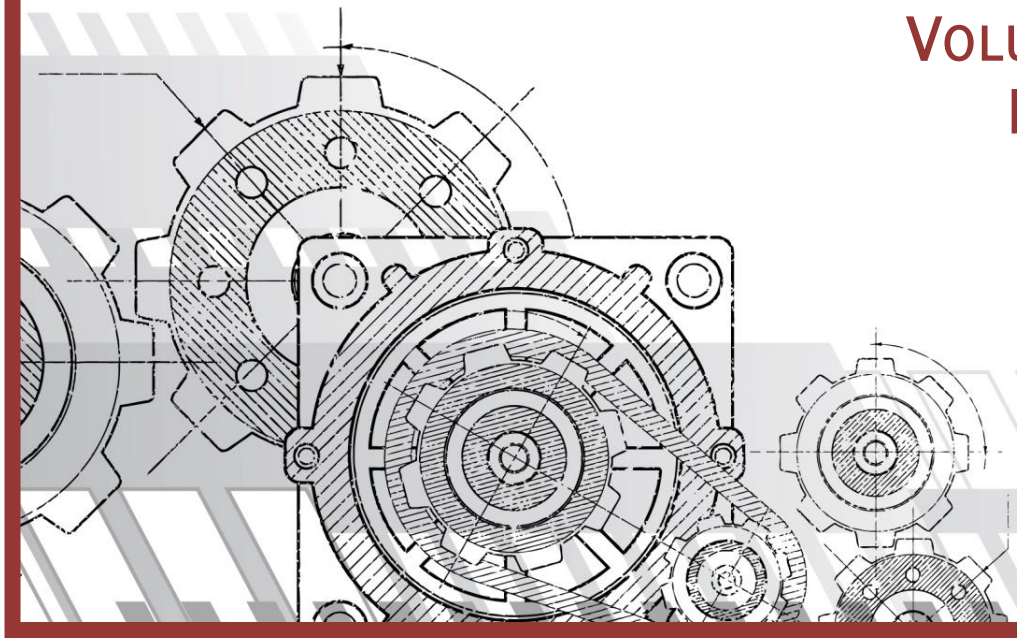
Energy Efficiency Technology Roadmap

Volume 6: Sensors, Meters, and Energy Management Systems



March 2015

Enhanced PDF Functionality

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

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

Special Note

This document is one component of the Energy Efficiency Technology Roadmap (EE Roadmap), published by the Bonneville Power Administration (BPA) on behalf of regional stakeholders. For the background and purpose of the full EE Roadmap, a complete list of the project team and contributors, and other explanatory and complementary information, see Volume 1: Introduction & Background.

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

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

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

James V. Hillegas-Elting
Project Manager
BPA Technology Innovation
jvhillegas@bpa.gov, 503.230.5327

Back to Table of Contents

Table of Contents

In This Volume

Additional Content In Volume 1

INTRODUCTION TO THIS VOLUME

This section contains roadmaps in these residential and commercial sector Technology Areas:

- Smart Device-Level Controls Responsive to User and Environment
- Easy / Simple User Interface Controls
- Energy Management Services
- Low-Cost Savings Verification Techniques
- Real-Time Smart Electric Power Measurement of Facilities
- Enterprise Energy and Maintenance Management Systems
- ***NOTE:*** *For industrial strategic energy management research, see the Mechanical roadmap in Volume 7: Industrial Food Processing*

Technology Area Definitions

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.

Other Sources

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

Sources pending.

Back to Table of Contents

USING THE ROADMAP

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

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

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

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

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

Disclaimer

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

Roadmap "Swim Lane" Definitions

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

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

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

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

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

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

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

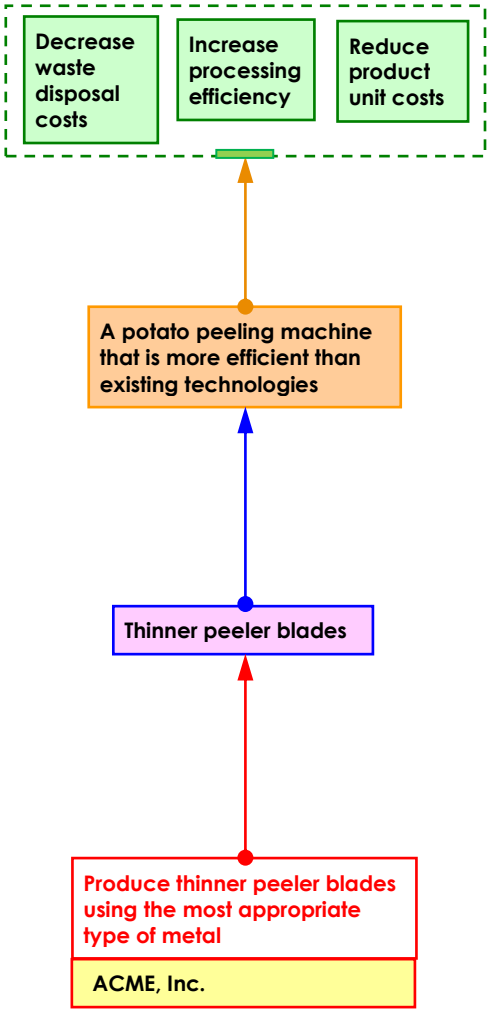
Faced with this situation, the company is facing three Drivers: 1) the desire to increase processing efficiency; 2) the desire to reduce product unit costs; and 3) the desire to reduce waste disposal costs.

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

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

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

The diagram to the right illustrates this example:



Drivers:

What are the reasons to change?

Capability Gaps:

What are the barriers to change?

Technology Characteristics:

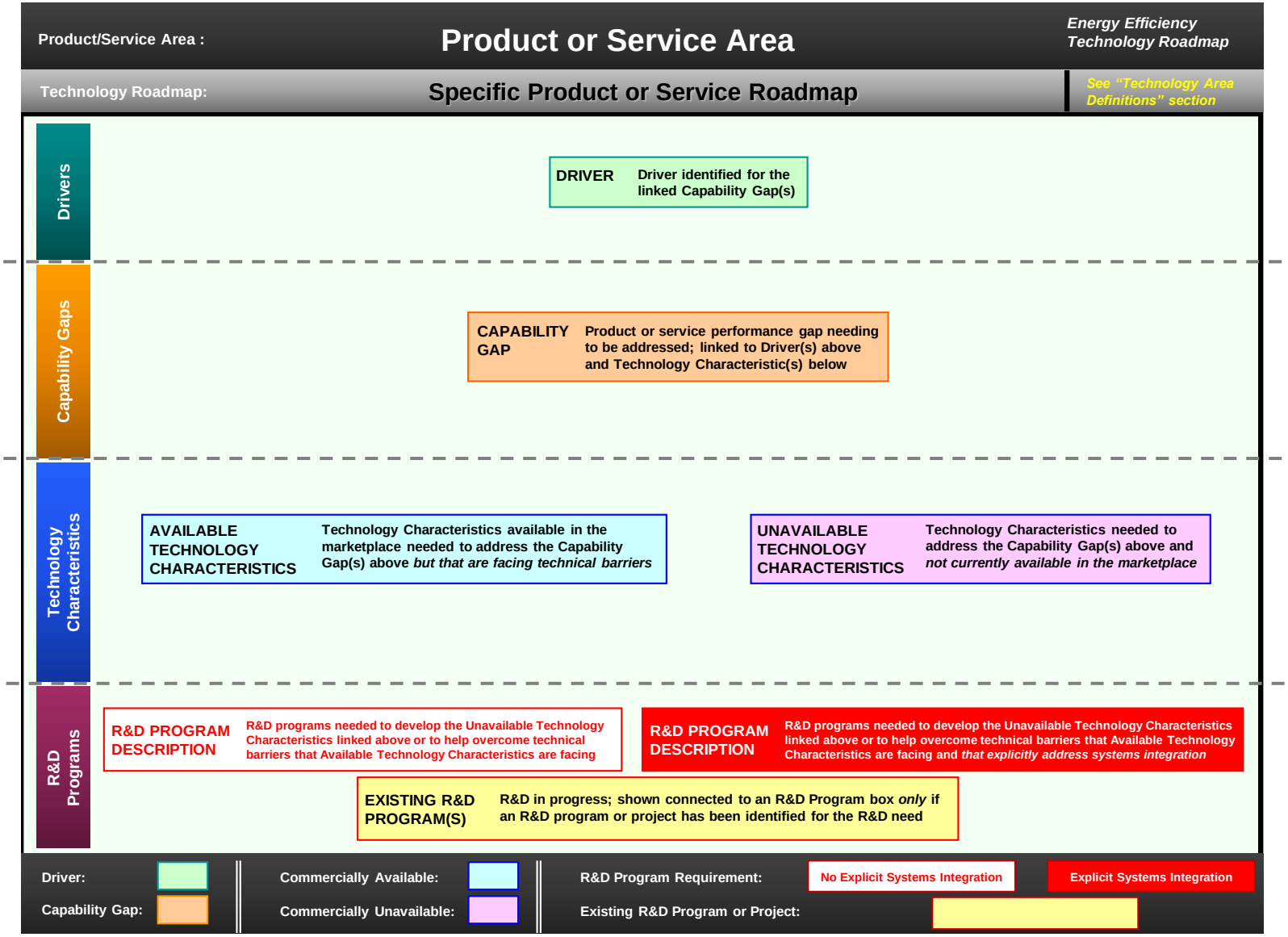
What are the technological solutions needed to overcome barriers to change?

R&D Programs:

What are the research programs and key research questions to pursue to develop technological solutions?

Back to Table of Contents

Roadmap Diagram Key



R&D Program Summaries Key

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

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

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

Key research questions:

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

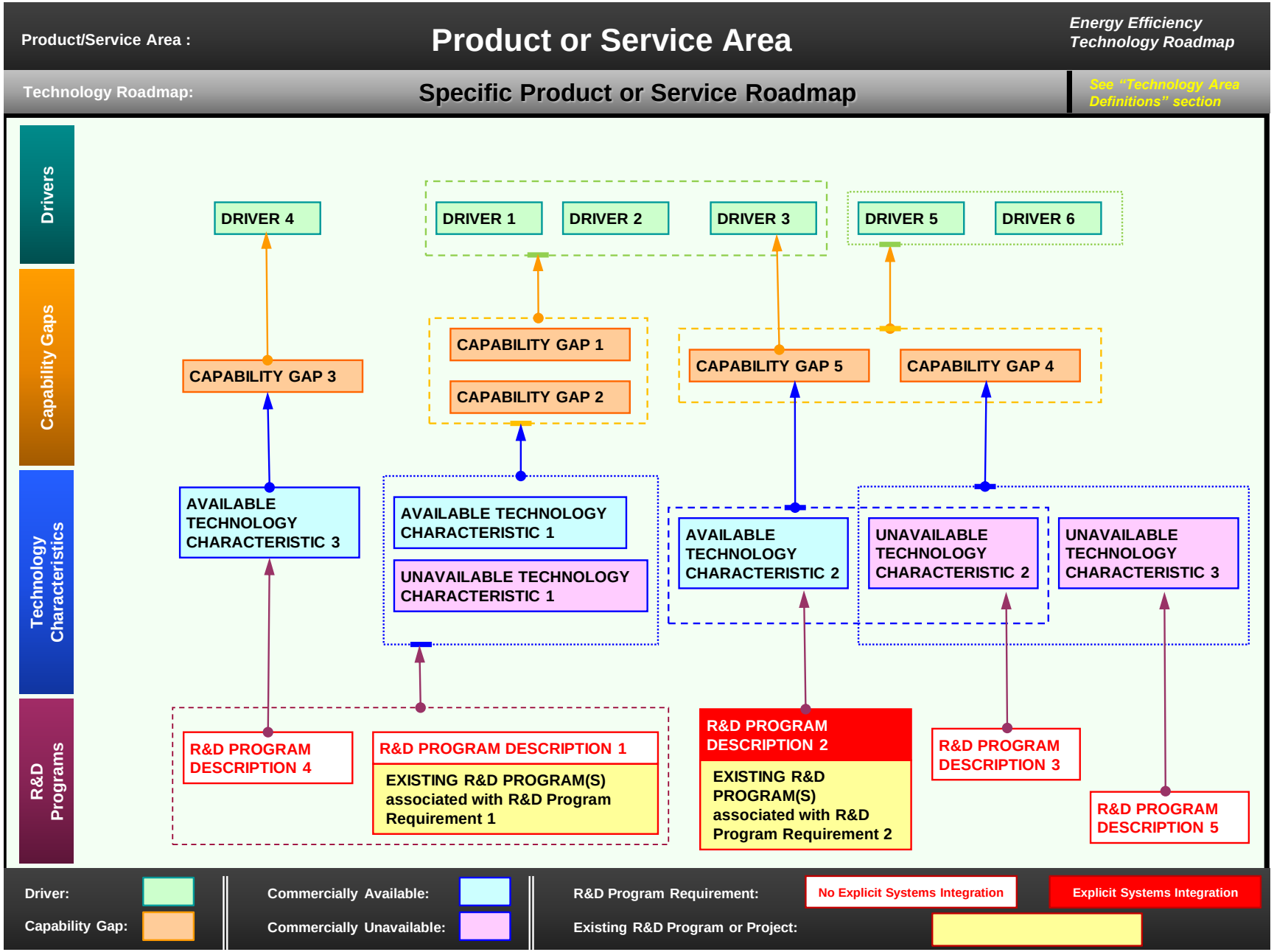
R&D Program Title. Brief summary of R&D program needed to develop the associated Unavailable Technology Characteristics or to help overcome technical barriers that Available Technology Characteristics are facing.

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

Key research questions:

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

How to Interpret Roadmap Pages



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

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

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

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

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

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

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

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

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

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

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

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

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

R&D 2 linked to D 3

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

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

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

Back to Table of Contents

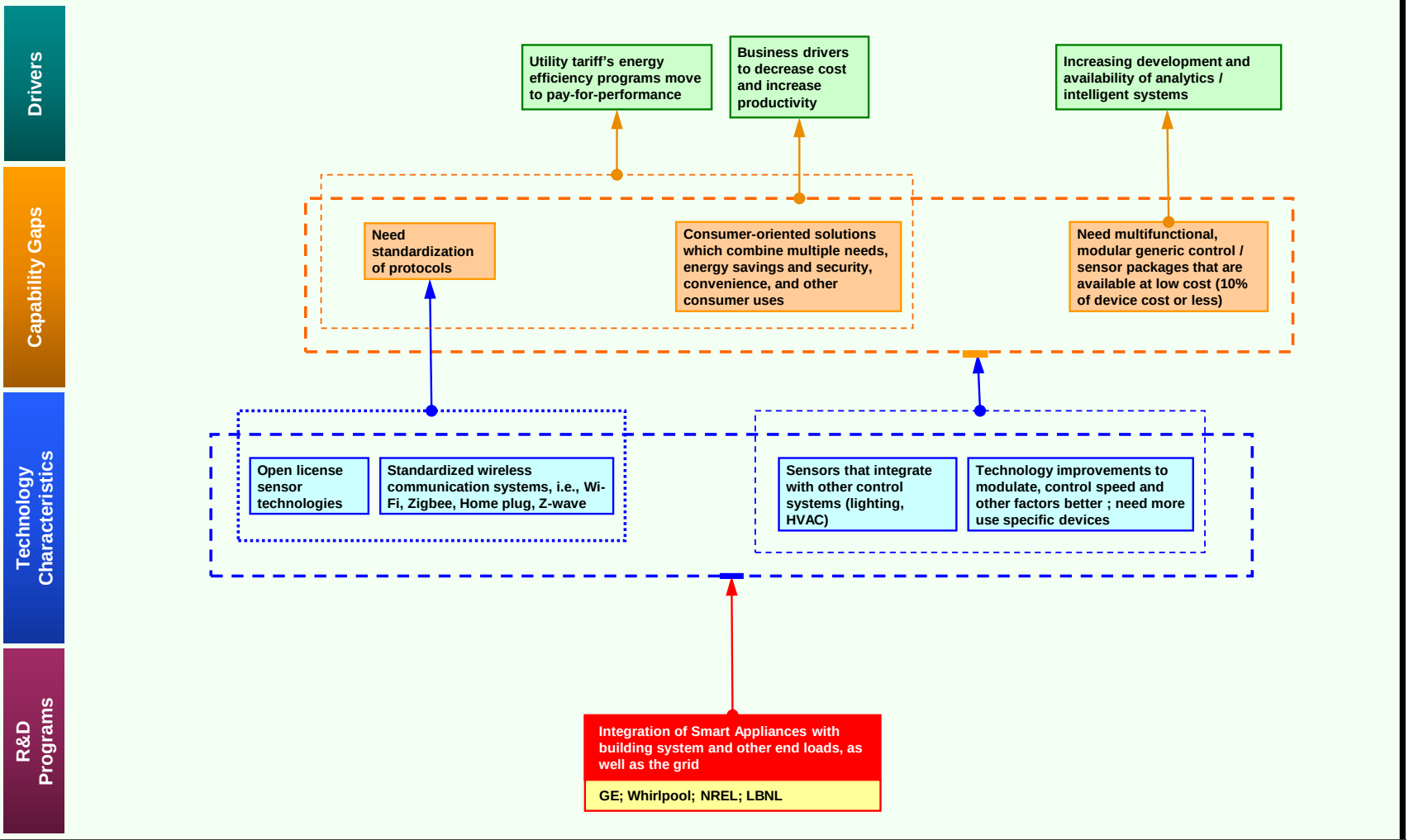
Back to Table of Contents

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 (1 of 5)**

See "Technology Area Definitions" section



Driver: Capability Gap: | Commercially Available: Commercially Unavailable: | R&D Program Requirement: No Explicit Systems Integration Explicit Systems Integration Existing R&D Program or Project:

R&D Program Summaries

Integration of smart appliances with building system and other end use loads, as well as the grid. To maximize benefits of small appliances for grid and energy savings and deliver value to both utility and building users.

Existing research: General Electric (GE), Whirpool, National Renewable Energy Laboratory (NREL), Lawrence Berkeley National Laboratory (LBNL).

- *[Summaries of existing research pending]*

Key research questions:

1. What are the practical limits for load shifting in an effective way without interfering with comfort or service (power, duration, frequency)?
2. What are the potential energy savings at the end use level (not just load shifting) as a result of smart communicating appliances?
3. Can we leverage safety, security, and convenience benefits to get consumers interested in smart appliances?

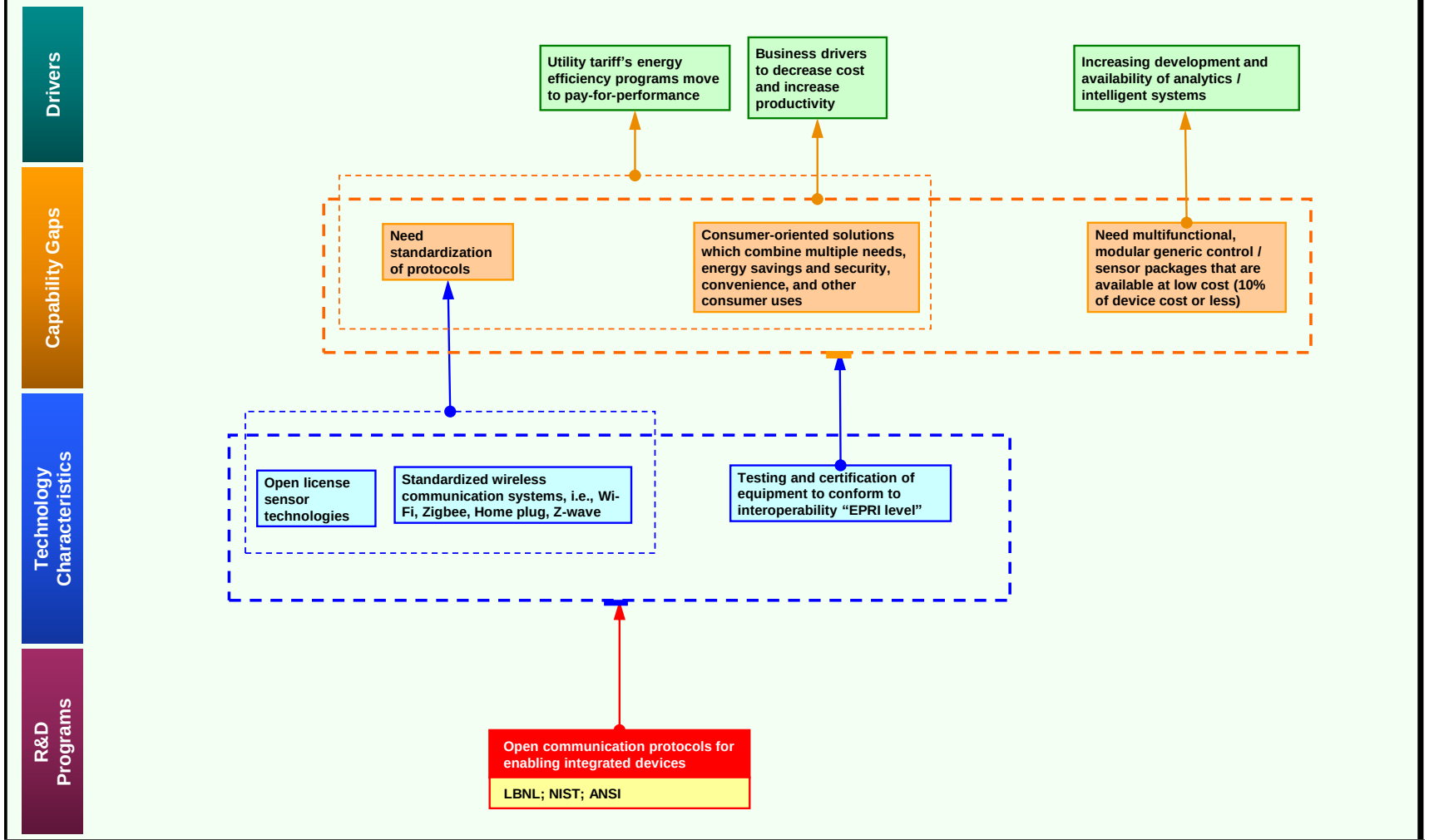
Back to Table of Contents

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 (2 of 5)**

See "Technology Area Definitions" section



Driver: | Capability Gap: | Commercially Available: | Commercially Unavailable: | R&D Program Requirement: No Explicit Systems Integration / Explicit Systems Integration | Existing R&D Program or Project:

R&D Program Summaries

Open communication protocols for enabling integrated devices. Lots of building systems cannot communicate to each other. This obstacle to communication limits interoperability and effective integrated building controls.

