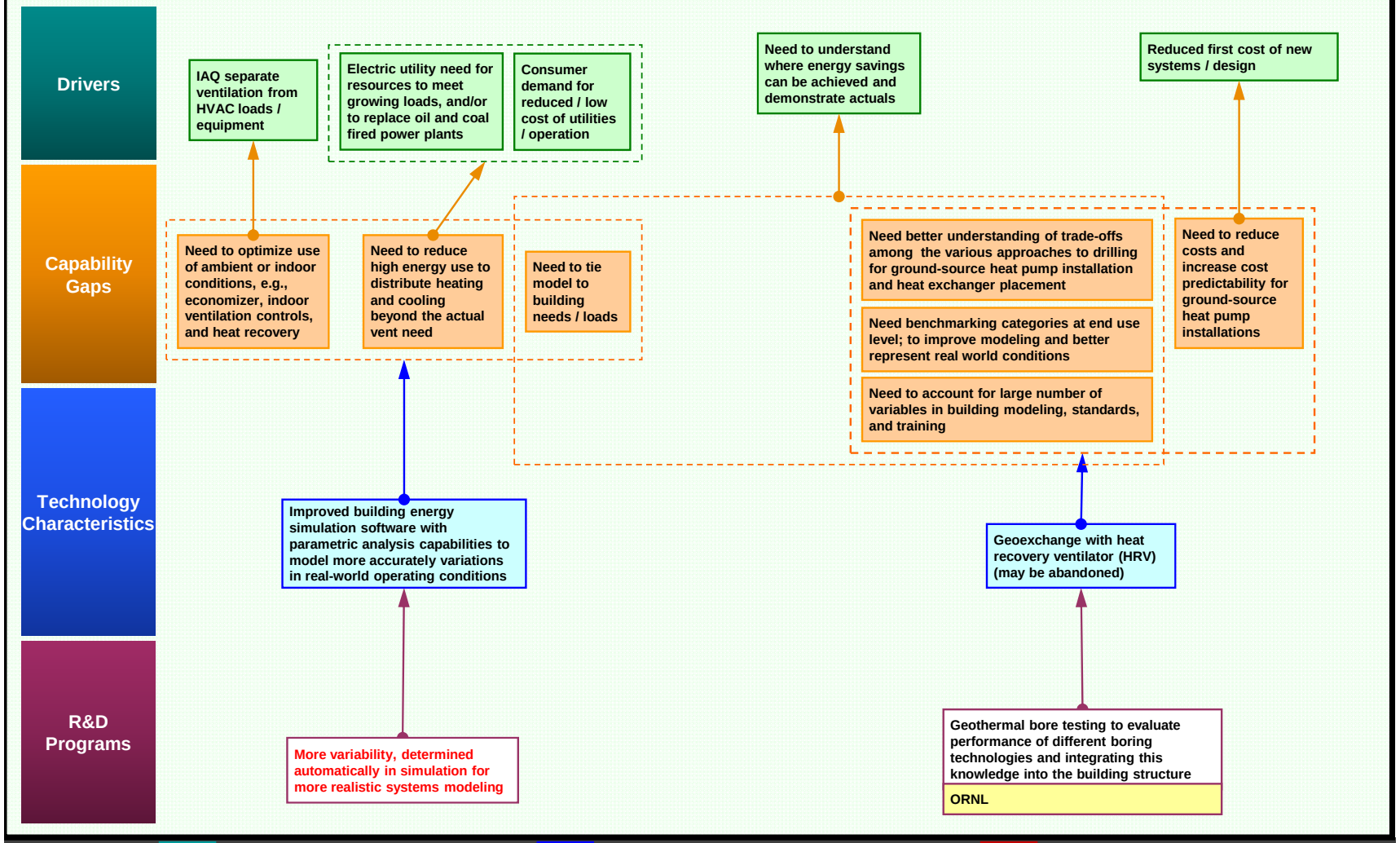
- MountainLogic, Inc., is working on a project funded by the BPA Technology Innovation office to develop a retrofit solution for central forced air HVAC systems that will provide predictive occupancy residential zone control. See Appendix B for more information.

Product/Service Area : **HEATING, VENTILATION, AND AIR CONDITIONING (HVAC)**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Modeling, Lab and Field Testing (2 of 2)**

Roadmap Definitions on pages ix-xii



Driver | Capability Gap | Commercially Available Technology | Commercially Unavailable Technology | Existing R&D Program or Project | R&D Program Requirement

R&D Project Summaries

Geothermal bore testing for different boring technology performance, integrating into the building structure: It would be worthwhile to have some good data on what kind of drilling is generally most cost-effective under certain conditions for geothermal heating and cooling systems. Test the different methods against each other for cost-effectiveness. If not already available, develop a best practices guide for what conditions favor which drilling techniques.

- In January 2011, E Source offered the following citations on work that may be relevant:
  - Harvey M. Sachs, *Geology and Drilling Methods for Ground-Source Heat Pump Installations: An Introduction for Engineers* (Atlanta, Ga.: American Society of Heating, Refrigerating, and Air-Conditioning Engineers, 2002).
  - Kevin B. McCray, "Guidelines for the Construction of Vertical Boreholes for Closed Loop Heat Pump Systems," (Westerville, Ohio: National Ground Water Association, n.d.) (http://intraweb.stockton.edu/eyos/energy_studies/content/docs/proceedings/MCCRA.PDF).
  - Publications through the National Groundwater Association (www.ngwa.org).

More variability, determined automatically in simulation for more realistic systems modeling: Building modeling for design has been a great boon to designing energy-efficient buildings, but there is much room for improvement. We need to develop the capability to program-in more variability for specific building conditions. Ideally, the program could anticipate some of the specific features. We should also make it much easier to try out alternative scenarios and perhaps have modules that would automatically suggest design optimization options.

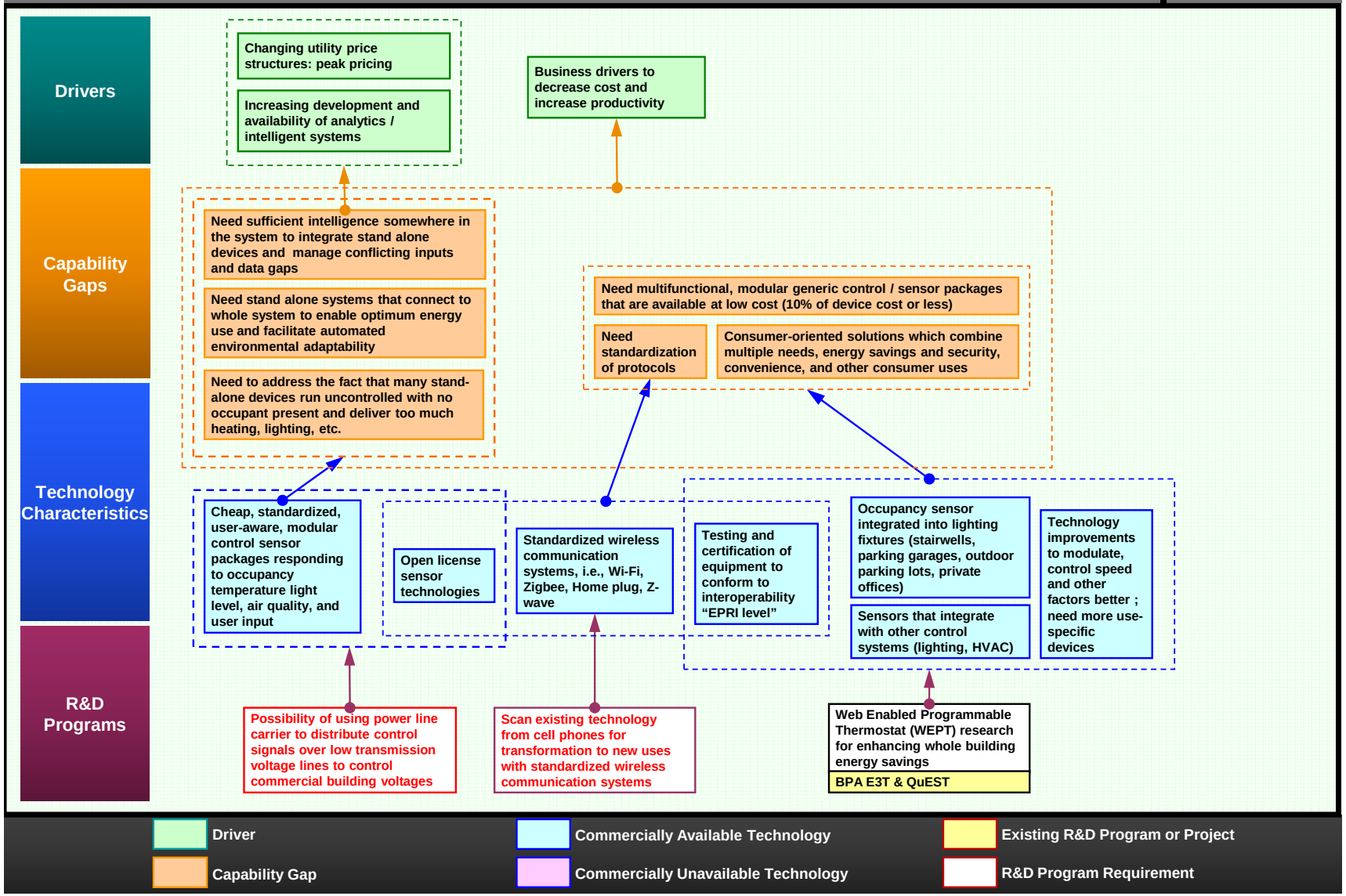
Sensors, Meters, and Energy Management System Roadmaps

Product/Service Area : **SENSORS, METERS, & ENERGY MANAGEMENT SYSTEMS**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Smart Device-Level Controls Responsive to User and Environment**

Roadmap Definitions on pages ix-xii



R&D Project Summaries

Web Enabled Programmable Thermostat (WEPT) research for enhancing whole building energy savings: Web-enabled programmable thermostats that control HVAC equipment can help deliver significant reductions in electricity use.

- Bonneville Power Administration's Energy Efficiency Emerging Technology (E3T) team is working with Quantum Energy Services (QuEST) and the Clark Public Utilities District to evaluate WEPT systems in modular classroom buildings at Several Washington State School Districts and develop a whole-building regression analysis tool to estimate and verify HVAC savings; see http://www.bpa.gov/energy/n/emerging_technology/WEPT.cfm.

Scan existing technology from cell phones for transformation to new uses with standardized wireless communication systems: Cell phones are now ubiquitous and versatile. Being able to send alarms to cell phones or change control settings via cell phone would add to the convenience of control systems. Additionally, operators may pay more attention to control systems without being distracted from other tasks. There is a need to identify current technologies before developing new systems.

- One example of such a system is the iPhone app for General Motors' Chevrolet Volt electric vehicle that allows users to monitor charging status and can be notified when charging ends (either on-schedule or prematurely). This system seems like it could easily lend itself to vehicle controllability via GM's On Star system. See http://gm-volt.com/2009/12/10/chevy-volt-will-connect-to-blackberry-iphone-and-apps/, http://www.chevrolet.com/volt-electric-car/. E Source reported in February 2011 that this application of cell phone technology appeared to be the only such project currently in development.

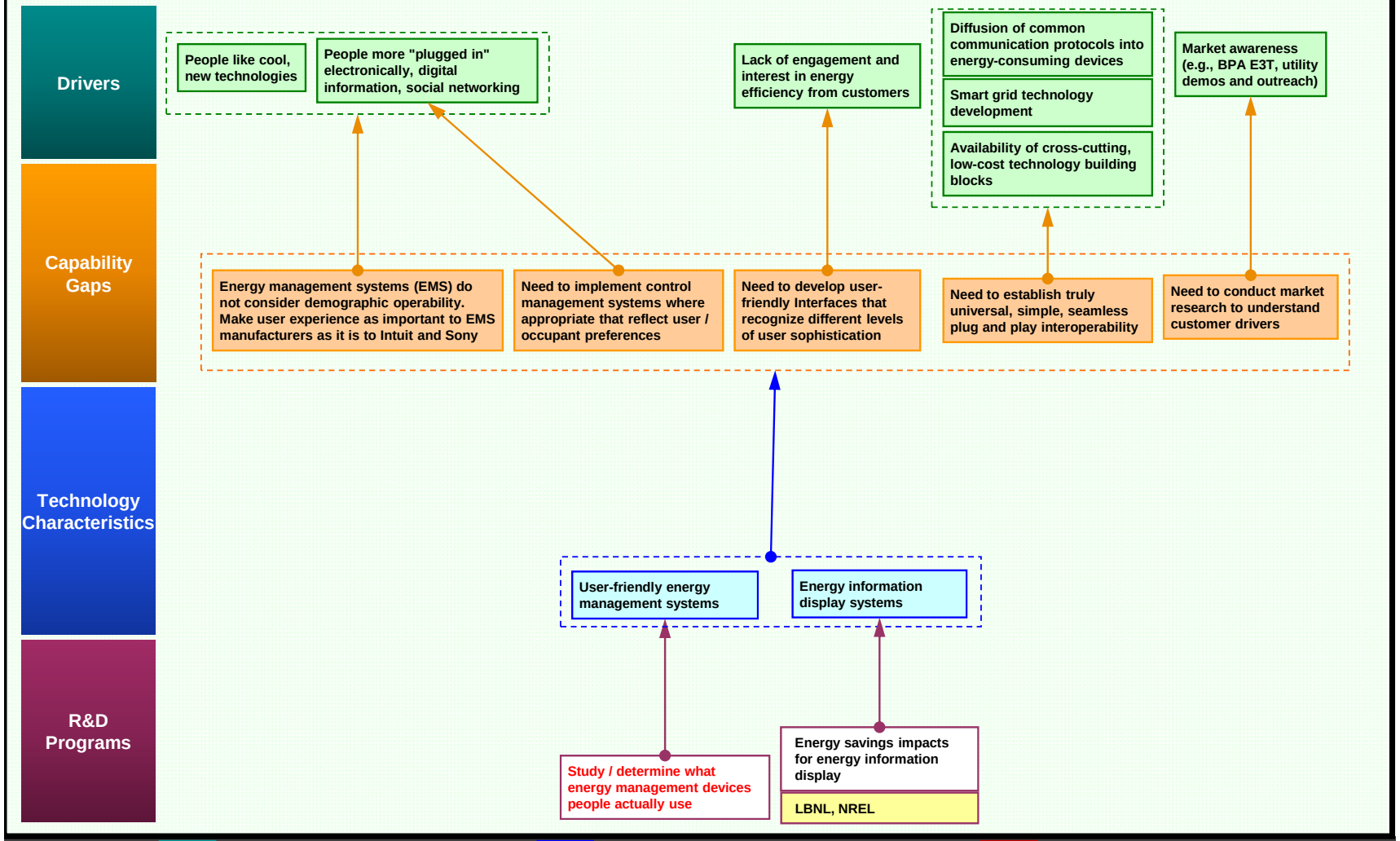
Possibility of using power line carrier to distribute control signals over low transmission voltage lines to control commercial building voltages: The attraction of power line carrier signals for controls is compelling. Power lines are available virtually wherever control is needed. This eliminates the need for installing an additional set of wires or more expensive wireless equipment. If barriers to implementing this in commercial applications could be removed, it could simplify and reduce the cost of installation of controls, especially for retrofit. Stakeholders asked originally if the Northwest Energy Technology Collaborative (NETC) was doing work in this area; since the publication of the 2011 Northwest Energy Efficiency Technology Roadmap Portfolio, the Northwest Energy Technology Collaborative (NETC) has become Innovate Washington (IW, http://innovatewashington.org/), and IW staff are not themselves doing research in this area nor are they aware of previous NETC research.

Product/Service Area : **SENSORS, METERS, & ENERGY MANAGEMENT SYSTEMS**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Easy / Simple User Interface Controls**

Roadmap Definitions on pages ix-xii



R&D Project Summaries

Energy savings impacts for energy information display: R&D and pilot tests are ongoing in this area to determine the persistence of energy efficiency savings of in-home energy displays (IHDs).

- Researchers at the Brattle Group reviewed twelve utility pilot programs in the U.S.A., Canada, and Japan focused on the energy conservation impact of IHDs and customer receptivity to these technologies. They conclude that consumers are more likely to use energy up to 7% more efficiently with the direct feedback provided by IHDs, and up to 14% more efficiently when IHDs are coupled with an electricity prepayment system. This study of pilot programs also finds that IHD feedback has positive time-of-use rates impacts upon demand response programs. See Ahmad Faruqui, Sanem Sergici, and Ahmed Sharif, "The Impact of Informational Feedback on Energy Consumption: A Survey of the Experimental Evidence," Energy 35 (2010), 1598-1608.
- Alan Meier, Senior scientist in the Energy Analysis Department of the Lawrence Berkeley National Laboratory (LBNL), studies ways to reduce energy consumption by analyzing how both people and equipment use energy. His research involves buildings, equipment and, transportation, including residential thermostats and real-time energy displays. See http://eetd.lbl.gov/ea/akmeier//.

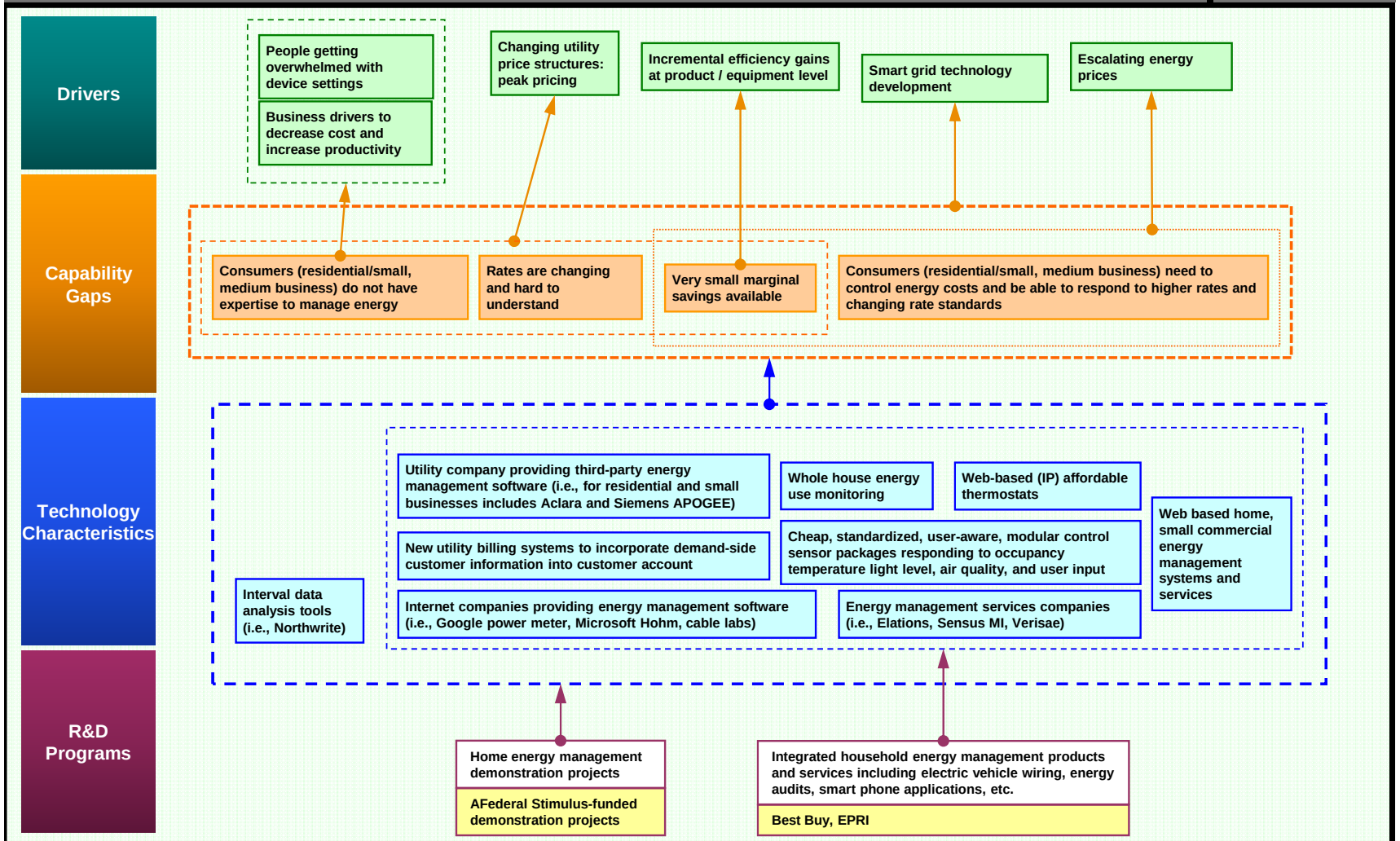
Study/determine what energy management devices people actually use: E Source reported in February 2011 that, to date, there has been much more research about which energy management devices (EMDs) people do not use, and little positive research relating to which EMDs people actually do use. This research suggests that consumers' good intentions in buying programmable thermostats, ECM furnaces, and other products do not often lead to overall energy savings because many consumers do not use take full advantage of the products' features or use the features incorrectly.

