Demand Response Technology Roadmap

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 for the March 2015 Demand Response Technology Roadmap

Development of this roadmap occurred in stages between May 2014 and February 2015. The Bonneville Power Administration (BPA) Demand Response Executive Sponsor Team decided upon the scope of the project in May. Two subsequent hands-on workshops were then held to gather input from regional and national subject matter experts. A team from the Portland State University Engineering and Technology Management Department transcribed workshop content into electronic files that a team from the Electric Power Research Institute then fact-checked and refined. Finally, project team members from the Bonneville Power Administration composed the text sections.

The first complete draft appeared in November 2014 and was made available for critical comment to all project participants and BPA's Technology Confirmation and Innovation Council. The March 2015 version reflects content refinement based on feedback received.

This roadmap is always to be considered a live, working document. Particularly since the current document is the culmination of a months-long, multi-stage process, readers may find errors, omissions, or opportunities to add other important content that would enhance this resource. The project team always welcomes opportunities to strengthen this roadmap and invites all readers to provide critical comment. Input received by January 15, 2015, will be vetted by members of the project team and considered for inclusion in the March 2015 version. This document will be part of the annual BPA Technology Innovation Office's Funding Opportunity Announcement.

For more information about the Demand Response Technology Roadmap or to offer revision suggestions, contact:

James V. Hillegas-Elting
Technology Roadmapping Project Manager
Bonneville Power Administration
jvhillegas@bpa.gov, 503.230.5327

DISCLAIMER

A primary goal in developing this roadmap was to distill the knowledge and experience of subject matter experts from throughout North America to help identify and address some important technology-based needs of utilities. In doing so, the document could then be used to pinpoint opportunities for organizations to work together to help deliver products and services into the marketplace more quickly and with less overall cost and risk to individual organizations. The net result, then, would be the continued delivery of safe, reliable, and cost-effective electricity for diverse stakeholder communities throughout North America.

Thirty organizations joined BPA in developing this document. Though this input was essential in its production, the contents do not necessarily reflect the opinions of everyone who participated. Further, while BPA endorses this roadmap and is using it to guide R&D investments, the other collaborating partners do not necessarily endorse all of the content.

This document is intended to highlight potential opportunities for collaboration and coordination among utilities and the research community and is properly considered a live, working document. It is not to be interpreted as providing a prescriptive or deterministic technology development path, nor to describe the only possible path forward in addressing important opportunities and challenges. Given the dynamic and complex nature of the utility industry and technological change, this document also does not claim to capture the full universe of technology requirements or research and development programs currently underway. Finally, though the project team has worked diligently to ensure accuracy, the roadmap does not claim to be free of unintended error or omission.

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

Back to Table of Contents

Letter of Introduction

At the Bonneville Power Administration we believe that technology plays a very important role in our ability to continue to provide low cost, reliable power to the Pacific Northwest. Since 2006, we have actively invested in a portfolio of research projects intended to help us achieve our strategic business objectives. Each year new projects are added while old ones are either completed or pruned.

A key component of the portfolio selection process is the roadmap, in this case the Demand Response (DR) Technology Roadmap, presented here. This roadmap clearly articulates the research needed in the DR technology area. Researchers throughout academia, laboratories, and industry can use this roadmap to understand how their work can benefit the electric power industry.

The roadmap also shows how research in a given area relates to capability gaps as well as strategic business drivers. Utility executives and stakeholders can use the roadmap to better understand how investments in DR technology can advance their business objectives. As we invest in new research and technologies, we must seek to understand what other utilities, universities, laboratories, and manufacturers are doing so to avoid wasteful duplication of effort.

Understanding the areas of mutual interest among DR providers can lead to more productive, collaborative research. That is why we have sought the help of EPRI and others in the utility industry, for development of the DR Technology Roadmap. The roadmap content was derived from two workshops with attendees representing utilities, national laboratories, universities, government agencies, and industry.

I would like to use this opportunity thank all of the people who have contributed to his effort. This includes the Electric Power Research Institute (EPRI) who partnered with us in this process. They have provided content and have contributed their time and expertise to guide the effort. EPRI played a key roll in participating in both of the two workshops, in fact checking, and in their review and edits of the workshop output. The PSU team provided the road mapping expertise and translated the workshop output into the diagrams you see in this document.

The DR Technology Roadmap is being made publicly available so that the entire industry may benefit. The four technology areas depicted in the roadmap represent only part of the areas of interest within the DR community. More work is needed to articulate research needs in the remaining technology areas identified during this process. It is my hope that others within the industry will find this roadmap useful and will apply this methodology to guide their research investments. Together we can ensure that the right technologies are available for the continued delivery of low cost reliable electric power for generations to come.

Terry Oliver
Chief Technology Innovation Officer
Bonneville Power Administration

Back to Table of Contents

Executive Summary

Technology roadmaps are used to guide investments in research, to articulate research questions of interest, and to inform stakeholders of the potential benefits of new technology. This document represents Bonneville Power Administration (BPA) first Demand Response (DR) Technology Roadmap. This roadmap and the revisions that will follow may be used in conjunction with BPA's annual R&D solicitation. The DR Technology roadmap will be revised and updated periodically to accurately reflect the current state of technology. The DR Technology Roadmap pilot effort was established to develop an entirely new roadmap based on the following principles:

- Create a demand response technology roadmap that utilizes industry best practices for roadmapping.
- Solicit participation from practitioners and other thought leaders in this sector to identify common areas of interest and possible collaboration.

The core team responsible for developing the roadmap consisted of BPA, the Portland State University Engineering and Technology Management Department (PSU), and the Electric Power Research Institute (EPRI). BPA provided project management and subject matter expertise. PSU provided road mapping best practices and processed workshop output. EPRI provided subject matter expertise and also provided third-party review of workshop content. Critically, fifty-four industry representatives from twenty-nine organizations throughout North America (identified at the end of this document) provided their invaluable subject matter expertise.

The BPA Demand Response Executive Sponsor Team met during the spring of 2014 to determine the project focus for the year. Roadmap content was then derived from the output of two workshops. The first workshop (June 2014) focused on Drivers and Capability Gaps. Participants included subject matter experts drawn largely from BPA and stakeholders in the Pacific Northwest.

This first phase of the DR Technology Roadmap project was originally focused on the five Technology Areas of greatest interest to the BPA DR Executive Sponsor Team and the agency's DR Team:

1) **DR in Grid Operations:** Technologies that can enable DR in response to load forecasts or dynamic grid energy or capacity requirements to allow system operators to respond to generation imbalances and increase system flexibility. They typically involve a DR management system that is also useful for grid regulation. This definition applies to real-time, hour-ahead, and day-ahead time horizons.
2) **DR in Transmission and Generation Planning:** Technologies used in planning processes to address existing and forecast transmission and generation needs. These assist grid operators in load management and enable improved system reliability and provide imbalance reserves. They may also enable participation in energy imbalance markets.
3) **Integration of DR and Energy Efficiency:** Technologies used at a site or group of sites to maximize energy efficiency and enable demand response. These can include integrated home and business energy management systems that enable DR and provide a real-time determination of available capacity, automatic lighting controls, and automated thermostats and plug load controls.
4) **DR in Generation Capacity Planning:** Technologies used in the generation capacity planning process to address capacity

Back to Table of Contents

needs, such as hydro-generation imbalance, and may also provide grid operators with other ancillary services.

5) **Measurement & Verification:** Technologies and protocols using the OPEN ADR 2.0b framework to measure and verify the load reductions or increases (INC/DEC) dispatched during a DR event, in comparison with an established energy use baseline at a site or aggregation of sites. Examples include technologies that provide measurement and verification (M&V) of DR events and event participation rates in addition to devices to assist in accurate DR event settlements.

Following DR Technology Roadmapping Workshop 1 in June 2014, the project team and executive sponsors came to an agreement that the Measurement and Verification Research Area would not be part of Workshop 2 or the final deliverable, but that content collected during Workshop 1 could form the basis for future work. This decision was based on the following rationale:

1) Extensive M&V operations are now ongoing on at other utilities and Independent System Operators (such as PJM). These typically involve multi-million dollar DR transactions, supporting the realization that existing M&V technologies are currently robust enough for parties to agree on for economic exchanges;
2) Subject matter experts in Workshop 1 identified two priority needs in the M&V Research Area: analytics to determine the baseline, and M&V through advanced metering infrastructure (AMI). Based on these needs:
    a. The project team agreed that baseline determinations are more a matter of policy than it is of developing new products or services through technology R&D;
    b. Research into using AMI for M&V is an important area for technology R&D with many utilities in the U.S.—however, this topic is not as important in the Pacific Northwest because AMI penetration rates among BPA customer utilities are still relatively small; and
    c. BPA would continue to work closely with EPRI and other utilities to keep abreast of ongoing M&V-related research and decide to participate in this technology R&D more actively as needs continue to evolve.

Development of past roadmaps has demonstrated the value in collaborating with other organizations with similar interests and needs. Research investments are best leveraged and optimized by identifying those research themes that are broadly applicable. Proper alignment of research effort results in mutually-beneficial outcomes.

Any technology roadmap must constantly evolve to reflect accurately the changing technology landscapes and business environments. This document accurately reflects the current state of DR Technology research needs in the four Research Areas listed above. Continued work is required to maintain the relevance of this information. The content of the roadmap should be refreshed periodically as research questions are answered and as new priorities emerge. The scope of the roadmap can be expanded to incorporate new roadmaps or even new Research Areas.

Table of Contents

Introduction

"A roadmap is an extended look at the future of a chosen field of inquiry composed from the collective knowledge and imagination of the brightest drivers of the change."

Robert Galvin, former Chairperson of Motorola

Roadmaps are used as communication tools to align technology plans with organizational strategies, to articulate long-term plans, and to prioritize research investments. The Bonneville Power Administration (BPA) has successfully demonstrated the benefits of engaging senior executives, subject-matter-experts, regional partners, and industry to develop several technology roadmaps for the utility industry. Roadmapping serves as the basis for developing a research portfolio that aligns with strategic agency needs. BPA has earned international acknowledgement for demonstrating roadmapping best practices, specifically in reference to the agency's work in energy efficiency technology roadmapping. Further evidence of BPA's ability to use roadmaps to drive a results-oriented research portfolio to demonstrate millions of dollars in savings to regional rate payers include energy-efficient ductless heat pumps and helical shunts for transmission conductors.

BPA developed its first set of technology roadmaps in 2006 with the help of Portland State University Engineering and Technology Management Department. These initial resource have been revised over the years as needs have changed and best practices have evolved, but there is always room for improvement.

BPA recognized this when enhancing its roadmaps for energy efficiency and transmission technologies and has reached out to other electric utility industry partners to develop roadmaps that would represent collective research needs. This diverse input is important because these other organizations represent a broader perspective; further, their technology needs may be somewhat different from—but complementary to—BPA's needs.

To enhance further BPA's collaborative network within the utility industry, agency staff also participate in the Research Technology Management (RTM) Forum, a national technology management benchmarking group. This entity is comprised of transmission owners and operators that have an interest in understanding how other institutions manage research and development (R&D) and have a desire to adopt the best practices in their own organizations.

In addition to utility and independent system operator (ISO) partners, BPA has worked closely with the Electric Power Research Institute (EPRI). EPRI is a recognized international leader in conducting research and development on behalf of the global utility industry. EPRI brings together its scientists and engineers, as well as experts from academia and industry, to help address electric power industry challenges through collaborative efforts with utilities and ISOs. EPRI also has been developing technology roadmaps for generation, transmission, distribution, and end-use customer segments, in collaboration with its member utilities and ISOs. The perspectives and expertise at BPA and EPRI complement one other, which has made for strong teams to develop these technology roadmaps.

This Demand Response Technology Roadmap represents the first time that the agency has specified and centralized its demand response-related technology R&D needs. It incorporates lessons learned from BPA and EPRI collaboration to produce the National Energy Efficiency Technology Roadmap Portfolio and the Collaborative Transmission Technology Roadmap (both of which can be found at www.bpa.gov/ti).

As with its previous roadmap projects, this document represents a sub-set of research topics within the fuller "universe" of topics. The intention is to

Back to Table of Contents

expand and enhance this resource as needs evolve and as other opportunities arise to collaborate with external partners. This fuller "universe" of research topics, as currently conceived, is represented in the "Organizational Chart" below.

In May 2014 the BPA Demand Response Executive Sponsor Team met to agree upon the content parameters of the 2014 project phase—the four Research Areas addressed in this document. With this direction the project team convened Workshop 1 in June to bring together "strategic-level" experts from the agency and key regional stakeholders. These experts identified the Drivers and Capability Gaps within each Research Area.

Workshop 2 followed in September to gather "tactical-level" information from a wider array of technical subject matter experts from utilities, national laboratories, universities, vendors, and other research entities from throughout North America. These experts included those with hands-on roles as operations managers or staff, plus technical specialists engaged in R&D. They linked R&D Programs and Technology Characteristics to the Capability Gaps and Drivers identified in Workshop 1.

The first draft of this document is being published in November 2014. Revisions will be incorporated into a March 2015 version that the BPA Technology Innovation Office will include in its annual R&D solicitation.

Table 1 summarizes this schedule,. See the appendix for supporting documentation and minutes from the workshops.

Table 1: Project Implementation

Event	Date	Summary
DR Executive Sponsor Meeting	May 15, 2014	**Principals from collaborating organizations** convened to establish pilot project parameters. Held in Charlotte, NC.
Workshop 1	June 13, 2014	**Strategic experts** to articulate key technology Drivers and the Capability Gaps: Executives, Senior leadership, and Senior-level operational managers. Held in Portland, OR.
Workshop 2	Sep. 18-19, 2014	**Tactical subject matter experts** to articulate Technology characteristics required to bridge Capability Gaps and R&D Program descriptions needed to develop these characteristics: Engineers, Operators, Researchers, and Academics. August mini-workshop held in Charlotte, NC; September workshop held in Portland, OR.
Publish Draft Roadmap	Nov. 14, 2014	First complete draft sent to all workshop participants and BPA Technology Confirmation and Innovation Council members.
BPA Technology Innovation Solicitation	March 2015	Revised roadmap to be published as part of BPA's annual R&D solicitation

References

Electric Power Research Institute, www.epri.com.

Asher Lessels, *Background Paper on Technology Roadmaps*, Technology Executive Committee of the United Nations Framework Convention on Climate Change, April, 2013, http://unfccc.int/ttclear/sunsetcms/storage/contents/stored-file-20130522123304914/TEC%20-%20background%20paper%20on%20technology%20roadmaps.pdf.

Collaborative Transmission Technology Roadmap (Portland, Oreg.: Bonneville Power Administration), March 2014, www.bpa.gov/ti.

National Energy Efficiency Technology Roadmap Portfolio (Portland, Oreg.: Bonneville Power Administration), March 2014, www.bpa.gov/ti.

What is Roadmapping?

Technology Roadmapping (TRM) is a strategic approach for research and development (R&D) planning. Since Motorola initiated the use of TRMs in the 1970s, this planning tool has become standard for R&D-driven organizations. Robert Galvin, former Chair of Motorola and an advocate of science and technology roadmaps, defines a roadmap as "an extended look at the future of a chosen field of inquiry composed from the collective knowledge and imagination of the brightest drivers of the change."

Technology roadmaps provide a framework for future innovations in a number of key technology areas and ensure that investment in technology and research is linked to key business drivers and market trends. These facilitate resource allocation decisions and help optimize R&D investments. Roadmaps also assist in filtering alternate technological options and to help decision makers focus on promising technologies. In today's competitive business environment it is crucial to make the right decisions at the appropriate time.

A wide array of public and private organizations use various roadmapping tools that are readily tailored and eminently scalable. These tools have been used to develop roadmaps that apply to specific products, broader technology areas, company-wide strategic plans, industry-wide alignment, or articulating common national and international goals. Private firms, non-governmental organizations, academic institutions, industry consortia, community groups, and government entities have found technology roadmapping a fruitful approach.

Concurrent with this diversity are the many applications to which a tailored roadmapping structure has been put—including the electronics, aerospace, defense, manufacturing, information technology, communications, healthcare, and transportation industries—and also to address pressing policy issues such as environmental remediation and climate change. Technology roadmaps have also been used in the energy sector at an increasing rate over the past decade.

There are four major phases in the roadmapping process:

1) Apply strategic planning tools—such as Strengths, Weaknesses, Opportunities, and Threats (SWOT) assessments—to articulate drivers confronting the organization;
2) Identify desired capabilities to help meet drivers;
3) Use technology forecasting or other methods to identify technologies to help deliver desired capabilities; and
4) Delineate R&D required to develop desired technologies, including specification of key research questions.

The purpose and goals of the particular roadmapping project determine the most suitable approach to take in developing the final deliverable:

- A high-level landscape analysis called an "*S–Plan*" or *Strategic Plan*.
- A more detailed product- or capability-focused approach known as a "*T–Plan*" or *Tactical Plan*.

These two categories are not mutually exclusive and, in fact, are quite complementary. S-Plans can be the first step in understanding the full landscape of opportunities and challenges, and once these have been articulated T-Plans can be developed to go into further detail on specific priority areas. T-Plans are more likely than S-Plans to be structured along a time scale not only to link R&D needs with important drivers (as an S-Plan does) but also to begin to identify stages of technology development and the necessary teams best equipped to lead particular work streams.

As with the National Energy Efficiency Technology Roadmap Portfolio and the Collaborative Transmission Technology Roadmap, this document has been developed using the S-Plan framework to provide the data necessary for future refinement of prioritized sections into T-Plans. Recognizing that these roadmapping projects are highly collaborative and

Back to Table of Contents

bring together organizations with broadly-shared goals but potentially very different corporate cultures, strategic plans, and legal mandates, neither document attempts to specify a technology development timeline that would apply to all contributors. However, collaborating entities may work together in the future to produce one or more T-Plan timelines to provide guidance to the research community regarding logical time-sequencing of R&D activities. Such future collaboration will benefit from the expertise consolidated within these pages.

References

M. Amer and Tugrul Daim, "Application of Technology Roadmaps for Renewable Energy Sector," *Technological Forecasting and Social Change* 77:8 (2010), 1355–1370.

O. H. Bray and M. L. Garcia, "Technology Roadmapping: The Integration of Strategic and Technology Planning for Competitiveness," *Innovation in Technology Management—The Key to Global Leadership: PICMET '97* (Portland International Conference on Management and Technology), 25–28.

Tugrul Daim, *et al.*, "Technology Roadmapping: Wind Energy for Pacific NW," *Journal of Cleaner Production* 20:1 (Jan. 2012), 27–37.

Tugrul Daim and Terry Oliver, "Implementing Technology Roadmap Process in the Energy Services Sector: A Case Study of a Government Agency," *Technology Forecasting and Social Change* 75:5 (June 2008), 687–720.

Tugrul Daim, Terry Oliver, and Jisun Kim, *Research and Technology Management in the Electric Industry*. New York: Springer, 2013.

D. Fenwick, Tugrul Daim, and N. Gerdsri, "Value Driven Technology Road Mapping (VTRM) Process Integrating Decision Making and Marketing Tools: Case of Internet Security Technologies," *Technological Forecasting and Social Change* 76:8 (2009), 1055–1077.

R. N. Kostoff and R. R. Schaller, "Science and Technology Roadmaps," *IEEE Transactions on Engineering Management* 48:2 (2001), 132–143.

A. Lamb, Tugrul Daim, and S. Leavengood, "Wood Pellet Technology Roadmap," *IEEE Transactions on Sustainable Energy* 3:2 (2012), 218–230.

A. Nauda and D.L. Hall, "Strategic Technology Planning: Developing Roadmaps for Competitive Advantage," *PICMET '91* (Portland International Conference on Management of Engineering and Technology), 745–748.

Robert Phaal, "Technology Roadmapping: A Planning Framework for Evolution and Revolution," *Technological Forecasting and Social Change* 71:1–2 (2004), 5-26.

Robert Phaal, Clare J. P. Farrukh, and David R. Probert, "Technology Roadmapping: A Planning Framework for Evolution and Revolution," *Technological Forecasting and Social Change* 71:1–2 (Jan.–Feb. 2004), 5–26.

D. R. Probert, Clare J. P. Farrukh, and Robert Phaal, "Technology Roadmapping: Developing a Practical Approach for Linking Resources to Strategic Goals," *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture* 217:9 (2003), 1183–1195.

D. R. Probert and M. Radnor, "Frontier Experiences from Industry-Academia Consortia," *Research Technology Management* 42:2 (2003), 27–30.

C. H. Willyard and C. W. McClees, "Motorola's Technology Roadmapping Process," *Research Management* Sept.-Oct. 1987, 13–19.

J. J. Winebrake, "Technology Roadmaps as a Tool for Energy Planning and Policy Decisions," *Energy Engineering: Journal of the Association of Energy Engineering* 101:4 (2004), 20–36.

Back to Table of Contents

How to Use This Roadmap

The Demand Response Technology 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 of technology development research needs within some important Research Areas.

The content herein is organized into four main sections based on the priority Research Areas that the BPA Demand Response Executive Sponsor Team decided upon in May 2014. The sections are:

Planning

1. Demand Response in Transmission and Generation Planning
2. Demand Response in Generation Capacity Planning

Integration

3. Demand Response in Grid Operations
4. Integration of Demand Response and Energy Efficiency

See the Appendix for process documents (including meeting minutes) for all workshops held to develop this resource.

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, to include: existing or pending regulations and standards; market conditions and projections; consumer behavior and preferences; 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, model, system, etc., necessary to overcome Capability Gaps. To be included in the technology roadmap these will either be: Commercially Available but facing technical barriers needing to be addressed; or Commercially Unavailable and needing to be developed.

R&D Programs: The iterative process undertaken at universities, national laboratories, some businesses, and related organizations to generate new ideas, evaluate these ideas, and deliver the needed Technology Characteristics. This represents current and planned R&D intended to develop models and prototypes, evaluate these in laboratory settings, demonstrate them in the field, and conduct engineering and production analyses. The generic abbreviation "R&D" is to be understood as including, when appropriate, design, deployment, and demonstration in addition to research and development.

Back to Table of Contents

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.

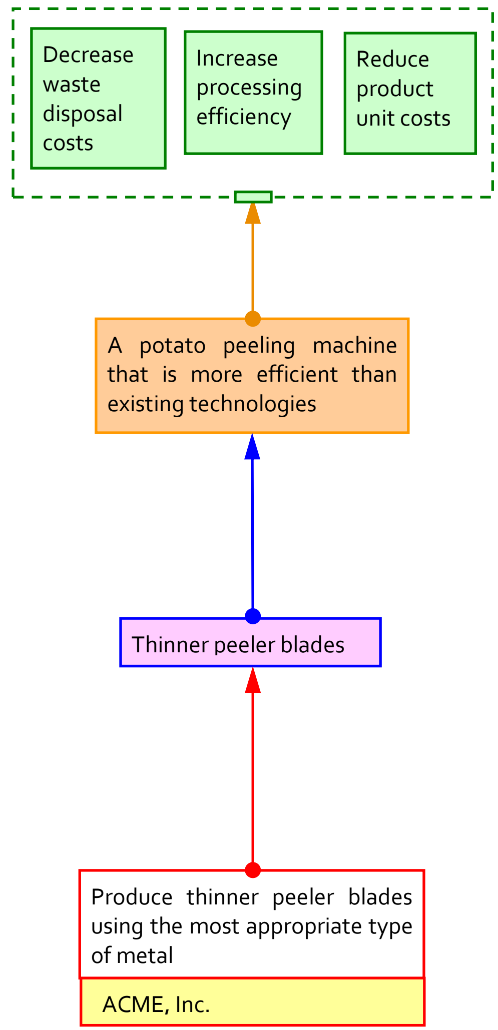
Faced with this situation, the company is facing three **Drivers**: 1) the desire to increase processing efficiency; 2) the desire to reduce product unit costs; and 3) the desire to reduce waste disposal costs.

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 blade they would be able to meet the requirements and overcome the **Capability Gap**. Thus the engineers have established a **Technology Characteristic**: thinner cutting blades.

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.

The diagram at right illustrates this example:



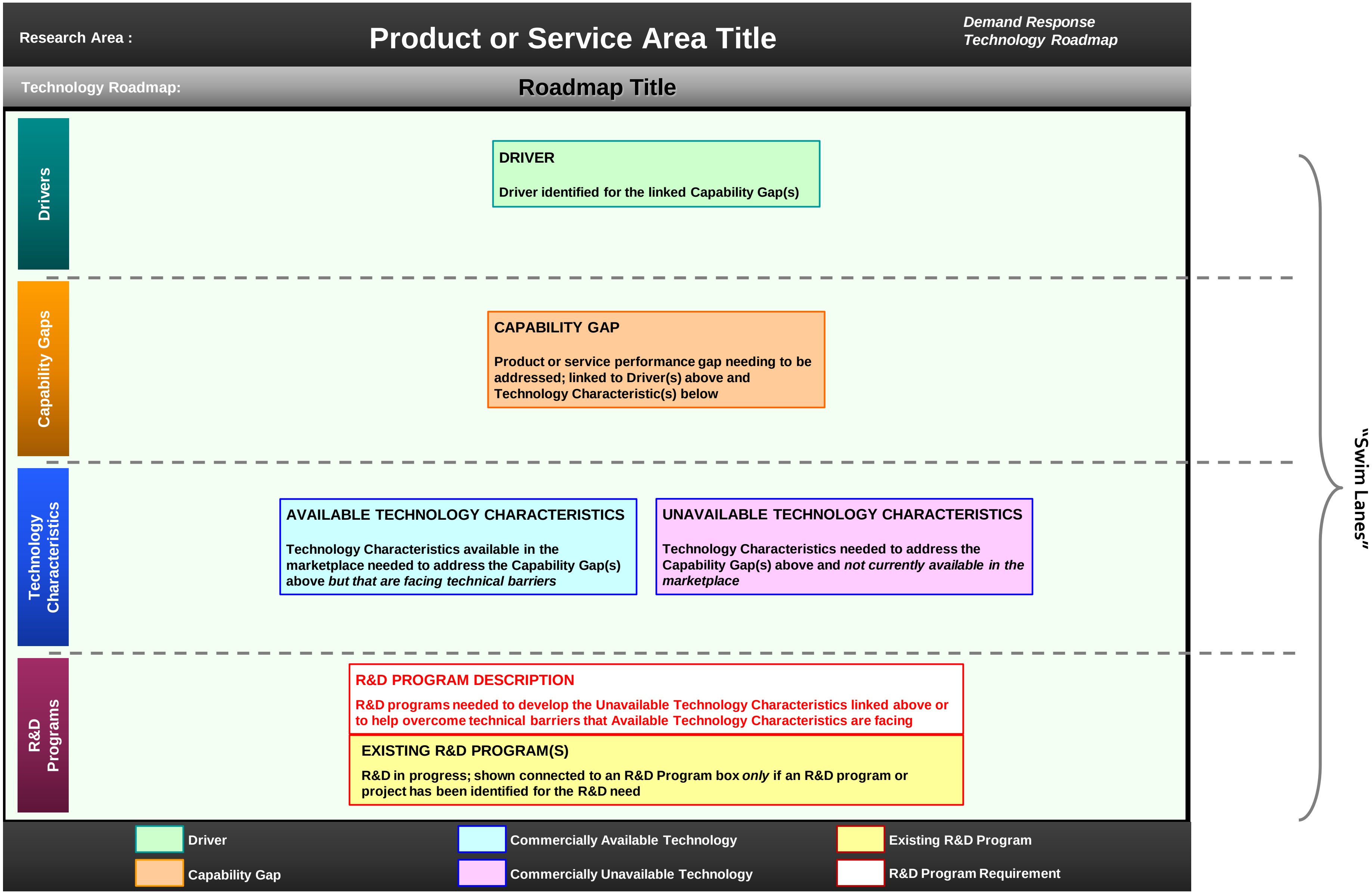
Drivers:
What are the reasons to change?

Capability Gaps:
What are the barriers to change?

Technology Characteristics:
What are the technological solutions needed to overcome barriers to change?

R&D Programs:
What are the research programs and key research questions to pursue to develop technological solutions?

Roadmap Key


Research Area :
Product or Service Area Title
Demand Response Technology Roadmap
Technology Roadmap:
Roadmap Title
Drivers
DRIVER
Driver identified for the linked Capability Gap(s)
Capability Gaps
CAPABILITY GAP
Product or service performance gap needing to be addressed; linked to Driver(s) above and Technology Characteristic(s) below
Technology Characteristics
AVAILABLE TECHNOLOGY CHARACTERISTICS
Technology Characteristics available in the marketplace needed to address the Capability Gap(s) above but that are facing technical barriers
UNAVAILABLE TECHNOLOGY CHARACTERISTICS
Technology Characteristics needed to address the Capability Gap(s) above and not currently available in the marketplace
R&D Programs
R&D PROGRAM DESCRIPTION
R&D programs needed to develop the Unavailable Technology Characteristics linked above or to help overcome technical barriers that Available Technology Characteristics are facing
EXISTING R&D PROGRAM(S)
R&D in progress; shown connected to an R&D Program box only if an R&D program or project has been identified for the R&D need
Driver
Capability Gap
Commercially Available Technology
Commercially Unavailable Technology
Existing R&D Program
R&D Program Requirement
"Swim Lanes"

R&D Program Summaries

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.

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.

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.

Organizational Chart

The four (originally five) Research Areas that served as the focus of the 2014 phase of the Demand Response Technology Roadmap project encompass areas of critical interest to Bonneville Power Administration (BPA) and regional stakeholders, but by no means represent the full breadth and depth of important topics. To help frame the complex interrelationships to be found in these topics while also articulating some agreed-upon boundaries, the project team developed the "organizational chart" in the following pages.

This structure is offered as one way to present, in summary form, the core research areas and topics within demand response. It is intended as a live, working document to help provide structure for the technology roadmapping process; it is subject to revision and refinement to reflect the dynamic nature of demand response and the input of stakeholders and subject matter experts.

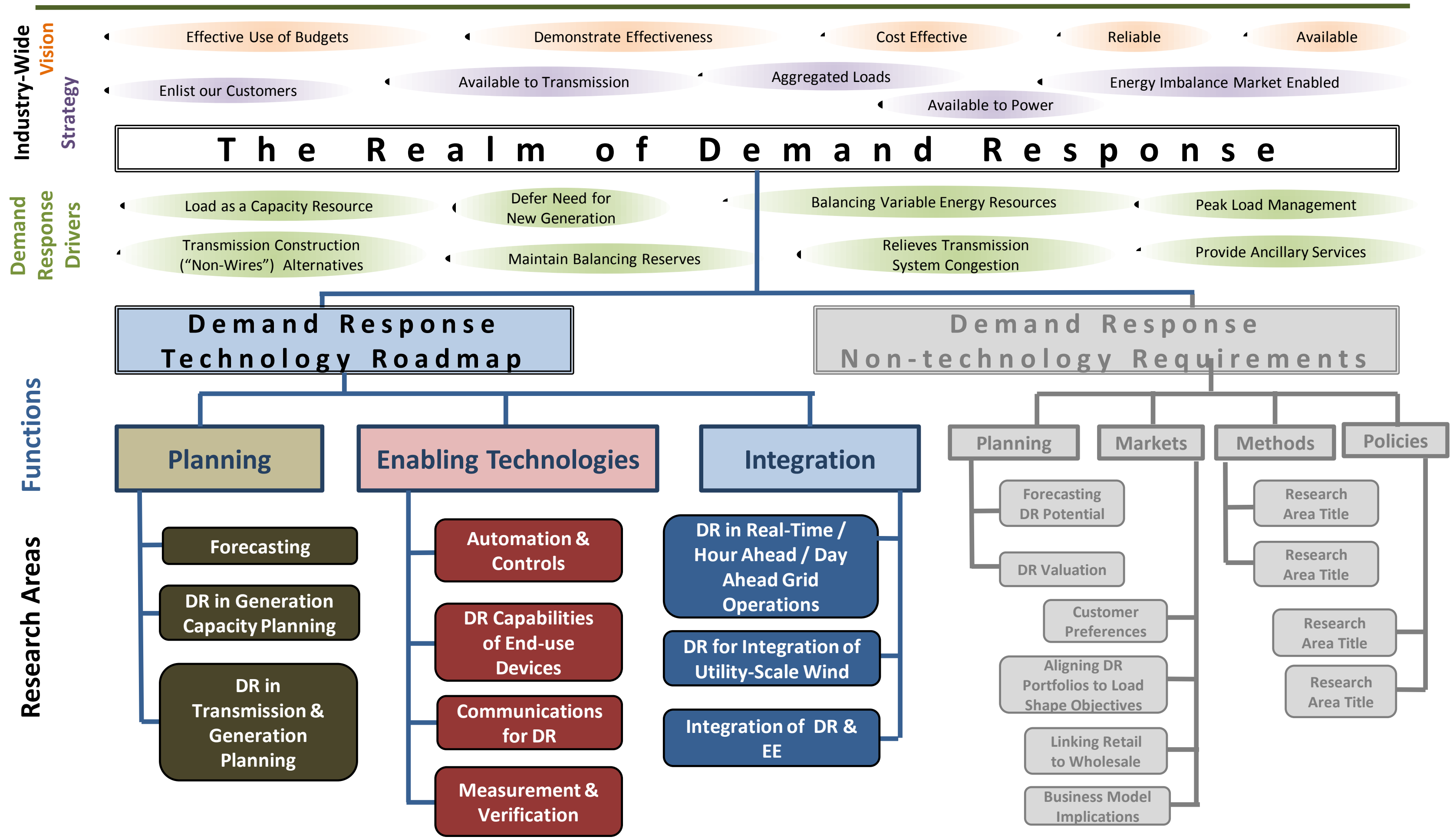
Recognizing that often there are not clear delineations between topics and that different groups of subject matter experts might categorize these topics differently (and as effectively), the project team prepared a first draft of this organizational chart for the May 2014 BPA DR Executive Sponsor Team meeting. This first version integrated ideas from the BPA Demand Response Team and the Electric Power Research Institute (EPRI). The project team used this draft structure as a place to begin dialogue and as a way for executive sponsors to select a discrete set of Research Areas on which the first phase of this project would focus. Participants of Workshops 1 and 2 were also presented with versions of this organizational structure and invited to revise, re-title, and re-organize individual roadmaps as needed.

The result of this ongoing dialogue is to be found below. The project team understands that this organizational structure is a work-in-progress that contributors will revise as necessary to ensure that roadmap content reflects the latest expertise and serves industry's needs most effectively.

The first image below provides the strategic context for the pages that follow. The "Strategy" and "Vision" rows are broad categories of drivers that generally apply to all utilities. Under this is the Demand Response Technology Roadmap, composed of Functions, Research Areas, and individual roadmaps within the Research Areas. The following image—a Venn diagram—provides another way to represent the complementarity of technology and non-technology requirements in the realm of demand response.

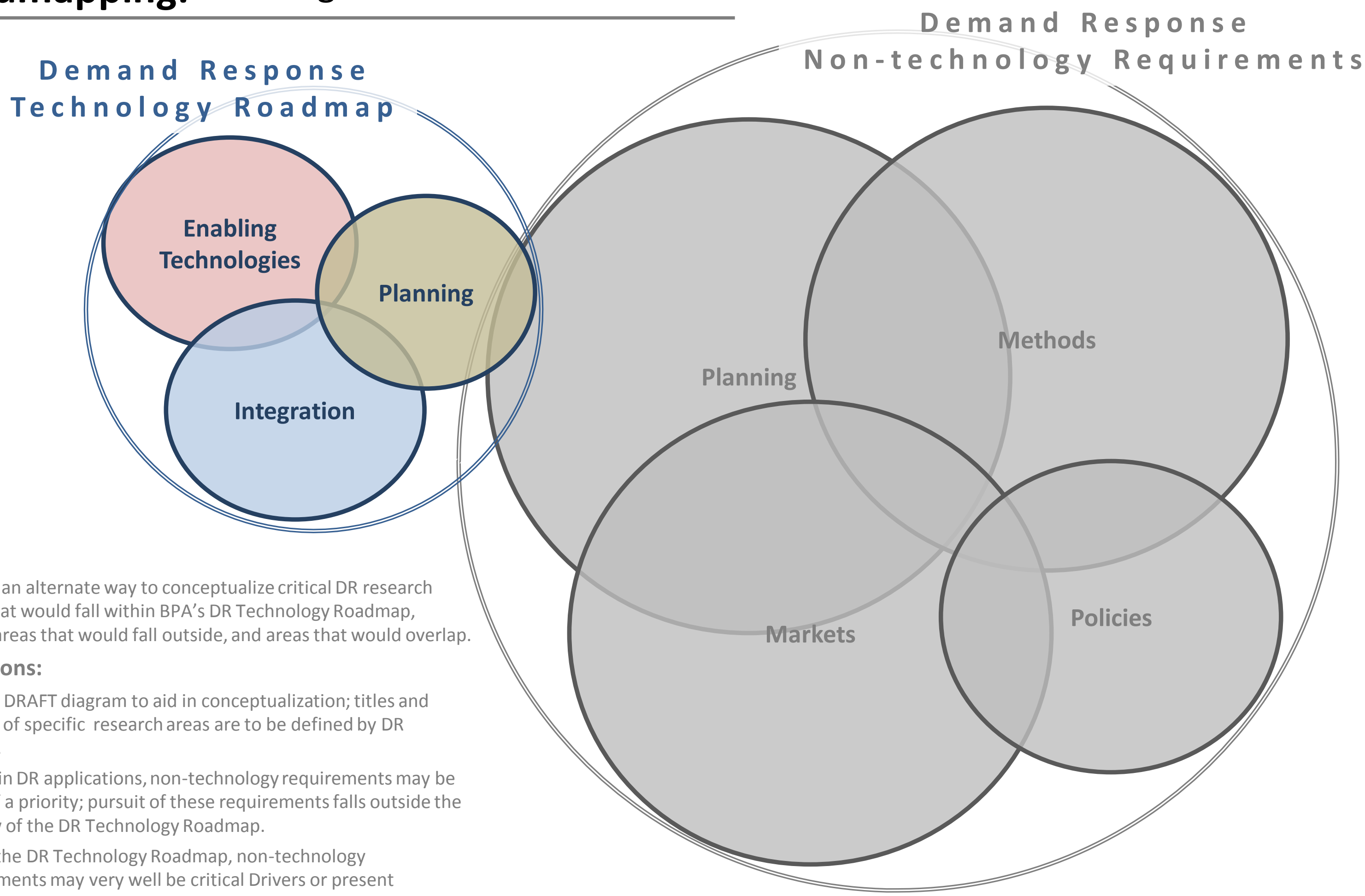
Back to Table of Contents

Strategy, Vision, and Structure of the Demand Response Technology Roadmap



See following pages for specific technology roadmaps within each Research Area

Demand Response Roadmapping: Representing the Distinctions Between and Interrelationships Among Critical Functions



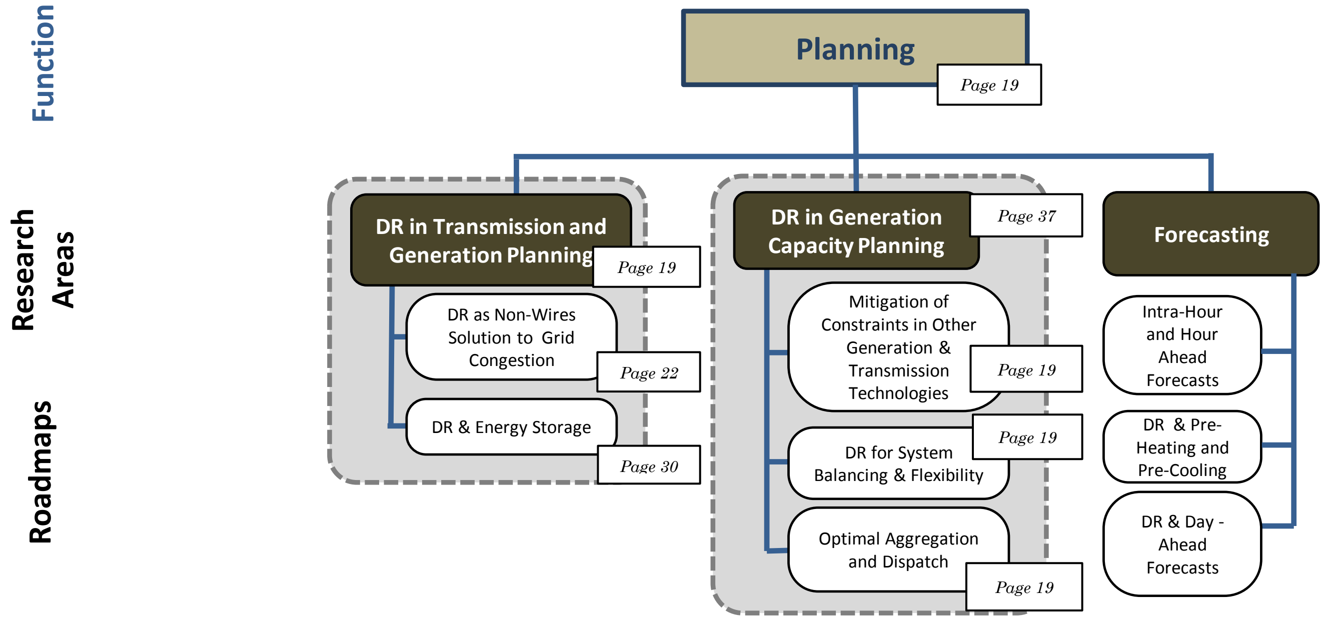
Purpose:

Provide an alternate way to conceptualize critical DR research areas that would fall within BPA's DR Technology Roadmap, critical areas that would fall outside, and areas that would overlap.

