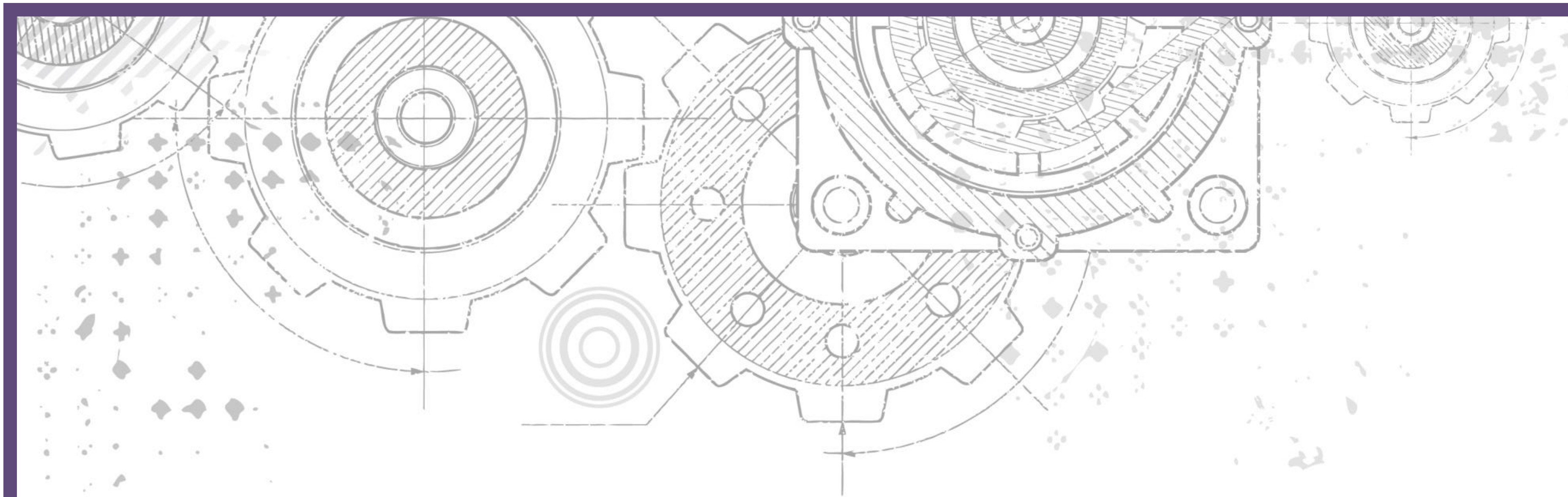
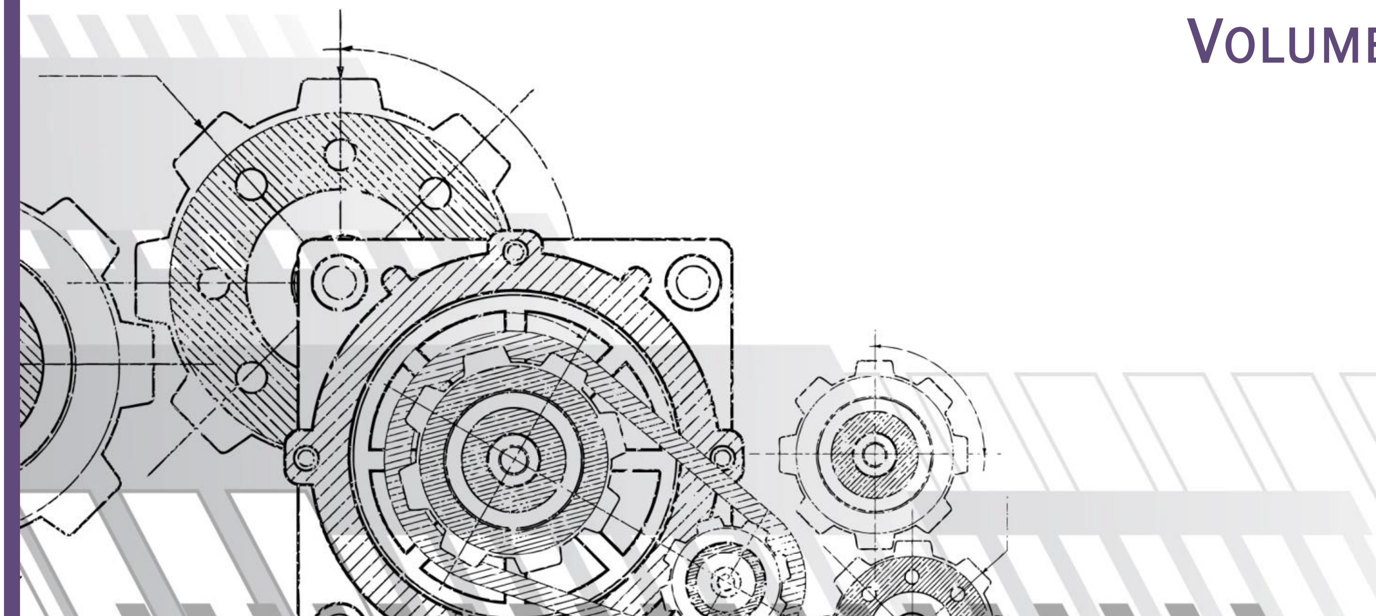


Energy Efficiency Technology Roadmap

Volume 4: Electronics



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:

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Project Manager
BPA Technology Innovation
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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:

- Direct Current (DC) Power
- Use and Virtualization
- Component-Level Efficiency
- Complete Electronic System
- Power Management Control and Communication

Technology Area Definitions

Direct Current (DC) Power Source

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

Use and Virtualization

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

Component-Level Efficiency

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

Complete Electronic System

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

Power Management Control and Communication

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

Other Sources

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

Staff at the Lawrence Berkeley National Laboratory held a direct current (DC) power workshop on Feb. 7, 2013, to define technology, policy, market adoption, and other barriers to wide-scale adoption of integrated DC power systems that include renewable generation, grid supply, energy storage, distribution, communication, demand control, and end uses. Workshop findings are pending as of March 2013.

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

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.

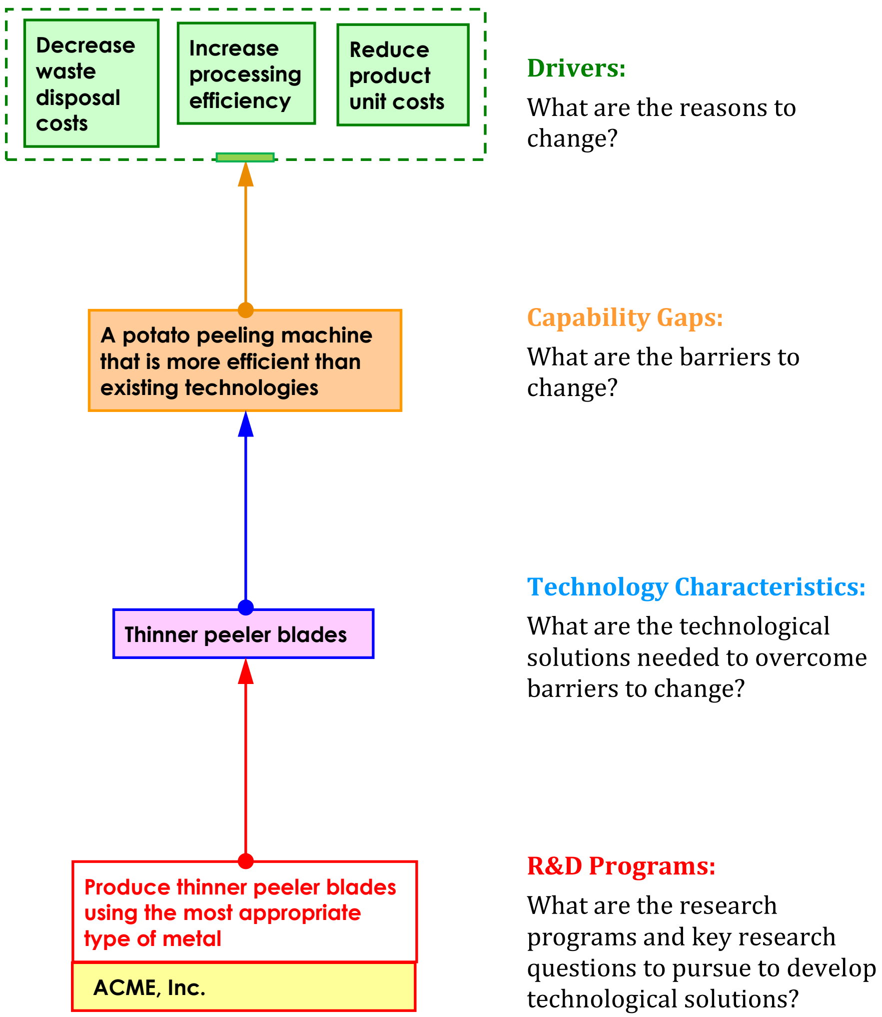
Faced with this situation, the company is facing three Drivers: 1) the desire to increase processing efficiency; 2) the desire to reduce product unit costs; and 3) the desire to reduce waste disposal costs.

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:



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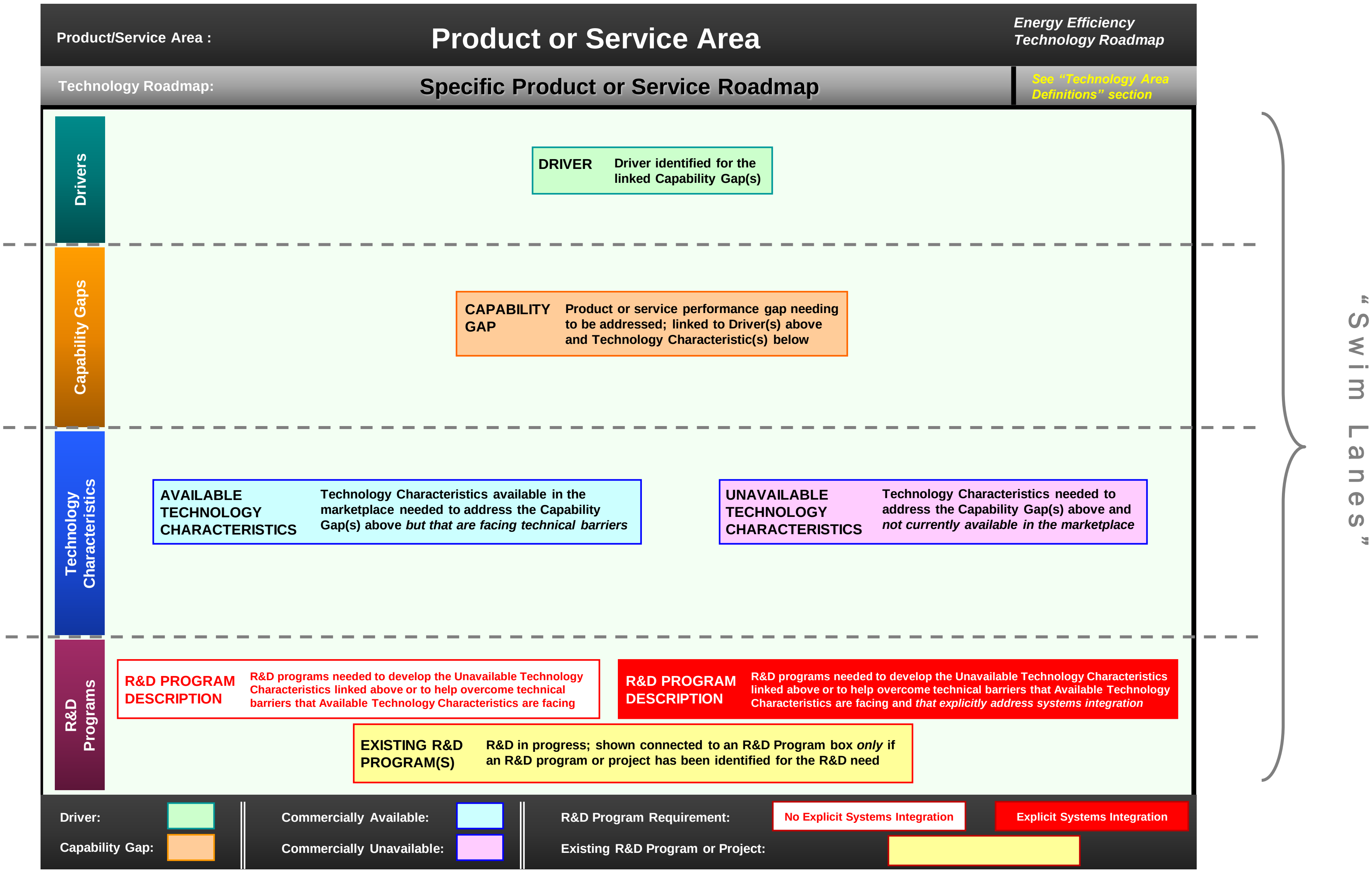
Roadmap Diagram Key



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.

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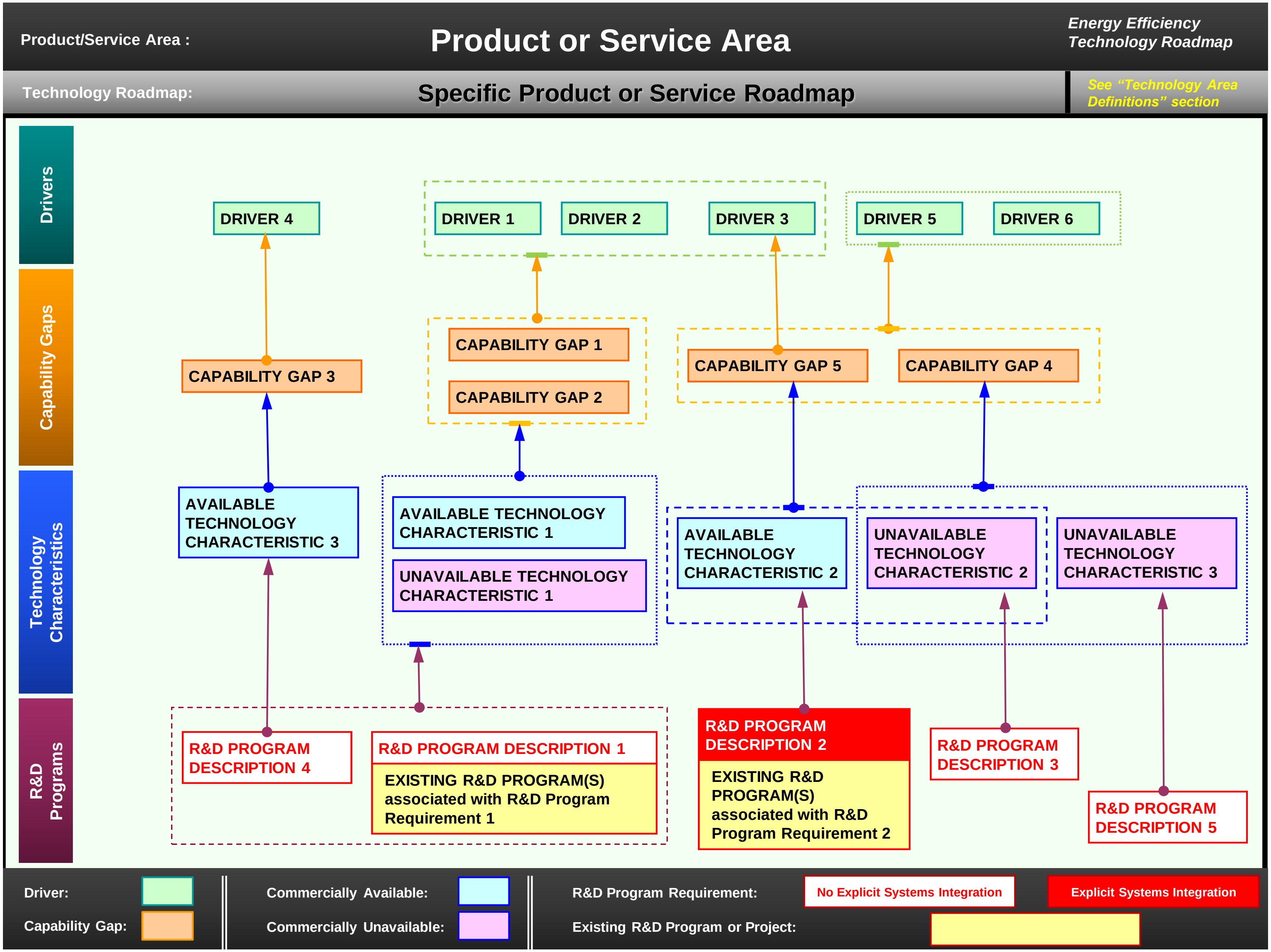
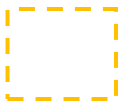
How to Interpret Roadmap Pages



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.

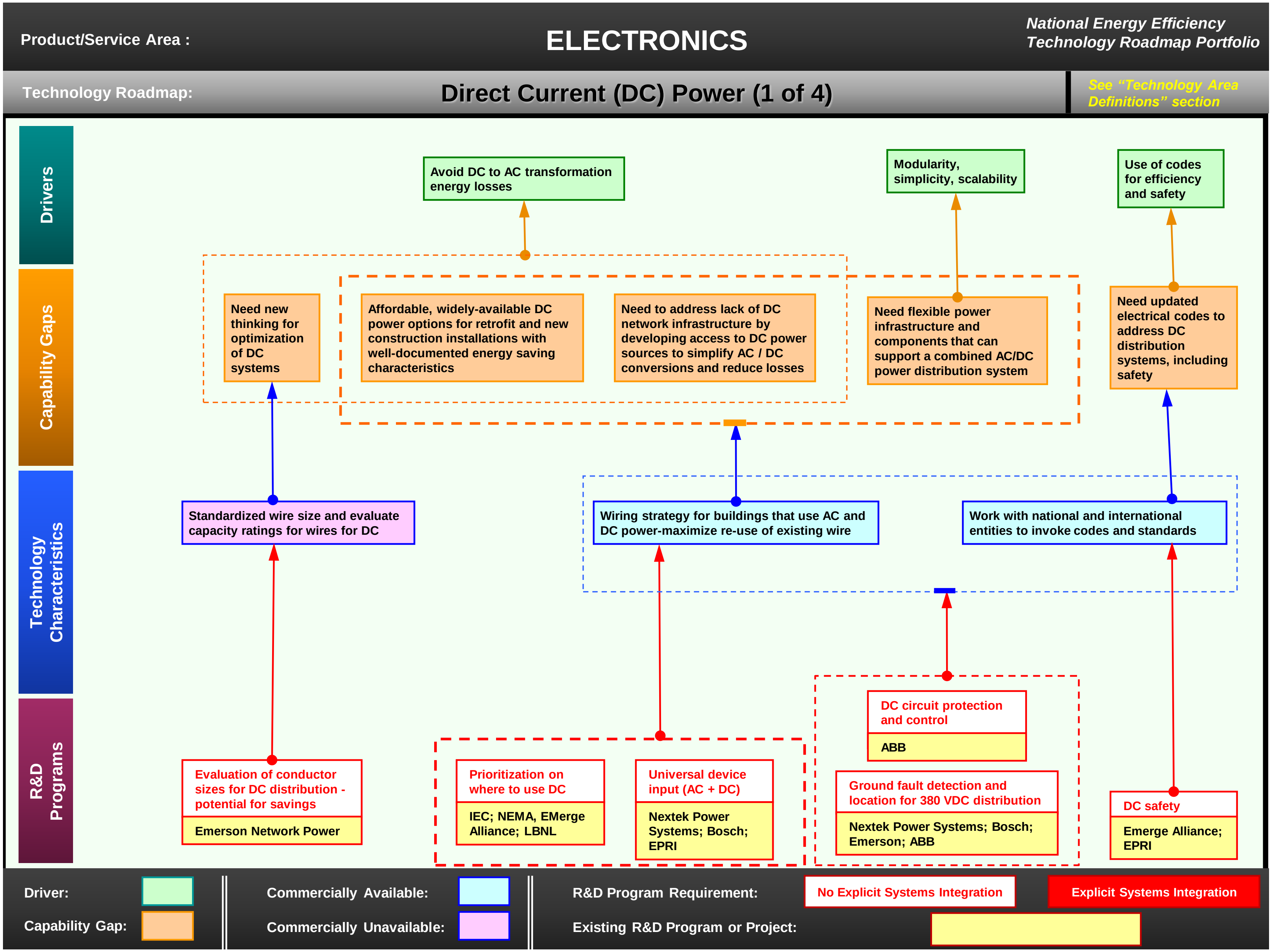
Though CG 4 and CG 5 are associated in their linkage to D 5 and D 6, CG 5 independently is linked to D 3, as the orange arrow connecting CG 5 and D 3 indicates.

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.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Direct Current (DC) Power (1 of 4)
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Technology Characteristics
R&D Programs
Avoid DC to AC transformation energy losses
Modularity, simplicity, scalability
Use of codes for efficiency and safety
Need new thinking for optimization of DC systems
Affordable, widely-available DC power options for retrofit and new construction installations with well-documented energy saving characteristics
Need to address lack of DC network infrastructure by developing access to DC power sources to simplify AC / DC conversions and reduce losses
Need flexible power infrastructure and components that can support a combined AC/DC power distribution system
Need updated electrical codes to address DC distribution systems, including safety
Standardized wire size and evaluate capacity ratings for wires for DC
Wiring strategy for buildings that use AC and DC power-maximize re-use of existing wire
Work with national and international entities to invoke codes and standards
DC circuit protection and control
ABB
Ground fault detection and location for 380 VDC distribution
Nextek Power Systems; Bosch; Emerson; ABB
Evaluation of conductor sizes for DC distribution - potential for savings
Emerson Network Power
Prioritization on where to use DC
IEC; NEMA, EMerge Alliance; LBNL
Universal device input (AC + DC)
Nextek Power Systems; Bosch; EPRI
DC safety
Emerge Alliance; EPRI
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

Evaluation of conductor sizes for DC distribution - potential for savings.

Optimize wire sizes for global applications. Conductor sizes coordinated globally-minimum sizes, insulation levels for DC applications only. Different wire sizes and insulation levels from requirements globally.

Existing research: Emerson Network Power.