Product/Service Area : **SENSORS, METERS, & ENERGY MANAGEMENT SYSTEMS**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Energy Management Services**

Roadmap Definitions on pages ix-xii



Driver
Capability Gap
Commercially Available Technology
Commercially Unavailable Technology
Existing R&D Program or Project
R&D Program Requirement

R&D Project Summaries

Home energy management demonstration projects: One of the foci of the federal stimulus package (American Recovery and Reinvestment Act (ARRA) of 2009, Public Law 111-5) was to foster energy efficiency by promoting and/or funding good home energy management (http://www.recovery.gov/Pages/default.aspx). An action item from the March 2011 Northwest Energy Efficiency Technology Roadmap Portfolio was to identify underway stimulus-funded projects both for the potential collaboration and to see if more funding is available. This research found that the federal Smart Grid Investment Grant Program closed August 2009 (http://www.grants.gov/search/search.do?mode=VIEW&oppId= 46833), and also identified three specific stimulus-funded projects:

- A search on the U.S. government's official website tracking Recovery Act spending (Recovery.gov) for the phrase "home energy management" returned hits for two projects:
  - Central Lincoln People's Utility District (Newport, Lincoln County, OR): Smart Grid Investment Grant Program (EISA 1306) Award Number OE0000370 for $9,936,950 in grants through the U.S. Dept. of Energy. Awarded in April 2010. Project to provide two-way communication between the utility and its 38,000 customers by building a smart grid network and other in-home energy management tools. As of January 2012, this project was less than 50% complete (http://www.recovery.gov/Transparency/RecipientReportedData/Pages/RecipientProjectSummary508.aspx?AwardIDSUR=102718&qtr=2011Q3).
  - Indianapolis Power and Light Company (Indianapolis, Marion County, IN): Smart Grid Investment Grant Program (EISA 1306) Award Number OE0000273 for $20,000,000 in grants through the U.S. Dept. of Energy. Awarded in April 2010. Project to install Advanced Metering Infrastructure, Customer Systems, and Electric Distribution System improvements to save energy, reduce peak demand, and improve reliability. As of January 2012, this project was more than 50% complete (http://www.recovery.gov/Transparency/RecipientReportedData/Pages/RecipientProjectSummary508.aspx?AwardIDSUR=107979&qtr=2011Q3).
- The U.S. Department of Energy's Recovery Act website (http://energy.gov/recovery-act) reports one home energy management initiative funded by the Recovery Act:
  - The Center for Commercialization of Electric Technology (CCET) in Austin, Texas (http://electrictechnologycenter.com/) received stimulus funds for its Smart Grid Regional Demonstration Project (http://electrictechnologycenter.com/reports.html). This project sought to increase system monitoring capabilities, improve operator visualization, and enhance load management through a variety of measures including home energy management systems (http://electrictechnologycenter.com/reports.html, http://energy.gov/articles/texas-uses-phasors-increase-electricity-reliability). June 2010 project report summary available at http://electrictechnologycenter.com/pdf/TS_WG%20ERCOT.pdf.

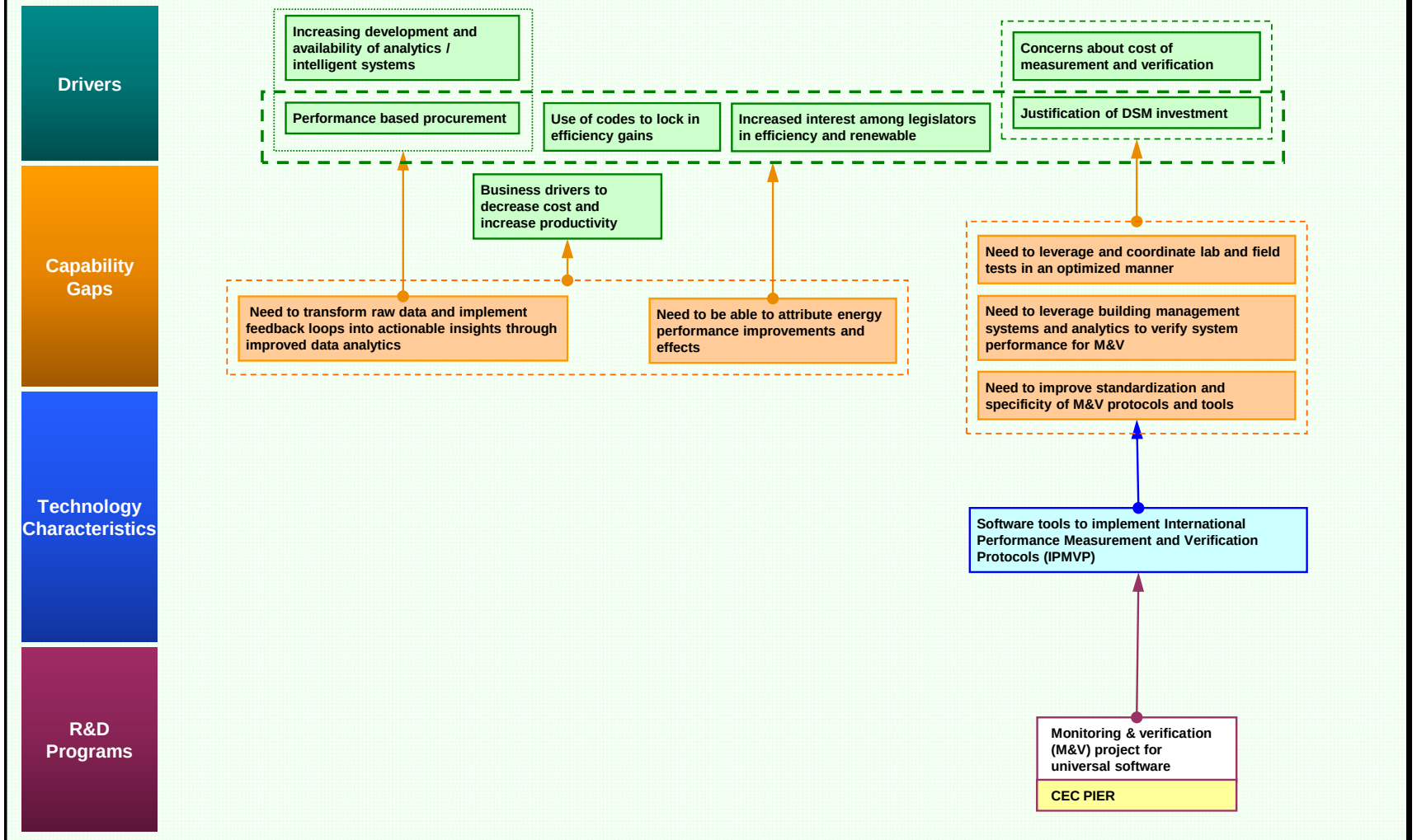
Integrated household energy management products and services including electric vehicle wiring, energy audits, smart phone applications, etc.: In November 2011, Minnesota-based Best Buy, Inc., introduced an enhanced Home Energy Management Department that provides tools and education through easily-accessible on-site and online sources (http://www.bestbuy.com/site/regularCat%3Apcmcat257000050007/Home-Energy-Why-Best-Buy/pcmcat257000050007.c?id=pcmcat257000050007). This approach could serve as a useful model for how to engage the under-served residential energy management market.

Product/Service Area : **SENSORS, METERS, & ENERGY MANAGEMENT SYSTEMS**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Low-Cost Savings Verification Techniques**

Roadmap Definitions on pages ix-xii



Monitoring and verification (M&V) project for universal software:

Universal software protocol for monitoring and verification (M&V) would increase the reliability of measurements from complex systems, simplify implementation, and reduce costs for savings verification procedures.

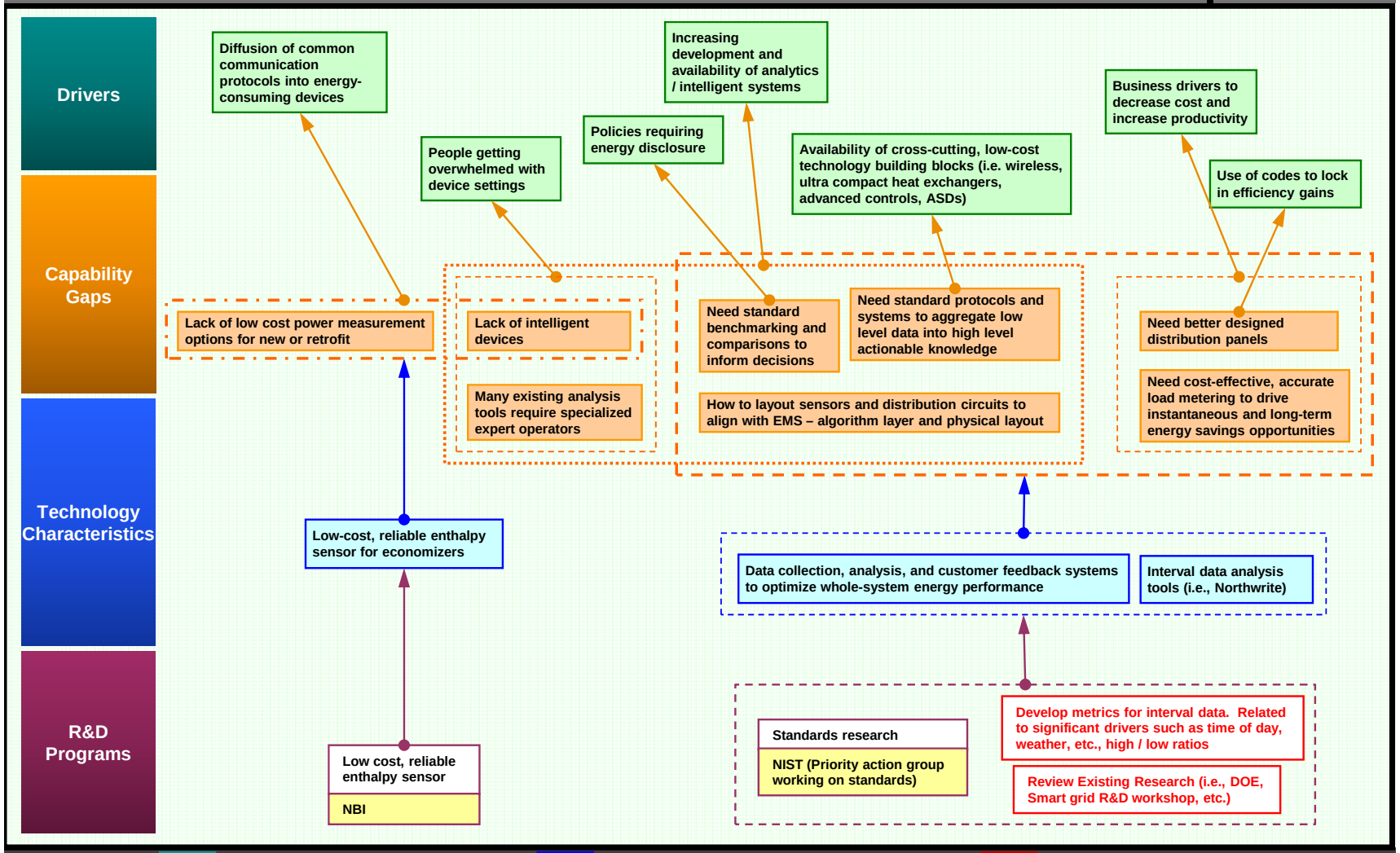
- The California Energy Commission's Public Interest Energy Research (PIER) program is currently working on that makes use of Pacific Gas & Electric's Universal Translator tool; see Appendix B for more information.

Product/Service Area : **SENSORS, METERS, & ENERGY MANAGEMENT SYSTEMS**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Real-time Smart Electric Power Measurement of Facilities**

Roadmap Definitions on pages ix-xii



R&D Project Summaries

Low cost, reliable enthalpy sensor: A low-cost, reliable enthalpy sensor would help gather much needed information for energy analysis. Stakeholders have indicated that work is ongoing in this area at the New Buildings Institute (http://newbuildings.org/), but as of Feb. 2012, no further information on such efforts have been uncovered.

Standards research: Developing standards for measuring facility energy use would help simplify and standardize energy measurement. Work with the National Institute of Standards and Technology (NIST) priority action group to help develop useful standards.

Develop metrics for interval data. Related to significant drivers such as time of day, weather, etc., high/low ratios: The first step to analyzing energy use is good data. Developing standardized metrics will help make the information more accessible, and make it easier for more people to be able to analyze the data.

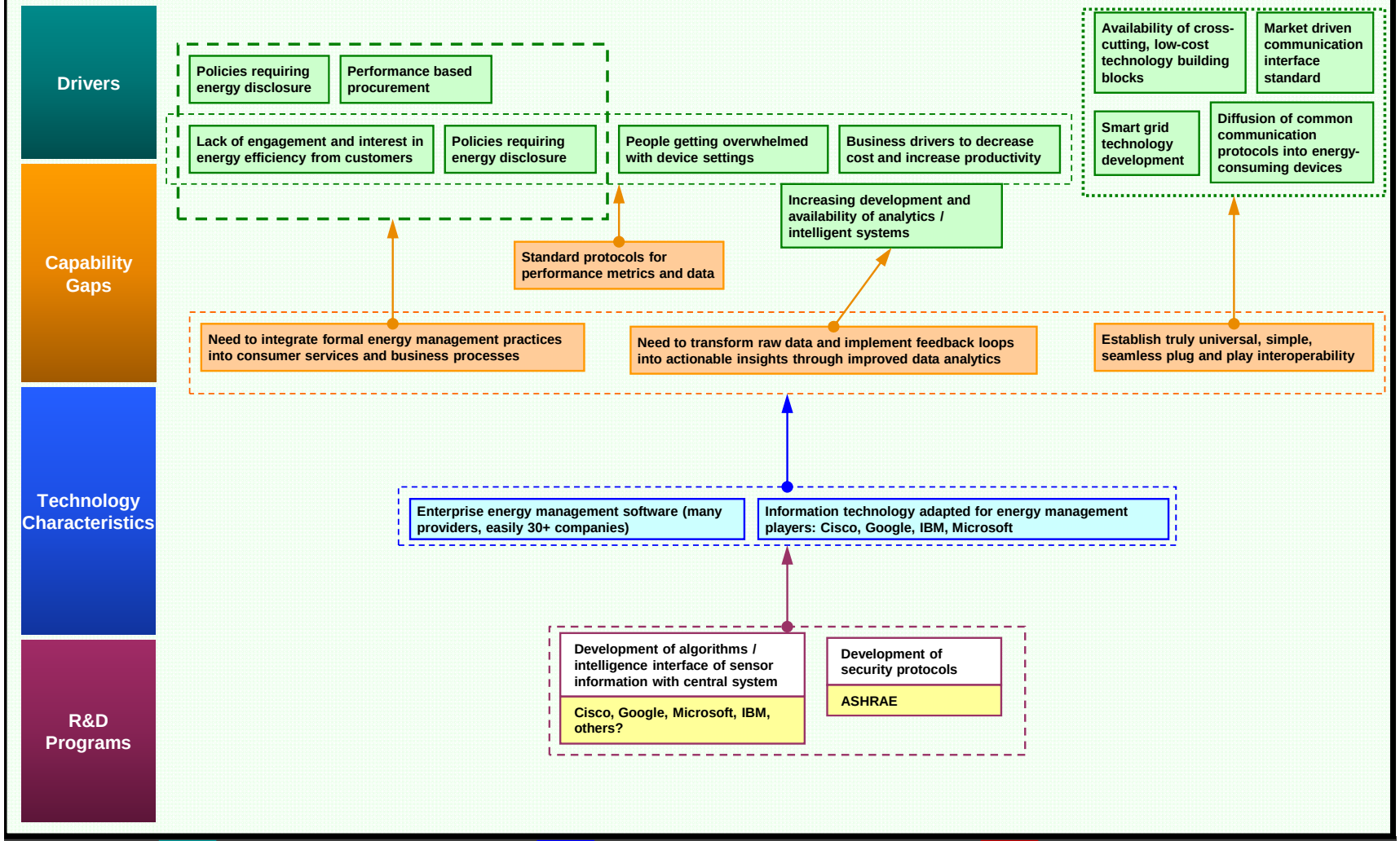
Review existing research on real-time smart electric power measurement of facilities: Some smart electric power measurement technologies are already available. Before putting too many resources into research, it would be worthwhile to do a thorough assessment of tools and systems that are already available, i.e., from the U.S. Department of Energy's smart grid R&D workshop.

Product/Service Area : **SENSORS, METERS, & ENERGY MANAGEMENT SYSTEMS**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Enterprise Energy and Maintenance Management Systems**

Roadmap Definitions on pages ix-xii



Development of security protocols: In developing and promulgating enterprise energy management systems, it is very desirable to standardize protocols for multiple reasons, including ways to communicate with a central system and for security. Stakeholders indicate that the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) is working on this. Other enterprises who are doing work in this area include Cisco, Google, IBM, Microsoft, and others; ongoing research from private firms tends largely to be proprietary and, therefore, not thoroughly or consistently reported through companies' web pages.

- Information about ASHRAE's work in this area is not readily apparent through their website; Bonneville Power Administration staff queried ASHRAE as of Feb. 2012 and are still awaiting reply.

Development of algorithms / intelligence interface of sensor information with central system: In developing and promulgating enterprise energy management systems, it is very desirable to standardize protocols for multiple reasons, including ways to communicate with a central system. Many programs and enterprises are working on this, including Cisco, Google, IBM, Microsoft, and others; ongoing research from private firms tends largely to be proprietary and, therefore, not thoroughly or consistently reported through companies' web pages.

- Some information about the work of Microsoft Research's Sensing and Energy Research Group in this area can be found in Appendix B.

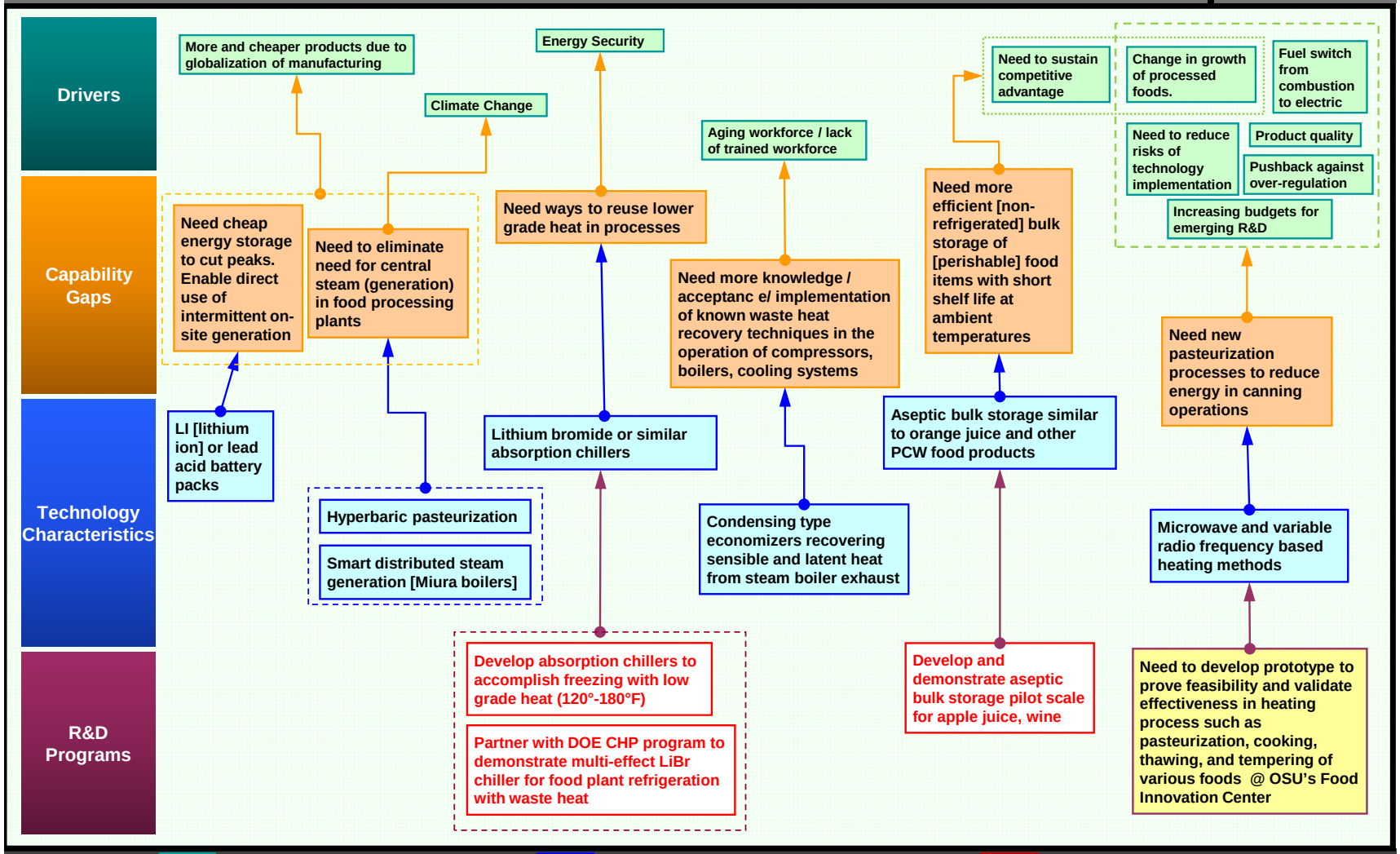
Industrial Food Processing Roadmaps

Product/Service Area : **Industrial Food Processing**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Heating (1of 2)**

Roadmap Definitions on pages ix-xii



R&D Project Summaries

- [ ] **Need to develop prototype to prove feasibility and validate the effectiveness in heating process** such as: pasteurization, cooking, thawing, tempering of various foods. Ongoing R&D in this area at Oregon State University's Food Innovation Center (http://fic.oregonstate.edu/).