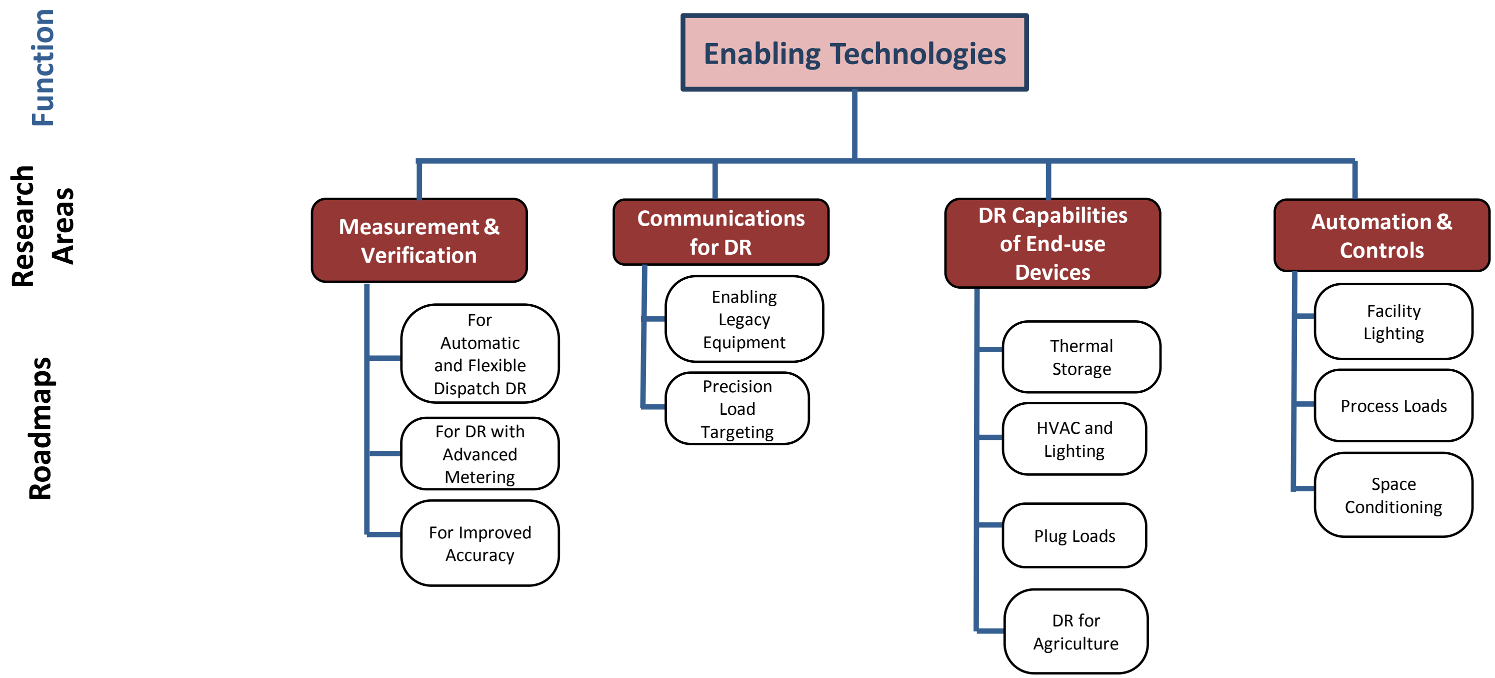
Assumptions:

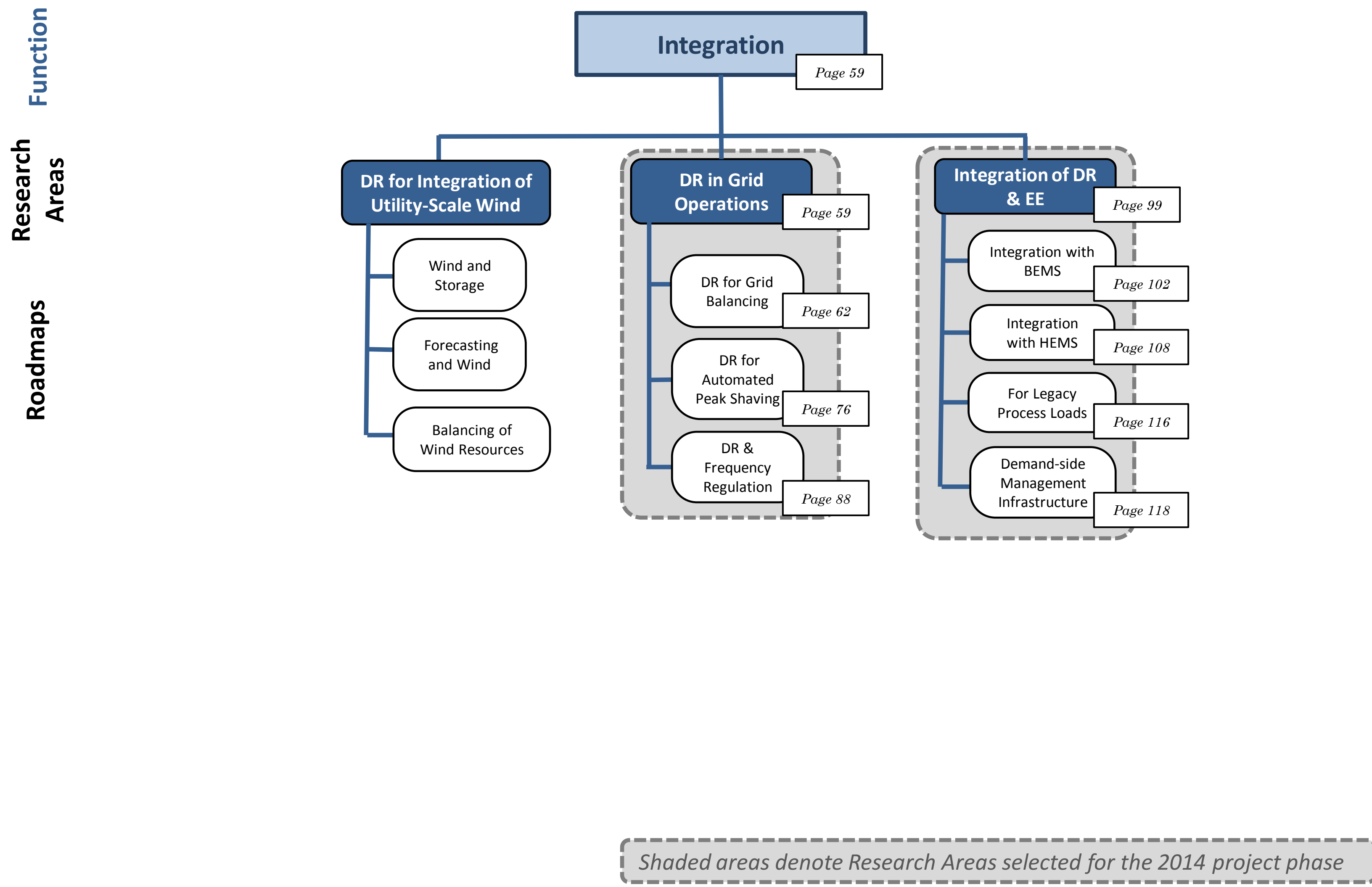
- This is a DRAFT diagram to aid in conceptualization; titles and content of specific research areas are to be defined by DR experts.
- In certain DR applications, non-technology requirements may be more of a priority; pursuit of these requirements falls outside the purview of the DR Technology Roadmap.
- Within the DR Technology Roadmap, non-technology requirements may very well be critical Drivers or present important Capability Gaps that can best be overcome by developing technologies (products or services).

Back to Table of Contents



Shading indicates Research Areas selected for the 2014 project phase


Function
Research Areas
Roadmaps
Enabling Technologies
Measurement & Verification
For Automatic and Flexible Dispatch DR
For DR with Advanced Metering
For Improved Accuracy
Communications for DR
Enabling Legacy Equipment
Precision Load Targeting
DR Capabilities of End-use Devices
Thermal Storage
HVAC and Lighting
Plug Loads
DR for Agriculture
Automation & Controls
Facility Lighting
Process Loads
Space Conditioning


Function
Research Areas
Roadmaps
Integration
Page 59
DR for Integration of Utility-Scale Wind
Wind and Storage
Forecasting and Wind
Balancing of Wind Resources
DR in Grid Operations
Page 59
DR for Grid Balancing
Page 62
DR for Automated Peak Shaving
Page 76
DR & Frequency Regulation
Page 88
Integration of DR & EE
Page 99
Integration with BEMS
Page 102
Integration with HEMS
Page 108
For Legacy Process Loads
Page 116
Demand-side Management Infrastructure
Page 118
Shaded areas denote Research Areas selected for the 2014 project phase

Definitions

The following definitions apply to some of the important specialized terms used throughout this roadmap.

Demand Response (DR): Changes in electric use by demand side resources from their normal consumption patterns in response to changes in the price of electricity, or to incentive payments designed to induce changes in consumption and/or when system reliability is jeopardized.[1]

Function: Planning

Technologies that facilitate, support, streamline, and otherwise enable and enhance transmission and generation planning.

DR in Transmission & Generation Planning involves the use of DR technologies in planning processes to address existing and forecast transmission and generation needs. These technologies assist grid operators in load management and enable improved system reliability and provide imbalance reserves. While providing improved system flexibility, they may also enable participation in energy imbalance markets.

Forecasting for DR involves technologies used to develop forecasts for day-ahead, hourly and sub-hourly system loads as well as balancing requirements for capacity. Examples include technologies that assist in pre-chilling and pre-heating for thermal storage, assisting in predictive control of DR assets, as well as providing improved responsiveness to month-ahead, day-ahead, or hour-ahead notification periods.

DR in Generation Capacity Planning involves the use of DR technologies in the generation capacity planning process to address BPA capacity needs, such as hydro-generation imbalance, and may also provide BPA grid operators with other ancillary services.

Function: Enabling Technologies

Technologies that enable demand response communication, controls, scheduling, confirmation, billing, and related activities.

Automation and Control for DR refers to technologies with the ability to respond dynamically to signals from the grid or grid operators to control loads (INCs or DECs). This includes DR enabled devices capable of responding to sub-hourly notification and devices that provide for automatic economic dispatch. These technologies increase customer engagement and provide reliable load reductions.

Communications for DR refers to the technologies and software protocols (BPA requires OPEN ADR2.0b) used to trigger, respond to and measure DR events. These technologies enable load augmentation in response to peak demands including technologies that are smart

[1] This operational definition of demand response is the same definition the Federal Energy Regulatory Commission uses; see "National Assessment & Action Plan on Demand Response," Feb. 2013, https://www.ferc.gov/industries/electric/indus-act/demand-response/dr-potential.asp, accessed June 20, 2014.

meter enabled. Utilizing two-way communications these technologies enable assets to provide additional capacity. These devices provide for cyber-secure economic dispatch and can facilitate participation in energy imbalance markets.

DR Capability of End Use Devices refers to technologies that respond to dynamic signals from the grid or grid operators to control loads (INCs or DECs) such as DR-enabled automatic lighting controls, automated thermostats, and devices for both electrical and thermal energy storage.

Measurement and Verification for DR refers to the technologies and protocols using the OPEN ADR 2.0b framework to measure and verify the load reductions or increases (INC/DEC) dispatched during a DR event, in comparison with an established energy use baseline at a site or aggregation of sites. Examples include technologies that provide measurement and verification of DR events and event participation rates in addition to devices to assist in accurate DR event settlements.

Function: Integration

Technologies that enable the integration of other components, systems, software, generation assets to facilitate demand response.

DR in Grid Operations refers to the technologies that can enable DR in response to load forecasts or dynamic grid energy or capacity requirements to allow system operators to respond to generation imbalances and increase system flexibility. These technologies typically involve a DR management system that is also useful for grid regulation. This definition applies to real-time, hour-ahead, and day-ahead time horizons.

DR for Integration of Utility Scale Wind refers to the use of DR technologies in addressing hydro-generation imbalances associated with oversupply of wind energy. These technologies assist in addressing generation oversupply and intermittent generation and provide grid regulation services that aid in wind integration.

Integration of DR and Energy Efficiency (EE) involves technologies used at a site or group of sites to maximize energy efficiency and enable demand response. These can include integrated home and business energy management systems that enable DR and provide a real-time determination of available capacity, automatic lighting controls, and automated thermostats and plug load controls.

Planning

Demand Response in Transmission and Generation Planning

Research Area Definition

DR in Transmission & Generation Planning involves the use of DR technologies in planning processes to address existing and forecast transmission and generation needs. These technologies assist grid operators in load management and enable improved system reliability and provide imbalance reserves. While providing improved system flexibility, they may also enable participation in energy imbalance markets.

DR as Non-Wires Solution to Grid Congestion

The group discussed constraints in existing generation and transmission systems and technologies. Several platforms were discussed; one was a CO_2-based dispatch which requires a production cost model. This allows you to optimize for CO_2 emissions rather than, post-hoc analysis of the CO_2 emissions.

DR and Energy Storage

For system operations the key to optimal aggregation and dispatch is to have direct experience with DR programs that have that show DR as a consistent and dependable resource. Once operators learn that a DR resource that can be there and is as available as a traditional generation resource, you greatly increase the likelihood of its use.

Another area identified for study would be a method for valuing the inherent capability of demand response resources or even a hydro resource. We need to determine a value for capacity resources. In the NW without a capacity market it's difficult to quantify that value. So we need to determine a value for the flexibility which also includes the value of the aggregated attributes. If you can get more flexibility out of a DR program, then you should receive a premium to a generation resource that can't move. With DR for large industrial loads you can have a guaranteed response, you know your loads really well, you know your process and you know how you can change it. If operators are sending out an Internet signal to an aggregator to cycle down some thermostats or water heaters then typically what's going to happen is that they're going to bid a very conservative amount into the capacity market.

System operators want to make sure they get the value of the total response into the transactions they're making. Currently, many DR programs are not going to have a tightly defined megawatt value for their response, but in a capacity market bid they probably would need to ensure at least fifty percent of what their total response would be. So if the

Back to Table of Contents

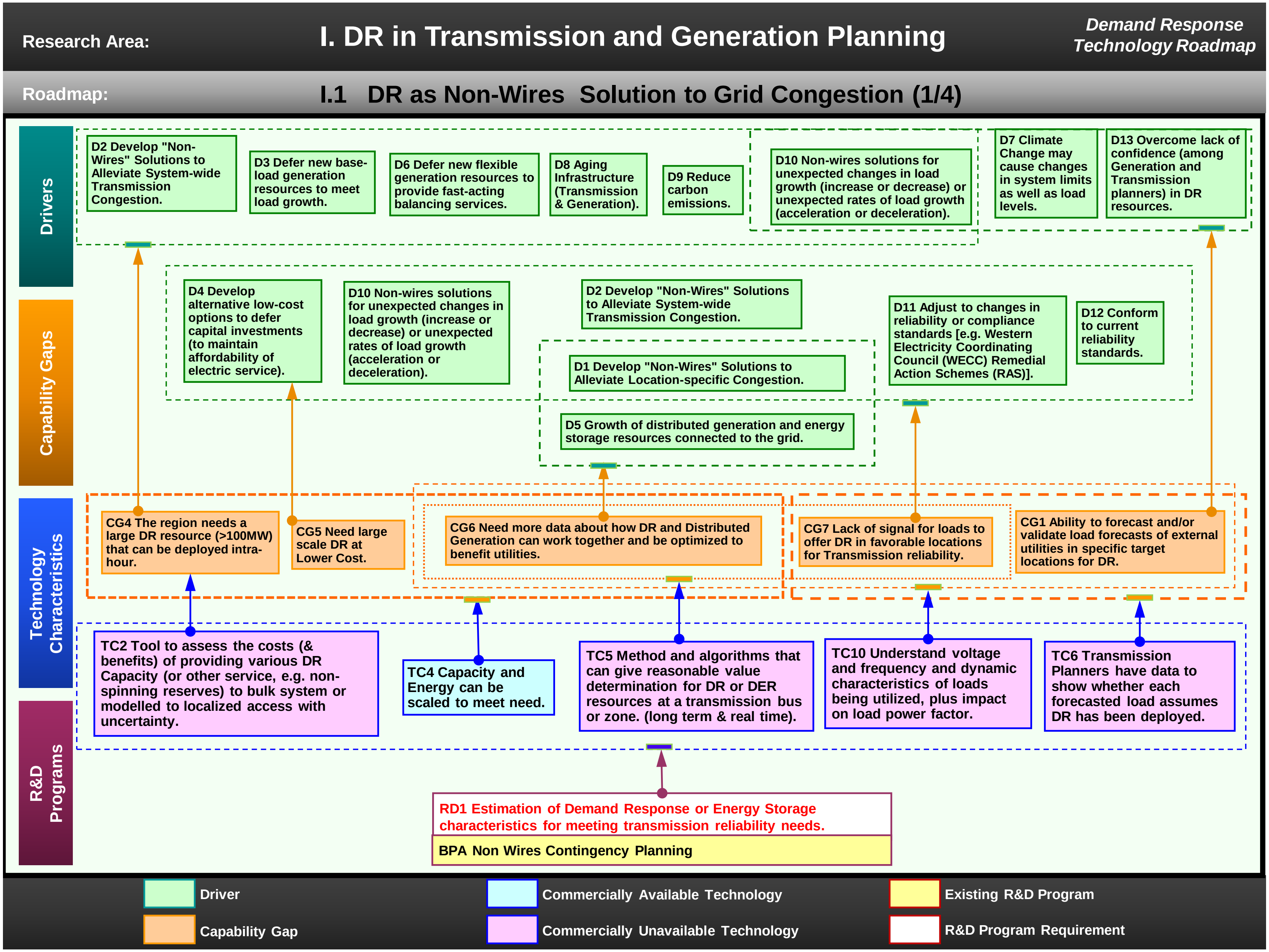
roadmap actually specifies that, then service providers designing their DR programs would take these technical requirements into account.

DR for System Balancing and Flexibility.

This topic is under the DR in Capacity Planning Research Area. However, it wasn't clear how increased DR flexibility could be addressed. The question is how do you make these decisions well in advance of actually procuring and operating the resources, and once again the participants had to allow the drivers and the capability gaps to determine what they were going to examine. In the capacity planning area, we need a scoping study that displays the amount of DR that's available, which could then be used for balancing or flexibility. Without this type of study planners wouldn't know how much DR to acquire.

The insights and observations above were distilled from the input of the following subject matter experts who participated in Workshop 2:

- Diane Broad (Oregon Department of Energy)
- Frank Brown (Bonneville Power Administration)
- Anders Johnson (Bonneville Power Administration)
- John Wang (ABB)
- Rob Pratt (Pacific Northwest National Laboratory)
- Aidan Tuohy (Electric Power Research Institute)


Research Area:
I. DR in Transmission and Generation Planning
Demand Response Technology Roadmap
Roadmap:
I.1 DR as Non-Wires Solution to Grid Congestion (1/4)
Drivers
D2 Develop "Non-Wires" Solutions to Alleviate System-wide Transmission Congestion.
D3 Defer new base-load generation resources to meet load growth.
D6 Defer new flexible generation resources to provide fast-acting balancing services.
D8 Aging Infrastructure (Transmission & Generation).
D9 Reduce carbon emissions.
D10 Non-wires solutions for unexpected changes in load growth (increase or decrease) or unexpected rates of load growth (acceleration or deceleration).
D7 Climate Change may cause changes in system limits as well as load levels.
D13 Overcome lack of confidence (among Generation and Transmission planners) in DR resources.
Capability Gaps
D4 Develop alternative low-cost options to defer capital investments (to maintain affordability of electric service).
D10 Non-wires solutions for unexpected changes in load growth (increase or decrease) or unexpected rates of load growth (acceleration or deceleration).
D2 Develop "Non-Wires" Solutions to Alleviate System-wide Transmission Congestion.
D1 Develop "Non-Wires" Solutions to Alleviate Location-specific Congestion.
D11 Adjust to changes in reliability or compliance standards [e.g. Western Electricity Coordinating Council (WECC) Remedial Action Schemes (RAS)].
D12 Conform to current reliability standards.
D5 Growth of distributed generation and energy storage resources connected to the grid.
Technology Characteristics
CG4 The region needs a large DR resource (>100MW) that can be deployed intra-hour.
CG5 Need large scale DR at Lower Cost.
CG6 Need more data about how DR and Distributed Generation can work together and be optimized to benefit utilities.
CG7 Lack of signal for loads to offer DR in favorable locations for Transmission reliability.
CG1 Ability to forecast and/or validate load forecasts of external utilities in specific target locations for DR.
TC2 Tool to assess the costs (& benefits) of providing various DR Capacity (or other service, e.g. non-spinning reserves) to bulk system or modelled to localized access with uncertainty.
TC4 Capacity and Energy can be scaled to meet need.
TC5 Method and algorithms that can give reasonable value determination for DR or DER resources at a transmission bus or zone. (long term & real time).
TC10 Understand voltage and frequency and dynamic characteristics of loads being utilized, plus impact on load power factor.
TC6 Transmission Planners have data to show whether each forecasted load assumes DR has been deployed.
R&D Programs
RD1 Estimation of Demand Response or Energy Storage characteristics for meeting transmission reliability needs.
BPA Non Wires Contingency Planning
Driver
Capability Gap
Commercially Available Technology
Commercially Unavailable Technology
Existing R&D Program
R&D Program Requirement

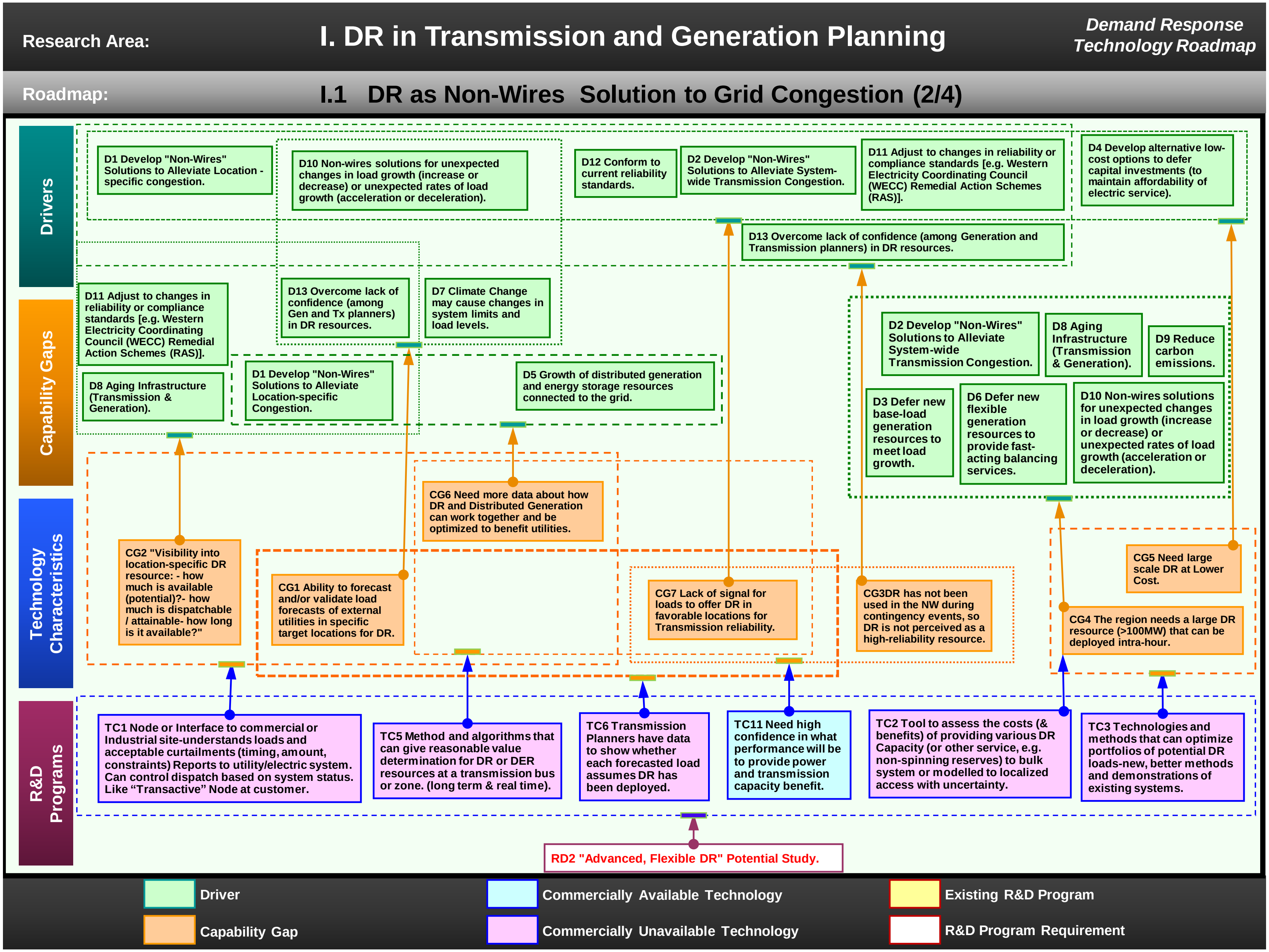
Estimation of Demand Response or Energy Storage characteristics for meeting transmission reliability needs. This program would provide better algorithms and simulation tools to system planners to estimate the duration and frequency of DR/storage need in addition to the peak magnitude for maintaining transmission reliability. This would complement existing planning tools that focus on the most severe hour of a season. It would also estimate the locational benefits for load areas and transmission paths.

Existing research: BPA Non Wire Contingency Planning.

- Details of existing research pending.

Key research questions:

1. How can the duration and frequency (hours per year, hours per event) of DR/ES be precisely estimated from available planning data (power flow base cases, historical usage data, load forecasts, security constrained economic dispatch cases, etc.?


Research Area:
I. DR in Transmission and Generation Planning
Demand Response Technology Roadmap
Roadmap:
I.1 DR as Non-Wires Solution to Grid Congestion (2/4)
Drivers
Capability Gaps
Technology Characteristics
R&D Programs
D1 Develop "Non-Wires" Solutions to Alleviate Location - specific congestion.
D10 Non-wires solutions for unexpected changes in load growth (increase or decrease) or unexpected rates of load growth (acceleration or deceleration).
D12 Conform to current reliability standards.
D2 Develop "Non-Wires" Solutions to Alleviate System-wide Transmission Congestion.
D11 Adjust to changes in reliability or compliance standards [e.g. Western Electricity Coordinating Council (WECC) Remedial Action Schemes (RAS)].
D4 Develop alternative low-cost options to defer capital investments (to maintain affordability of electric service).
D13 Overcome lack of confidence (among Generation and Transmission planners) in DR resources.
D11 Adjust to changes in reliability or compliance standards [e.g. Western Electricity Coordinating Council (WECC) Remedial Action Schemes (RAS)].
D13 Overcome lack of confidence (among Gen and Tx planners) in DR resources.
D7 Climate Change may cause changes in system limits and load levels.
D8 Aging Infrastructure (Transmission & Generation).
D1 Develop "Non-Wires" Solutions to Alleviate Location-specific Congestion.
D5 Growth of distributed generation and energy storage resources connected to the grid.
D2 Develop "Non-Wires" Solutions to Alleviate System-wide Transmission Congestion.
D8 Aging Infrastructure (Transmission & Generation).
D9 Reduce carbon emissions.
D3 Defer new base-load generation resources to meet load growth.
D6 Defer new flexible generation resources to provide fast-acting balancing services.
D10 Non-wires solutions for unexpected changes in load growth (increase or decrease) or unexpected rates of load growth (acceleration or deceleration).
CG6 Need more data about how DR and Distributed Generation can work together and be optimized to benefit utilities.
CG2 "Visibility into location-specific DR resource: - how much is available (potential)?- how much is dispatchable / attainable- how long is it available?"
CG1 Ability to forecast and/or validate load forecasts of external utilities in specific target locations for DR.
CG7 Lack of signal for loads to offer DR in favorable locations for Transmission reliability.
CG3DR has not been used in the NW during contingency events, so DR is not perceived as a high-reliability resource.
CG5 Need large scale DR at Lower Cost.
CG4 The region needs a large DR resource (>100MW) that can be deployed intra-hour.
TC1 Node or Interface to commercial or Industrial site-understands loads and acceptable curtailments (timing, amount, constraints) Reports to utility/electric system. Can control dispatch based on system status. Like "Transactive" Node at customer.
TC5 Method and algorithms that can give reasonable value determination for DR or DER resources at a transmission bus or zone. (long term & real time).
TC6 Transmission Planners have data to show whether each forecasted load assumes DR has been deployed.
TC11 Need high confidence in what performance will be to provide power and transmission capacity benefit.
TC2 Tool to assess the costs (& benefits) of providing various DR Capacity (or other service, e.g. non-spinning reserves) to bulk system or modelled to localized access with uncertainty.
TC3 Technologies and methods that can optimize portfolios of potential DR loads-new, better methods and demonstrations of existing systems.
RD2 "Advanced, Flexible DR" Potential Study.
Driver
Capability Gap
Commercially Available Technology
Commercially Unavailable Technology
Existing R&D Program
R&D Program Requirement

"Advanced, Flexible DR" Potential Study. Analyze how much "DR" is avail in a geographic area. But, not just traditional peak-load DR. Flexible load management for balancing and quick response include an analysis of aggregation optimization.

Existing research: None identified.

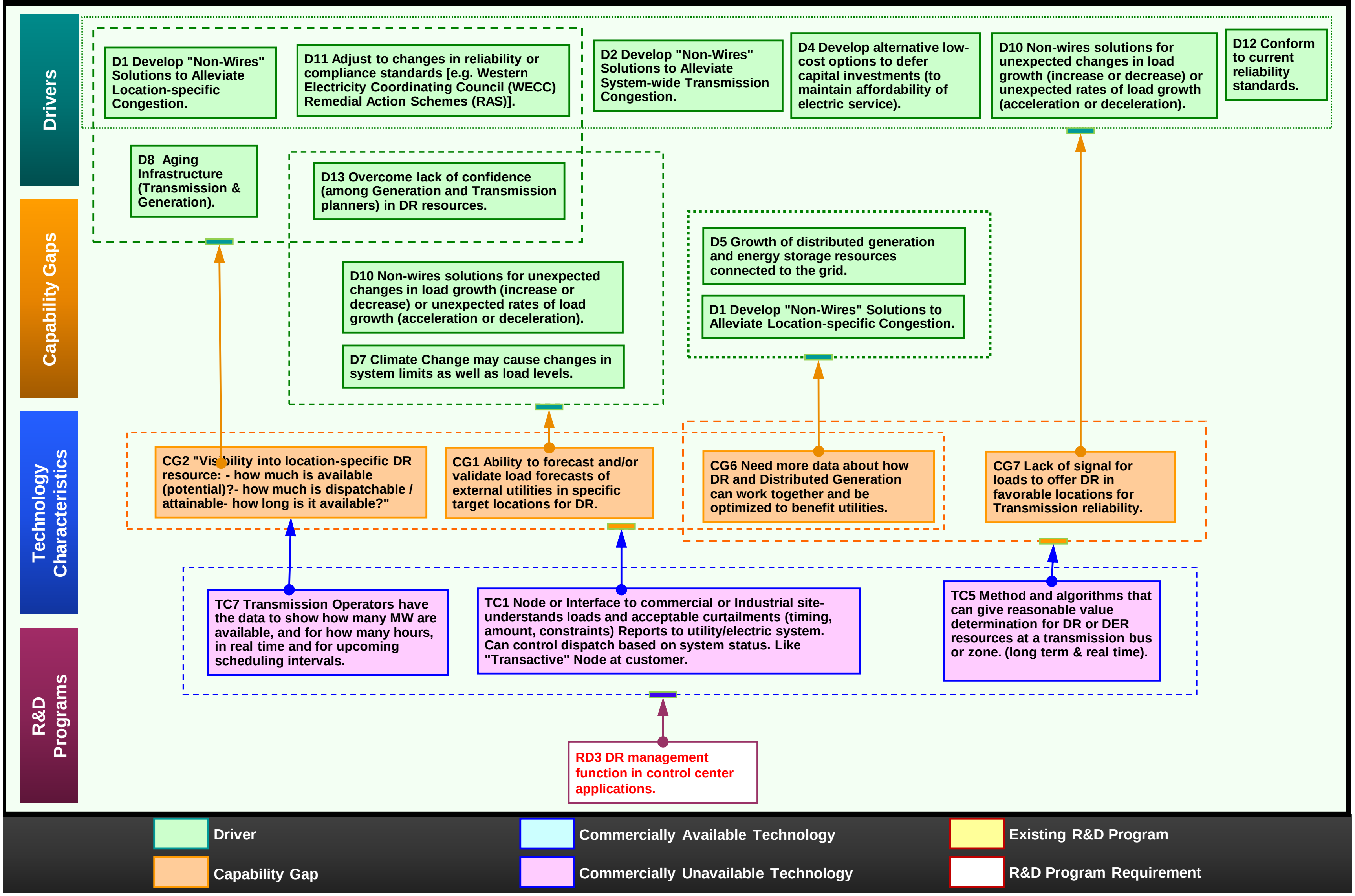
Key research questions:

1. Characterize types of loads and what flexible services they can provide (e.g. water treatment pump provide regulation).
2. Understand accepted uses (hours of dispatch, constraints for different customer types (canonical).
3. Assess technical, economic and market potential for different flexibility services (e.g. Spring Peak "absorption" vs non-spin capacity).
4. Economic Potential requires cost effectiveness and uncertainty analysis.
5. Develop supply curve (with uncertainty) for different services.

Research Area: **I. DR in Transmission and Generation Planning**

Demand Response Technology Roadmap

Roadmap: **I.1 DR as Non-Wires Solution to Grid Congestion (3/4)**



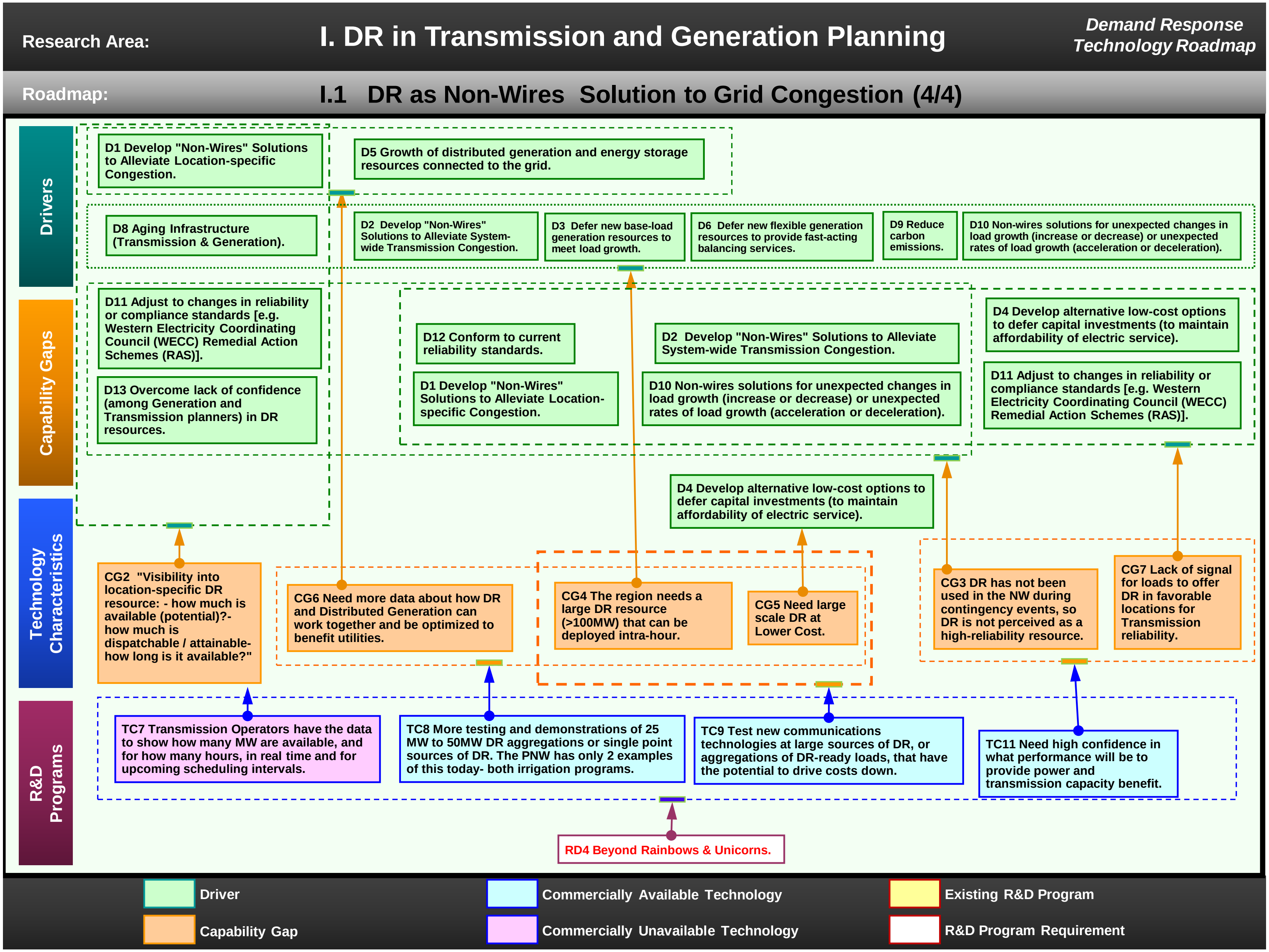
R&D Program Summaries

DR management function in control center applications. An optimization algorithm that can take into consideration conventional and DR resources, their current status and forecasted uncertainties, as well as forecasted loads to minimize the system costs (nuclear generation). The algorithm has to be formulated and validated using real system data.