- *[Summaries of existing research pending]*

Key research questions:

1. Can DC cable size decrease (compared to AC) due to lack of harmonics, skin effect, proximity effect and smaller voltage drop (compared to the National Electrical Code (NEC))?
2. Is it feasible to propose a global wire size chart coordinated with breaker sizes?
3. Is it feasible to develop (specifically for DC) temperature de-rating tables in “A” capacity rather than apply de-rating factors?
4. Is it feasible to optimize insulation levels to optimize current carrying capacity?
5. Can we define derating for bundling?
6. Can we use existing building wiring for DC power distribution?

Ground fault detection and location for 380 VDC distribution.

Enhanced personal safety. Integrated DC system including DC microgrids. Rapid detection, location and correction of potential ground faults and leakage current caused by insulation breakdown or aging.

Existing research: Emerson Network Power, ABB, Nextek Power Systems, Bosch.

- *[Summaries of existing research pending]*

Key research questions:

1. What are the best methods to detect ground faults in the DC distribution system including the end use equipment?
2. What sensors and components are needed for ground faults and where should they be located?
3. How can these sensors, components and alarms ne scaled to different size installations?
4. What is the cost of implementing these ground fault detection, location and correction systems?
5. What additional training is needed to implement these systems to assure proper operation?

Continued . . .

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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.

Existing research: Emerge Alliance and the Electric Power Research Institute (EPRI) are working to develop DC power standards for commercial buildings that address safety concerns..

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

Key research questions:

1. What codes and standards needed to be changed or developed for DC power?
2. What training facilities are available to train people on DC power?
3. What training requirements are needed for DC compared to AC systems?

DC circuit protection and control. Explore existing, new and potential new technologies for DC circuit protection and control.

Existing research: ABB.

- *[Summaries of existing research pending]*

Key research questions:

1. What short circuit testing can be done for DC power distribution?
2. What circuit breakers and fuses are available for DC circuit protection?
3. How can rectifiers and other DC power source subsystems and controls be used to limit arc flash and enhance load flow control?
4. How can power electronics (i.e., integrated circuits (ICs)) be used to improve circuit protection and control in DC power systems?
5. What new technologies are available to enhance circuit protection and control for DC power systems?

Prioritization on where to use DC. DC systems will need to transition from existing AC systems. The goal is to identify how to make the transitioning by identifying the highest profile opportunities for DC based on efficiency gains and cost of implementation.

Existing research: IEC Electronics Corporation, National Electrical Manufacturers Association (NEMA), and EMerge Alliance are working in this space. As of early 2013 there is also an ongoing scoping study of DC power opportunities led by the Lawrence Berkeley National Laboratory and involving the Pacific Northwest National Laboratory, Department of Energy, and other stakeholders.

- *[Summaries of existing research pending]*

Key research questions:

1. Where are the key locations in the buildings where efficiency can be achieved?
2. What is the amount of efficiency that can be gained?
3. How much DC supply is available and how should it be best used in the buildings?
4. Based on the DC supply available which equipment should be converted to DC first?

Continued . . .

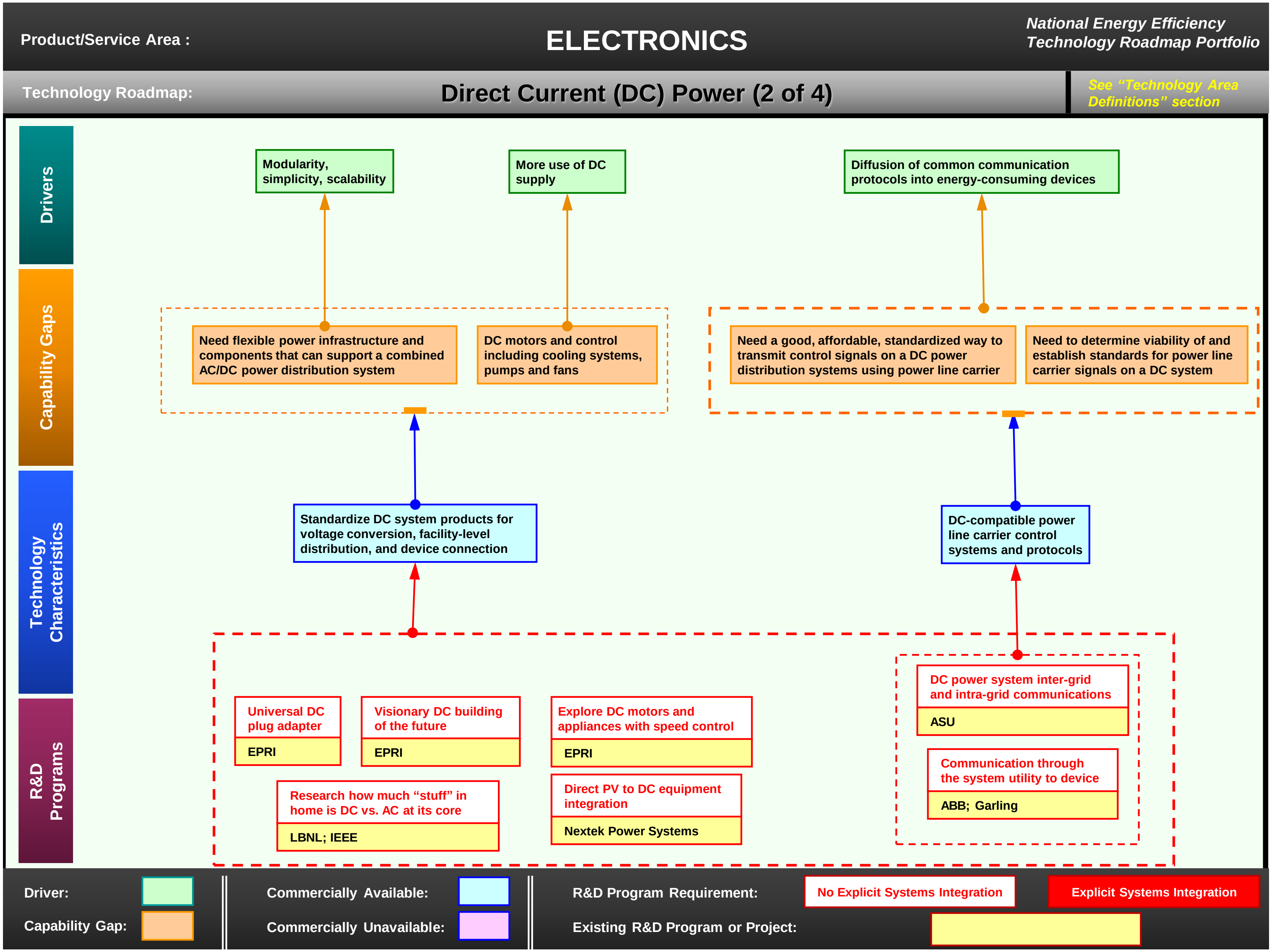
Universal device input (AC + DC). Device circuit technology for common electrical devices that can accept either connection to an AC or DC power distribution system.

Existing research: The Electric Power Research Institute (EPRI), Nextek Power Systems, and Bosch are conducting research in this area.

- For EPRI's research in this area, see Appendix B for more information
- *[Summaries of other existing research pending]*

Key research questions:

1. Circuit design for AC/DC inputs.
2. Low cost design with minimal premium cost.
3. Safety issues.
4. Code issues.
5. Cords and connector designs.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Modularity, simplicity, scalability
More use of DC supply
Diffusion of common communication protocols into energy-consuming devices
Need flexible power infrastructure and components that can support a combined AC/DC power distribution system
DC motors and control including cooling systems, pumps and fans
Need a good, affordable, standardized way to transmit control signals on a DC power distribution systems using power line carrier
Need to determine viability of and establish standards for power line carrier signals on a DC system
Standardize DC system products for voltage conversion, facility-level distribution, and device connection
DC-compatible power line carrier control systems and protocols
Universal DC plug adapter
EPRI
Visionary DC building of the future
EPRI
Explore DC motors and appliances with speed control
EPRI
Research how much "stuff" in home is DC vs. AC at its core
LBNL; IEEE
Direct PV to DC equipment integration
Nextek Power Systems
DC power system inter-grid and intra-grid communications
ASU
Communication through the system utility to device
ABB; Garling
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

Explore DC motors and appliances with speed control. Since variable speed is easy to do with 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.

Existing research: Electric Power Research Institute (EPRI).

- *[Summaries of existing research pending]*

Key research questions:

1. What are the efficiency gains with brushless DC motors?
2. What are the control benefits of DC motors, i.e., higher speeds, faster response, torque characteristics?
3. What are the benefits of DC motors for size, maintenance and heat removal?
4. What are the benefits of brushless DC motors for reduced radio frequency interference (RFI)?
5. What components can be removed when transitioning from AC variable frequency drives (VFDs) to brushless DC motors?

Universal DC plug adapter. One of the issues with converting to DC is that plug and sockets are totally non-standard. The development of a universal plug for DC will greatly aid adoption.

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

Key research questions:

1. How do different DC plugs and sockets currently available handle and control arc-flash?
2. Can the existing Institute of Electrical and Electronics Engineers International Electrotechnical Commission (IEC) 309 pin and sleeve connectors cover "all" of the high wattage DC product needs?
3. What is the best solution(s) for the lower wattage DC products?

Research how much "stuff" in home is DC vs. AC at its core. 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.

Existing research: Lawrence Berkeley National Laboratory (LBNL), Institute of Electrical and Electronics Engineers (IEEE).

- *[Summaries of existing research pending]*

Key research questions:

1. Questions not yet specified.

Continued . . .

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Direct PV to DC equipment integration. Solar photovoltaic (PV) systems may supply DC directly rather than converting to 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.

Existing research: Nextek Power Systems.

- *[Summaries of existing research pending]*

Key research questions:

1. Which DC powered devices offer the best opportunity to be powered directly in residential and commercial applications?
2. What types of buildings are best suited? What system characteristics define the best opportunities in new buildings?
3. Where is PV added to existing buildings/facilities? What additional equipment and systems (safety, control, and integration) are needed?

Visionary DC building of the future. Taking a new approach to create an all DC environment that includes electrical configuration, storage, end use devices, distribution, safety devices.

Existing research: Electric Power Research Institute (EPRI).

- *[Summaries of existing research pending]*

Key research questions:

1. What metered resource savings can be achieved?
2. What are the technical challenges, lessons learned in putting this together?
3. What are the areas of this optimal solution that cannot be addressed by code?
4. What are the energy savings and the distribution of these savings?

DC power system inter-grid and intra-grid communications. The creation of arbitrary networks of grids of varying scales with dynamic plug and play interoperability.

Existing research: Arizona State University (ASU)

- *[Summaries of existing research pending]*

Key research questions:

1. Can we create a network of grids that are interconnected and exchanging power based on price signals?
2. Can a grid be built that communicates with individual devices and includes price signals?
3. Can we define specific gateways between grids for both electrical and communication connections for grid to grid data interchange?

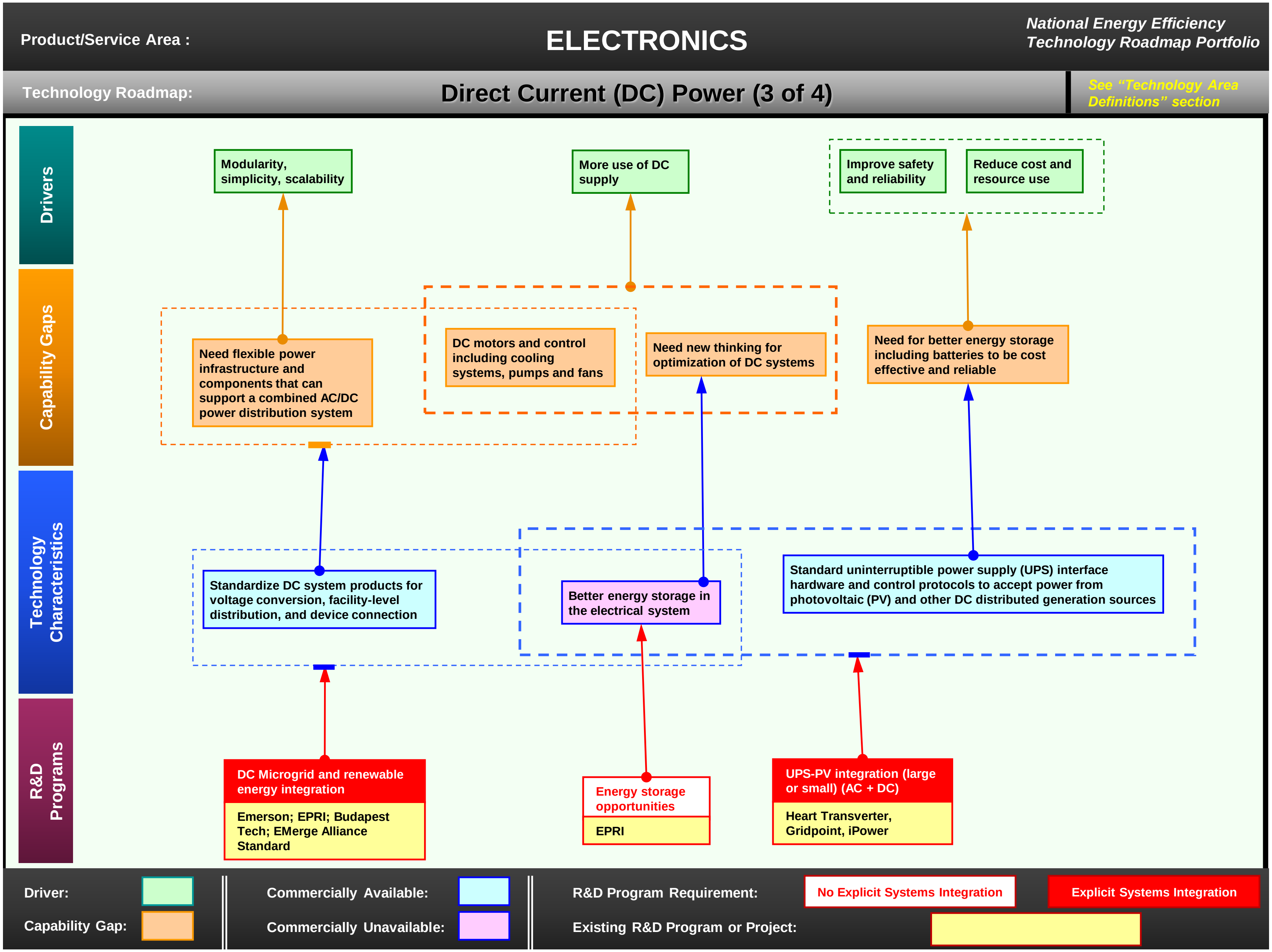
Communication through the system utility to device. With DC systems information can more reliably be sent via carrier signals on the same infrastructure (wires).

Existing research: ABB and Garling are working on breakers.

- *[Summaries of existing research pending]*

Key research questions:

1. Can carrier signals be effectively used to communicate peer to peer between appliances as well as connecting communication to utility signals?
2. How can carrier signals transfer across DC voltage conversion devices?
3. What communications protocol is the best to use on DC wiring?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More use of DC supply
Improve safety and reliability
Reduce cost and resource use
Need flexible power infrastructure and components that can support a combined AC/DC power distribution system
DC motors and control including cooling systems, pumps and fans
Need new thinking for optimization of DC systems
Need for better energy storage including batteries to be cost effective and reliable
Standardize DC system products for voltage conversion, facility-level distribution, and device connection
Better energy storage in the electrical system
Standard uninterruptible power supply (UPS) interface hardware and control protocols to accept power from photovoltaic (PV) and other DC distributed generation sources
DC Microgrid and renewable energy integration
Emerson; EPRI; Budapest Tech; EMerge Alliance Standard
Energy storage opportunities
EPRI
UPS-PV integration (large or small) (AC + DC)
Heart Transverter, Gridpoint, iPower
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

Energy storage opportunities. New options exist for the integration of energy storage into a DC power system since the entire system can act as a DC link.

Existing research: Electric Power Research Institute (EPRI).

- *[Summaries of existing research pending]*

Key research questions:

1. How and where can batteries and/or other energy storage systems be connected within a DC system?
2. How can electric vehicles (EVs) be connected to DC systems for charge and discharge requirements?
3. Can batteries and/or other battery storage systems be located and connected at various locations in a DC power system in order to meet differing component level reliability requirements?

DC Micro grid and renewable energy integration. DC power enables the opportunity to create DC microgrids which integrate, multiple power sources and can feed multiple loads while in both island mode and grid connected mode.

Existing research: Emerson, Electric Power Research Institute (EPRI), Budapest Tech [Budapest University of Technology and Economics?], EMerge Alliance Standard.

- *[Summaries of existing research pending]*

Key research questions:

1. How can a DC microgrid be designed, built, and operated?
2. Can fuel *[not discernible]* be used to power a DC power system?

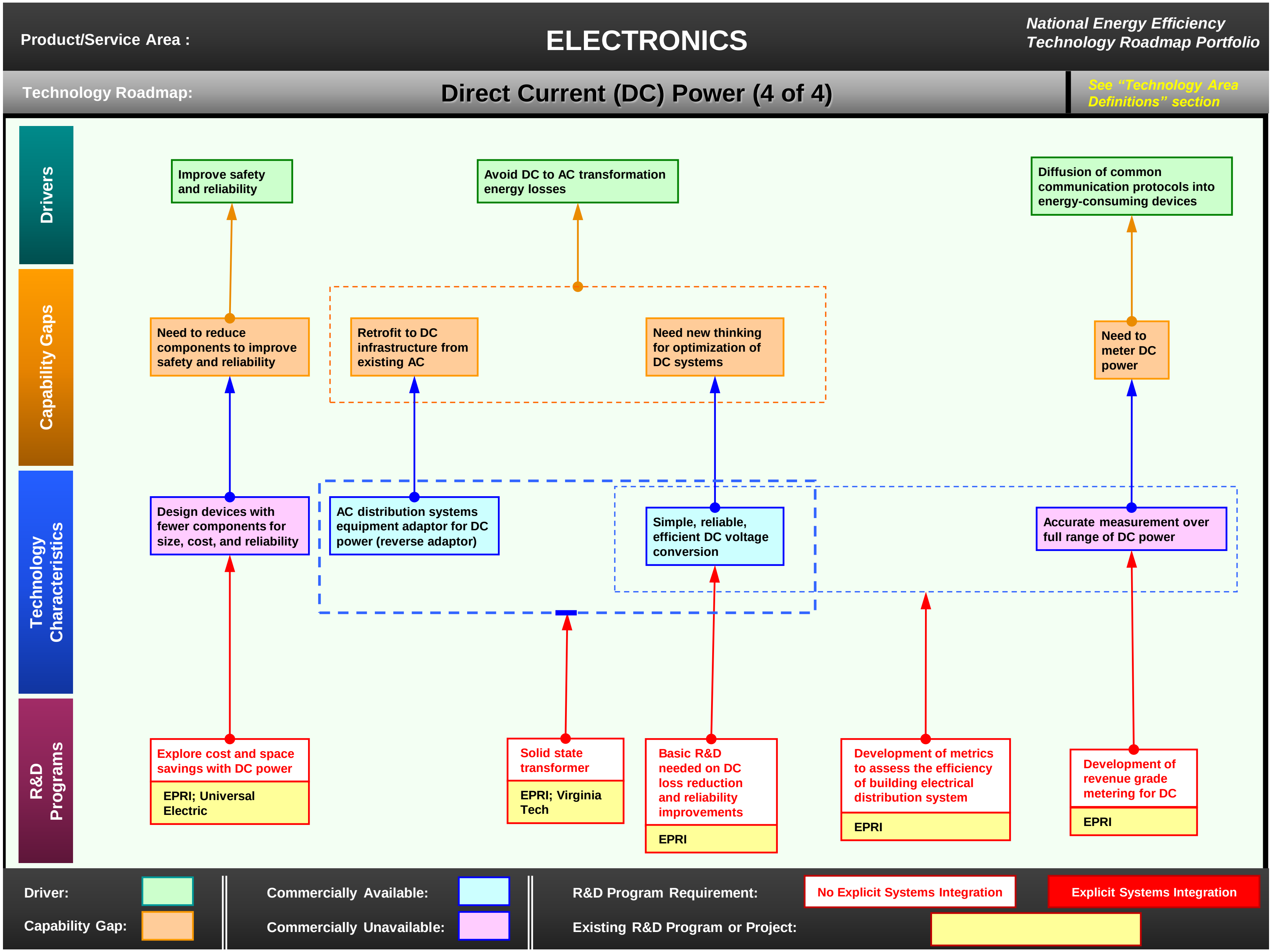
UPS -PV integration (large or small). A common entry point for DC power (such as DV system or fuel cells) is to integrate with uninterruptible power systems (UPS) that use batteries as the storage element. These systems can be used in a large variety of backup systems from small back-up to datacenters to E-power for buildings. Solar photovoltaic (PV) systems, too, may supply DC directly rather than converting to AC and back again. Research is needed to determine how most effectively to do this.

Existing research: Heart Transverter, Gridpoint , and iPower are working in this area.

- 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.
-

Key research questions:

1. Do different batteries (deep cycle) need to be used compared to existing UPS systems?
2. How much overall system efficiency can be achieved?
3. Can UPS system be more designed like grid independent PV battery systems? What are the differences and how can the experiences of grid independent systems be copied to UPS systems?
4. What are the differences in UPS systems from data centers to E-power systems for commercial and residential buildings?



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Improve safety and reliability
Avoid DC to AC transformation energy losses
Diffusion of common communication protocols into energy-consuming devices
Need to reduce components to improve safety and reliability
Retrofit to DC infrastructure from existing AC
Need new thinking for optimization of DC systems
Need to meter DC power
Design devices with fewer components for size, cost, and reliability
AC distribution systems equipment adaptor for DC power (reverse adaptor)
Simple, reliable, efficient DC voltage conversion
Accurate measurement over full range of DC power
Explore cost and space savings with DC power
EPRI; Universal Electric
Solid state transformer
EPRI; Virginia Tech
Basic R&D needed on DC loss reduction and reliability improvements
EPRI
Development of metrics to assess the efficiency of building electrical distribution system
EPRI
Development of revenue grade metering for DC
EPRI
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

Basic R&D needed on DC loss reduction and reliability improvements. The concept of using 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 AC supply voltage (230V.). Basic proof-of-concept and maybe some small trials are needed before expanding further.