- [ ] **Develop absorption chillers to accomplish freezing with low grade heat (120-180F).**

- [ ] **Develop and demonstrate aseptic bulk storage pilot scale for apple juice, wine.**

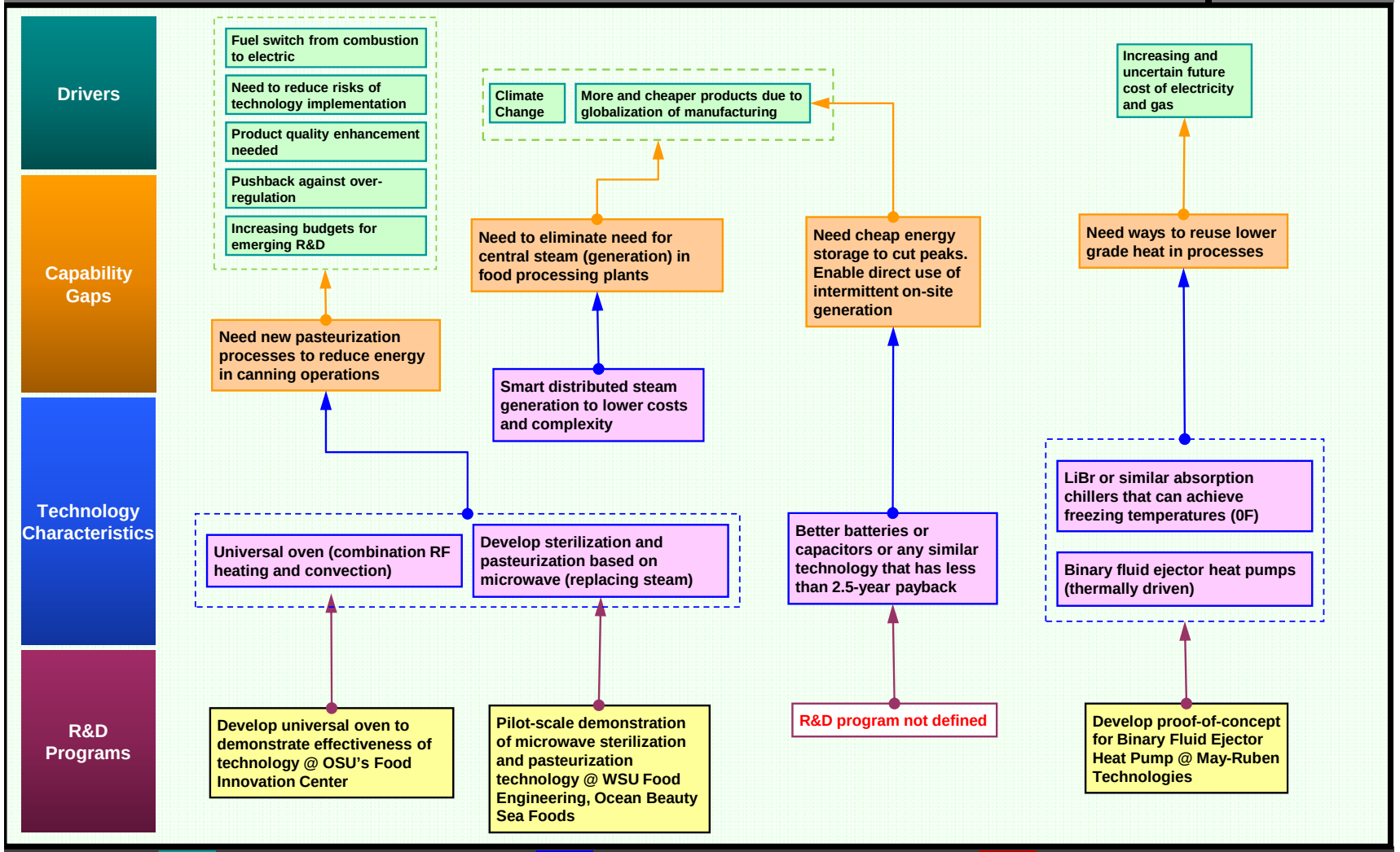
- [ ] **Partner with DOE CHP program to demonstrate multi-effect lithium bromide (LiBr) chiller for food plant refrigeration with waste heat.**

Product/Service Area : **Industrial Food Processing**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Heating (2of 2)**

Roadmap Definitions on pages ix-xii



R&D Project Summaries

Develop proof-of-concept for Binary Fluid Ejector Heat Pump. R&D ongoing at May-Ruben Technologies (http://may-rubentechnologies.com/), contact Research Support Officer Chelsea Ruben, http://may-rubentechnologies.com/index.php?option=com_content&view=article&id=76&Itemid=116.

Develop universal oven to demonstrate effectiveness of technology. Ongoing R&D in this area at Oregon State University's Food Innovation Center (http://fic.oregonstate.edu/).

Pilot-scale demonstration of microwave sterilization and pasteurization technology. Ongoing R&D in this area involving the Food Engineering team of Washington State University's (WSU) Biological Systems Engineering department (http://bsyse.wsu.edu/core/research/Emphasis/Food/Food.html), and at Ocean Beauty Sea Foods, LLC (http://www.oceanbeauty.com/).

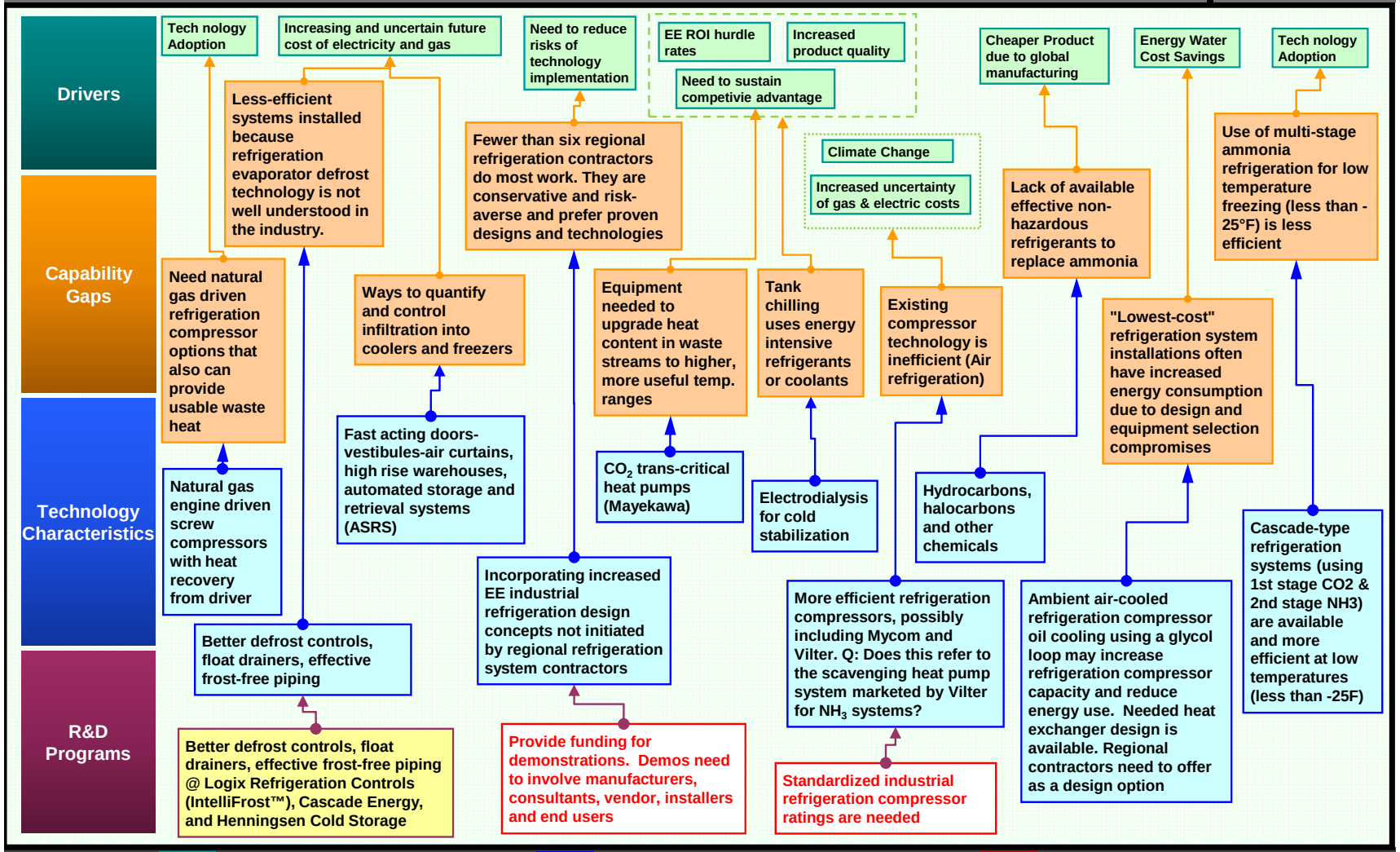
Better batteries or capacitors or any similar technology that has less than 2.5-year payback. Stakeholders did not define a prospective R&D program for this currently unavailable technology.

Product/Service Area : **Industrial Food Processing**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Cooling (1 of 2)**

Roadmap Definitions on pages ix-xii



R&D Project Summaries

Better defrost controls, float drainers, effective frost-free piping: Stakeholders referred to R&D that includes Logix Refrigeration Controls' IntelliFrost™ product and work at Cascade Energy and Henningsen Cold Storage.

- Logix® IntelliFrost™ Automatic Defrost System: http://www.logix-controls.com/docs/Logix_IntelliFrost_ Technical_Brief.pdf.
- Cascade Energy: http://www.cascadeenergy.com/default.asp.
- Henningsen Cold Storage: henningsen.com.

Provide funding for demonstrations. Demos need to involve manufacturers, consultants, vendor, installers and end users.

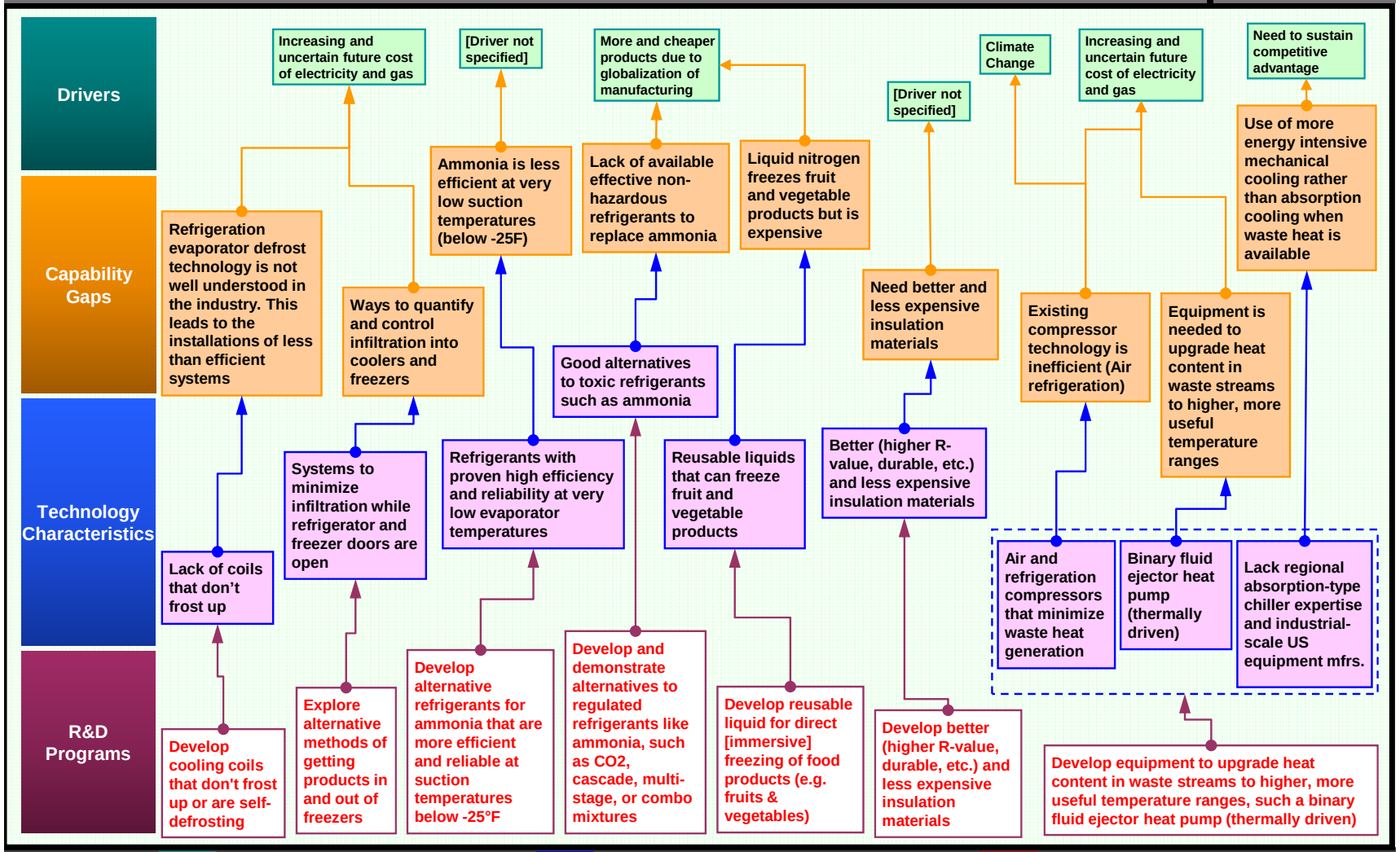
Standardized industrial refrigeration compressor ratings are needed.

Product/Service Area : **Industrial Food Processing**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Cooling (2 of 2)**

Roadmap Definitions on pages ix-xii



R&D Project Summaries

- [ ] Develop alternative refrigerants for ammonia that are more efficient and reliable at suction temperatures below -25°F.

- [ ] Develop and demonstrate alternatives to regulated refrigerants like ammonia, such as CO2, cascade, multi-stage, or combo mixtures.

- [ ] Develop better (higher R-value, durable, etc.) and less expensive insulation materials.

- [ ] Develop cooling coils that don't frost up or are self-defrosting.

- [ ] Develop equipment to upgrade heat content in waste streams to higher, more useful temperature ranges, such a binary fluid ejector heat pump (thermally driven).

- [ ] Develop reusable liquid for direct [immersive] freezing of food products (e.g. fruits & vegetables).

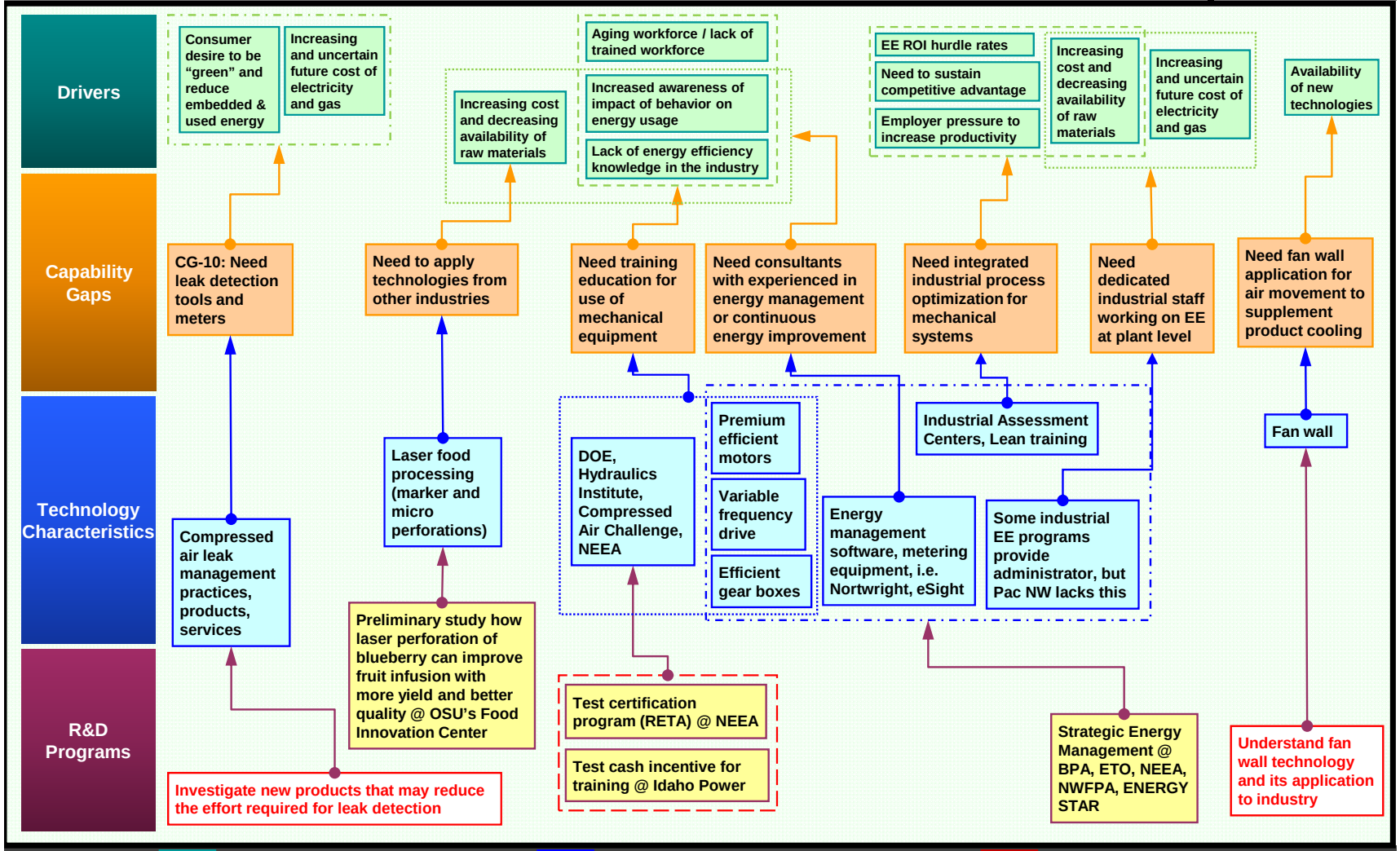
- [ ] Explore alternative methods of getting products in and out of freezers.

Product/Service Area : **Industrial Food Processing**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Mechanical (1 of 2)**

Roadmap Definitions on pages ix-xii



R&D Project Summaries

Preliminary study how laser perforation of blueberry can improve fruit infusion with more yield and better quality. Ongoing R&D in this area at Oregon State University's Food Innovation Center (http://fic.oregonstate.edu/).

Strategic Energy Management. The Northwest Energy Efficiency Alliance (NEEA), the ENERGY STAR program, Bonneville Power Administration (BPA), and the Northwest Food Processors Association (NWFPA) are involved in developing Strategic Energy Management solutions.

- NEEA's work in this area includes a Strategic Energy Management study they released in January 2012; see http://neea.org/research/reportdetail.aspx?ID=1619.
- ENERGY STAR Strategic Energy Management approach: http://www.energystar.gov/index.cfm?c=guidelines.guidelines_index.
- BPA Energy Efficiency staff are working in this area ().
- NWFPA's work in this area can be found at http://www.nwfpa.org/nwfpa.info/component/content/article/37-boiler/55--energy-roadmap-projects-put-nwfpa-membership-on-the-road-.

Test cash incentive for training. Stakeholders indicated that the Northwest Energy Efficiency Alliance (NEEA) is working in this area; see http://neea.org/.

Test certification program. Refrigerating Engineers & Technicians Association (RETA), http://www.reta.com/; see also the Northwest Energy Efficiency Alliance (NEEA); http://neea.org/.

Investigate new products that may reduce the effort required for leak detection.

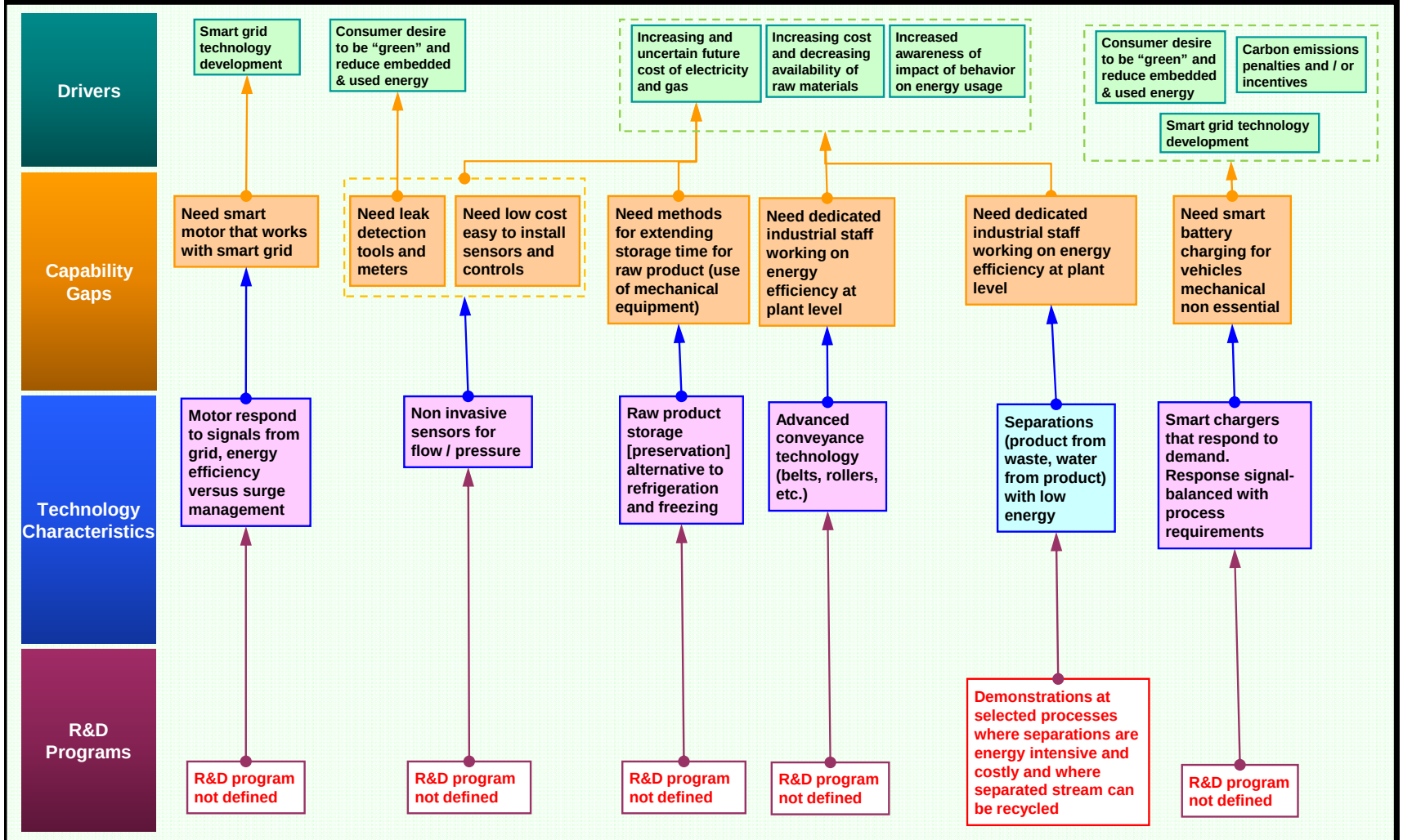
Understand the fan wall technology and its application to industry.

