The Benefits and Costs of Smart Grid Enabled Demand Side Management

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Abstract

This paper discusses the Demand Response and Energy Efficiency results from the U.S. Pacific Northwest Smart Grid Regional Business Case (RBC).[1.]

Demand side management (DSM) is becoming a more accepted and important component of integrated resource planning across international regulatory jurisdictions. At the same time new, *smart* technologies are increasing the effectiveness and flexibility of DSM, and enabling demand side resources to provide new capabilities, such as helping balance intermittent renewables and provide ancillary services in international markets.

The increasing importance of DSM in electricity systems globally has been evidenced in Europe, where regional and national policy has incentivized the introduction of demand side measures to enhance system reliability and flexibility. This has become even more visible in the last few years, with the high levels of penetration of intermittent renewable energy sources in several parts of the European power grid creating instabilities that could be addressed in-part with the use of DSM.

However, because of the greater level of initial investment and capital cost for these new approaches, there is rightly some concern that these “smart grid enabled DSM programs” will fail to cost effectively deliver the promised benefits. To date, there hasn’t been a widely available and comprehensive effort to estimate costs and benefits of these new approaches to DSM.

This session addresses these questions, summarizing the results of the “bottom-up” modeling analysis performed on the Pacific Northwest Region in the US. It describes key elements of the analysis approach to facilitate understanding, and tries to draw lessons that apply to other geographical regions. The analysis demonstrates that there is a significant and substantial benefits case for smart grid enabled demand response (DR); but, that the benefit case for smart grid enabled energy efficiency is less clear.

Introduction

A basic overview of regional electricity characteristics as well as an explanation of high-level results of the smart grid Regional Business Case are useful context for understanding the DSM analysis results. These are provided in the subsections below.

Regional Comparison with EU Countries-- The Pacific Northwest Region covers a four state area, which includes a wide range of characteristics—from dense urban, coastal cities to mountains to low-density agricultural areas. It includes diverse weather zones as well as multiple regulatory jurisdictions.

The map in Figure 1 shows the region in North America that was used in this study.

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1 The results presented leverage a unique and comprehensive benefit-cost modeling approach developed through work sponsored by the Bonneville Power Administration (A U.S. Federal transmission and generation authority) over the past four years. A detailed overview of the methodology and other results of the Regional Business Case (RBC) can be found in the white paper posted on the Bonneville Power Authority website at: http://www.bpa.gov/Projects/Initiatives/SmartGrid/Pages/default.aspx

Figure 1. Map of the Pacific Northwest Region Considered in the RBC[2]

Electricity system characteristics of this region are provided in the Table 1 below, along with characteristics of several EU countries for comparison purposes.

Country/Geography	Number of DSOs 2011	Number of DSOs with > 100,000 customers	Total Number of Connected Customers	TWh/yr (2010)	MW Peak (2010)
Pacific Northwest (U.S.)*	141	10	6,365,036	161,000,000	60,657
Austria	138	13	5,870,000	65,000,000	21,400
Belgium	24	15	5,243,796	90,000,000	18,322
Czech Republic	3	3	5,837,119	64,000,000	20,073
Denmark	72	6	3,277,000	35,000,000	13,420
France	160**	5	33,999,393	513,000,000	123,783
Germany	880	75	49,294,962	565,000,000	166,329
Greece	2	1	8,195,725	59,000,000	16,729
Hungary	6	6	5,527,463	40,000,000	8,753
Ireland	1	1	2,237,232	25,000,000	8,495
Italy	144	2	31,423,623	331,000,000	106,489
Netherlands	11	8	8,110,000	117,000,000	26,636
Poland	184	5	16,478,000	142,000,000	32,832
Portugal	13	3	6,137,611	55,000,000	18,797
Spain	350**	5	27,786,798	278,000,000	98,837
Sweden	173	6	5,309,000	147,000,000	35,701
United Kingdom	7	7	30,828,266	366,000,000	93,146
Total EU	1839	195	263,370,337	3,276,000,000	907,406