Existing research: 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.

Key research questions:

1. Can we set up a permanent national DC power test lab where public, industry and government can see a proof of concept system in operation?

Explore cost and space savings with DC power. Comparing similar power distribution system designs for AC + DC systems. What are the cost and space savings when going from AC to DC.

Existing research: Electric Power Research Institute (EPRI), Universal Electric.

- *[Summaries of existing research pending]*

Key research questions:

1. How does DC power compare with a similar AC systems regarding total cost of ownership (TCO)?
2. How does DC power compare with similar AC systems regarding equipment space requirements?

Development of revenue grade metering for DC. (Summary not yet provided.)

Existing research: Electric Power Research Institute (EPRI).

- *[Summaries of existing research pending]*

Key research questions:

1. Can we measure accurately over the entire range of end use devices?
2. What is needed to make these meters compatible with current generation of AC meters?

Continued . . .

Back to Table of Contents

Development of metrics to assess the efficiency of building electrical distribution system. Create a distribution efficiency metric. 100% efficient systems should have no losses.

Existing research: Electric Power Research Institute (EPRI).

- *[Summaries of existing research pending]*

Key research questions:

1. What is the efficiency of the distribution system in different building types?
2. Where are the losses?
3. What is the efficiency of a DC based buildings?
4. What are the key metrics of success and the measurement protocol to determine?
5. Are there analytical means to define the metric?

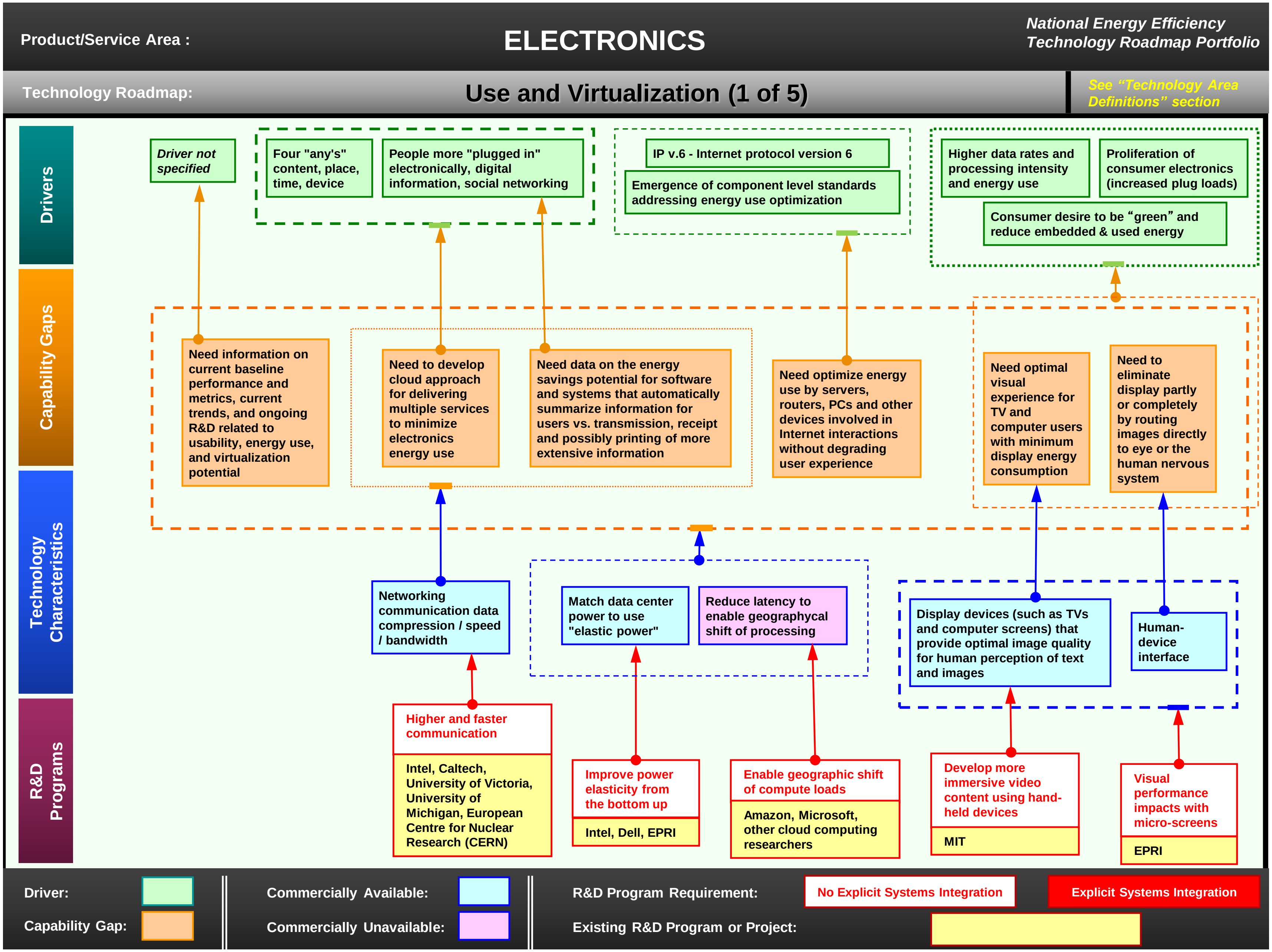
Solid state transformer. It is desired to incorporate voltage transformation with rectification of building power. This will reduce conversion losses and number of power devices.

Existing research: Electric Power Research Institute (EPRI), Virginia Polytechnic Institute and State University.

- *[Summaries of existing research pending]*

Key research questions:

1. How can you efficiently and reliably convert utility distribution power (at 12 kV) to 380 VDC or any other desired voltage?


Product/Service Area :
ELECTRONICS
National Energy Efficiency Technology Roadmap Portfolio
Technology Roadmap:
Use and Virtualization (1 of 5)
See “Technology Area Definitions” section
Drivers
Capability Gaps
Technology Characteristics
R&D Programs
Driver not specified
Four "any's" content, place, time, device
People more "plugged in" electronically, digital information, social networking
IP v.6 - Internet protocol version 6
Emergence of component level standards addressing energy use optimization
Higher data rates and processing intensity and energy use
Proliferation of consumer electronics (increased plug loads)
Consumer desire to be “green” and reduce embedded & used energy
Need information on current baseline performance and metrics, current trends, and ongoing R&D related to usability, energy use, and virtualization potential
Need to develop cloud approach for delivering multiple services to minimize electronics energy use
Need data on the energy savings potential for software and systems that automatically summarize information for users vs. transmission, receipt and possibly printing of more extensive information
Need optimize energy use by servers, routers, PCs and other devices involved in Internet interactions without degrading user experience
Need optimal visual experience for TV and computer users with minimum display energy consumption
Need to eliminate display partly or completely by routing images directly to eye or the human nervous system
Networking communication data compression / speed / bandwidth
Match data center power to use "elastic power"
Reduce latency to enable geographycal shift of processing
Display devices (such as TVs and computer screens) that provide optimal image quality for human perception of text and images
Human-device interface
Higher and faster communication
Intel, Caltech, University of Victoria, University of Michigan, European Centre for Nuclear Research (CERN)
Improve power elasticity from the bottom up
Intel, Dell, EPRI
Enable geographic shift of compute loads
Amazon, Microsoft, other cloud computing researchers
Develop more immersive video content using hand-held devices
MIT
Visual performance impacts with micro-screens
EPRI
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

Improve power elasticity from the bottom up. Components are good at scaling energy use with load but that capability is lost in populations of machines and applications. Explore ways to extend elastic power use from component to data centers.

Existing research: Intel, Dell, Electric Power Research Institute (EPRI).

- *[Summaries of existing research pending]*

Key research questions:

1. Why do applications not show the same power elasticity as chips, i.e., reducing energy consumption with reduce load?
2. Why do data centers not show the same elasticity as machines, i.e., whole building power elasticity compared to SPEC-power capabilities?

Higher and faster communication. Investigate the family of technology options that are effective at transferring larger amounts of data at higher rates. This includes examining compression techniques, communication protocols, expansion of bandwidth and the use of networks. The work should addressed both distributed and control processing.

Existing research: Intel, Caltech, University of Victoria (British Columbia), University of Michigan, European Centre for Nuclear Research (CERN).

- *[Summaries of existing research pending]*

Key research questions:

1. Which data compression techniques are available?
2. What are the best communication protocols?
3. What are practical networking/communication speeds?
4. How can communication bandwidth be expanded as well as utilization of bandwidths?
5. How much processing can be applied at distributed devices versus being connected server/host?

Continued . . .

Enable geographic shift of computer loads. The vast majority of applications are interactive or human driven, requiring sub-second response times. Latency between several consumers drives geographic proximity today. Break the link between geography and application performance.

Existing research: Amazon, Microsoft, other cloud computing researchers.

- *[Summaries of existing research pending]*

Key research questions:

1. Programming techniques that enable high latency between server and network edge; be able to see results on smart phones in Europe with acceptable performance from servers in the U.S. This would enable load shifting without regard to geography.
2. What percentage of apps is interactive/human driven? What percentage could be geography independent with proper programming methods?

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. Finding one user preference when performing different tasks. Reduce unnecessary devices if we can optimize user experience.

Existing research: Electric Power Research Institute (EPRI).

- *[Summaries of existing research pending]*

Key research questions:

1. What is optimal micro-screen size for different devices?
2. Is there a need for a bigger than 65" TV? (4K TV)
3. What are the pros and cons between liquid crystal display (LCD) Vs Plasma Vs. light-emitting diode (LED)?

Develop more immersive video content using hand-held devices. 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.

Existing research: Massachusetts Institute of Technology (MIT) Media Lab.

- The MIT Media Lab is currently researching VR viewing technology; see Appendix B for more information.

Key research questions:

1. Questions not yet specified.

Product/Service Area :

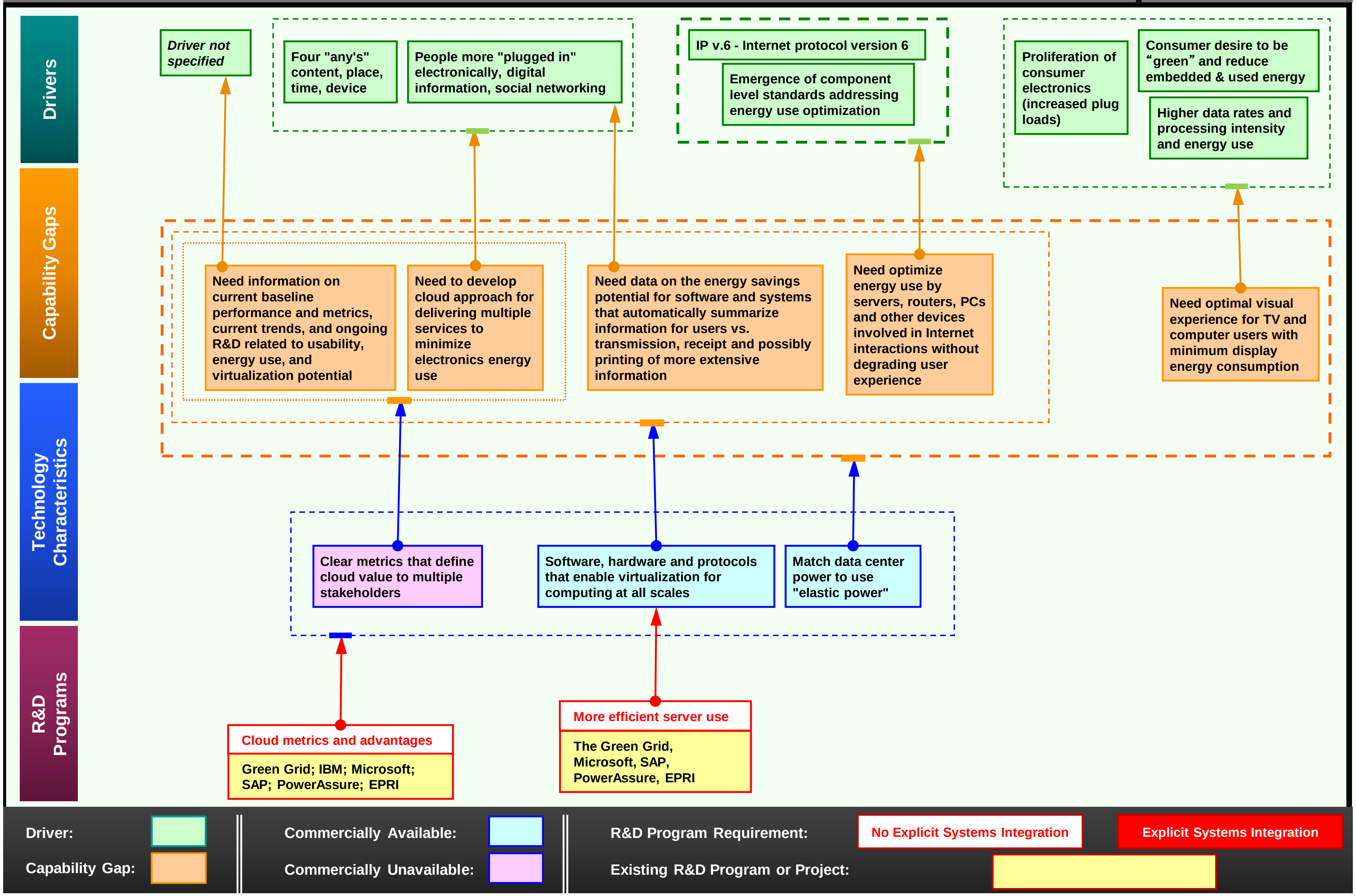
ELECTRONICS

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap:

Use and Virtualization (2 of 5)

See "Technology Area Definitions" section



R&D Program Summaries

Cloud metrics and advantages. Develop metrics that quantify the intuitive understanding that cloud computing is more efficient than disaggregated computing models.

Existing research: Green Grid, IBM, Microsoft, SAP, PowerAssure.

- Dr. Zeydy Ortiz, Senior Performance Engineer in the Systems & Technology Group at IBM (http://expertintegratedsystemsblog.com/index.php/author/zeydy-ortiz/).
- Subject matter experts in September 2012 referred to the work of Timo Szeltzer at SAP.
- Clemens Pfeiffer, Chief Technology Officer at PowerAssure (http://www.powerassure.com/).

Key research questions:

1. What are the barriers to adoption of aggregated (i.e., cloud or centralized) computing?
2. Define metrics and demonstrate the utility (usefulness) of many dimensions of cloud, e.g., cost reliability.
3. Quantify the benefits of moving compute capacity to centralized resources, e.g., dumber. Cheaper. More efficient edge devices (smart phones) and more efficient centralized compute utilities (cloud). How much system-wide savings (cost, energy, carbon, etc)?
4. What else could solve this besides cloud?

More efficient server use. Quantify generic capacity and utilization metrics that address "Z sigma" (i.e., 60-70%) of data center metric needs. Focus on enterprise/small medium business.

Existing research: The Green Grid, Microsoft, SAP, PowerAssure, Electric Power Research Institute (EPRI).

- *[Summaries of existing research pending]*

Key research questions:

1. How should compute requirement (capacity) be quantified?
2. Develop a generic "yardstick" ala "MIPS" that can be used to better plan hardware (HW) capacity and measure utilization.
3. As providers manage hardware (HW) pools compared to computer demand what metrics unit do they use to maximize profits?

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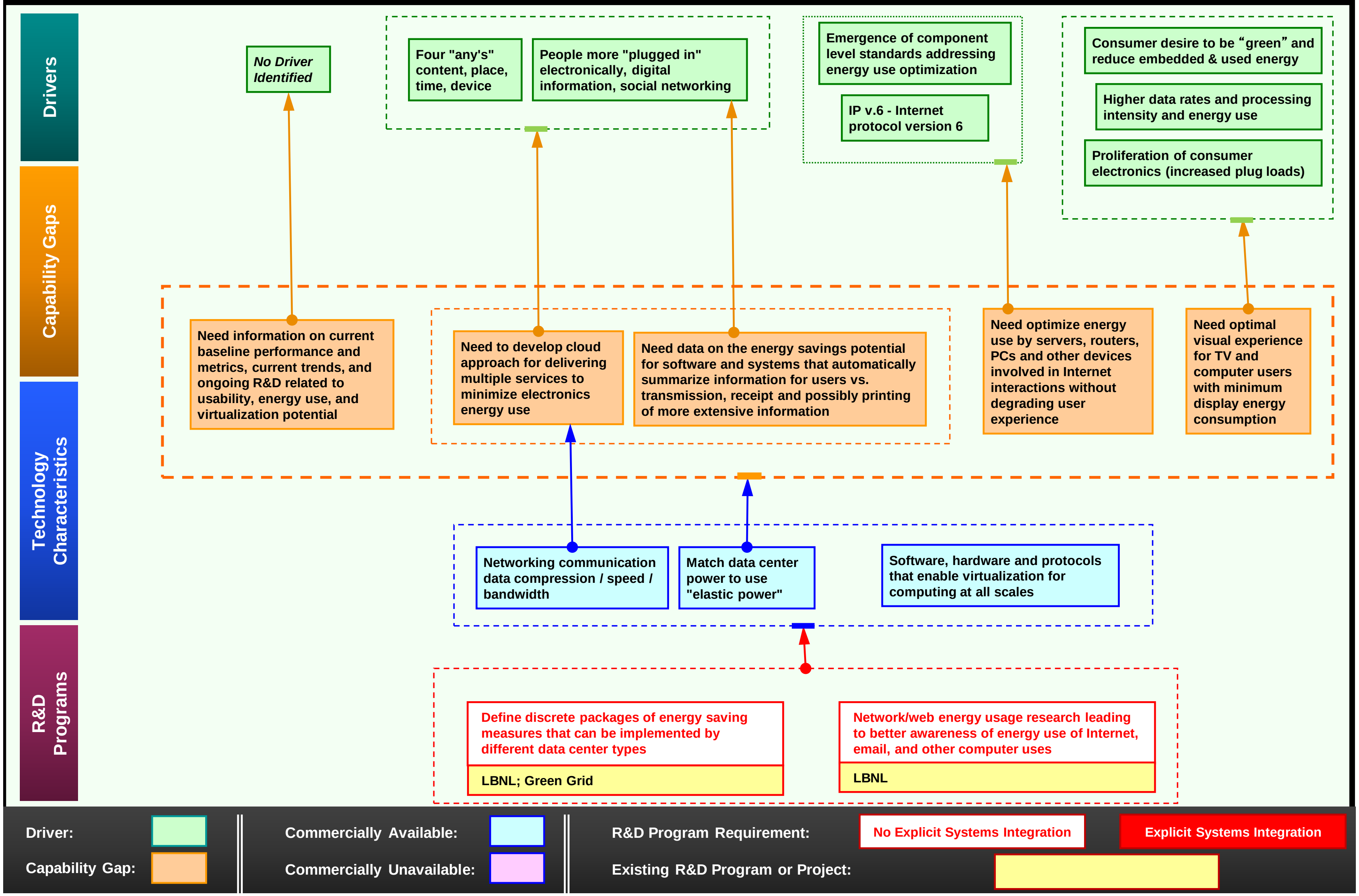
Product/Service Area : **ELECTRONICS**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Use and Virtualization (3 of 5)**

See "Technology Area Definitions" section



R&D Program Summaries

Define discrete packages of energy saving measures that can be implemented by different data center types. Small data centers are different needs and issues than large data centers. How can lesson learned from large data centers be applied to small data centers?.

Existing research: Lawrence Berkeley National Laboratory (LBNL), Green Grid.

- *[Summaries of existing research pending]*

Key research questions:

1. Are there simple measures that reduce energy use of small data centers?
2. What are the achievable cost effective levels of energy savings?
3. What are barriers that increase savings cost and/or reduce the magnitude of achievable savings?

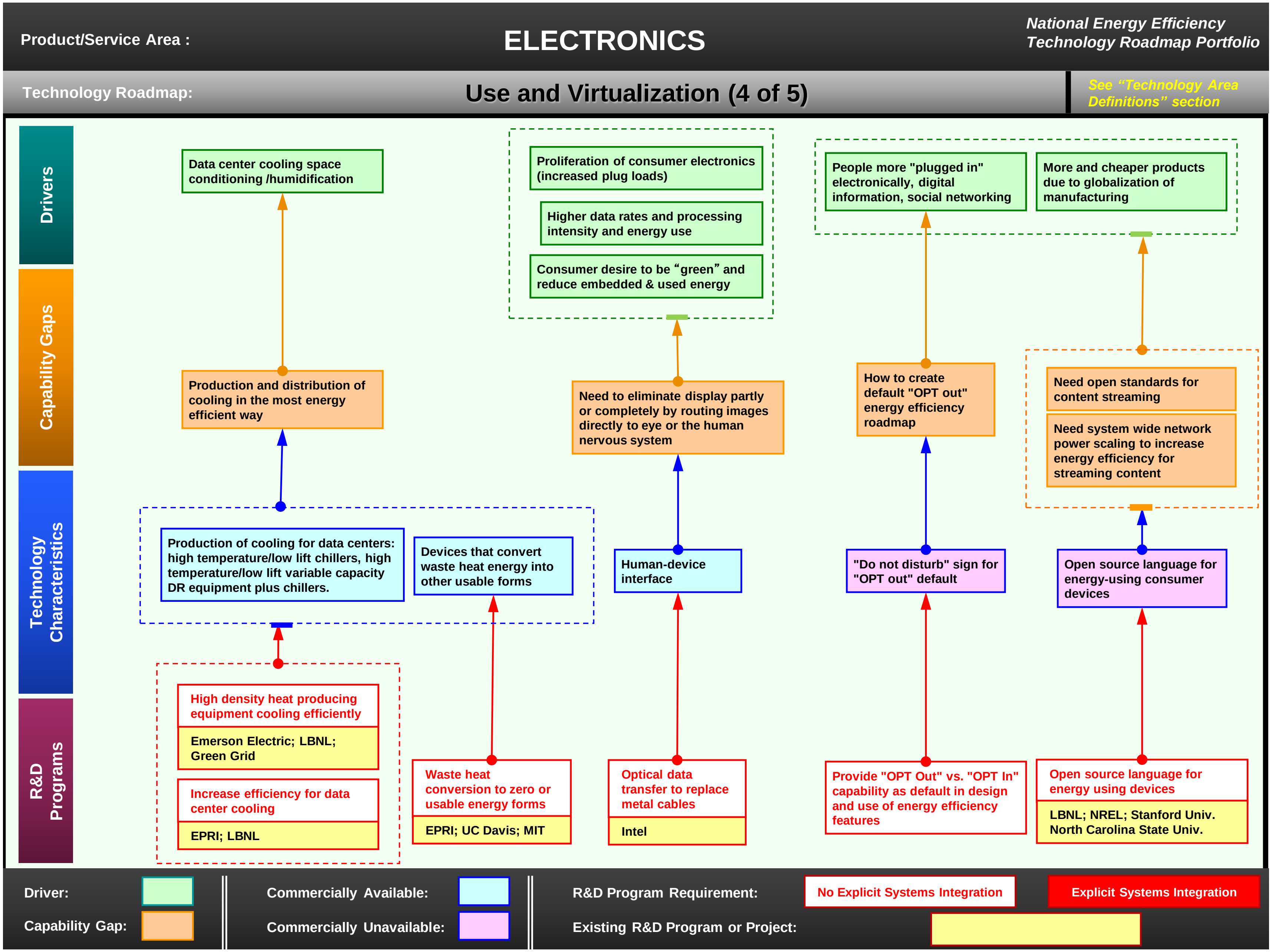
Network/web energy usage research leading to better awareness of energy use of Internet, email, and other computer uses. Many users consider it environmentally benign to transfer information electronically rather than with paper, but there is substantial energy use for this; research this and raise user 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.