Existing research: Lawrence Berkeley National Laboratory (LBNL), National Institute of Standards and Technology (NIST)(ZigBee and WiFi); American National Standards Institute (ANSI).

- *[Summaries of existing research pending]*

Key research questions:

1. What kind of universal performance specification could be developed to motivate OEMs to interoperate open communication protocols into their products?

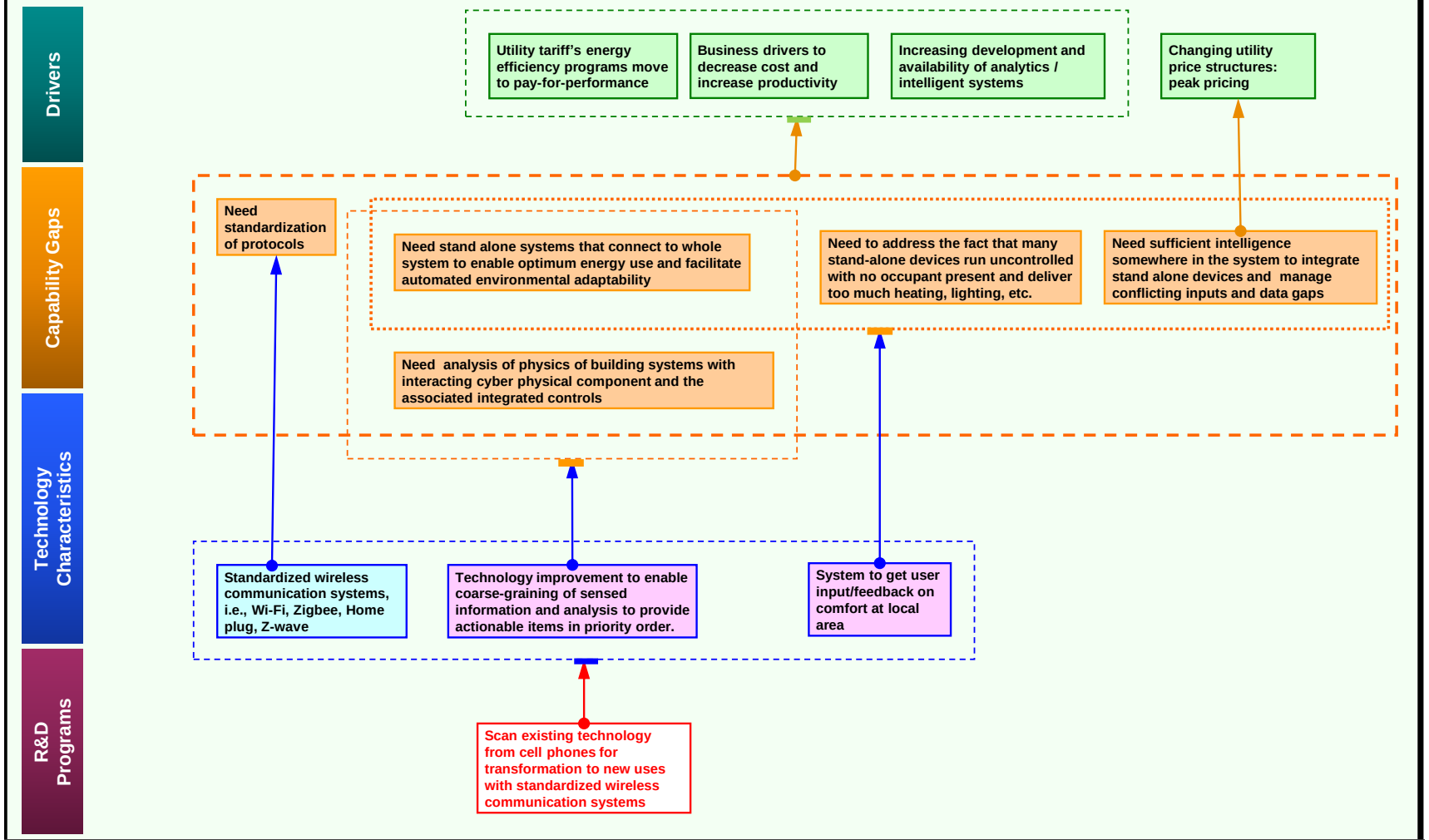
Back to Table of Contents

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 (3 of 5)**

See "Technology Area Definitions" section



Driver: Capability Gap: | Commercially Available: Commercially Unavailable: | R&D Program Requirement: No Explicit Systems Integration / Explicit Systems Integration | Existing R&D Program or Project:

R&D Program Summaries

Scan existing technology from cell phones for transformation to new uses with standardized wireless communication systems. Cell phones are now ubiquitous and versatile. Cell phones and buildings can exchange information. Cell phones are mobile sensors and remote interface / communication devices. Operators can require alarms or change control settings remotely, and occupants can send preferences to the central system.

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.

Existing research: None identified.

Key research questions:

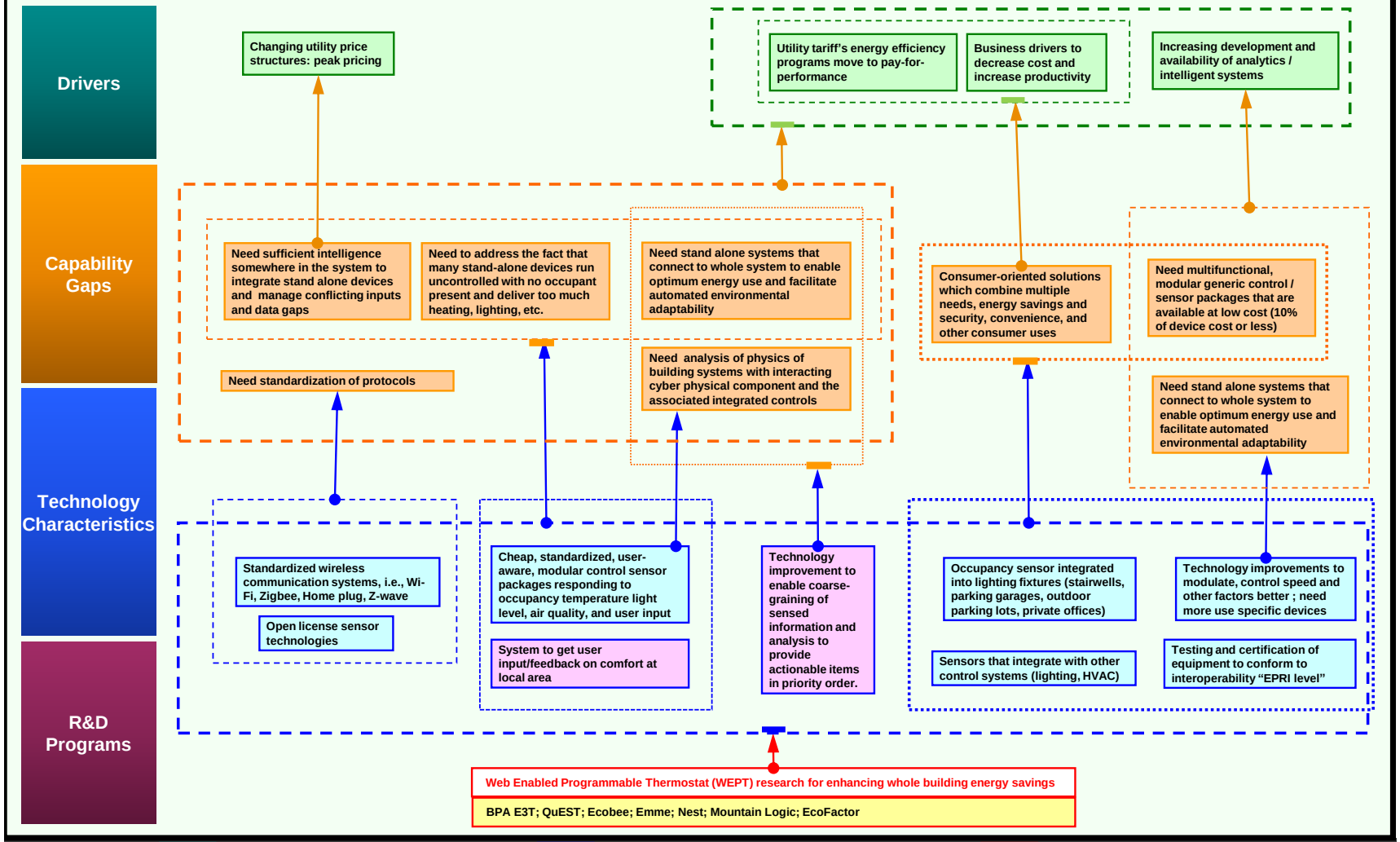
1. What is an effective system architecture for using cell phones in commercial applications?
2. What are the opportunities for integrating cell phones into energy management and building control systems?
3. How can location information be used by energy management and building control systems?
4. What sensors could be added/built in to cell phones to make them more useful as part of building energy management systems?

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 (4 of 5)**

See "Technology Area Definitions" section



R&D Program Summaries

Web enabled programmable thermostat research for enhancing whole building energy savings. Web enabled programmable thermostats that control HVAC equipment and integrate with other systems can help deliver significant reductions in energy use and improve occupant comfort and convenience.

Existing research: Bonneville Power Administration (BPA) Energy Efficiency Emerging Technologies (E3T), QuEST, Ecobee, Nest, Mountain Logic, EcoFactor.

- 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.
- *[Summaries of other existing research pending]*

Key research questions:

1. What is the minimum dataset needed to be collected?
2. How much energy is existing web based systems saving?
3. How can / is data being used / processed to save energy?
4. What additional opportunities to save more energy with all systems?
5. What level of control / automation is needed?

Self-reporting performance. Recently a number of new products have been introduced that have the capability to gather and report performance data at of unprecedented value and low cost. Examples include residential smart thermostats, digital lighting control systems, and HVAC rooftop unit controllers. There is a need to develop new approaches and methods of energy savings performance verification that leverages the ability of this type of self-reporting equipment.

Several potential elements of new approaches are listed below for illustration:

- The unit of analysis would not be individual devices; rather it should be vendor's networked groups of devices that individually or collectively meet measurable performance standards.
- Performance metrics would be developed to measure and report energy savings performance.
- Energy savings would be verified with active performance monitoring of installed equipment. Field trials could be designed to work with vendors to structure tests and collect the data using the vendor's data systems for group's equipment.
- This approach relies on the newly installed equipment to gather data and report performance, so measurement of existing baseline equipment (as need for calculating energy savings) is not directly supported. Two approaches might be used:
  - A post/post verification approach that utilizes on/off periods alternating the efficient case with emulation of the pre-installation baseline case. Emulation of the pre-installation baseline can be challenging, so this might be addressed with simplified measurements of relevant independent variables such as temperature or light level of pre-installation baseline.
  - Using surveys or other baseline data to establish generic baseline performance.

Existing research: No existing research identified.

Key research questions:

1. Establishing standard ways to access and aggregate data from various vendors.
2. Establishing performance metrics for comparing the energy efficiency performance of specific technologies.
3. Developing techniques to emulate or otherwise establish baseline performance.
4. Establishing national scale standard testing for qualifying products (e.g., Energy Star).

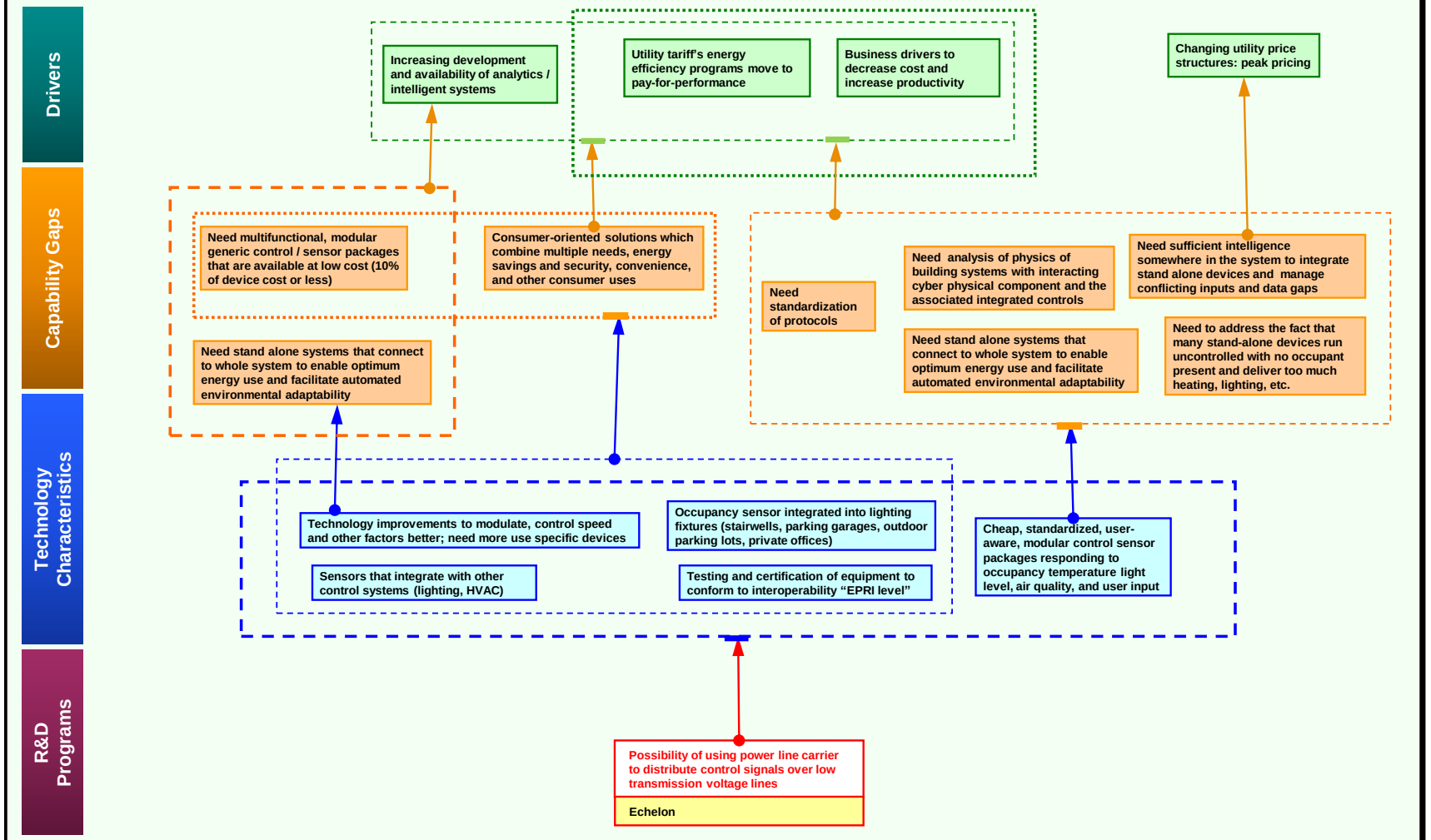
Back to Table of Contents

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 (5 of 5)**

See "Technology Area Definitions" section



R&D Program Summaries

Possibility of using power line carrier to distribute control signals over low transmission voltage lines. 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.

Existing research: Echelon.

- *[Summaries of existing research pending]*

Key research questions:

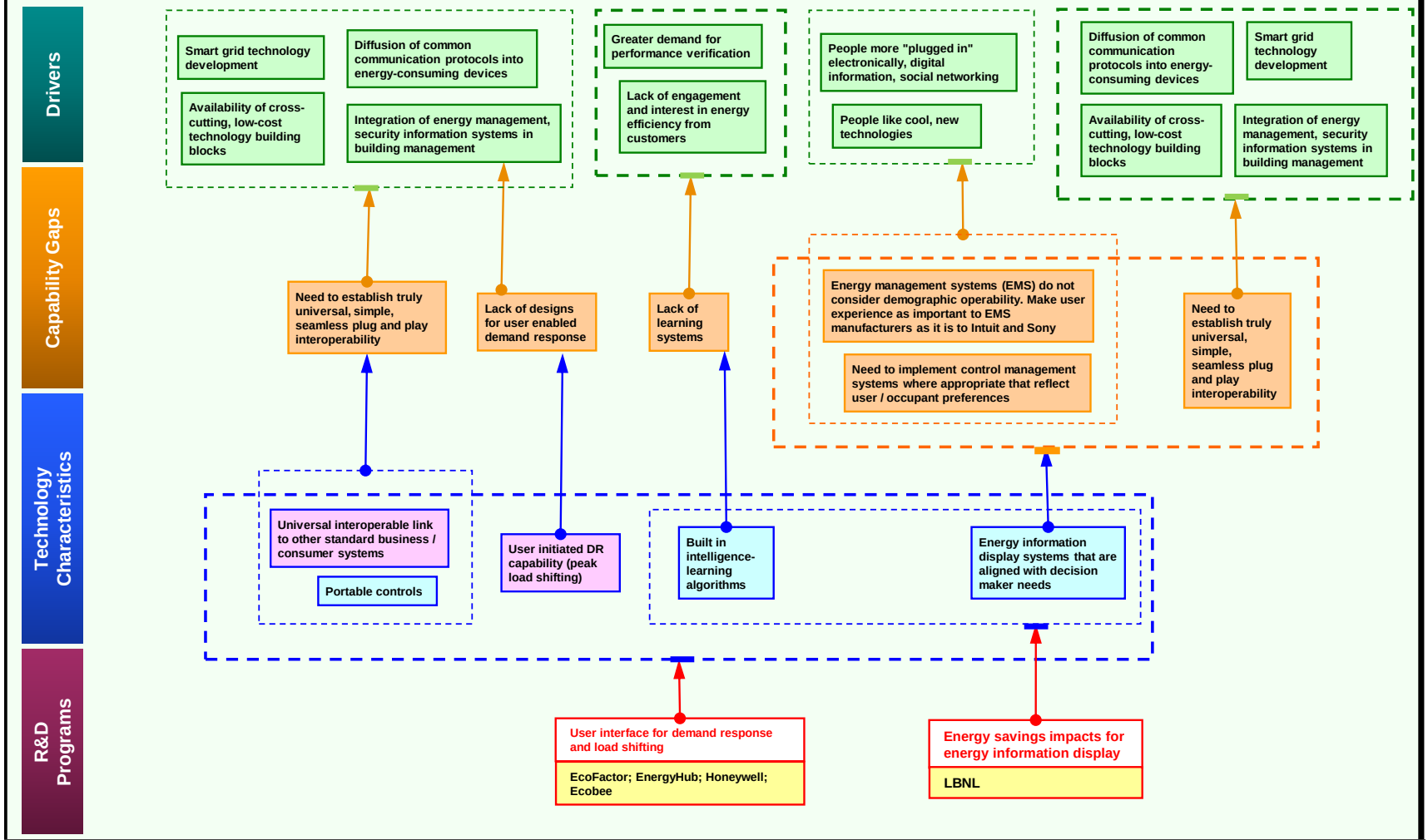
1. Is it cheaper or cost effective?
2. What are the full characterizations of data transfer capabilities (e.g. bandwidth, security) compared to wireless protocols?
3. What are current roadblocks for large scale implementation?