* Source for numbers for Pacific Northwest is U.S. EIA, and all numbers are from 2011

**Source: Eclareon and Oko-Institut (2012), Integration of electricity from renewables to the electricity grid and to the electricity market

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[2] A more detailed map of the specific regional boundaries can be found at: [http://www.bpa.gov/news/pubs/maps/Tlines_Dams_SAB.pdf.](http://www.bpa.gov/news/pubs/maps/Tlines_Dams_SAB.pdf)

Table 1: Comparison of Regional Electricity System Characteristics

The Pacific Northwest region considered here represents about 5% of total U.S. energy consumption. The shaded rows in Table 1 represent countries with similar electricity customer base at that of the Pacific Northwest; however, annual energy consumption and peak demand are typically lower for these countries.

High Level Results from the Regional Business Case--The RBC assesses the benefits, costs, and risks of a comprehensive regional smart grid deployment. The smart grid promises many benefits for the Region, including better reliability, more efficient and flexible operation of the grid, lower rates, and reduced carbon emissions. Although many new technologies have been successfully demonstrated and have shown promising preliminary results, many benefits are still unproven. Utilities and regulators will rightly approach these investments with caution until the technologies, investment risks, and business case are more fully understood.

The analysis uses a simple definition of Smart Grid—smart grid capabilities use **two-way communications and some level of automation**[3]**-**and it covers a 30 year time horizon. This analysis is different from others that have been done in several important respects:

- It Uses a “Bottom-up” approach, looking at specific technology deployments
- Looks at a 30 year time horizon, estimating out past the year 2040
- Takes a Conservative Approach
    - E.g., no carbon costs, no speculative benefits such as safety, health
- Leverages integrated uncertainty and risk analysis
- Examines *incremental* costs and benefits that can be attributed to deployment of smart grid technologies.

The overall results of the smart grid benefit-cost analysis, across all technologies and benefits categories, are shown in Figure 2. This figure shows the range and likelihood of the benefits and costs associated with a deployment spanning to 2040 in the Pacific Northwest. Benefits are expected to surpass costs, with €10.7B in total benefits and €7.4B in costs over the analysis time frame. The low and high values shown in the inset table represent the 5th and 95th percentile likelihood of occurrence in the analysis. The NPV is expected to surpass zero (i.e., producing a net benefit) with 96 percent confidence.

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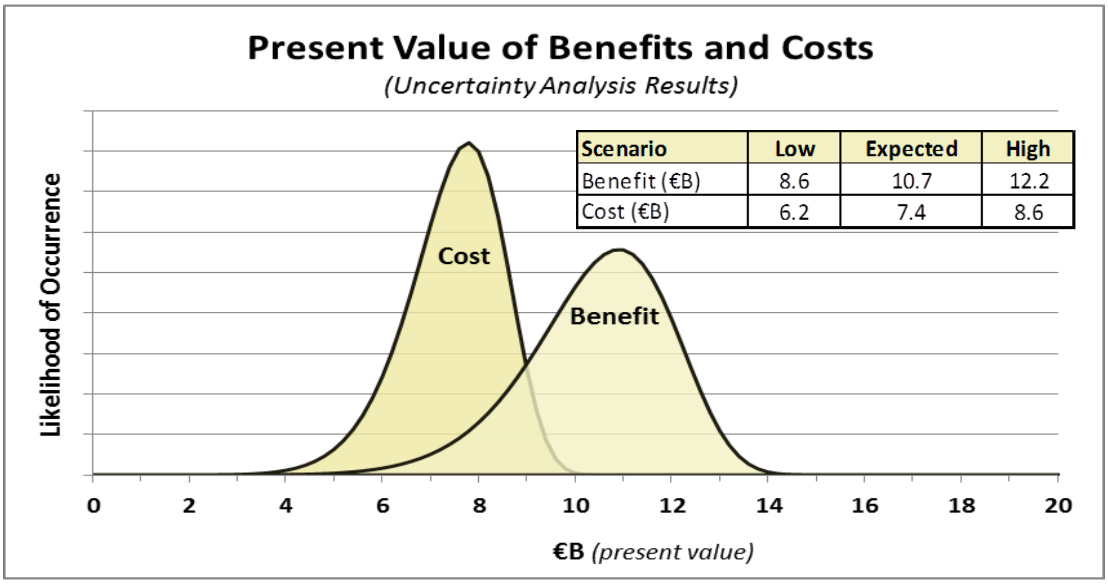
[3] For example, some traditional demand response programs provide peak load reduction benefits using one-way wireless communication signals. The benefits and costs of such traditional programs are not included as smart grid benefits and costs in the RBC analysis. Benefits achieved using two-way communications would be attributed to smart grid.