Existing research: Lawrence Berkeley National Laboratory (LBNL).

- For more information on LBNL research in this area, see Appendix B

Key research questions:

1. Are there simple measures that reduce energy use of small data centers?
2. What are the achievable cost effective levels of energy savings?
3. What are barriers that increase savings cost and/or reduce the magnitude of achievable savings?


Product/Service Area :
ELECTRONICS
National Energy Efficiency Technology Roadmap Portfolio
Technology Roadmap:
Use and Virtualization (4 of 5)
See "Technology Area Definitions" section
Drivers
Capability Gaps
Technology Characteristics
R&D Programs
Data center cooling space conditioning /humidification
Proliferation of consumer electronics (increased plug loads)
Higher data rates and processing intensity and energy use
Consumer desire to be "green" and reduce embedded & used energy
People more "plugged in" electronically, digital information, social networking
More and cheaper products due to globalization of manufacturing
Production and distribution of cooling in the most energy efficient way
Need to eliminate display partly or completely by routing images directly to eye or the human nervous system
How to create default "OPT out" energy efficiency roadmap
Need open standards for content streaming
Need system wide network power scaling to increase energy efficiency for streaming content
Production of cooling for data centers: high temperature/low lift chillers, high temperature/low lift variable capacity DR equipment plus chillers.
Devices that convert waste heat energy into other usable forms
Human-device interface
"Do not disturb" sign for "OPT out" default
Open source language for energy-using consumer devices
High density heat producing equipment cooling efficiently
Emerson Electric; LBNL; Green Grid
Increase efficiency for data center cooling
EPRI; LBNL
Waste heat conversion to zero or usable energy forms
EPRI; UC Davis; MIT
Optical data transfer to replace metal cables
Intel
Provide "OPT Out" vs. "OPT In" capability as default in design and use of energy efficiency features
Open source language for energy using devices
LBNL; NREL; Stanford Univ. North Carolina State Univ.
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

High density heat producing equipment cooling efficiently. investigate efficient cooling solution for IT equipment other than grounded correction air cooling.

Existing research: Emerson Electric,Lawrence Berkeley National Laboratory (LBNL), Green Grid.

- Subject matter experts in September 2012 referenced immersion cooling research at Emerson Electric.
- *[Summaries of other existing research pending]*

Key research questions:

1. Increasing equipment power densities. Is increasing need for efficient cooling to control temperature?
2. Are there more efficient ways to reject heat, cold plate, radiative cooling, and immersion cooling in dielectric oil baths?

Increase efficiency for data center cooling. What can be done to reduce energy use in cooling data centers? How can the mechanical equipment design and operations be optimized for data center cooling?.

Existing research: Lawrence Berkeley National Laboratory (LBNL), Electric Power Research Institute (EPRI).

- *[Summaries of existing research pending]*

Key research questions:

1. Equipment design and operation for comfort cooling is not optimized for IT equipment cooling in data centers.
2. need high temperature (~60-65F supply temperature Vs ~45F for human comfort application) chillers with low lift.
3. What is the energy saving potential of such equipment and how could these be developed?
4. How can the low grade waste heat generated from IT equipment be used effectively?
5. What are energy efficient solutions and how can these be developed for data centers?

Waste heat conversion to zero or usable energy forms. The development of practical waste heat conversion systems to create alternative energy forms.

Existing research: Electric Power Research Institute (EPRI), Massachusetts Institute of Technology (MIT), University of California Davis.

- *[Summaries of existing research pending]*

Key research questions:

1. What useful waste heat conversions can be practically achieved?
2. What conversion efficiency is achievable?

Continued . . .

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Open source language for energy using devices. Energy using devices need to communicate with each other and control systems in a vendor-independent fashion.

Existing research: Lawrence Berkeley National Laboratory (LBNL), National Renewable Energy Laboratory (NREL), Stanford University, North Carolina State University.

- *[Summaries of existing research pending]*

Key research questions:

1. What is the basic set of info that energy devices should tell about itself?
2. What is a standard way for devices to exchange info?

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.

Existing research: Intel.

- *[Summaries of existing research pending]*

Key research questions:

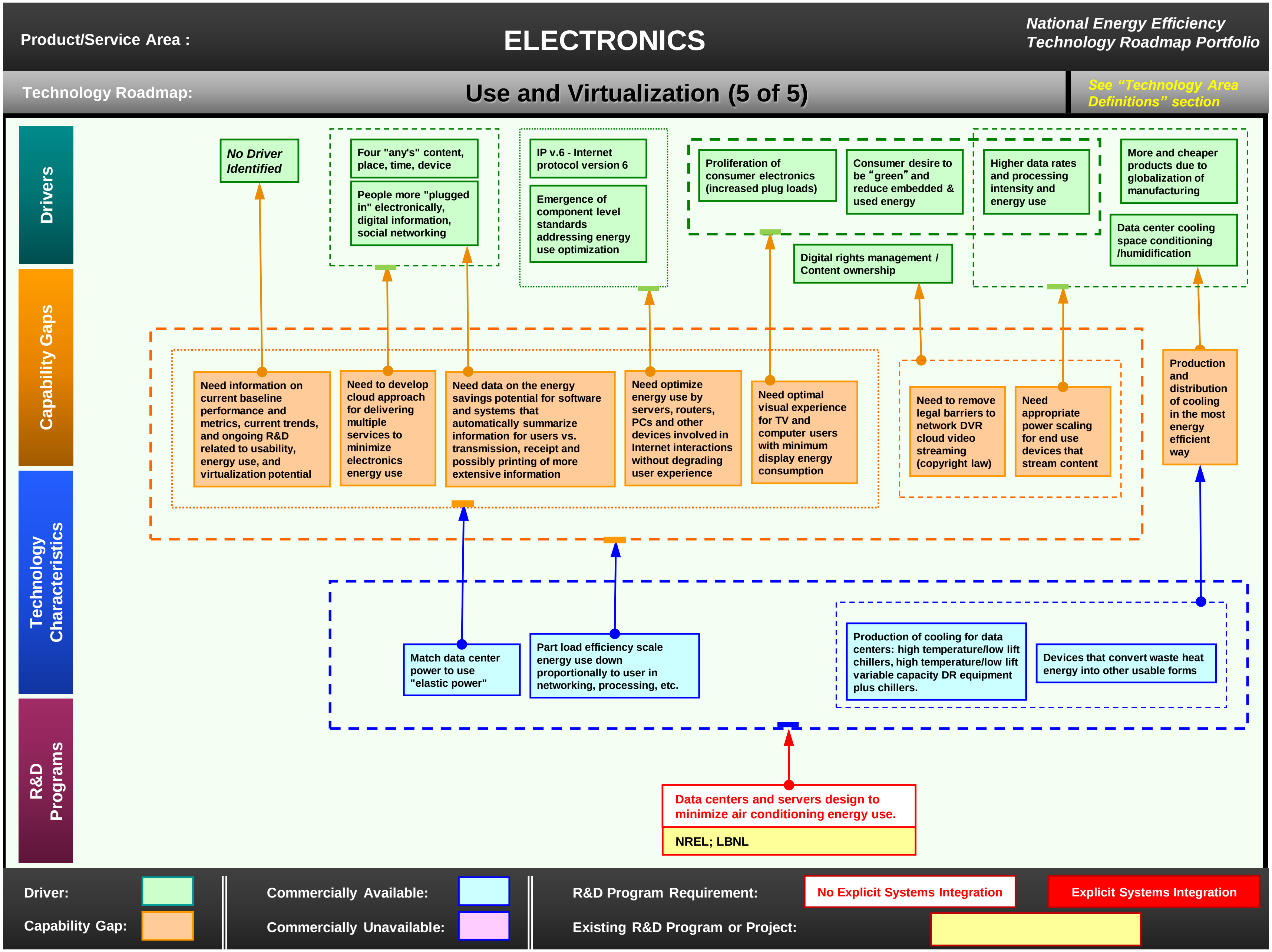
1. Does it take less energy to transmit 1 petabyte (PB) of data over optical fiber compared to metal cable?
2. How much less and is it economically compelling? How does this depend on data density?
3. What would be a way of replacing existing metal cable infrastructure with optical and what would be the magnitude of savings?

Provide "OPT Out" vs. "OPT In" capability as default in design and use of energy efficiency features. Default features are invariably used and making the energy efficiency and default features will increase it use. Also when developers are developing design/software/apps, they would resolve any issues related to these features will ensure that apps work.

Existing research: None identified.

Key research questions:

1. How do we inculcate the culture of energy efficiency features as default rather than after thought?


Product/Service Area :
ELECTRONICS
National Energy Efficiency Technology Roadmap Portfolio
Technology Roadmap:
Use and Virtualization (5 of 5)
See "Technology Area Definitions" section
Drivers
Capability Gaps
Technology Characteristics
R&D Programs
No Driver Identified
Four "any's" content, place, time, device
People more "plugged in" electronically, digital information, social networking
IP v.6 - Internet protocol version 6
Emergence of component level standards addressing energy use optimization
Proliferation of consumer electronics (increased plug loads)
Consumer desire to be "green" and reduce embedded & used energy
Higher data rates and processing intensity and energy use
More and cheaper products due to globalization of manufacturing
Data center cooling space conditioning /humidification
Digital rights management / Content ownership
Need information on current baseline performance and metrics, current trends, and ongoing R&D related to usability, energy use, and virtualization potential
Need to develop cloud approach for delivering multiple services to minimize electronics energy use
Need data on the energy savings potential for software and systems that automatically summarize information for users vs. transmission, receipt and possibly printing of more extensive information
Need optimize energy use by servers, routers, PCs and other devices involved in Internet interactions without degrading user experience
Need optimal visual experience for TV and computer users with minimum display energy consumption
Need to remove legal barriers to network DVR cloud video streaming (copyright law)
Need appropriate power scaling for end use devices that stream content
Production and distribution of cooling in the most energy efficient way
Match data center power to use "elastic power"
Part load efficiency scale energy use down proportionally to user in networking, processing, etc.
Production of cooling for data centers: high temperature/low lift chillers, high temperature/low lift variable capacity DR equipment plus chillers.
Devices that convert waste heat energy into other usable forms
Data centers and servers design to minimize air conditioning energy use.
NREL; LBNL
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

Data centers and servers design to minimize air conditioning energy use. Goal is to design data centers to maximize heat recovery and minimize space air conditioning energy use.

Existing research: National Renewable Energy Laboratory (NREL), Lawrence Berkeley National Laboratory (LBNL).

- *[Summaries of existing research pending]*

Key research questions:

1. What are cost and performance tradeoffs with different air conditioning approaches?
2. What are cost and performance tradeoffs with different heat recovery technologies?
3. How does air conditioning and heat recovery efficiency scale with data center size and location?

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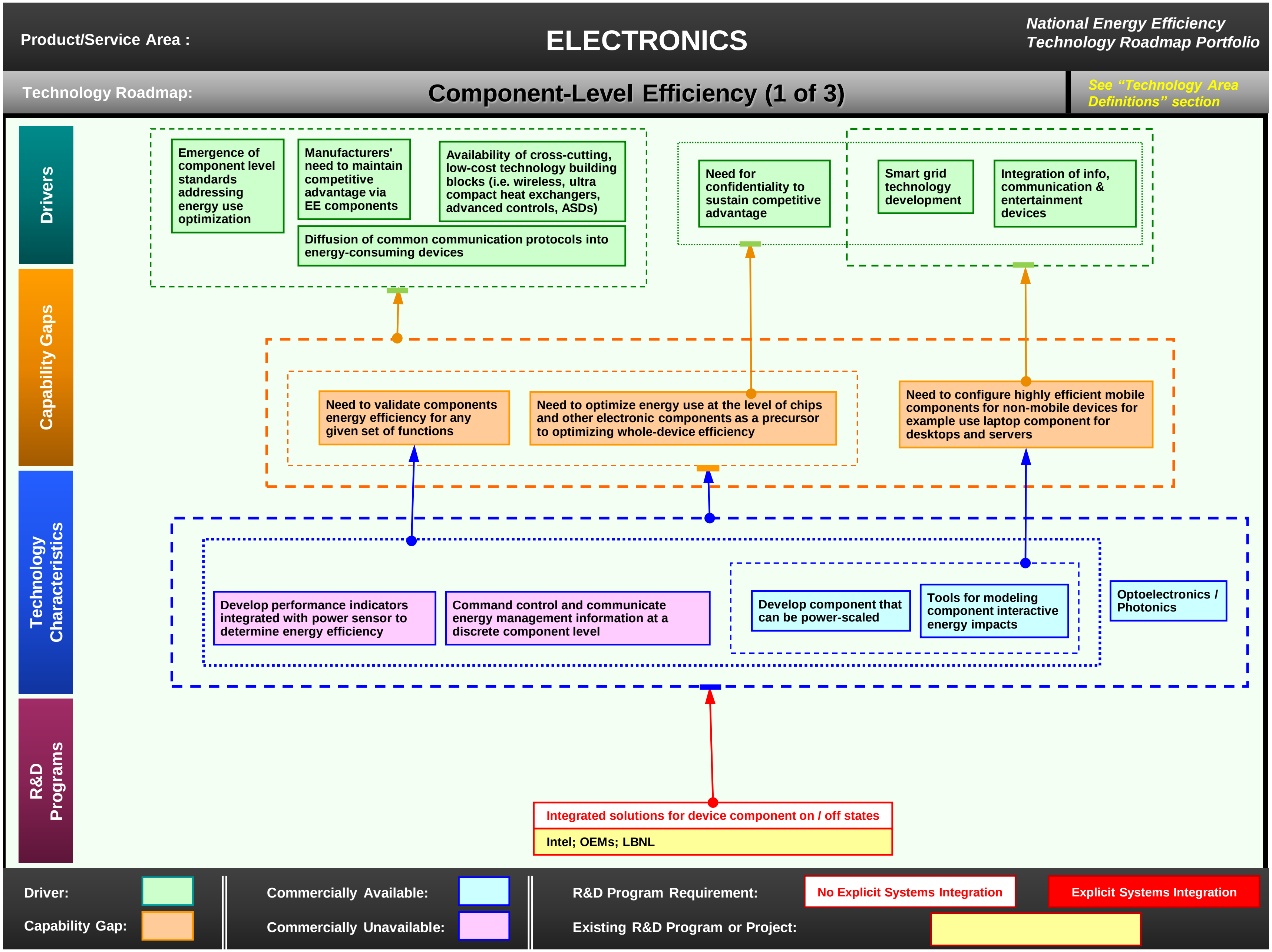
Product/Service Area :
ELECTRONICS
National Energy Efficiency Technology Roadmap Portfolio
Technology Roadmap:
Component-Level Efficiency (1 of 3)
See "Technology Area Definitions" section
Drivers
Capability Gaps
Technology Characteristics
R&D Programs
Emergence of component level standards addressing energy use optimization
Manufacturers' need to maintain competitive advantage via EE components
Availability of cross-cutting, low-cost technology building blocks (i.e. wireless, ultra compact heat exchangers, advanced controls, ASDs)
Diffusion of common communication protocols into energy-consuming devices
Need for confidentiality to sustain competitive advantage
Smart grid technology development
Integration of info, communication & entertainment devices
Need to validate components energy efficiency for any given set of functions
Need to optimize energy use at the level of chips and other electronic components as a precursor to optimizing whole-device efficiency
Need to configure highly efficient mobile components for non-mobile devices for example use laptop component for desktops and servers
Develop performance indicators integrated with power sensor to determine energy efficiency
Command control and communicate energy management information at a discrete component level
Develop component that can be power-scaled
Tools for modeling component interactive energy impacts
Optoelectronics / Photonics
Integrated solutions for device component on / off states
Intel; OEMs; LBNL
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 solutions for device component on / off states. Identify and quantify for potentials for high impact products where the reduction of component standby losses can result in significant savings.

Existing research: Intel, original equipment manufacturers (OEMs), Lawrence Berkeley National Laboratory (LBNL).

- *[Summaries of existing research pending]*

Key research questions:

1. Can we identify energy loss mechanisms in the system?
2. Can we quantify energy saving potential?
3. What is cost/benefit of entering/leaving standby state?
4. Can we validate through demonstration?

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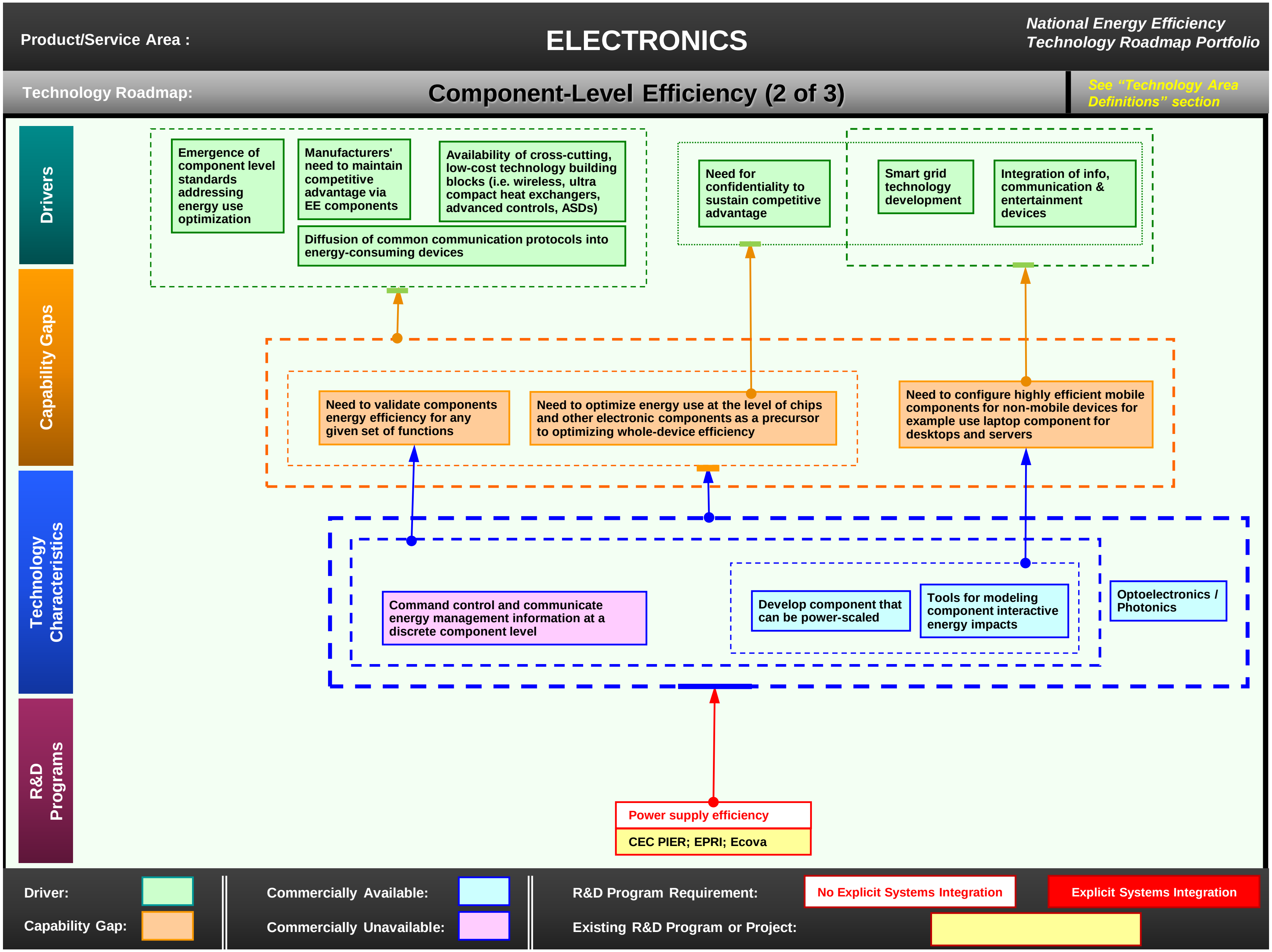

Product/Service Area :
ELECTRONICS
National Energy Efficiency Technology Roadmap Portfolio
Technology Roadmap:
Component-Level Efficiency (2 of 3)
See "Technology Area Definitions" section
Drivers
Capability Gaps
Technology Characteristics
R&D Programs
Emergence of component level standards addressing energy use optimization
Manufacturers' need to maintain competitive advantage via EE components
Availability of cross-cutting, low-cost technology building blocks (i.e. wireless, ultra compact heat exchangers, advanced controls, ASDs)
Diffusion of common communication protocols into energy-consuming devices
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Need to optimize energy use at the level of chips and other electronic components as a precursor to optimizing whole-device efficiency
Need to configure highly efficient mobile components for non-mobile devices for example use laptop component for desktops and servers
Command control and communicate energy management information at a discrete component level
Develop component that can be power-scaled
Tools for modeling component interactive energy impacts
Optoelectronics / Photonics
Power supply efficiency
CEC PIER; EPRI; Ecova
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

Power supply efficiency. Continue advancing R&D efforts that target power supply efficiency expand beyond computer category.