Existing research: None identified.

Key research questions:

1. How to model and mitigate the effect of DR resource forecasting uncertainties?
2. How to get the required data into the place so that the algorithm can use them?
3. How to design a DR data model, when mandated, the users are willing to provide the data while ensure the data quality (reliability)?
4. How to design the optimization algorithm to ensure the performance under extreme system conditions?



Research Area:
I. DR in Transmission and Generation Planning
Demand Response Technology Roadmap
Roadmap:
I.1 DR as Non-Wires Solution to Grid Congestion (4/4)
Drivers
Capability Gaps
Technology Characteristics
R&D Programs
D1 Develop "Non-Wires" Solutions to Alleviate Location-specific Congestion.
D5 Growth of distributed generation and energy storage resources connected to the grid.
D8 Aging Infrastructure (Transmission & Generation).
D2 Develop "Non-Wires" Solutions to Alleviate System-wide Transmission Congestion.
D3 Defer new base-load generation resources to meet load growth.
D6 Defer new flexible generation resources to provide fast-acting balancing services.
D9 Reduce carbon emissions.
D10 Non-wires solutions for unexpected changes in load growth (increase or decrease) or unexpected rates of load growth (acceleration or deceleration).
D11 Adjust to changes in reliability or compliance standards [e.g. Western Electricity Coordinating Council (WECC) Remedial Action Schemes (RAS)].
D13 Overcome lack of confidence (among Generation and Transmission planners) in DR resources.
D12 Conform to current reliability standards.
D2 Develop "Non-Wires" Solutions to Alleviate System-wide Transmission Congestion.
D1 Develop "Non-Wires" Solutions to Alleviate Location-specific Congestion.
D10 Non-wires solutions for unexpected changes in load growth (increase or decrease) or unexpected rates of load growth (acceleration or deceleration).
D4 Develop alternative low-cost options to defer capital investments (to maintain affordability of electric service).
D11 Adjust to changes in reliability or compliance standards [e.g. Western Electricity Coordinating Council (WECC) Remedial Action Schemes (RAS)].
D4 Develop alternative low-cost options to defer capital investments (to maintain affordability of electric service).
CG2 "Visibility into location-specific DR resource: - how much is available (potential)?- how much is dispatchable / attainable- how long is it available?"
CG6 Need more data about how DR and Distributed Generation can work together and be optimized to benefit utilities.
CG4 The region needs a large DR resource (>100MW) that can be deployed intra-hour.
CG5 Need large scale DR at Lower Cost.
CG3 DR has not been used in the NW during contingency events, so DR is not perceived as a high-reliability resource.
CG7 Lack of signal for loads to offer DR in favorable locations for Transmission reliability.
TC7 Transmission Operators have the data to show how many MW are available, and for how many hours, in real time and for upcoming scheduling intervals.
TC8 More testing and demonstrations of 25 MW to 50MW DR aggregations or single point sources of DR. The PNW has only 2 examples of this today- both irrigation programs.
TC9 Test new communications technologies at large sources of DR, or aggregations of DR-ready loads, that have the potential to drive costs down.
TC11 Need high confidence in what performance will be to provide power and transmission capacity benefit.
RD4 Beyond Rainbows & Unicorns.
Driver
Capability Gap
Commercially Available Technology
Commercially Unavailable Technology
Existing R&D Program
R&D Program Requirement

R&D Program Summaries

Beyond Rainbows & Unicorns. Test and demonstrate single - point DR resource or aggregated DR resources at the scale of 25 MW to 50 MW (or higher).

Existing research: None identified.

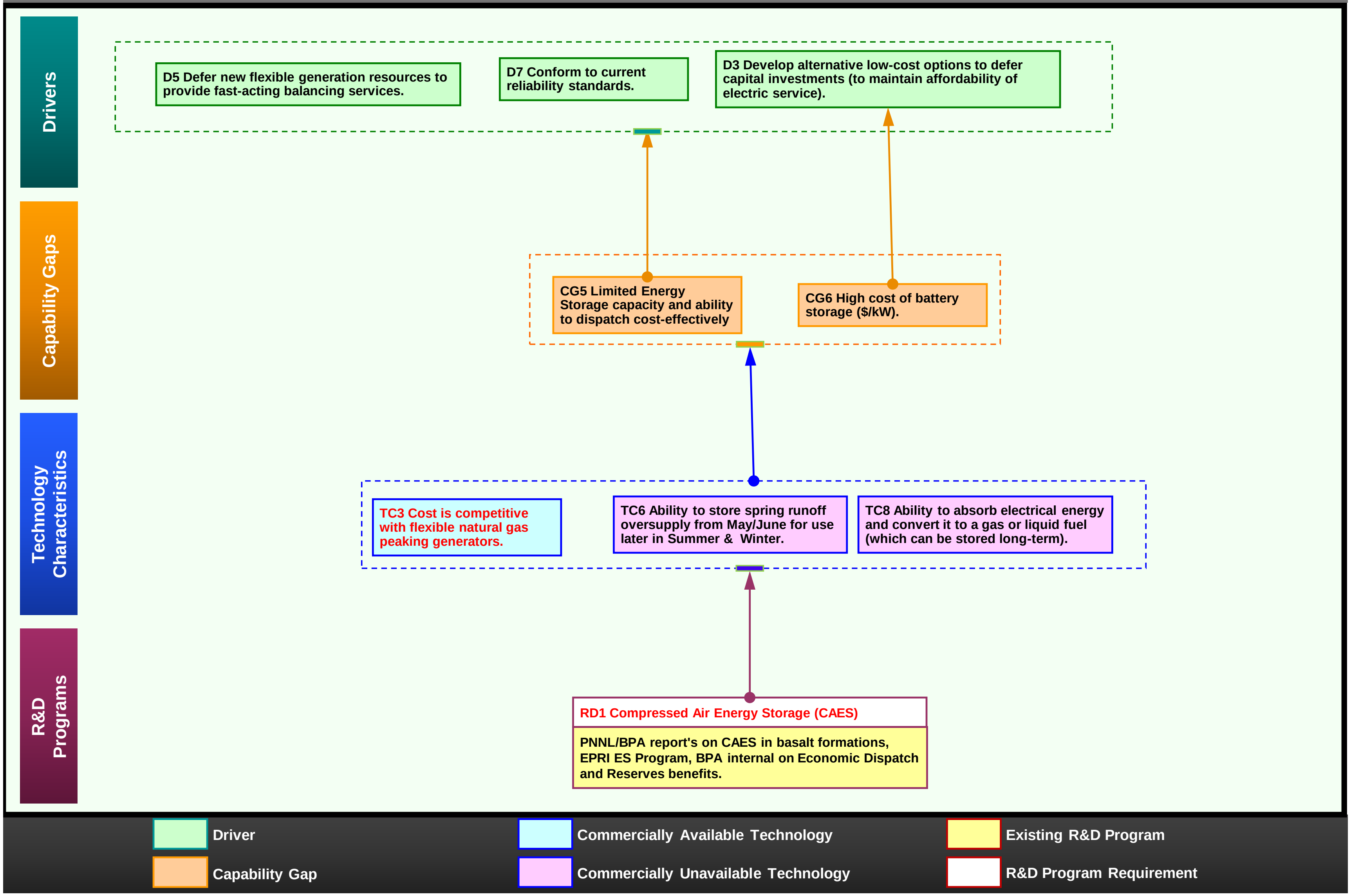
Key research questions:

1. What is the capacity benefit - both power and transmission? Define the confidence interval.
2. Is the load visible to the control center operators? Are we moving the needle on the dashboard?
3. Seek continuous cost reductions in the communications technology.
4. What are alternative financing and contracting mechanisms to ensure profitable implementation?
5. Prove locational value of the DR resource.

Research Area: **I. DR in Transmission and Generation Planning**

Demand Response Technology Roadmap

Roadmap: **I.2 DR & Energy Storage (1/3)**



R&D Program Summaries

Compressed Air Energy Storage (CAES). Analyze the feasibility and estimate the benefits of CAES for economic dispatch, capacity, and ancillary services.

Existing research: PNNL/BPA report's on CAES in basalt formations, EPRI ES Program, BPA internal on Economic Dispatch and Reserves benefits.

- Details of existing research pending.

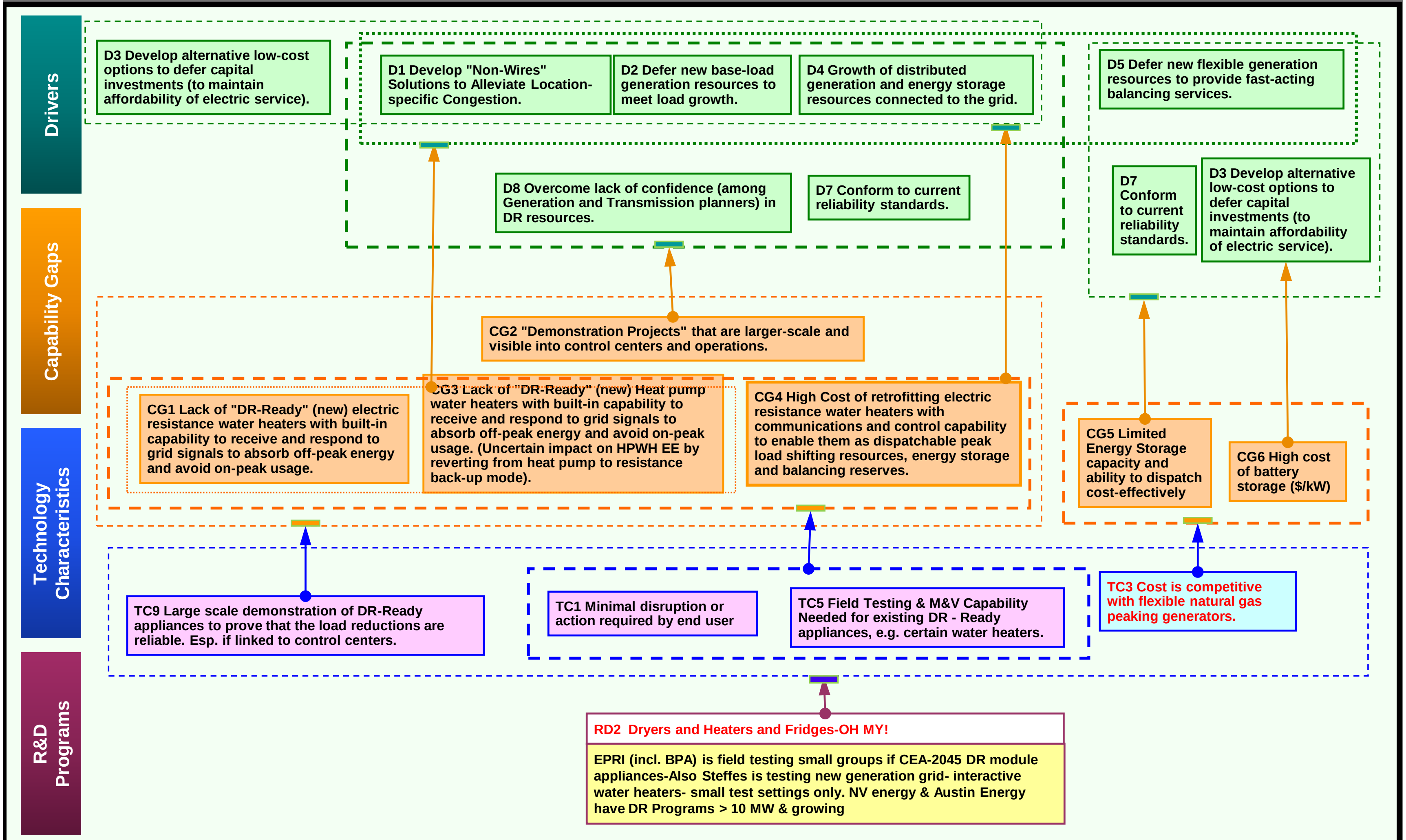
Key research questions:

1. Is CAES cost effective compared with traditional flexible natural gas fired peakers and battery storage.
2. How could pumping and storing algorithms be optimized to address multiple uses with differing time horizons.
3. How could the volatility reduction benefit of storage be more accurately estimated looking at future time periods?

Research Area: **I. DR in Transmission and Generation Planning**

Demand Response Technology Roadmap

Roadmap: **I.2 DR & Energy Storage (2/3)**



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

Back to Table of Contents

R&D Program Summaries

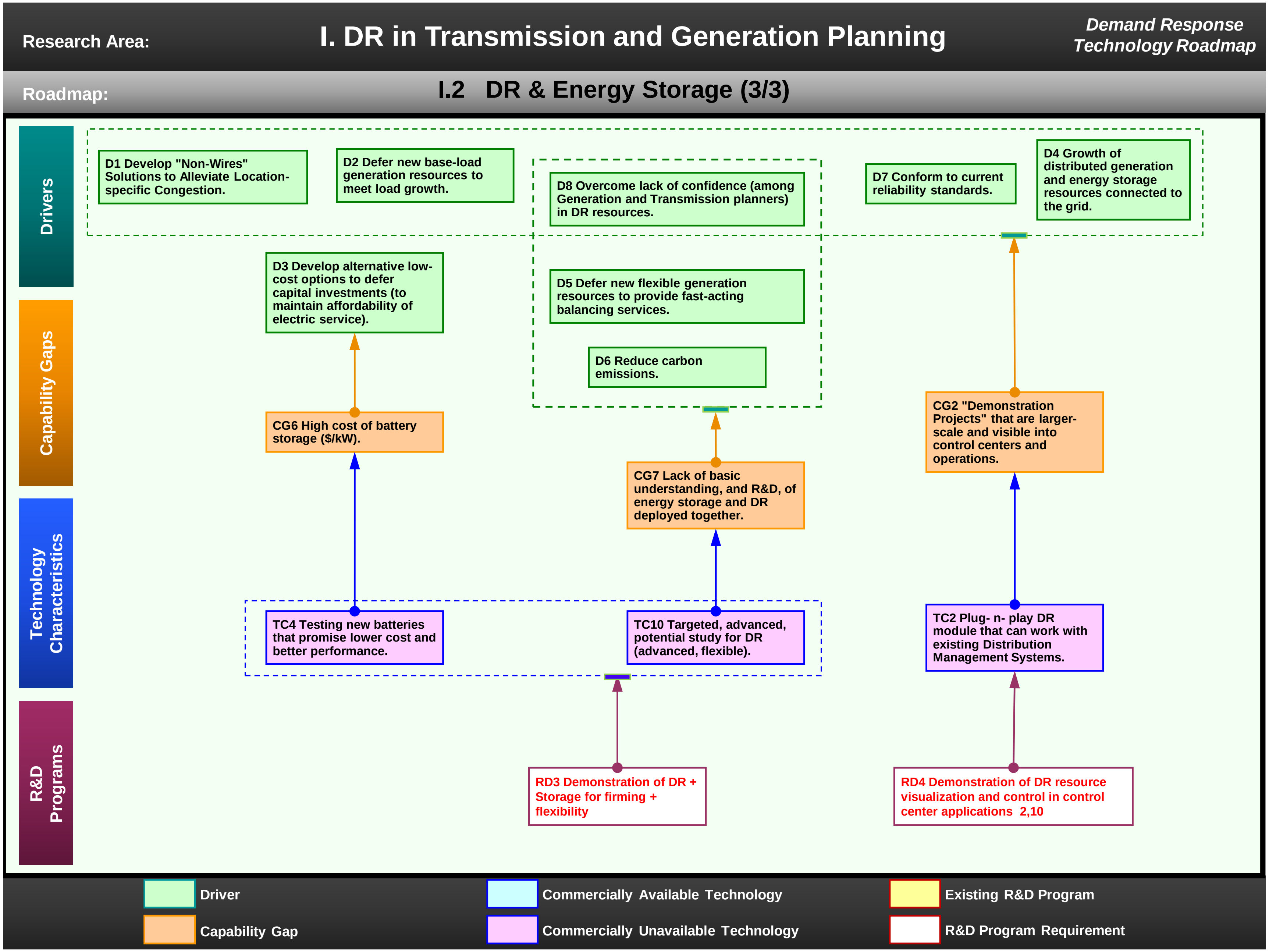
Dryers and Heaters and Fridges-OH MY! Large-scale demonstration of DR-ready appliances. Focus on residential and commercial loads with capability to deliver DR with minimal disruption or action required by the end user. Demo of > 5 MW, visible in the system control center.

Existing research: EPRI (incl. BPA) is field testing small groups if CEA-2045 DR module appliances-Also Steffes is testing new generation grid-interactive water heaters- small test settings only. NV energy & Austin Energy have DR Programs > 10 MW & growing.

- Details of existing research pending.

Key research questions:

1. What types of loads are commercially available as DR-ready, and what are the load characteristics? (on at peak? How flexible? thermal storage?)
2. Do the devices provide reliable DR, as seen at the distribution and transmission level?
3. Are DR-ready appliances truly usable "out of the box"? Verify communications and adequate M&V.
4. How do the control center operators view the resource? How often is it deployed? All 5 MW, or larger blocks?
5. What is the cost and what services are provided to the regional grid? Is this resource competitive with natural gas peaker?



Research Area:
I. DR in Transmission and Generation Planning
Demand Response Technology Roadmap
Roadmap:
I.2 DR & Energy Storage (3/3)
Drivers
Capability Gaps
Technology Characteristics
R&D Programs
D1 Develop "Non-Wires" Solutions to Alleviate Location-specific Congestion.
D2 Defer new base-load generation resources to meet load growth.
D8 Overcome lack of confidence (among Generation and Transmission planners) in DR resources.
D7 Conform to current reliability standards.
D4 Growth of distributed generation and energy storage resources connected to the grid.
D3 Develop alternative low-cost options to defer capital investments (to maintain affordability of electric service).
D5 Defer new flexible generation resources to provide fast-acting balancing services.
D6 Reduce carbon emissions.
CG6 High cost of battery storage ($/kW).
CG7 Lack of basic understanding, and R&D, of energy storage and DR deployed together.
CG2 "Demonstration Projects" that are larger-scale and visible into control centers and operations.
TC4 Testing new batteries that promise lower cost and better performance.
TC10 Targeted, advanced, potential study for DR (advanced, flexible).
TC2 Plug- n- play DR module that can work with existing Distribution Management Systems.
RD3 Demonstration of DR + Storage for firming + flexibility
RD4 Demonstration of DR resource visualization and control in control center applications 2,10
Driver
Capability Gap
Commercially Available Technology
Commercially Unavailable Technology
Existing R&D Program
R&D Program Requirement

R&D Program Summaries

Demonstration of DR + Storage for firming + flexibility. Optimize amount of DR vs Storage to get cost effective resource at higher/acceptable reliability.

Existing research: None identified.

Key research questions:

1. Test new battery technology
2. Control algorithm to coordinate
3. Examine performance for different services → peak, energy absorption, balancing, and frequency response.
4. Examine reliability & cost effectiveness.

Demonstration of DR resource visualization and control in control center applications. Link a distribution utility's DMS with BPA's control center in terms of DR information and control signal. Demonstrate the engineering process is easy and streamlined. Demonstrate the integration works.

Existing research: None identified.

Key research questions:

1. Standard protocol or appropriatory protocol, which one is more secure and easy to engineer?
2. Is the visualization of the DR information acceptable to operators?
3. What's the minimum amount of data have to be transferred between the DMS and BPA control center application?

DEMAND RESPONSE IN GENERATION CAPACITY PLANNING

Research Area Definition

DR in Generation Capacity Planning involves the use of DR technologies in the generation capacity planning process to address BPA capacity needs. These technologies address hydro-generation imbalance and may provide BPA grid operators with other ancillary services.

Mitigation of Constraints in Other Generation & Transmission Technologies

Participants in this area were interested in research to better understand the potential CO2 emission impacts from the substitution of DR for balancing reserves as opposed to new fossil generation. This research could also be part of a process to determine an environmental dispatch algorithm that when combined with production cost models could facilitate DR dispatch as well as potential CO2 reductions from the use of DR. Additional research on the valuation of flexible DR as related to long-term capacity planning was also identified.

DR for System Balancing & Flexibility

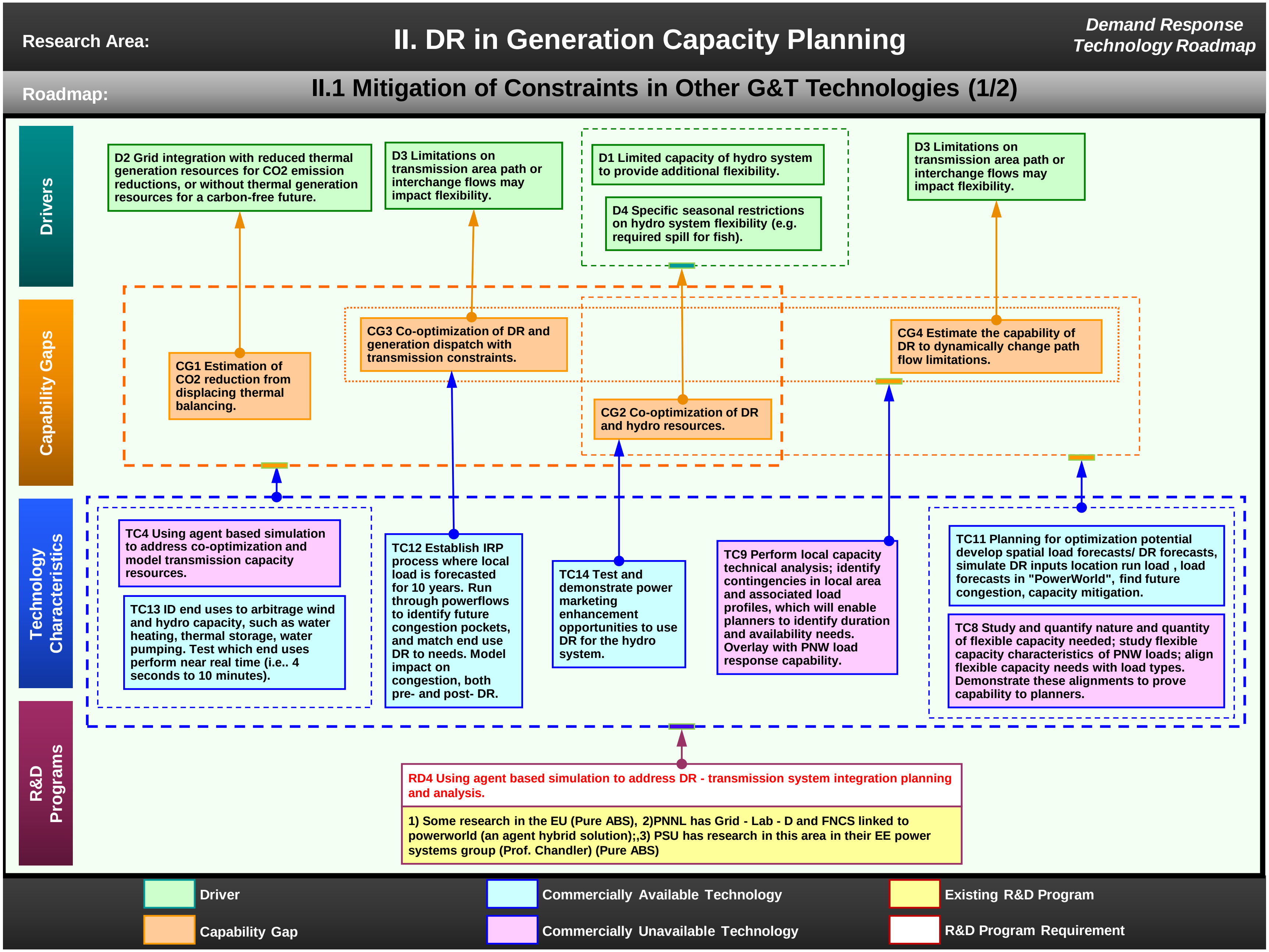
Here twenty- year estimations of DR potentials incorporating summer and winter peak demands as well as the balancing requirements for the NW wind fleet were of interest. Also of interest were studies to determine the extent to which DR resource diversity impacts reliability. Participant research requests also involved communication platforms to measure both the reliability of DR assets and the potential interactions with distributed generation. In particular, the possibility of expanding ICCP to deliver cogent exchange of DR data between BA control centers. For capacity planning purposes the ability to demonstrate DR reliability over time across the transmission grid was determined to be of value.

Optimal Aggregation and Dispatch

Participants were interested in research involving the use of DR to simulate energy storage for energy (KWh) and capacity (KW) including round-trip efficiencies as well as DR assets used sequentially to produce combined effects that single DR assets couldn't produce. Other technology needs identified include technologies to monitor and measure DR asset availability to allow multi-tenancy use of DR assets while avoiding temporal conflicts by either the utility or BPA. Another need identified by participants was a time-series simulation of the NW grid, including transmission power flows, generation dispatch as well as a DR end-use resource model for improved visibility of dispatched DR assets. The need for research to determine the locational marginal value of regional DR resources based on topology and power flows as well the ability to create algorithms designed to meet BPA operational objectives was identified. Determining the economic value of DR to both BPA and the local distribution benefits was also of interest to workshop participants. For transmission planners, research on the use of DR for increasing Available Transfer Capability and as a Remedial Action Scheme is also desirable.

The insights and observations above were distilled from the input of the following subject matter experts who participated in Workshop 2:

- Shawn Chandler (Bonneville Power Administration)
- Erik Gilbert (Navigant)
- John Goodin (California Independent System Operator)
- Ben Kujala (Northwest Power and Conservation Council)
- Tom Osterhus (Integral Analytics)
- Omar Siddiqui (Electric Power Research Institute)


Research Area:
II. DR in Generation Capacity Planning
Demand Response Technology Roadmap
Roadmap:
II.1 Mitigation of Constraints in Other G&T Technologies (1/2)
Drivers
Capability Gaps
Technology Characteristics
R&D Programs
D2 Grid integration with reduced thermal generation resources for CO2 emission reductions, or without thermal generation resources for a carbon-free future.
D3 Limitations on transmission area path or interchange flows may impact flexibility.
D1 Limited capacity of hydro system to provide additional flexibility.
D4 Specific seasonal restrictions on hydro system flexibility (e.g. required spill for fish).
D3 Limitations on transmission area path or interchange flows may impact flexibility.
CG1 Estimation of CO2 reduction from displacing thermal balancing.
CG3 Co-optimization of DR and generation dispatch with transmission constraints.
CG2 Co-optimization of DR and hydro resources.
CG4 Estimate the capability of DR to dynamically change path flow limitations.
TC4 Using agent based simulation to address co-optimization and model transmission capacity resources.
TC13 ID end uses to arbitrage wind and hydro capacity, such as water heating, thermal storage, water pumping. Test which end uses perform near real time (i.e.. 4 seconds to 10 minutes).
TC12 Establish IRP process where local load is forecasted for 10 years. Run through powerflows to identify future congestion pockets, and match end use DR to needs. Model impact on congestion, both pre- and post- DR.
TC14 Test and demonstrate power marketing enhancement opportunities to use DR for the hydro system.
TC9 Perform local capacity technical analysis; identify contingencies in local area and associated load profiles, which will enable planners to identify duration and availability needs. Overlay with PNW load response capability.
TC11 Planning for optimization potential develop spatial load forecasts/ DR forecasts, simulate DR inputs location run load , load forecasts in "PowerWorld", find future congestion, capacity mitigation.
TC8 Study and quantify nature and quantity of flexible capacity needed; study flexible capacity characteristics of PNW loads; align flexible capacity needs with load types. Demonstrate these alignments to prove capability to planners.
RD4 Using agent based simulation to address DR - transmission system integration planning and analysis.
1) Some research in the EU (Pure ABS), 2)PNNL has Grid - Lab - D and FNCS linked to powerworld (an agent hybrid solution);,3) PSU has research in this area in their EE power systems group (Prof. Chandler) (Pure ABS)
Driver
Capability Gap
Commercially Available Technology
Commercially Unavailable Technology
Existing R&D Program
R&D Program Requirement

R&D Program Summaries

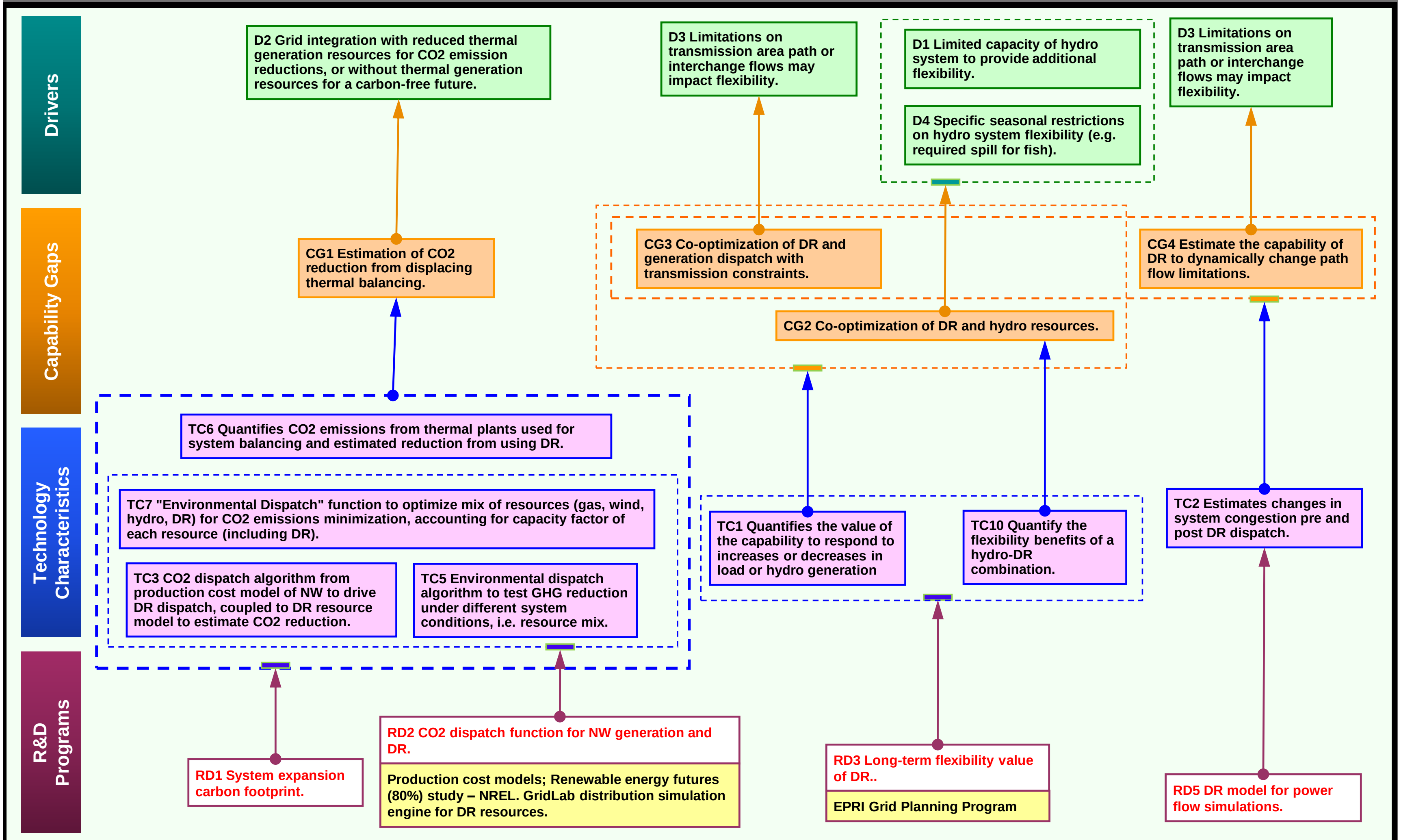
Using agent based simulation to address DR - transmission system integration planning and analysis. Study and identify loads and regional capacity needs to contrast with transmission planning studies and inform DR product needs.

Existing research: Some research in the European Union (Pure ABS). PNNL has GridLAB-D and FNCS linked to PowerWorld (an agent hybrid solution). Portland State University (PSU) has research in this area in their electrical engineering power systems group (Prof. Chandler) (Pure ABS).

- Details of existing research pending.

Key research questions:

1. Perform local capacity analysis, contingency and load profile dynamics with specific load types (agents) and time ranges (1 year, 3 years, 10 years).
2. Flexible capacity study – estimate maximum continuous ramping, regulation, and load-following needs by locality and time.
3. Over-generation: how much capacity do I need to address load consumption in an over-generation situation?
4. Study resource characteristics to address response time, duration, available start/stop constraints, and other non-linear characteristics to identify agent types and classifications for transmission system capacity products.
5. Address the effects of distribution system dynamics between localities in the transmission system flow model.



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

R&D Program Summaries

CO2 dispatch function for NW generation and DR. Environmental dispatch algorithm/function to combine with production cost models of NW generation to drive DR dispatch. Couple that to DR resource model to estimate CO2 displacement by DR.

Existing research: Production cost models. Renewable energy futures (80%) study – NREL. GridLAB-D simulation engine for DR resources.

- Details of existing research pending.

Key research questions:

1. What is the inherent CO2 displacement of the NW's (future) DR resource?
2. To what extent does this displacement vary as a function of configuration and use of DR resources?
3. If CO2 benefits were driving DR dispatch, how much larger would the benefit be?
4. How would that change the nature of the DR resource we want?
5. If we add in CO2 dispatch of all generation, how do the answers to 1- 4 (above) change?

Long-term flexibility value of DR. Study methods for valuing system flexibility attributes of DR for long-term capacity needs.

Existing research: EPRI Grid Planning Program.

- Details of existing research pending.

Key research questions:

1. How do you value the capability of load or generation to increase or decrease, separate from compensation for responding, e.g. in a capacity market setting?
2. How do you address fuel constraints for hydro in this value?

System expansion carbon footprint. How do system expansion and thermal plant construction decisions impact future CO_2 emissions?

Existing research: None identified.

Key research questions:

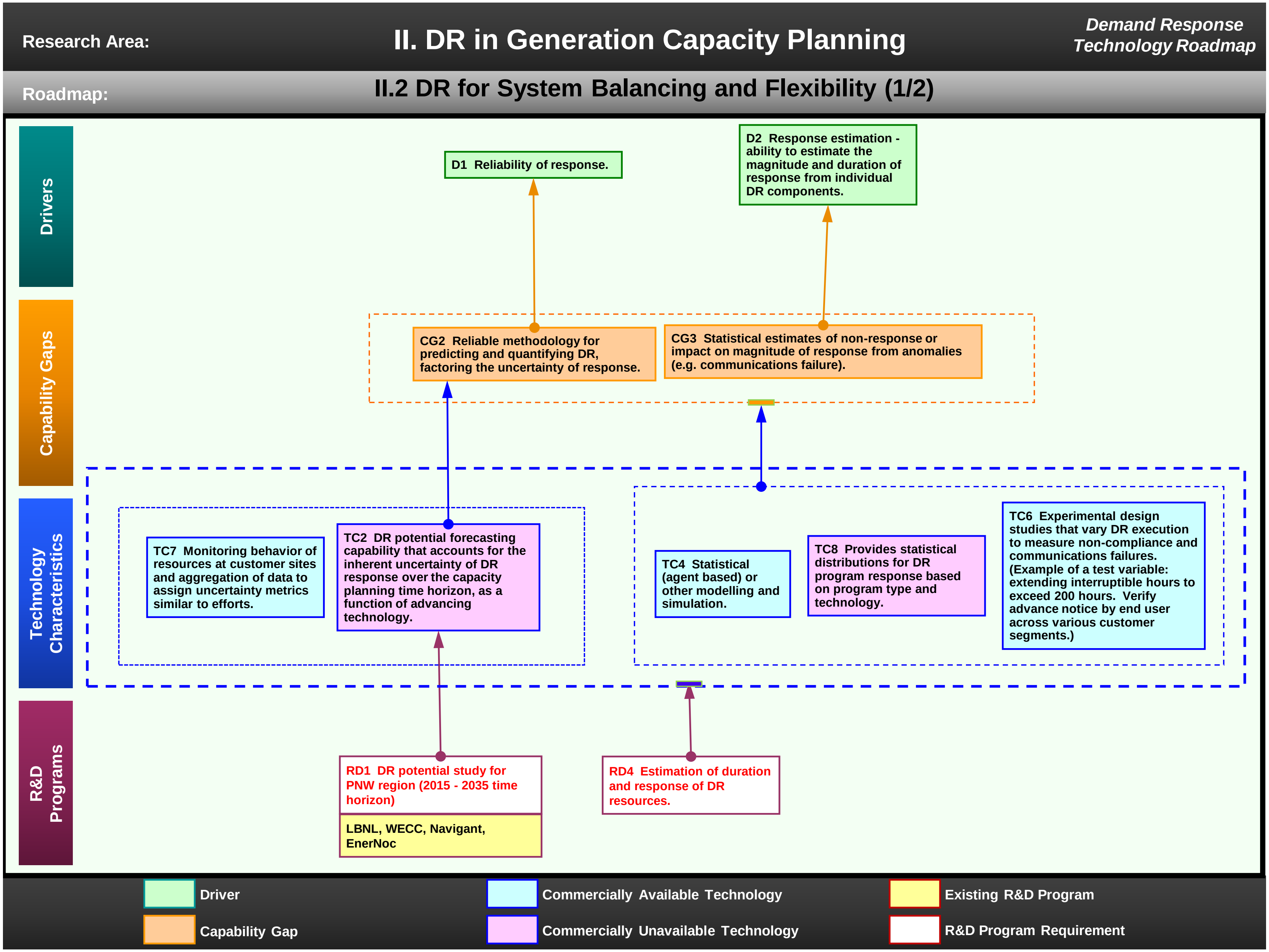
1. What is the CO_2 footprint of system balancing?
2. Can it be reduced using DR?
3. How can a reduction in construction of thermal plants for balancing, due to increasing DR usage for balancing, be quantified in terms of CO_2?