Product/Service Area : **Industrial Food Processing**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Mechanical (2 of 2)**

Roadmap Definitions on pages ix-xii



R&D Project Summaries

- [ ] Advanced conveyance technology (belts, rollers, etc.).

- [ ] Demonstrations at selected processes where separations are energy intensive and costly and where separated stream can be recycled.

- [ ] Motor respond to signals from grid, energy efficiency versus surge management.

- [ ] Non invasive sensors for flow / pressure.

- [ ] Raw product storage [preservation] alternative to refrigeration and freezing.

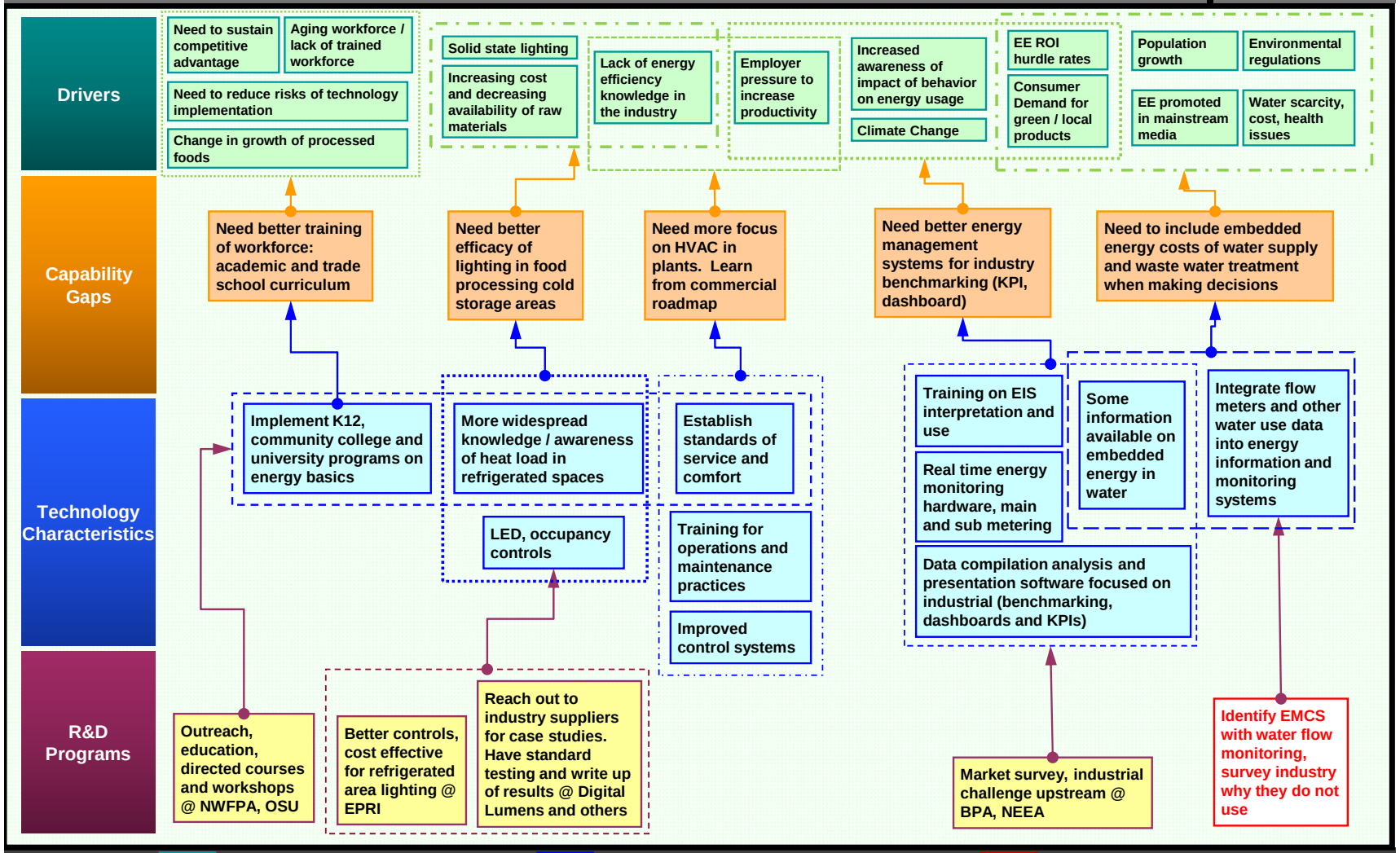
- [ ] Smart chargers that respond to demand. Response signal-balanced with process requirements.

Product/Service Area : **Industrial Food Processing**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Infrastructure (1 of 3)**

Roadmap Definitions on pages ix-xii



R&D Project Summaries

Better controls, cost effective for refrigerated area lighting. Ongoing R&D at the Electric Power Research Institute (EPRI, http://et.epri.com/index.html).

Outreach, education, directed courses and workshops. Ongoing R&D at the Northwest Food Processors Association (NWFPA, http://www.nwfpa.org/) and in Oregon State University's (OSU) Department of Food Science and Technology (http://oregonstate.edu/dept/foodsci/extservices/ext_index.htm).

Market survey, industrial challenge upstream. Ongoing R&D at the Bonneville Power Administration's (BPA) Energy Efficiency department (http://www.bpa.gov/Energy/N/) and the Northwest Energy Efficiency Alliance (NEEA, http://neea.org/).

Reach-out to industry suppliers for case studies. Have standard testing and write up of results. Stakeholders indicated ongoing R&D at Digital Lumens (www.digitallumens.com) and others.

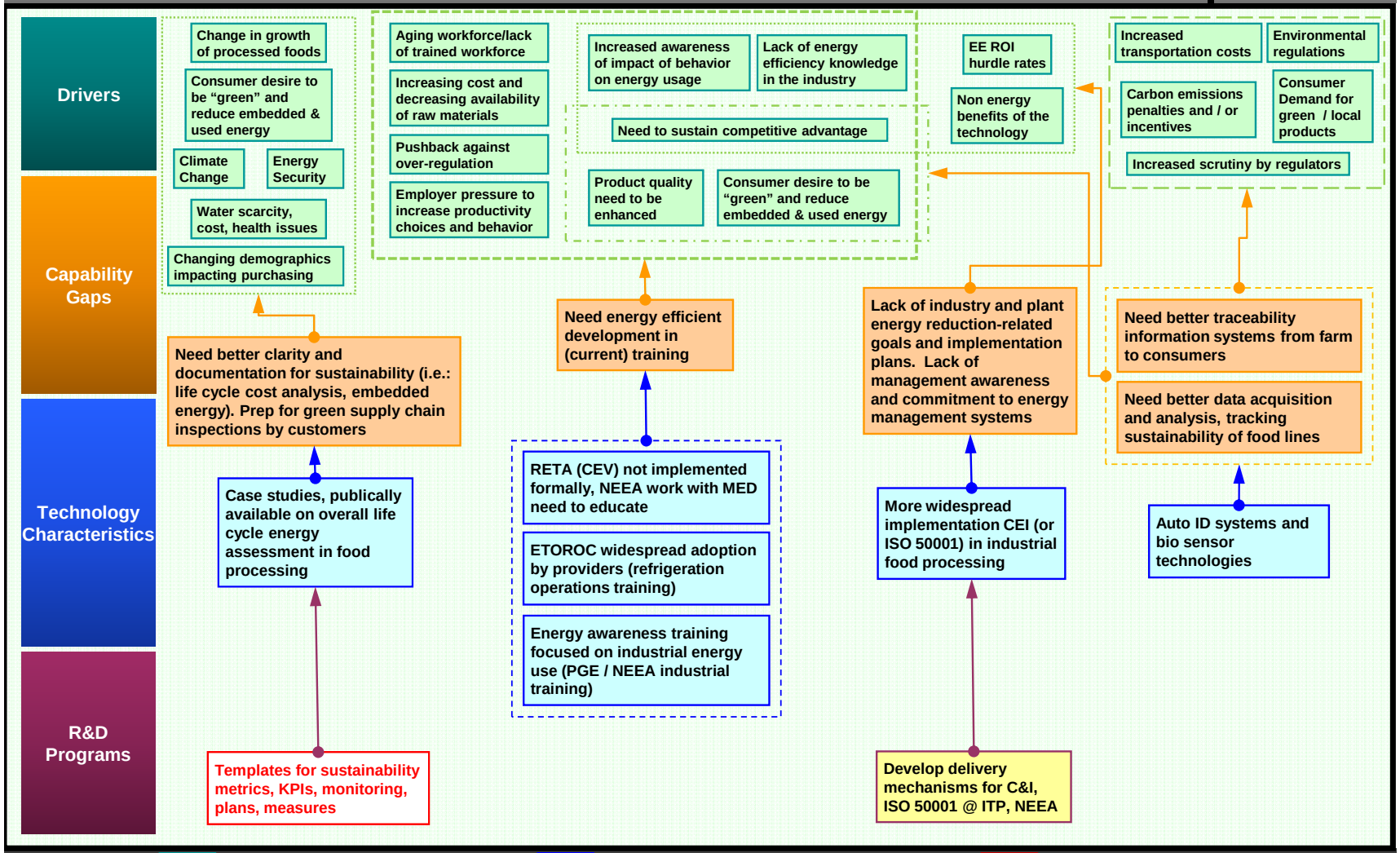
Identify EMCS with water flow monitoring, survey industry why they do not use.

Product/Service Area : **Industrial Food Processing**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Infrastructure (2 of 3)**

Roadmap Definitions on pages ix-xii



R&D Project Summaries

Develop delivery mechanisms for C&I, ISO 50001. Research in this area is ongoing at the U.S. Department of Energy's (DOE) Advanced Manufacturing Office (AMO, formerly known as the Industrial Technologies Program or ITP; see http://www1.eere.energy.gov/ manufacturing/) and Northwest Energy Efficiency Alliance (NEEA, http://neea.org/).

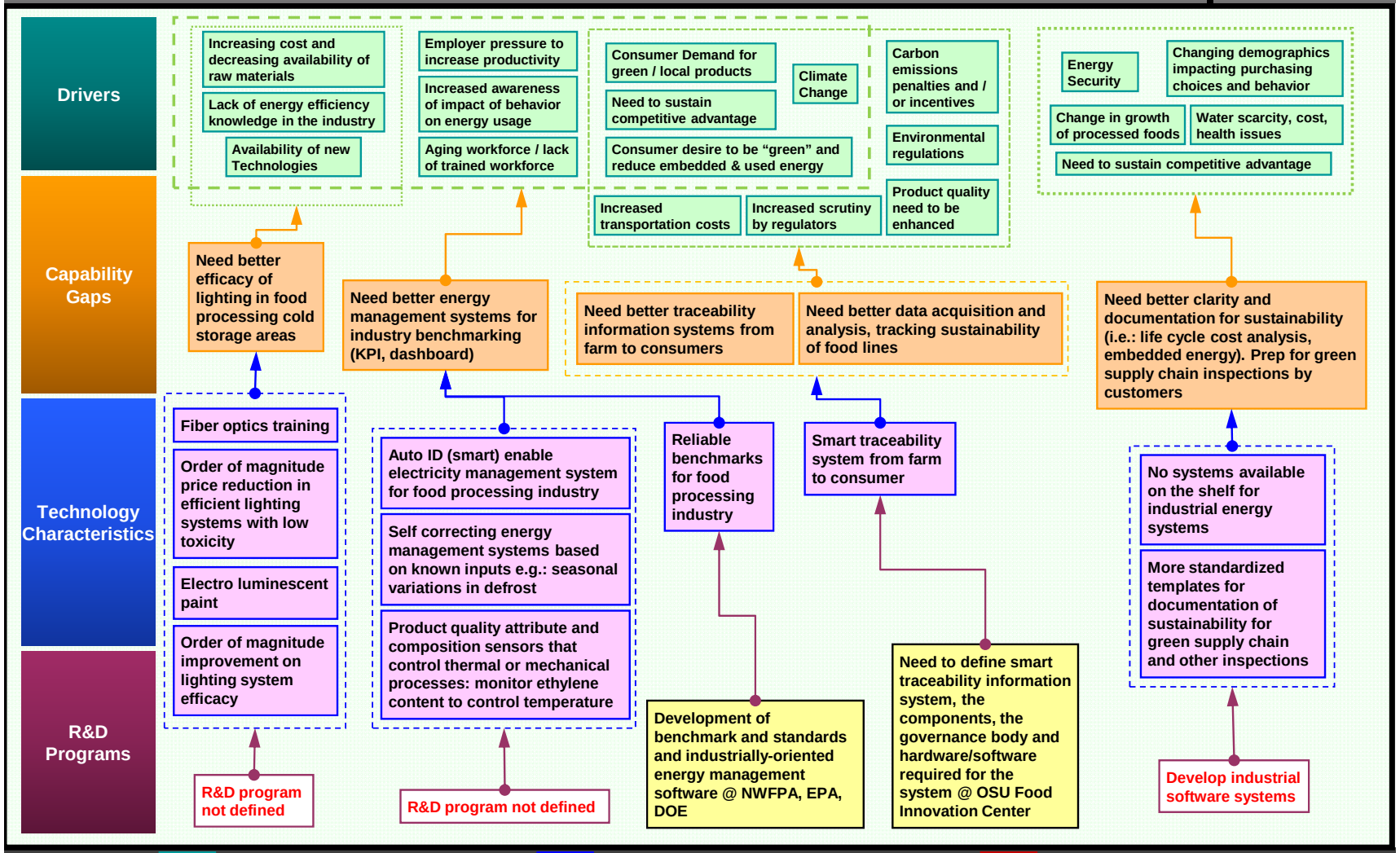
Templates for sustainability metrics, KPIs, monitoring, plans, measures.

Product/Service Area : **Industrial Food Processing**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Infrastructure (3 of 3)**

Roadmap Definitions on pages ix-xii



R&D Project Summaries

Development of benchmark and standards and industrially-oriented energy management software. Research ongoing at the Northwest Food Processors Association (NWFPA, http://www.nwfpa.org/) and at the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Energy (DOE) [is this EPA-DOE collaboration the ENERGY STAR program? See http://www.energystar.gov/index.cfm?c=home.index).

Need to define smart traceability information system, the components, the governance body and hardware/software required for the system. Research is ongoing at the Oregon State University (OSU) Food Innovation Center (http://fic.oregonstate.edu/).

Develop industrial software systems. Stakeholders did not define a potential R&D area for this area.

Need better efficacy of lighting in food processing cold storage areas. Stakeholders did not define a potential R&D area for this area.

Need better energy management systems for industry benchmarking (KPI, dashboard). Stakeholders did not define a potential R&D area for this area.

Combined Heat and Power (CHP) Roadmaps

Selected Sources Regarding Combined Heat and Power Research and Development in the United States

BCS, Incorporated, *Waste Heat Recovery: Technology and Opportunities in U.S. Industry*. Washington, D.C.: U.S. Department of Energy Industrial Technologies Program, March 2008.

Energy and Environmental Analysis, Inc., "Combined Heat and Power Installation Database," [last updated May 10, 2010], http://www.eea-inc.com/chpdata/, accessed March 2, 2012.

Heat is Power, http://www.heatispower.org/.

Anna Shipley, Anne Hampson, Bruce Hedman, Patti Garland, and Paul Bautista. *Combined Heat and Power: Effective Energy Solutions for a Sustainable Future*. ORNL/TM-2008/224. Oak Ridge, Tenn.: Oak Ridge National Laboratory, Dec. 2008.

William Steigelmann and Barry Hinkle, "CHP: The 'Ugly Duckling' of Energy Efficiency," Report 1335, International Energy Program Evaluation Conference, 2009, http://www.cee1.org/eval/db_pdf_es/1335es.pdf.

U.S. Clean Heat and Power Association, http://www.uschpa.org/i4a/pages/index.cfm?pageid=1.

U.S. Clean Heat and Power Association, "National CHP Roadmap: Doubling Combined Heat and Power Capacity in the United States by 2010," March 2001, http://www1.eere.energy.gov/manufacturing/distributedenergy/pdfs/chp_national_roadmap.pdf, accessed March 2, 2012.

U.S. Environmental Protection Agency. "Combined Heat and Power Partnership." http://www.epa.gov/chp/.

U.S. Department of Energy Northwest Clean Energy Application Center. http://www.chpcenternw.org/.

Combined Heat and Power and Waste Heat Recovery Policy Landscape in the Pacific Northwest

To develop a more nuanced idea of what barrier(s) exist for CHP and waste heat recovery development in the Pacific Northwest, in late 2011 Bonneville Power Administration staff began developing a "Combined Heat and Power / Waste Heat Recovery Policy Landscape Report." External stakeholders will provide critical commentary to the draft report prior to its completion, tentatively scheduled for early 2013.

Once completed, the Policy Landscape Report will be paired with the CHP Energy Efficiency Technology Roadmap to provide regional stakeholders with a much more complete understanding of the technology and policy barriers associated with any future investments in combined heat and power and waste heat recovery systems.

Product/Service Area :

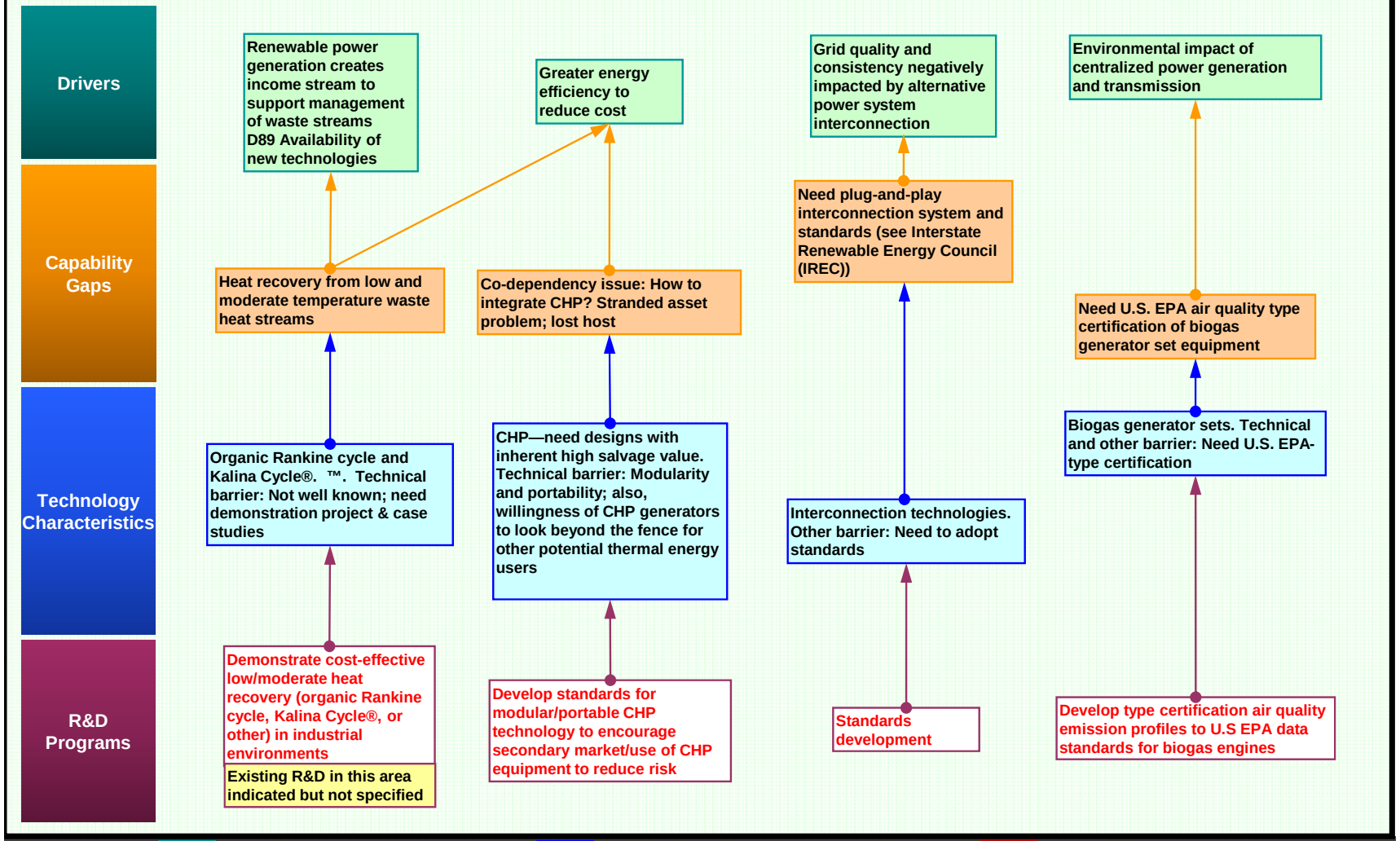
Combined Heat and Power (CHP)

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap:

Production (1 of 6)

Roadmap Definitions on pages ix-xii



R&D Project Summaries

☐ Demonstrate cost-effective low/moderate heat recovery (organic Rankine cycle, Kalina Cycle®, or other) in industrial environments: Existing R&D in this area indicated but not specified as of march 2012.

☐ Develop standards for modular/portable CHP technology to encourage secondary market/use of CHP equipment to reduce risk.