Existing research: 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.

Key research questions:

1. Can we develop smart wall warts with load sensing?
2. Can we expand categories under the 80 PLUS voluntary certification program?
3. "Smart" communication protocols to manage charging process or to distinguish AC/DC input.
4. Can we incorporate wide band gap transistors in design?
5. Can we mitigate conducted and radiated emissions?

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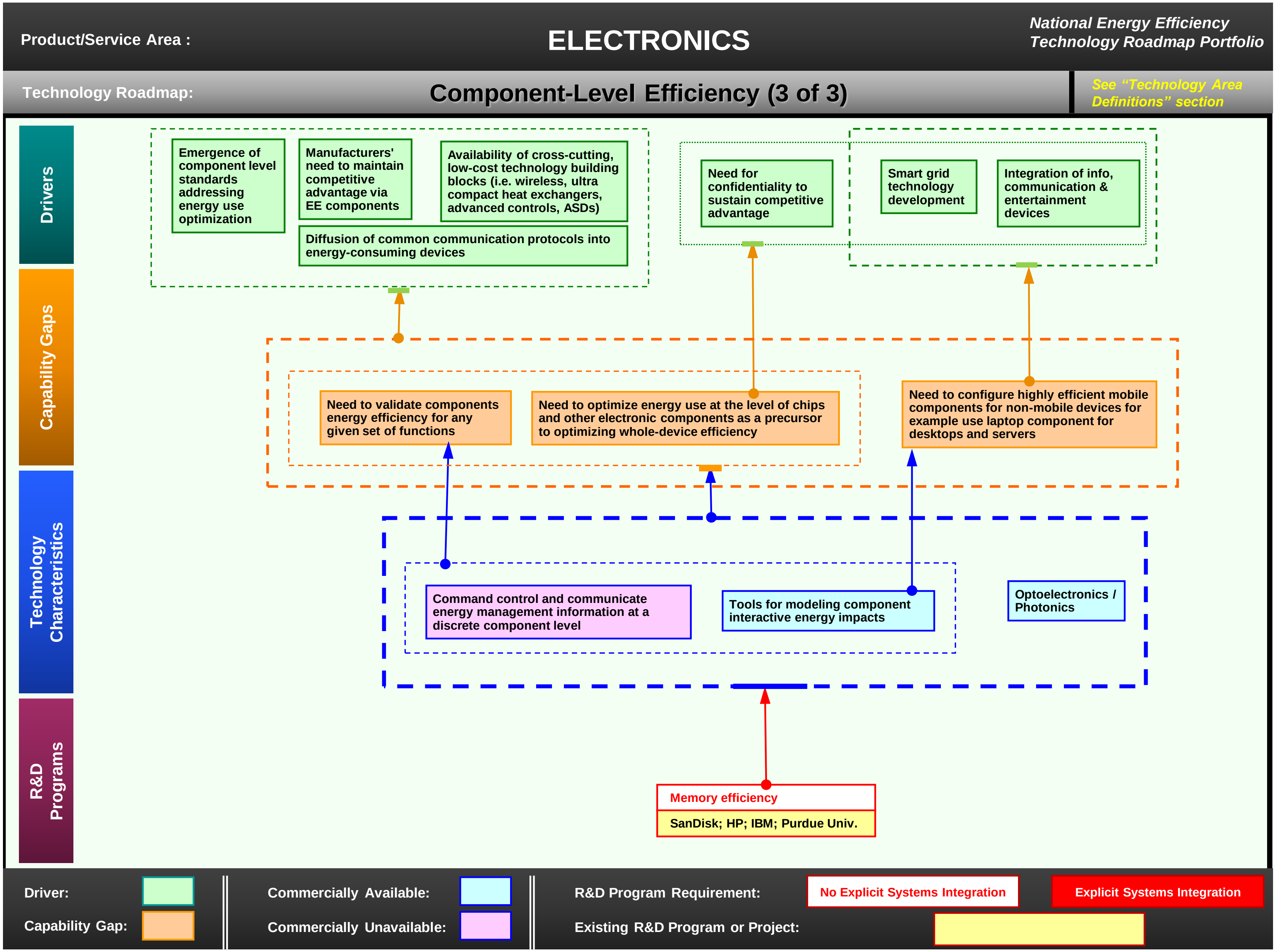
Product/Service Area :
ELECTRONICS
National Energy Efficiency Technology Roadmap Portfolio
Technology Roadmap:
Component-Level Efficiency (3 of 3)
See "Technology Area Definitions" section
Drivers
Capability Gaps
Technology Characteristics
R&D Programs
Emergence of component level standards addressing energy use optimization
Manufacturers' need to maintain competitive advantage via EE components
Availability of cross-cutting, low-cost technology building blocks (i.e. wireless, ultra compact heat exchangers, advanced controls, ASDs)
Diffusion of common communication protocols into energy-consuming devices
Need for confidentiality to sustain competitive advantage
Smart grid technology development
Integration of info, communication & entertainment devices
Need to validate components energy efficiency for any given set of functions
Need to optimize energy use at the level of chips and other electronic components as a precursor to optimizing whole-device efficiency
Need to configure highly efficient mobile components for non-mobile devices for example use laptop component for desktops and servers
Command control and communicate energy management information at a discrete component level
Tools for modeling component interactive energy impacts
Optoelectronics / Photonics
Memory efficiency
SanDisk; HP; IBM; Purdue Univ.
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

Memory efficiency. Continue advancing R&D efforts that target memory efficiency, including development of new, lower-power memory technologies.

Existing research: Subject matter experts report that research is ongoing at SanDisk, IBM, Hewlett-Packard, and other manufacturers. Ongoing research from manufacturers tends largely to be proprietary and, therefore, not thoroughly or consistently reported through companies' web pages. There is also ongoing research at Purdue University.

- SanDisk: http://www.sandisk.com/.
- *[Summaries of other existing research pending.]*

Key research questions:

1. Quantify energy savings of alternate memory technologies.
2. Quantify reliability and performance at alternate memory technologies.
3. Quantify costs of alternate memory technologies.
4. Establish benchmark of existing state of the art memory technologies relative to criteria 1-3 above.

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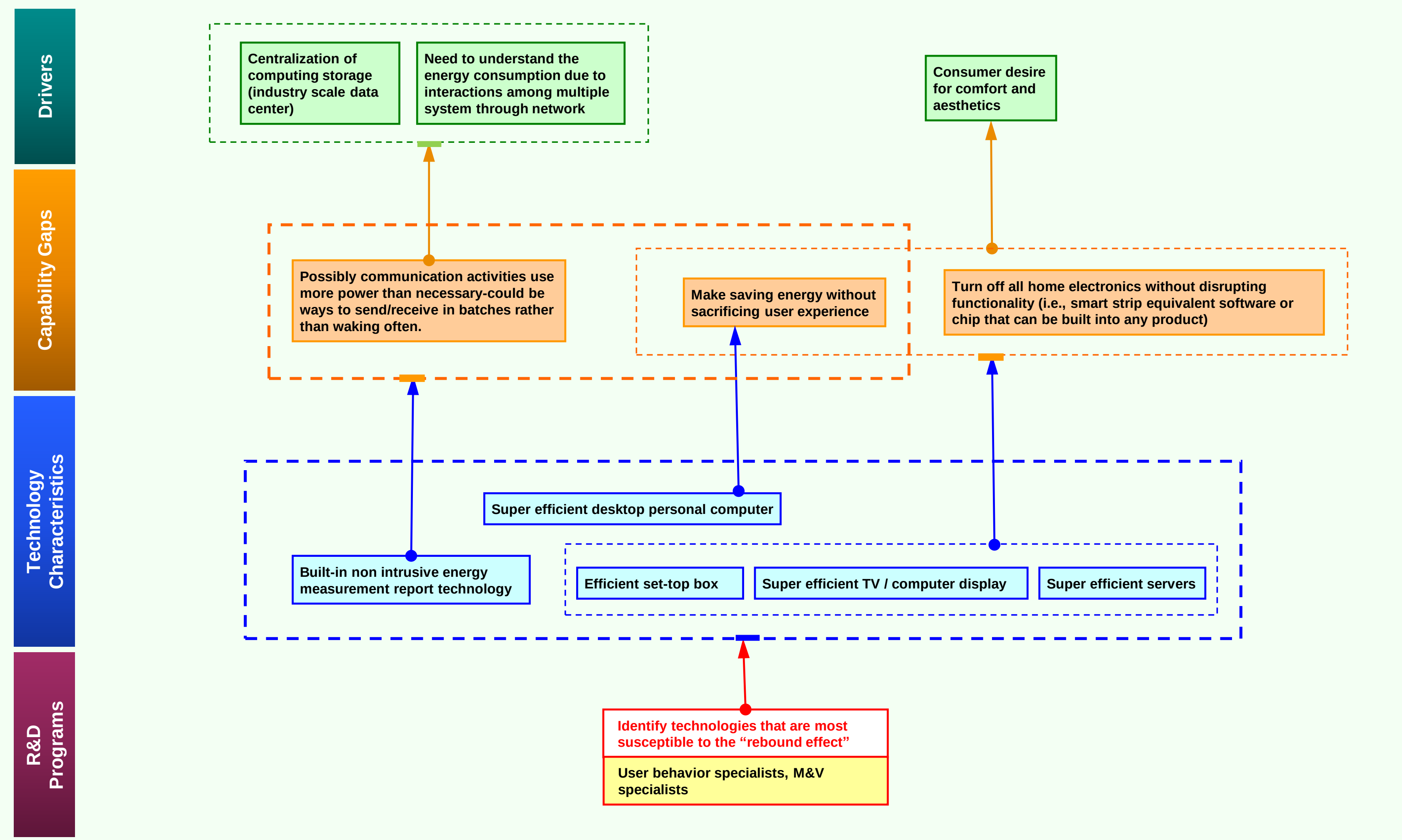
Product/Service Area : **ELECTRONICS**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Complete Electronic System (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

Identify technologies that 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.

Existing research: 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. 2013.

- *[Summaries of existing research pending]*

Key research questions:

1. How to quantify Everyday Electronic Materials (EEMs) with largest energy saving variances between the baseline and efficient technologies?
2. How to quantify cross-measure influences where "rebound effect" occurs?
3. How to identify primary driver for rebound, based on Everyday Electronic Materials (EEMs)?

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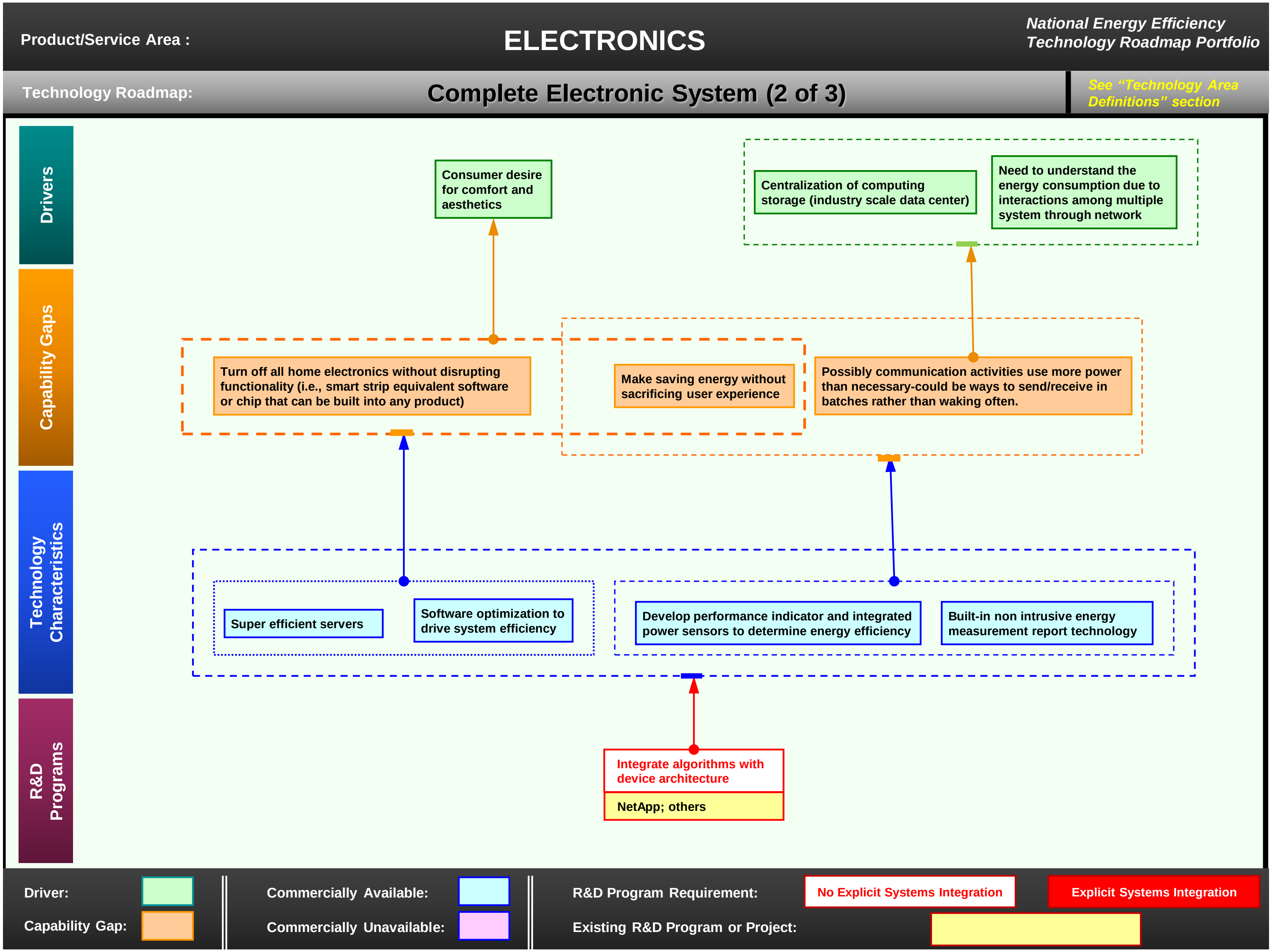
Product/Service Area :
ELECTRONICS
National Energy Efficiency Technology Roadmap Portfolio
Technology Roadmap:
Complete Electronic System (2 of 3)
See "Technology Area Definitions" section
Drivers
Capability Gaps
Technology Characteristics
R&D Programs
Consumer desire for comfort and aesthetics
Centralization of computing storage (industry scale data center)
Need to understand the energy consumption due to interactions among multiple system through network
Turn off all home electronics without disrupting functionality (i.e., smart strip equivalent software or chip that can be built into any product)
Make saving energy without sacrificing user experience
Possibly communication activities use more power than necessary-could be ways to send/receive in batches rather than waking often.
Super efficient servers
Software optimization to drive system efficiency
Develop performance indicator and integrated power sensors to determine energy efficiency
Built-in non intrusive energy measurement report technology
Integrate algorithms with device architecture
NetApp; others
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

Integrate algorithms with device architecture. Measure the energy consumed by servers, storage, and networks for services, select appropriate hardware and software for better energy efficiency.

Existing research: 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.

- *[Summaries of existing research pending]*

Key research questions:

1. How to quantify and minimize the energy consumption for a given service?
2. How to develop a validated methodology for energy efficiency software in distributed systems?
3. How to schedule services for balancing and minimizing consumption in data centers?

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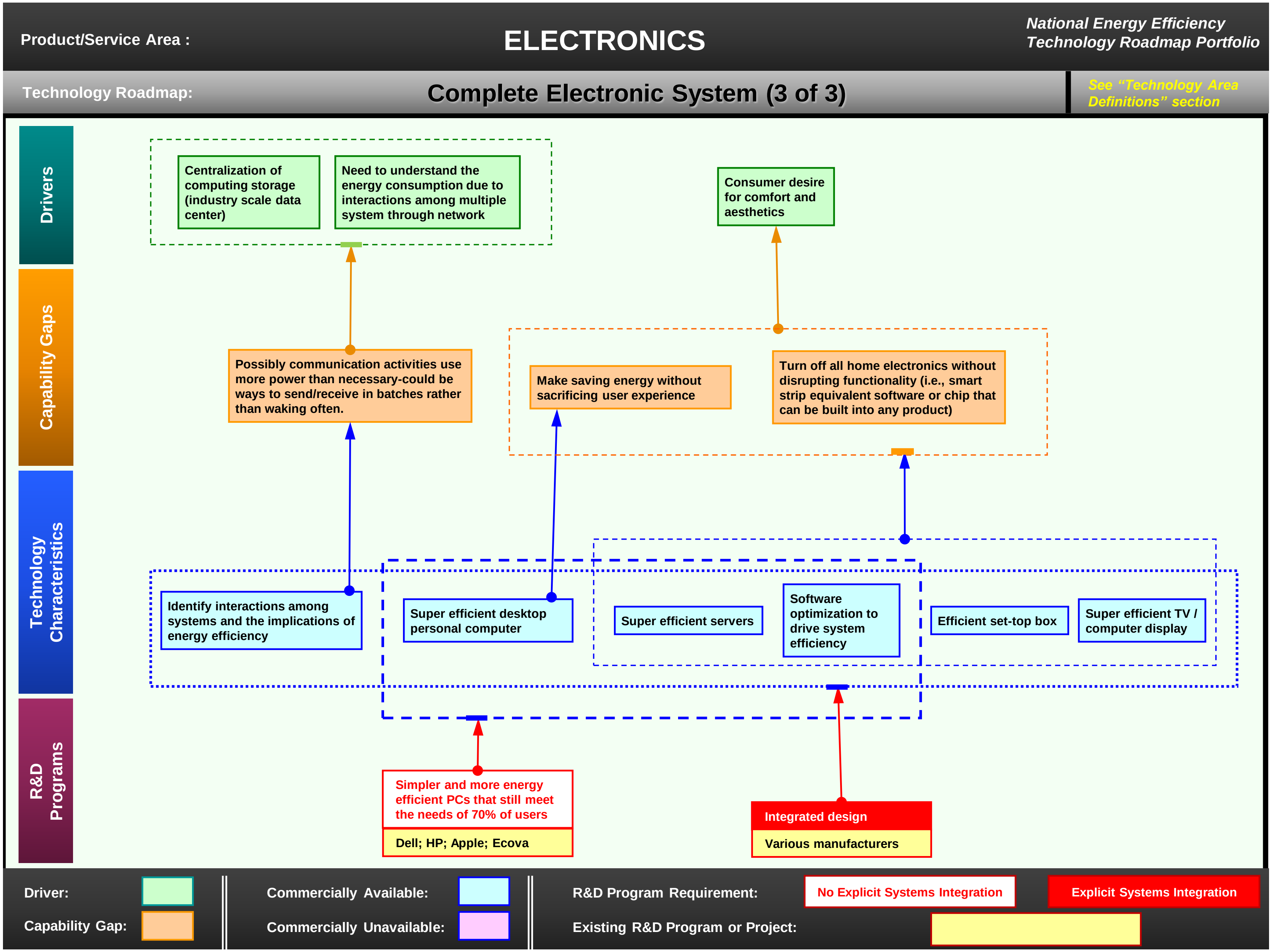

Product/Service Area :
ELECTRONICS
National Energy Efficiency Technology Roadmap Portfolio
Technology Roadmap:
Complete Electronic System (3 of 3)
See "Technology Area Definitions" section
Drivers
Capability Gaps
Technology Characteristics
R&D Programs
Centralization of computing storage (industry scale data center)
Need to understand the energy consumption due to interactions among multiple system through network
Consumer desire for comfort and aesthetics
Possibly communication activities use more power than necessary-could be ways to send/receive in batches rather than waking often.
Make saving energy without sacrificing user experience
Turn off all home electronics without disrupting functionality (i.e., smart strip equivalent software or chip that can be built into any product)
Identify interactions among systems and the implications of energy efficiency
Super efficient desktop personal computer
Super efficient servers
Software optimization to drive system efficiency
Efficient set-top box
Super efficient TV / computer display
Simpler and more energy efficient PCs that still meet the needs of 70% of users
Dell; HP; Apple; Ecova
Integrated design
Various manufacturers
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 design. Develop tools and approaches to help manufacturers do whole-system designs that achieve ultra-low energy consumption.

Existing research: 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.

- *[Summaries of existing research pending]*

Key research questions:

1. Can we develop consistent methodologies/benchmarking to measure efficiency (open standard)?
2. Can we define categories that are easily bounded with common energy characteristics to enable measurements?

Simpler and more energy efficient PCs that still meet the needs of 70% of users. Explore innovative approaches to reducing energy use by mass-market PCs. Issue challenge to industry for best design.

Existing research: 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. There is also ongoing research at Ecova.

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

Key research questions:

1. Can we develop net zero laptop for a given set of function?
2. What subsystems can be optimized?
3. What components are needed for optimization?