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

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Easy / Simple User Interface Controls (1 of 3)**

See "Technology Area Definitions" section



Driver: Capability Gap: Commercially Available: Commercially Unavailable: R&D Program Requirement: No Explicit Systems Integration Explicit Systems Integration Existing R&D Program or Project:

R&D Program Summaries

User interface for demand response and load shifting. Demand response (DR) has a large consumers acceptance barrier due to perceived inconvenience. User interfaces can learn occupant preferences and provide "seamless demand response" and add value to EMS.

Existing research: EcoFactor, EnergyHub, Honeywell, and Ecobee.

- *[Summaries of existing research pending]*

Key research questions:

1. How can we program devices for DR?
2. How can customer feedback mitigate perceived inconvenience of demand response?
3. How can two-way communication enable better DR program?
4. How can DR feature be used for site renewables integration?

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).

Existing research: Lawrence Berkeley National Laboratory (LBNL).

- 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//.

Key research questions:

1. Questions not yet specified.

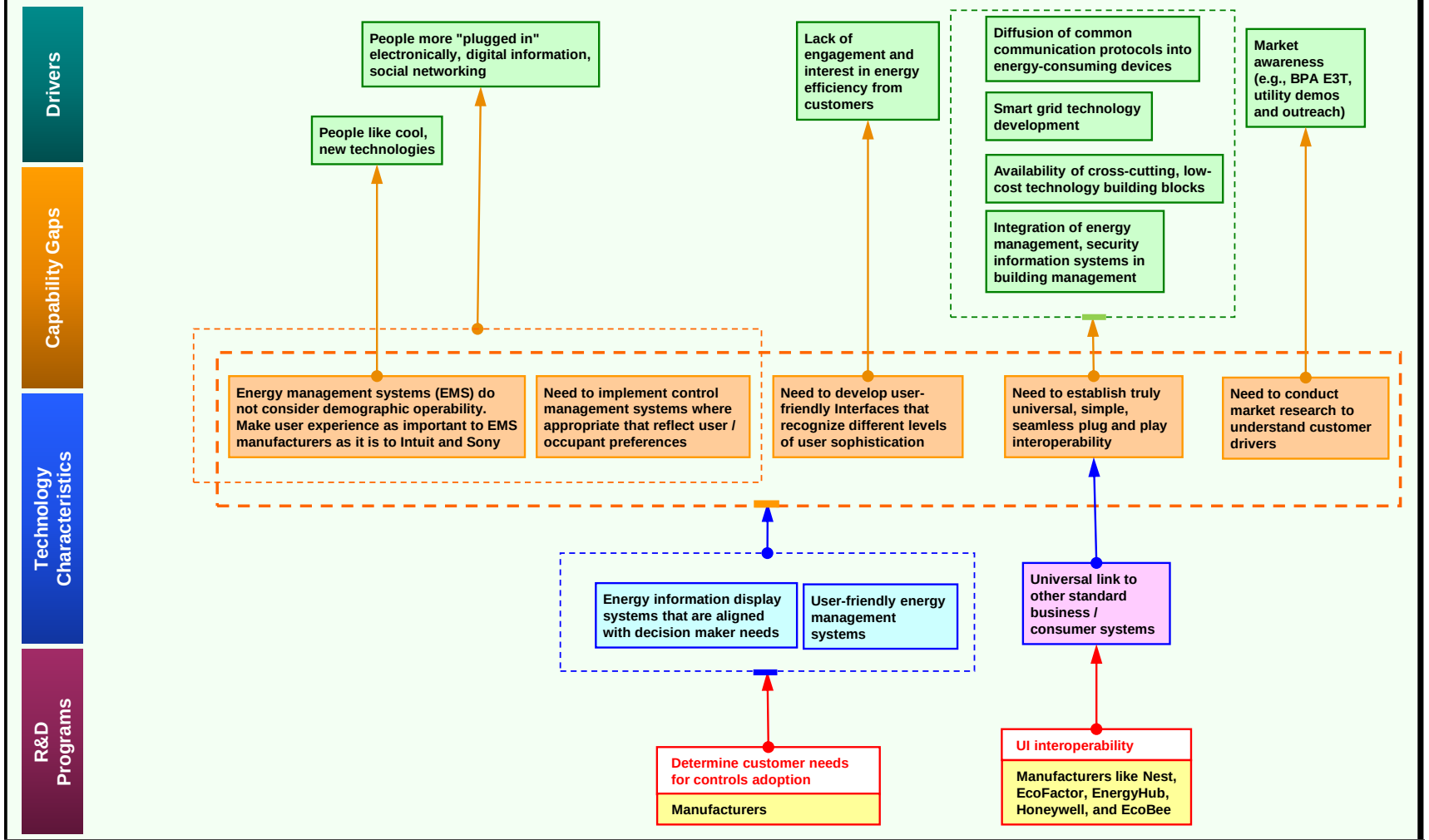
Back to Table of Contents

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

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Easy / Simple User Interface Controls (2 of 3)**

See "Technology Area Definitions" section



Driver: Capability Gap: | Commercially Available: Commercially Unavailable: | R&D Program Requirement: No Explicit Systems Integration / Explicit Systems Integration | Existing R&D Program or Project:

R&D Program Summaries

UI interoperability. User interface (UI) enhancement through application programming interfaces (APIs) for energy management systems (EMS) and other applications.

Existing research: Manufacturers.

- *[Summaries of existing research pending]*

Key research questions:

1. What are the appropriate "APIs" that would link EE to top SW system, not just BMs but ERP, outlook, etc.

Determine customer needs for controls adoption. Conduct R&D to determine customer needs for easy/simple GUI for controls and then design R&D profile to develop a comprehensive/integrated user interface system that customer can understand and use and test it in customer sites.

Existing research: Manufacturers like Nest; EcoFactor; EnergyHub; Honeywell and EcoBee.

- *[Summaries of existing research pending]*

Key research questions:

1. Which type of GUI's the customer will mostly likely prefer?
2. How does the integrated system, feedback and protocols act as sub system in a manner to enable simple customer experience?
3. what will be the behavior change and how to quantify and evaluate the change?

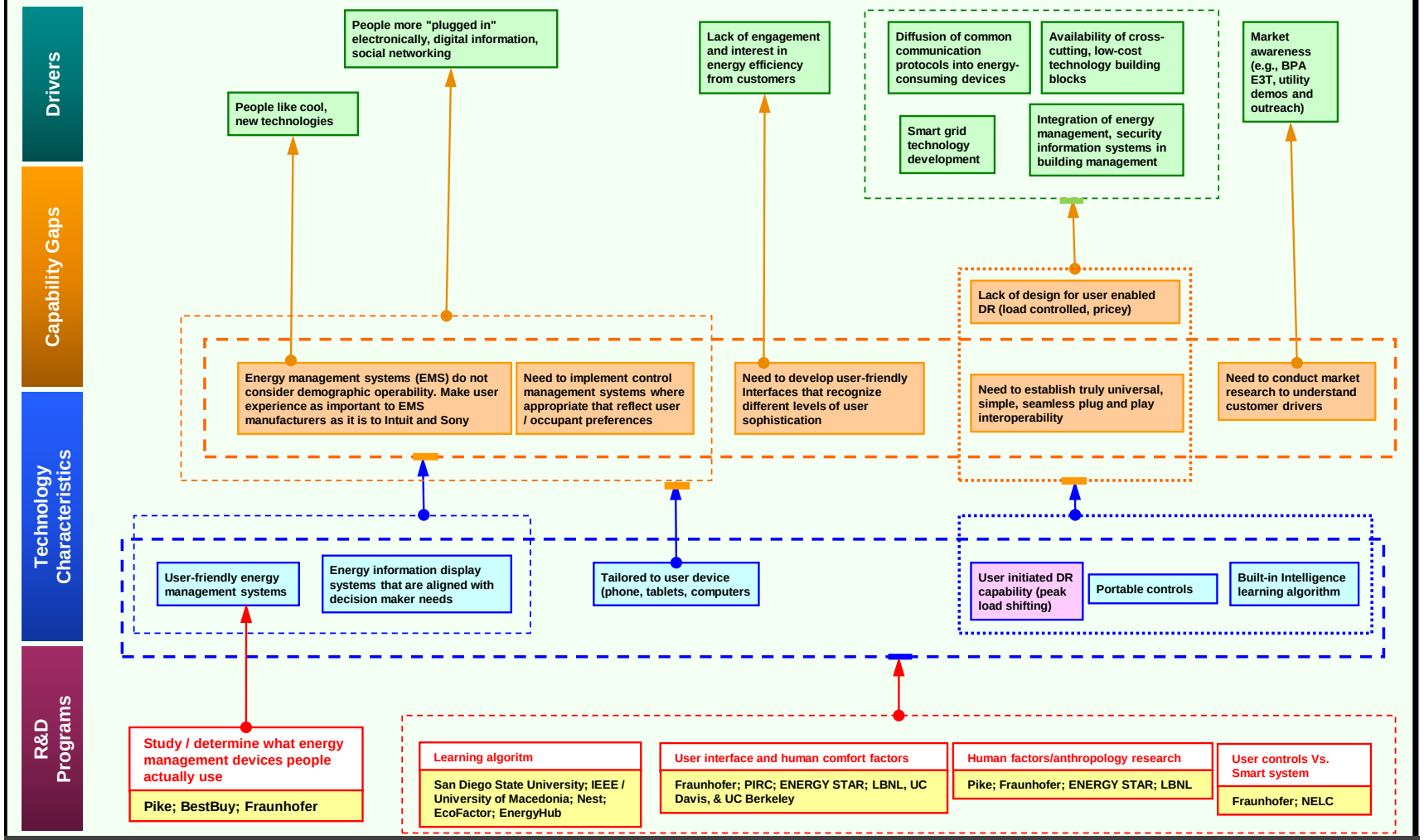
Back to Table of Contents

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

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Easy / Simple User Interface Controls (3 of 3)**

See "Technology Area Definitions" section



Driver:

Capability Gap:

Commercially Available:

Commercially Unavailable:

R&D Program Requirement: No Explicit Systems Integration | Explicit Systems Integration

Existing R&D Program or Project:

R&D Program Summaries

User controls vs. smart system. As system become smarter and learn to improve efficiency, what level of user override should be allowed?

Existing research: Fraunhofer; National Energy Leadership Corps (NELC).

- *[Summaries of existing research pending]*

Key research questions:

1. In what circumstances should user override be allowed? How should this parameters be incorporated into user interface?

Learning algorithm. User inputs and outputs with smart/learning EMs systems.

Existing research: San Diego State University, Institute of Electrical and Electronics Engineers (IEEE) with the University of Macedonia, Nest, EcoFactor, EnergyHub.

- *[Summaries of existing research pending]*

Key research questions:

1. What are the variables and parameters that a learning systems need to utilize?
2. How much guidance along those lines can/should the user provide either when setting up or during usage of the system?
3. How much output of "smart" system should be shared with user and to what end?

User interface and human comfort factors. What user interfaces link to more advanced human comfort system, e.g., radiant, conductive and ventilation system that affect comfort envelope.

Existing research: Fraunhofer, U.S. Department of Energy Building America Program Partnership for Improved Residential Construction (PIRC), ENERGY STAR, National Renewable Energy Laboratory (NREL). Also a collaboration among Lawrence Berkeley National Laboratory (LBNL), University of California Davis, and University of California Berkeley.

- Subject matter experts reported in September 2012: "LBNL/UC Davis/UC Berkeley (on thermostats)."
- NREL: See Appendix B.
- *[Summaries of existing research pending]*

Key research questions:

1. Beyond air temp, what user interfaces best represent/link to user perception of comfort to control advanced HVAC systems?
2. similarly for lighting, what new SSL systems, tasks and ambient, what user interface best interact with user perceptions/needs?

Human factors and anthropometric research. Research into human factors/resources to energy management systems to explore what are the key characteristics.

Existing research: Pike, Fraunhofer, ENERGY STAR (for thermostats initially); LBNL.

- *[Summaries of existing research pending]*

Key research questions:

1. What are different needs for different sector decision makers—e.g building manager compared to residential customer compared to industrial plant manager?
2. What other apps should energy management be integrated with customers?
3. What devices should use interface be integrated into?

Back to Table of Contents

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.

Existing research: Pike, BestBuy and Fraunhofer.

- *[Summaries of existing research pending]*

Key research questions:

1. Why don't consumer use the feature?
2. What is buyer's motivation to purchase?

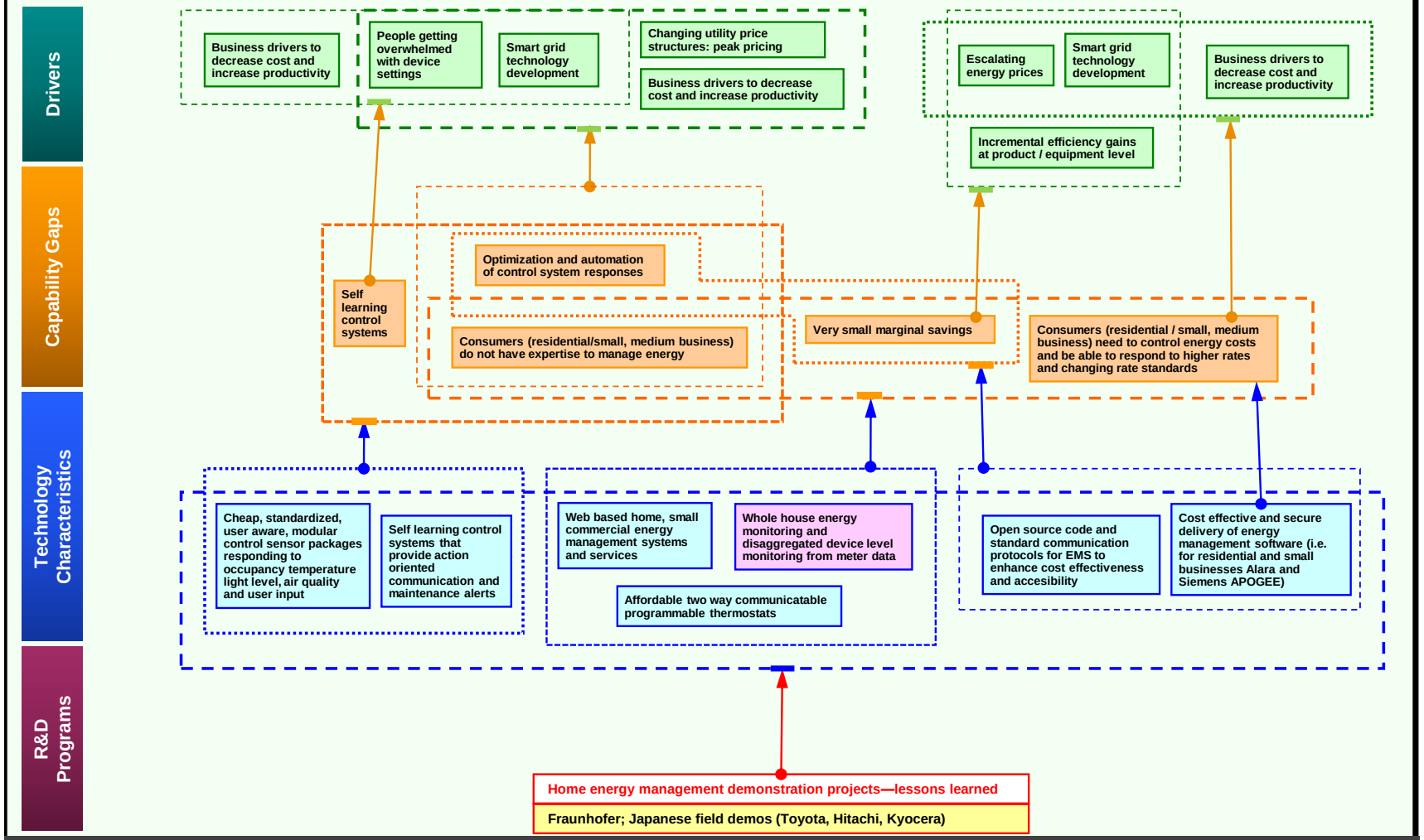
Back to Table of Contents

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

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Energy Management Services (1 of 4)**

See "Technology Area Definitions" section



Driver:

Capability Gap:

Commercially Available:

Commercially Unavailable:

R&D Program Requirement: No Explicit Systems Integration | Explicit Systems Integration

Existing R&D Program or Project:

R&D Program Summaries

Home energy management demonstration projects—lessons learned. 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).

Existing research: Fraunhofer demo lab; Japanese field demos (Toyota, Hitachi, Kyocera).

Key research questions:

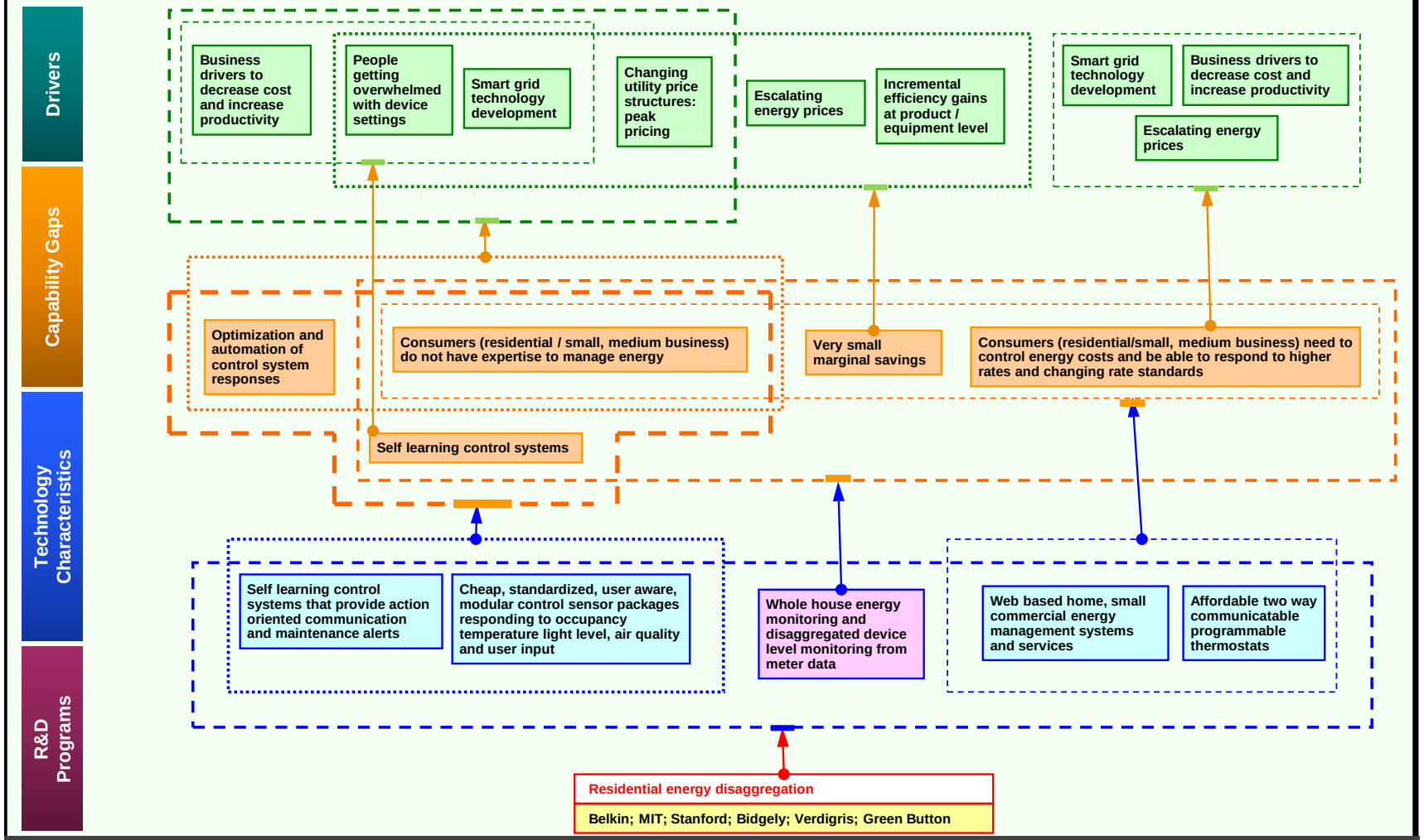
1. Finding and synchronizing learnings across funded projects?