☐ Standards development.

☐ Develop type certification air quality emission profiles to U.S EPA data standards for biogas engines.

Product/Service Area :

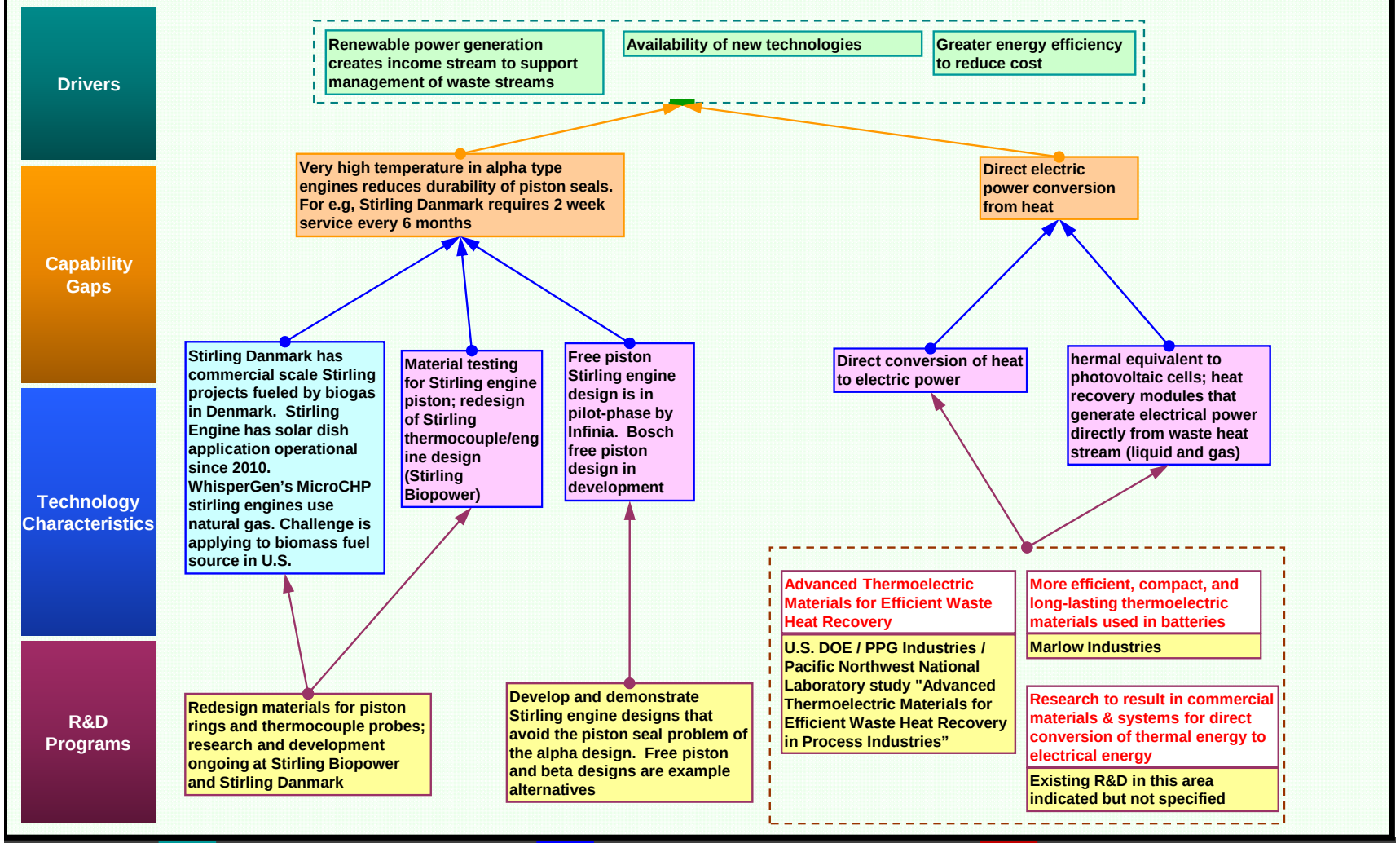
Combined Heat and Power (CHP)

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap:

Production (2 of 6)

Roadmap Definitions on pages ix-xii



R&D Project Summaries

Advanced Thermoelectric Materials for Efficient Waste Heat Recovery: U.S. DOE / PPG Industries / Pacific Northwest National Laboratory study, see "Advanced Thermoelectric Materials for Efficient Waste Heat Recovery in Process Industries" (http://www1.eere.energy.gov/industry/imf/pdfs/14cps_16947_advanced_thermoelectric_materials.pdf).

Develop and demonstrate Stirling engine designs that avoid the piston seal problem of the alpha design. Free piston and beta designs are example alternatives.

More efficient, compact, and long-lasting thermoelectric materials used in batteries. See Marlow Industries (http://www.marlow.com/resources/future-concepts/power-generators-page2.html).

Redesign materials for piston rings and thermocouple probes; research and development ongoing at Stirling Biopower (www.stirlingbiopower.com/) and Stirling Danmark (www.stirling.dk).

Research to result in commercial materials & systems for direct conversion of thermal energy to electrical energy.

Product/Service Area :

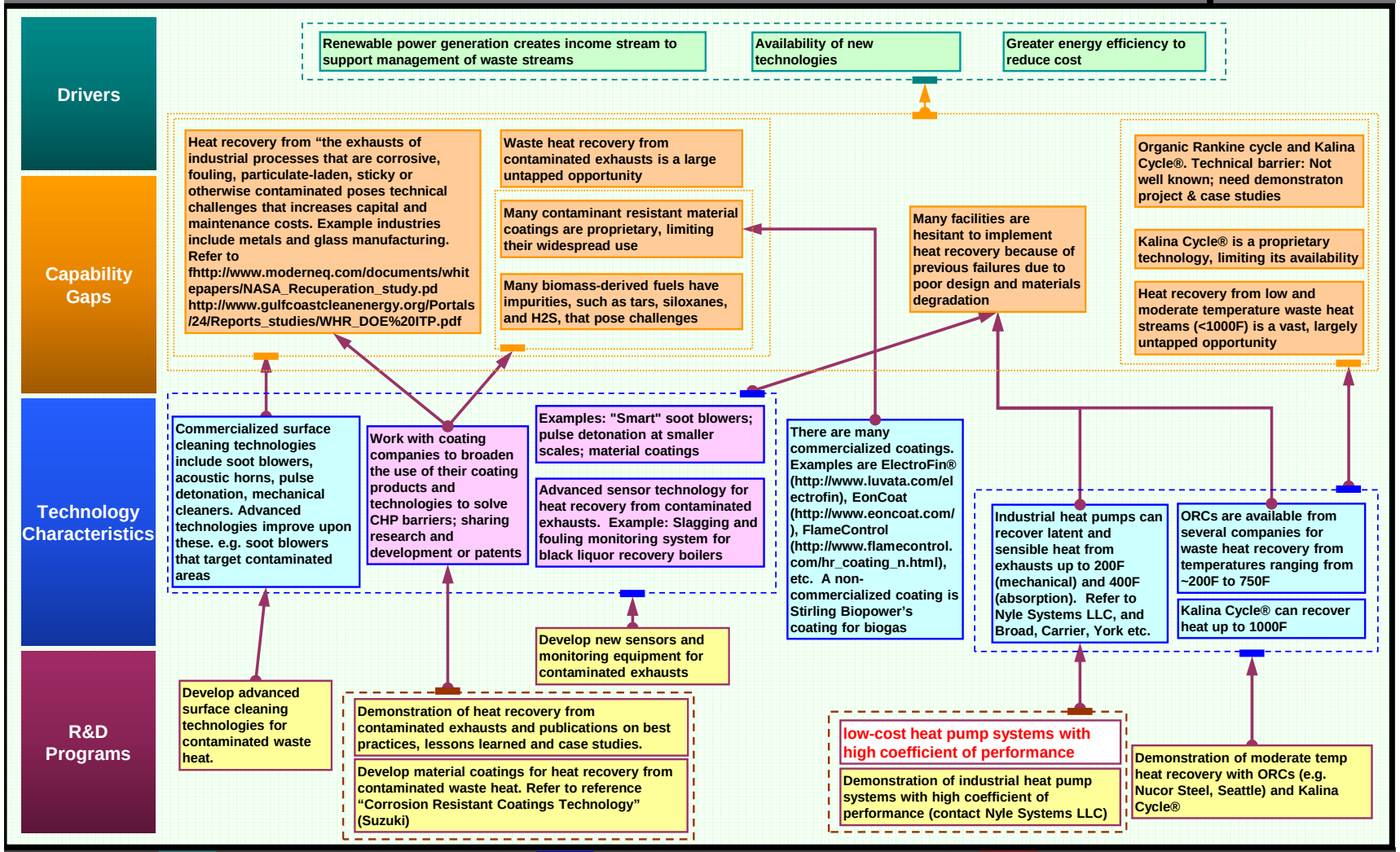
Combined Heat and Power (CHP)

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap:

Production (3 of 6)

Roadmap Definitions on pages ix-xii



R&D Project Summaries

- [ ] Demonstration of heat recovery from contaminated exhausts and publications on best practices, lessons learned and case studies.

- [ ] Demonstration of industrial heat pump systems with high coefficient of performance (contact Nyle Systems LLC, www.nyle.com).

- [ ] Demonstration of moderate temp heat recovery with Organic Rankine Cycles (ORCs) (e.g. Nucor Steel, Seattle, www.nucor.com) and Kalina Cycle®.

- [ ] Develop advanced surface cleaning technologies for contaminated waste heat.

- [ ] Develop new sensors and monitoring equipment for contaminated exhausts.

- [ ] Develop material coatings for heat recovery from contaminated waste heat. Refer to Ichiro Suzuki, *Corrosion-Resistant Coatings Technology* (New York: Marcel Dekker [Taylor & Franicis Group], 1989).

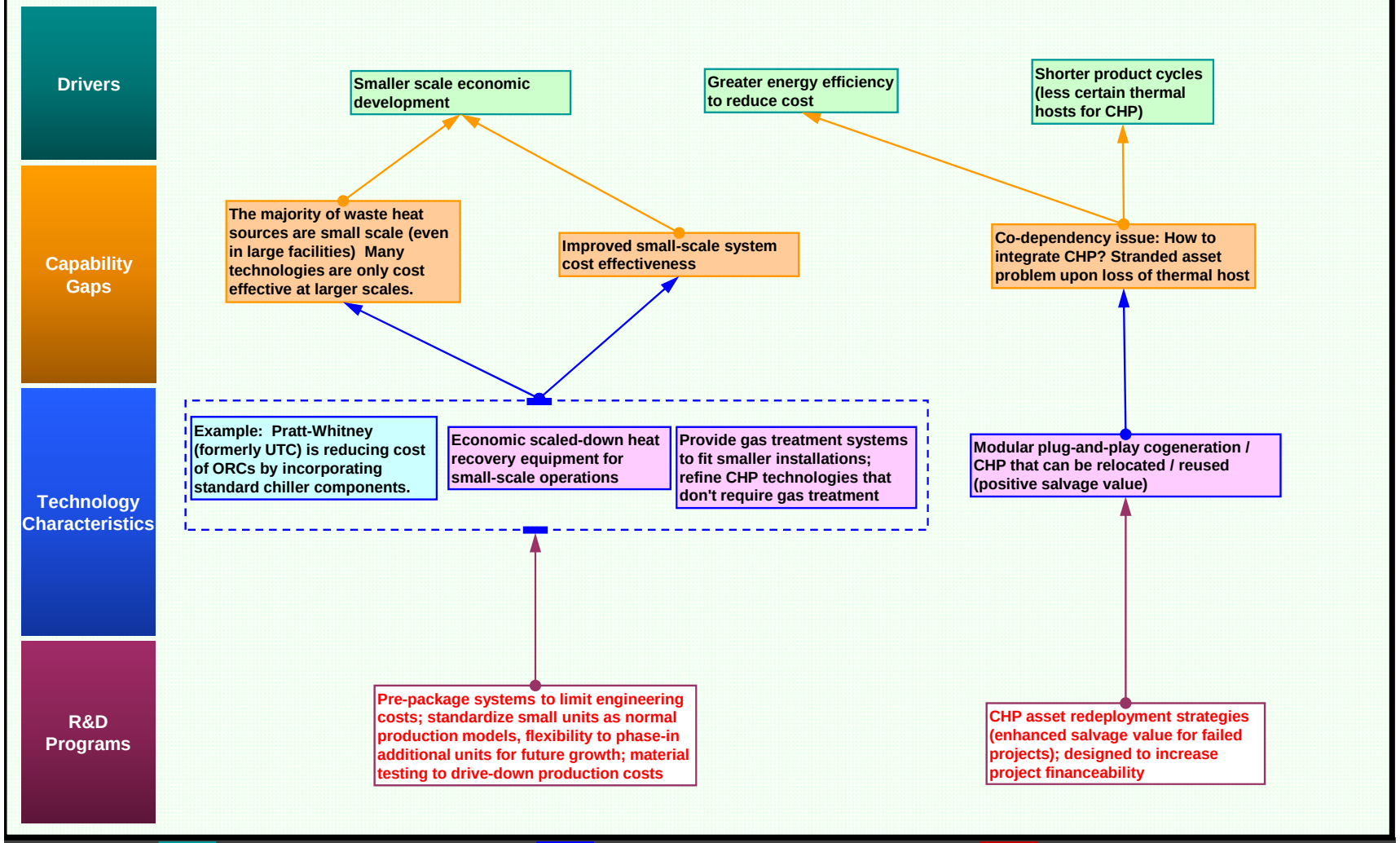
- [ ] Low-cost heat pump systems with high coefficient of performance.

Product/Service Area : **Combined Heat and Power (CHP)**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Production (4 of 6)**

Roadmap Definitions on pages ix-xii



R&D Project Summaries

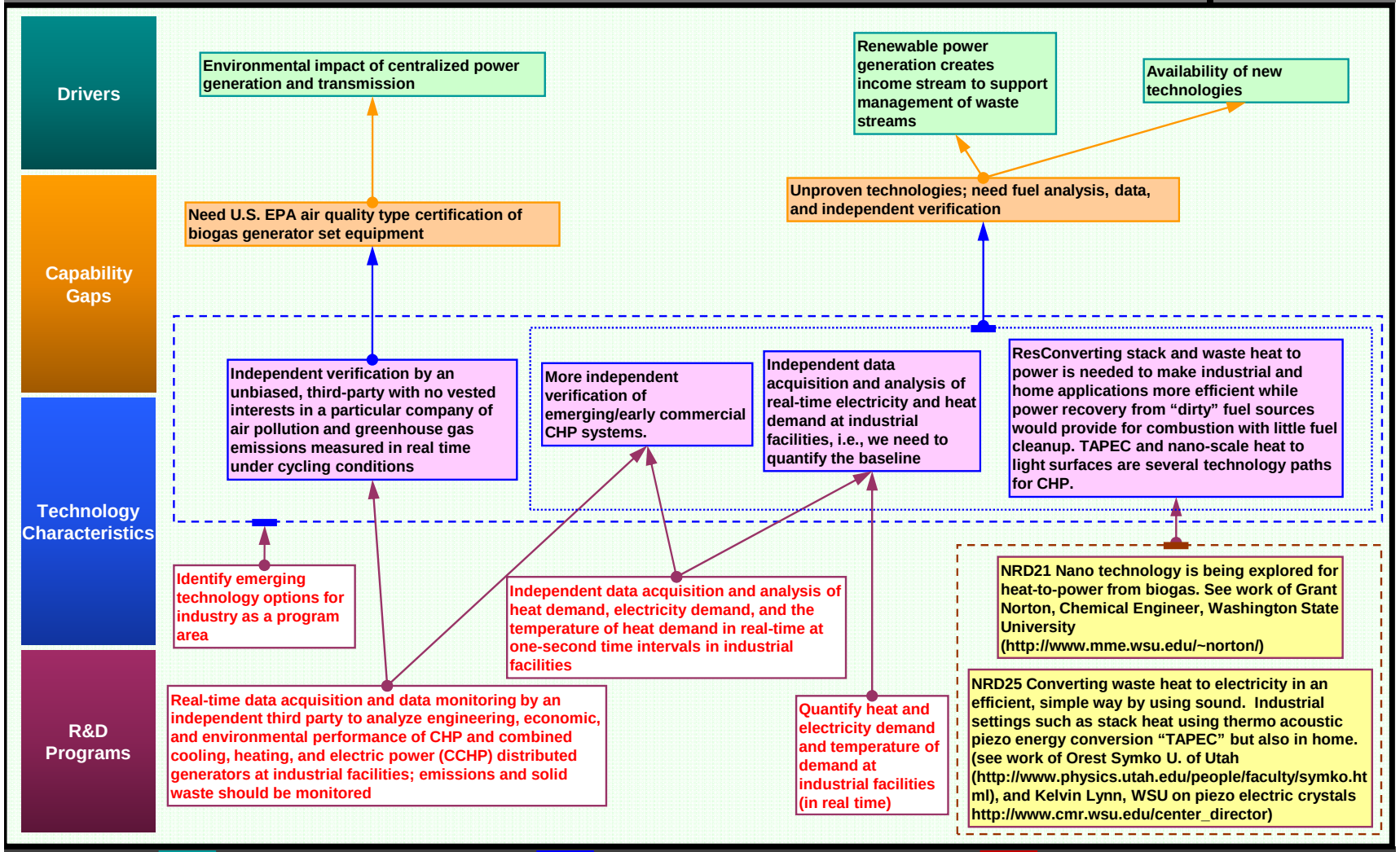
- **CHP asset redeployment strategies** (enhanced salvage value for failed projects); designed to increase project financeability.
- **Pre-package systems** to limit engineering costs; standardize small units as normal production models, flexibility to phase-in additional units for future growth; material testing to drive-down production costs.

Product/Service Area : **Combined Heat and Power (CHP)**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Production (5 of 6)**

Roadmap Definitions on pages ix-xii



R&D Project Summaries

Converting waste heat to electricity in an efficient, simple way by using sound. Industrial settings such as stack heat using thermo acoustic piezo energy conversion (TAPEC) but also in home. (see work of Orest Symko U. of Utah (http://www.physics.utah.edu/people/faculty/symko.html), and Kelvin Lynn, WSU on piezo electric crystals http://www.cmr.wsu.edu/center_director).

Nano technology is being explored for heat-to-power from biogas. See work of Grant Norton, Chemical Engineer, Washington State University (http://www.mme.wsu.edu/~norton/).

Identify emerging technology options for industry as a program area.

Independent data acquisition and analysis of heat demand, electricity demand, and the temperature of heat demand in real-time at one-second time intervals in industrial facilities.

Real-time data acquisition and data monitoring by an independent third party to analyze engineering, economic, and environmental performance of CHP and combined cooling, heating, and electric power (CCHP) distributed generators at industrial facilities; emissions and solid waste should be monitored.

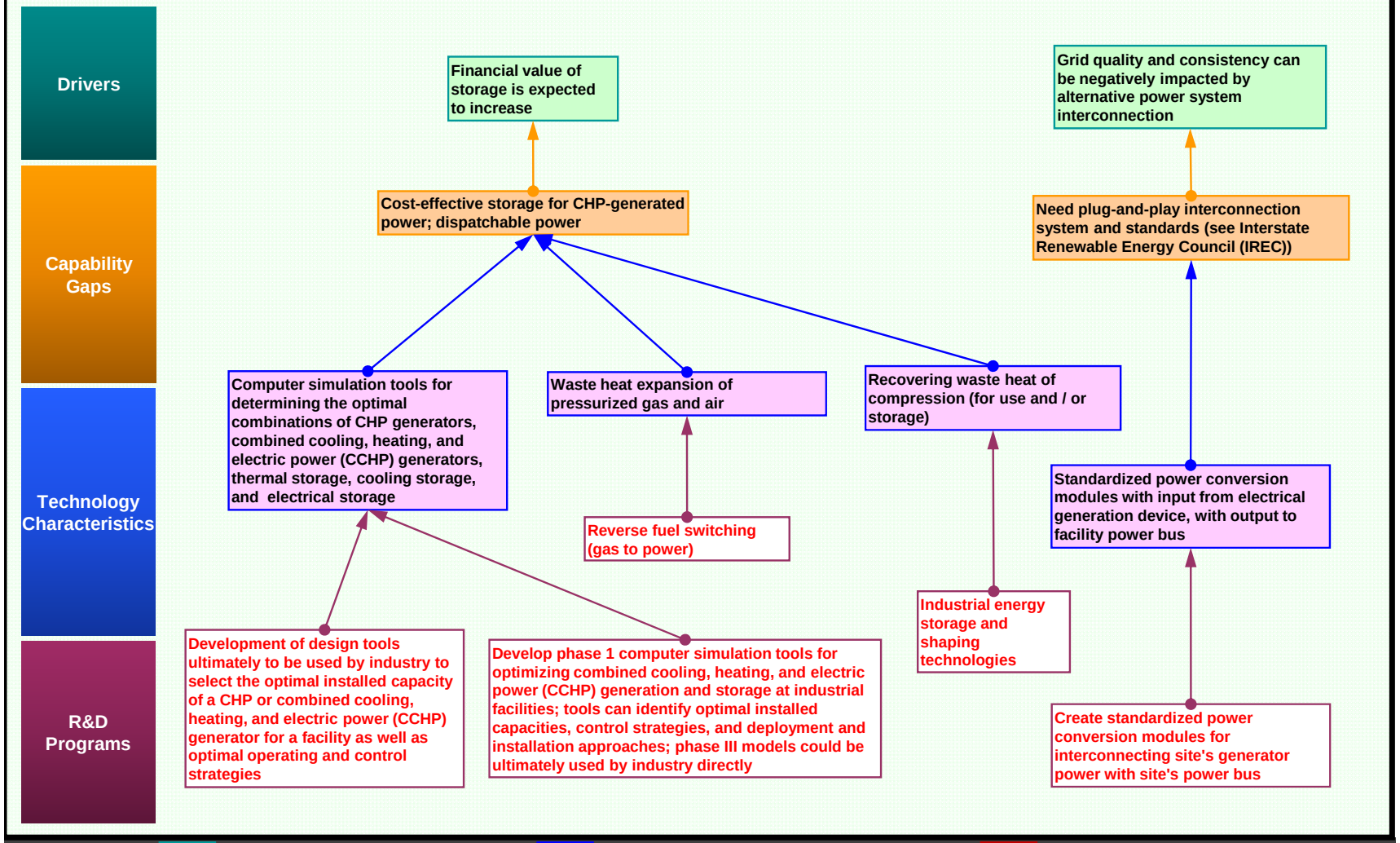
Quantify heat and electricity demand and temperature of demand at industrial facilities (in real time).