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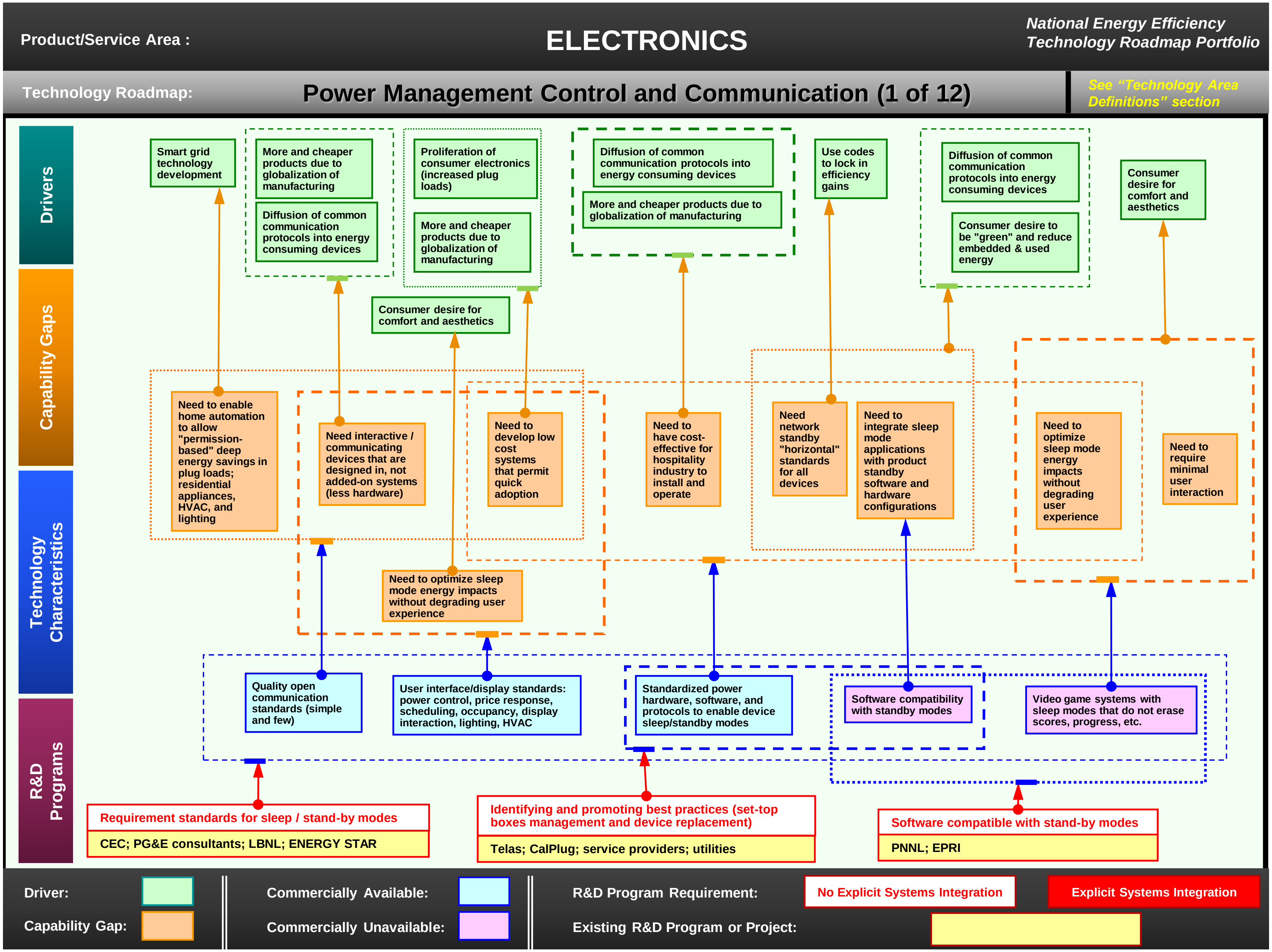
Product/Service Area :
ELECTRONICS
National Energy Efficiency Technology Roadmap Portfolio
Technology Roadmap:
Power Management Control and Communication (1 of 12)
See "Technology Area Definitions" section
Drivers
Capability Gaps
Technology Characteristics
R&D Programs
Smart grid technology development
More and cheaper products due to globalization of manufacturing
Diffusion of common communication protocols into energy consuming devices
Proliferation of consumer electronics (increased plug loads)
More and cheaper products due to globalization of manufacturing
Diffusion of common communication protocols into energy consuming devices
More and cheaper products due to globalization of manufacturing
Use codes to lock in efficiency gains
Diffusion of common communication protocols into energy consuming devices
Consumer desire to be "green" and reduce embedded & used energy
Consumer desire for comfort and aesthetics
Consumer desire for comfort and aesthetics
Need to enable home automation to allow "permission-based" deep energy savings in plug loads; residential appliances, HVAC, and lighting
Need interactive / communicating devices that are designed in, not added-on systems (less hardware)
Need to develop low cost systems that permit quick adoption
Need to have cost-effective for hospitality industry to install and operate
Need network standby "horizontal" standards for all devices
Need to integrate sleep mode applications with product standby software and hardware configurations
Need to optimize sleep mode energy impacts without degrading user experience
Need to require minimal user interaction
Need to optimize sleep mode energy impacts without degrading user experience
Quality open communication standards (simple and few)
User interface/display standards: power control, price response, scheduling, occupancy, display interaction, lighting, HVAC
Standardized power hardware, software, and protocols to enable device sleep/standby modes
Software compatibility with standby modes
Video game systems with sleep modes that do not erase scores, progress, etc.
Requirement standards for sleep / stand-by modes
CEC; PG&E consultants; LBNL; ENERGY STAR
Identifying and promoting best practices (set-top boxes management and device replacement)
Telas; CalPlug; service providers; utilities
Software compatible with stand-by modes
PNNL; EPRI
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

Requirement standards for sleep / stand-by modes.

Develop equipment and code-based approaches to eliminating product energy consumption when not in use.

Existing research: Research is ongoing at the California Energy Commission (CEC), Pacific Gas & Electric (PG&E), the Lawrence Berkeley National Laboratory (LBNL), and ENERGY STAR.

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

Key research questions:

1. How can a product stay aware in a low power state to be powered up when needed?
2. How can a product seamlessly be updated from a low power state (e.g. software update, firmware updates, programs guides)?
3. How does a product know when it can go to sleep? How can a user opt-art?
4. What user interface standard can be used for users to understand power state and how to wake it up?

Identifying and promoting best practices (STB power management and device replacement).

Some devices will operate much beyond the time new versions, that are significantly more efficient, are available. What justifications are needed for retirement (recycling and level of energy savings) to occur?.

Existing research: Telas, California Plug Load Research Center (CalPlug), service providers, utilities.

- See the CalPlug Set Top Box roadmap at http://www.calplug.uci.edu/index.php/pubs?layout=edit&id=44.
- *[Summaries of other existing research pending]*

Key research questions:

1. What best practices are being used by to save energy (ie. set top boxes) through power management? Identify what and where this is occurring?
2. What incentive levels can be justified (if they can) for a particular device to be retired based on energy savings and repurposing options?

Software compatible 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.

Existing research: Pacific Northwest National Laboratory (PNNL), Electric Power Research Institute (EPRI).

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

Key research questions:

1. Games need sleep mode that save all information so not overridden.
2. Game controls need to be shipped and sleep mode activated.

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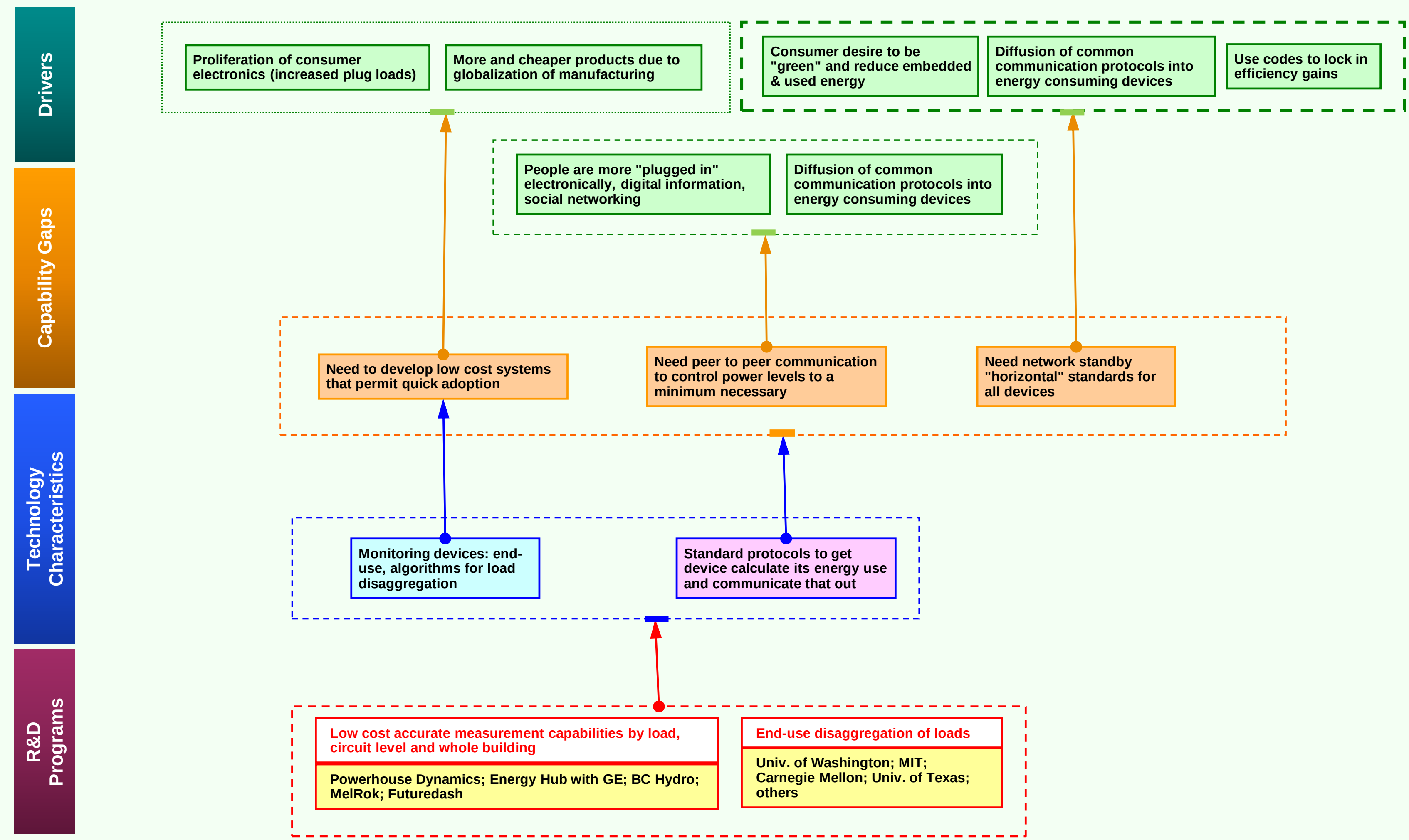
Product/Service Area : **ELECTRONICS**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Power Management Control and Communication (2 of 12)**

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 accurate measurement capabilities by load, circuit level and whole building. A simple (to the customer) method of measuring unit energy use is needed to aid our understanding of the device's significance in building energy use. Measurement must be non-intrusive and reasonably accurate. This also serves as a signal to manufacturers.

Existing research: Powerhouse Dynamics, Energy Hub with General Electric (GE), BC Hydro, MelRok, Futuredash.

- EnergyHub: http://www.energyhub.com/.
- eMonitor by Powerhouse Dynamics: http://www.powerhousedynamics.com/.
- BC Hydro's load research group: http://www.bchydro.com/index.html.
- MelRok: http://www.melrok.com/.
- EnergyBuddy by Futuredash: http://www.futuredash.com/energybuddy.
- *[Summaries of existing research pending]*

Key research questions:

1. Determine what is needed via computation capabilities and monitoring of device's state to calculate energy use over time. Protocol for manufactures.
2. Would a standard serve to provide manufactures with what they need to embed capability within device?
3. What software/app requirements are needed to capture device's energy use?
4. How can advanced measurement be used for evaluation of energy efficiency programs in this area?

End-use disaggregation of loads. Development of non-intrusive load monitoring (NILM) methods and tools.

Existing research: University of Washington, Massachusetts Institute of Technology (MIT), Carnegie Mellon University, University of Texas.

- *[Summaries of existing research pending]*

Key research questions:

1. Appliance end-use disaggregation (based on circuit – or building – level measurement) algorithm development.
2. Define accuracy and sample interval requirements for various inventory, control, and M&V needs to evaluate available NILM technology against.

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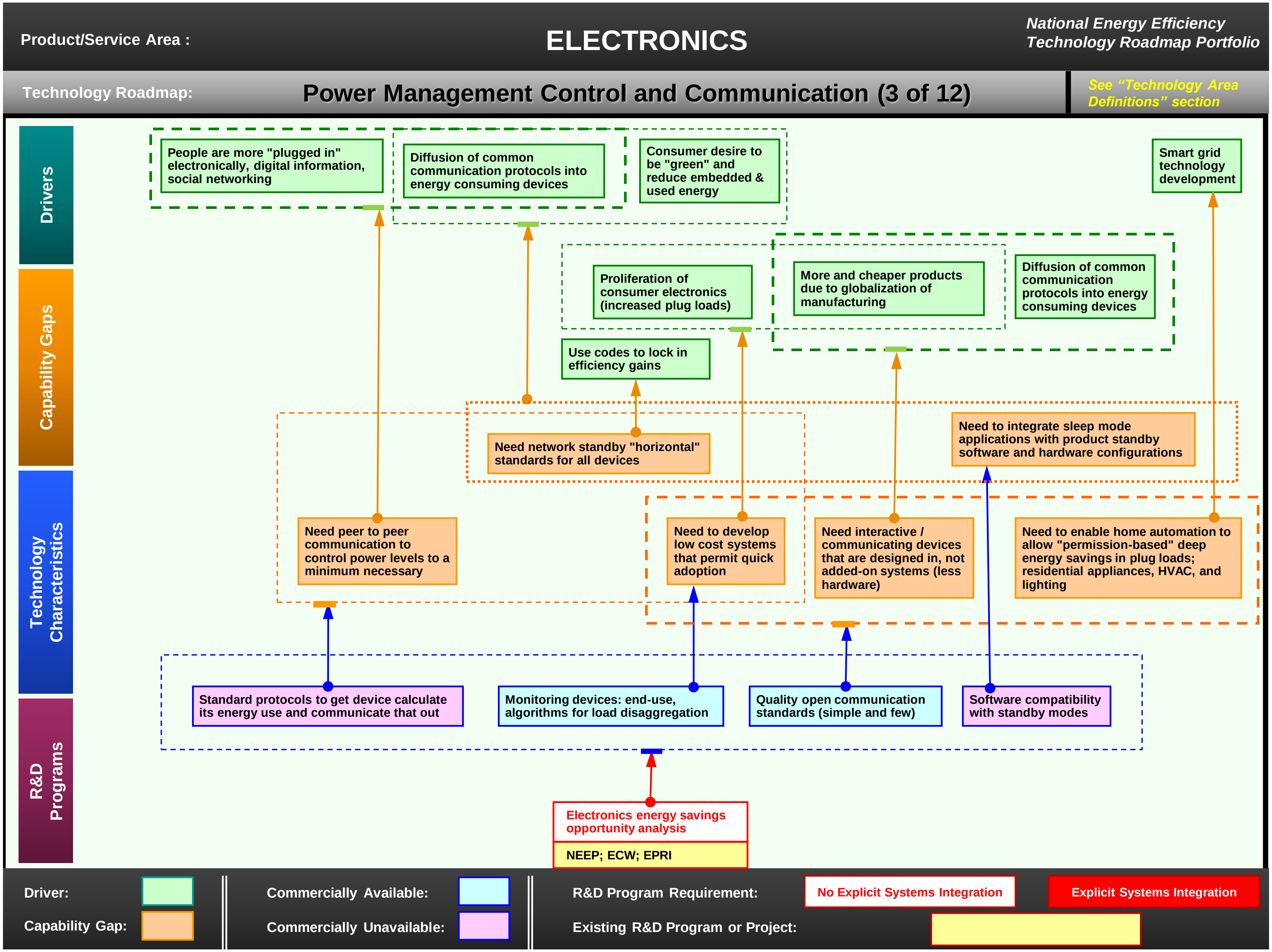
Product/Service Area :
ELECTRONICS
National Energy Efficiency Technology Roadmap Portfolio
Technology Roadmap:
Power Management Control and Communication (3 of 12)
See "Technology Area Definitions" section
Drivers
Capability Gaps
Technology Characteristics
R&D Programs
People are more "plugged in" electronically, digital information, social networking
Diffusion of common communication protocols into energy consuming devices
Consumer desire to be "green" and reduce embedded & used energy
Smart grid technology development
Proliferation of consumer electronics (increased plug loads)
More and cheaper products due to globalization of manufacturing
Diffusion of common communication protocols into energy consuming devices
Use codes to lock in efficiency gains
Need network standby "horizontal" standards for all devices
Need to integrate sleep mode applications with product standby software and hardware configurations
Need peer to peer communication to control power levels to a minimum necessary
Need to develop low cost systems that permit quick adoption
Need interactive / communicating devices that are designed in, not added-on systems (less hardware)
Need to enable home automation to allow "permission-based" deep energy savings in plug loads; residential appliances, HVAC, and lighting
Standard protocols to get device calculate its energy use and communicate that out
Monitoring devices: end-use, algorithms for load disaggregation
Quality open communication standards (simple and few)
Software compatibility with standby modes
Electronics energy savings opportunity analysis
NEEP; ECW; EPRI
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

Electronics energy savings opportunity analysis. Analysis of plug-load including changing, mobile, and off-grid devices savings opportunities and cost/benefit characterization to develop effective strategies for active energy management and purchase/replacement decisions.

Existing research: Energy Efficiency Partnerships (NEEP), Energy Center of Wisconsin (ECW), Electric Power Research Institute (EPRI).

- ECW: http://www.ecw.org/.
- NEEP: http://www.neep.org/.
- *[Summaries of existing research pending]*

Key research questions:

1. Need detailed inventory of plug loads and analysis of energy savings opportunities for individual devices.
2. What is the total energy use attributed to plug loads? (all electronics, all miscellaneous devices; all other plug tools)
3. Useful life assessment and data on typical replacement timelines. How often are devices replaced (for each type of device)? How often should they be replaced? What is really happening to legacy devices (recycled or re-used in the kids' room)?

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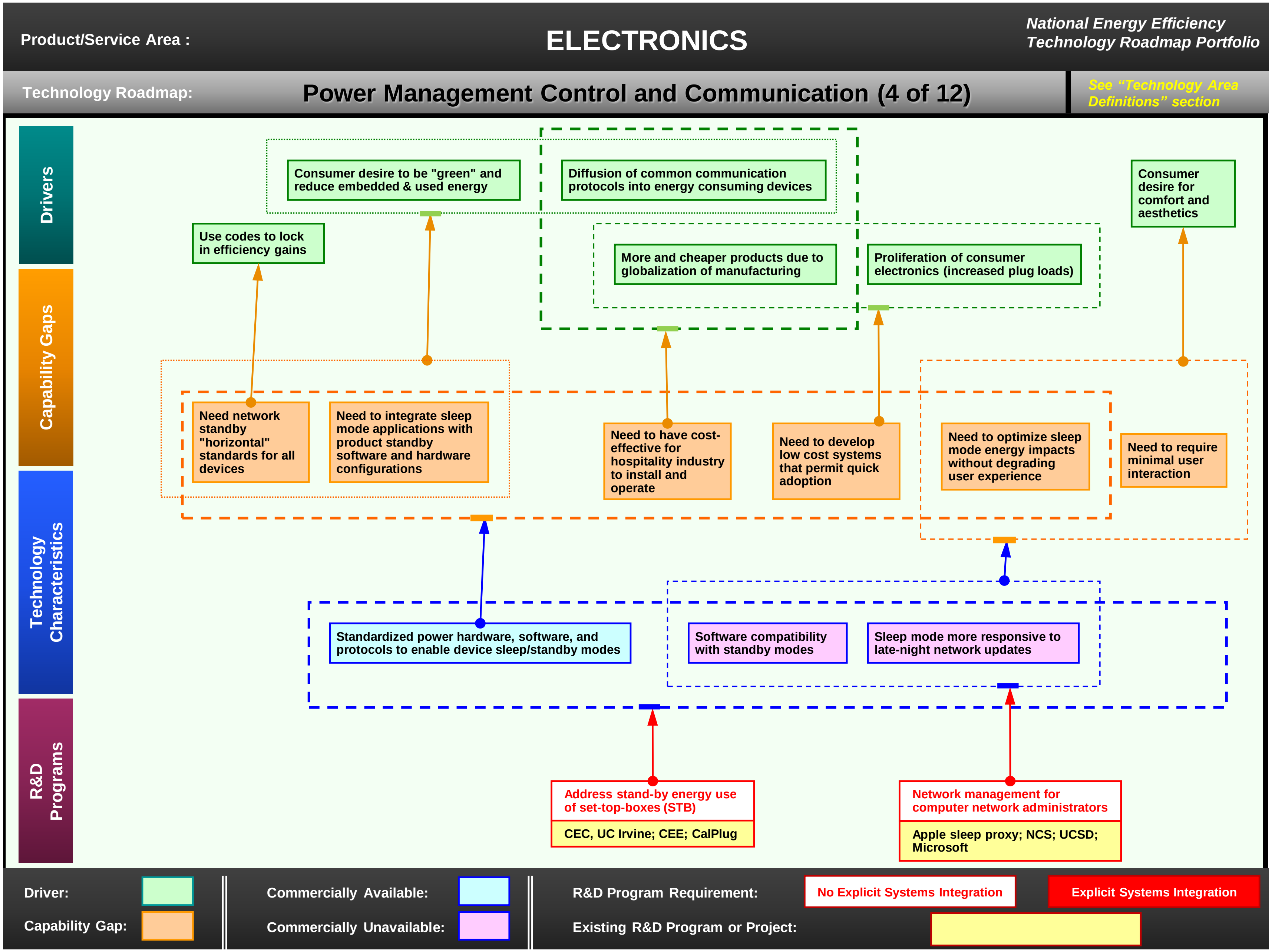

Product/Service Area :
ELECTRONICS
National Energy Efficiency Technology Roadmap Portfolio
Technology Roadmap:
Power Management Control and Communication (4 of 12)
See "Technology Area Definitions" section
Drivers
Capability Gaps
Technology Characteristics
R&D Programs
Consumer desire to be "green" and reduce embedded & used energy
Diffusion of common communication protocols into energy consuming devices
Consumer desire for comfort and aesthetics
Use codes to lock in efficiency gains
More and cheaper products due to globalization of manufacturing
Proliferation of consumer electronics (increased plug loads)
Need network standby "horizontal" standards for all devices
Need to integrate sleep mode applications with product standby software and hardware configurations
Need to have cost-effective for hospitality industry to install and operate
Need to develop low cost systems that permit quick adoption
Need to optimize sleep mode energy impacts without degrading user experience
Need to require minimal user interaction
Standardized power hardware, software, and protocols to enable device sleep/standby modes
Software compatibility with standby modes
Sleep mode more responsive to late-night network updates
Address stand-by energy use of set-top-boxes (STB)
CEC, UC Irvine; CEE; CalPlug
Network management for computer network administrators
Apple sleep proxy; NCS; UCSD; Microsoft
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

Network management for computer network administrators. 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. For example, sleep mode must become more responsive to late night network admin updates.