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

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Energy Management Services (2 of 4)**

See "Technology Area Definitions" section



Driver: Capability Gap: Commercially Available: Commercially Unavailable: R&D Program Requirement: No Explicit Systems Integration Explicit Systems Integration Existing R&D Program or Project:

R&D Program Summaries

Residential energy disaggregation. Disaggregate whole house energy consumption by device level. Use smart meters or CTC lamps to read load. Use software to disaggregate load and inform homeowners of energy use with suggestions to save energy.

Existing research: Belkin, Massachusetts Institute of Technology (MIT), Stanford University, Bidgely, Verdigris, Green Button.

- *[Summaries of existing research pending]*

Key research questions:

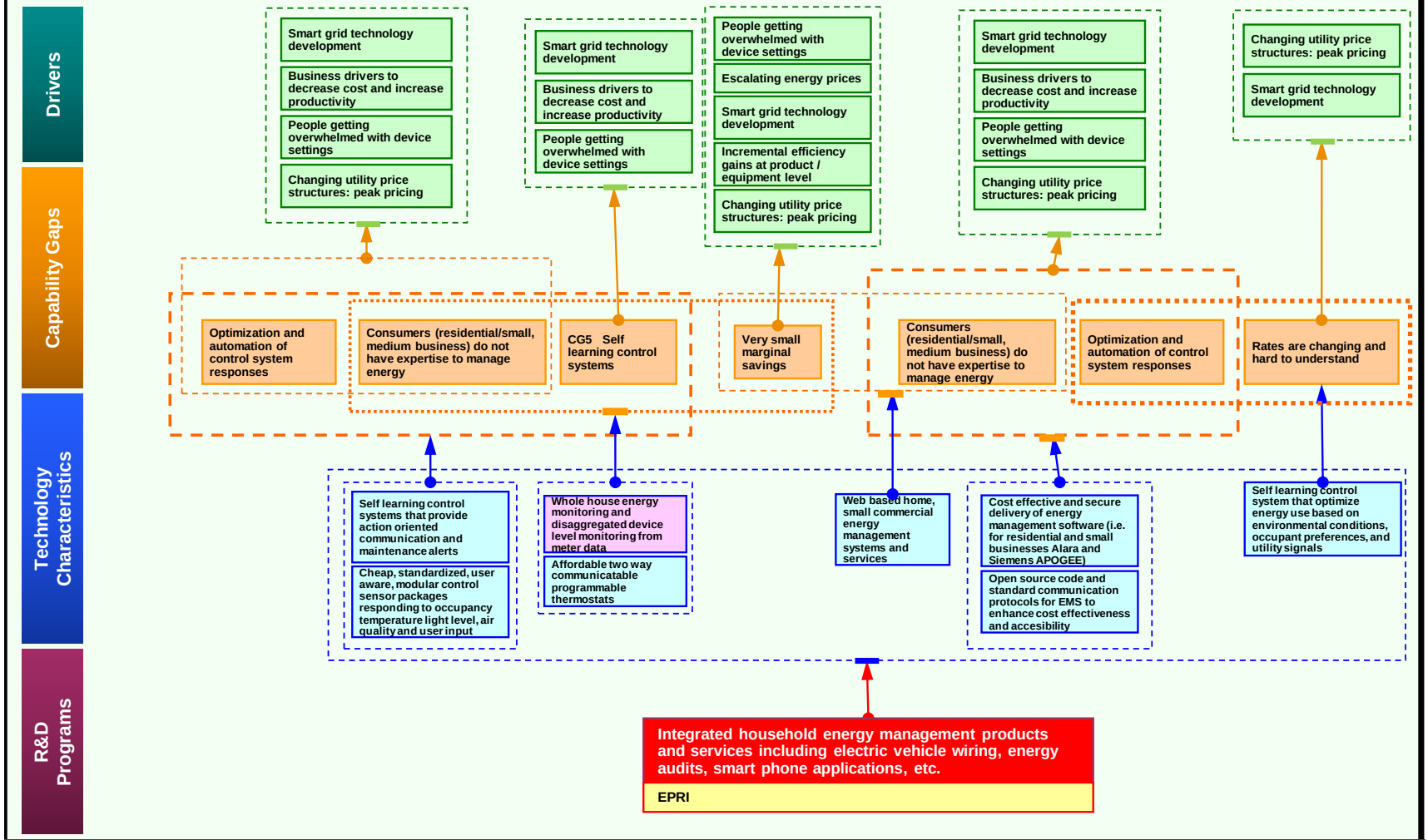
1. How much energy do homeowners save by knowing their energy use?
2. Which level of granularity is necessary to achieve significant savings? (1 kHz, 1Hz, 1min, 1hr)?
3. What suggestions will the software provide?
4. How can the utility provide a rebate for these tools?
5. What is the cost per home?

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

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Energy Management Services (3 of 4)**

See "Technology Area Definitions" section



Driver:

Capability Gap:

Commercially Available:

Commercially Unavailable:

R&D Program Requirement: No Explicit Systems Integration | Explicit Systems Integration

Existing R&D Program or Project:

R&D Program Summaries

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.

Existing research: Research on this topic at the Electric Power Research Institute (EPRI); see Appendix B.

Key research questions:

2. Questions not yet specified.

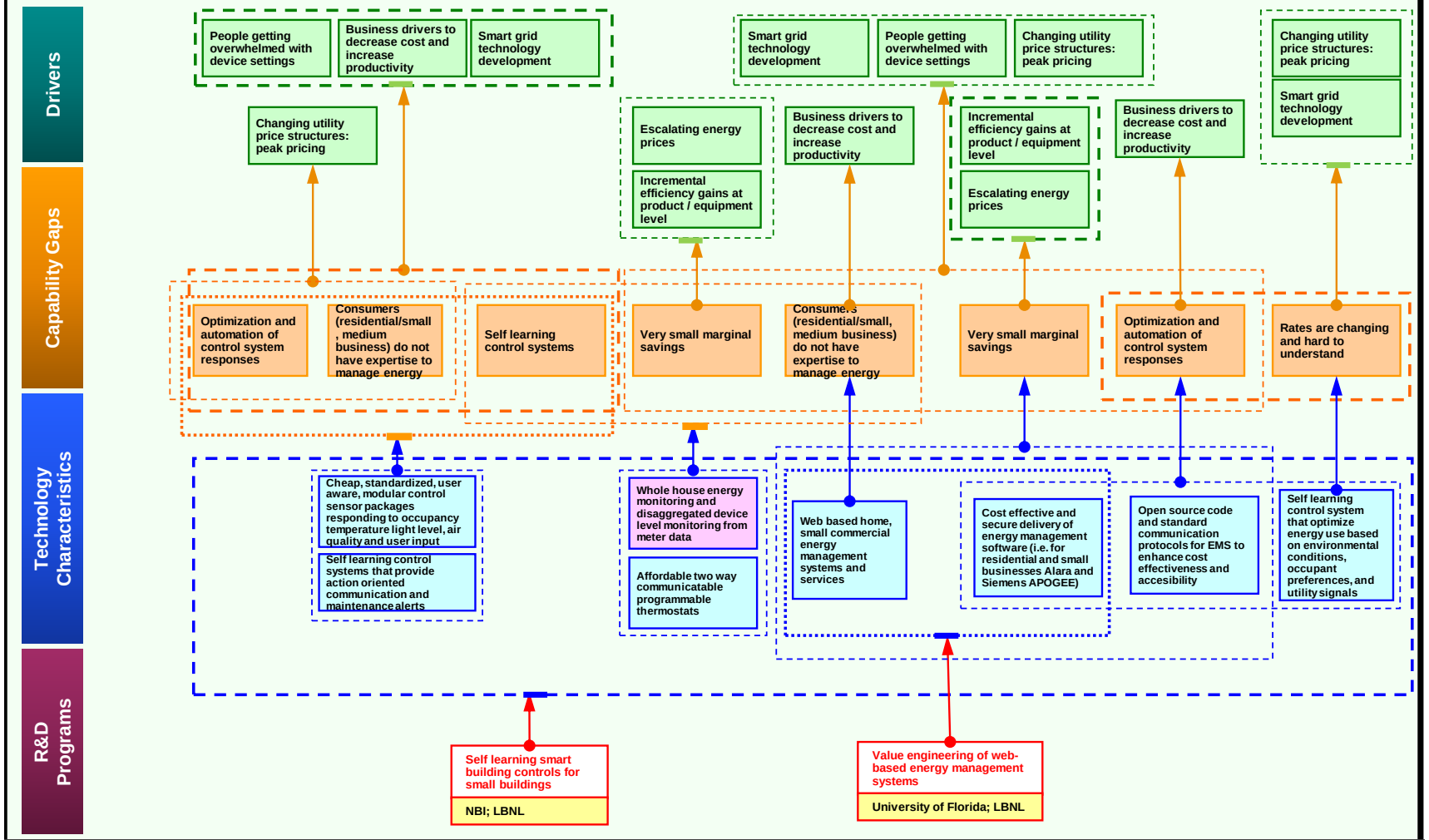
Back to Table of Contents

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

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Energy Management Services (4 of 4)**

See "Technology Area Definitions" section



Driver: Capability Gap: Commercially Available: Commercially Unavailable: R&D Program Requirement: No Explicit Systems Integration Explicit Systems Integration Existing R&D Program or Project:

R&D Program Summaries

Self learning smart building controls for small buildings. Develop, test and deploy technology that allows customers, utilities and service providers to optimize building operation with little if any technical expertise and engagement.

Existing research: New Buildings Institute (NBI), Lawrence Berkeley National Laboratory (LBNL).

- *[Summaries of existing research pending]*

Key research questions:

1. What human interface is needed?
2. What types of sensors are needed?
3. What are the analytic protocols to make learning work?
4. What level of automation is needed now and in the future?
5. How is optimization achieved?
6. Notification protocols?

Value engineering of web-based energy management systems. Examine the cost structure of energy management systems to identify levers to pull to reduce costs. For example, if sensors are a key barrier to cost effectiveness how can these costs be brought down?.

Existing research: University of Florida, Lawrence Berkeley National Laboratory (LBNL).

- *[Summaries of existing research pending]*

Key research questions:

1. What elements of systems are key drivers of cost?
2. Can these drivers be influenced by technology advances?
3. What additional research should be done to reduce costs?

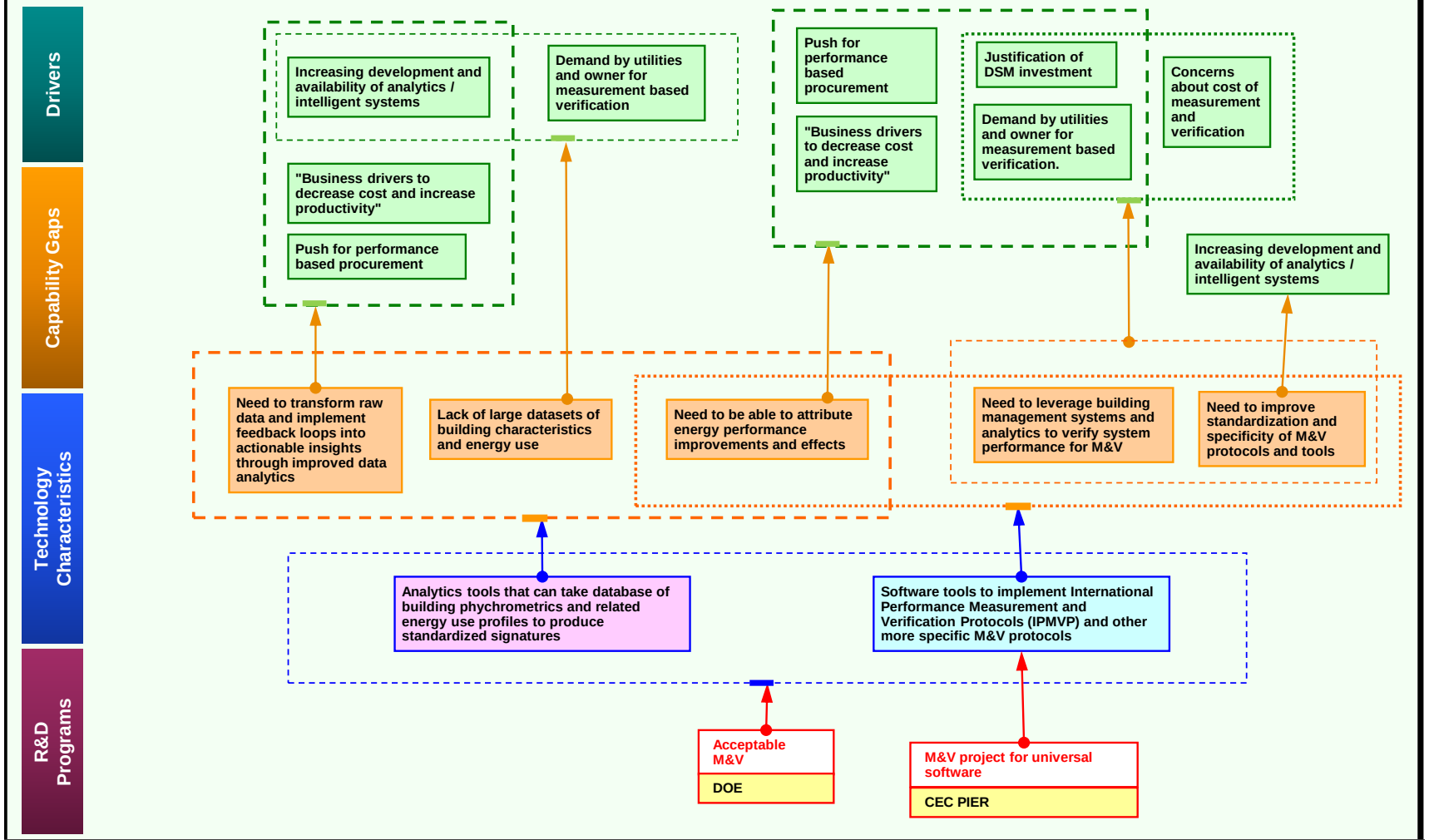
Back to Table of Contents

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

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Low-Cost Savings Verification Techniques (1 of 7)**

See "Technology Area Definitions" section



R&D Program Summaries

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.

Existing research: California Energy Commission (CEC) Public Interest Energy Research (PIER) program.

- The CEC PIER program is currently working on that makes use of Pacific Gas & Electric's Universal Translator tool; see Appendix B for more information.

Key research questions:

1. Questions not yet specified.

Acceptable M&V. (Summary not yet provided.)

Existing research: U.S. Department of Energy (DOE) Uniform Methods Project.

- *[Summaries of existing research pending]*

Key research questions:

1. Questions not yet specified.

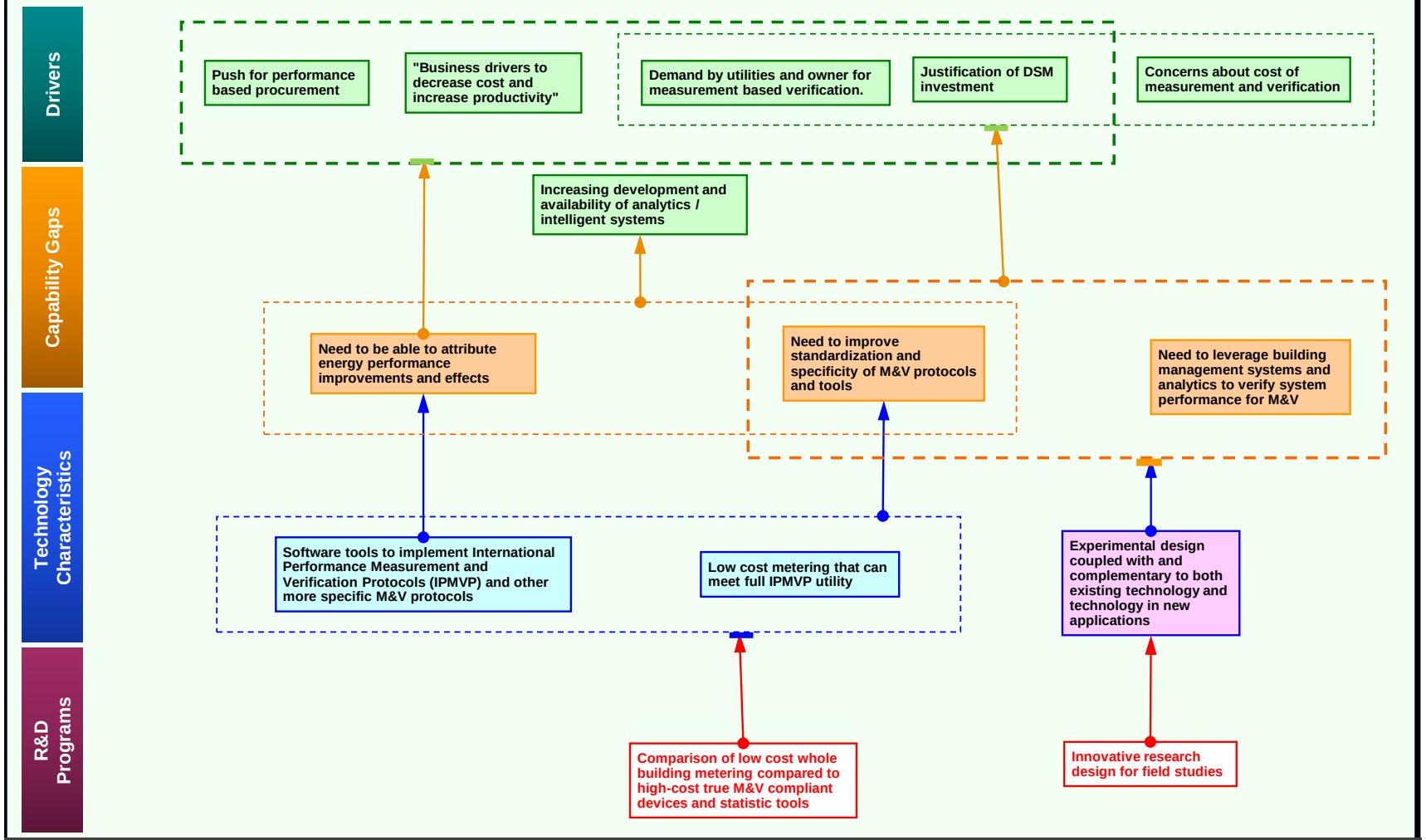
Back to Table of Contents

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

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Low-Cost Savings Verification Techniques (2 of 7)**

See "Technology Area Definitions" section



Driver:

Capability Gap:

Commercially Available:

Commercially Unavailable:

R&D Program Requirement: No Explicit Systems Integration | Explicit Systems Integration

Existing R&D Program or Project:

R&D Program Summaries

Comparison of low cost whole building metering compared to high-cost true M&V compliant devices and statistic tools. There are numerous approaches electric bill disaggregation with varying cost and accuracy.

Existing research: None identified.

Key research questions:

1. What approaches or hybrid methods can be used for different contexts?
2. Is amp only metering drastically different from true power metering?
3. Is true cost of International Performance Measurement and Verification (IPMVP) compliance worth it?
4. Comparison of measuring/modelling tools:
    a. Low cost data logging;
    b. statistical analysis;
    c. revenue quality metering;
    d. variance in accuracy; and
    e. cost effectiveness.

Innovative research design for field studies. Innovative field study design approaches that can dramatically reduce cost and time requirements. Current practice for field studies typically involves a one-off study design for a particular measure (e.g. heat pump water heaters installed in 40 homes with multi-channel 1-minute interval data collected for 1 year). Installation of test technologies in multiple field sites and in-field metering is inherently expensive and time consuming.

As an illustrative example, consider an upfront experiment design which integrates a longer term approach for reuse of data, uses permanent real-time systems for speed, limits field studies to measurement of key independent variables and confines equipment testing to lab setting. Envisioned is an intelligently designed permanent field test installation in real homes, collecting data in real time on key variables which can be used in conjunction with lab tests. Effectively this will create a real time study of the region with data stores easily accessible for use in testing new technologies in the laboratory, modeling them with computers, or utilizing in other ways. Ultimately combining emerging technologies, bringing metering to the next level, combining web capabilities; predict energy savings for order of magnitude reductions in time and expenses.

Existing research: None identified.