Product/Service Area : **Combined Heat and Power (CHP)**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Production (6 of 6)**

Roadmap Definitions on pages ix-xii



R&D Project Summaries

- **Create standardized power conversion modules** for interconnecting site's generator power with site's power bus.

- **Develop phase 1 computer simulation tools** for optimizing combined cooling, heating, and electric power (CCHP) generation and storage at industrial facilities; tools can identify optimal installed capacities, control strategies, and deployment and installation approaches; phase III models could be ultimately used by industry directly.

- **Development of design tools** ultimately to be used by industry to select the optimal installed capacity of a CHP or combined cooling, heating, and electric power (CCHP) generator for a facility as well as optimal operating and control strategies.

- **Industrial energy storage and shaping technologies.**

- **Reverse fuel switching** (gas to power).

Product/Service Area :

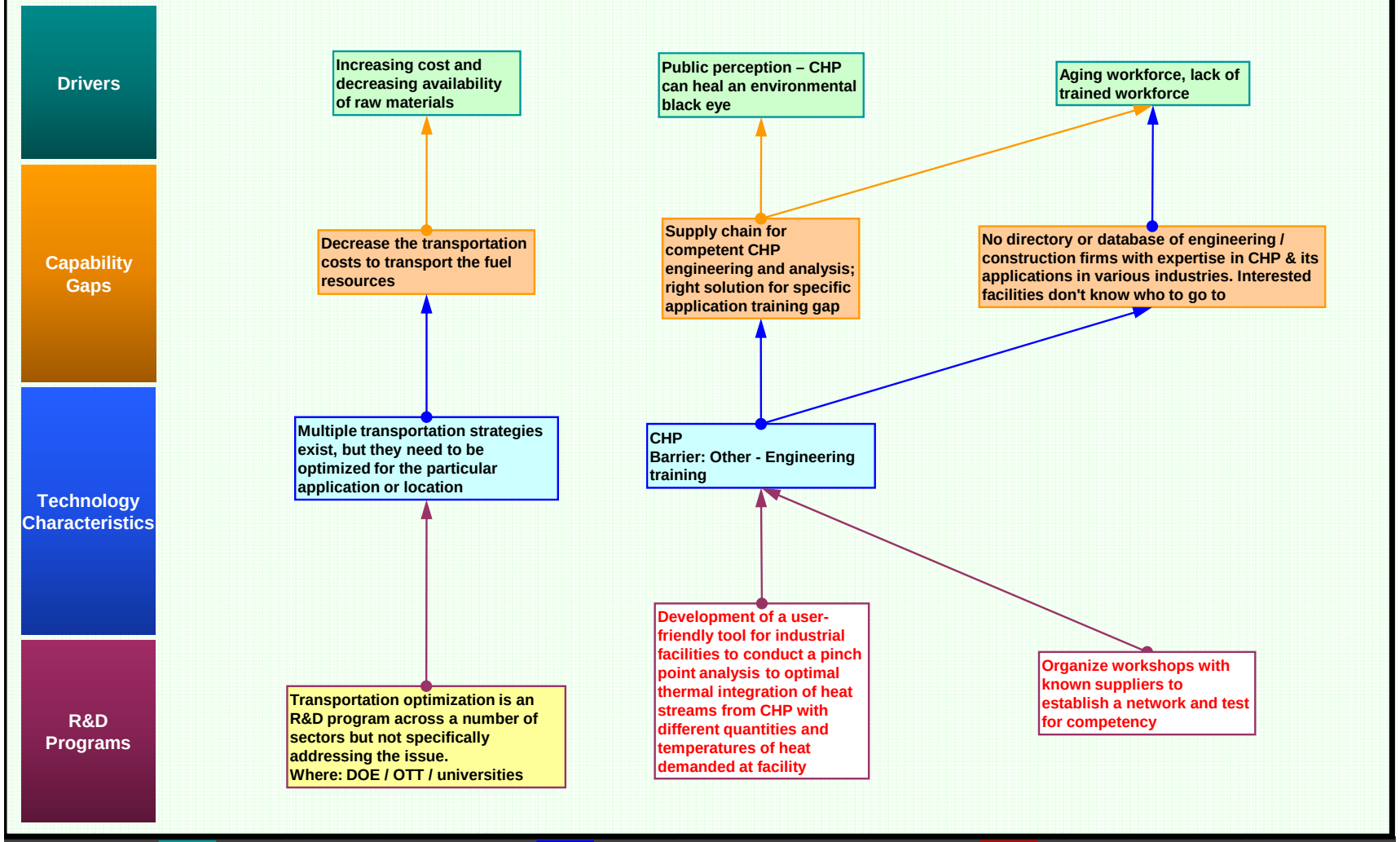
Combined Heat and Power (CHP)

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap:

Resources (1 of 6)

Roadmap Definitions on pages ix-xii



Driver
Capability Gap
Commercially Available Technology
Commercially Unavailable Technology
Existing R&D Program or Project
R&D Program Requirement

R&D Project Summaries

Transportation optimization is an R&D program across a number of sectors but not specifically addressing the issue. Stakeholders indicated ongoing research at the U.S. Department of Energy (DOE) and the DOE's Office of Transportation Technologies (OTT) within the Energy Efficiency and Renewable Energy (EERE), as well as at universities.

- DOE's Office of Transportation Technologies (OTT): http://www1.eere.energy.gov/vehiclesandfuels/.

Development of a user-friendly tool for industrial facilities to conduct a pinch point analysis to optimal thermal integration of heat streams from CHP with different quantities and temperatures of heat demanded at facility.

Organize workshops with known suppliers to establish a network and test for competency.

Product/Service Area :

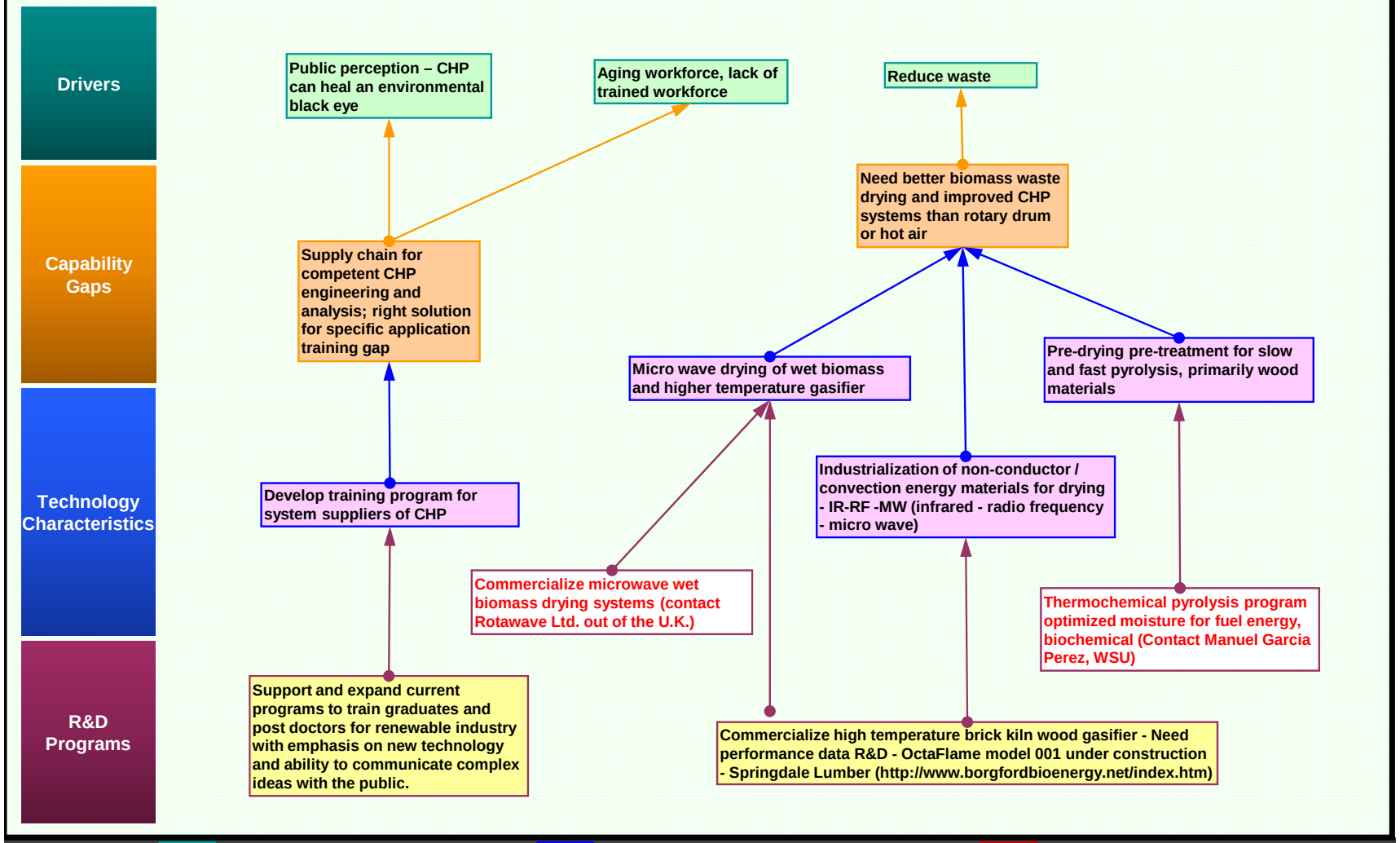
Combined Heat and Power (CHP)

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap:

Resources (2 of 6)

Roadmap Definitions on pages ix-xii



R&D Project Summaries

Commercialize high temperature brick kiln wood gasifier. Need performance data R&D on brick kiln wood gasifier system now being evaluated at Springdale Lumber in Spokane, Washington.

- Borgford BioEnergy LLC's OctaFlame model 001 is under construction at Springdale Lumber; see http://www.borgfordbioenergy.net/index.htm.

Support and expand current programs to train graduates and post doctors for renewable industry with emphasis on new technology and ability to communicate complex ideas with the public.

Commercialize microwave wet biomass drying systems (contact Rotawave Ltd. out of the U.K., rotawave.com).

Thermochemical pyrolysis program optimized moisture for fuel energy, biochemical (Contact Manuel Garcia Perez at Washington State University, www.bsyse.wsu.edu/garcia-perez).

Product/Service Area :

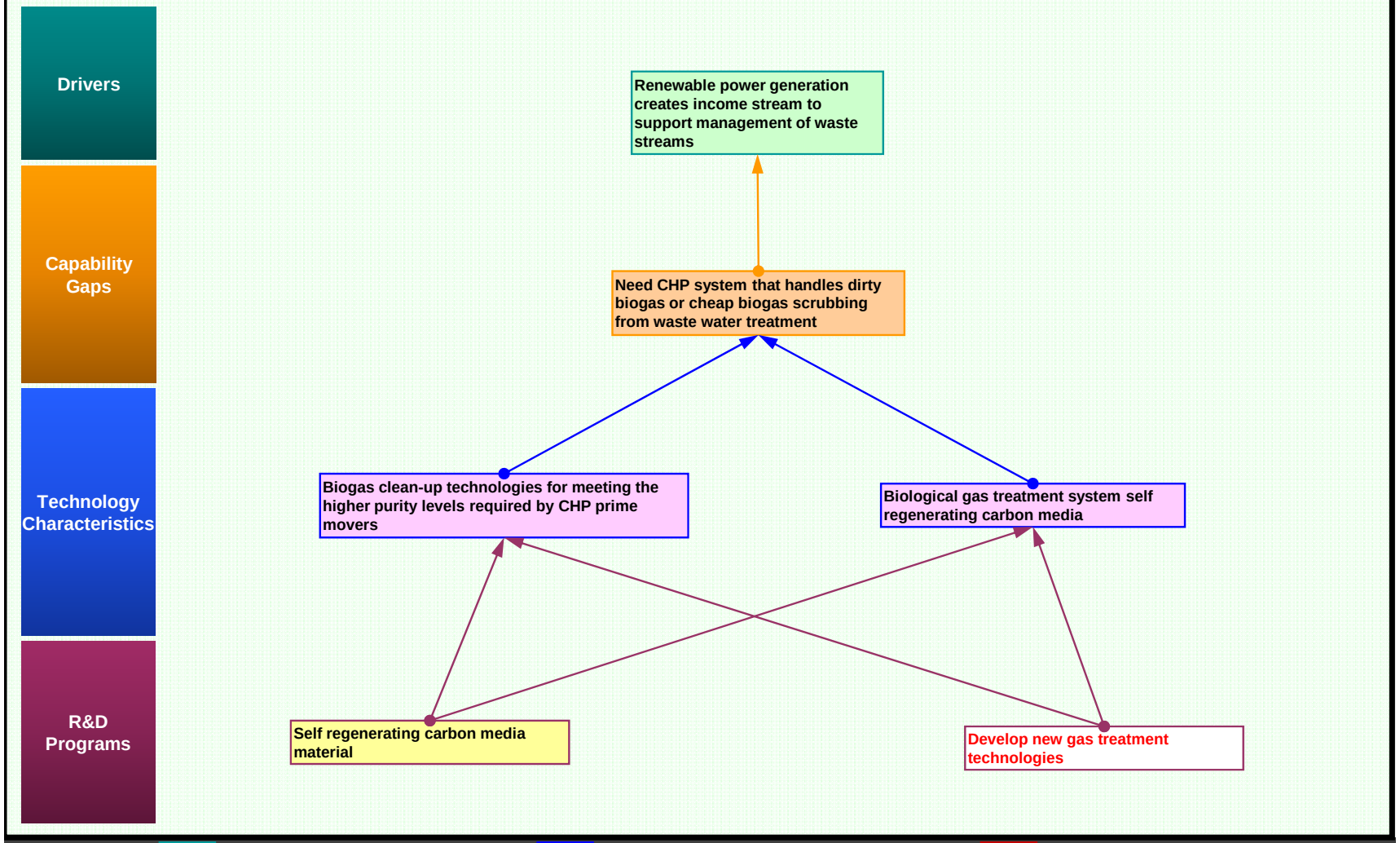
Combined Heat and Power (CHP)

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap:

Resources (3 of 6)

Roadmap Definitions on pages ix-xii



Driver
Capability Gap
Commercially Available Technology
Commercially Unavailable Technology
Existing R&D Program or Project
R&D Program Requirement

R&D Project Summaries

- [ ] Self regenerating carbon media material.
- [ ] Develop new gas treatment technologies.

Product/Service Area :

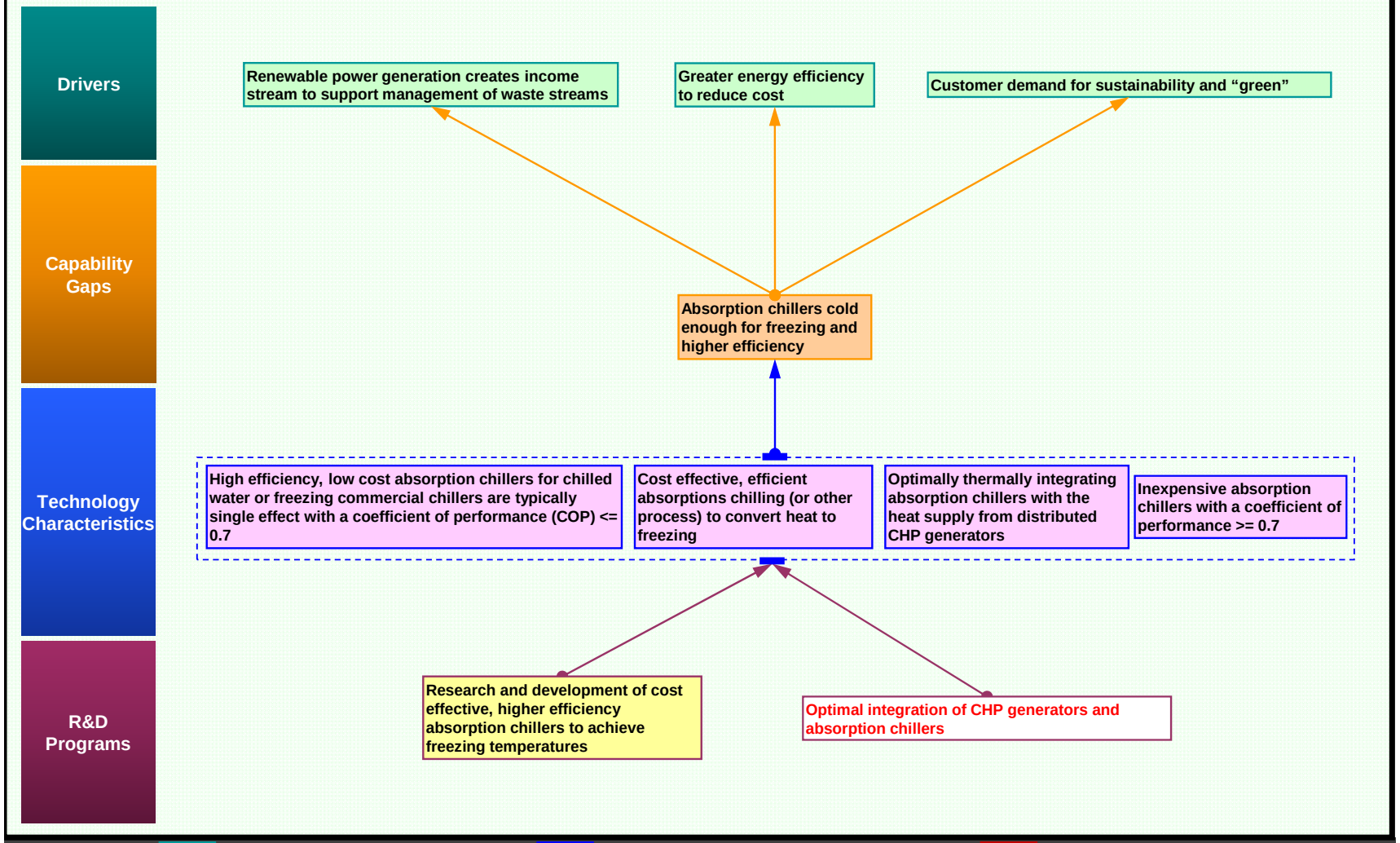
Combined Heat and Power (CHP)

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap:

Resources (4 of 6)

Roadmap Definitions on pages ix-xii



Driver
Capability Gap
Commercially Available Technology
Commercially Unavailable Technology
Existing R&D Program or Project
R&D Program Requirement

R&D Project Summaries

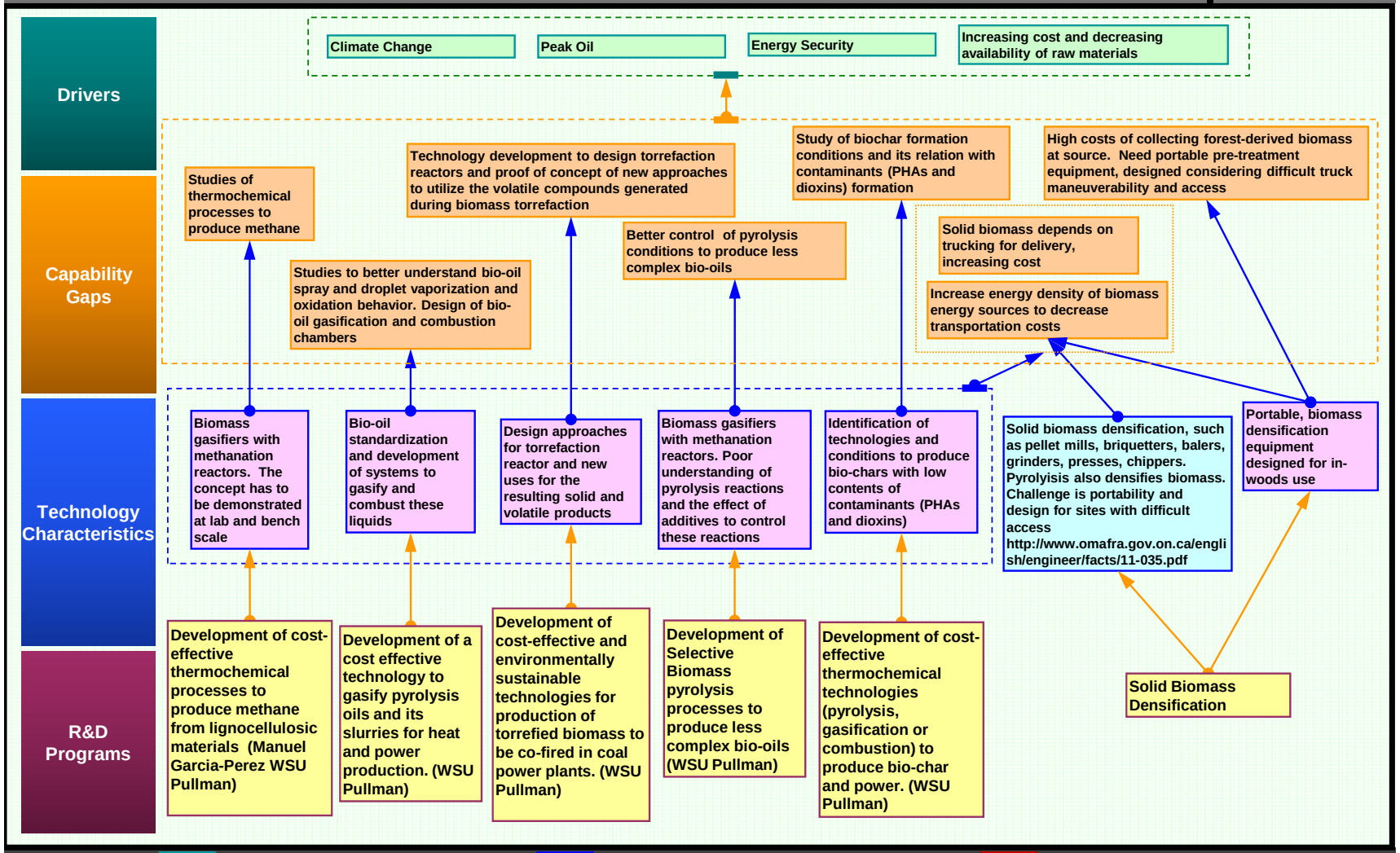
- Research and development of cost effective, higher efficiency absorption chillers to achieve freezing temperatures.
- Optimal integration of CHP generators and absorption chillers.