Existing research: Researchers at U.C. San Diego (UCSD) and at Microsoft are working in this area; others include Apple sleep proxy and NCS.

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

Key research questions:

1. Conduct in-depth survey of network administrators segmented by network size and sector to determine their needs that may conflict with existing sleep modes.
2. How do networks administrators needs align with features and functions of desktop, laptop, net books, etc. computers available today?
3. How to integrate changes or enhancements to computer sleep modes that overcome existing barriers?
4. How to move forward to incorporate the admin's needs and sleep mode enhancements?

Address stand-by energy use of STBs. Facilitate and monitor industry progress towards low-energy sleep modes for STB. Potential for dramatic energy reductions in the U.S. households in 5 years.

Existing research: California Energy Commission (CEC), University of California Irvine, Consortium for Energy Efficiency (CEE).

- Subject matter experts in September 2012 referred to the work of CEE's Electronics Committee.
  - See the CalPlug Set Top Box roadmap at http://www.calplug.uci.edu/index.php/pubs?layout=edit&id=44.
- *[Summaries of other existing research pending]*

Key research questions:

1. What is industry progress towards low-energy stand-by for STB?
2. Can avoiding STB cable card be used to drop STB stand-by power to lower 10 Watts?
3. What can be done to assist industry in reaching a successful and timely result?
4. Monitoring or pilot testing of low-energy STBs?
5. Can we eliminate STBs by removing the legal barriers to network our implementation?

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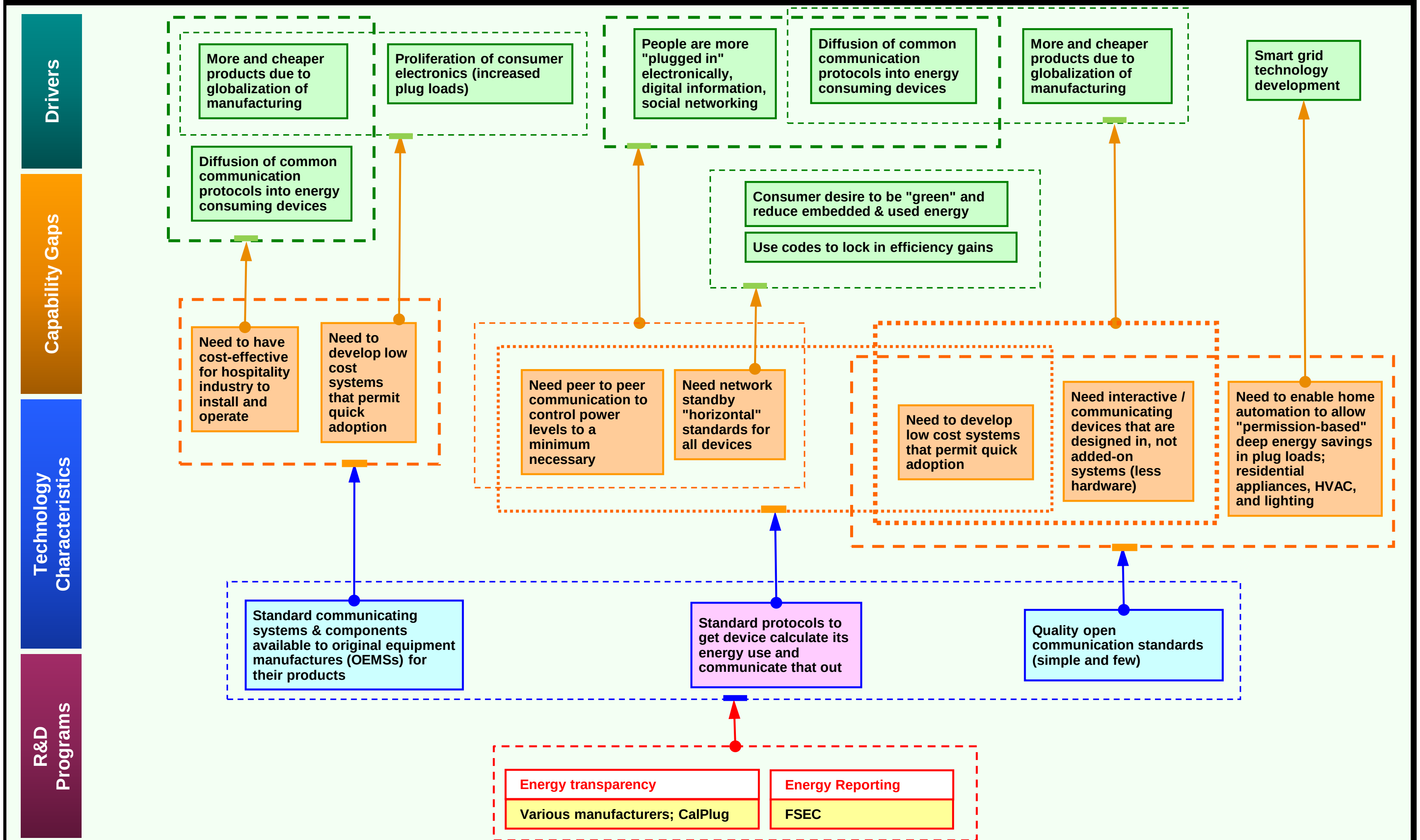
Product/Service Area : **ELECTRONICS**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Power Management Control and Communication (5 of 12)**

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

Energy transparency. Create technologies and policy structures so that actual energy use of devices is available to building occupants, owners, manufacturers, regulators, researches, and policy analysts.

Existing research: Various manufacturers, California Plug Load Research Center (CalPlug).

- CalPlug: http://calplug.uci.edu/.
- *[Summaries of existing research pending]*

Key research questions:

1. What mechanisms exist to report energy use to network?
2. How could this be exported outside the building for general use? What is needed to assure privacy and security?
3. How can this information be used by above stakeholders?

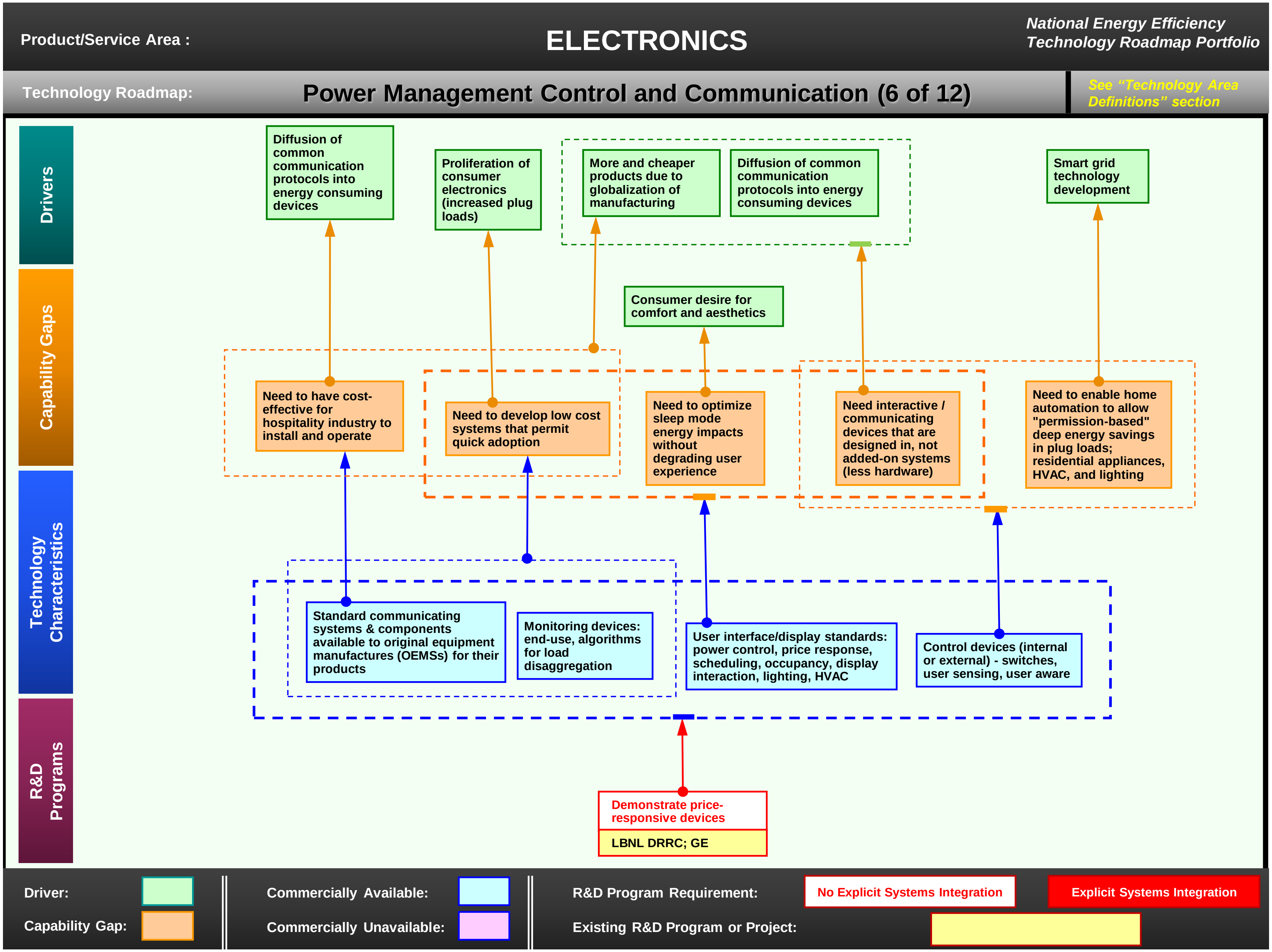
Energy Reporting. Identify needs for protocols that report energy use (and related info) of device to network. Identify existing protocols (or ones in development) that do this and evaluate for quality, completeness, application scope, etc. Revise standards as needed. Identify preferred standards.

Existing research: Florida Solar Energy Center (FSEC).

- *[Summaries of existing research pending]*

Key research questions:

1. What needs to be reported?
2. What protocols are relevant?
3. What protocols are there?
4. How to fill them?
5. Can data exchange in a standardized format be used to foster information in energy feedback, reporting and control?


Product/Service Area :
ELECTRONICS
National Energy Efficiency Technology Roadmap Portfolio
Technology Roadmap:
Power Management Control and Communication (6 of 12)
See "Technology Area Definitions" section
Drivers
Capability Gaps
Technology Characteristics
R&D Programs
Diffusion of common communication protocols into energy consuming devices
Proliferation of consumer electronics (increased plug loads)
More and cheaper products due to globalization of manufacturing
Diffusion of common communication protocols into energy consuming devices
Smart grid technology development
Consumer desire for comfort and aesthetics
Need to have cost-effective for hospitality industry to install and operate
Need to develop low cost systems that permit quick adoption
Need to optimize sleep mode energy impacts without degrading user experience
Need interactive / communicating devices that are designed in, not added-on systems (less hardware)
Need to enable home automation to allow "permission-based" deep energy savings in plug loads; residential appliances, HVAC, and lighting
Standard communicating systems & components available to original equipment manufactures (OEMSs) for their products
Monitoring devices: end-use, algorithms for load disaggregation
User interface/display standards: power control, price response, scheduling, occupancy, display interaction, lighting, HVAC
Control devices (internal or external) - switches, user sensing, user aware
Demonstrate price-responsive devices
LBNL DRRC; GE
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

Demonstrate price-responsive devices. Modify electronic devices (e.g. PC, monitor, printer, etc) to be able to receive dynamic prize signals over network and alter behavior in response. Also, do other devices such as refrigerator, lights.

Existing research: Lawrence Berkeley National Laboratory (LBNL) Demand Response Research Center (DRRC), General Electric (GE).

- DRRC: http://drrc.lbl.gov/.
- *[Summaries of existing research pending]*

Key research questions:

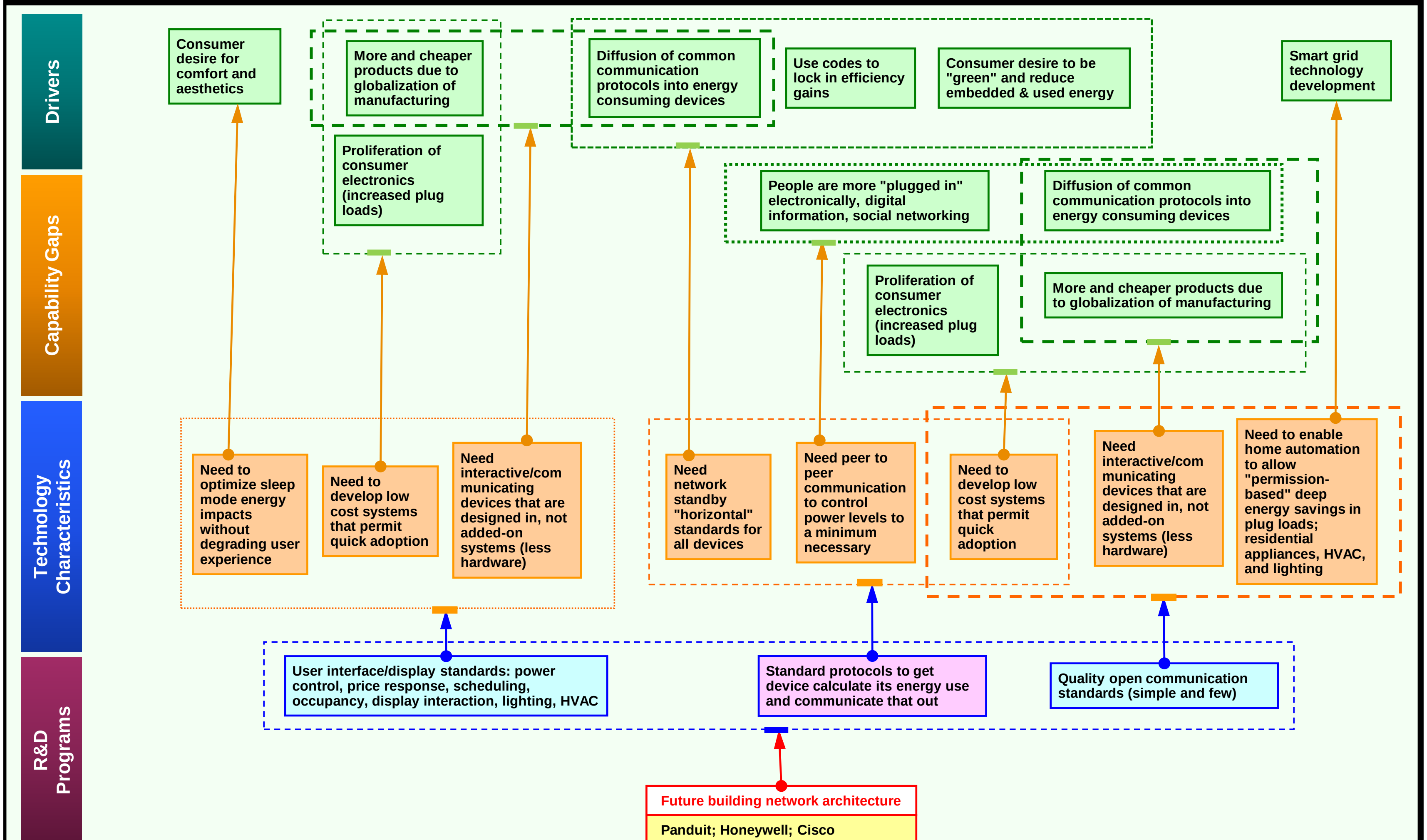
1. How can price signals be relayed within a building?
2. What can different price signals do to alter their energy use patterns?
3. What algorithms work well to determine operator?
4. Does it work?
5. Does it add hardware cost to the product?

Product/Service Area : **ELECTRONICS**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Power Management Control and Communication (8 of 12)**

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

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.

Existing research: Various manufacturers.

- 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).

Key research questions:

1. Questions not yet specified.

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.

Existing research: Various manufacturers.

- *[Summaries of existing research pending]*

Key research questions:

1. Questions not yet specified.

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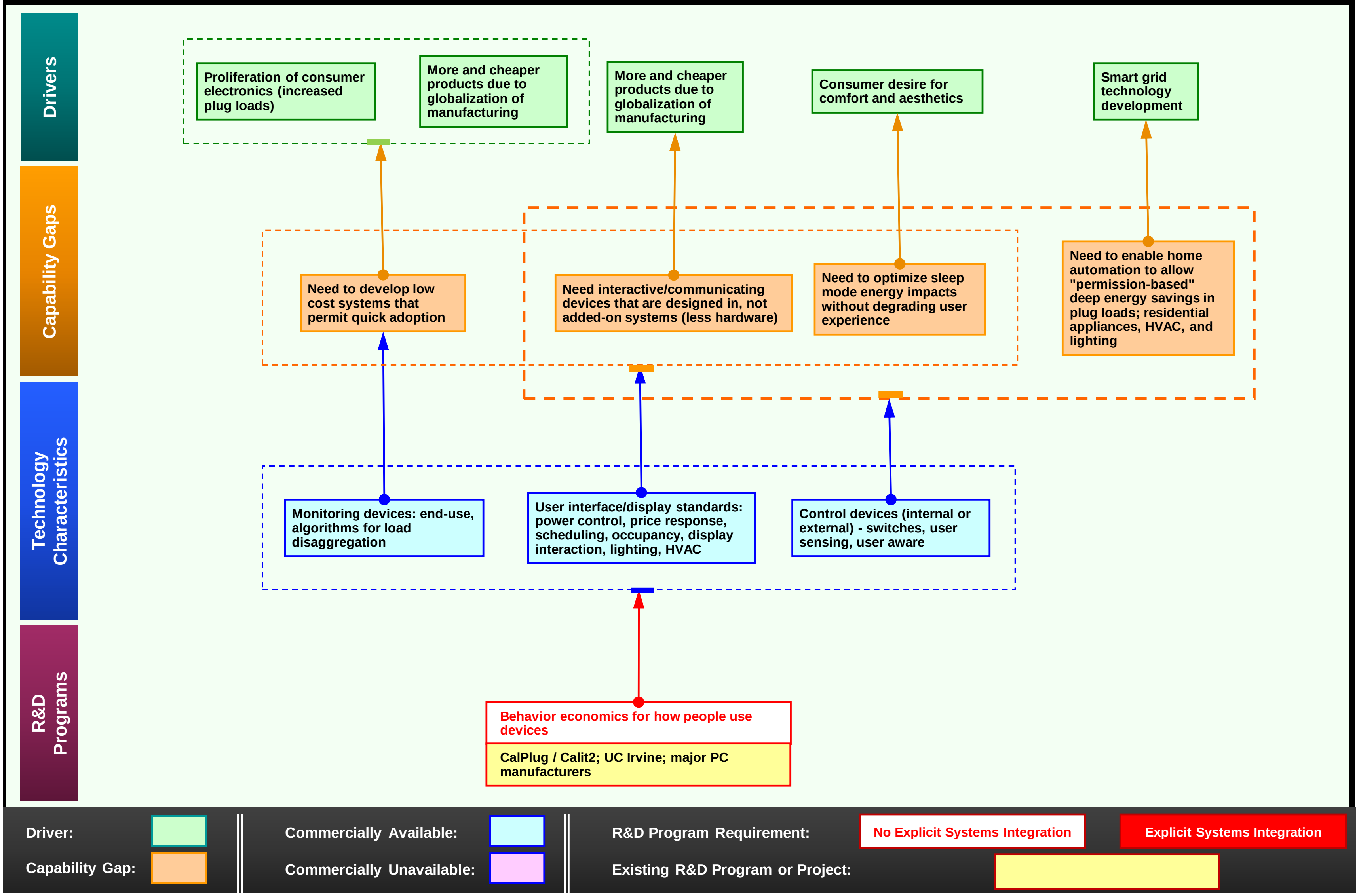
Product/Service Area : **ELECTRONICS**

National Energy Efficiency Technology Roadmap Portfolio

Technology Roadmap: **Power Management Control and Communication (9 of 12)**

See "Technology Area Definitions" section



R&D Program Summaries

Future building network architecture. Describe possible approaches to overall structure of networking among all energy-using devices in buildings. Consider all layers of communication. Consider centralized, distributed, and hybrid architecture. Can a standardized protocol be agreed upon?.

Existing research: Panduit, Honeywell, Cisco.

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

Key research questions:

1. What are system designs to consider?
2. What are advantages and disadvantages of each?
3. What pieces of this already exist?
4. What is “ideal” architecture?