Key research questions:

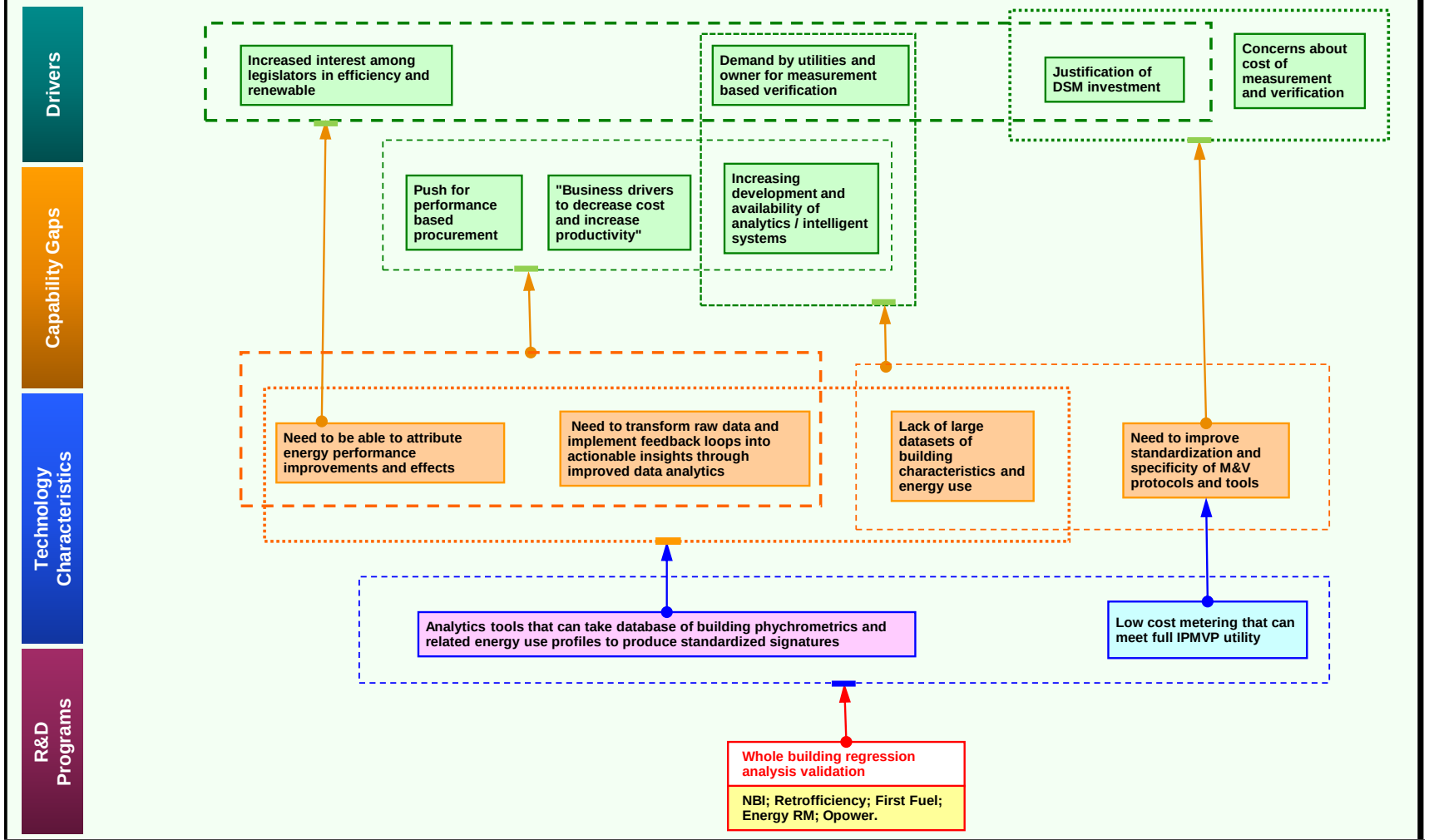
1. How can this standard approach be improved upon?
2. Are there better combinations of secondary research, lab testing, and field measurements?
3. To minimize costs, what is best measured in the field, what does not need to be measured in the field?
4. Are there more effective ways to combine lab test and field tests? How can one-off studies be replaced with reusable real-time information systems?
5. How can relatively expensive engineering time be replaced?
6. Are there synergies available by combining a series of improvements in the end-to-end process?
7. Are there better experimental design approaches streamline the entire process?

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

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Low-Cost Savings Verification Techniques (3 of 7)**

See "Technology Area Definitions" section



Driver: Capability Gap: | Commercially Available: Commercially Unavailable: | R&D Program Requirement: No Explicit Systems Integration / Explicit Systems Integration | Existing R&D Program or Project:

R&D Program Summaries

Whole building regression analysis validation. Validation of multi fuel engineering based regression analysis to show whole building energy use by end-use. The primary target is commercial buildings. Focus is on standardization of signatures of routine and non-routine changes.

Existing research: New Buildings Institute (NBI), Retrofficiency, First Fuel, Energy RM, Opower.

- *[Summaries of existing research pending]*

Key research questions:

1. What level of accuracy can be achieved by this method?
2. how well can routine and non-routine changes in buildings be identified and quantified?
3. can the method achieve the 10x reduction in M&V cost needed to open the market?
4. what is being done currently and by whom?
5. How much is the R&D is public domain Vs. private?

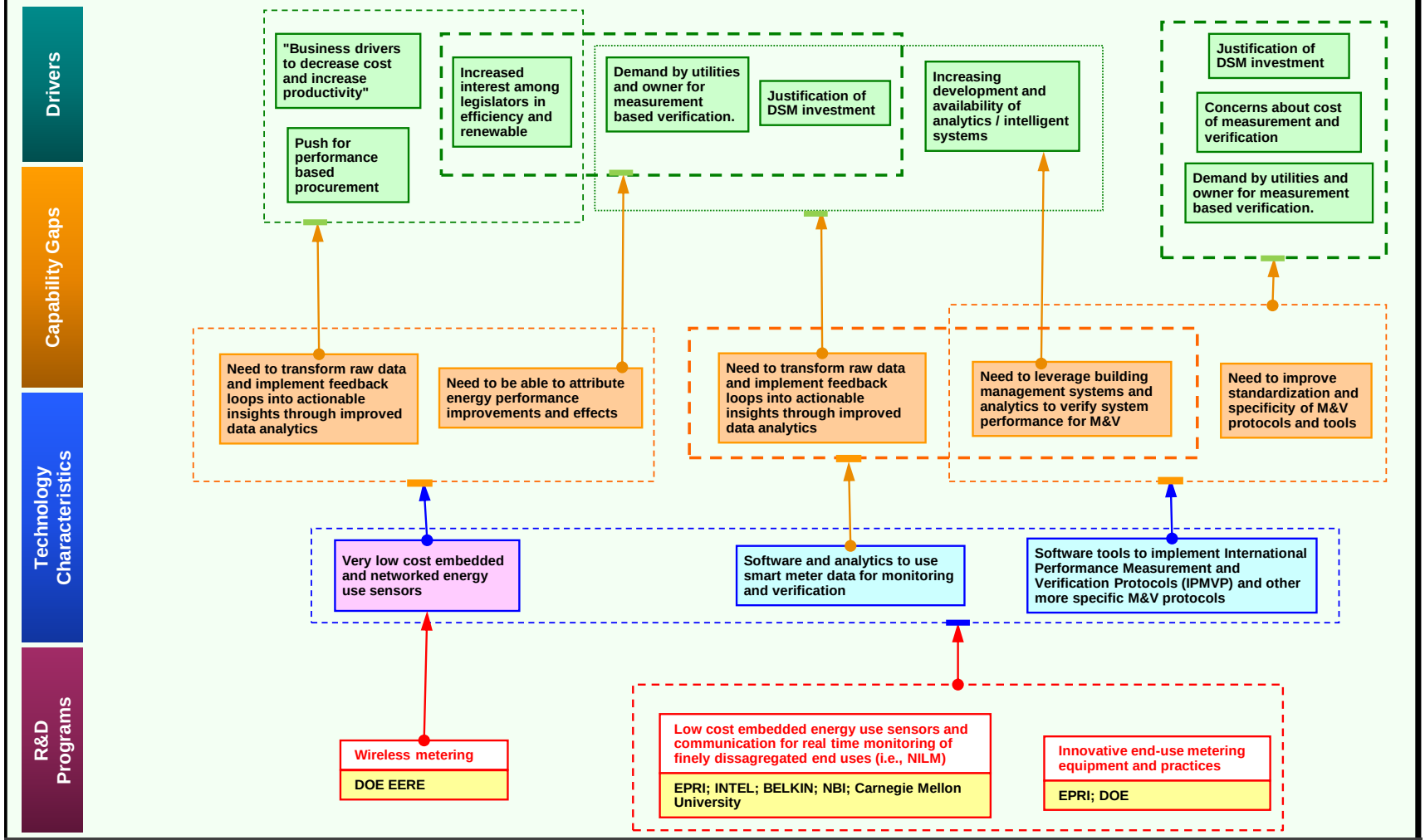
Back to Table of Contents

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

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Low-Cost Savings Verification Techniques (4 of 7)**

See "Technology Area Definitions" section



Driver: Capability Gap: Commercially Available: Commercially Unavailable: R&D Program Requirement: No Explicit Systems Integration Explicit Systems Integration Existing R&D Program or Project:

R&D Program Summaries

Low cost embedded energy use sensors and communication for real time monitoring of finely disaggregated end uses. Embedding energy use sensors and communication into all energy using equipment by OEMS will provide the scale to drive down the price of end use metering, utilizing real time communications enables as needed low cost monitoring (for example, non-intrusive load monitoring (NILM)).

Existing research: Electric Power Research Institute (EPRI), Intel, Belka, University of Washington, Carnegie Mellon University, New Buildings Institute (NBI).

- *[Summaries of existing research pending]*

Key research questions:

1. Develop low cost, small kw sensors with integrated communication chips.
2. Develop communication systems and protocols for standardized reporting
3. can we drive the equipment and transaction cost so low that OEMs will want to integrate into their products.
4. How does this energy info system integrate into building controls?
5. what standards and protocols are needed to communicate, what the devise is, where it is.
6. Are the advantages to including other sensors such as pressure temp occupancy etc?
7. should higher level efficiency meterics be incorporated into sensor bundle?

Wireless metering. According to a 2006 Federal Energy Management Program study, energy costs can be reduced by taking action to resolve problems identified by examining metered data. While metering systems do not directly improve energy efficiency, they do enable focused, energy efficiency actions and upgrades. It is estimated that using systems results in energy efficient actions that deliver electricity energy savings of at least 2%.

Existing research: The U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) Federal Energy Management Program issued a Wireless Metering Challenge in 2013; see http://www1.eere.energy.gov/buildings/news_detail.html?news_id=19132.

Key research questions:

1. Questions to address include development of wireless meters with low costs, essential requirements for electrical energy measurement, and wireless data transmission to an onsite collection point.

Innovative end-use metering equipment and practices. Need for innovative end-use metering and data management equipment and approaches that can dramatically reduce costs and time requirements for installation, configuration, communication, and data management during field studies. Approaches could include nonintrusive load monitoring–digital signal based load disaggregation and low cost end use sensors and communications.

Existing research: Electric Power Research Institute (EPRI), U.S. Department of Energy (DOE).

- The U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) Federal Energy Management Program issued a Wireless Metering Challenge in 2013; see http://www1.eere.energy.gov/buildings/news_detail.html?news_id=19132.
- EPRI is researching nonintrusive load monitoring.

Key research questions:

1. Are there options for low cost sensors, data loggers, and communications?
2. Are there intrinsically safe, easy to install, self configuring sensors and meters?
3. Are there integrated sensor-logger-communication- web site-analysis-presentation systems?
4. Can powerful low cost consumer and IT technology be applied to field studies?
5. Can public networks and software services be leveraged?
6. Is there simple sensor-data logging equipment that can be installed by untrained homeowners?
7. Are there innovative low cost sensors that can be leveraged?

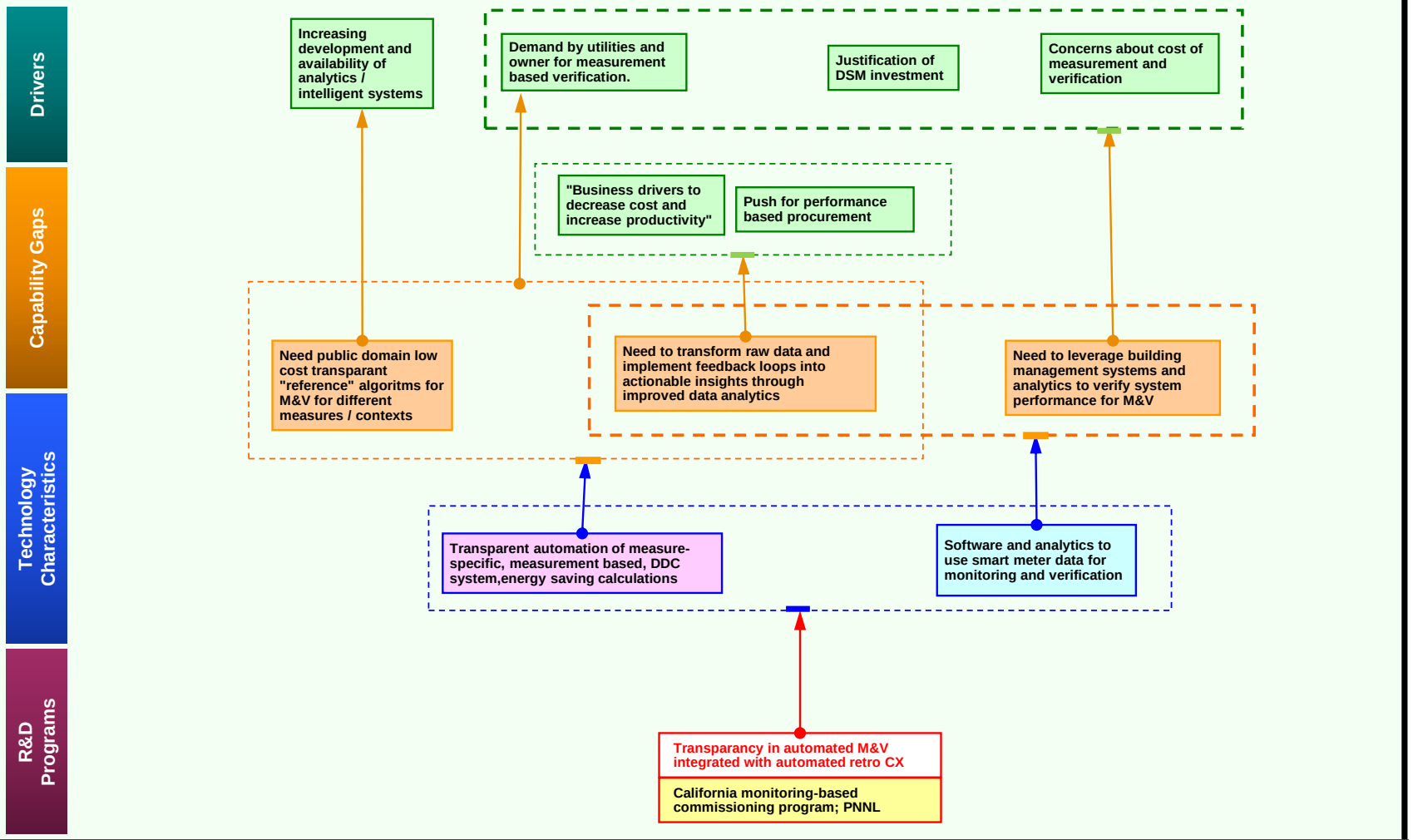
Back to Table of Contents

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

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Low-Cost Savings Verification Techniques (5 of 7)**

See "Technology Area Definitions" section



Driver: Capability Gap: | Commercially Available: Commercially Unavailable: | R&D Program Requirement: No Explicit Systems Integration / Explicit Systems Integration | Existing R&D Program or Project:

R&D Program Summaries

Transparency in automated M&V integrated with automated retro commissioning.

Identify DDC system points to monitor efficiency increase to valc [?].

Existing research: California monitoring-based commissioning program, Pacific Northwest National Laboratory (PNNL)returning projects.

- *[Summaries of existing research pending]*

Key research questions:

1. How to quantify system based on baseline and past installation direct digital controller (DDC) building automation systems (BAS) trends?
2. How to create permanent efficinecy index?
3. How to provide online documentation?
4. How to trend data without slowing down control?

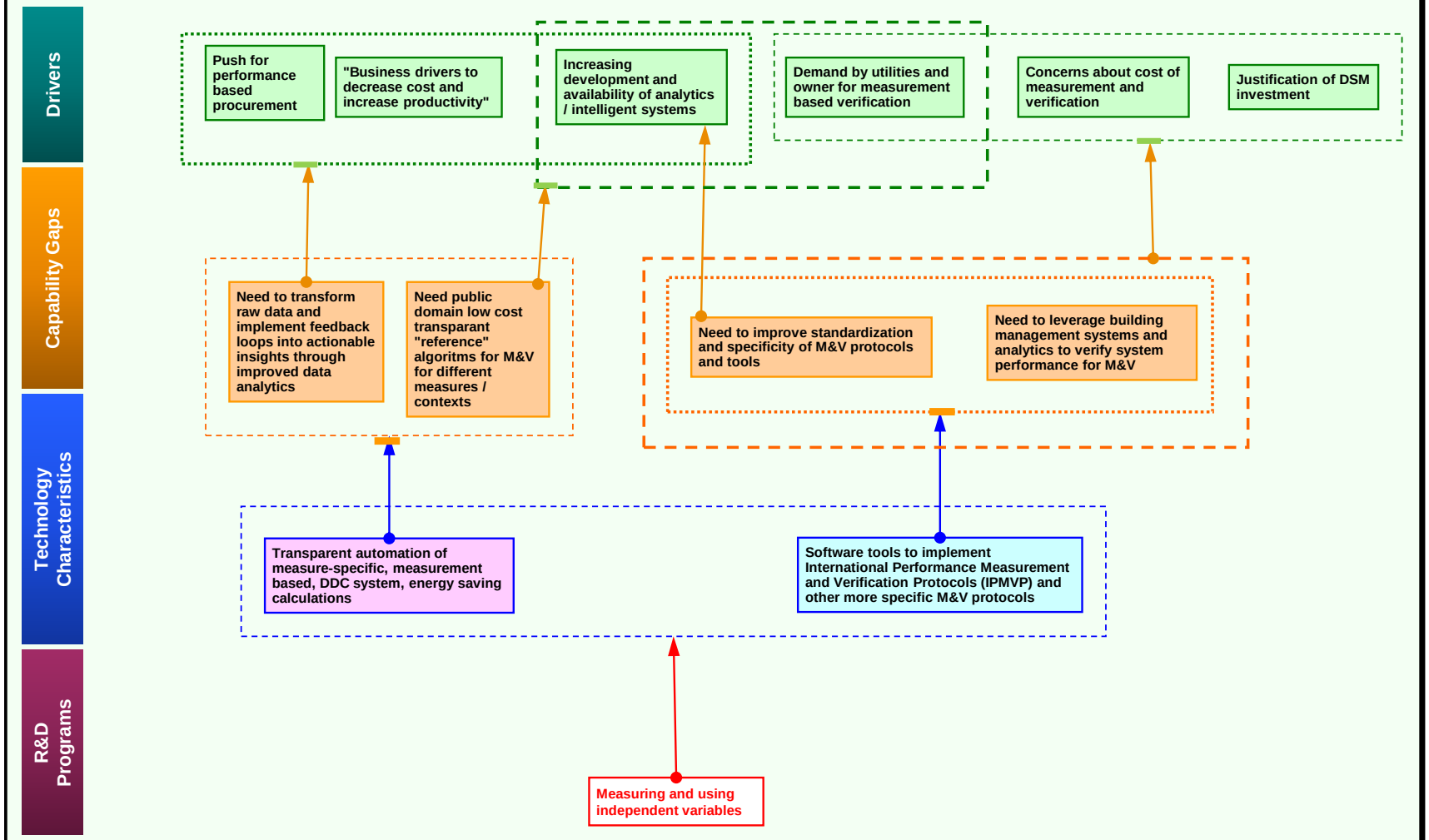
Back to Table of Contents

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

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Low-Cost Savings Verification Techniques (6 of 7)**

See "Technology Area Definitions" section



Driver: Capability Gap: | Commercially Available: Commercially Unavailable: | R&D Program Requirement: No Explicit Systems Integration / Explicit Systems Integration | Existing R&D Program or Project:

R&D Program Summaries

Measuring and using independent variables. Develop methods to better utilize independent variable.

Existing research: None identified.