Product/Service Area : **Combined Heat and Power (CHP)**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Resources (5 of 6)**

Roadmap Definitions on pages ix-xii



R&D Project Summaries

Cost-effective and environmentally sustainable technologies for production of torrefied biomass to be co-fired in coal power plants. R&D ongoing at Washington State University (WSU) Center for Sustaining Agriculture and Natural Resources (CSANR).

- Researchers at WSU's CSANR are conducting R&D about producing torrefied biomass; see http://csanr.wsu.edu/.

Cost-effective technology to gasify pyrolysis oils and its slurries for heat and power production. R&D ongoing at Washington State University (WSU) Center for Sustaining Agriculture and Natural Resources (CSANR).

- Researchers at WSU's CSANR are conducting R&D about gasifying pyrolysis oils and its slurries; see http://csanr.wsu.edu/.

Cost-effective thermochemical processes to produce methane from lignocellulosic materials. (Contact Manuel Garcia Perez at Washington State University, www.bsyse.wsu.edu/garcia-perez).

Cost-effective thermochemical technologies (pyrolysis, gasification or combustion) to produce bio-char and power. R&D ongoing at Washington State University (WSU) Center for Sustaining Agriculture and Natural Resources (CSANR).

- Researchers at WSU's CSANR are conducting R&D about producing bio-char and power using Cost-effective thermochemical technologies; see http://csanr.wsu.edu/.

Selective biomass pyrolysis processes to produce less complex bio-oils. R&D ongoing at Washington State University (WSU) Center for Sustaining Agriculture and Natural Resources (CSANR).

- Researchers at WSU's CSANR are conducting R&D about producing less complex bio-oils from the pyrolysis processes; see http://csanr.wsu.edu/.

Solid biomass densification.

Product/Service Area :

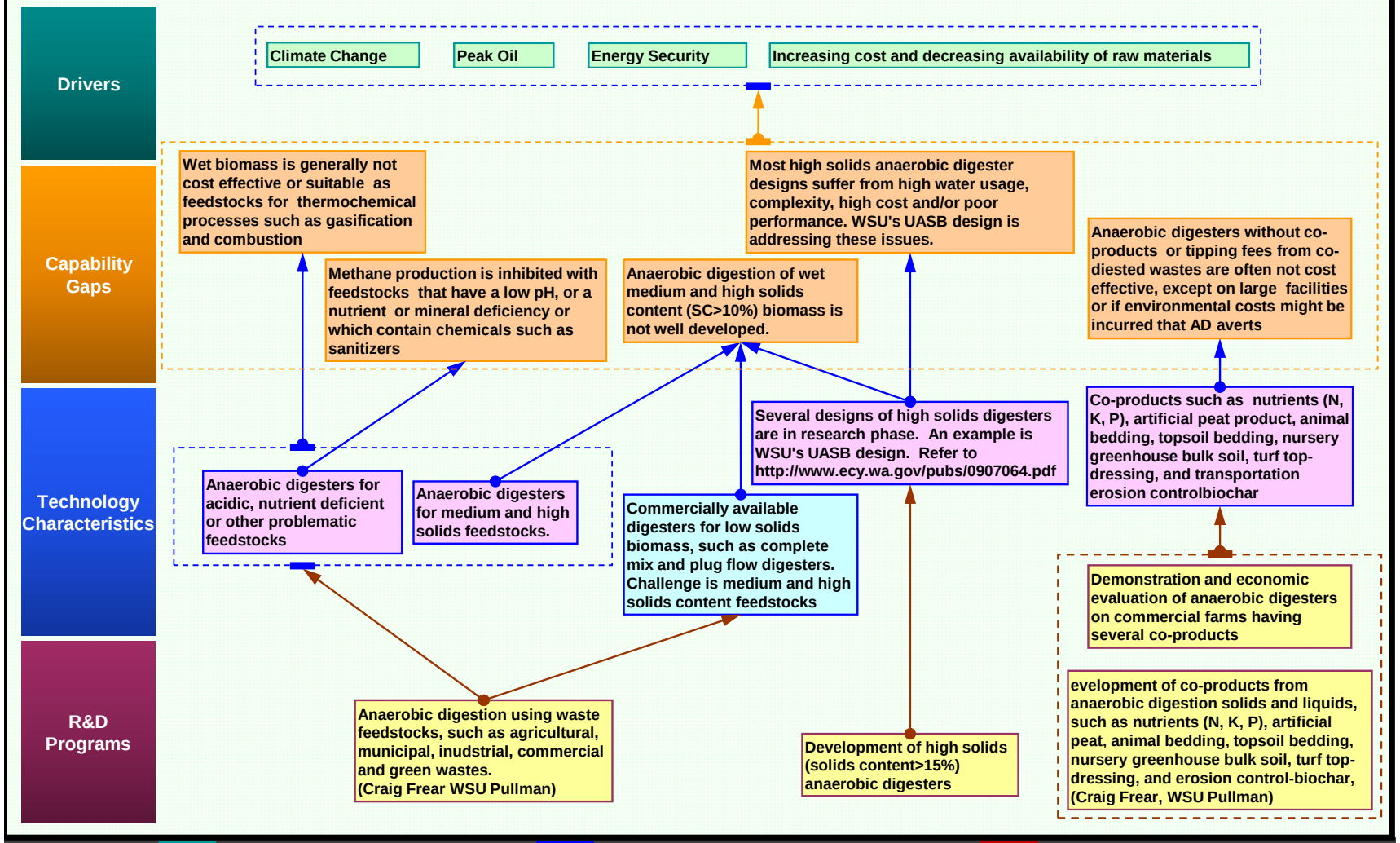
Combined Heat and Power (CHP)

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap:

Resources (6 of 6)

Roadmap Definitions on pages ix-xii



R&D Project Summaries

Anaerobic digestion using waste feedstocks, such as agricultural, municipal, inudstrial, commercial and green wastes.
(Contact Craig Frear, Washington State University, http://www.bsyse.wsu.edu/core/directory/faculty/cfrear.html).

Demonstration and economic evaluation of anaerobic digesters on commercial farms having several co-products.

Develop co-products from anaerobic digestion solids and liquids, such as nutrients (N, K, P), artificial peat, animal bedding, topsoil bedding, nursery greenhouse bulk soil, turf top-dressing, and erosion control-biochar.
(Contact Craig Frear, Washington State University, http://www.bsyse.wsu.edu/core/directory/faculty/cfrear.html).

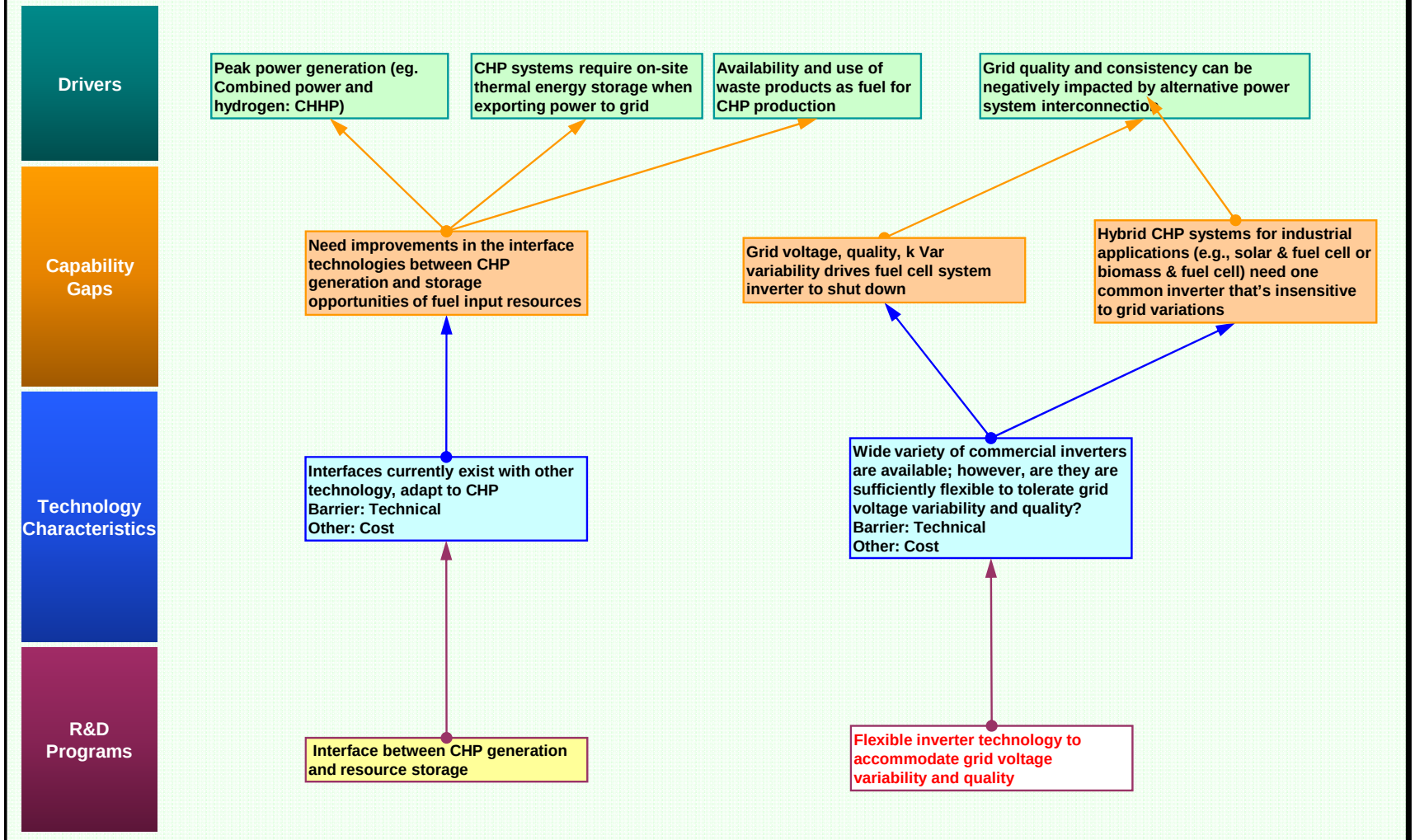
Develop high solids (solids content >15%) anaerobic digesters.

Product/Service Area : **Combined Heat and Power (CHP)**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Delivery (1 of 8)**

Roadmap Definitions on pages ix-xii



R&D Project Summaries

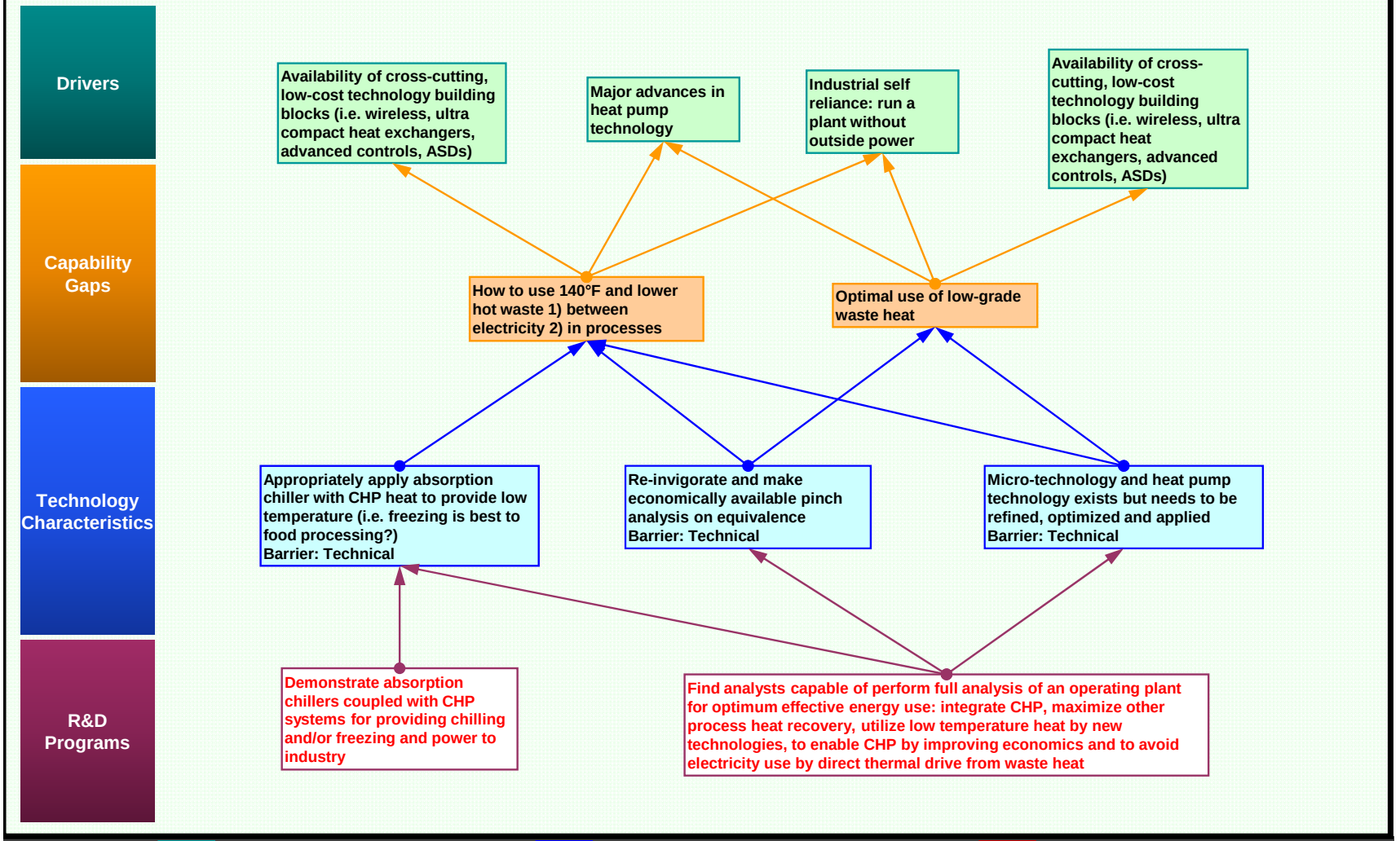
- Interface between CHP generation and resource storage.
- Flexible inverter technology to accommodate grid voltage variability and quality.

Product/Service Area : **Combined Heat and Power (CHP)**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Delivery (2 of 8)**

Roadmap Definitions on pages ix-xii



Driver | Capability Gap | Commercially Available Technology | Commercially Unavailable Technology | Existing R&D Program or Project | R&D Program Requirement

R&D Project Summaries

- [ ] **Demonstrate absorption chillers coupled with CHP systems** for providing chilling and/or freezing and power to industry

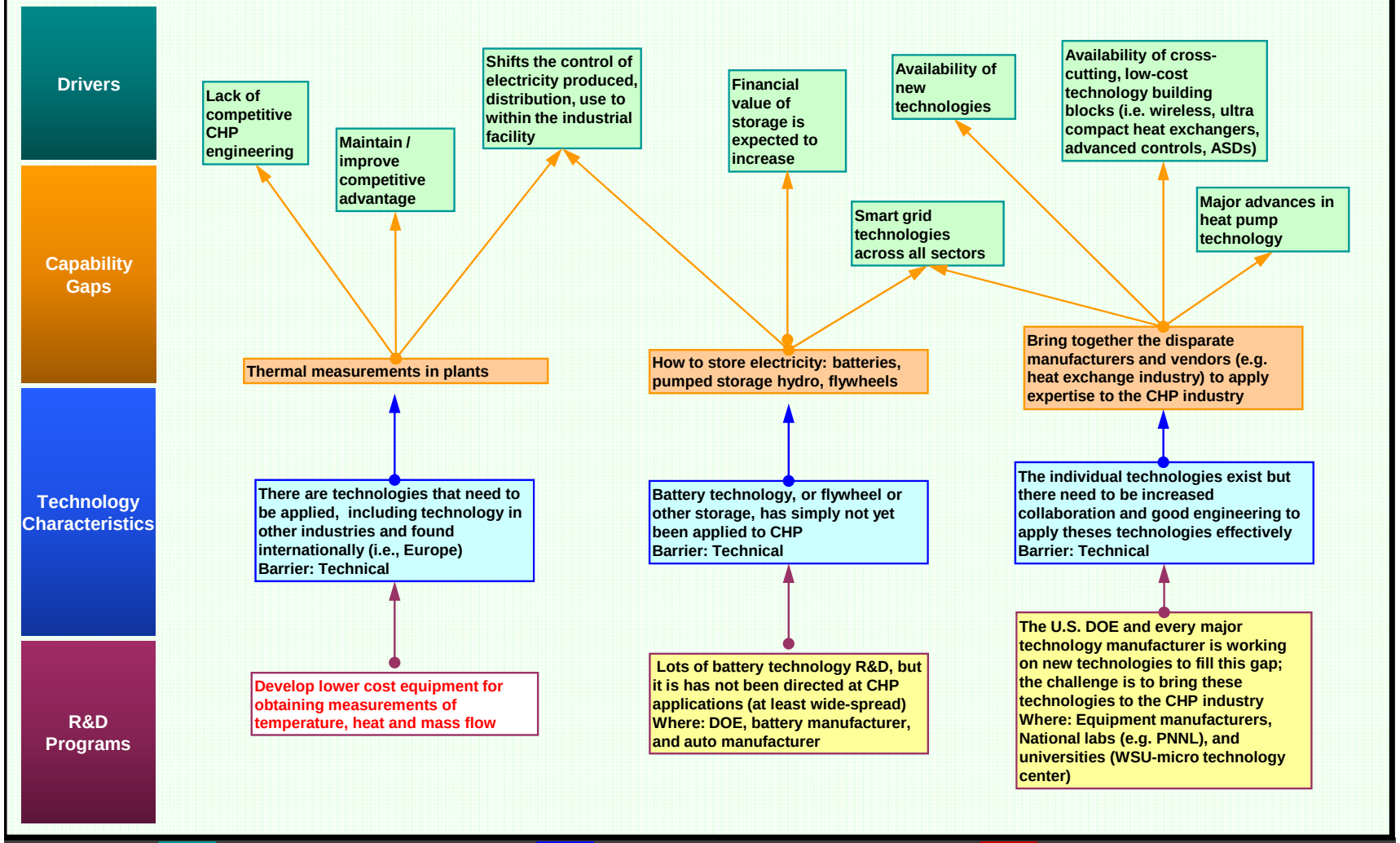
- [ ] **Find analysts capable of perform full analysis of an operating plant for optimum effective energy use:** integrate CHP, maximize other process heat recovery, utilize low temperature heat by new technologies, to enable CHP by improving economics and to avoid electricity use by direct thermal drive from waste heat

Product/Service Area : **Combined Heat and Power (CHP)**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Delivery (3 of 8)**

Roadmap Definitions on pages ix-xii



Driver | Capability Gap | Commercially Available Technology | Commercially Unavailable Technology | Existing R&D Program or Project | R&D Program Requirement

R&D Project Summaries

Battery technology applied to CHP: Lots of battery technology R&D, but it is has not been directed at CHP applications (at least wide-spread) @ DOE, battery manufacturers, and auto manufacturers.

New CHP technologies: U.S. DOE and every major technology manufacturer is working on new technologies to fill this gap; the challenge is to bring these technologies to the CHP industry @ equipment manufacturers, National labs (e.g. PNNL), and universities (WSU-micro technology center).

Develop lower-cost equipment for obtaining measurements of temperature, heat, and mass flow.