Scenario	Low	Expected	High
Benefit (€B)	8.6	10.7	12.2
Cost (€B)	6.2	7.4	8.6

Figure 2. Smart Grid Investment Looks Attractive Overall.

These aggregate results indicate that sufficient information exists today to create beneficial, region-wide smart grid deployment plans in the Pacific Northwest. Uncertainties remain high in some areas, however, as is discussed in more detail in the sections below. Furthermore, results in different jurisdictions vary due to a number of parameters (e.g., weather, capacity constraints) that may cause results for specific technologies to diverge from this regional average view.[4]

Investment Outlook Varies by Category, with Clear Winners Emerging

The broad aggregate results shown in Figure 2 above can be broken out into six broad investment categories to facilitate understanding.[5] The analysis results presented in this paper focus on two of these categories: *Dynamic and Responsive Demand* and *End-Use Energy Efficiency*. However, it is useful to briefly review all six categories to provide context.

Analysis results indicate that smart grid investments in Transmission and Distribution (T&D) Optimization, Grid Reliability, and Dynamic and Responsive Demand are generally expected to be attractive and low risk. Smart grid investments to enhance End-Use Energy Efficiency (EE) and Grid Storage Integration and Control are not seen to be generally attractive. Smart grid enhancements to utility operational efficiency are expected to produce a small net benefit, but the analysis results show high uncertainty. Figure 3 below indicates the range of the benefits and costs associated with each of these investment categories.

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4 Note: Individual utilities should consider their local situation and, perform their own analysis to confirm that the results shown in the various areas are indicative of what they might expect in their specific service territories.

5 The six categories used here are the result of a multi-year methodology development effort that leverages research and thinking from a wide range of prior efforts, including those of US DOE and various national energy labs. The RBC analysis actually characterizes 34 smart grid capabilities . The individual capabilities underwent extensive research—including review of related secondary publications, analysis of available BPA data, and interviews with regional stakeholders—to develop an appropriate methodology and model inputs..