DR model for power flow simulations. Create a DR model with a range of programs that can integrate with commercial power flow models (PSLF, Power World).

Existing research: None identified.

Key research questions:

1. What is the impact of a DR event on a power flow?
2. What is the difference between responses of a single large load versus distributed loads?


Research Area:
II. DR in Generation Capacity Planning
Demand Response Technology Roadmap
Roadmap:
II.2 DR for System Balancing and Flexibility (1/2)
Drivers
Capability Gaps
Technology Characteristics
R&D Programs
D1 Reliability of response.
D2 Response estimation - ability to estimate the magnitude and duration of response from individual DR components.
CG2 Reliable methodology for predicting and quantifying DR, factoring the uncertainty of response.
CG3 Statistical estimates of non-response or impact on magnitude of response from anomalies (e.g. communications failure).
TC7 Monitoring behavior of resources at customer sites and aggregation of data to assign uncertainty metrics similar to efforts.
TC2 DR potential forecasting capability that accounts for the inherent uncertainty of DR response over the capacity planning time horizon, as a function of advancing technology.
TC4 Statistical (agent based) or other modelling and simulation.
TC8 Provides statistical distributions for DR program response based on program type and technology.
TC6 Experimental design studies that vary DR execution to measure non-compliance and communications failures. (Example of a test variable: extending interruptible hours to exceed 200 hours. Verify advance notice by end user across various customer segments.)
RD1 DR potential study for PNW region (2015 - 2035 time horizon)
LBNL, WECC, Navigant, EnerNoc
RD4 Estimation of duration and response of DR resources.
Driver
Capability Gap
Commercially Available Technology
Commercially Unavailable Technology
Existing R&D Program
R&D Program Requirement

R&D Program Summaries

DR potential study for PNW region (2015 – 2035 time horizon). Estimate DR potential for PNW region over the next 20 years as a function of: (a) summer peak demand reduction; (b) winter peak demand reduction; (c) ramp up/down to balance wind.

Existing research: LBNL; WECC; Navigant; EnerNoc.

- Details of existing research pending.

Key research questions:

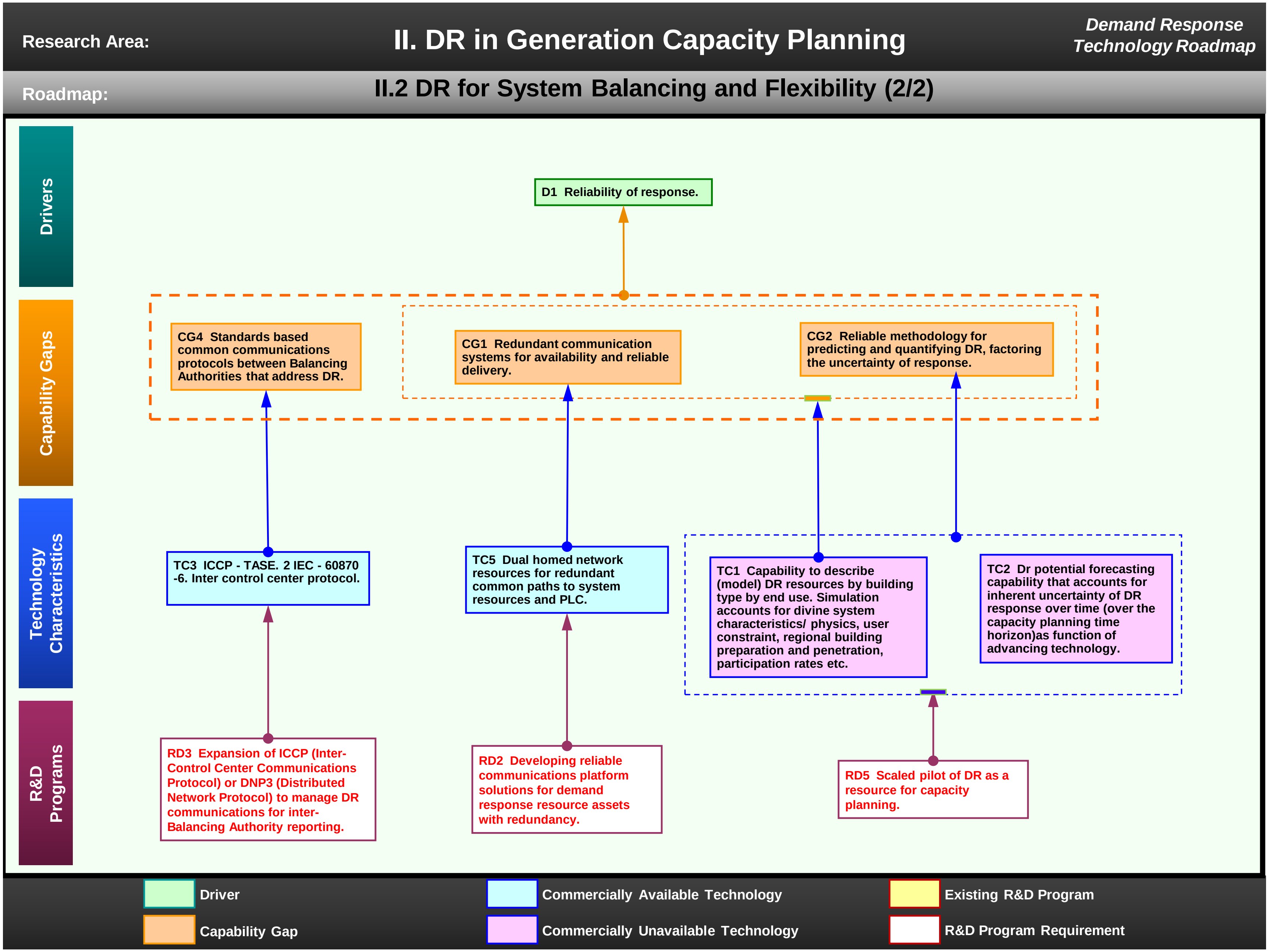
1. How much DR is now, and will be over the next 20 years for (a) summer peak demand reduction; (b) winter peak demand reduction; (c) ramping?
2. For long duration peak reduction, is there enough DR for segmented dispatch, whereby only a certain segment is called for DR for a short period, replaced by another segment for another period (say 1 hour), and so on to collectively meet the reduction need for the entire x-hour period?

Estimation of duration and responses of DR resources. DR is often less reliable than supply. Reliability needs to be quantified by resource in magnitude (non-compliance) and duration (availability). Quantify this by resource and region.

Existing research: None identified.

Key research questions:

1. Focus on existing resources that have scale potential. Use past observations of forward/planned experimental design.
2. Quantify statistical performance distributions per resource and for each of X regions and Y customer segments and years.
3. Vary operational testing in forward tests to extend hours, interrupt advance notice, and explore other factors to quantify performance by attribute and over varied weather conditions.
4. Identify the extent to which resource diversity effects performance.


Research Area:
II. DR in Generation Capacity Planning
Demand Response Technology Roadmap
Roadmap:
II.2 DR for System Balancing and Flexibility (2/2)
Drivers
Capability Gaps
Technology Characteristics
R&D Programs
D1 Reliability of response.
CG4 Standards based common communications protocols between Balancing Authorities that address DR.
CG1 Redundant communication systems for availability and reliable delivery.
CG2 Reliable methodology for predicting and quantifying DR, factoring the uncertainty of response.
TC3 ICCP - TASE. 2 IEC - 60870 -6. Inter control center protocol.
TC5 Dual homed network resources for redundant common paths to system resources and PLC.
TC1 Capability to describe (model) DR resources by building type by end use. Simulation accounts for divine system characteristics/ physics, user constraint, regional building preparation and penetration, participation rates etc.
TC2 Dr potential forecasting capability that accounts for inherent uncertainty of DR response over time (over the capacity planning time horizon)as function of advancing technology.
RD3 Expansion of ICCP (Inter-Control Center Communications Protocol) or DNP3 (Distributed Network Protocol) to manage DR communications for inter-Balancing Authority reporting.
RD2 Developing reliable communications platform solutions for demand response resource assets with redundancy.
RD5 Scaled pilot of DR as a resource for capacity planning.
Driver
Capability Gap
Commercially Available Technology
Commercially Unavailable Technology
Existing R&D Program
R&D Program Requirement

Expansion of Inter-control Center Communications Protocol (ICCP) or DNP3 (Distributed Network Protocol) to manage DR communications for inter- Balancing Authority reporting. Expand the IEC 60860–6 TASE.2 protocol standard to include demand response data stream characteristics for inter- Balancing Authority reporting.

Existing research: None identified.

Key research questions:

1. Can ICCP be expanded to deliver cogent exchange of DR data between Balancing Authority control centers?
2. Demonstrate capability between nodes?
3. Deliver a protocol schema (and define data to be delivered)?

Developing reliable communications platform solution for demand response resource assets with redundancy. Develop and demonstrate a reliable and redundant platform for communications between DR distributed resources and transmission capacity planning organization in order to study the effects of reliability related to forced outage, price response, and other communications failures.

Existing research: None identified.

Key research questions:

1. Can a subscription-based IEC – 61970 compliant solution be developed to address reliability of DR assets?
2. Can a model of asset "offline" behavior be demonstrated to mitigate communications outages in short-term and long-term case studies?

Scaled pilot of DR as a resource for capacity planning. Demonstration of Demand Response (over a season or calendar year) at a scale suitable for generation planners to acknowledge.

(a) Magnitude of DR

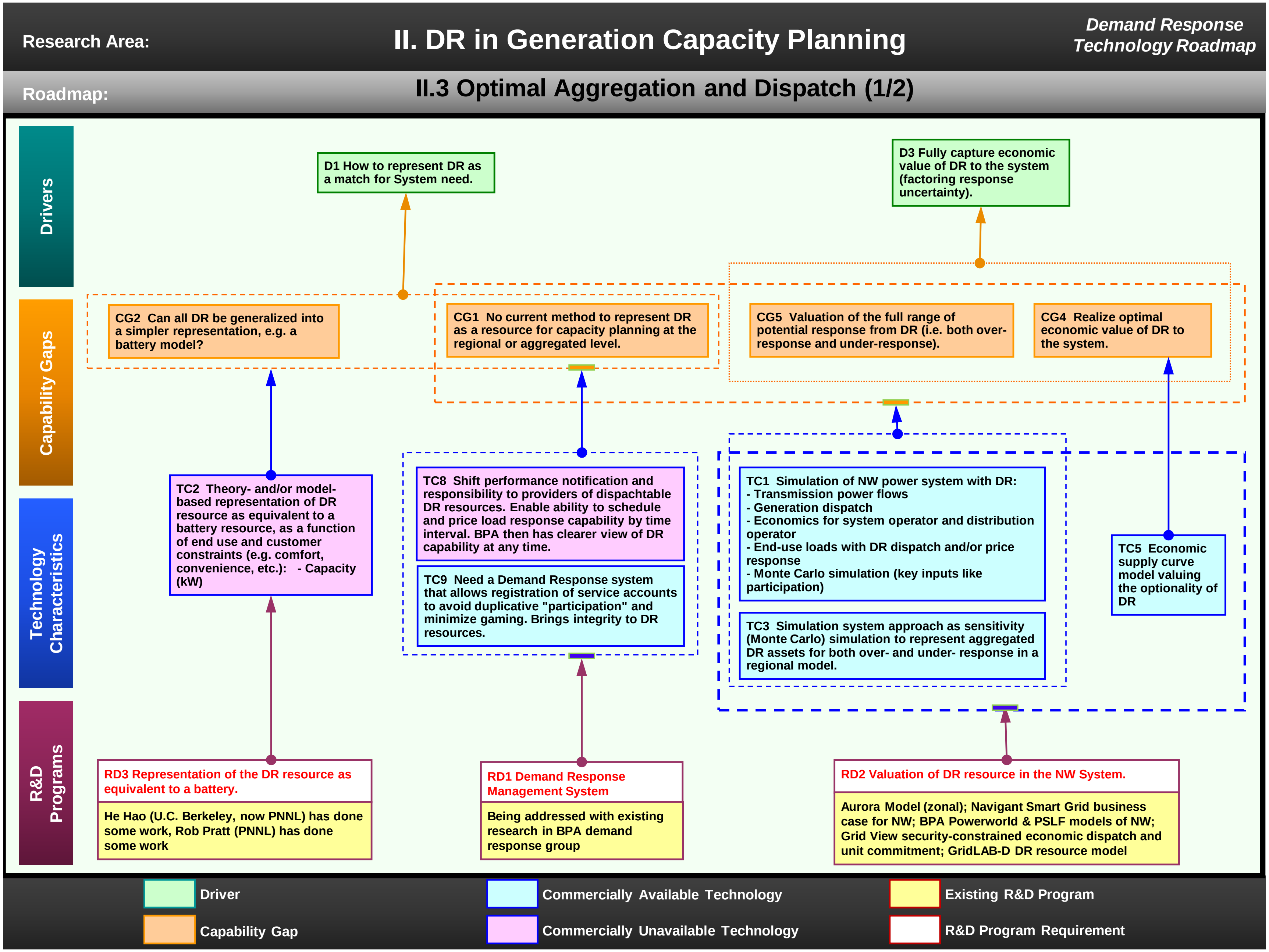
(b) Reliability of DR: duration; ratio of $\frac{\text{DR called}}{\text{DR realized}}$

c) Locational dispatchability of DR

Existing research: None identified.

Key research questions:

1. What scale of DR demonstration is suitable/adequate to convince capacity planners of DR applicability?
2. Can DR be relied upon to meet capacity requirements, specifically to defer or avoid investments in new generation?
3. What share of MW's called for through DR and actually realized; and how does this change as demand-side control technology advances?
4. Can DR be dispatched geographically (at scale)? (i.e., with spatial differentiation).


Research Area:
II. DR in Generation Capacity Planning
Demand Response Technology Roadmap
Roadmap:
II.3 Optimal Aggregation and Dispatch (1/2)
Drivers
Capability Gaps
Technology Characteristics
R&D Programs
D1 How to represent DR as a match for System need.
D3 Fully capture economic value of DR to the system (factoring response uncertainty).
CG2 Can all DR be generalized into a simpler representation, e.g. a battery model?
CG1 No current method to represent DR as a resource for capacity planning at the regional or aggregated level.
CG5 Valuation of the full range of potential response from DR (i.e. both over-response and under-response).
CG4 Realize optimal economic value of DR to the system.
TC2 Theory- and/or model-based representation of DR resource as equivalent to a battery resource, as a function of end use and customer constraints (e.g. comfort, convenience, etc.): - Capacity (kW)
TC8 Shift performance notification and responsibility to providers of dispatchable DR resources. Enable ability to schedule and price load response capability by time interval. BPA then has clearer view of DR capability at any time.
TC9 Need a Demand Response system that allows registration of service accounts to avoid duplicative "participation" and minimize gaming. Brings integrity to DR resources.
TC1 Simulation of NW power system with DR:
- Transmission power flows
- Generation dispatch
- Economics for system operator and distribution operator
- End-use loads with DR dispatch and/or price response
- Monte Carlo simulation (key inputs like participation)
TC3 Simulation system approach as sensitivity (Monte Carlo) simulation to represent aggregated DR assets for both over- and under- response in a regional model.
TC5 Economic supply curve model valuing the optionality of DR
RD3 Representation of the DR resource as equivalent to a battery.
He Hao (U.C. Berkeley, now PNNL) has done some work, Rob Pratt (PNNL) has done some work
RD1 Demand Response Management System
Being addressed with existing research in BPA demand response group
RD2 Valuation of DR resource in the NW System.
Aurora Model (zonal); Navigant Smart Grid business case for NW; BPA Powerworld & PSLF models of NW; Grid View security-constrained economic dispatch and unit commitment; GridLAB-D DR resource model
Driver
Capability Gap
Commercially Available Technology
Commercially Unavailable Technology
Existing R&D Program
R&D Program Requirement

R&D Program Summaries

Representation of the DR resource as equivalent to a battery. Theory-based and/or model-based translation of a DR resource into terms used to describe a battery resource, e.g. capacity (kW), energy (kWh), round-trip efficiency, etc. Provide as function of end use and customer constraints on comfort, convenience, etc.

Existing research: He Hao (UC Berkeley, now PNNL) has done some work. Rob Pratt (PNNL) has done some work.

- Details of existing research pending.

Key research questions:

1. How can population of DR resources be used together, sequentially, to produce combined effect that single resource cannot? E.g. Longer duration.
2. How well (accurately) can DR characteristics be represented as a battery?
3. How convenient is this representation for planning models? Operational models?
4. How can we represent various levels of customer tolerance for DR? E.g. constraints imposed by user for comfort, convenience, etc.

Demand Response Management System. System to manage and monitor DR resources available for dispatch by BPA. Bring integrity, auditability, and oversight to DR resources that are depended upon to serve BPA's reliability needs.

Existing research: Being addressed with existing research in BPA demand response group today.

- Details of existing research pending.

Key research questions:

1. System that allows DR providers to register service accounts so no duplication of DR end-users. Ensures integrity of DR resources. Minimizes gaming.
2. System to schedule DR availability, for DR providers to give updated information to BPA on MW availability. Puts burden of performance assessment on the DR provider.
3. Demonstrate ability of DR providers to provide timely and accurate DR capability to BPA; hold DR providers accountable for response and capacity commitments.

Back to Table of Contents

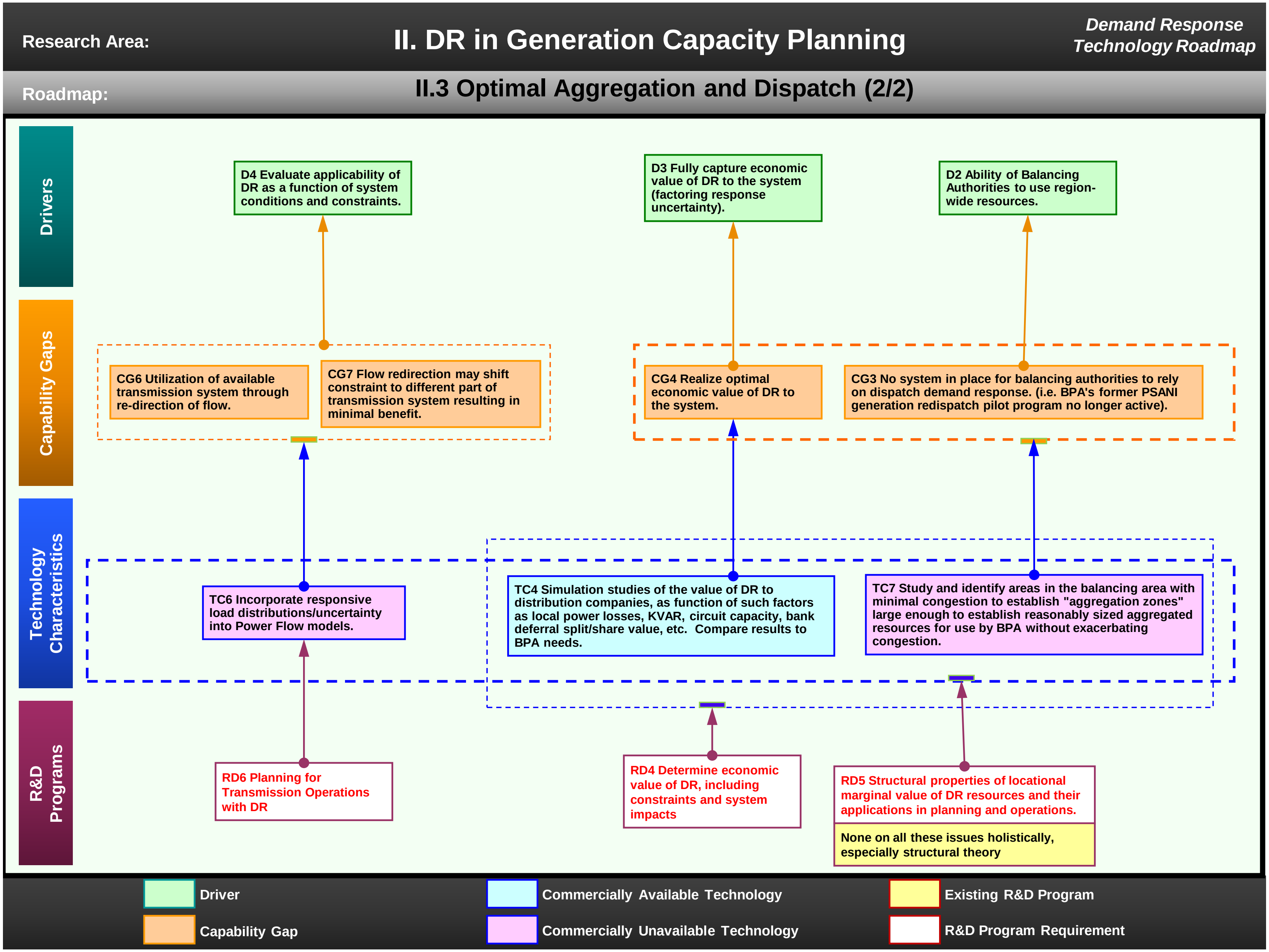
Valuation of DR resource in the NW system. Develop time-series system simulation of NW Grid, including transmission power-flow, generation dispatch, DR end-use resource model, DR dispatch and/or price response. Include system and distribution LSE economics. Monte Carlo capability for exploring key inputs, random events, etc.

Existing research: Aurora model (zonal). Navigant smart grid business case for NW. BPA PowerWorld & PSLF models of NW. Grid View security-constrained economic dispatch and unit commitment. GridLAB-D DR resource model.

- Details of existing research pending.

Key research questions:

1. What is the DR resource for the Region?
2. What are the uncertainties around that estimate?
3. What is the value of that resource, with and without uncertainty?
4. What is the cost of over- or under- response to any given need?
5. What does the supply curve for DR look like by DR resource? By operational objective for DR?


Research Area:
II. DR in Generation Capacity Planning
Demand Response Technology Roadmap
Roadmap:
II.3 Optimal Aggregation and Dispatch (2/2)
Drivers
Capability Gaps
Technology Characteristics
R&D Programs
D4 Evaluate applicability of DR as a function of system conditions and constraints.
D3 Fully capture economic value of DR to the system (factoring response uncertainty).
D2 Ability of Balancing Authorities to use region-wide resources.
CG6 Utilization of available transmission system through re-direction of flow.
CG7 Flow redirection may shift constraint to different part of transmission system resulting in minimal benefit.
CG4 Realize optimal economic value of DR to the system.
CG3 No system in place for balancing authorities to rely on dispatch demand response. (i.e. BPA's former PSANI generation redispatch pilot program no longer active).
TC6 Incorporate responsive load distributions/uncertainty into Power Flow models.
TC4 Simulation studies of the value of DR to distribution companies, as function of such factors as local power losses, KVAR, circuit capacity, bank deferral split/share value, etc. Compare results to BPA needs.
TC7 Study and identify areas in the balancing area with minimal congestion to establish "aggregation zones" large enough to establish reasonably sized aggregated resources for use by BPA without exacerbating congestion.
RD6 Planning for Transmission Operations with DR
RD4 Determine economic value of DR, including constraints and system impacts
RD5 Structural properties of locational marginal value of DR resources and their applications in planning and operations.
None on all these issues holistically, especially structural theory
Driver
Capability Gap
Commercially Available Technology
Commercially Unavailable Technology
Existing R&D Program
R&D Program Requirement

Structural properties of locational marginal value of DR resources and their applications in planning and operations. The locational marginal value (LMV) of DR resources depends critically on network structure (e.g. topology) and network conditions (e.g. power flows). This project will develop structural/qualitative insights of LMV, develop control, dispatch and planning algorithms, and evaluate these algorithms in simulations.

Existing research: None on all these issues holistically, especially structural theory.

- Details of existing research pending.

Key research questions:

1. How do network structures (topology R/X ratios, etc.) and network conditions (load profile, status of switches, etc.) affect LMV of DR resources?
2. How to compute LMV, in real time or off line, based on possibly incomplete, noisy, outdated data?
3. How to design optimal planning/operations based on these structural insights?
4. How to validate and evaluate these algorithms for specific applications (e.g. capacity planning, DR program, grid balancing, frequency regulation, etc.)?
5. How do generator-side control interact with distribution/ load side control?

Planning for Transmission Operations with DR. Incorporate DR into transmission planning studies.

Existing research: None identified.

Key research questions:

1. Can DR be used to increase ATC (Available Transfer Capability)?
2. Can DR use as RAS (Remedial Action Scheme)?
3. Can power flow software be modified to "dispatch" DR for congestion?

Determine economic value of DR, including constraints and system impacts. The full value of DR resources remains unknown. Quantify the complete value of DR resources to the system (and to BPA customers). **Existing research:** None identified.	Key research questions: 1. Quantify the value of DR resources inclusive of both BPA value and value to local distribution companies. 2. Perform local load forecasts per substation using spatial and/or agent modeling, inclusive of forecasted DER, EV in addition to traditional regression/forecast of future congestion. 3. Using #2, cluster substations into homogeneous areas where future congestion links are broken (create new group). 4. Quantify value over different weather, value to ancillary services, deferred bank/sub (distribution company), distribution losses, KVAR, etc. and #3 above. 5. Determine value ascribable to BPA vs. distribution company, per region, per resource. 6. Create aggregation zones in balancing area based on system congestion evaluation.

Back to Table of Contents

Demand Response in Grid Operations

Research Area Definition

DR in Grid Operations refers to the technologies that can enable demand response in response to load forecasts or dynamic grid energy or capacity requirements. These technologies allow system operators to respond to generation imbalances and result in increased system flexibility. These technologies which may typically involve a DR management system are also useful for grid regulation.

DR for Grid Balancing

This often is referred to as going beyond "DR 1.0" to "2.0" in that its not just about when the loads are turned off, but it's also when they're turned on, and how do they get turned on. This involves DR used for grid balancing in both directions. There are some patterns and similarities here, because if you can use DR for frequency regulation, you can use it for a lot of other services.

There is also a need to advance the research agenda so that the same resource or asset used for DR can also be used for different services. One way to do that is to have a common information model, so that the system the planners and operators use knows exactly what this asset can really do. To do that we need to characterize DR capabilities not just for services they provide, but also for temporal factors when these services are available.

Using a cognitive information model you have a hierarchy of information that is passed not just from the RTO / ISO down to the aggregation level, but also to the asset level itself, the resource and then the asset level. Using a common information model that can have pieces that can be transferred allows you go to higher levels in the hierarchy, aggregating that information so that it's presented in a way that's useful and actionable to the operators and planners.

There's also been a lot of advancement at the transmission level information but as we have more resources on the distribution level, we need to be able to leverage that data. There is also a need to have power flows models that also take into account what's going on in the distribution side.

We have to understand how to integrate the analysis of transmission and distribution systems and the resources they're connected to, like storage and variable energy resources. DR can be used for many different purposes or use cases across the electricity value chain, so how do we value DR for transmission, distribution and capacity? And then how can we then decide where and when to use these assets, and how is their use in comparison with to other system modifications operators could make?

DR for Automated Peak Shaving

This addresses not just traditional generation peak, but also grid peaks which means congestion would fall under this area. These R&D program have to do with addressing the gap regarding a working DRMS [DR Management Systems]. This Capability Gap includes integrated dispatch systems for multiple DR programs. This could be addressed by enabling hierarchical or advanced demand response management system, or DRMS, with certain capabilities and characteristics. These DRMS systems will know locational information as to where the DR assets are and what the resource capabilities are. That information is crucial if you want to use DR beyond your total generation system peak, on a more to a locational basis.

There was also agreement among participants that base-lining the DR resources is very important to measure the response you can get from demand response programs.

x

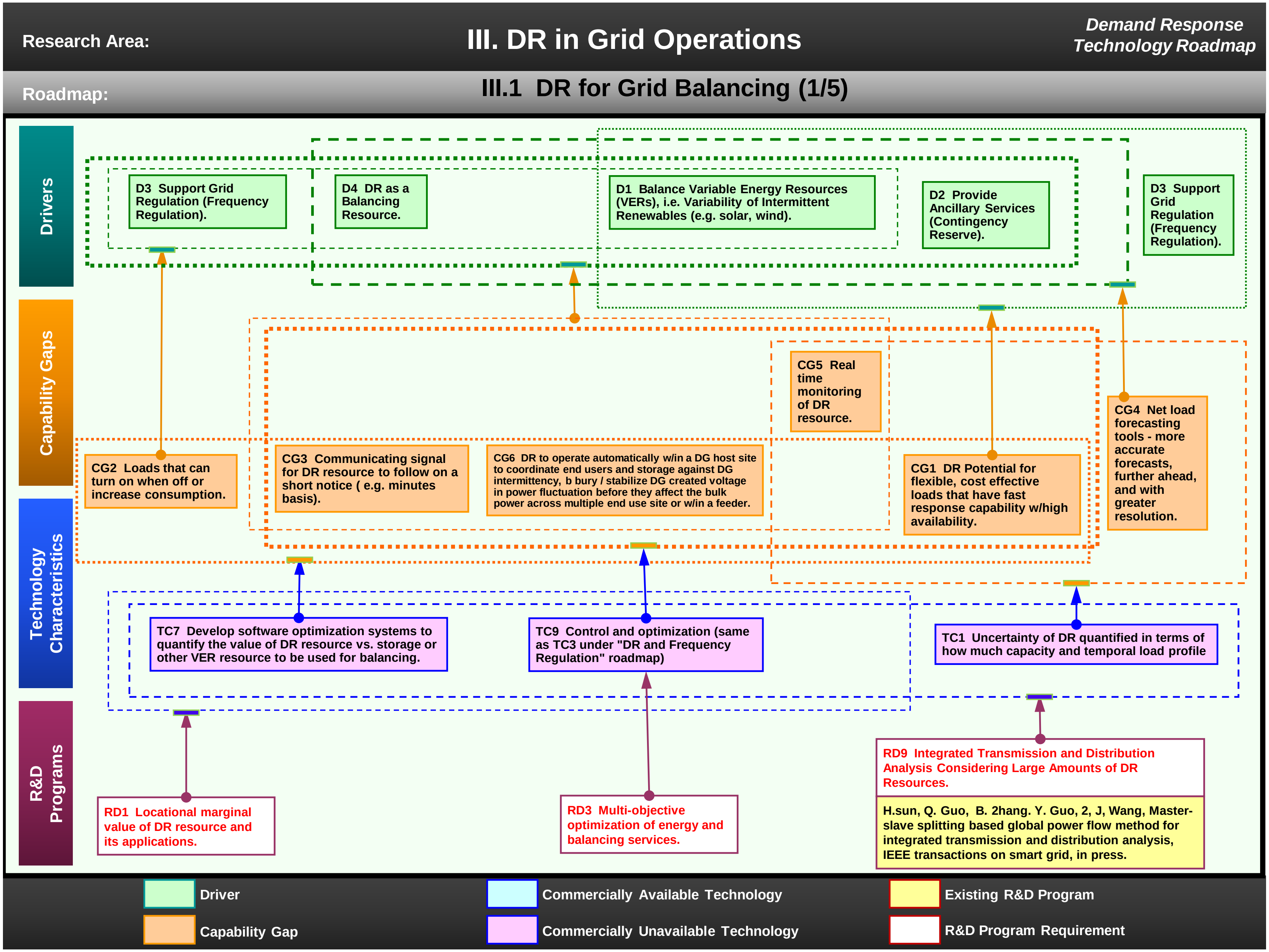
DR & Frequency Regulation

With very fast DR response assets, signals can be on the order of seconds. Therefore using DR for frequency Regulation requires cost effective telemetry. This is currently a major gap, because if you want to do DR for frequency regulation it has proved difficult to be both cost effective and to meet the fast response requirements. R&D programs should focus on how to do that, and looking at the different cost effective communications technologies makes sense

---

The insights and observations above were distilled from the input of the following subject matter experts who participated in Workshop 2 and Mini-Workshop 2:

- Farrokh Albuyeh (Open Access Technology Int'l, Inc.)
- Tom Brim (Bonneville Power Administration)
- Kwok Cheung (Alstom Grid)
- Angela Chuang (Electric Power Research Institute)
- Ifty Hasan (Entouch Controls)
- Karanjit Kalsi (Pacific Northwest Nat'l Laboratory)
- Sila Kiliccote (Lawrence Berkeley Nat'l Laboratory)
- Steven Low (California Institute of Technology)
- Ning Lu (North Carolina State University)
- Kaj Skov Nielsen (Siemens)
- Alex Papalexpolus (ECCO International)
- Anurag Srivastava (Washington State University)
- Jianhui Wang (Argonne Nat'l Laboratory)
- Le Xie (Texas A & M University)


Research Area:
III. DR in Grid Operations
Demand Response Technology Roadmap
Roadmap:
III.1 DR for Grid Balancing (1/5)
Drivers
Capability Gaps
Technology Characteristics
R&D Programs
D3 Support Grid Regulation (Frequency Regulation).
D4 DR as a Balancing Resource.
D1 Balance Variable Energy Resources (VERs), i.e. Variability of Intermittent Renewables (e.g. solar, wind).
D2 Provide Ancillary Services (Contingency Reserve).
D3 Support Grid Regulation (Frequency Regulation).
CG5 Real time monitoring of DR resource.
CG4 Net load forecasting tools - more accurate forecasts, further ahead, and with greater resolution.
CG2 Loads that can turn on when off or increase consumption.
CG3 Communicating signal for DR resource to follow on a short notice (e.g. minutes basis).
CG6 DR to operate automatically w/in a DG host site to coordinate end users and storage against DG intermittency, b bury / stabilize DG created voltage in power fluctuation before they affect the bulk power across multiple end use site or w/in a feeder.
CG1 DR Potential for flexible, cost effective loads that have fast response capability w/high availability.
TC7 Develop software optimization systems to quantify the value of DR resource vs. storage or other VER resource to be used for balancing.
TC9 Control and optimization (same as TC3 under "DR and Frequency Regulation" roadmap)
TC1 Uncertainty of DR quantified in terms of how much capacity and temporal load profile
RD9 Integrated Transmission and Distribution Analysis Considering Large Amounts of DR Resources.
H.sun, Q. Guo, B. 2hang. Y. Guo, 2, J, Wang, Master-slave splitting based global power flow method for integrated transmission and distribution analysis, IEEE transactions on smart grid, in press.
RD1 Locational marginal value of DR resource and its applications.
RD3 Multi-objective optimization of energy and balancing resources.
Driver
Capability Gap
Commercially Available Technology
Commercially Unavailable Technology
Existing R&D Program
R&D Program Requirement

Integrated Transmission and Distribution Analysis Considering Large Amounts of DR Resources. Develop advanced "integrated" transmission and distribution analysis tools that can coordinate and co-optimize transmission and distribution-level resources including DR.

Existing research: See H. Sun, Q. Guo, B. Zhang, Y. Guo, J, Wang, "Master-Slave Splitting Based Global Power Flow Method for Integrated Transmission and Distribution Analysis," *IEEE Transactions on Smart Grid*, in press.

- Details of existing research pending.

Key research questions:

1. With increasing active distribution networks including DR, how to optimally coordinate transmission and distribution, and co-optimize them?
2. How to conduct and co-optimize integrated T&D analysis with large amounts of DR including power flow analysis, contingent analysis, and state estimation, etc.?
3. How to reflect model DR resources on both transmission and distribution levels?

Locational marginal value of DR resources and its applications. The marginal value od an additional unit of DR resource depends on (i) network structure and (ii) network conditions. The optimization and control of DR, at different time scale for different applications (frequency regulation, grid balancing, planning, etc.) should exploit the locational marginal value of DR and locational marginal costs of load.

Existing research: None identified.