Key research questions:

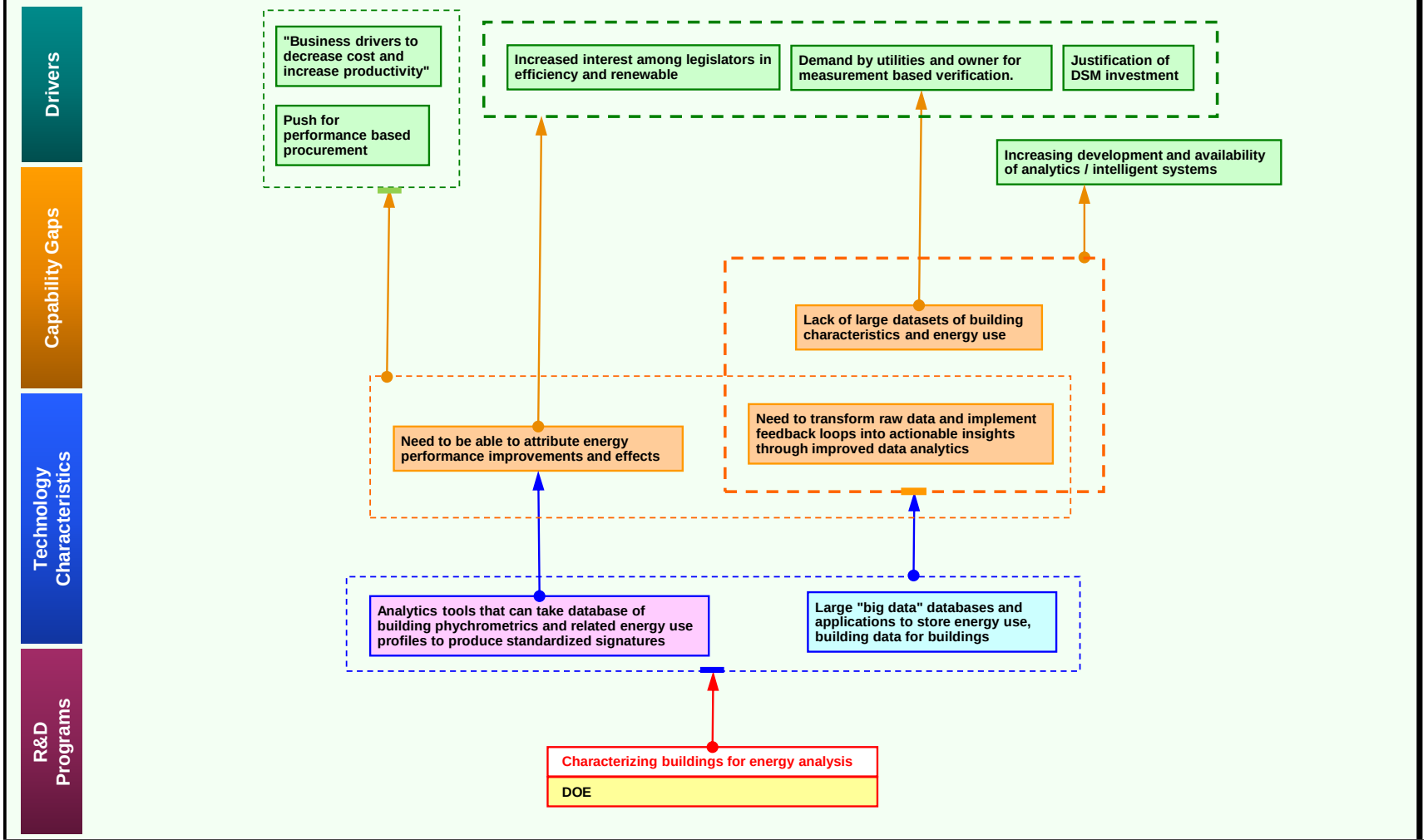
1. What independent variables can be used as proxies for energy (e.g. variable frequency drive (VFD) speed as proxy for KW?)
2. What are the key independent variables for important energy efficiency measures?
3. can these independent variables be monitored independently in the field and then combined with lab test (of energy use as a function of these field measured independent variables)?

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

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Low-Cost Savings Verification Techniques (7 of 7)**

See "Technology Area Definitions" section



Driver: Capability Gap: | Commercially Available: Commercially Unavailable: | R&D Program Requirement: No Explicit Systems Integration / Explicit Systems Integration | Existing R&D Program or Project:

R&D Program Summaries

Characterizing buildings for energy analysis. Naked energy data without context has limited value. Need to understand building and usage characteristics and do this at very low cost.

Existing research: U.S. Department of Energy (DOE)-building performance database.

- DOE: Buildings Performance Database, https://www1.eere.energy.gov/buildings/commercial/bpd.html.

Key research questions:

1. What information could be gathered with the "ideal" meter?
2. How do we affordably characterized buildings in term of construction HVAC so we can design smart retrofit program?
3. Can we create standard taxonomy for building system and components?

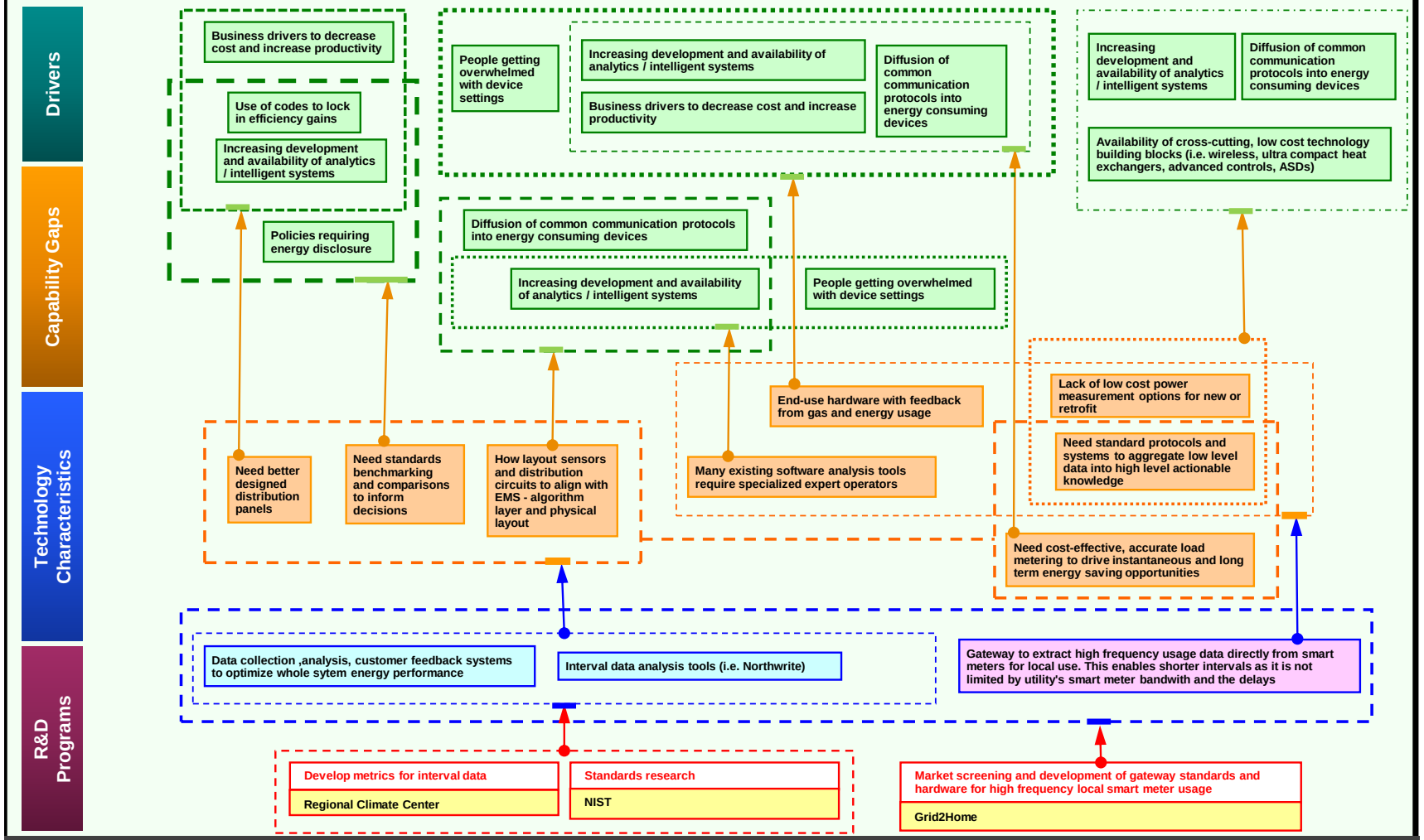
Back to Table of Contents

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

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Real time smart electric power measurement of facilities (1 of 3)**

See "Technology Area Definitions" section



Driver: Capability Gap: | Commercially Available: Commercially Unavailable: | R&D Program Requirement: No Explicit Systems Integration / Explicit Systems Integration | Existing R&D Program or Project:

R&D Program Summaries

Standards research. Developing standards for measuring facility energy use would help simplify and standardize energy measurement. Work with NIST priority action group to help develop useful standards.

Existing research: National Institute of Standards and Technology (NIST).

- *[Summaries of existing research pending]*

Key research questions:

1. Is there a universal metric that can be applied to all sectors?
2. How does the cost of the measurement compare to the value?

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.

Existing research: Regional Climate Center.

- *[Summaries of existing research pending]*

Key research questions:

1. What type of meter sensing is needed for what size businesses?
2. How can this information be shared and leveraged?
3. Who is responsible and what quality data is required?

Market screening and development of gateway standards and hardware for high frequency local smart meter usage. This program will enable customers to capture and react to high frequency data from existing utility smart meters by accessing local channels rather than going through the utility cloud.

Existing research: Grid2Home.

- *[Summaries of existing research pending]*

Key research questions:

1. Screen existing smart meter market and identify availability and protocols for local ports / channels that can provide smart meter interval data directly to the customer.
2. Develop standards for communicating and organizing this data.
3. Develop hardware that will access, store and present this data to customers directly.
4. Provide access to this database for third parties. (e.g. disaggregators, auditors) to use this data for analytics.

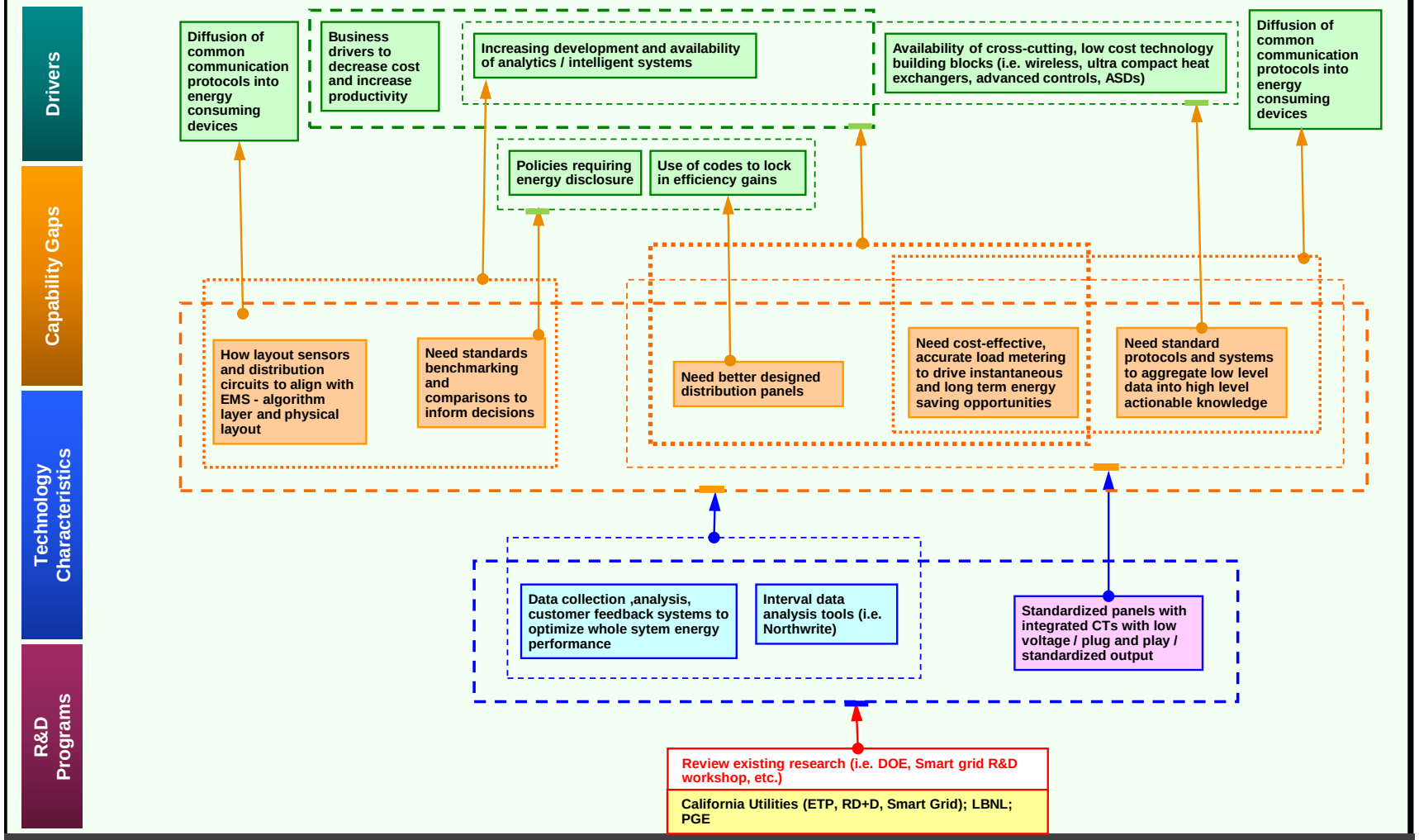
Back to Table of Contents

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

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Real time smart electric power measurement of facilities (2 of 3)**

See "Technology Area Definitions" section



Driver: Capability Gap: | Commercially Available: Commercially Unavailable: | R&D Program Requirement: No Explicit Systems Integration / Explicit Systems Integration | Existing R&D Program or Project:

R&D Program Summaries

Review existing research (i.e. DOE, Smart grid R&D workshop, etc.). To develop continuously updated database of existing technologies to include characteristics such as; building size, building type, frequency of data, number of installations, stage of technology development, local compared to cloud, analytics compared to no analytics, software compared to no software, control compared to no control.

Existing research: California Utilities (ETP, RD+D, Smart Grid), Lawrence Berkeley National Laboratory (LBNL), Portland General Electric (PGE).

- *[Summaries of existing research pending]*

Key research questions:

1. Populate database based on existing technologies.
2. Maintain this database continuously for X years through outreach and regular market screening efforts.
3. Proactively distribute and measure use of this database accordingly to key players.

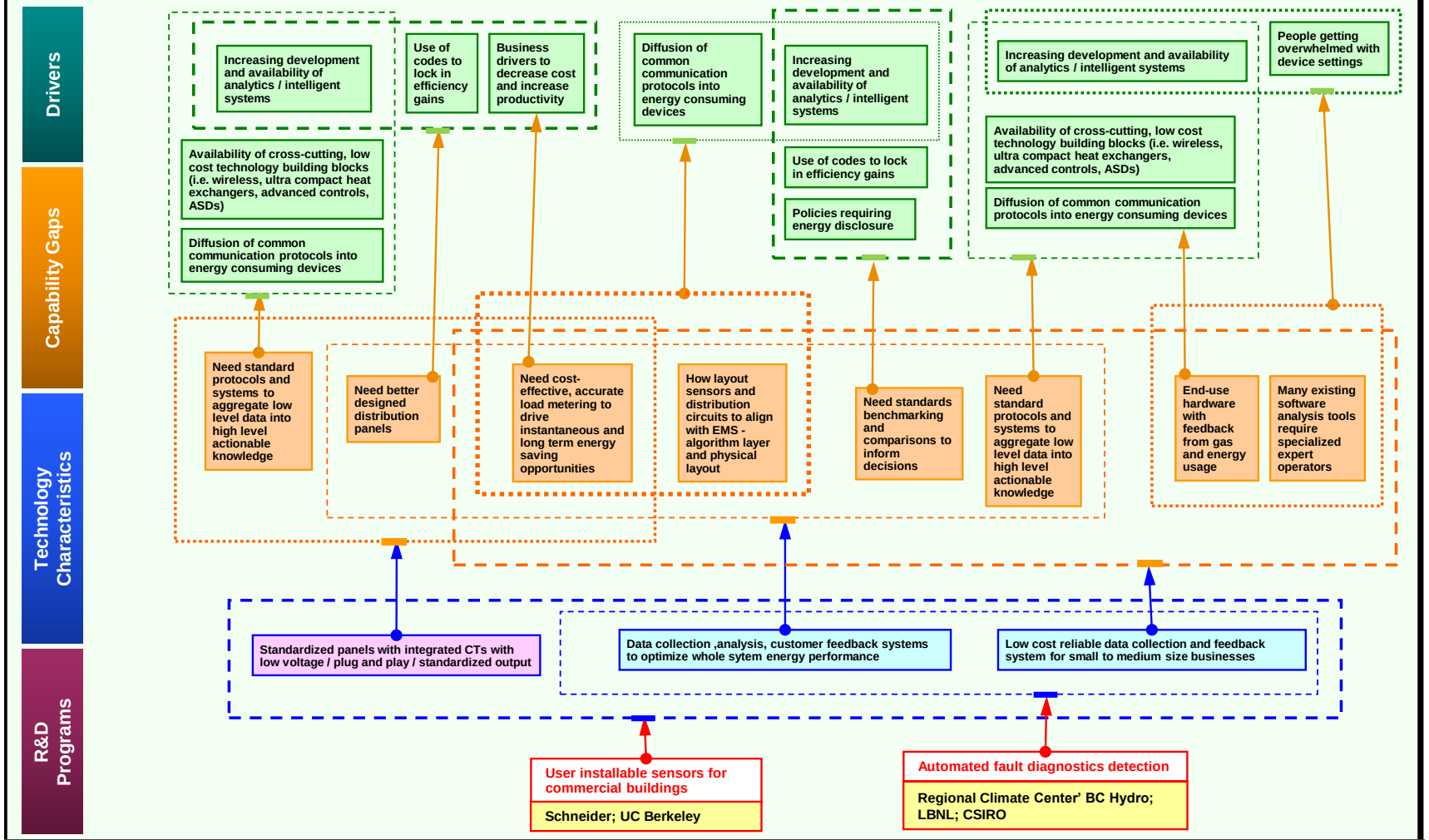
Back to Table of Contents

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

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Real time smart electric power measurement of facilities (3 of 3)**

See "Technology Area Definitions" section



R&D Program Summaries

User-installable sensors for commercial buildings. M&V diagnostics and efficiency require monitoring that is load specific and inexpensive to install. Research is needed for systems that can be safely and quickly installed to collect critical metrics.

Existing research: Schneider, University of California Berkeley.

- *[Summaries of existing research pending]*

Key research questions:

1. What sensing technology would be suitable as a low/no cost add-on for circuit breaker panels?
2. How can voltage be measures on multiple phases without needing an electrician to install loads?
3. Can a low voltage connector be added to new breakers or meters that allow for high bandwidth metering (8kHz) for fault diagnostics and load disaggregation?

Automated fault diagnostics detection. Fault diagnostics to auto detect opportunities by leveraging existing data collection.

Existing research: BC Hydro, Regional Climate Center, Commonwealth Scientific and Industrial Research Organisation (CSIRO).

- *[Summaries of existing research pending]*

Key research questions:

1. Can we help end use customers (by way of evaluation tools) to gauge which fault detection (FD) products are suited for their needs?
2. Guide sophistication of fault detection (FD) products to get to the point where they pin-point a problem and recommend a fix action?
3. Can fault detection (FD) product performance be standardized?