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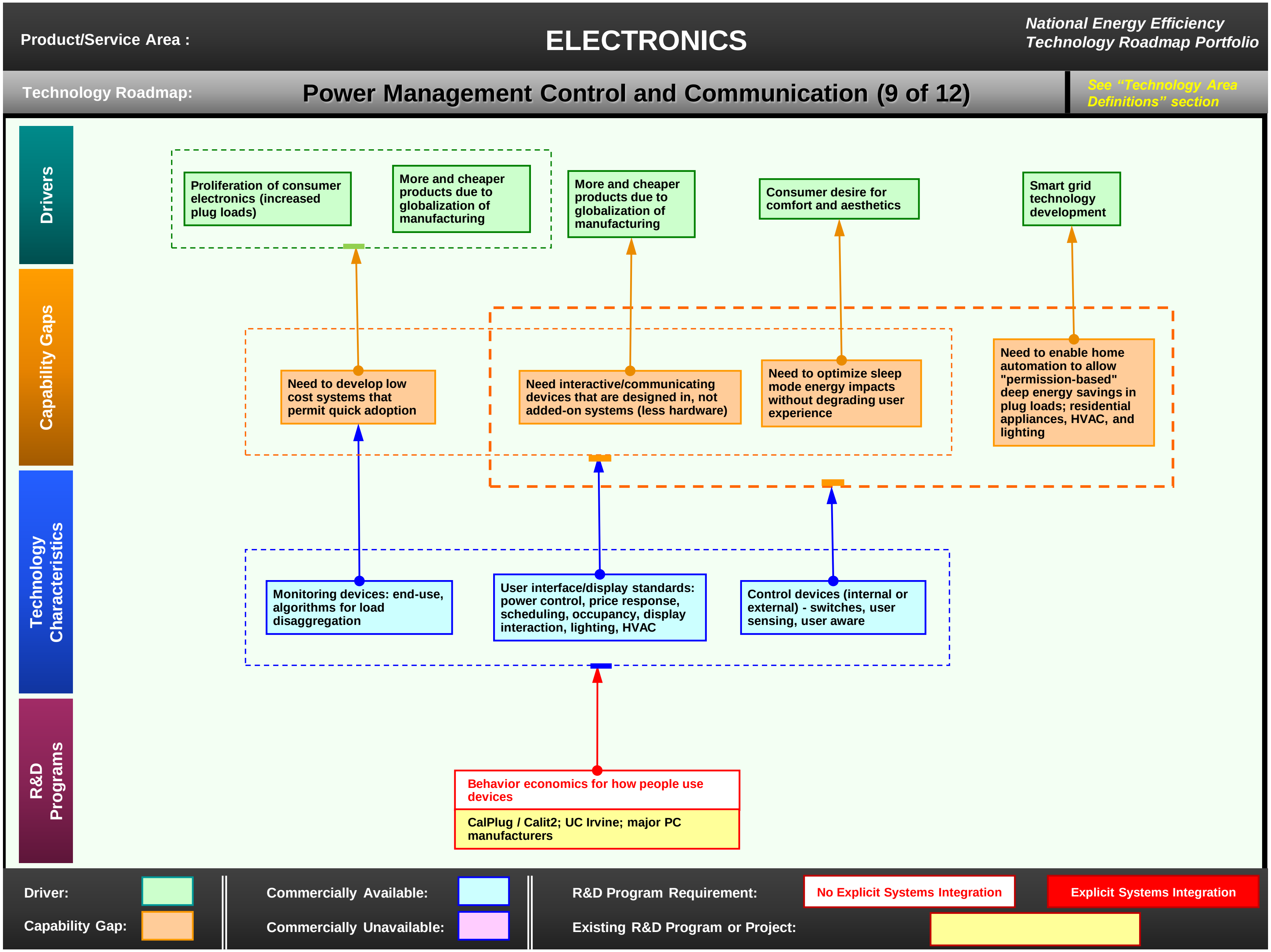
Product/Service Area :
ELECTRONICS
National Energy Efficiency Technology Roadmap Portfolio
Technology Roadmap:
Power Management Control and Communication (9 of 12)
See "Technology Area Definitions" section
Drivers
Capability Gaps
Technology Characteristics
R&D Programs
Proliferation of consumer electronics (increased plug loads)
More and cheaper products due to globalization of manufacturing
More and cheaper products due to globalization of manufacturing
Consumer desire for comfort and aesthetics
Smart grid technology development
Need to develop low cost systems that permit quick adoption
Need interactive/communicating devices that are designed in, not added-on systems (less hardware)
Need to optimize sleep mode energy impacts without degrading user experience
Need to enable home automation to allow "permission-based" deep energy savings in plug loads; residential appliances, HVAC, and lighting
Monitoring devices: end-use, algorithms for load disaggregation
User interface/display standards: power control, price response, scheduling, occupancy, display interaction, lighting, HVAC
Control devices (internal or external) - switches, user sensing, user aware
Behavior economics for how people use devices
CalPlug / Calit2; UC Irvine; major PC manufacturers
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

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.

Existing research: California Plug Load Research Center (CalPlug) with California Institute for Telecommunications and Information Technology (CALIT2), University of California Irvine, Major PC manufacturers.

- CalPlug:http://calplug.uci.edu/.
- CALIT2: http://www.calit2.net/.
- *[Summaries of existing research pending]*

Key research questions:

1. When is putting devices into low power modes acceptable to users?
2. How do users "wake" devices? How do they want to?
3. Which devices do people have connected together? Which devices do they use to control other devices?

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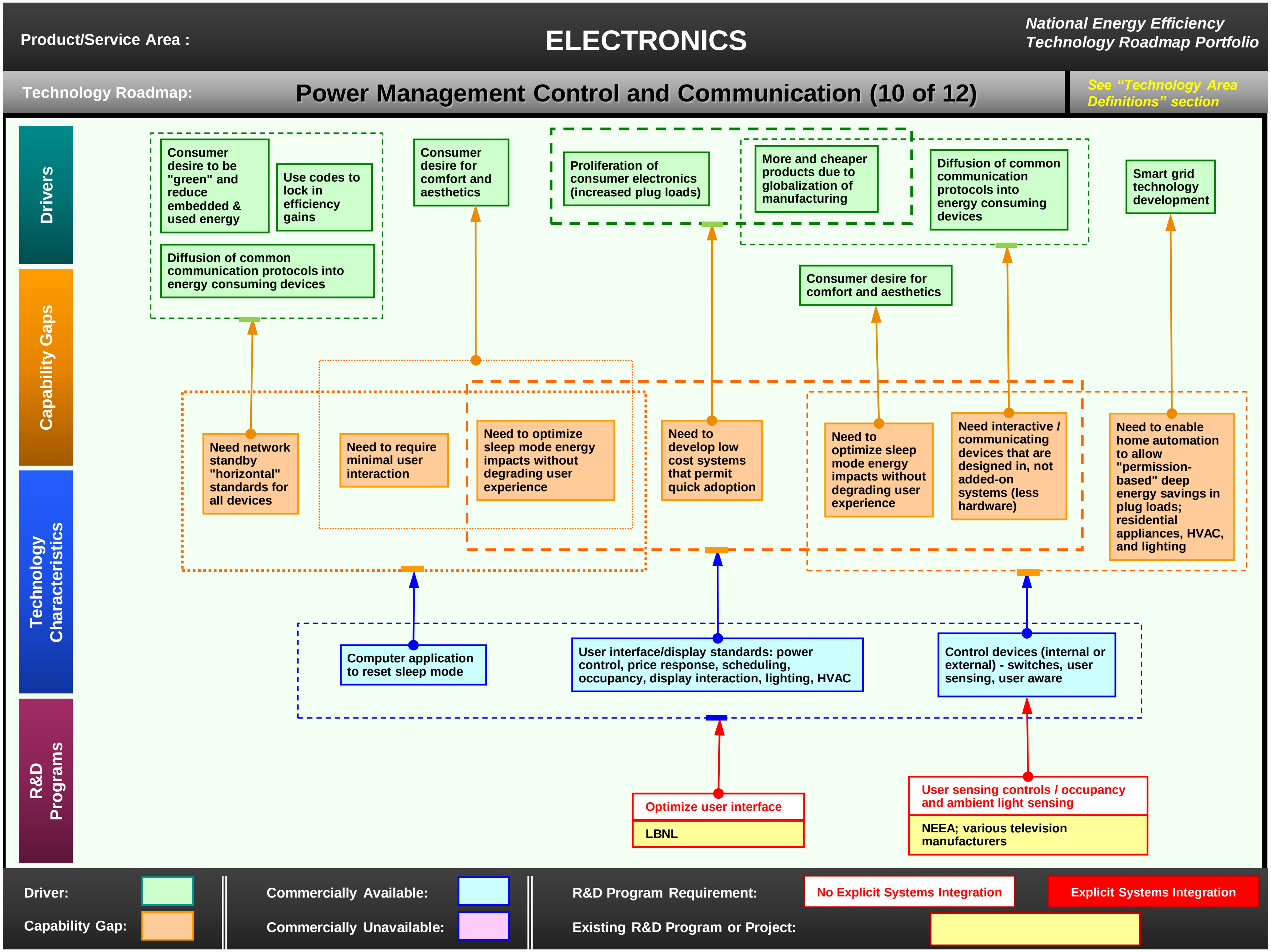
Product/Service Area :
ELECTRONICS
National Energy Efficiency Technology Roadmap Portfolio
Technology Roadmap:
Power Management Control and Communication (10 of 12)
See "Technology Area Definitions" section
Drivers
Capability Gaps
Technology Characteristics
R&D Programs
Consumer desire to be "green" and reduce embedded & used energy
Use codes to lock in efficiency gains
Diffusion of common communication protocols into energy consuming devices
Consumer desire for comfort and aesthetics
Proliferation of consumer electronics (increased plug loads)
More and cheaper products due to globalization of manufacturing
Diffusion of common communication protocols into energy consuming devices
Smart grid technology development
Consumer desire for comfort and aesthetics
Need network standby "horizontal" standards for all devices
Need to require minimal user interaction
Need to optimize sleep mode energy impacts without degrading user experience
Need to develop low cost systems that permit quick adoption
Need to optimize sleep mode energy impacts without degrading user experience
Need interactive / communicating devices that are designed in, not added-on systems (less hardware)
Need to enable home automation to allow "permission-based" deep energy savings in plug loads; residential appliances, HVAC, and lighting
Computer application to reset sleep mode
User interface/display standards: power control, price response, scheduling, occupancy, display interaction, lighting, HVAC
Control devices (internal or external) - switches, user sensing, user aware
Optimize user interface
LBNL
User sensing controls / occupancy and ambient light sensing
NEEA; various television manufacturers
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

Optimize user interface. ilitate widespread adoption low power mode technology by developing optimized, intuitive, and tailored user interface and control capabilities.

Existing research: Lawrence Berkeley National Laboratory (LBNL).

- 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/).
- LBNL has also 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

Key research questions:

1. What interface cues do people respond to?
2. What display standards should be consistent from device to device?
3. What metric should be used to report energy use?
4. What is relationship to monitoring, control, and communication characteristics?
5. What user interface standards should be developed or updated—power control, occupancy, scheduling, pricing, lighting, HVAC?

User sensing controls/occupancy and ambient light sensing. Stakeholders indicate that research in this area is underway at a variety of television manufactures, but 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.

Existing research: Various television manufactures, Northwest Energy Efficiency Alliance (NEEA).

- NEEA's "Energy Forward NW" initiative: http://energyefficientelectronics.org/news/.
- *[Summaries of existing research pending]*

Key research questions:

1. How to asses occupancy or usage? What sensors and measurements can help decide what power mode devices should be in?
2. Are required sensors mature? Or is more development required?
3. How can occupancy and light information be communicated to the network?

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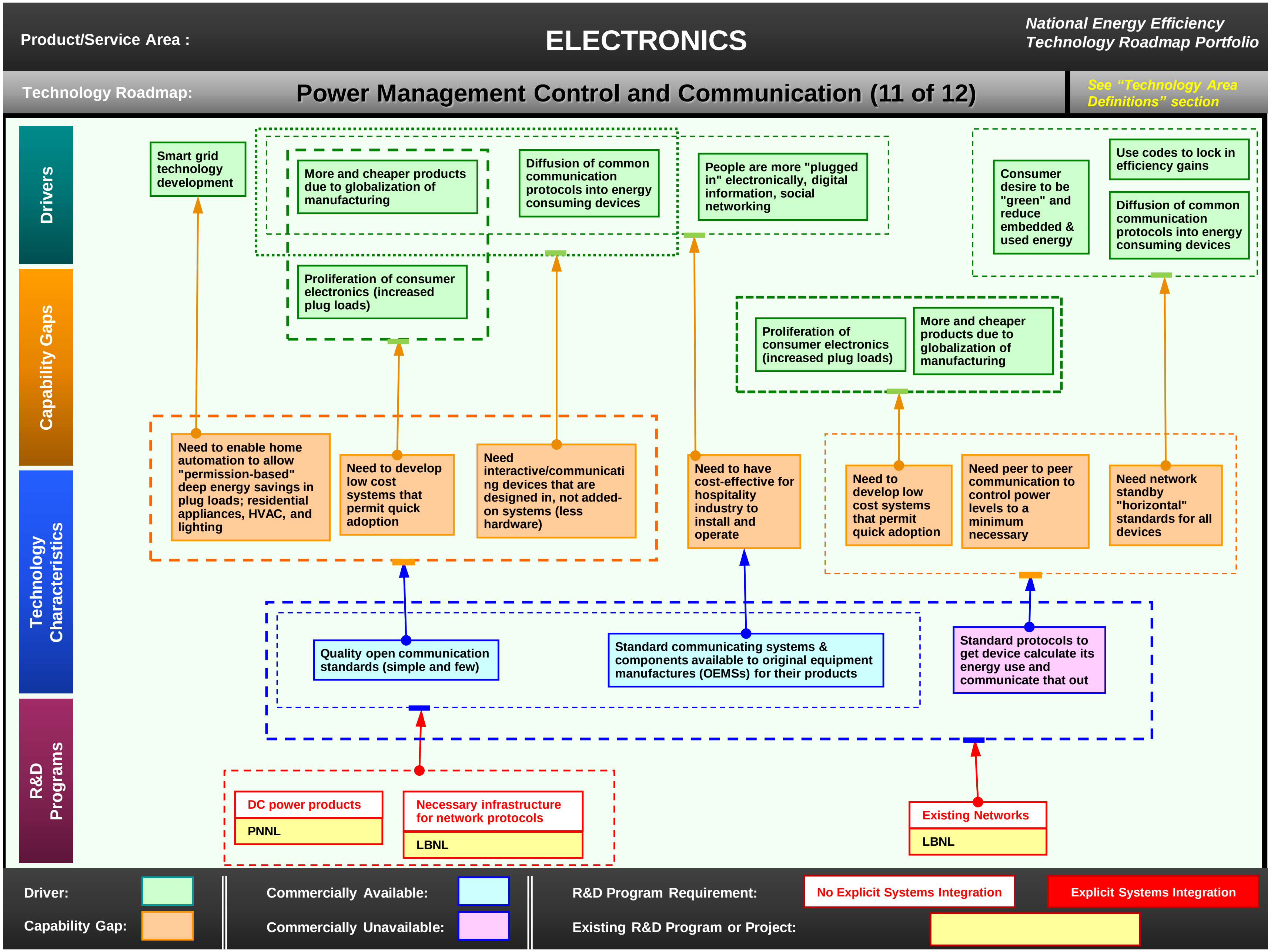
Product/Service Area :
ELECTRONICS
National Energy Efficiency Technology Roadmap Portfolio
Technology Roadmap:
Power Management Control and Communication (11 of 12)
See "Technology Area Definitions" section
Drivers
Capability Gaps
Technology Characteristics
R&D Programs
Smart grid technology development
More and cheaper products due to globalization of manufacturing
Diffusion of common communication protocols into energy consuming devices
People are more "plugged in" electronically, digital information, social networking
Consumer desire to be "green" and reduce embedded & used energy
Use codes to lock in efficiency gains
Diffusion of common communication protocols into energy consuming devices
Proliferation of consumer electronics (increased plug loads)
Proliferation of consumer electronics (increased plug loads)
More and cheaper products due to globalization of manufacturing
Need to enable home automation to allow "permission-based" deep energy savings in plug loads; residential appliances, HVAC, and lighting
Need to develop low cost systems that permit quick adoption
Need interactive/communicating devices that are designed in, not added-on systems (less hardware)
Need to have cost-effective for hospitality industry to install and operate
Need to develop low cost systems that permit quick adoption
Need peer to peer communication to control power levels to a minimum necessary
Need network standby "horizontal" standards for all devices
Quality open communication standards (simple and few)
Standard communicating systems & components available to original equipment manufactures (OEMSs) for their products
Standard protocols to get device calculate its energy use and communicate that out
DC power products
PNNL
Necessary infrastructure for network protocols
LBNL
Existing Networks
LBNL
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

DC power products. How can DC powering reduce energy use in small devices?

Existing research: Pacific Northwest National Laboratory (PNNL).

- *[Summaries of existing research pending]*

Key research questions:

1. What standard DC power technologies exist? What are relevant efficiencies of DC supplies or when source is AC or DC supply
2. What is measured energy use of DC devices vs. AC counterparts?
3. Where is DC a good solution for energy or other purposes?
4. What updates to DC power technologies would be helpful?

Necessary infrastructure for network protocols. Establish basic semantic descriptions of real world information so it can be represented in network protocols. Examples include device taxonomy (perhaps several), location, occupancy/presence, pricing, scheduling.

Existing research: Lawrence Berkeley National Laboratory (LBNL) .

- *[Summaries of existing research pending]*

Key research questions:

1. What existing standards or concepts are relevant?
2. What standards org. should host end result?
3. What process should be done to provide results?

Existing Networks. Hardware presented in buildings today—network equipment and devices connected to networks—can provide information useful for energy purposes. Examples include status, occupancy, temperature, etc. This data is rarely utilized. Explore what could be gleaned from existing hardware and demonstrate how to do it. Includes data delivered to other devices as well as to people.

Existing research: Lawrence Berkeley National Laboratory (LBNL) .

- *[Summaries of existing research pending]*

Key research questions:

1. What information is or could be available?
2. What could small additional investments bring (e.g. USB temp-sensor or wireless access point)?
3. How do we get info out to be useful?
4. How could software / firmware upgrades make this work even better?

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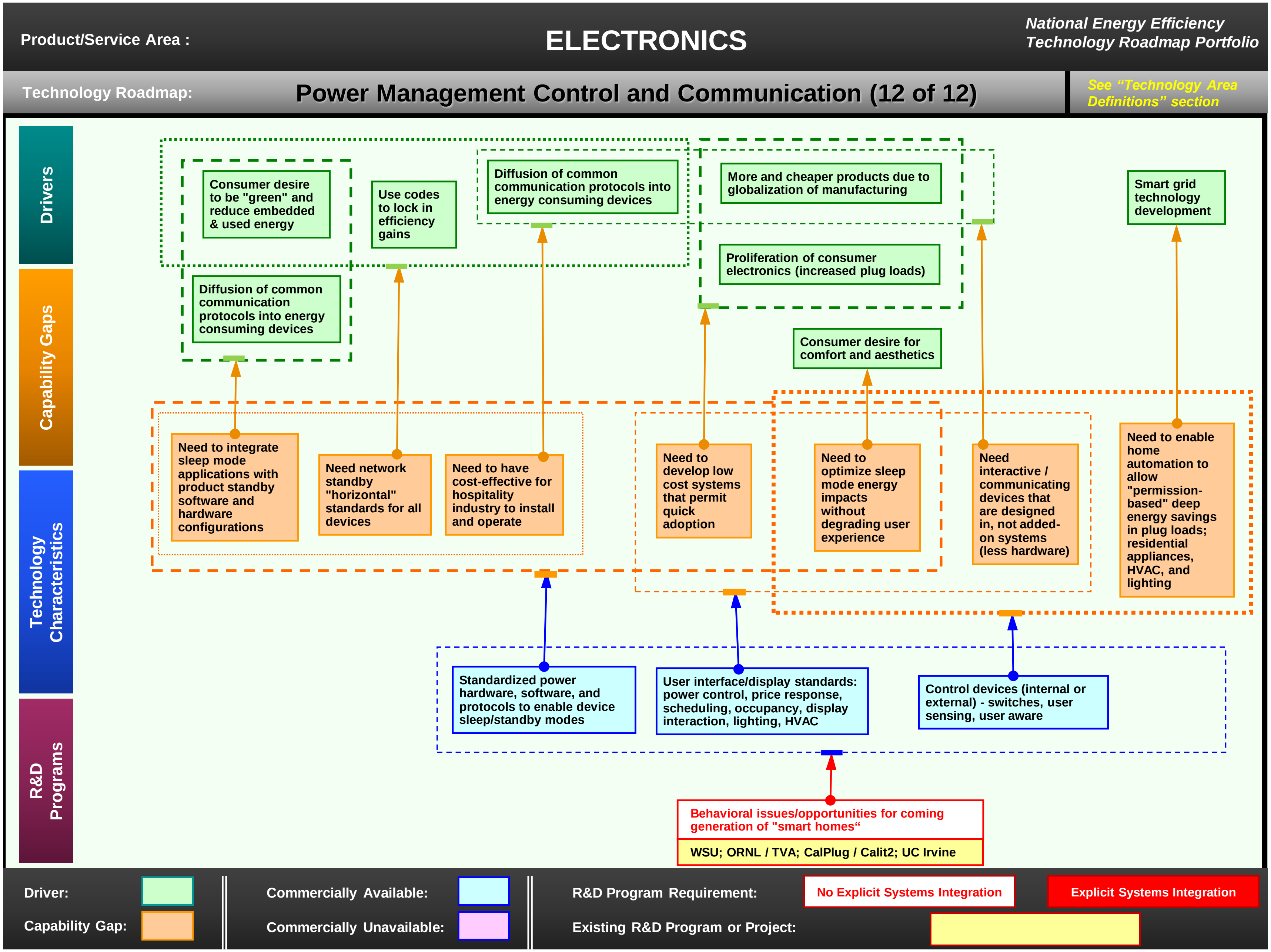
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Smart grid technology development
Diffusion of common communication protocols into energy consuming devices
Proliferation of consumer electronics (increased plug loads)
Consumer desire for comfort and aesthetics
Need to integrate sleep mode applications with product standby software and hardware configurations
Need network standby "horizontal" standards for all devices
Need to have cost-effective for hospitality industry to install and operate
Need to develop low cost systems that permit quick adoption
Need to optimize sleep mode energy impacts without degrading user experience
Need interactive / communicating devices that are designed in, not added-on systems (less hardware)
Need to enable home automation to allow "permission-based" deep energy savings in plug loads; residential appliances, HVAC, and lighting
Standardized power hardware, software, and protocols to enable device sleep/standby modes
User interface/display standards: power control, price response, scheduling, occupancy, display interaction, lighting, HVAC
Control devices (internal or external) - switches, user sensing, user aware
Behavioral issues/opportunities for coming generation of "smart homes"
WSU; ORNL / TVA; CalPlug / Calit2; UC Irvine
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

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.

Existing research: Washington State University (WSU); Oak Ridge National Laboratory (ORNL) with Tennessee Valley Authority (TVA); California Plug Load Research Center (CalPlug) with California Institute for Telecommunications and Information Technology (CALIT2), University of California Irvine.

- CalPlug:http://calplug.uci.edu/.
- CALIT2: http://www.calit2.net/.
- *[Summaries of existing research pending]*

Key research questions:

1. What are consumer/customer/homeowner motivations?
2. What are the biggest barriers to energy savings using home energy management systems?