Key research questions:

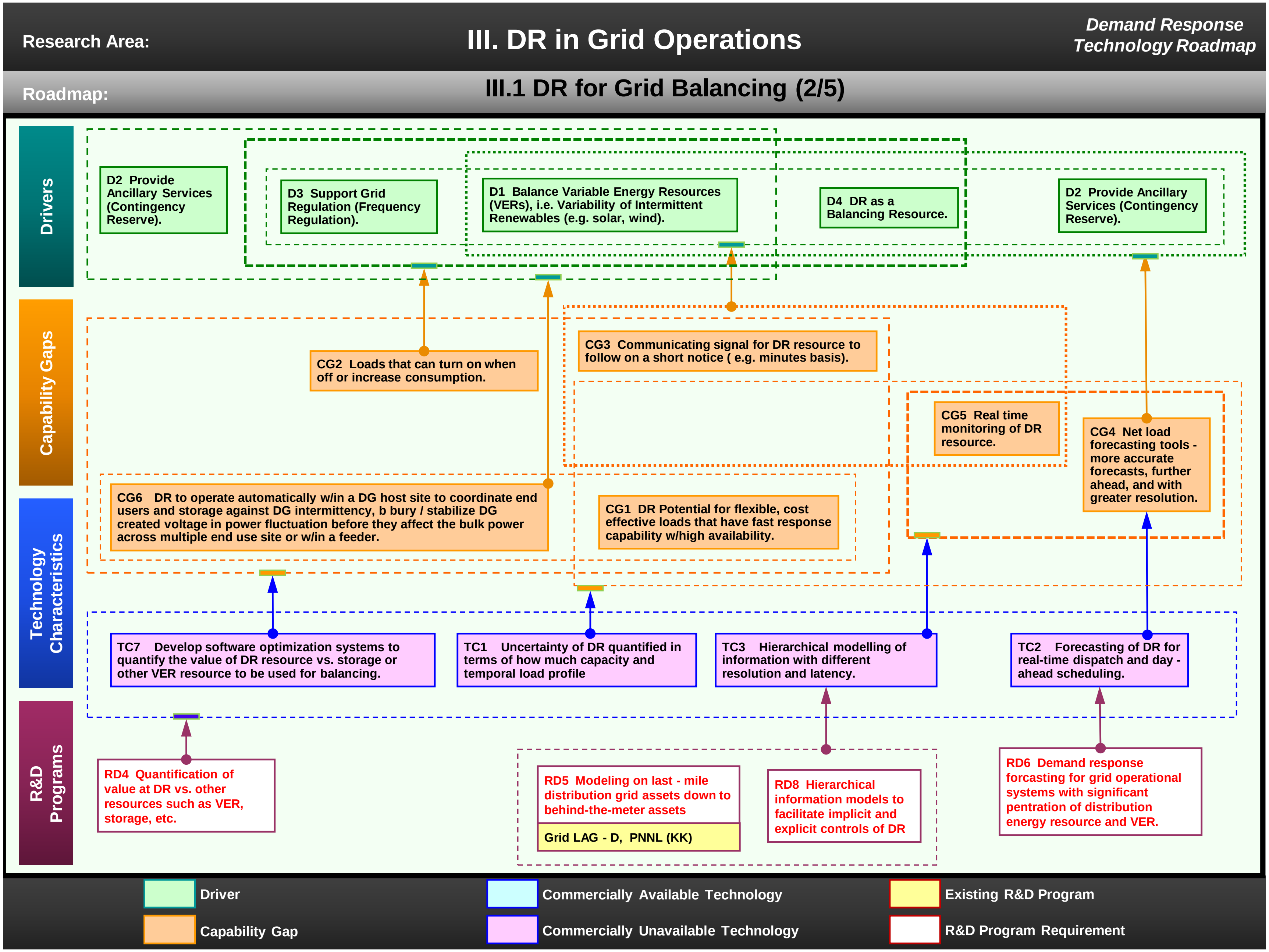
1. What is the impact of network structure (topology, R/x ratio, etc) on the locational marginal value of DR?
2. What is the true impact of network structure on locational marginal costs of load?
3. How to compute LMV of DR? How to estimate LMV of DR from incomplete , outdated, noisy, time varying data (on infrastructure, on network state, on loads, on DR capacity)?
4. How to optimally dispatch generations/DR based on LMV of DR and LM cost of loads?
5. How does uncertainty in generation (e.g. wind) and loads and in DR resources impact all of the above?
6. How to develop a prototype to validate in simulation and in field.

Multi-objective optimization of energy and balancing services. Design mechanisms (market or other) to co-optimize loads to simultaneously provide ancillary and energy services. Provide a level playing field for loads with conditional generation resources.

Existing research: None identified.

Key research questions:

1. How do you engage loads to participate in multiple "markets" simultaneously?
2. What does the control structure at the device level look like?
3. When do you predict the availability of the loads to participate in different markets?
4. What incentive structures need to be put in place?


Research Area:
III. DR in Grid Operations
Demand Response Technology Roadmap
Roadmap:
III.1 DR for Grid Balancing (2/5)
Drivers
Capability Gaps
Technology Characteristics
R&D Programs
D2 Provide Ancillary Services (Contingency Reserve).
D3 Support Grid Regulation (Frequency Regulation).
D1 Balance Variable Energy Resources (VERs), i.e. Variability of Intermittent Renewables (e.g. solar, wind).
D4 DR as a Balancing Resource.
D2 Provide Ancillary Services (Contingency Reserve).
CG3 Communicating signal for DR resource to follow on a short notice (e.g. minutes basis).
CG2 Loads that can turn on when off or increase consumption.
CG5 Real time monitoring of DR resource.
CG4 Net load forecasting tools - more accurate forecasts, further ahead, and with greater resolution.
CG6 DR to operate automatically w/in a DG host site to coordinate end users and storage against DG intermittency, b bury / stabilize DG created voltage in power fluctuation before they affect the bulk power across multiple end use site or w/in a feeder.
CG1 DR Potential for flexible, cost effective loads that have fast response capability w/high availability.
TC7 Develop software optimization systems to quantify the value of DR resource vs. storage or other VER resource to be used for balancing.
TC1 Uncertainty of DR quantified in terms of how much capacity and temporal load profile
TC3 Hierarchical modelling of information with different resolution and latency.
TC2 Forecasting of DR for real-time dispatch and day - ahead scheduling.
RD4 Quantification of value at DR vs. other resources such as VER, storage, etc.
RD5 Modeling on last - mile distribution grid assets down to behind-the-meter assets
Grid LAG - D, PNNL (KK)
RD8 Hierarchical information models to facilitate implicit and explicit controls of DR
RD6 Demand response forcasting for grid operational systems with significant pentration of distribution energy resource and VER.
Driver
Capability Gap
Commercially Available Technology
Commercially Unavailable Technology
Existing R&D Program
R&D Program Requirement

R&D Program Summaries

Modeling on last-mile distribution grid assets down to behind-the-meter assets. Capability to provide situational awareness for grid and customer-side assets extending from distribution substations to behind-the-meter assets.

Existing research: Grid LAG - D, PNNL.

- Details of existing research pending.

Key research questions:

1. Use AMI/ Smart meter data.
2. Use GIS data to develop topology.
3. Integrate DSM/SCADA data where available.
4. Calculate/estimate state.

Quantification of value at DR vs. other resources such as VER, storage, etc. New types of resources such as DF, VER, storage, etc. are becoming available. Need to develop methodologies to quantify value of these resources to be used in Integrate Dispatch models.

Existing research: None identified.

Key research questions:

1. What is the value of various DR products for reliability, T&D investments, capacity invest, etc.?
2. What is the value of other resources such as storage and other VER resources?
3. How DR compares with these other resources for dispatch process?
4. Develop scenarios and business cases.

Hierarchical information models to facilitate implicit and explicit controls of DR. Modeling of power system resource entities at different hierarchical levels. Define information exchange among different levels and the transformation required to harmonize different models with different data resolution and latency in time.

Existing research: None identified.

Key research questions:

1. Identify information exchange among different hierarchical entities (grid operators, DSO, asset load).
2. Identify data transformation required at each level.
3. Identify information models require at each other.
4. How to automate the transformation?
5. How to harmonize models with different resolution and latency?

Demand response forecasting for grid operational systems with significant penetration of distribution energy resource and VER. Assess impact of net load forecasting due to demand response is important. DR forecasting methods are devised to accurately estimate short-term, mid-term DR at the transmission level taken into consideration of aggregation and uncertainty of DR at the distribution level.

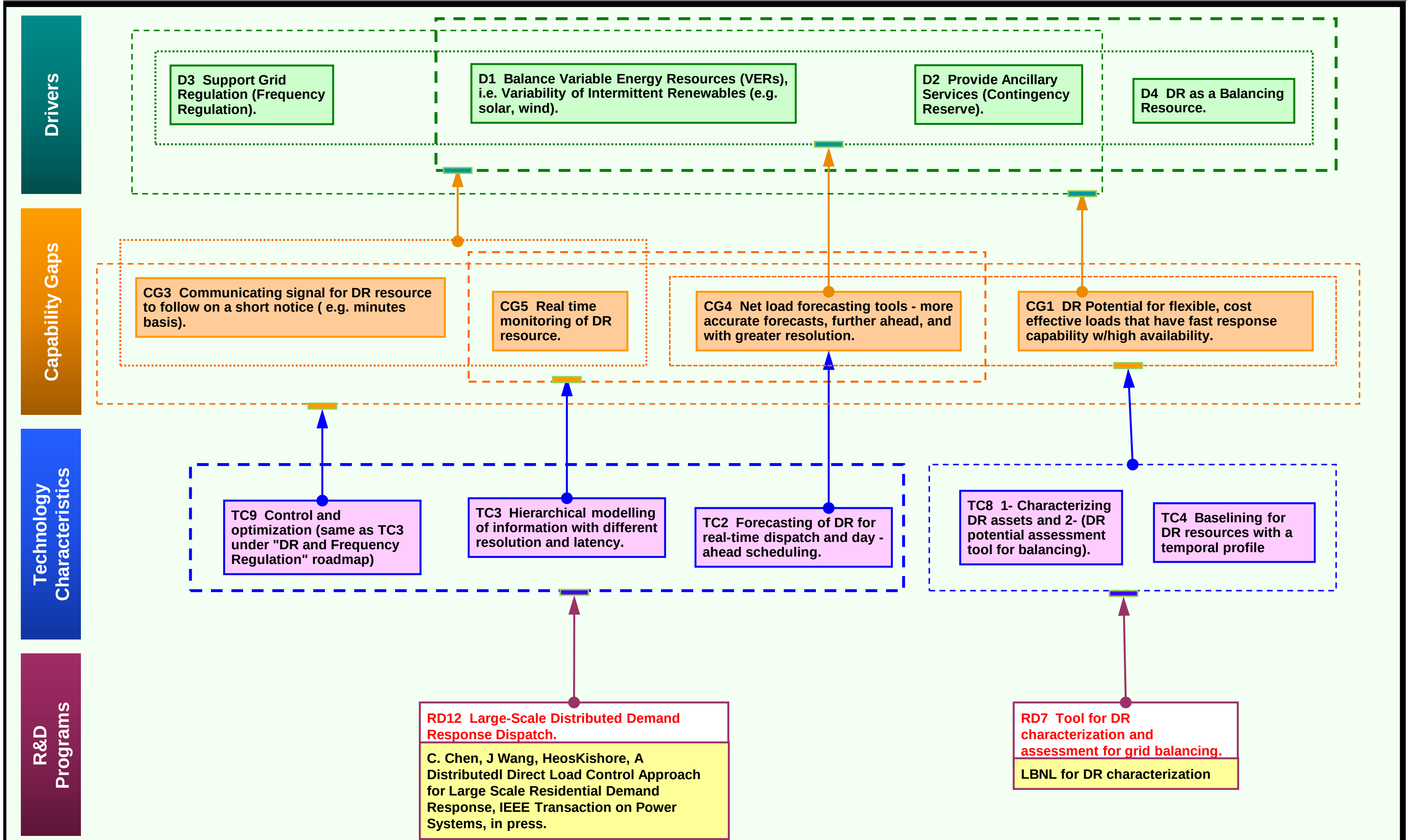
Existing research: None identified.

Key research questions:

1. Assess impact of net load forecasting.
2. Uncertainty accuracy of DR taking into consideration of responsiveness of various DR programs.
3. Real-time (5 min.) short-term DR forecasting.
4. Pay-ahead DR forecasting (mid-term).
5. Aggregation of forecasting of DR (expected value, standard deviation).

Research Area: **III. DR in Grid Operations** *Demand Response Technology Roadmap*

Roadmap: **III.1 DR for Grid Balancing (3/5)**



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

Back to Table of Contents

R&D Program Summaries

Large-Scale Distributed Demand Response Dispatch. Develop a large-scale distributed, accurate, and optimal dispatch algorithms for Demand Response.

Existing research: C. Chen, J Wang, Heos Kishore, "A Distributed Direct Load Control Approach for Large Scale Residential Demand Response," *IEEE Transaction on Power Systems*, in press.

- Details of existing research pending.

Key research questions:

1. How to communicate with and optimally dispatch a large amount of DR resources?
2. What is the optimal control architecture for DR dispatch – centralized vs. decentralized?
3. How to achieve optimality, robustness stability, efficiency of the design algorithms?
4. How to ensure the set points sent to DR resources can be accurately followed by DR owners?
5. How to seamlessly connect DR aggregators and system operators?
6. How to better address DR forecast errors?

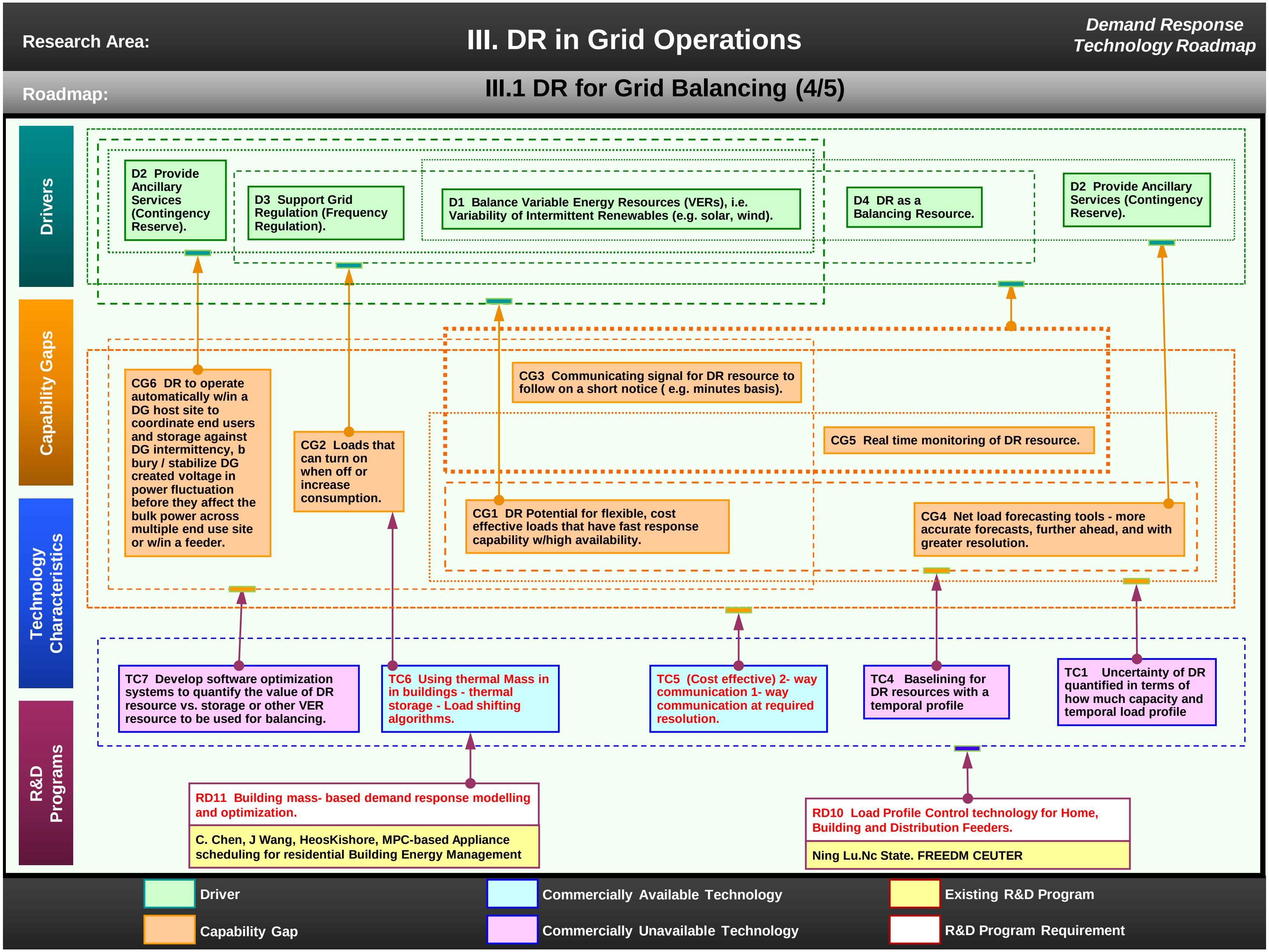
Tool for DR characterization and assessment for grid balancing. Different types of DR need to be characterized and asses for grid balancing in methodological manner considering ramp limit, time coordination, and data flow/exchange, uncertainty and social aspect.

Existing research: LBNL for DR characterization.

- Details of existing research pending.

Key research questions:

1. How to characterize DR based on need and given constraints.
2. Assess the DR potential for grid balancing given constraints and uncertainty.
3. Setting up requirements for data interface, communication, entity involved, and interoperability.



Back to Table of Contents

Building mass-based demand response modeling and optimization. Develop advanced modeling and optimation methods for building-mass based DR.

Existing research: C. Chen, J. Wang, Y. Heo, S. Kishore, "MPC-Based Appliance Scheduling for Residential Building Energy Management Controller," *IEEE Transactions on Smart Grid* 4:3 (2013), 1401-1410.

- Details of existing research pending.

Key research questions:

1. How to model and simulate DR resources based on building thermal mass?
2. How to incorporate building thermal mass-based DR into home energy management?
3. How to scale building thermal mass-based DR to a large-scale application to many homes?
4. How to achieve non-intrusive load monitoring?

Load Profile Control technology for Home, Building and Distribution Feeders. Load resource categorization. Meter data analysis for load resource forecast. Direct load control of residential load through home energy management systems.

Existing research: Ning Lu, North Carolina State University Future Renewable Electric Energy Delivery and Management Systems (FREEDM) Center.

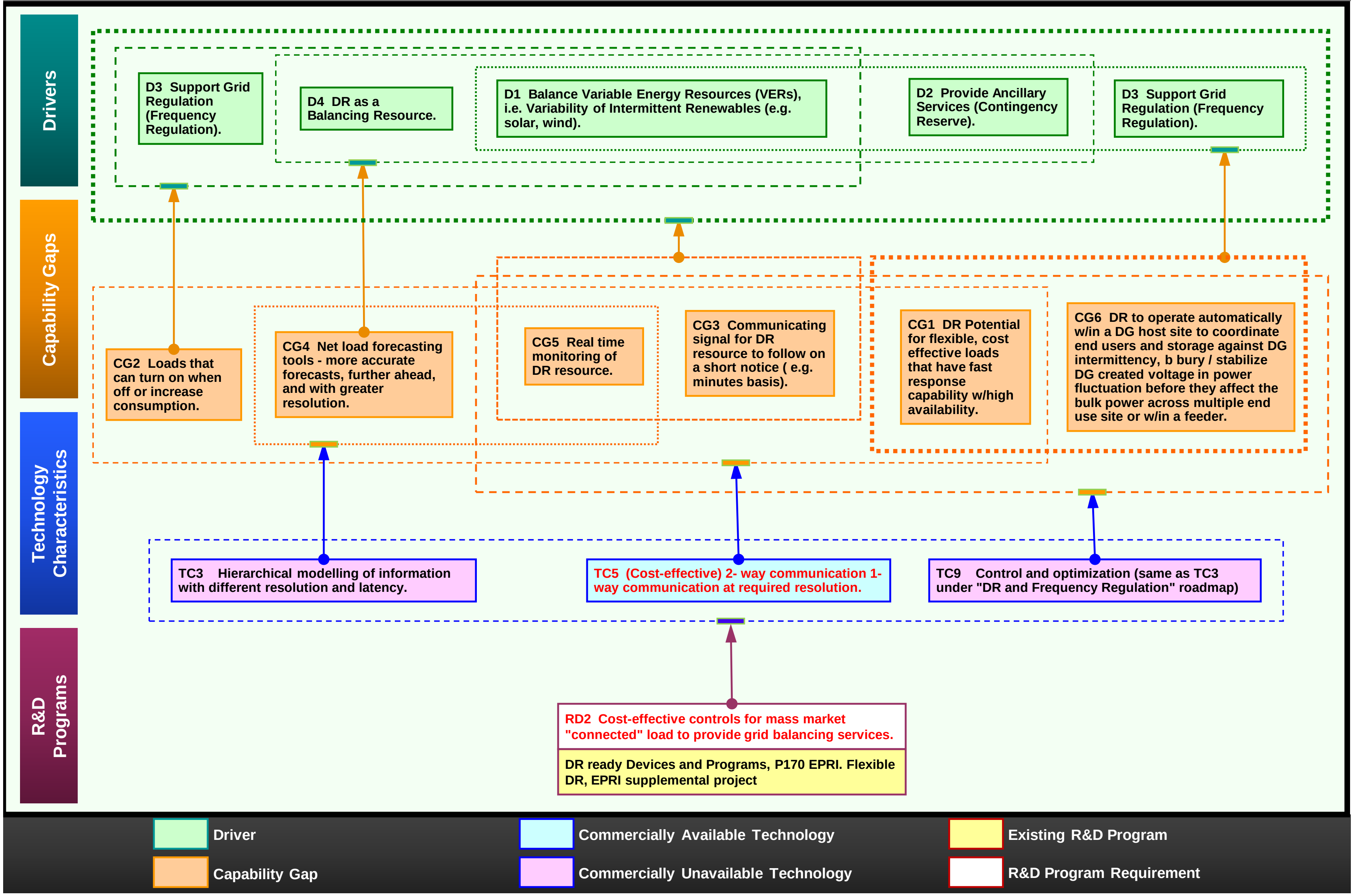
- Goals of the FREEDM Center, funded by the National Science Foundation, are "to create a culture of innovation in engineering research and education that links scientific discovery to technological innovation through transformational engineered systems research" and "make advances in technology and produce engineering graduates who will be creative innovators in a global economy" (http://www.freedm.ncsu.edu/).

Key research questions:

1. How to control the aggregated load, so that it can follow a forecasted baseline load in no-control mode?
2. How much up and down capability the load control can do against the baseline load to provide load following and load shifting/peak shaving?
3. How many load resources are needed to achieve the above control objectives?

Research Area: **III. DR in Grid Operations** *Demand Response Technology Roadmap*

Roadmap: **III.1 DR for Grid Balancing (5/5)**



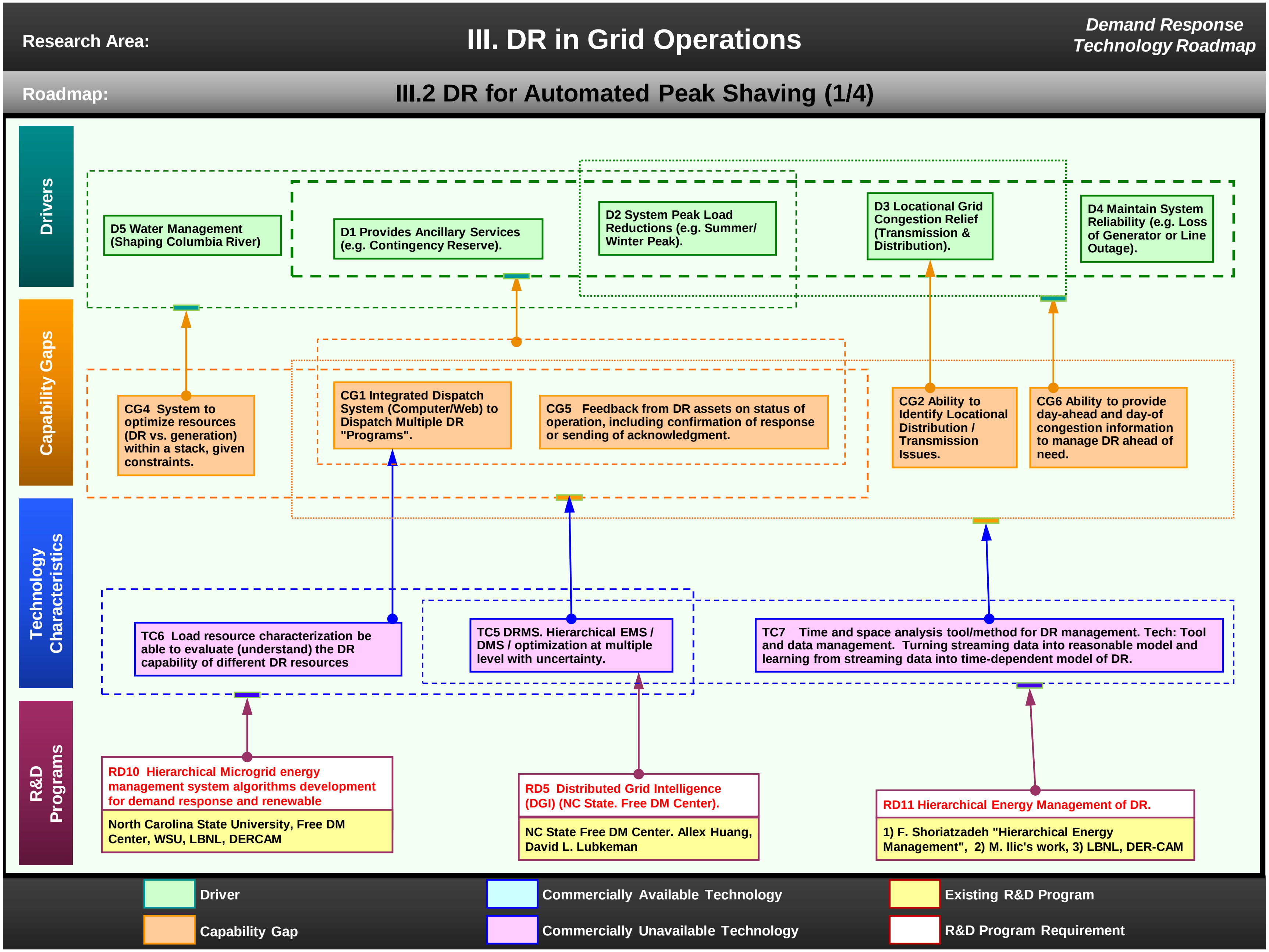
Cost-effective controls for mass market "connected" load to provide grid balancing services. Collaboratively identify common functional modes of operation for mass market end-use products to support balancing needs. The resulting controls technology desired are cost-effective for manufactures to support, perform of value to system operators and maintain consumer comfort across end-use product categories considered.

Existing research: DR ready Devices and Programs, P170 EPRI. Flexible DR, EPRI supplemental project.

- Details of existing research pending.

Key research questions:

1. What types of connected mass market loads / end-use products have electronic controls that can be augmented to support balancing services?
2. What is the cost increment target for updating existing controls to support balancing services, cost- effectively?
3. What are the functional requi8rements for mass market end-use products, etc.to provide balancing services (e.g. response time, communications, etc.?
4. To what extent can algorithms of control be remote firmware upgraded to support existing (or additional) requirements for balancing?
5. What is the DR potential for grid balancing in the Pacific Northwest, and from which top end-use categories?
6. What common modes of operation can be defined to support grid balancing needs? So mass market loads can be triggered.


Research Area:
III. DR in Grid Operations
Demand Response Technology Roadmap
Roadmap:
III.2 DR for Automated Peak Shaving (1/4)
Drivers
Capability Gaps
Technology Characteristics
R&D Programs
D5 Water Management (Shaping Columbia River)
D1 Provides Ancillary Services (e.g. Contingency Reserve).
D2 System Peak Load Reductions (e.g. Summer/ Winter Peak).
D3 Locational Grid Congestion Relief (Transmission & Distribution).
D4 Maintain System Reliability (e.g. Loss of Generator or Line Outage).
CG4 System to optimize resources (DR vs. generation) within a stack, given constraints.
CG1 Integrated Dispatch System (Computer/Web) to Dispatch Multiple DR "Programs".
CG5 Feedback from DR assets on status of operation, including confirmation of response or sending of acknowledgment.
CG2 Ability to Identify Locational Distribution / Transmission Issues.
CG6 Ability to provide day-ahead and day-of congestion information to manage DR ahead of need.
TC6 Load resource characterization be able to evaluate (understand) the DR capability of different DR resources
TC5 DRMS. Hierarchical EMS / DMS / optimization at multiple level with uncertainty.
TC7 Time and space analysis tool/method for DR management. Tech: Tool and data management. Turning streaming data into reasonable model and learning from streaming data into time-dependent model of DR.
RD10 Hierarchical Microgrid energy management system algorithms development for demand response and renewable
North Carolina State University, Free DM Center, WSU, LBNL, DERCAM
RD5 Distributed Grid Intelligence (DGI) (NC State. Free DM Center).
NC State Free DM Center. Allex Huang, David L. Lubkeman
RD11 Hierarchical Energy Management of DR.
1) F. Shoriatzadeh "Hierarchical Energy Management", 2) M. Ilic's work, 3) LBNL, DER-CAM
Driver
Capability Gap
Commercially Available Technology
Commercially Unavailable Technology
Existing R&D Program
R&D Program Requirement

Hierarchical Microgrid energy management system algorithms development for demand response and renewable integration (mainly PV). Build home-level, transformer level, then feeder level energy management systems for demand response, islanding operation and renewable integration. Implement in a hardware test based (IMWH microgrid with PV, energy storage, electric vehicles, and actual home loads).

Existing research: Washington State University (WSU); Lawrence Berkeley National Laboratory (LBNL); LBNL's Distributed Energy Resources Customer Adoption Model (DER-CAM); North Carolina State University Future Renewable Electric Energy Delivery and Management Systems (FREEDM) Center.

- Goals of the FREEDM Center, funded by the National Science Foundation, are "to create a culture of innovation in engineering research and education that links scientific discovery to technological innovation through transformational engineered systems research" and "make advances in technology and produce engineering graduates who will be creative innovators in a global economy" (http://www.freedm.ncsu.edu/).
- Details of other research pending.

Key research questions:

1. At individual home level, at distribution transformer level, and at feeder/aggregator level, what is DR capability? (magnitude, duration, availability)
2. If integrating PV, ES, EV, whether we achieve better DR capability?
3. What is the cost of implementation?
4. What is the benefit?
5. If we use a bottom up approach, how we can scale up to system level?

Hierarchical Energy Management of DR. Develop analytical tools for time and space coordination of DR assets in coordination with utility level assets.

Existing research: F. Shoriatzadeh "Hierarchical Energy Management." M. Ilic's work. LBNL's Distributed Energy Resources Customer Adoption Model (DER-CAM).

- Details of existing research pending.

Key research questions:

1. How to coordinate data exchange between different entities for DR management?
2. How to do time coordination for information exchange between different entities?
3. How to develop control algorithms for signal generation to coordinate DR?

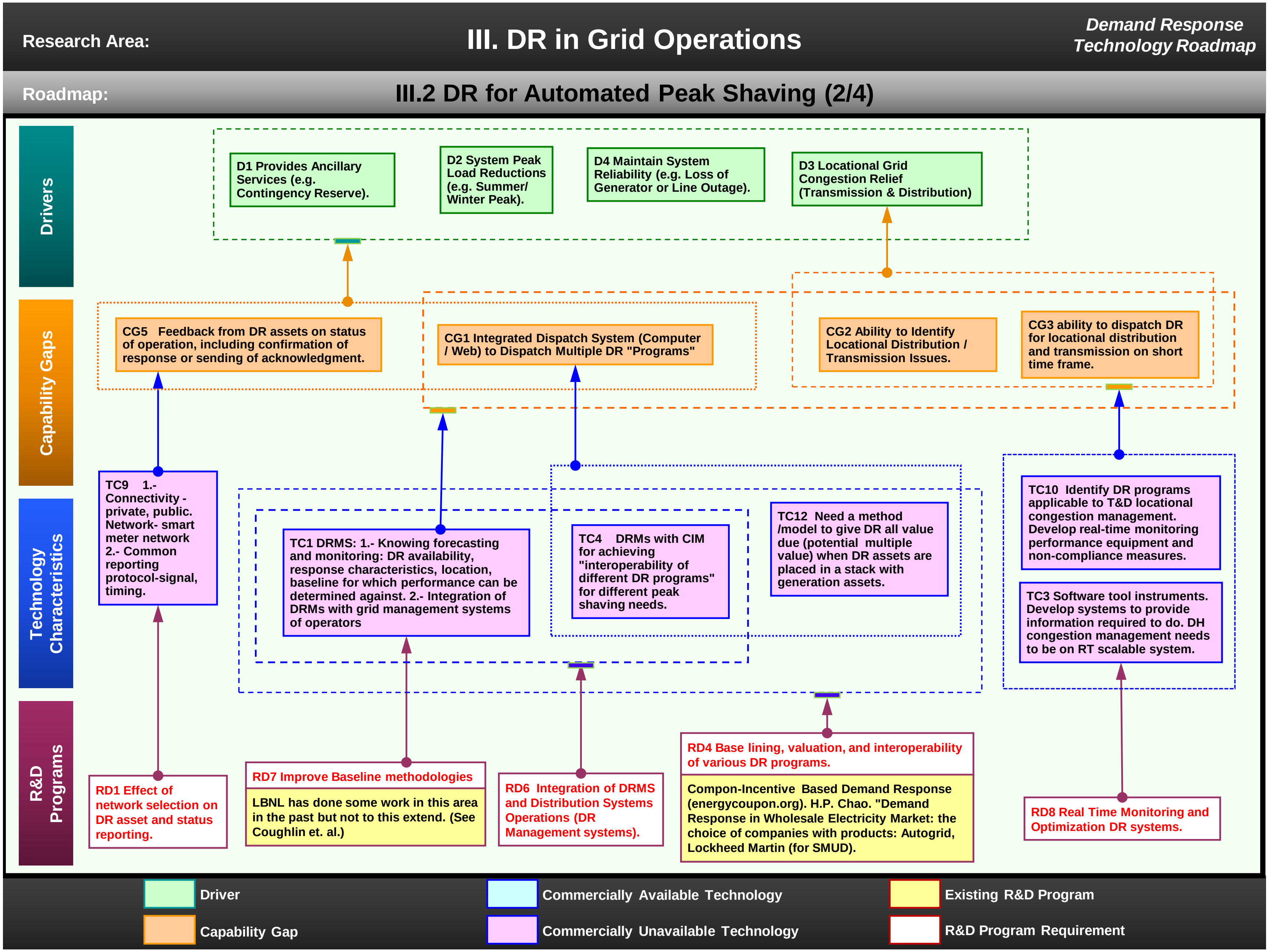
Distributed Grid Intelligence (DGI). The goal of this research is to develop a common information management and communication control platform to allow distributed energy resources and home energy management to share information and coordinate for implementing different micro grid functionalities (include DR).

Existing research: Allex Huang, David L. Lubkeman. North Carolina State University Future Renewable Electric Energy Delivery and Management Systems (FREEDM) Center.

- Goals of the FREEDM Center, funded by the National Science Foundation, are "to create a culture of innovation in engineering research and education that links scientific discovery to technological innovation through transformational engineered systems research" and "make advances in technology and produce engineering graduates who will be creative innovators in a global economy" (http://www.freedm.ncsu.edu/).
- Details of other existing research pending.

Key research questions:

1. For different controllers and energy management systems, how much information storage, processing and communication capability we shall have to implement a specific functionality such as DR functions?
2. What control shall be centralized and what shall be distributed?
3. How to make sure devices talk with each other through different channels?


Research Area:
III. DR in Grid Operations
Demand Response Technology Roadmap
Roadmap:
III.2 DR for Automated Peak Shaving (2/4)
Drivers
Capability Gaps
Technology Characteristics
R&D Programs
D1 Provides Ancillary Services (e.g. Contingency Reserve).
D2 System Peak Load Reductions (e.g. Summer/ Winter Peak).
D4 Maintain System Reliability (e.g. Loss of Generator or Line Outage).
D3 Locational Grid Congestion Relief (Transmission & Distribution)
CG5 Feedback from DR assets on status of operation, including confirmation of response or sending of acknowledgment.
CG1 Integrated Dispatch System (Computer / Web) to Dispatch Multiple DR "Programs"
CG2 Ability to Identify Locational Distribution / Transmission Issues.
CG3 ability to dispatch DR for locational distribution and transmission on short time frame.
TC9 1.- Connectivity - private, public. Network- smart meter network 2.- Common reporting protocol-signal, timing.
TC1 DRMS: 1.- Knowing forecasting and monitoring: DR availability, response characteristics, location, baseline for which performance can be determined against. 2.- Integration of DRMs with grid management systems of operators
TC4 DRMs with CIM for achieving "interoperability of different DR programs" for different peak shaving needs.
TC12 Need a method /model to give DR all value due (potential multiple value) when DR assets are placed in a stack with generation assets.
TC10 Identify DR programs applicable to T&D locational congestion management. Develop real-time monitoring performance equipment and non-compliance measures.
TC3 Software tool instruments. Develop systems to provide information required to do. DH congestion management needs to be on RT scalable system.
RD1 Effect of network selection on DR asset and status reporting.
RD7 Improve Baseline methodologies
LBNL has done some work in this area in the past but not to this extend. (See Coughlin et. al.)
RD6 Integration of DRMS and Distribution Systems Operations (DR Management systems).
RD4 Base lining, valuation, and interoperability of various DR programs.
Compon-Incentive Based Demand Response (energycoupon.org). H.P. Chao. "Demand Response in Wholesale Electricity Market: the choice of companies with products: Autogrid, Lockheed Martin (for SMUD).
RD8 Real Time Monitoring and Optimization DR systems.
Driver
Capability Gap
Commercially Available Technology
Commercially Unavailable Technology
Existing R&D Program
R&D Program Requirement

Improve Baseline methodologies. When it comes to baselines, one methodology does not fit all sorts of loads: the purpose of the research is to determine which baseline methodologies work with what kinds of loads and what timescales..

Existing research: LBNL has done some work in this area in the past but not to this extend. (See Coughlin et. al.).

- Details of existing research pending.

Key research questions:

1. How can we characterize loads to determine most accurate and least based baselines?
2. What kinds of baseline methods are more accurate for short timescales and which one for multiple-hour participation.
3. What are the standard ways to test bias and accuracy of baselines?
4. Should different baselines be used for individual facilities vs. aggregated loads?
5. Can sensory and measurement improve baseline accuracy? If so, what are the minimum cost and measurement requirements?

Baselining, valuation, and interoperability of various DR programs. Several DR program exist today (price-based, incentive-based, direct load control, interruptible load contracts). A key goal of this research is to develop algorithms that are able to baseline DR program in the otherwise inactive mode, and provide bulk operator a clear understanding of benefits from various DR mechanisms.

Existing research: Coupon-Incentive Based Demand Response (energycoupon.org). Hung-po Chao, "Demand Response in Wholesale Electricity Market: The Choice of Customer Baseline," *Journal of Regulatory Economics* 39 (2012), 68-88. Companies with Products: Autogrid, Lockheed Martin (for SMUD).

- Details of existing research pending.

Key research questions:

1. How to develop analytical tools that learn from historical behavior the baseline of DR programs?
2. How to make such baselining robust against temporal variations, response uncertainty, and gaming of the system?
3. How to compare "apples" and "oranges" in the sense of benefits of various DR mechanisms (e.g. Energy Compon vs. price-based vs. Direct Load Control?
4. How do we build risk models for aggregation of large uncertain individual DR programs?
5. How to create common protocol that serves as a levelized playfield for different DR programs?

Effect of network selection on DR asset and status reporting. This project will model and verify the cost, reliability, and effectiveness of three different network selections for data transferring: 1) Private (customer owned); 2) Public (standard telecommunication); and 3) Smart meter network.

Existing research: None identified.

Key research questions:

1. What are the limitations of private network? Availability, security.
2. Public network – cost, technology shift.
3. Smart meter network – Can it be shared with basic need of the metering?

Integration of DRMS and Distribution Systems Operations (DR Management systems). The goal of this program is to explore how to operationalize demand-side resources especially based on location of the resources. The goal is to provide operators the capabilities to seamlessly integrate DR as a least-cost resource.

Existing research: None identified.