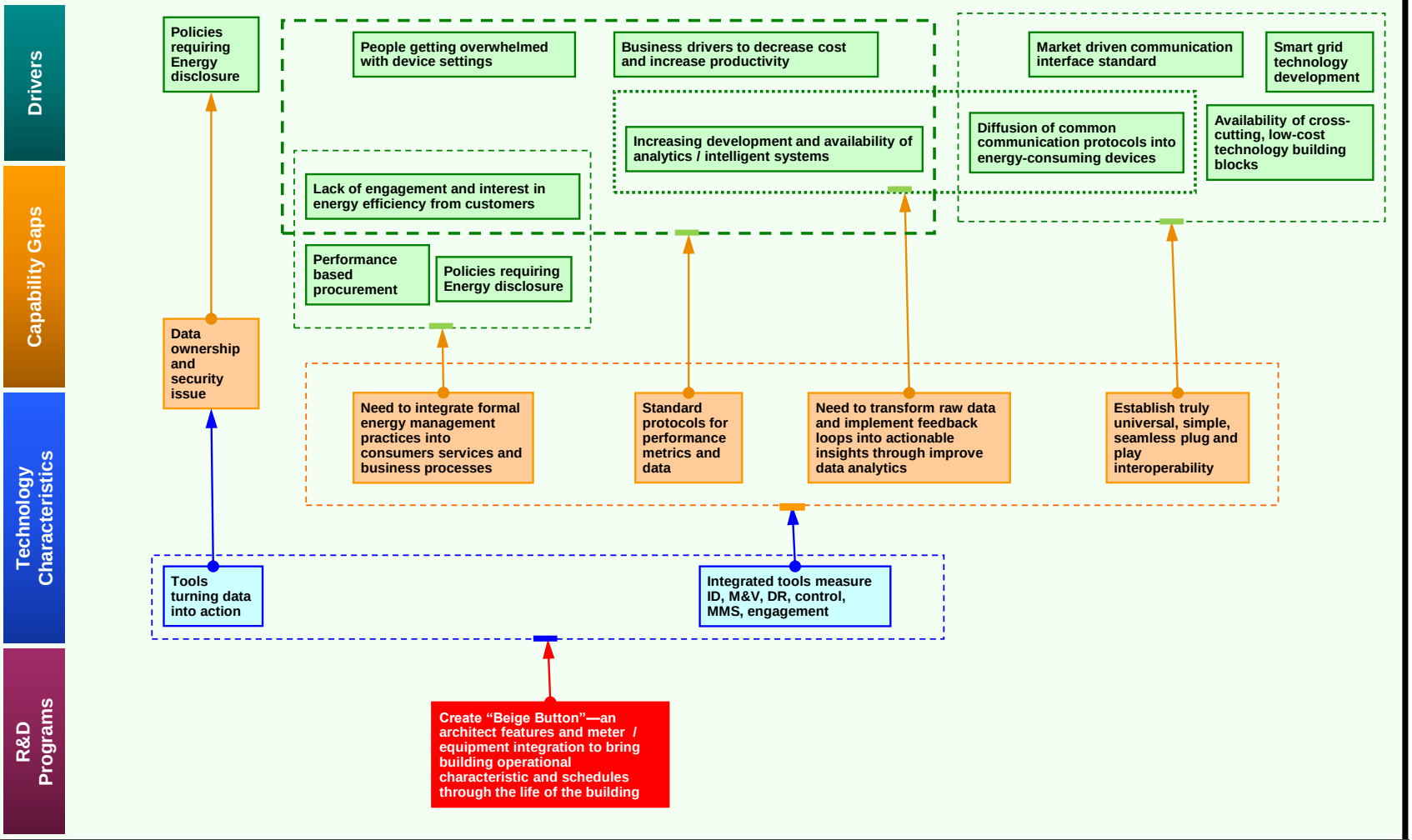
Back to Table of Contents

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

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Enterprise and Maintenance Management Systems (1 of 9)**

See "Technology Area Definitions" section



Driver: Capability Gap: | Commercially Available: Commercially Unavailable: | R&D Program Requirement: No Explicit Systems Integration / Explicit Systems Integration | Existing R&D Program or Project:

R&D Program Summaries

Create "Beige Button"—architect features and meter/equipment integration to bring building operational characteristic and schedules through the life of the building.

Integrating physical features (assumed energy simulation models), operational assumptions, and other characteristics that affect performance and link them to meters/equipment for full picture of whole buildings and portfolios.

Existing research: None identified.

Key research questions:

1. Does any toll currently track all these?
2. How to integrate hard architecture vs. fast moving technology software?
3. Prevent silos.

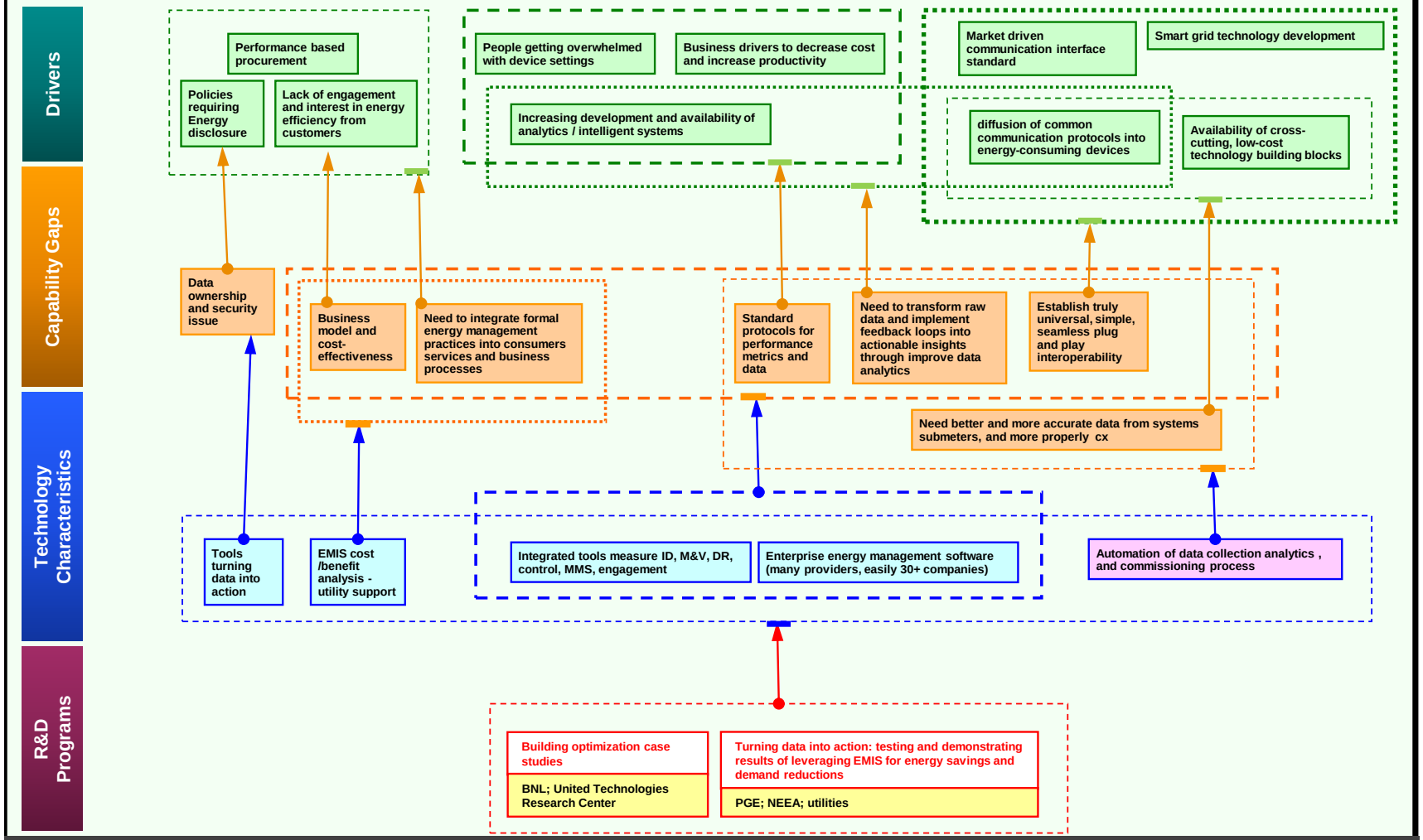
Back to Table of Contents

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

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Enterprise and Maintenance Management Systems (2 of 9)**

See "Technology Area Definitions" section



Driver:

Capability Gap:

Commercially Available:

Commercially Unavailable:

R&D Program Requirement: No Explicit Systems Integration | Explicit Systems Integration

Existing R&D Program or Project:

R&D Program Summaries

Turning data into action: testing and demonstrating results of leveraging EMIS for energy savings and demand reductions. Utilities across the country are interested in achieving O&M and behavioral savings for commercial buildings through utilizing technology. But no one really knows which approaches are the most effective in turning ubiquitous data into action. This research project will examine average savings from case studies and demonstrations of different EMIS applications to more specifically determine expected energy saving results.

Existing research: Portland General Electric (PGE), Northwest Energy Efficiency Alliance (NEEA), utilities across country.

- *[Summaries of existing research pending]*

Key research questions:

1. What percentage savings can we expect from different applications of Energy Management Information Systems (EMIS) and do these savings persist (or how can we ensure they persist)?
    a. Behavior / competition (behavior only).
    b. Monitoring-based commissioning (operations and maintenance plus retrofit).
    c. Energy coaching.

Building optimization case studies. Need for independent data based and technically valid (IMPU) studies to validate and document actual savings achieved. Too many self-savings "claimed" results.

Existing research: Brookhaven National Laboratory (BNL), United Technologies Research Center (UTRC).

- *[Summaries of existing research pending]*

Key research questions:

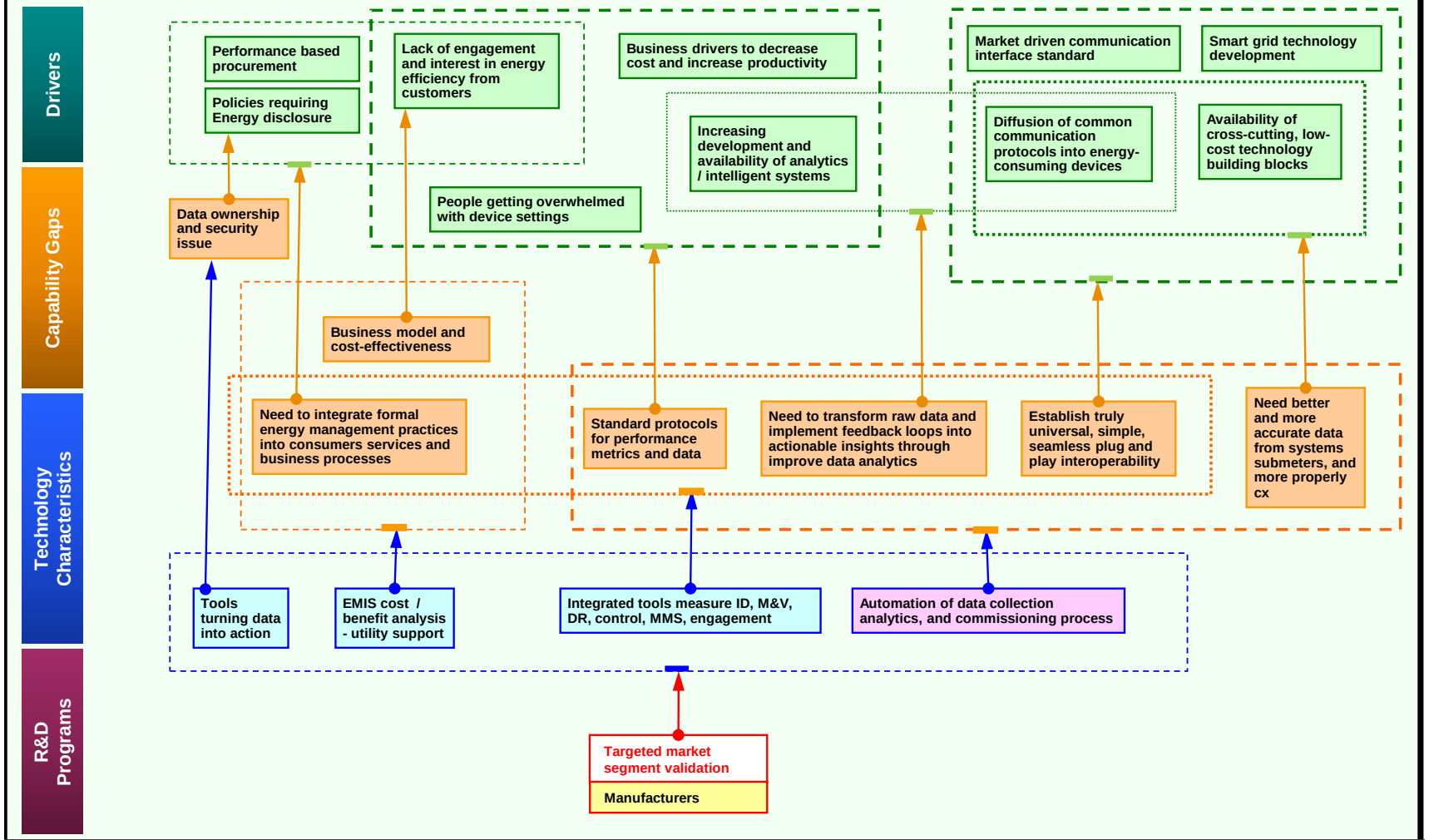
1. Base line energy use.
2. Identify all projects and operational changes.
3. Adjust for weather, seasonality, independent business changes.
4. Determine actual implementation costs.
5. Determine actual achieved savings.
6. Calculate achieved return on investment as forecasted.

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

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Enterprise and Maintenance Management Systems (3 of 9)**

See "Technology Area Definitions" section



Driver: Capability Gap: | Commercially Available: Commercially Unavailable: | R&D Program Requirement: No Explicit Systems Integration / Explicit Systems Integration | Existing R&D Program or Project:

R&D Program Summaries

Targeted market segment validation. Prioritize key building type/market segments to test and validate energy analytic tools. Focus on limited building types will allow focused analytic development rather than trying to do everything.

Existing research: Manufacturers.

- *[Summaries of existing research pending]*

Key research questions:

1. How well does analytics model actual building energy use/performance?
2. How well does model identify savings opportunities?
3. How well do predicted savings match forecasted?

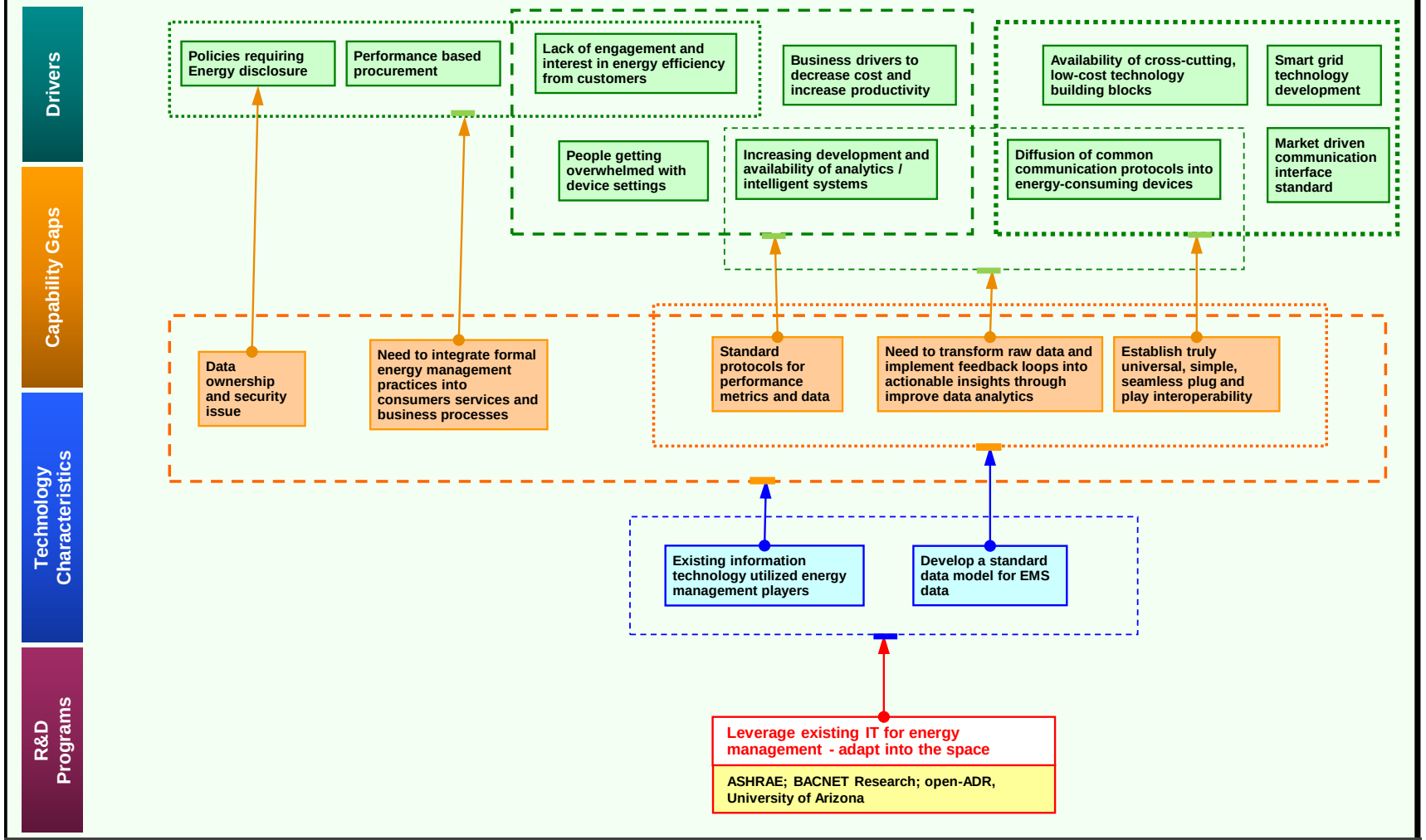
Back to Table of Contents

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

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Enterprise and Maintenance Management Systems (4 of 9)**

See "Technology Area Definitions" section



Driver: Capability Gap: Commercially Available: Commercially Unavailable: R&D Program Requirement: No Explicit Systems Integration Explicit Systems Integration Existing R&D Program or Project:

R&D Program Summaries

Leverage existing IT for energy management - adapt into the space. Leverage existing information technologies (IT) such as ethernet, XML, etc., so as to not inventing anything.

Existing research: American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE), BACNET Research, open-ADR, University of Arizona.

- University of Arizona: Autonomic Computing Laboratory, http://acl.ece.arizona.edu/.
- *[Summaries of existing research pending]*

Key research questions:

1. Standardized data models protocols.
2. Define consistent performance metric definitions and benchmarking data.
3. Protocols still allowing proprietary systems—effect interoperability.

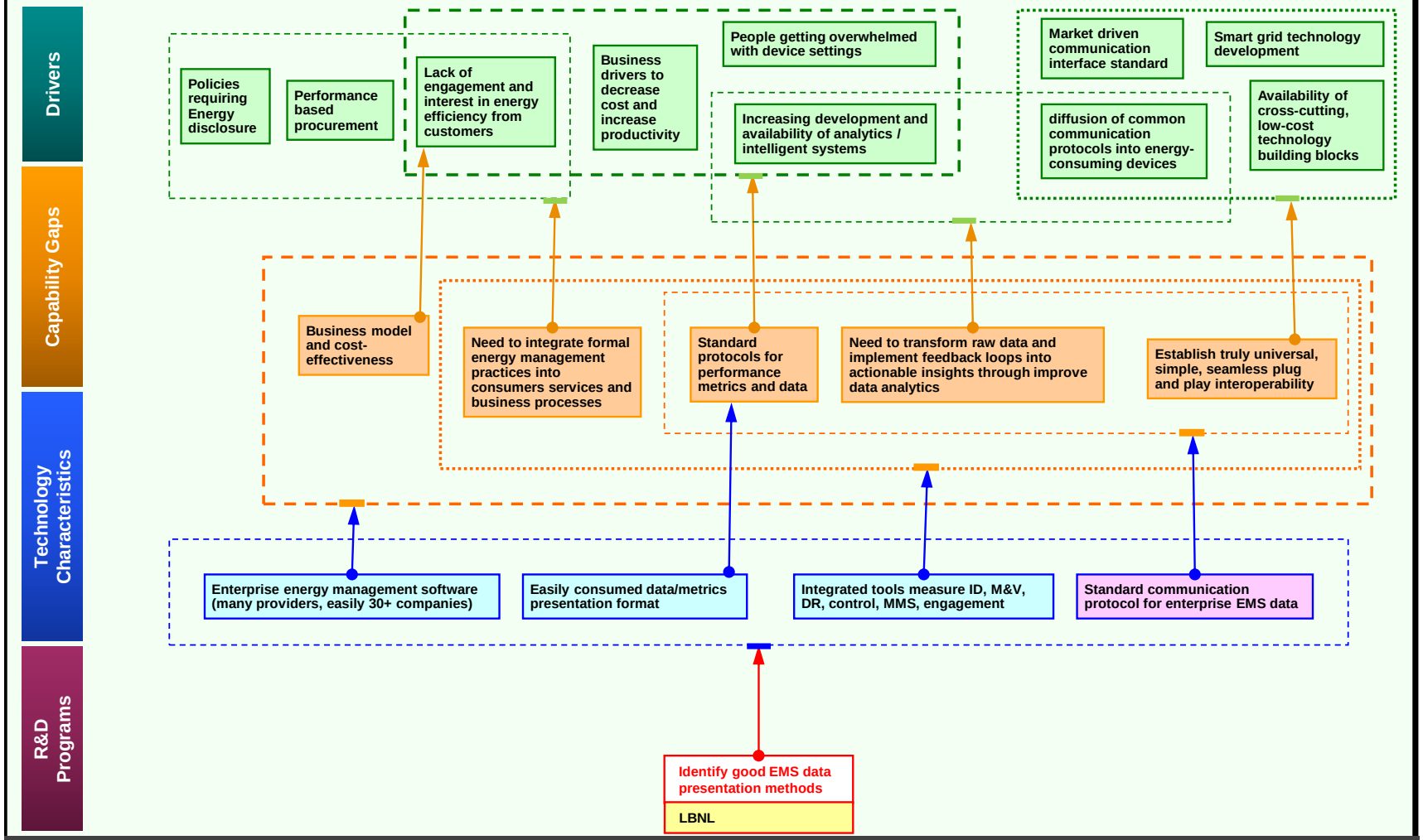
Back to Table of Contents

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

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Enterprise and Maintenance Management Systems (5 of 9)**

See "Technology Area Definitions" section



Driver: Capability Gap: | Commercially Available: Commercially Unavailable: | R&D Program Requirement: No Explicit Systems Integration / Explicit Systems Integration; Existing R&D Program or Project:

R&D Program Summaries

Identify good EMS data presentation methods. Data and form of presentations (user interface design).