Product/Service Area :

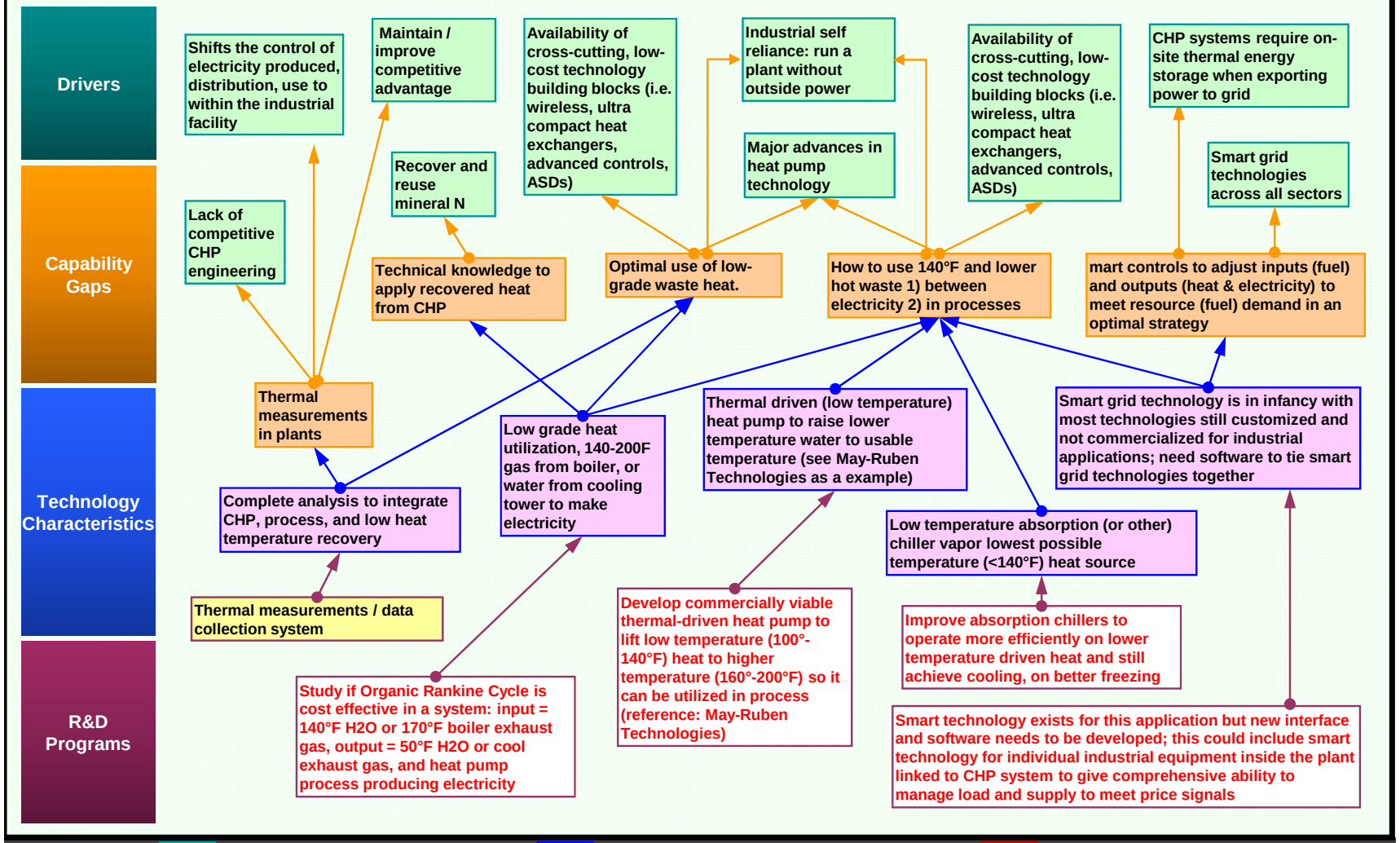
Combined Heat and Power (CHP)

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap:

Delivery (4 of 8)

Roadmap Definitions on pages ix-xii



R&D Project Summaries

- [ ] **Thermal measurements / data collection system.**

- [ ] **Develop commercially viable thermal-driven heat pump** to lift low temperature (100°-140°F) heat to higher temperature (160°-200°F) so it can be utilized in process (reference: May-Ruben Technologies).

- [ ] **Develop new interface and software for existing smart technologies;** this could include smart technology for individual industrial equipment inside the plant linked to CHP system to give comprehensive ability to manage load and supply to meet price signals.

- [ ] **Improve absorption chillers to operate more efficiently** on lower temperature driven heat and still achieve cooling, on better freezing.

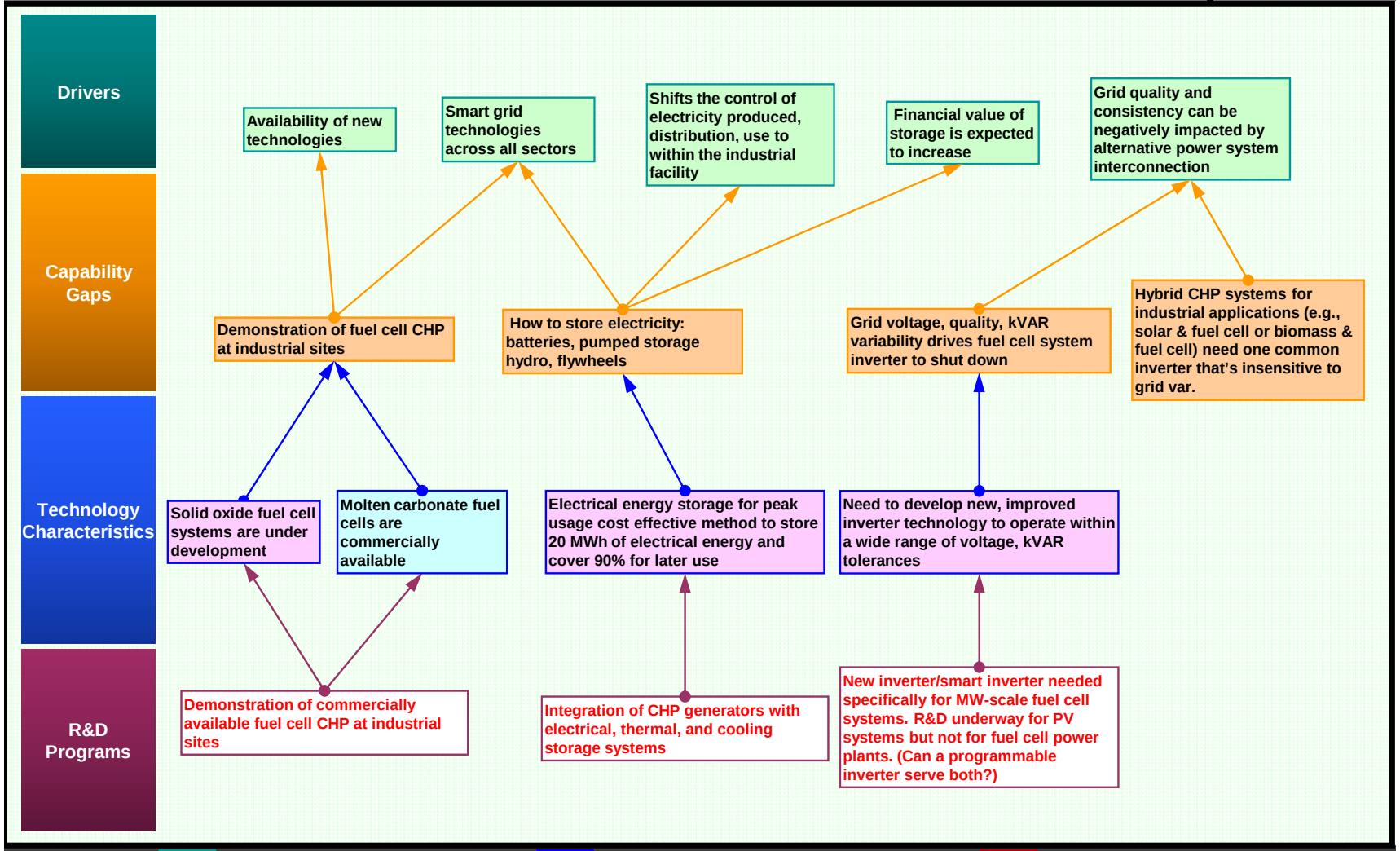
- [ ] **Study if Organic Rankine Cycle is cost effective in a system:** input = 140°F H20 or 170°F boiler exhaust gas, output = 50°F H20 or cool exhaust gas, and heat pump process producing electricity.

Product/Service Area : **Combined Heat and Power (CHP)**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Delivery (5 of 8)**

Roadmap Definitions on pages ix-xii



R&D Project Summaries

☐ Demonstrate commercially-available fuel cell CHP at industrial sites.

☐ Integrate CHP generators with electrical, thermal, and cooling storage systems.

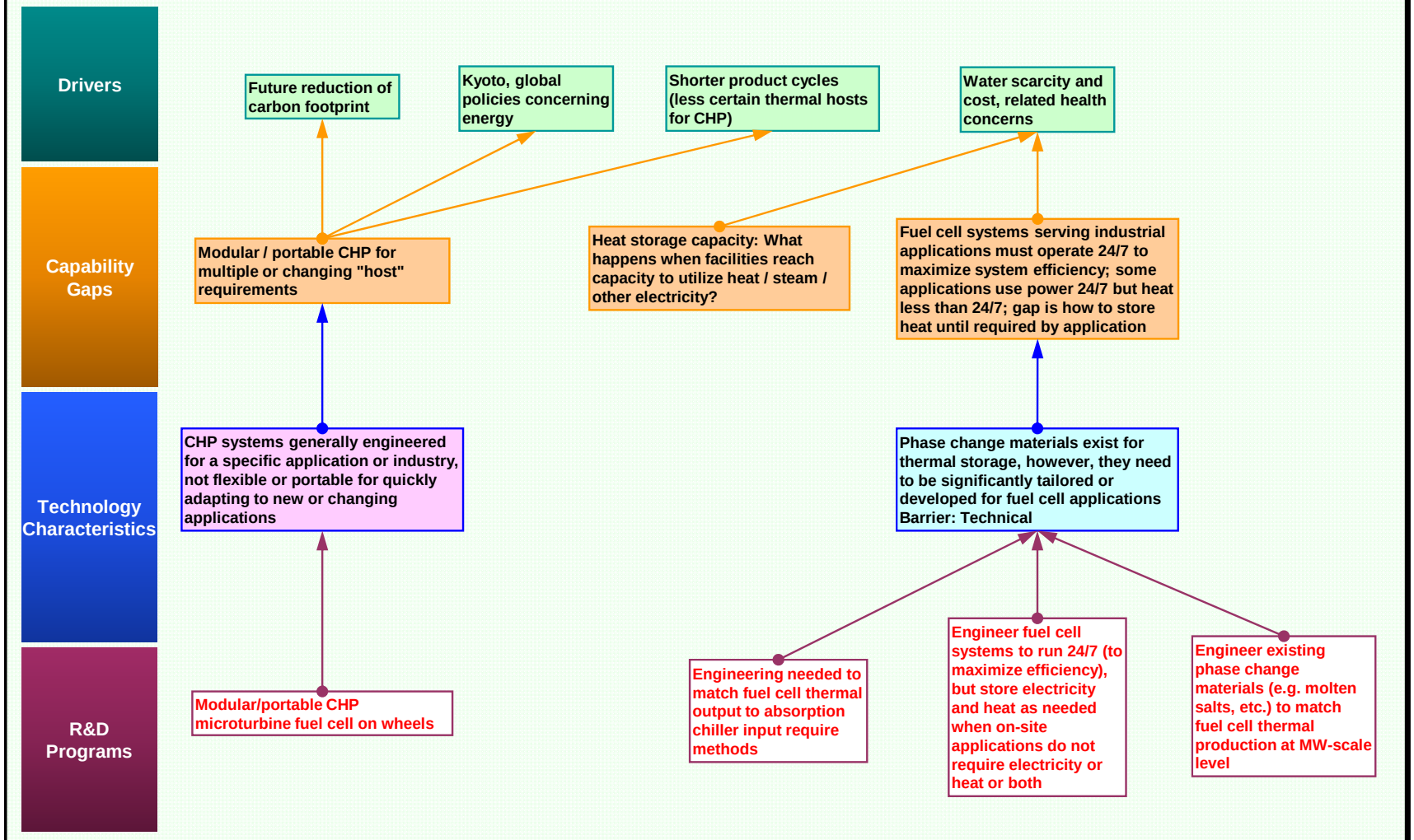
☐ New inverter / smart inverter needed specifically for MW-scale fuel cell systems. R&D underway for PV systems but not for fuel cell power plants. (Can a programmable inverter serve both?).

Product/Service Area : **Combined Heat and Power (CHP)**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Delivery (6 of 8)**

Roadmap Definitions on pages ix-xii



Driver
Capability Gap
Commercially Available Technology
Commercially Unavailable Technology
Existing R&D Program or Project
R&D Program Requirement

R&D Project Summaries

☐ Engineer existing phase change materials (e.g. molten salts, etc.) to match fuel cell thermal production at MW-scale level.

☐ Engineering needed to match fuel cell thermal output to absorption chiller input require methods.

☐ Engineer fuel cell systems to run 24/7 (to maximize efficiency), but store electricity and heat as needed when on-site applications do not require electricity or heat or both.

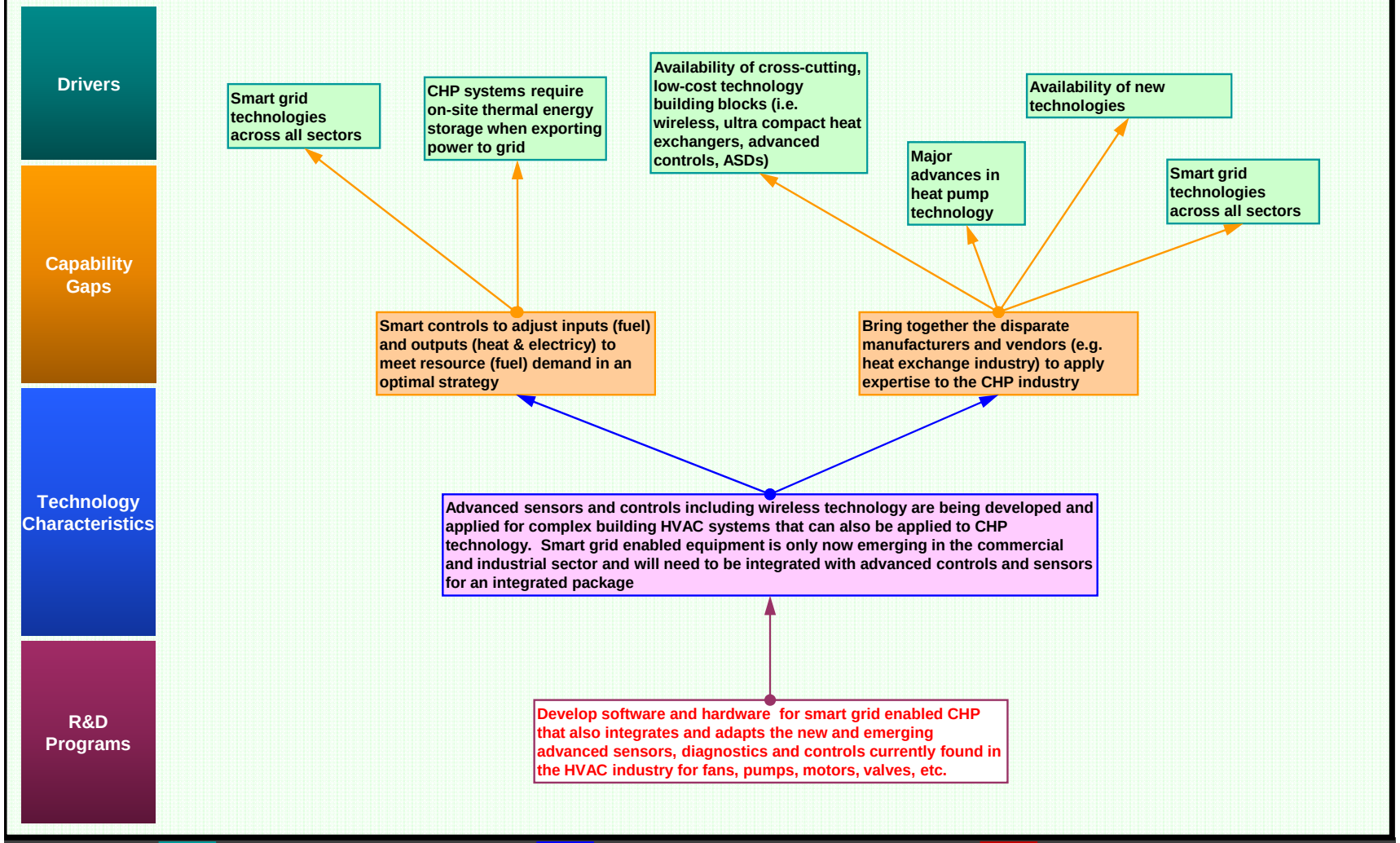
☐ Modular / portable CHP microturbine fuel cell on wheels.

Product/Service Area : **Combined Heat and Power (CHP)**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Delivery (7 of 8)**

Roadmap Definitions on pages ix-xii



R&D Project Summaries

- **Develop software and hardware for smart grid-enabled CHP** that also integrates and adapts the new and emerging advanced sensors, diagnostics and controls currently found in the HVAC industry for fans, pumps, motors, valves, etc.

Product/Service Area :

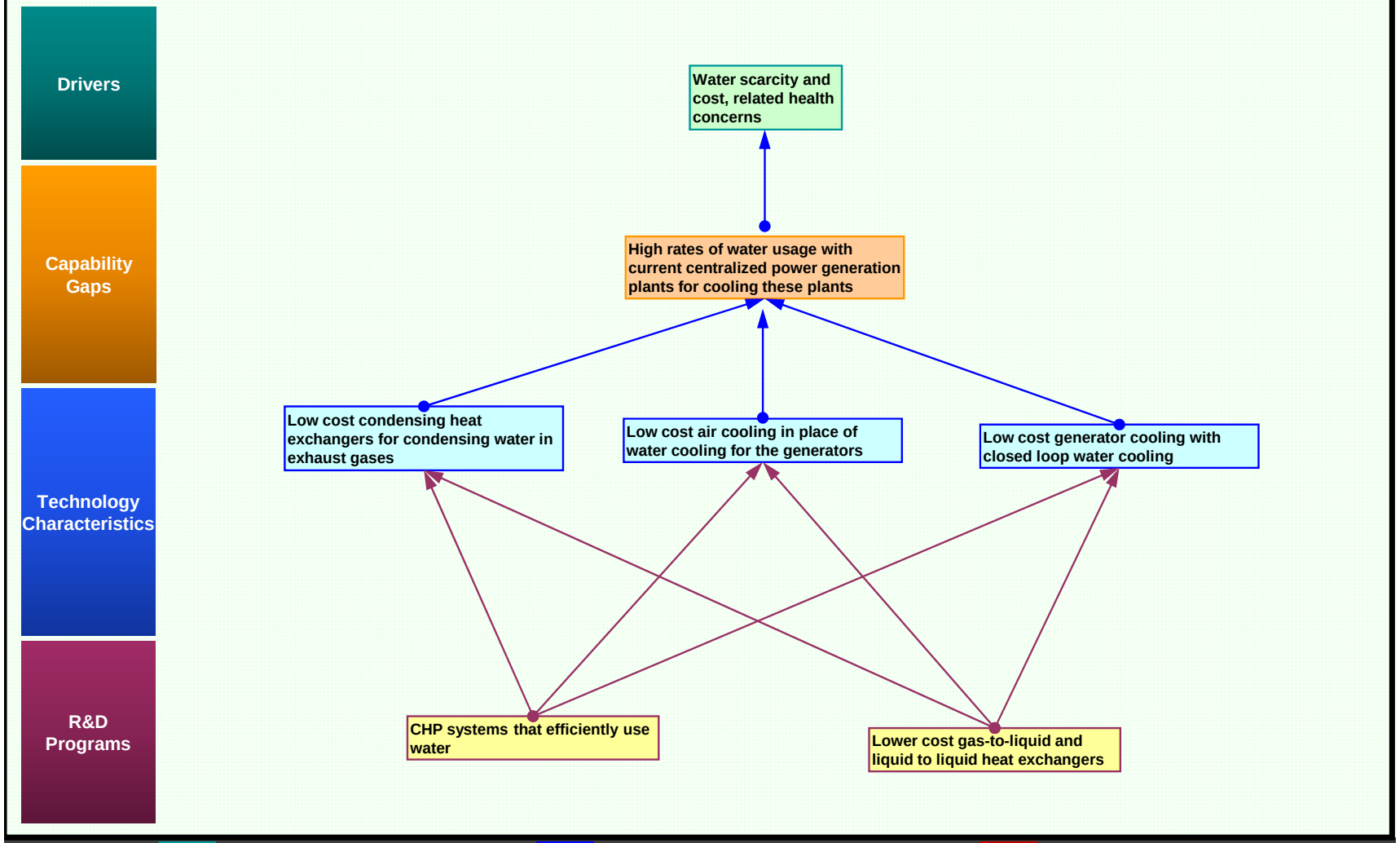
Combined Heat and Power (CHP)

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap:

Delivery (8 of 8)

Roadmap Definitions on pages ix-xii



Driver
Capability Gap
Commercially Available Technology
Commercially Unavailable Technology
Existing R&D Program or Project
R&D Program Requirement

R&D Project Summaries

- CHP systems that efficiently use water.
- Lower cost gas-to-liquid and liquid to liquid heat exchangers.

Abbreviations

AC	Alternating Current
AC	Air Conditioning
BECC	Behavior, Energy and Climate Change
CCT	Correlated Color Temperature (in K)
CFL	Compact Fluorescent Light
CLTC	California Lighting Technology Center
CRI	Color Rendering Index
DC	Direct Current
DHW	Domestic Hot Water
ECM	Electronically Commutated Motor
EMS	Energy Management System
ETO	Energy Trust of Oregon
EV	Electric Vehicle
FCL	Fault Current Limiter
GHG	Greenhouse Gas
HPWH	Heat Pump Water Heater
HRV	Heat Recovery Ventilator
IES	Illuminating Engineering Society
IP	Internet Protocol
IPMVP	International Performance Measurement and Verification Protocol
IR	Infrared
LED	Light-emitting Diode
lm	lumen
M&V	Monitoring and Verification
MTBF	Mean Time Between Failures
NBI	New Buildings Institute
NC	New Construction
NETC	National Energy Trade Commission
NIST	National Institute of Science and Technology
PC	Personal Computer
PCM	Phase Change Material
QC	Quality Control
RFID	Radio-Frequency Identification
RTU	Roof Top Unit
SHGC	Solar Heat Gain Coefficient
SSL	Solid State Lighting
UBC	University of British Columbia
UPS	Uninterruptible Power Supply
VRF	Variable Refrigerant Flow
WCEC	Western Cooling Efficiency Center
ZNE	Zero Net Energy