Key research questions:

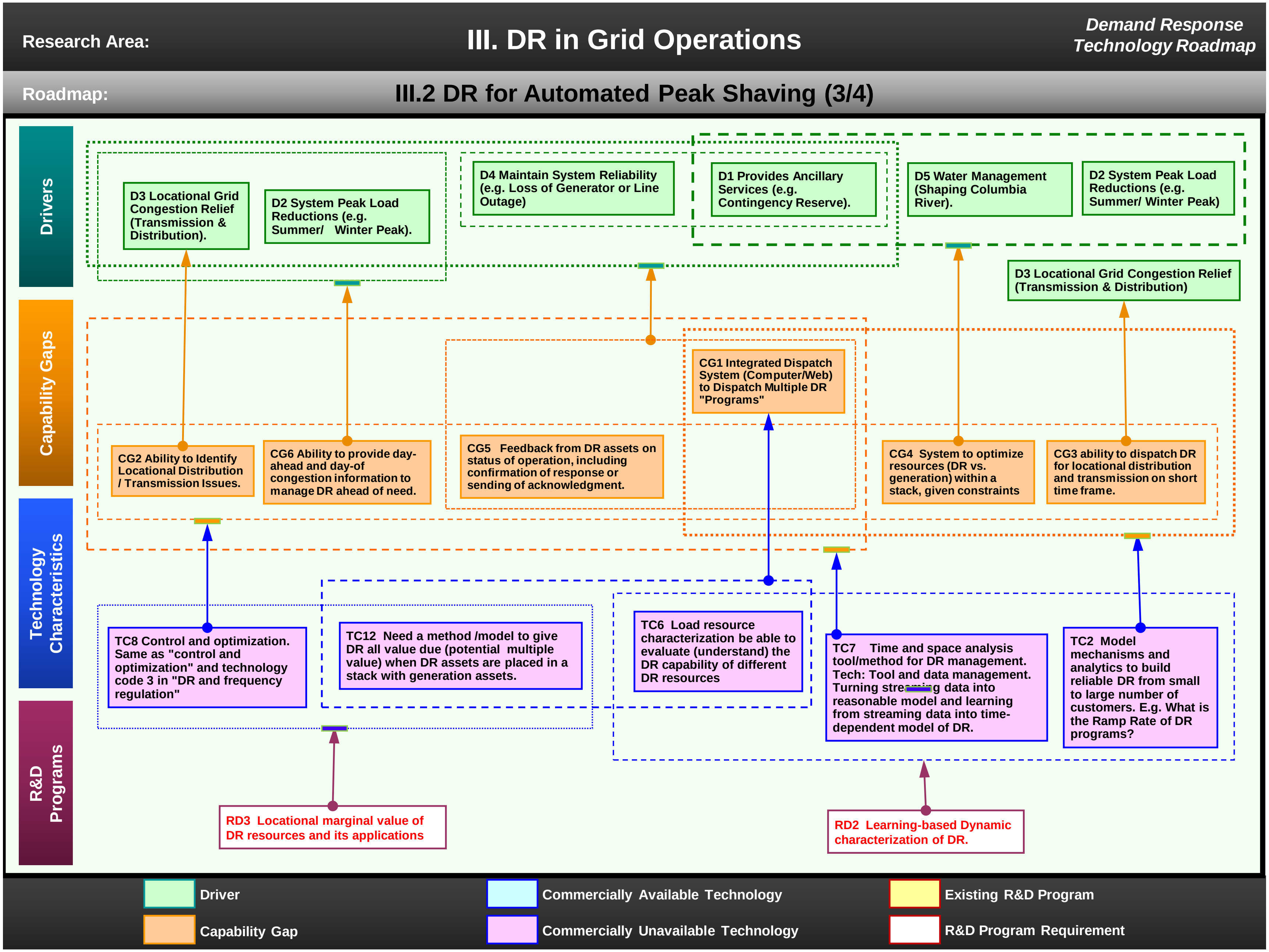
1. How are distribution and transmission operators integrate DR resources now?
2. What kinds of tools, data, visibility, control, etc. they need to trigger these resources?
3. If there is a system that integrates the two, how often would it be used and how it would change the ways DR is being used by operators?

Real Time Monitoring and Optimization DR Systems. DR resources connected to distribution (and transmission) can be monitored dispatched to solve congestion and defer T&D investments in various loads events where congestion may appear as a result of DER resources.

Existing research: None identified.

Key research questions:

1. What are the monitoring requirements for optimal T&D locational congestion managements?
2. What are the optimal dispatch requirements for real-time optimization of DR resources in the distribution system?
3. What other information requirements are to be met for optimal dispatch?
4. Develop optimal dispatch of DR in T&D level?


Research Area:
III. DR in Grid Operations
Demand Response Technology Roadmap
Roadmap:
III.2 DR for Automated Peak Shaving (3/4)
Drivers
Capability Gaps
Technology Characteristics
R&D Programs
D3 Locational Grid Congestion Relief (Transmission & Distribution).
D2 System Peak Load Reductions (e.g. Summer/ Winter Peak).
D4 Maintain System Reliability (e.g. Loss of Generator or Line Outage)
D1 Provides Ancillary Services (e.g. Contingency Reserve).
D5 Water Management (Shaping Columbia River).
D2 System Peak Load Reductions (e.g. Summer/ Winter Peak)
D3 Locational Grid Congestion Relief (Transmission & Distribution)
CG1 Integrated Dispatch System (Computer/Web) to Dispatch Multiple DR "Programs"
CG2 Ability to Identify Locational Distribution / Transmission Issues.
CG6 Ability to provide day-ahead and day-of congestion information to manage DR ahead of need.
CG5 Feedback from DR assets on status of operation, including confirmation of response or sending of acknowledgment.
CG4 System to optimize resources (DR vs. generation) within a stack, given constraints
CG3 ability to dispatch DR for locational distribution and transmission on short time frame.
TC8 Control and optimization. Same as "control and optimization" and technology code 3 in "DR and frequency regulation"
TC12 Need a method /model to give DR all value due (potential multiple value) when DR assets are placed in a stack with generation assets.
TC6 Load resource characterization be able to evaluate (understand) the DR capability of different DR resources
TC7 Time and space analysis tool/method for DR management. Tech: Tool and data management. Turning streaming data into reasonable model and learning from streaming data into time-dependent model of DR.
TC2 Model mechanisms and analytics to build reliable DR from small to large number of customers. E.g. What is the Ramp Rate of DR programs?
RD3 Locational marginal value of DR resources and its applications
RD2 Learning-based Dynamic characterization of DR.
Driver
Capability Gap
Commercially Available Technology
Commercially Unavailable Technology
Existing R&D Program
R&D Program Requirement

R&D Program Summaries

Locational marginal value of DR resource and its applications. The marginal value od an additional unit of DR resource depends on (i) network structure and (ii) network conditions. The optimization and control of DR, at different time scale for different applications (frequency regulation, grid balancing, planning, etc.) should exploit the locational marginal value of DR and locational marginal costs of load.

Existing research: None that addresses theses questions holistically.

Key research questions:

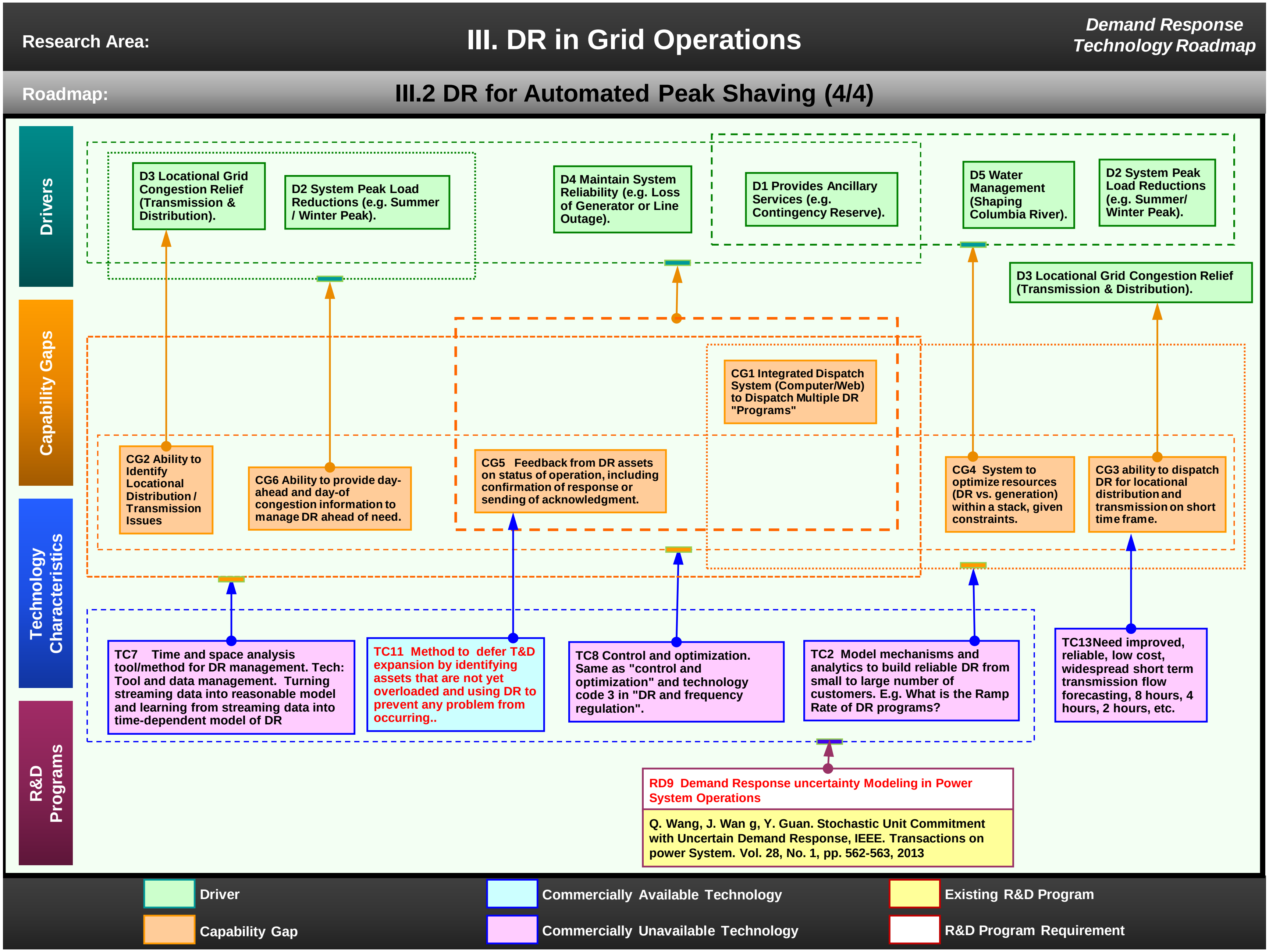
1. What is the impact of network structure (topology, R/x ratio, etc) on the locational marginal value of DR?
2. What is the true impact of network structure on locational marginal costs of load?
3. How to compute LMV of DR? How to estimate LMV of DR from incomplete , outdated, noisy, time varying data (on infrastructure, on network state, on loads, on DR capacity)?
4. How to optimally dispatch generations/DR based on LMV of DR and LM cost of loads?
5. How does uncertainty in generation (e.g. wind) and loads and in DR resources impact all of the above?

Learning-based Dynamic characterization of DR. To develop the model, analytics, and software necessary to characterize the time-varying and location-dependent DR bulk power systems. To recognize that such model can be developed and updated from [online data].

Existing research: None identified.

Key research questions:

1. How do we learn from empirical data and build reliable DR model out of small-large number of customers?
2. What is an appropriate DYNAMIC characterization of DR? (e.g. What is the equivalent ramp rate of DR at given "time"?).
3. How does an aggregator interact between bulk transmission operator and customers to have optimal DR?
4. How to incorporate the dynamic, uncertain DR aggregated model into the dispatch and control?


Research Area:
III. DR in Grid Operations
Demand Response Technology Roadmap
Roadmap:
III.2 DR for Automated Peak Shaving (4/4)
Drivers
Capability Gaps
Technology Characteristics
R&D Programs
D3 Locational Grid Congestion Relief (Transmission & Distribution).
D2 System Peak Load Reductions (e.g. Summer / Winter Peak).
D4 Maintain System Reliability (e.g. Loss of Generator or Line Outage).
D1 Provides Ancillary Services (e.g. Contingency Reserve).
D5 Water Management (Shaping Columbia River).
D2 System Peak Load Reductions (e.g. Summer/ Winter Peak).
D3 Locational Grid Congestion Relief (Transmission & Distribution).
CG1 Integrated Dispatch System (Computer/Web) to Dispatch Multiple DR "Programs"
CG2 Ability to Identify Locational Distribution / Transmission Issues
CG6 Ability to provide day-ahead and day-of congestion information to manage DR ahead of need.
CG5 Feedback from DR assets on status of operation, including confirmation of response or sending of acknowledgment.
CG4 System to optimize resources (DR vs. generation) within a stack, given constraints.
CG3 ability to dispatch DR for locational distribution and transmission on short time frame.
TC7 Time and space analysis tool/method for DR management. Tech: Tool and data management. Turning streaming data into reasonable model and learning from streaming data into time-dependent model of DR
TC11 Method to defer T&D expansion by identifying assets that are not yet overloaded and using DR to prevent any problem from occurring..
TC8 Control and optimization. Same as "control and optimization" and technology code 3 in "DR and frequency regulation".
TC2 Model mechanisms and analytics to build reliable DR from small to large number of customers. E.g. What is the Ramp Rate of DR programs?
TC13Need improved, reliable, low cost, widespread short term transmission flow forecasting, 8 hours, 4 hours, 2 hours, etc.
RD9 Demand Response uncertainty Modeling in Power System Operations
Q. Wang, J. Wan g, Y. Guan. Stochastic Unit Commitment with Uncertain Demand Response, IEEE. Transactions on power System. Vol. 28, No. 1, pp. 562-563, 2013
Driver
Capability Gap
Commercially Available Technology
Commercially Unavailable Technology
Existing R&D Program
R&D Program Requirement

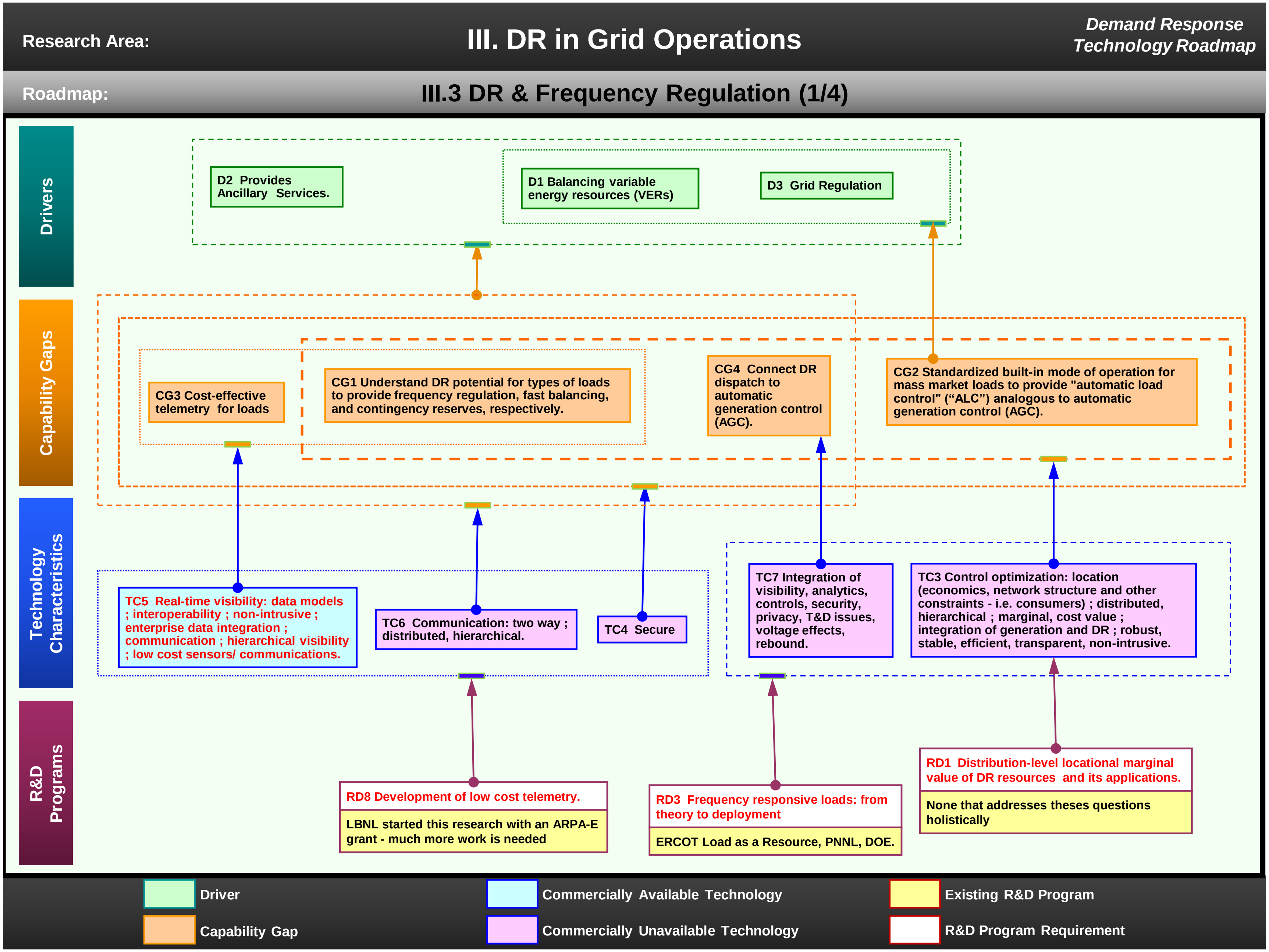
Demand Response Uncertainty Modeling in Power System Operations. Develop advanced Power System operation methods to model and address the uncertainty and errors for demand response forecast.

Existing research: Q. Wang, J. Wang, Y. Guan, "Stochastic Unit Commitment with Uncertain Demand Response," *IEEE Transactions on Power Systems* 28:1 (2013) 562-563.

- Details of existing research pending.

Key research questions:

1. How to model the demand response availability and forecast errors in power system operations?
2. How to revise and improve the power system operation method to take care of DR uncertainties?
3. How to ensure the proposed power system operation methods to be robust, optimal, and capable of handling large system cases?
4. What stochastic or probabilistic methods can be leveraged to address this problem?


Research Area:
III. DR in Grid Operations
Demand Response Technology Roadmap
Roadmap:
III.3 DR & Frequency Regulation (1/4)
Drivers
Capability Gaps
Technology Characteristics
R&D Programs
D2 Provides Ancillary Services.
D1 Balancing variable energy resources (VERs)
D3 Grid Regulation
CG3 Cost-effective telemetry for loads
CG1 Understand DR potential for types of loads to provide frequency regulation, fast balancing, and contingency reserves, respectively.
CG4 Connect DR dispatch to automatic generation control (AGC).
CG2 Standardized built-in mode of operation for mass market loads to provide "automatic load control" ("ALC") analogous to automatic generation control (AGC).
TC5 Real-time visibility: data models ; interoperability ; non-intrusive ; enterprise data integration ; communication ; hierarchical visibility ; low cost sensors/ communications.
TC6 Communication: two way ; distributed, hierarchical.
TC4 Secure
TC7 Integration of visibility, analytics, controls, security, privacy, T&D issues, voltage effects, rebound.
TC3 Control optimization: location (economics, network structure and other constraints - i.e. consumers) ; distributed, hierarchical ; marginal, cost value ; integration of generation and DR ; robust, stable, efficient, transparent, non-intrusive.
RD8 Development of low cost telemetry.
LBNL started this research with an ARPA-E grant - much more work is needed
RD3 Frequency responsive loads: from theory to deployment
ERCOT Load as a Resource, PNNL, DOE.
RD1 Distribution-level locational marginal value of DR resources and its applications.
None that addresses theses questions holistically
Driver
Capability Gap
Commercially Available Technology
Commercially Unavailable Technology
Existing R&D Program
R&D Program Requirement

R&D Program Summaries

Development of low cost telemetry. The goal is to develop low cost telemetry hardware and communications.

Existing research: LBNL started this research with an ARPA-E grant - much more work is needed.

- Details of existing research pending.

Key research questions:

1. What is the lowest cost hardware that can meet accuracy and requirements?

   For mass market, can we measure a sample and extrapolate to the population?
2. What are the low cost communication methods and what are the latencies associated with telemetry communications?

Frequency responsive loads: firm theory to deployment. Hierarchical distributed robust control of frequency loads systematically account for end-use constraints. Consider wide-range of system operating conditions. Provide primary frequency response and adequate voltage viability.

Existing research: Loads as a resource PNNL, DOE.

- Details of existing research pending.

Key research questions:

1. What does the structure/architecture of control look like?
2. What simulation platforms (integrate TTD dynamic simulation) need to be developed to validate preferred control strategies?
3. What mechanisms need to be put in place to engage end-use loads to provide frequency regulation + voltage stability?
4. What impacts (voltage side-effects) does this control scheme have in the distribution feeders?
5. How to incorporate end-use load constraints into the control strategy?

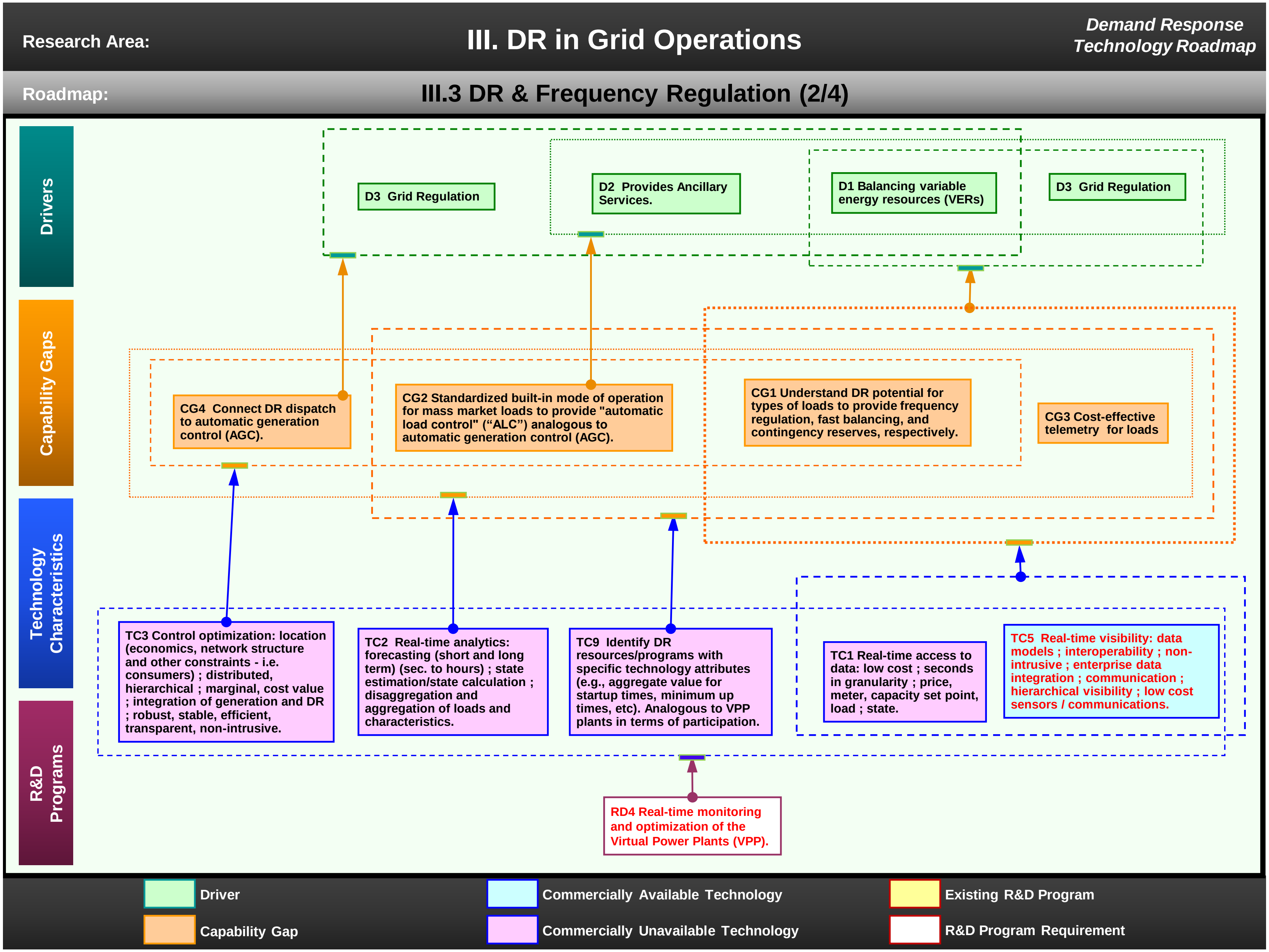
Distribution-level locational marginal value of DR resources and its applications. The marginal value od an additional unit of DR resource depends on (i) network structure and (ii) network conditions. The optimization and control of DR, at different time scale for different applications (frequency regulation, grid balancing, planning, etc.) should exploit the locational marginal value of DR and locational marginal costs of load.

Existing research: None that addresses theses questions holistically.

- Details of existing research pending.

Key research questions:

1. What is the impact of network structure (topology, R/x ratio, etc) on the locational marginal value of DR?
2. What is the true impact of network structure on locational marginal costs of load?
3. How to compute LMV of DR? How to estimate LMV of DR from incomplete , outdated, noisy, time varying data (on infrastructure, on network state, on loads, on DR capacity)?
4. How to optimally dispatch generations/DR based on LMV of DR and LM cost of loads?
5. How does uncertainty in generation (e.g. wind) and loads and in DR resources impact all of the above?
6. How to develop a prototype to validate in simulation and in field?



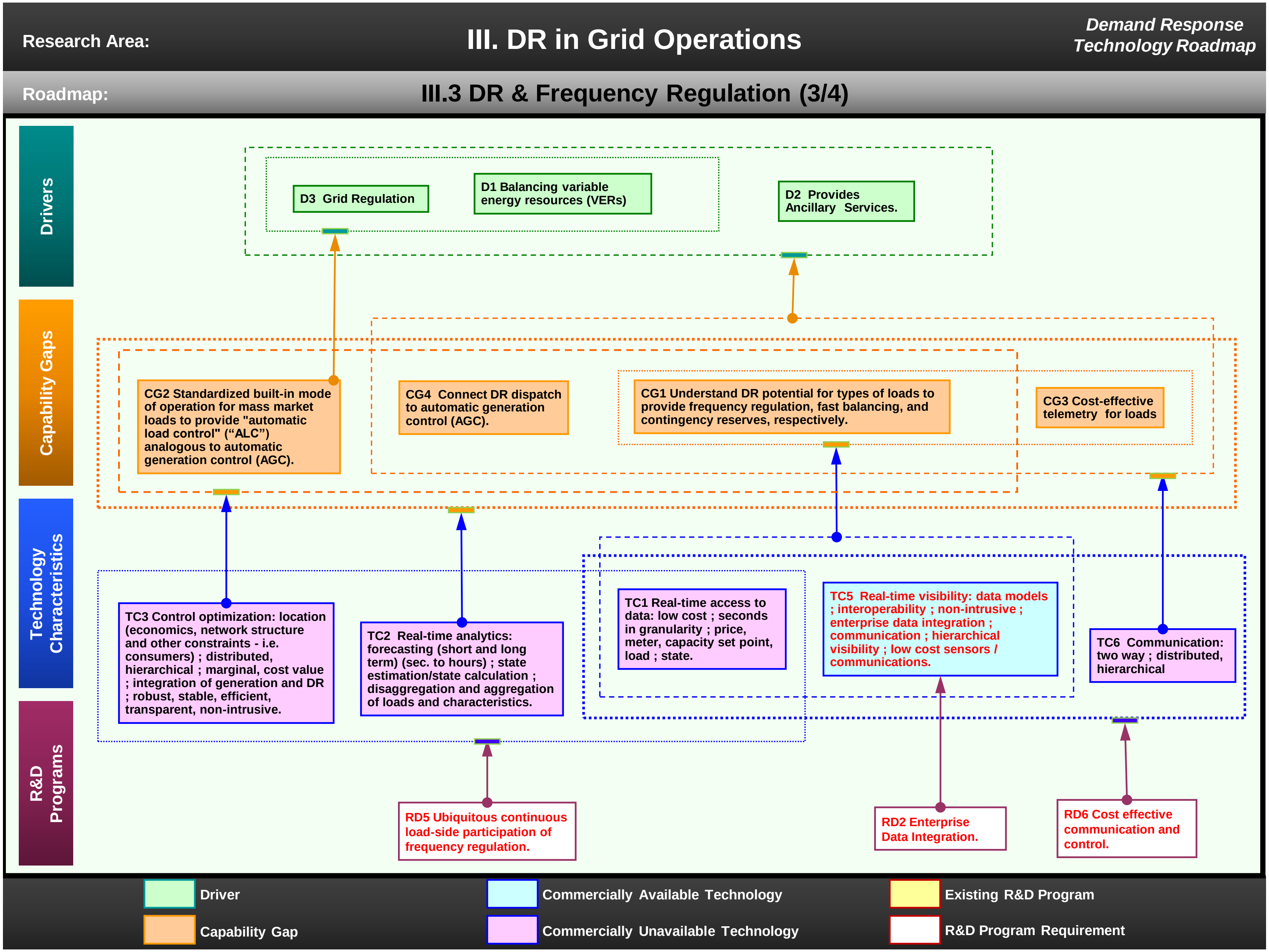
Back to Table of Contents

Real-time monitoring and optimization of the virtual power plants (VPP). Develop the technological attributes of aggregated DR resources (aggregate ramping start-up time, minimum up time, etc). Develop mechanisms for monitoring/optimizing in wholesale meters VPPs.

Existing research: None identified.

Key research questions:

1. What is the attributed ramping rate of aggregated DR resources (also start-up time, minimum up time, etc)?
2. How to produce optimal bidding strategies for participating in wholesale markets?
3. What are the minimum requirements for participation of VPP`s in the market in terms of metering, telemetry, performance, schedule and bidding requirements?



Back to Table of Contents

R&D Program Summaries

Ubiquitous continuous load-side participation of frequency regulation. How to design load side participation of frequency regulation algorithms for distributed DR systematic/programmatic response? Demonstrate, design, architecture.

Existing research: None identified.

Key research questions:

1. Analyze the stability and robustness of the feedback systems. Interaction of the load side control + generation side control (contrast + deliver performance + sensitivity).

Enterprise data Integration. Provide the capability of break data silos in a typical utility organization to create a unified and complete database to support DR/DER operations.

Existing research: None identified.

Key research questions:

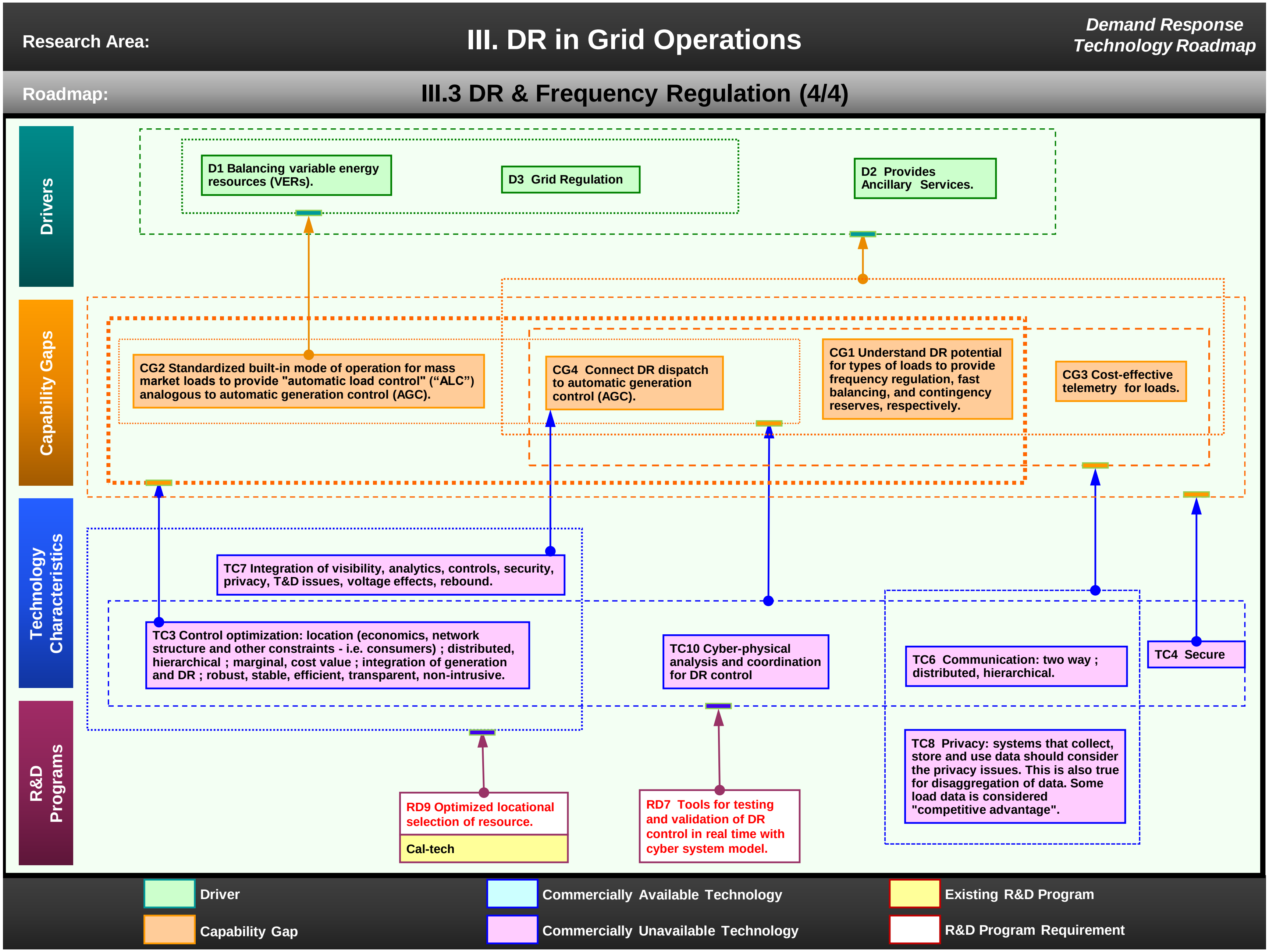
1. Integrate data from SCADA/DMS, AMI/MDM, GIS, CIS, CRM.

Cost effective communication and control. Develop low cost sensing, communication, and control hardware/software technology.

Existing research: None identified.

Key research questions:

1. Data collections and control capability In real-time or near real-time (2-6 seconds).
2. Cost of customer side hardware < $100.
3. Support cellular, wi-fi, IP.
4. Support RTU protocols DNP3, MODUS.
5. Support Open ADR 2.0, Multispeak, SEP.
6. Cyber security, data privacy.
7. Non-intrusive.


Research Area:
III. DR in Grid Operations
Demand Response Technology Roadmap
Roadmap:
III.3 DR & Frequency Regulation (4/4)
Drivers
Capability Gaps
Technology Characteristics
R&D Programs
D1 Balancing variable energy resources (VERs).
D3 Grid Regulation
D2 Provides Ancillary Services.
CG2 Standardized built-in mode of operation for mass market loads to provide "automatic load control" ("ALC") analogous to automatic generation control (AGC).
CG4 Connect DR dispatch to automatic generation control (AGC).
CG1 Understand DR potential for types of loads to provide frequency regulation, fast balancing, and contingency reserves, respectively.
CG3 Cost-effective telemetry for loads.
TC7 Integration of visibility, analytics, controls, security, privacy, T&D issues, voltage effects, rebound.
TC3 Control optimization: location (economics, network structure and other constraints - i.e. consumers) ; distributed, hierarchical ; marginal, cost value ; integration of generation and DR ; robust, stable, efficient, transparent, non-intrusive.
TC10 Cyber-physical analysis and coordination for DR control
TC6 Communication: two way ; distributed, hierarchical.
TC4 Secure
TC8 Privacy: systems that collect, store and use data should consider the privacy issues. This is also true for disaggregation of data. Some load data is considered "competitive advantage".
RD9 Optimized locational selection of resource.
Cal-tech
RD7 Tools for testing and validation of DR control in real time with cyber system model.
Driver
Capability Gap
Commercially Available Technology
Commercially Unavailable Technology
Existing R&D Program
R&D Program Requirement

Optimized locational selection of resource. The purpose of the program is to develop and demonstrate optimal locational selection of resources based on a problem to be solved, the goal is to select the resources that solve the problem at a least cost (and/or low carbon) level.

Existing research: Cal-tech? Not sure if they are doing this research.

- Details of existing research pending.

Key research questions:

1. What are typical problems at the distribution level that DR, DER and storage (and solve together)?
2. What is the cost of not solving the problem or what is the value for the solution?
3. How can the decision-making mechanism or tool have access to the resource availability information?
4. What are the key elements of optimization algorithms and how can they be tested and evaluated?
5. How can the optimized selection be operationalized at the distribution or transmission level?
6. How can we incorporate uncertainty of resource availability?

Tools for testing and validation of DR control in real time with cyber system model. Analyze the DR control & short term dynamics of system with consideration of supporting cyber system. This is critical given DR timeline being short enough to be impacted by communications timeline.

Existing research: None identified.

Key research questions:

1. Analyze interdependencies of cyber & physical system for DR management.
2. Analyze system dynamics & impact of DR
3. Analyze and validate developed algorithms with consideration of power system, control algorithms, communication network and data management.

Integration

Integration of Demand Response and Energy Efficiency

Research Area Definition

Integration of DR and EE involves technologies used at a site or group of sites to maximize energy efficiency and enable demand response. Examples here include integrated home and business energy management systems that enable DR and provide a real-time determination of available capacity. These technologies include automatic lighting controls as well as automated thermostats and plug load controls.

Integration with Building Energy Management Systems (BEMS)

Some of the questions involved how to screen for the most appropriate building candidates and then encourage adoption of BEMS, especially in those mid-sized commercial buildings that do not contain separately metered tenants.

There is also a need to develop open-source plug and play solutions. This involves identification of those building loads that coincide with the peak and also those assets with the most predictable loads.

Another study would involve developing improved interoperability for BEMS controls to help enable DR readiness.

Building commissioning was also identified as a potential area of study, to best determine which commissioning tests are needed and how can commissioning identify some of the potential DR assets.

On the building occupant level, additional research on capturing occupant preferences to optimize DR as well as how integrated DR controls impact tenant adoption rates is important.