Existing research: Lawrence Berkeley National Laboratory (LBNL).

- *[Summaries of existing research pending]*

Key research questions:

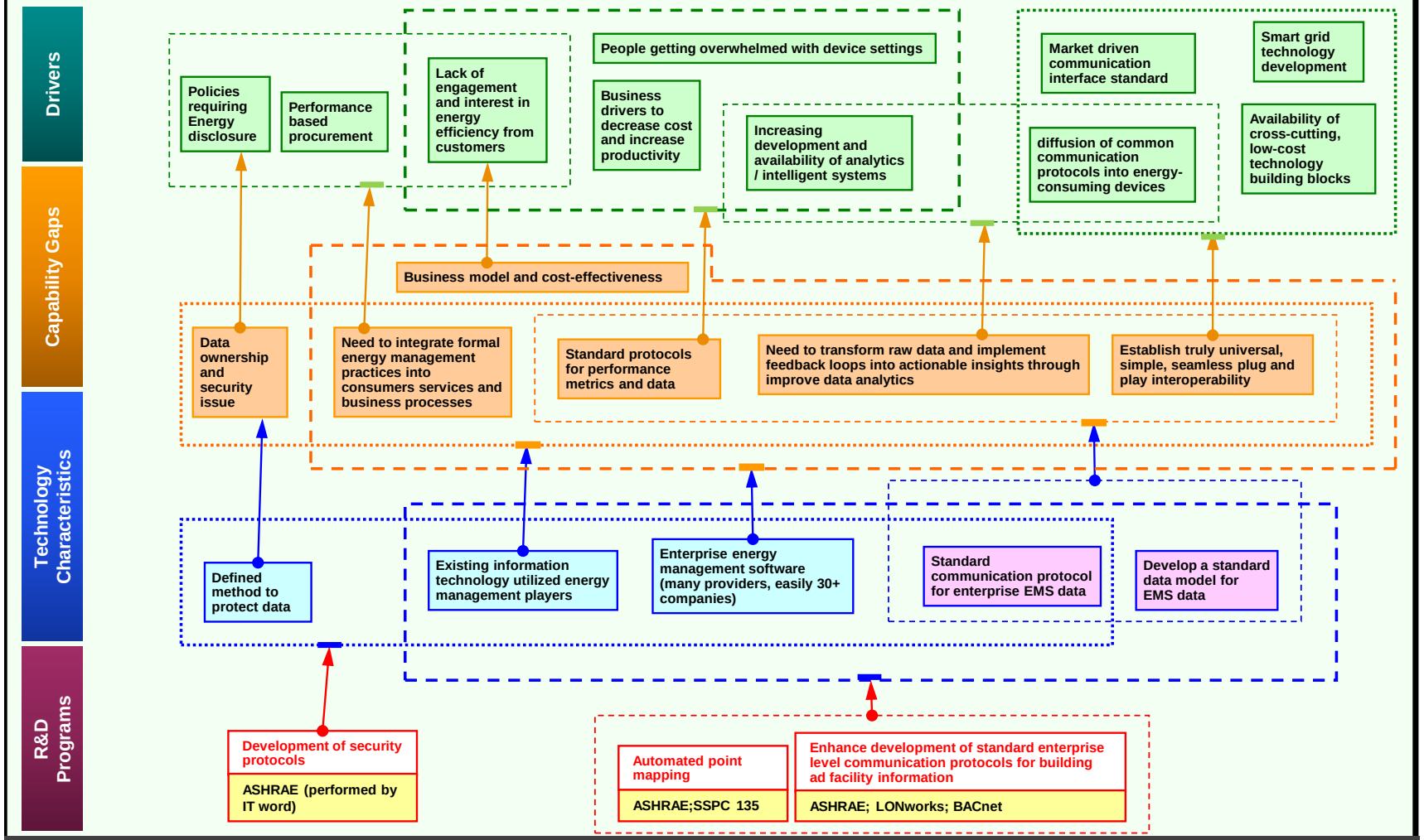
1. What data is most relevant for an energy management?
2. What forms should EMS data and analytics be presented to user?
3. What data expression forms are best suited for identifying?
4. Review current market and tools.
5. Relate presentation form/data to target actions.
6. Energy savings outcomes of different programs designs.

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

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Enterprise and Maintenance Management Systems (6 of 9)**

See "Technology Area Definitions" section



Driver: Capability Gap: | Commercially Available: Commercially Unavailable: | R&D Program Requirement: No Explicit Systems Integration / Explicit Systems Integration | Existing R&D Program or Project:

R&D Program Summaries

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.

Existing research: Stakeholders indicate that the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) is working on this (through IT word).

- *[Summaries of existing research pending]*

Key research questions:

1. What are agreed protocols for security?
2. How data gets used and who owns it?

Automated point mapping. Inaction often results from data provided by enterprise energy and maintenance systems because the gathered data and inaccurate. This data is incorrect because point mapping (assign a variable name and description to a measurement point methods an enterprise energy and maintenance management system) is manual, tedious and error prone process.

Existing research: ASHRAE, SSPC 135.

- *[Summaries of existing research pending]*

Key research questions:

1. Are there semi-automated process to improve point mapping?
2. Are there semi-automated pathways to perform quality assurance (QA) / quality control (QC)steps for the point mapping process?
3. Are there ways to automate point mapping?

Enhance development of standard enterprise level communication protocols for building ad facility information. Bacnet, Obix and other communication effort are improving greatly, but there are key aspects that are not being addressed by these standards bodies.

Existing research: American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE), LONworks, BacNet.

- *[Summaries of existing research pending]*

Key research questions:

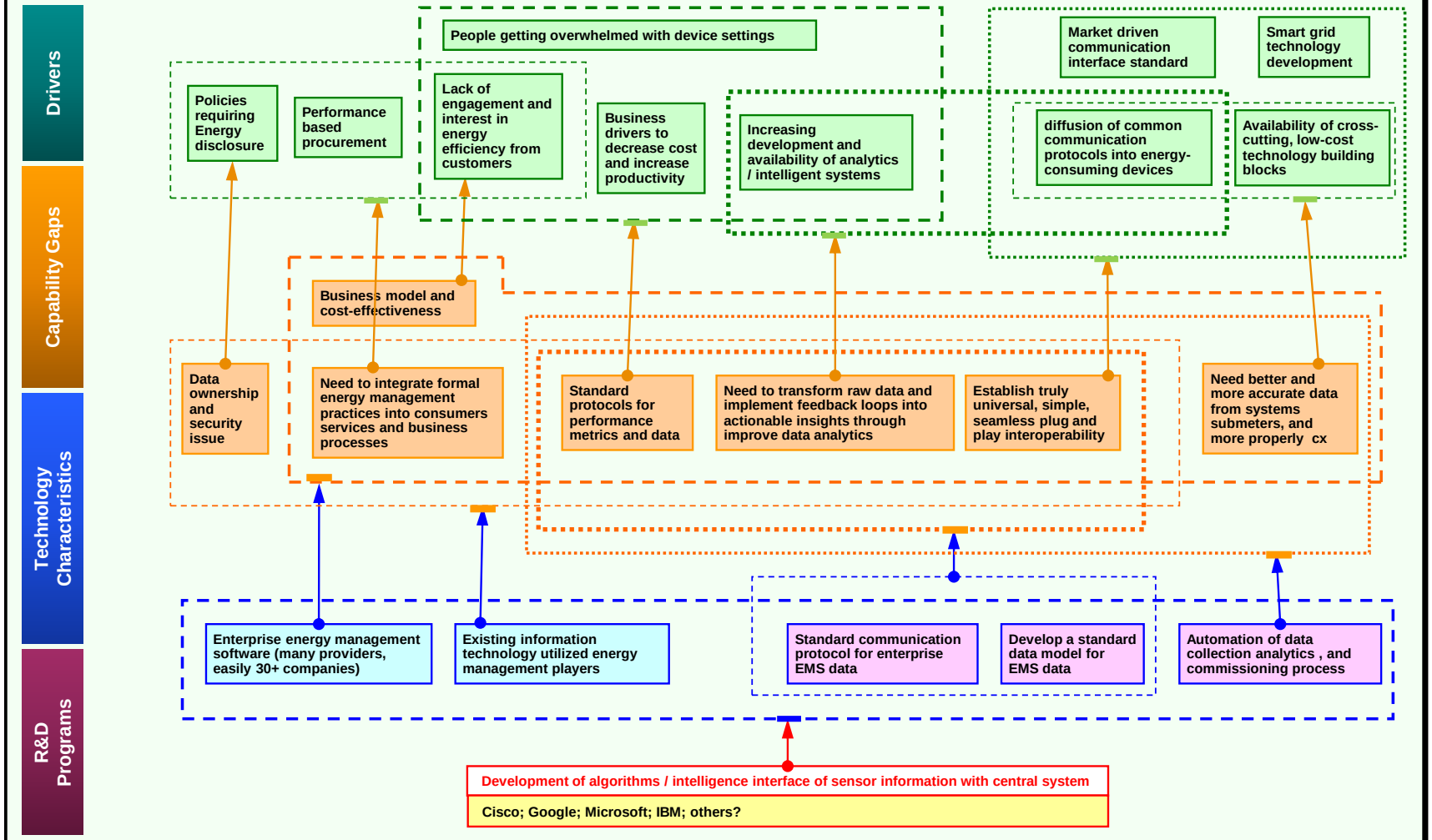
1. Can details, satirized point mapping (Assign a variable name and description to a measurement point within an enterprise energy and maintenance management system) occur and be supported by existing enterprise level communication standards for building and facility information?

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

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Enterprise and Maintenance Management Systems (7 of 9)**

See "Technology Area Definitions" section



Driver: Capability Gap: | Commercially Available: Commercially Unavailable: | R&D Program Requirement: No Explicit Systems Integration / Explicit Systems Integration | Existing R&D Program or Project:

R&D Program Summaries

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.

Existing research: 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.

Key research questions:

1. Questions not yet specified.

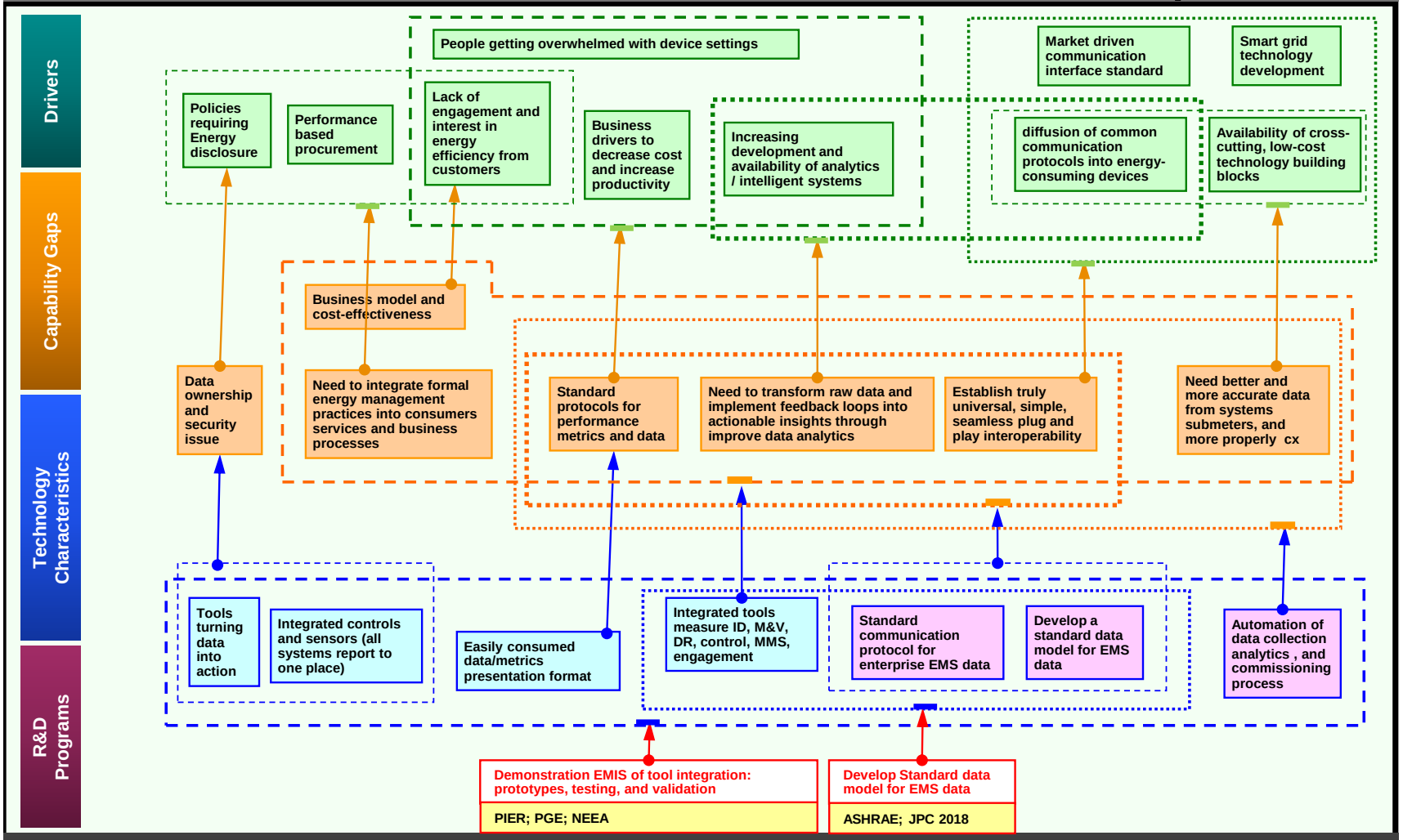
Back to Table of Contents

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

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Enterprise and Maintenance Management Systems (8 of 9)**

See "Technology Area Definitions" section



Driver: Capability Gap: | Commercially Available: Commercially Unavailable: | R&D Program Requirement: No Explicit Systems Integration Explicit Systems Integration | Existing R&D Program or Project:

R&D Program Summaries

Develop Standard data model for EMS data. (Summary not yet provided.)

Existing research: American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE), JPC 2018.

- *[Summaries of existing research pending]*

Key research questions:

1. What data do you collect?
2. What format do you provide the data?
3. How do you provide the data?

Demonstration EMIS of tool integration: prototypes, testing, and validation. In commercial energy management and information system software market, there are many functionalities available currently. The future will require integrated solutions that combine EMIS with enabling functions for energy savings, demand response, building control, and M&V. This research project will test integrated prototypes propose by industry (key that research does not need to develop the approaches, but test what is already commercialized), validating the accuracy of the algorithms and capability of approach.

Existing research: California Energy Commission (CEC) Public Interest Energy Research (PIER) program, Portland General Electric (PGE), Northwest Energy Efficiency Alliance (NEEA).

- *[Summaries of existing research pending]*

Key research questions:

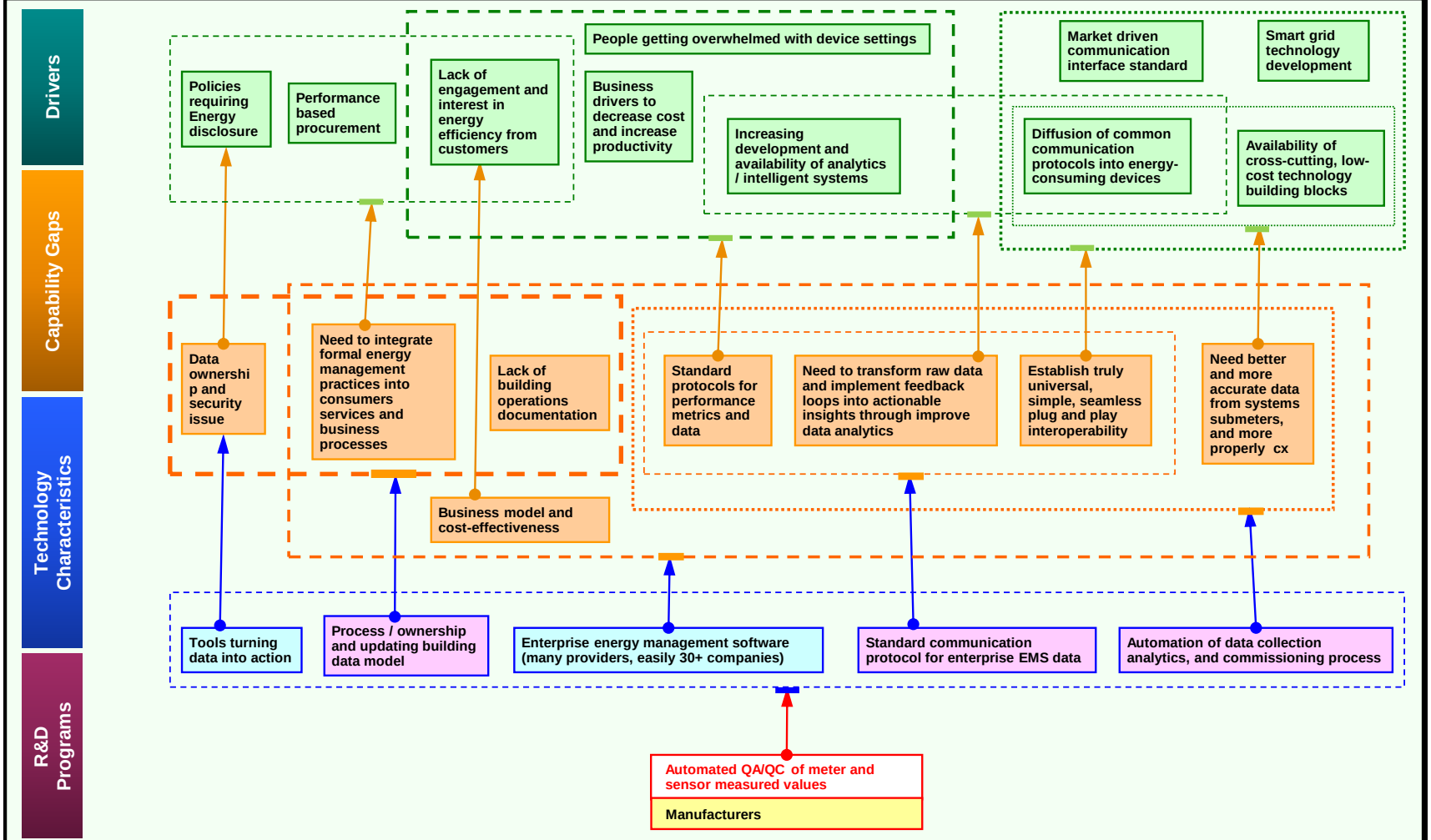
1. How accurate are rapid building assessment techniques (low-touch audits using interval data), and how specifically can these techniques identify building EE and RD opportunities?
2. How accurate are fault detection and diagnostic algorithms (using system-level data) and how actionable are the recommendations?
3. What energy-savings opportunities can automatically be addressed through automated system optimization and which require human analysis and intervention?
4. How can tools with integrated M&V be used to quantify savings at whole building level? What bar for rigor must be met?

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

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Enterprise and Maintenance Management Systems (9 of 9)**

See "Technology Area Definitions" section



Driver:

Capability Gap:

Commercially Available:

Commercially Unavailable:

R&D Program Requirement: No Explicit Systems Integration | Explicit Systems Integration

Existing R&D Program or Project:

R&D Program Summaries

Automated QA / QC of meter and sensor measured values. Inaction often results from data provided by enterprise energy and maintenance management systems because the captured data and inaccurate. This data is incorrect because meters and sensors are often installed and configured incorrectly.

Existing research: Manufacturers.

- *[Summaries of existing research pending]*

Key research questions:

1. Are there ways to automate quality assurance (QA) / quality control (QC) of installation and configuration of meters and sensors?
2. Are there ways to semi-automate quality assurance (QA) / quality control (QC) of installations and configuration of meters and sensors?
3. Are there effective guidance documents for implementing quality assurance (QA) / quality control (QC) of meters and sensors

Back to Table of Contents