Integration with Home Energy Management Systems (HEMS)

Similar to the BEMS roadmap, studies to optimize end use assets without negatively impacting residents were identified. This requires algorithms that are capable of monitoring a variety of residential loads (i.e. HVAC, dryers, water heaters, and EV's) at the individual residence level as well as across an aggregated network, while optimizing the load response from these assets.

Cyber security concerns were also identified given the array of communications platforms employed by different HEMS.

Residential behavioral studies are needed, including a better understanding of consumer preferences and values was identified by participants to better ensure and enhance long-term participation.

For Legacy Process Loads

Similar to the other workgroups working with DSM, HEMS or BEMS roadmaps, working with DR for legacy loads requires studies on determining accurate end-use controls and load measurement technologies. This includes researching low cost sub-metering to monitor loads at the device level to validate usage, as well as load response.

The need for technology platforms using OpenADR 2.0 for aggregated loads designed to provide visibility on asset location and ability to respond were also identified.

Demand-side Management Infrastructure

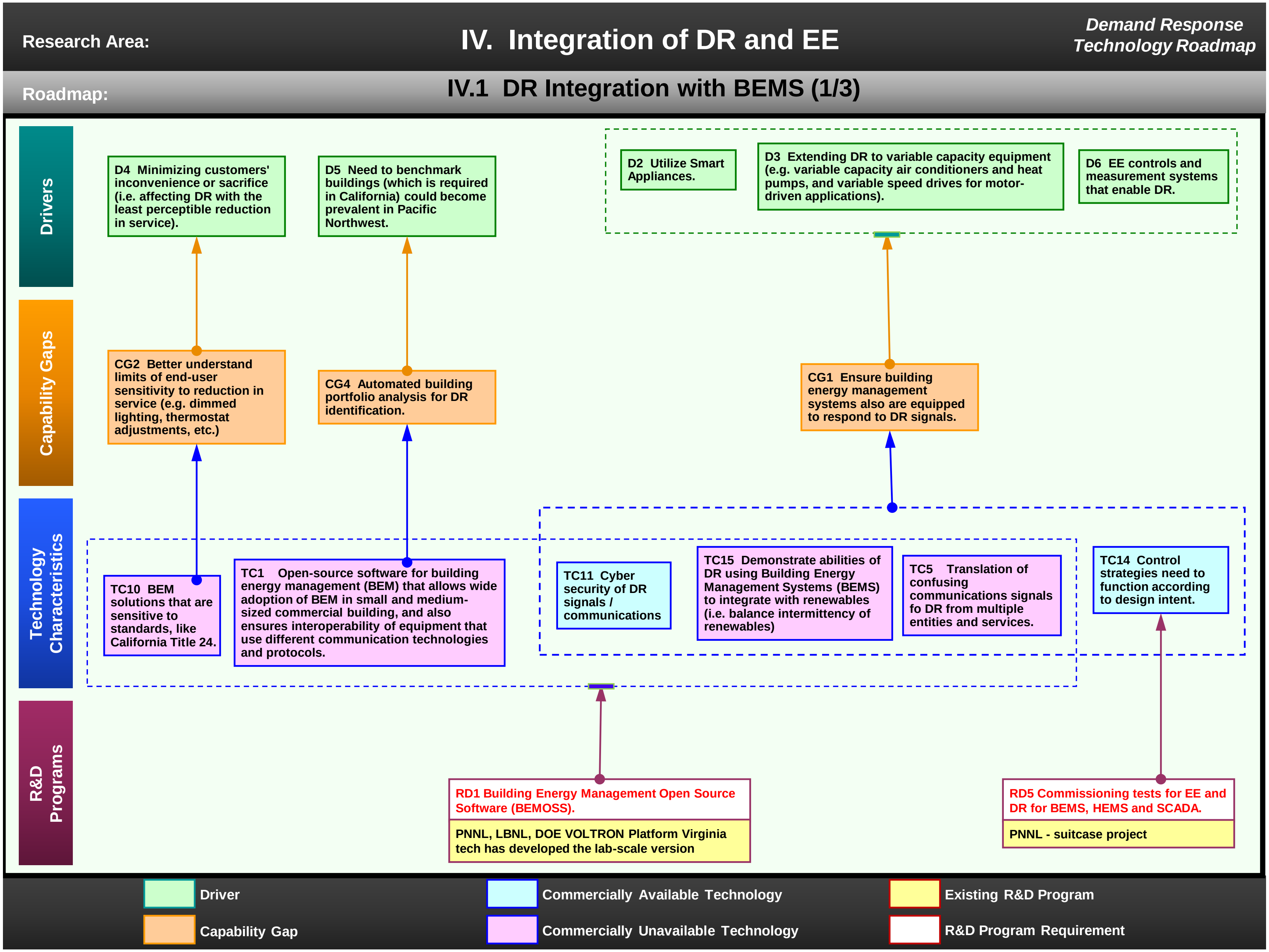
Which EE audit methods are best utilized for DR and how accurate are they? We also need studies to better understand the impact of whole building controls for commercial buildings, as well as how to integrate HVAC, lighting and plug loads to maximize load shift capabilities? This also involves development of improved predictive control systems to better coordinate EE and DR control strategies.

A better understanding of load shapes across various different customer classes would also be helpful especially if it can supplement or supplant existing AMI data.

The benefits and costs of various communications platforms need to be examined as well as the types of utility rate designs that promotes DR participation.

The insights and observations above were distilled from the input of all the subject matter experts who participated in Workshop 2.

- Chen Chen (Argonne Nat'l Laboratory)
- Ryan Fedie (Bonneville Power Administration)
- Carl Linvill (Regulatory Assistance Project)
- Ebony Mayhorn (Pacific Northwest Nat'l Laboratory)
- Ram Narayanamurthy (Electric Power Research Institute)
- Mary Ann Piette (Lawrence Berkeley Nat'l Laboratory)
- Manisa Pipattanasomporn (Virginia Tech)
- Jill Powers (California Independent System Operator)
- Farrokh Rahimi (Open Access Technology Int'l, Inc.)
- Alison Silverstein (N. American Synchrophasor Initiative)
- Megan Stratman (Northwest Requirements Utilities)
- Heather Williams (Opower)


Research Area:
IV. Integration of DR and EE
Demand Response Technology Roadmap
Roadmap:
IV.1 DR Integration with BEMS (1/3)
Drivers
Capability Gaps
Technology Characteristics
R&D Programs
D4 Minimizing customers' inconvenience or sacrifice (i.e. affecting DR with the least perceptible reduction in service).
D5 Need to benchmark buildings (which is required in California) could become prevalent in Pacific Northwest.
D2 Utilize Smart Appliances.
D3 Extending DR to variable capacity equipment (e.g. variable capacity air conditioners and heat pumps, and variable speed drives for motor-driven applications).
D6 EE controls and measurement systems that enable DR.
CG2 Better understand limits of end-user sensitivity to reduction in service (e.g. dimmed lighting, thermostat adjustments, etc.)
CG4 Automated building portfolio analysis for DR identification.
CG1 Ensure building energy management systems also are equipped to respond to DR signals.
TC10 BEM solutions that are sensitive to standards, like California Title 24.
TC1 Open-source software for building energy management (BEM) that allows wide adoption of BEM in small and medium-sized commercial building, and also ensures interoperability of equipment that use different communication technologies and protocols.
TC11 Cyber security of DR signals / communications
TC15 Demonstrate abilities of DR using Building Energy Management Systems (BEMS) to integrate with renewables (i.e. balance intermittency of renewables)
TC5 Translation of confusing communications signals fo DR from multiple entities and services.
TC14 Control strategies need to function according to design intent.
RD1 Building Energy Management Open Source Software (BEMOSS).
PNNL, LBNL, DOE VOLTRON Platform Virginia tech has developed the lab-scale version
RD5 Commissioning tests for EE and DR for BEMS, HEMS and SCADA.
PNNL - suitcase project
Driver
Capability Gap
Commercially Available Technology
Commercially Unavailable Technology
Existing R&D Program
R&D Program Requirement

Building Energy Management Open Source Software (BEMOSS). Develop a building energy management open-source software platform for controlling major loads (e.g. HVAC, lighting and plug loads) in small and medium-sized commercial buildings.

Existing research: PNNL, LBNL, DOE VOLTRON Platform. Virginia Tech has developed the lab-scale version, contact: Dr. Manisa Pipattanasomporn (mpipatta@vt.edu).

- Details of existing research pending.

Key research questions:

1. How to encourage wide adoption of BEM in small and medium-sized commercial buildings? Right now, about 90% of small and medium-sized commercial buildings do not use BEM systems due to:
    a. high cost of proprietary BEM solutions;
    b. most tenants do not pay for electricity;
    c. no BEM solutions that address interoperability among different products that use different communication technologies and protocols?
2. How to develop BEM solutions that are open-source, have plug-and-play interoperability, secure, sensitive to customer requirements (e.g. California Title 24) and low cost?

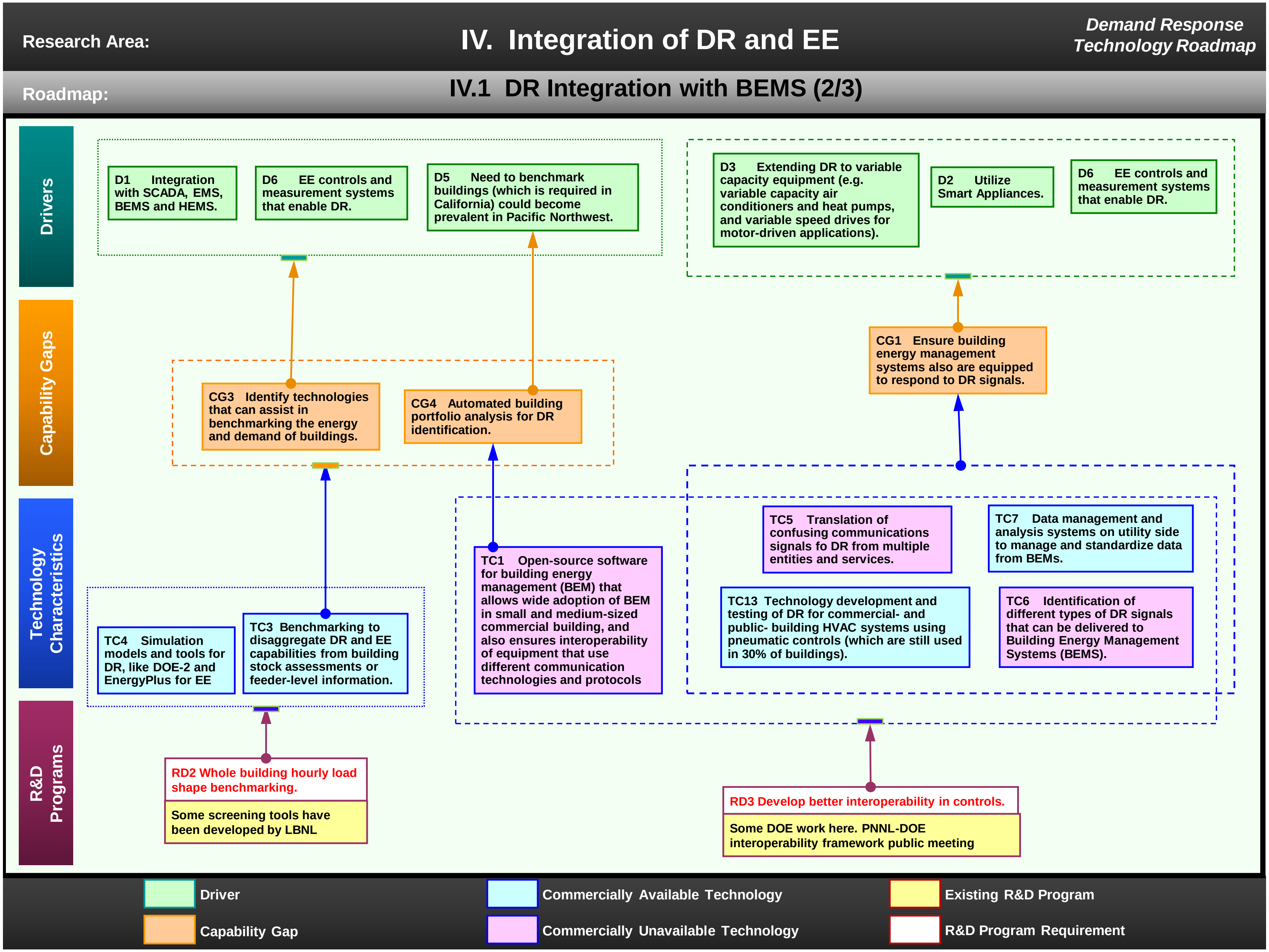
Commissioning tests for EE and DR for BEMS, HEMS and SCADA. Since DR in buildings and industry require controls to function - we need commissioning tests to ensure DR performs as expected. Develop DR commissioning capability to increase predictability of building response by leveraging commissioning field expertise, may require different form for new construction and existing building.

Existing research: PNNL - suitcase project, fully automated EMS/BMS is its own commissioning, doesn't need all process.

- Details of existing research pending.

Key research questions:

1. What DR commissioning tests are needed?
2. How can commissioning test be developed to ensure efficiency and DR goals are met?
3. What commissioning is needed for new construction?
4. Development of DR function testing methods, tests.
5. Training of commissioning practices for DR.



Back to Table of Contents

R&D Program Summaries

Whole building hourly load shape benchmarking. Develop methods to screen building stock to determine and identify which building may be the best candidate for DR.

Existing research: Some screening tools have been developed by LBNL.

- Details of existing research pending.

Key research questions:

1. Identify which buildings are best candidates for DR.
2. Which building loads are the most predictable?
3. Evaluate seasonality of loads.
4. Which loads / building peak at the same time as the grid?

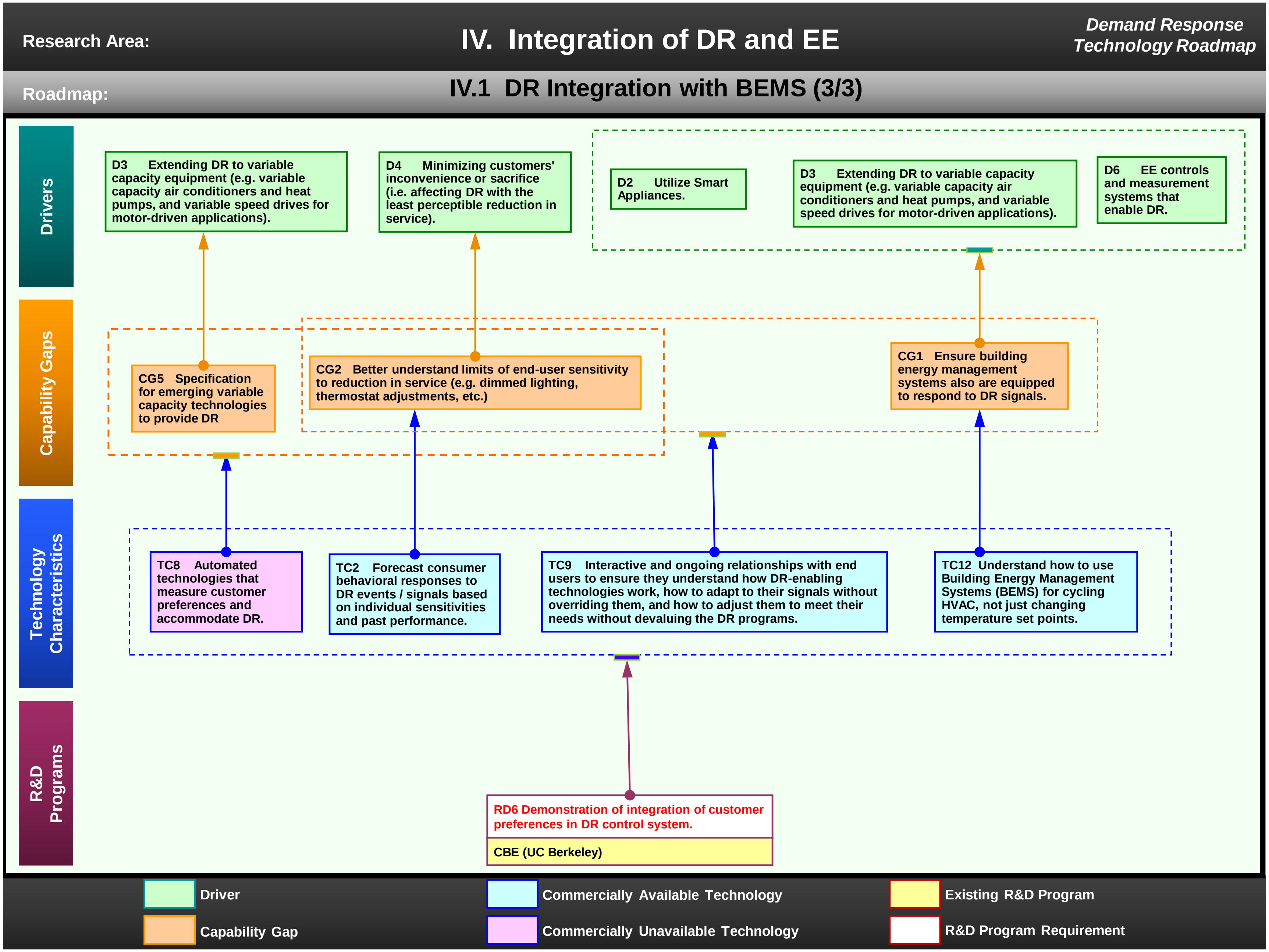
Develop better interoperability in controls. Begin to develop a common taxonomy among end-uses-shades, lights, HVAC, plugs, etc. to share data for interoperable controls.

Existing research: Some DOE work here. PNNL-DOE interoperability framework public meeting.

- Details of existing research pending.

Key research questions:

1. How can we engage manufacturers to develop open APIs (application program interface) to enable whole building control?
2. How can owners specify interoperability? This will help both EE and DR?


Research Area:
IV. Integration of DR and EE
Demand Response Technology Roadmap
Roadmap:
IV.1 DR Integration with BEMS (3/3)
Drivers
Capability Gaps
Technology Characteristics
R&D Programs
D3 Extending DR to variable capacity equipment (e.g. variable capacity air conditioners and heat pumps, and variable speed drives for motor-driven applications).
D4 Minimizing customers' inconvenience or sacrifice (i.e. affecting DR with the least perceptible reduction in service).
D2 Utilize Smart Appliances.
D3 Extending DR to variable capacity equipment (e.g. variable capacity air conditioners and heat pumps, and variable speed drives for motor-driven applications).
D6 EE controls and measurement systems that enable DR.
CG5 Specification for emerging variable capacity technologies to provide DR
CG2 Better understand limits of end-user sensitivity to reduction in service (e.g. dimmed lighting, thermostat adjustments, etc.)
CG1 Ensure building energy management systems also are equipped to respond to DR signals.
TC8 Automated technologies that measure customer preferences and accommodate DR.
TC2 Forecast consumer behavioral responses to DR events / signals based on individual sensitivities and past performance.
TC9 Interactive and ongoing relationships with end users to ensure they understand how DR-enabling technologies work, how to adapt to their signals without overriding them, and how to adjust them to meet their needs without devaluing the DR programs.
TC12 Understand how to use Building Energy Management Systems (BEMS) for cycling HVAC, not just changing temperature set points.
RD6 Demonstration of integration of customer preferences in DR control system.
CBE (UC Berkeley)
Driver
Capability Gap
Commercially Available Technology
Commercially Unavailable Technology
Existing R&D Program
R&D Program Requirement

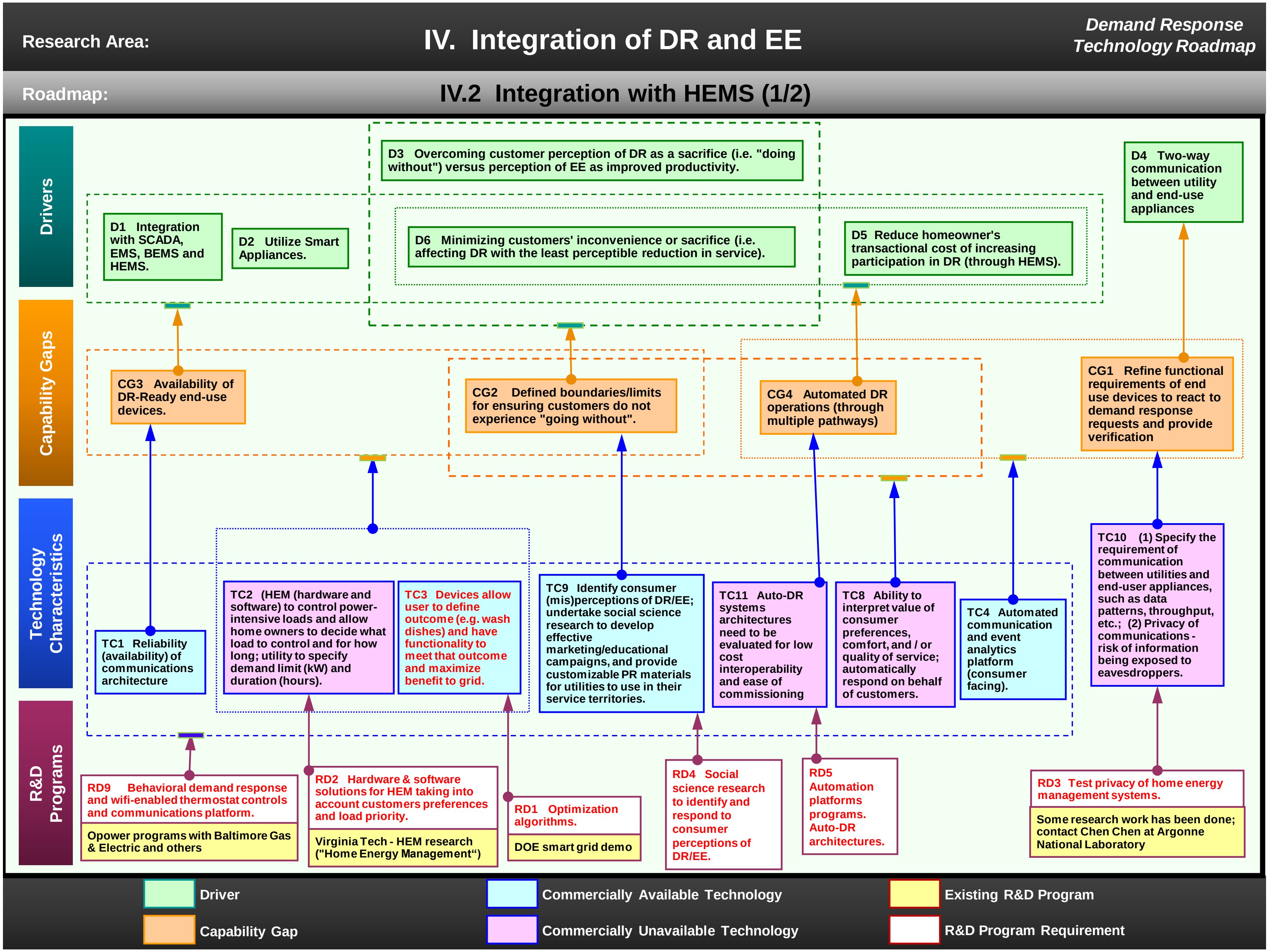
Demonstration of integration of customer preferences in DR control system. How do you measure, capture customer / occupant preferences in commercial buildings and how do you leverage that for optimizing DR?

Existing research: PNNL, LBNL, DOE VOLTRON Platform. Virginia tech has developed the lab-scale version, contact: Dr. Manisa Pipattanasomporn (mpipatta@vt.edu).

- Details of existing research pending.

Key research questions:

1. Creating customer preference "yours" for DR operation.
2. Outlining line between EE and DR based on consumer preferences.
3. Ability/Capability to integrate the measured preference to predict DR.
4. Comparing adoption rate for DR when preferences are integrated.


Research Area:
IV. Integration of DR and EE
Demand Response Technology Roadmap
Roadmap:
IV.2 Integration with HEMS (1/2)
Drivers
Capability Gaps
Technology Characteristics
R&D Programs
D3 Overcoming customer perception of DR as a sacrifice (i.e. "doing without") versus perception of EE as improved productivity.
D4 Two-way communication between utility and end-use appliances
D1 Integration with SCADA, EMS, BEMS and HEMS.
D2 Utilize Smart Appliances.
D6 Minimizing customers' inconvenience or sacrifice (i.e. affecting DR with the least perceptible reduction in service).
D5 Reduce homeowner's transactional cost of increasing participation in DR (through HEMS).
CG3 Availability of DR-Ready end-use devices.
CG2 Defined boundaries/limits for ensuring customers do not experience "going without".
CG4 Automated DR operations (through multiple pathways)
CG1 Refine functional requirements of end use devices to react to demand response requests and provide verification
TC1 Reliability (availability) of communications architecture
TC2 (HEM (hardware and software) to control power-intensive loads and allow home owners to decide what load to control and for how long; utility to specify demand limit (kW) and duration (hours).
TC3 Devices allow user to define outcome (e.g. wash dishes) and have functionality to meet that outcome and maximize benefit to grid.
TC9 Identify consumer (mis)perceptions of DR/EE; undertake social science research to develop effective marketing/educational campaigns, and provide customizable PR materials for utilities to use in their service territories.
TC11 Auto-DR systems architectures need to be evaluated for low cost interoperability and ease of commissioning
TC8 Ability to interpret value of consumer preferences, comfort, and / or quality of service; automatically respond on behalf of customers.
TC4 Automated communication and event analytics platform (consumer facing).
TC10 (1) Specify the requirement of communication between utilities and end-user appliances, such as data patterns, throughput, etc.; (2) Privacy of communications - risk of information being exposed to eavesdroppers.
RD9 Behavioral demand response and wifi-enabled thermostat controls and communications platform.
Opower programs with Baltimore Gas & Electric and others
RD2 Hardware & software solutions for HEM taking into account customers preferences and load priority.
Virginia Tech - HEM research ("Home Energy Management")
RD1 Optimization algorithms.
DOE smart grid demo
RD4 Social science research to identify and respond to consumer perceptions of DR/EE.
RD5 Automation platforms programs. Auto-DR architectures.
RD3 Test privacy of home energy management systems.
Some research work has been done; contact Chen Chen at Argonne National Laboratory
Driver
Capability Gap
Commercially Available Technology
Commercially Unavailable Technology
Existing R&D Program
R&D Program Requirement

R&D Program Summaries

Hardware & software solutions for HEM taking into account customers preferences and load priority. Hardware solutions for HEM must be able to monitor / control power intensive loads in a house (i.e. HVAC, clothes dryers, hater heaters, electric vehicles). Software solution must include algorithms that are sensitive to customer needs (i.e. customer comfort, preference and load priority) and utility needs (i.e. DR requirement specified in terms of demand limit to customers (kW) and duration (hours)).

Existing research: Virginia Tech - HEM research, contact Dr. Manisa Pipattanasomporn: mpipatta@vt.edu.

- Details of existing research pending.

Key research questions:

1. How to perform load control with minimum interruption to customer life-style? And at the same time satisfying utility needs?
2. What hardware solutions are available to control power-intensive loads in a house (240V, hardwire) as very few customers will buy small appliances?

Optimization algorithms. Create test algorithms to allow for autonomous optimization of end-users devices to maximize grid benefit without impacting user defined needs.

Existing research: DOE smart grid demos (i.e. PNW Smart Grid Demonstration); Transactive control/energy; Vendors-proprietary.

- Details of existing research pending.

Key research questions:

1. Define optimization parameters and use cases.

Behavioral demand response and Wi-Fi enabled thermostat controls and communications platform. Pilot behavioral demand response and Wi-Fi thermostat control via apps/web to test impact in NW , acceptance, scalability, and technology that is strategically designed around known consume behavior.

Existing research: Opower programs with Baltimore Gas&Electric and others.

- Details of existing research pending.

Key research questions:

1. What impact does behavioral science have when layered with demand response in the NW?
2. Will customers in the NW accept behavioral DR? (i.e. customer sat & overall sentiment)?
3. Can behavioral DR be automated and scaled sufficiently to be cost-effective in the NW?
4. Besides past participation & consumption, are there any other characteristics that can be used to reliably forecast future behavioral DR?
5. Can archetypes based on 8760 load shapes be used successfully to target customers opt-out behavioral DR?
6. How can customer segmentation and targeting be used to promote behavioral DR thru personalized messaging?

Test privacy of home energy management systems. Use information theory to quantify the privacy information exposed to the eavesdropper or attacker. Based on that, propose mitigation strategies.

Existing research: Some research work has been done, for more information contact Dr. Chen Chen at the Argonne National Laboratory, morningchen@anl.gov.

- Details of existing research pending.

Key research questions:

1. How to quantify the privacy information exposed to attackers?
2. What methods can be used to mitigate the privacy exposures?
3. Study trade-off between the privacy and utility it can achieve.

Social science research to identify and respond to consumer perceptions of DR/EE. Identify consumer (mis)perceptions of DR/EE. Engage in social science research to develop effective educational/marketing materials.Provide such materials to be customized by local utilities and distribute as PR/educational materials within their service territories.

Existing research: None identified.

Key research questions:

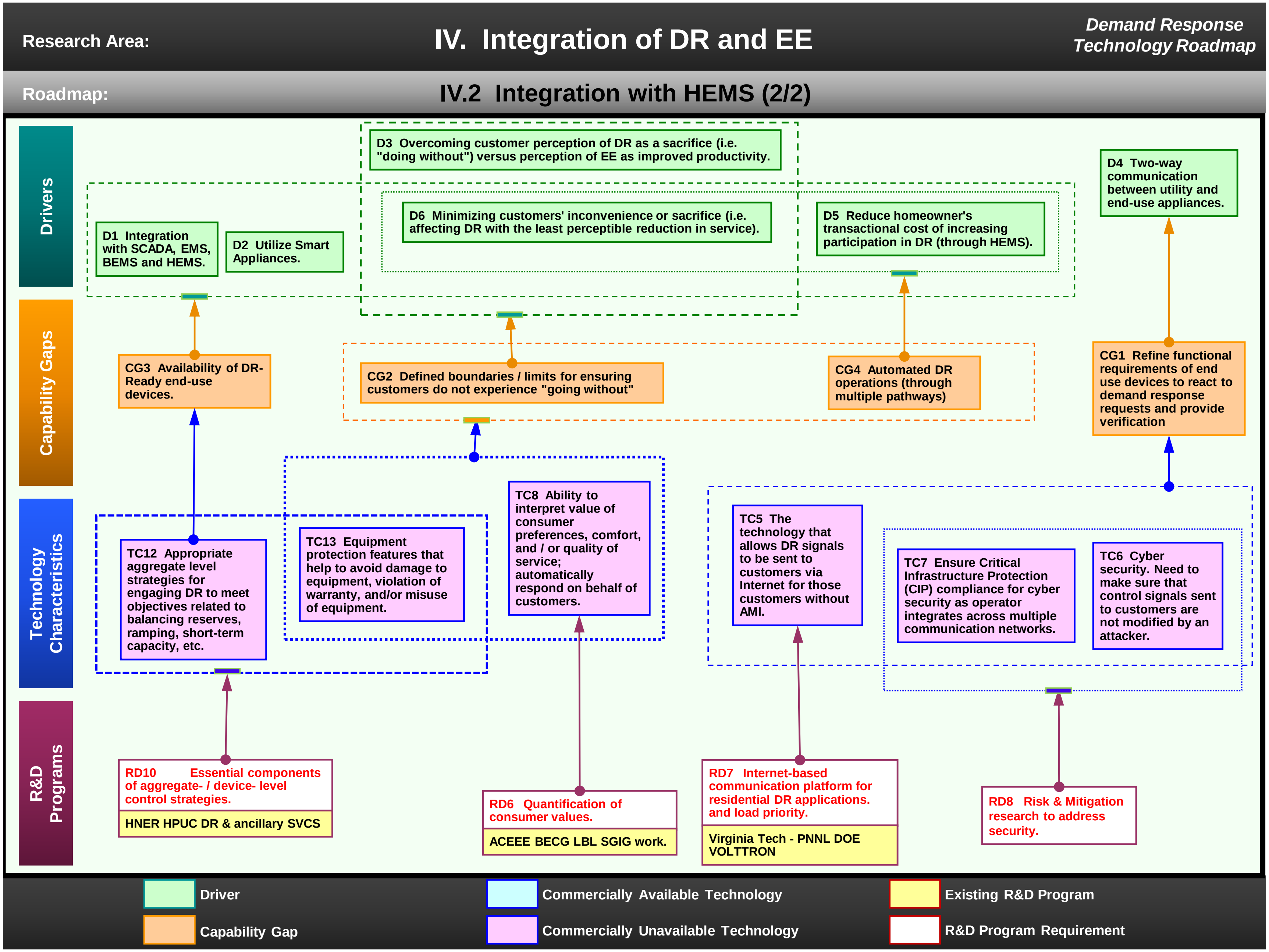
1. How do consumers perceive DR? Rural / business / urban / residential?
2. How can we convey pros of actual realities of DR to consumers (possible by subtypes rural / urban / residential / business)?

Automation platforms programs. Auto-DR architectures. What are the pros and cons of different HEMS and BEMS DR automation architectures. *One participant at the September 2014 workshop wrote: "Let the market figure this out!"*

Existing research: None identified.

Key research questions:

1. Pros and cons of different architectures for DR automate.
2. Different modes of communication, wifi, RDS, FM, Meter AMI.
3. Who needs what data for end-use devices?
4. Can we maintain customer satisfaction?
5. How often can you call a customer , for how long?
6. What embedded platforms or vendor neutral interoperability needs one key?


Research Area:
IV. Integration of DR and EE
Demand Response Technology Roadmap
Roadmap:
IV.2 Integration with HEMS (2/2)
Drivers
Capability Gaps
Technology Characteristics
R&D Programs
D3 Overcoming customer perception of DR as a sacrifice (i.e. "doing without") versus perception of EE as improved productivity.
D4 Two-way communication between utility and end-use appliances.
D6 Minimizing customers' inconvenience or sacrifice (i.e. affecting DR with the least perceptible reduction in service).
D5 Reduce homeowner's transactional cost of increasing participation in DR (through HEMS).
D1 Integration with SCADA, EMS, BEMS and HEMS.
D2 Utilize Smart Appliances.
CG3 Availability of DR-Ready end-use devices.
CG2 Defined boundaries / limits for ensuring customers do not experience "going without"
CG4 Automated DR operations (through multiple pathways)
CG1 Refine functional requirements of end use devices to react to demand response requests and provide verification
TC12 Appropriate aggregate level strategies for engaging DR to meet objectives related to balancing reserves, ramping, short-term capacity, etc.
TC13 Equipment protection features that help to avoid damage to equipment, violation of warranty, and/or misuse of equipment.
TC8 Ability to interpret value of consumer preferences, comfort, and / or quality of service; automatically respond on behalf of customers.
TC5 The technology that allows DR signals to be sent to customers via Internet for those customers without AMI.
TC7 Ensure Critical Infrastructure Protection (CIP) compliance for cyber security as operator integrates across multiple communication networks.
TC6 Cyber security. Need to make sure that control signals sent to customers are not modified by an attacker.
RD10 Essential components of aggregate- / device- level control strategies.
HNER HPUC DR & ancillary SVCS
RD6 Quantification of consumer values.
ACEEE BECG LBL SGIG work.
RD7 Internet-based communication platform for residential DR applications. and load priority.
Virginia Tech - PNNL DOE VOLTTRON
RD8 Risk & Mitigation research to address security.
Driver
Capability Gap
Commercially Available Technology
Commercially Unavailable Technology
Existing R&D Program
R&D Program Requirement

Essential components of aggregate / device level control strategies. DR technologies will be expected to provide very short-term (i.e. regulation), short-term (ramping), and long-term (e.g. peak load management) responses on a more frequent basis. Availability and capability can be understood and used to design population/aggregate level control strategies and device level control features to ensure involved stakeholders are able to meet minimum service requirements and consumer satisfaction.

Existing research: See HNER HPUC DR & ancillary SVCS study by EE consulting. Other issues vendor proprietary.

- Details of existing research pending.

Key research questions:

1. What essential features or elements are necessary for aggregate level control approaches to meet aggregate level objectives and retain consumers in DR programs?
2. What essential elements are necessary for the individual devices to protect equipment from misuse or damage when engaged in DR?
3. What models and approaches can be used to standardize and assess the benefit of using DR technologies for providing grid ancillary services?
4. What tools are needed to evaluate benefits from aggregator and consumer perspective?
5. What metrics should be used?

Quantification of consumer values. To automate DR, the needs to be an understanding of consumer values and an ability to interpret value in terms of information given to make a decision to respond.

Existing research: See SGIG research & existing behavioral programs ; ACEEE BECG LBL SGIG work.

- Details of existing research pending.

Key research questions:

1. How do we assign value to comfort, preferences and/or quality of services (QoS)?
2. How do we trade-off efficiency, DR and preferences / QoS / comfort?
3. What data/info would be needed to interpret preferences and respond on behalf of consumers?
4. How do we validate and verify approaches?

Internet-based communication platform for residential DR applications. Need internet-based communication platform suitable for deployment of residential DR applications that do not rely on smart meters. The security & privacy of customer information needs to be ensured.

Existing research: Vendors; ongoing research at Virginia Tech - mpipatta@vt.edu; PNNL DOE VOLTTRON There have been public meetings.

- Details of existing research pending.

Key research questions:

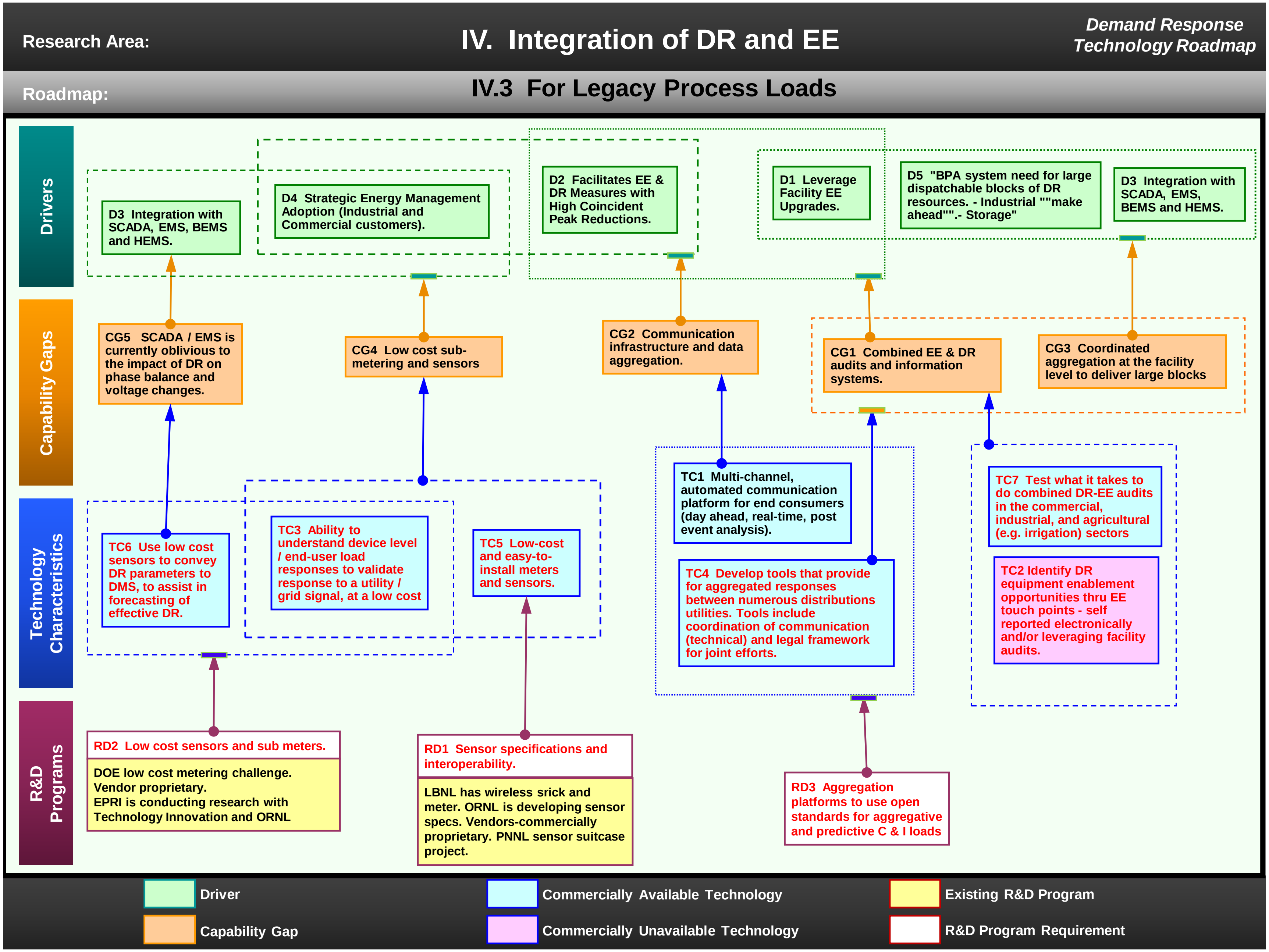
1. How to send DR signals to customers without AMI? This can come to homeowners using existing Internet infrastructure?

Risk & Mitigation research to address security. Need risk & mitigation research that complies with CIP to address security issues in DR for residential customers.

Existing research: None identified.

Key research questions:

1. Does deploying a CIP-compliance platform negatively impact DR performance at large scale?
2. What is the quality assurance of platform enhancements to continue cyber security CIP compliance?
3. What is the algorithm that can learn past DR behaviors and prevent any unusual actions to perform load control at all levels: ISO- aggregators ; ISO – utilities ; Utility – home ; HEM – appliances?



Back to Table of Contents

Low cost sensors and sub meters. Develop low cost sensors and sub-meters for monitoring loads and sub systems within a facility (beyond the utility meter) to enable device level information to validate usage/response.

Existing research: U.S. Department of Energy. Proprietary research at vendors.

- U.S. Department of Energy's Wireless Meter Challenge (http://energy.gov/articles/federal-and-industry-partners-issue-challenge-manufacturers).

Key research questions:

1. Can you lower the cost to sub-meter a facility an order of magnitude, including costs for capturing and analyzing data?

Sensor specification and interoperability. Need to develop measurement and sensing for end-use control for efficiency and DR.

Existing research: LBNL has wireless stick and meter. ORNL is developing sensor specs. Vendors-commercially proprietary. PNNL sensor suitcase project.

- Details of existing research pending.

Key research questions:

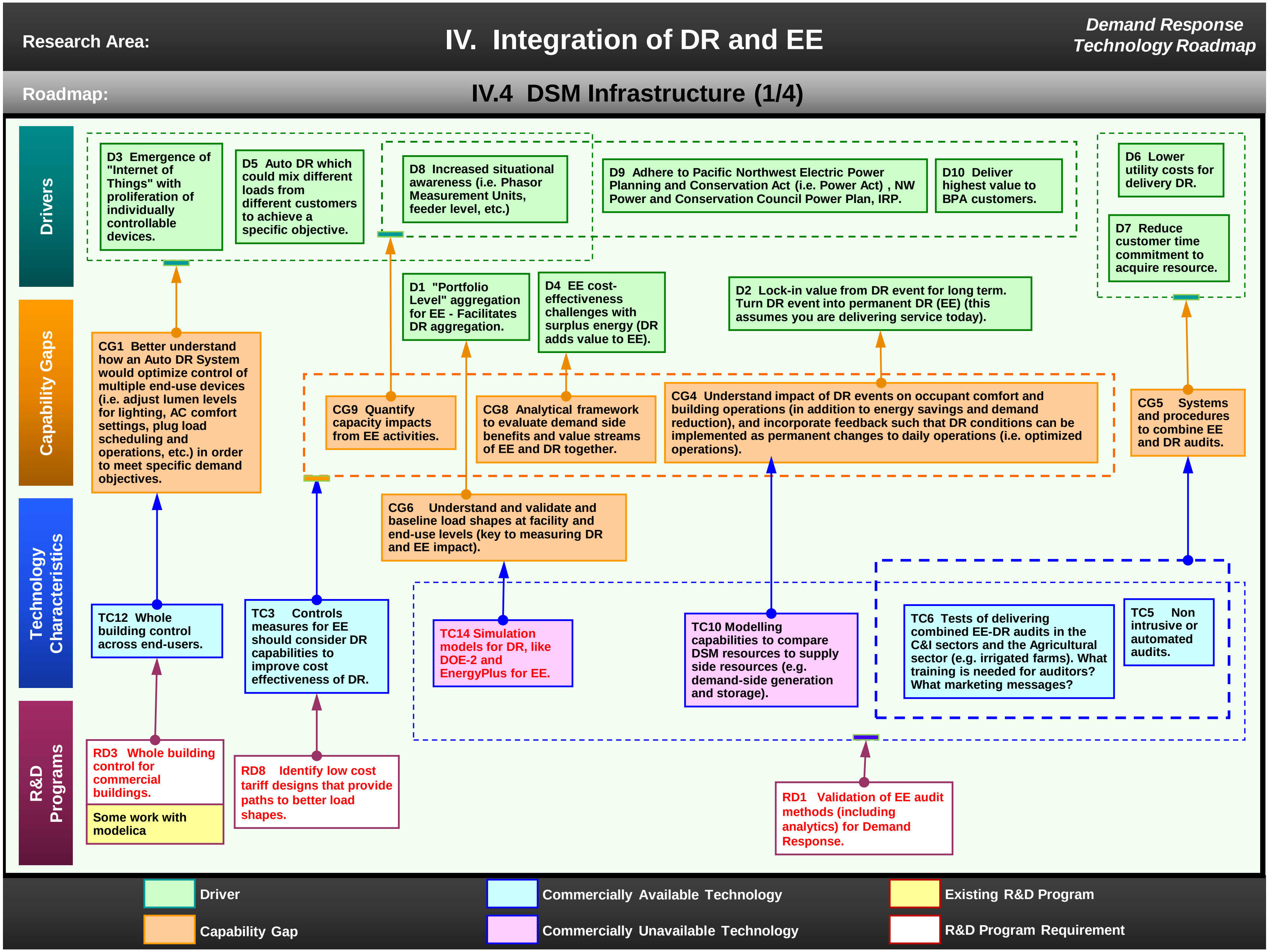
1. Low cost sensors for electric loads
2. Sensors for airflow management, space conditioning and comfort, lighting levels, etc.
3. Whole building power meters and sub-meters.

Aggregation platforms to use open standards for aggregative and predictive C&I loads. Demonstrate open standards-based platform for aggregation that showcases locational capability and visibility to response.

Existing research: None identified.

Key research questions:

1. What are the requirements for an aggregation platform that can be shared between BPA/DSOs?
2. Demonstration of aggregation with open data access.


Research Area:
IV. Integration of DR and EE
Demand Response Technology Roadmap
Roadmap:
IV.4 DSM Infrastructure (1/4)
Drivers
Capability Gaps
Technology Characteristics
R&D Programs
D3 Emergence of "Internet of Things" with proliferation of individually controllable devices.
D5 Auto DR which could mix different loads from different customers to achieve a specific objective.
D8 Increased situational awareness (i.e. Phasor Measurement Units, feeder level, etc.)
D9 Adhere to Pacific Northwest Electric Power Planning and Conservation Act (i.e. Power Act) , NW Power and Conservation Council Power Plan, IRP.
D10 Deliver highest value to BPA customers.
D6 Lower utility costs for delivery DR.
D7 Reduce customer time commitment to acquire resource.
D1 "Portfolio Level" aggregation for EE - Facilitates DR aggregation.
D4 EE cost-effectiveness challenges with surplus energy (DR adds value to EE).
D2 Lock-in value from DR event for long term. Turn DR event into permanent DR (EE) (this assumes you are delivering service today).
CG1 Better understand how an Auto DR System would optimize control of multiple end-use devices (i.e. adjust lumen levels for lighting, AC comfort settings, plug load scheduling and operations, etc.) in order to meet specific demand objectives.
CG9 Quantify capacity impacts from EE activities.
CG8 Analytical framework to evaluate demand side benefits and value streams of EE and DR together.
CG4 Understand impact of DR events on occupant comfort and building operations (in addition to energy savings and demand reduction), and incorporate feedback such that DR conditions can be implemented as permanent changes to daily operations (i.e. optimized operations).
CG5 Systems and procedures to combine EE and DR audits.
CG6 Understand and validate and baseline load shapes at facility and end-use levels (key to measuring DR and EE impact).
TC12 Whole building control across end-users.
TC3 Controls measures for EE should consider DR capabilities to improve cost effectiveness of DR.
TC14 Simulation models for DR, like DOE-2 and EnergyPlus for EE.
TC10 Modelling capabilities to compare DSM resources to supply side resources (e.g. demand-side generation and storage).
TC6 Tests of delivering combined EE-DR audits in the C&I sectors and the Agricultural sector (e.g. irrigated farms). What training is needed for auditors? What marketing messages?
TC5 Non intrusive or automated audits.
RD3 Whole building control for commercial buildings.
Some work with modelica
RD8 Identify low cost tariff designs that provide paths to better load shapes.
RD1 Validation of EE audit methods (including analytics) for Demand Response.
Driver
Capability Gap
Commercially Available Technology
Commercially Unavailable Technology
Existing R&D Program
R&D Program Requirement

R&D Program Summaries

Whole building control for commercial buildings. Allow integration of building end-uses for Demand Response.

Existing research: Some work with Modelica and Matlab commercially available.

- Details of existing research pending.

Key research questions:

1. How to integrate HVAC, Lighting and plug loads.
2. Load shape prediction.
3. EE and DR control strategies.
4. Develop model predictive control systems to provide for its diagnostics low energy use and DR.

Identify low cost tariff designs that provide paths to better load shapes. Evaluate opportunities for TOU, dynamic pricing, and low cost price response strategies, also controls pricing-responsive DR.

Existing research: None identified.

Key research questions:

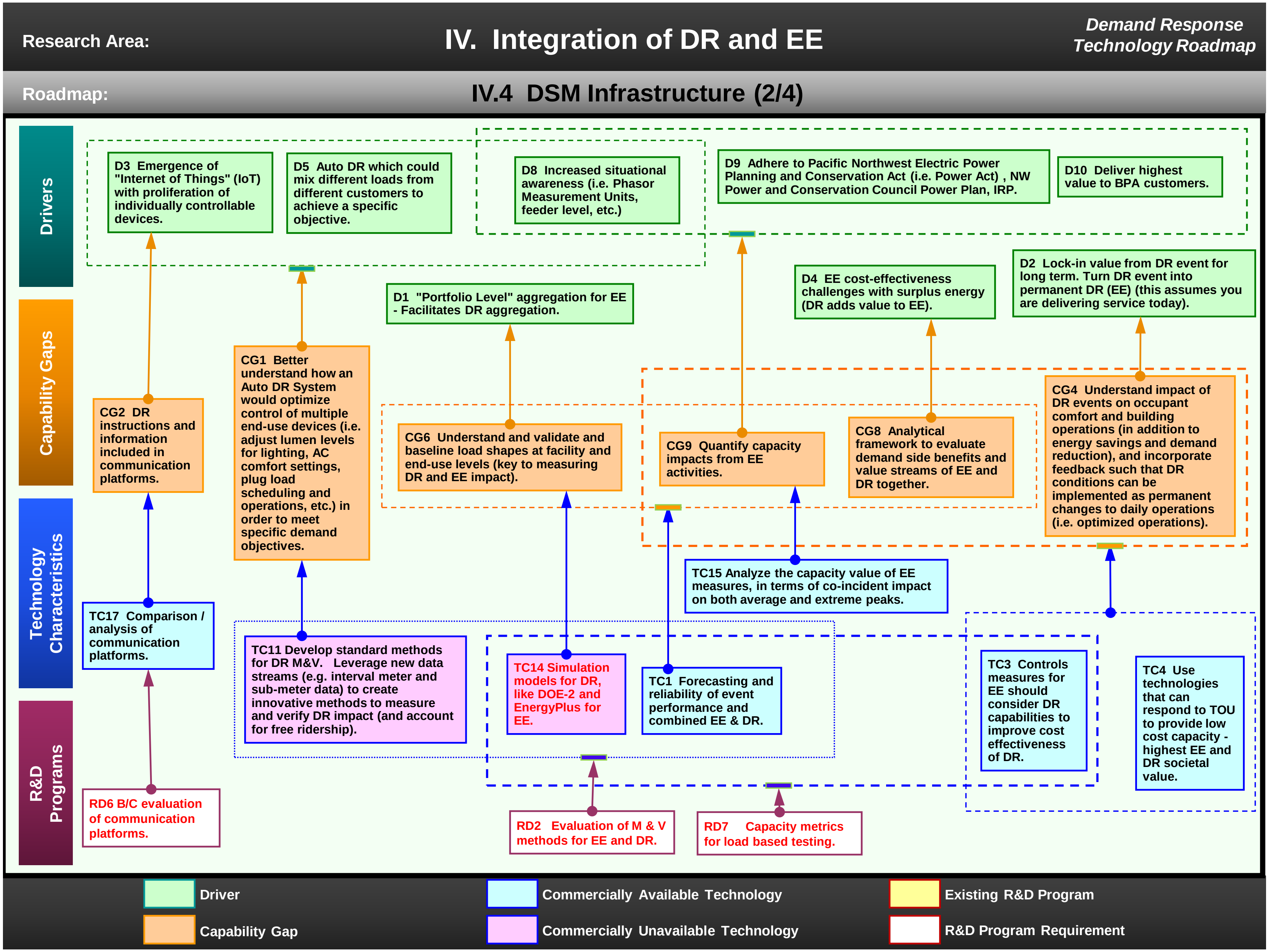
1. What type of tariff designs lead toward greater DR participation?
2. What end-use loads and control systems are best candidates for cost effective TOU and DR systems?

Validation of EE audit methods (including analytics) for Demand Response. Summary not yet provided.

Existing research: None identified.

Key research questions:

1. Which EE audit method can be utilized for DR?
2. Accuracy of DR audits - what is it?


Research Area:
IV. Integration of DR and EE
Demand Response Technology Roadmap
Roadmap:
IV.4 DSM Infrastructure (2/4)
Drivers
Capability Gaps
Technology Characteristics
R&D Programs
D3 Emergence of "Internet of Things" (IoT) with proliferation of individually controllable devices.
D5 Auto DR which could mix different loads from different customers to achieve a specific objective.
D8 Increased situational awareness (i.e. Phasor Measurement Units, feeder level, etc.)
D9 Adhere to Pacific Northwest Electric Power Planning and Conservation Act (i.e. Power Act) , NW Power and Conservation Council Power Plan, IRP.
D10 Deliver highest value to BPA customers.
D1 "Portfolio Level" aggregation for EE - Facilitates DR aggregation.
D4 EE cost-effectiveness challenges with surplus energy (DR adds value to EE).
D2 Lock-in value from DR event for long term. Turn DR event into permanent DR (EE) (this assumes you are delivering service today).
CG2 DR instructions and information included in communication platforms.
CG1 Better understand how an Auto DR System would optimize control of multiple end-use devices (i.e. adjust lumen levels for lighting, AC comfort settings, plug load scheduling and operations, etc.) in order to meet specific demand objectives.
CG6 Understand and validate and baseline load shapes at facility and end-use levels (key to measuring DR and EE impact).
CG9 Quantify capacity impacts from EE activities.
CG8 Analytical framework to evaluate demand side benefits and value streams of EE and DR together.
CG4 Understand impact of DR events on occupant comfort and building operations (in addition to energy savings and demand reduction), and incorporate feedback such that DR conditions can be implemented as permanent changes to daily operations (i.e. optimized operations).
TC15 Analyze the capacity value of EE measures, in terms of co-incident impact on both average and extreme peaks.
TC17 Comparison / analysis of communication platforms.
TC11 Develop standard methods for DR M&V. Leverage new data streams (e.g. interval meter and sub-meter data) to create innovative methods to measure and verify DR impact (and account for free ridership).
TC14 Simulation models for DR, like DOE-2 and EnergyPlus for EE.
TC1 Forecasting and reliability of event performance and combined EE & DR.
TC3 Controls measures for EE should consider DR capabilities to improve cost effectiveness of DR.
TC4 Use technologies that can respond to TOU to provide low cost capacity - highest EE and DR societal value.
RD6 B/C evaluation of communication platforms.
RD2 Evaluation of M & V methods for EE and DR.
RD7 Capacity metrics for load based testing.
Driver
Capability Gap
Commercially Available Technology
Commercially Unavailable Technology
Existing R&D Program
R&D Program Requirement

Benefits / Cost (B / C) evaluation of communication platforms. How do we compare b/c of communication platforms as they evolve. Need comparison tests, reports on use cases.

Existing research: Participants at the September 2014 workshop wrote: "Let the market and vendors figure out platform—utilities should be using and open to every platform." They also noted the DOE VOLTTRON Platform.

Key research questions:

1. What are the ownership / operations costs/benefits?
2. How are the platforms evolving?
3. Do you need utility grade communications, can you rely on WIFI or what are the response / persistence of WIFI deployment for end use devices?
4. Can you more standby power on WIFI and / or does it matters?

Evaluation of M & V methods for EE and DR. Need different timescales for M & V years, months, day, hours.

Existing research: None identified.

Key research questions:

1. How to consider multiple programs EE and DR time frames of M & V?
2. Develop data interoperability methods?
3. How can we collect occupancy of process load data?

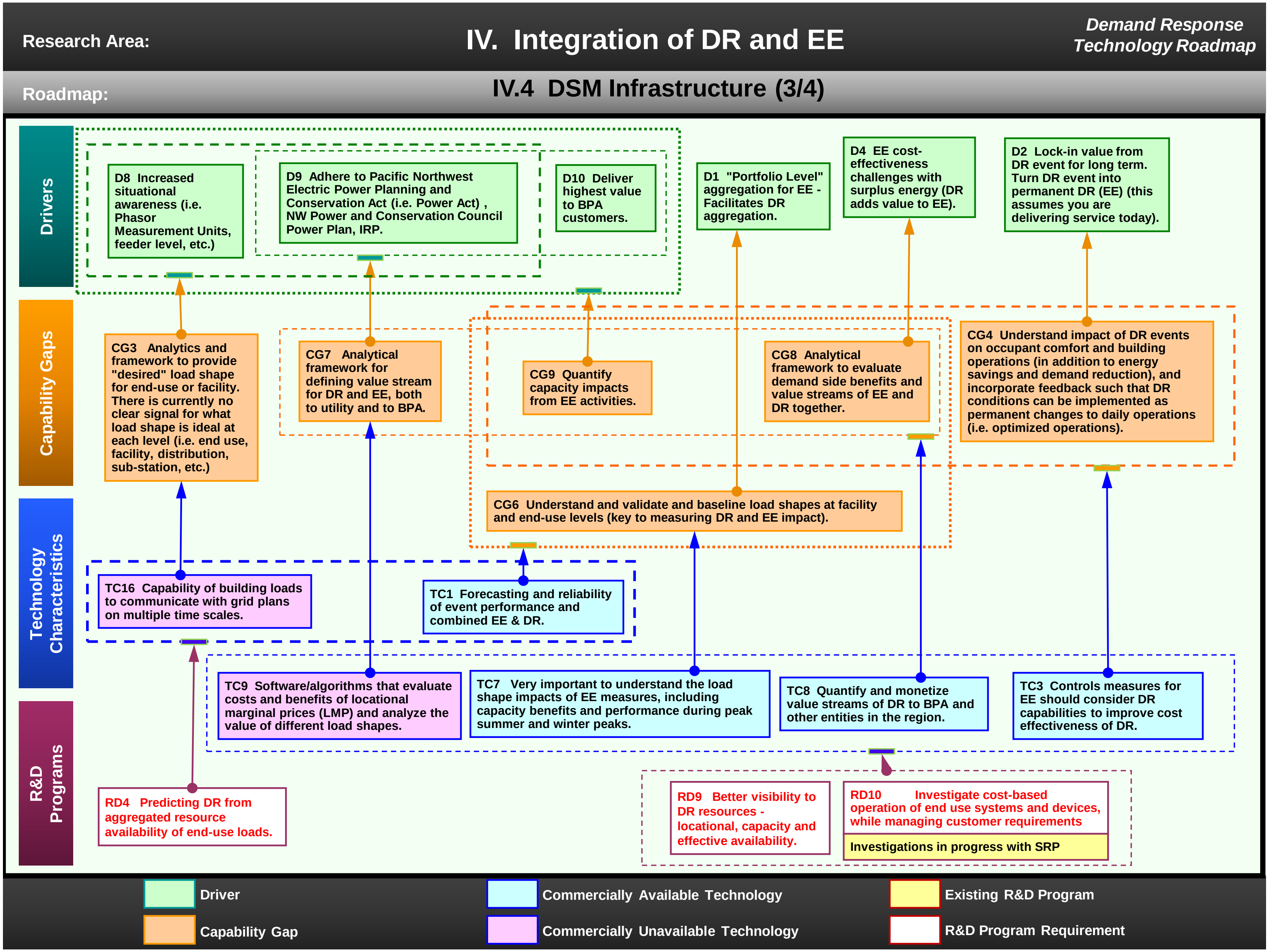
Capacity metrics for load-based testing. Lab testing of equipment traditionally captures performance at power to determine energy use metrics. New equipment energy use depends much more on controls and algorithms. Propose load-based lab testing to measure inputs of controls operations of equipment, not just the static performance. Conduct this testing using capacity metrics.

Existing research: Look at DOE appliance efficient standard process. Load based testing: BPA, EPRI, and ASHRAE; contacts: Jack Callahan (BPA), Ron Domitrovic (EPRI).

Key research questions:

1. Determine capacity metrics for load based testing.
2. Incorporate metrics into load based testing requirements.

Back to Table of Contents



Research Area:
IV. Integration of DR and EE
Demand Response Technology Roadmap
Roadmap:
IV.4 DSM Infrastructure (3/4)
Drivers
Capability Gaps
Technology Characteristics
R&D Programs
D8 Increased situational awareness (i.e. Phasor Measurement Units, feeder level, etc.)
D9 Adhere to Pacific Northwest Electric Power Planning and Conservation Act (i.e. Power Act) , NW Power and Conservation Council Power Plan, IRP.
D10 Deliver highest value to BPA customers.
D1 "Portfolio Level" aggregation for EE - Facilitates DR aggregation.
D4 EE cost-effectiveness challenges with surplus energy (DR adds value to EE).
D2 Lock-in value from DR event for long term. Turn DR event into permanent DR (EE) (this assumes you are delivering service today).
CG3 Analytics and framework to provide "desired" load shape for end-use or facility. There is currently no clear signal for what load shape is ideal at each level (i.e. end use, facility, distribution, sub-station, etc.)
CG7 Analytical framework for defining value stream for DR and EE, both to utility and to BPA.
CG9 Quantify capacity impacts from EE activities.
CG8 Analytical framework to evaluate demand side benefits and value streams of EE and DR together.
CG4 Understand impact of DR events on occupant comfort and building operations (in addition to energy savings and demand reduction), and incorporate feedback such that DR conditions can be implemented as permanent changes to daily operations (i.e. optimized operations).
CG6 Understand and validate and baseline load shapes at facility and end-use levels (key to measuring DR and EE impact).
TC16 Capability of building loads to communicate with grid plans on multiple time scales.
TC1 Forecasting and reliability of event performance and combined EE & DR.
TC9 Software/algorithms that evaluate costs and benefits of locational marginal prices (LMP) and analyze the value of different load shapes.
TC7 Very important to understand the load shape impacts of EE measures, including capacity benefits and performance during peak summer and winter peaks.
TC8 Quantify and monetize value streams of DR to BPA and other entities in the region.
TC3 Controls measures for EE should consider DR capabilities to improve cost effectiveness of DR.
RD4 Predicting DR from aggregated resource availability of end-use loads.
RD9 Better visibility to DR resources - locational, capacity and effective availability.
RD10 Investigate cost-based operation of end use systems and devices, while managing customer requirements
Investigations in progress with SRP
Driver
Capability Gap
Commercially Available Technology
Commercially Unavailable Technology
Existing R&D Program
R&D Program Requirement

R&D Program Summaries

Investigate cost-based operation of end use systems and devices, while managing customer requirements. Summary pending.

Existing research: Summary pending.

- Details of existing research pending.

Key research questions:

1. Research questions pending.

Predicting DR from aggregated resource availability of end-use loads. Predictability of loads, need to better measure and predict DR for different customer classes.

Different vendors and DR business models will produce different results.

Existing research: None identified.

Key research questions:

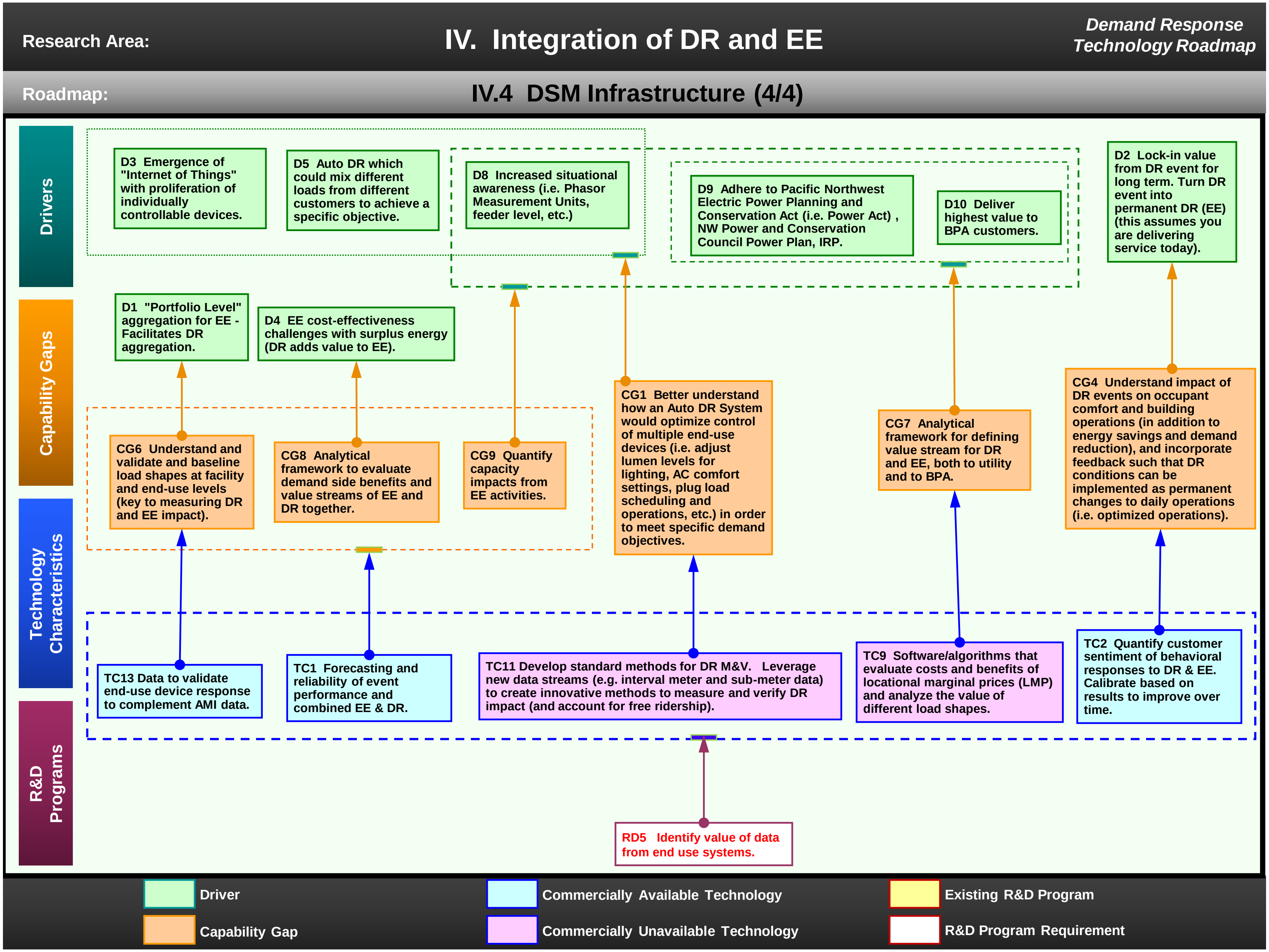
1. What DR can the building / customer provide a different time scales?
2. Model based methods.
3. Data driven methods - historic and data.
4. Can a building participate in multiple programs and decide which to participate in real time?
5. Customer class, day ahead - how ahead?

Better visibility to DR resources - locational, capacity and effective availability. Leveraging new technologies to pinpoint availability of demand response resources. This will help with managing resources at the TSO.

Existing research: None identified, but participants at the September 2014 workshop noted "Some vendors can do this now."

Key research questions:

1. Can we demonstrate visibility of demand response resource at the distribution grid?
2. Can we demonstrate controllability at a specific location of DR resource at the DSO?
3. Can we establish coordinated control of distributed resource?
4. Can we establish certainty of DR availability for a certain purpose?



Research Area:
IV. Integration of DR and EE
Demand Response Technology Roadmap
Roadmap:
IV.4 DSM Infrastructure (4/4)
Drivers
Capability Gaps
Technology Characteristics
R&D Programs
D3 Emergence of "Internet of Things" with proliferation of individually controllable devices.
D5 Auto DR which could mix different loads from different customers to achieve a specific objective.
D8 Increased situational awareness (i.e. Phasor Measurement Units, feeder level, etc.)
D9 Adhere to Pacific Northwest Electric Power Planning and Conservation Act (i.e. Power Act) , NW Power and Conservation Council Power Plan, IRP.
D10 Deliver highest value to BPA customers.
D2 Lock-in value from DR event for long term. Turn DR event into permanent DR (EE) (this assumes you are delivering service today).
D1 "Portfolio Level" aggregation for EE - Facilitates DR aggregation.
D4 EE cost-effectiveness challenges with surplus energy (DR adds value to EE).
CG6 Understand and validate and baseline load shapes at facility and end-use levels (key to measuring DR and EE impact).
CG8 Analytical framework to evaluate demand side benefits and value streams of EE and DR together.
CG9 Quantify capacity impacts from EE activities.
CG1 Better understand how an Auto DR System would optimize control of multiple end-use devices (i.e. adjust lumen levels for lighting, AC comfort settings, plug load scheduling and operations, etc.) in order to meet specific demand objectives.
CG7 Analytical framework for defining value stream for DR and EE, both to utility and to BPA.
CG4 Understand impact of DR events on occupant comfort and building operations (in addition to energy savings and demand reduction), and incorporate feedback such that DR conditions can be implemented as permanent changes to daily operations (i.e. optimized operations).
TC13 Data to validate end-use device response to complement AMI data.
TC1 Forecasting and reliability of event performance and combined EE & DR.
TC11 Develop standard methods for DR M&V. Leverage new data streams (e.g. interval meter and sub-meter data) to create innovative methods to measure and verify DR impact (and account for free ridership).
TC9 Software/algorithms that evaluate costs and benefits of locational marginal prices (LMP) and analyze the value of different load shapes.
TC2 Quantify customer sentiment of behavioral responses to DR & EE. Calibrate based on results to improve over time.
RD5 Identify value of data from end use systems.
Driver
Capability Gap
Commercially Available Technology
Commercially Unavailable Technology
Existing R&D Program
R&D Program Requirement

Identify value of data from end use systems. Evaluate what data from systems is required by TSO. Data access or analyzed data, demonstration of end-end data transfer, specification of data requirements.

Existing research: None identified.

Key research questions:

1. What data is required from devices and building control system?
2. Can this data be used to supplant/supplement AMI data?
3. What is the way to ensure data availability? Participation requirements / other incentives?
4. Development of analytical to changes to manage the data.

PROJECT TEAM

BPA Demand Response Executive Sponsor Team

Mark Gendron, Senior Vice President, Power Services

Richard Shaheen, Senior Vice President, Transmission Services

Cathy Ehli, Executive Vice President, Corporate Strategy

Suzanne Cooper, Vice President, Bulk Marketing

Richard Génecé, Vice President, Energy Efficiency

Robert King, Vice President, Transmission Marketing and Sales (Acting)

Larry Kitchen, Director, Long Term Sales and Purchases

BPA Project Sponsor Team

Terry Oliver, Chief Technology Innovation Officer

Kim Thompson, Energy Efficiency Implementation Director / Demand Response Program Manager (Acting)

Ryan Fedie, Manager, Energy Efficiency Engineering Services

Project Implementation Team

Project Manager & Workshop Facilitation

James V. Hillegas-Elting, Bonneville Power Administration

Demand Response Subject Matter Expert

Thor Hinckley, Bonneville Power Administration

Strategy Consultant

Tugrul Daim, Portland State University Engineering and Technology Management Department

Facilitation, Logistics, & Other Support

Bonneville Power Administration: Judith Estep, Jim Bowen, Jisun Kim

Portland State University Engineering and Technology Management Department: Edwin Garces, Fahad Aldhaban, Kevin van Blommestein, Yonghee (Joseph) Cho, Momtaj Khanam, João Lavoie, Chih-Jen Yu

Transcription, Fact Checking, & Technical Content Review

Portland State University Engineering and Technology Management Department: Yonghee (Joseph) Cho, Edwin Garces, Kevin van Blommestein

Electric Power Research Institute: Omar Siddiqui, Ammi Amarnath, Angela Chuang, Ram Narayanamurthy, Aidan Tuohy

Document Production

Editor, Lead Author, and Design: James V. Hillegas-Elting

Content Contributors: Tugrul Daim, Judith Estep, Thor Hinckley

Contributors

Workshop Participants

Workshop 1, June 13, 2014

Demand Response in Grid Operations

1. Tom Brim, Bonneville Power Administration
2. Angela Chuang, Electric Power Research Institute
3. Pete Pengilly, Idaho Power Company

Integration of Demand Response and Energy Efficiency

4. Ryan Fedie, Bonneville Power Administration
5. Richard Génecé, Bonneville Power Administration
6. Jeff Harris, Northwest Energy Efficiency Alliance
7. Jess Kincaid, Oregon Department of Energy
8. Jenny Roehm, Advanced Load Control Alliance

Measurement and Verification

9. Ammi Amarnath, Electric Power Research Institute
10. Ken Dragoon, Ecofys
11. Will Price, Eugene Water & Electric Board

Demand Response in Transmission and Generation Planning

12. Sarah Arison, Bonneville Power Administration
13. Diane Broad, Oregon Department of Energy
14. Debbie Hammack, Bonneville Power Administration
15. Omar Siddiqui, Electric Power Research Institute
16. Don Watkins, Bonneville Power Administration
17. Nita Zimmerman, Bonneville Power Administration

Demand Response in Generator Capacity Planning

18. Lee Hall, Bonneville Power Administration
19. Ben Kujala, Northwest Power and Conservation Council
20. Jeff Newby, Bonneville Power Administration

Back to Table of Contents

Workshop 2, Sep. 18-19, 2014

Demand Response in Grid Operations

1. Farrokh Albuyeh, Open Access Technology Int'l, Inc.
2. Tom Brim, Bonneville Power Administration
3. Kwok Cheung, Alstom Grid
4. Angela Chuang, Electric Power Research Institute
5. Ifty Hasan, Entouch Controls
6. Karanjit Kalsi, Pacific Northwest Nat'l Laboratory
7. Sila Kiliccote, Lawrence Berkeley Nat'l Laboratory
8. Steven Low, California Institute of Technology
9. Ning Lu, North Carolina State University
10. Kaj Skov Nielsen, Siemens
11. Alex Papalexpolus, ECCO International
12. Anurag Srivastava, Washington State University
13. Jianhui Wang, Argonne Nat'l Laboratory
14. Le Xie, Texas A & M University

Integration of Demand Response and Energy Efficiency

15. Chen Chen, Argonne Nat'l Laboratory
16. Ryan Fedie, Bonneville Power Administration
17. Carl Linvill, Regulatory Assistance Project
18. Ebony Mayhorn, Pacific Northwest Nat'l Laboratory
19. Ram Narayanamurthy, Electric Power Research Institute
20. Mary Ann Piette, Lawrence Berkeley Nat'l Laboratory
21. Manisa Pipattanasomporn, Virginia Tech
22. Jill Powers, California Independent System Operator
23. Farrokh Rahimi, Open Access Technology Int'l, Inc.
24. Alison Silverstein, N. American Synchrophasor Initiative
25. Megan Stratman, Northwest Requirements Utilities
26. Heather Williams, Opower

Demand Response in Transmission and Generation Planning

27. Diane Broad, Oregon Department of Energy
28. Frank Brown, Bonneville Power Administration
29. Anders Johnson, Bonneville Power Administration
30. John Wang, ABB
31. Rob Pratt, Pacific Northwest National Laboratory
32. Aidan Tuohy, Electric Power Research Institute

Demand Response in Generator Capacity Planning

33. Shawn Chandler, Bonneville Power Administration
34. Erik Gilbert, Navigant
35. John Goodin, California Independent System Operator
36. Ben Kujala, Northwest Power and Conservation Council
37. Tom Osterhus, Integral Analytics
38. Omar Siddiqui, Electric Power Research Institute

Back to Table of Contents