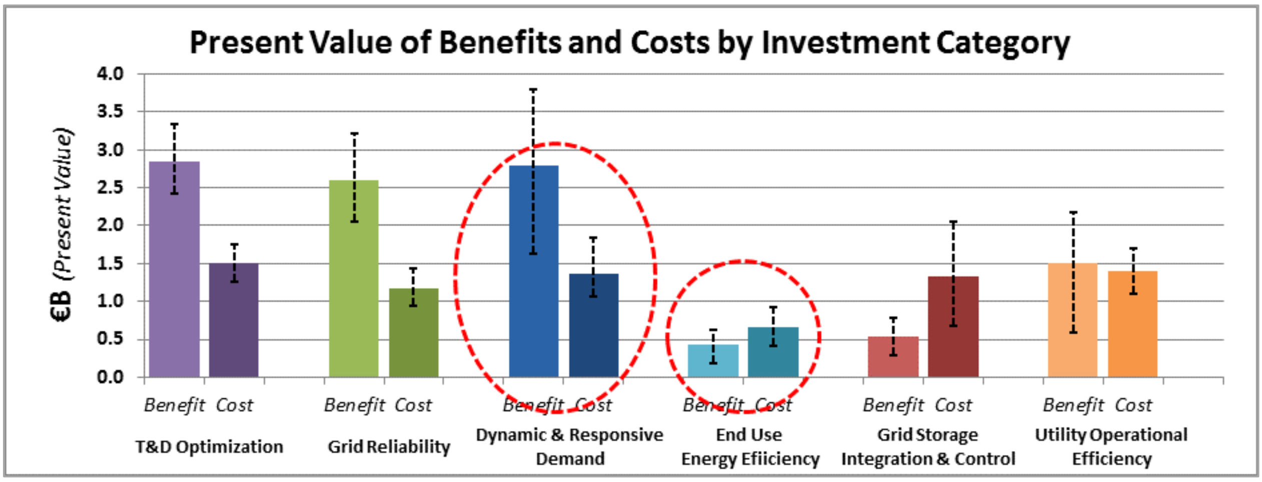

Figure 3. Six Investment Categories Show Different Returns and Risks.

T&D Optimization--this encompasses smart grid capabilities that improve the control and utilization of electrical infrastructure assets, leading to more efficient delivery of electricity. Example capabilities include conservation voltage reduction (CVR) and power factor control.[6]

Grid Reliability--includes smart grid capabilities that reduce the likelihood, duration or geographic extent of electricity service interruption, and maintain or improve the quality of delivered power. Example capabilities include fault location, isolation, and service restoration (FLISR), enhanced fault prevention, and wide area monitoring (WAM).

Dynamic and Responsive Demand (Smart DR)--includes smart grid capabilities that allow short-term influence of end-use consumption by signals provided through the electricity supply chain. Results for this area are discussed in more detail below.

Smart End-Use Energy Efficiency—includes smart grid capabilities that reduce energy consumed by customers through enhanced information feedback and other means. Results for this area are discussed in more detail below.

Grid Storage Integration and Control—encompasses all smart grid capabilities that provide the ability to store electrical energy in battery systems. This includes battery systems sited at end-use facilities (i.e., residential, small commercial and industrial [C&I], large C&I, and institutional facilities), on the distribution system, on the transmission system, and electric vehicle batteries when connected to charging stations.

Utility Operational Efficiency—smart grid capabilities that improve the ability of a utility to deliver energy with the same reliability and efficiency, but with lower operations and maintenance costs. Example capabilities include automated meter reading and billing, reduced truck rolls from targeted repair work, and improved planning and forecasting.

The analysis results presented in this paper focus on two of these categories: *Dynamic and End-Use Energy Efficiency* and *Responsive Demand*, which are examined in the two subsequent sections.

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[6] Utilities have long engaged in T&D investment and optimization activities using traditional (i.e., non-smart) technologies. Only optimization activities that apply two-way communications and some form of automated intelligence are included in the RBC analysis.

Initial Findings for End-Use Energy Efficiency Investment Area

Smart end-use energy efficiency encompasses smart grid capabilities that reduce energy consumed by customers through enhanced information feedback, identification of poorly performing equipment as candidates for replacement or maintenance, and other enhancements to EE that require smart grid functionality. Capabilities encompass consumer behavior change, automated energy management, efficiency equipment upgrades, and improved maintenance.

Investment in smart EE does not appear to be attractive. Note that this analysis does not address the cost effectiveness of *traditional* end-use energy efficiency measures, and only addresses end-use efficiency to the degree it is impacted by smart grid functionality.

Lighting Example--A good example to help understand the incremental benefit of smart grid is to examine commercial building lighting. To save energy used for lighting, a traditional step has been to replace older, less efficient lights with more efficient ones (e.g., CFLs or increasingly LED lights), and of course this does not require smart grid. For additional incremental savings, it's possible to install occupancy sensors and perhaps day-lighting sensors to control the light based on local conditions. This can keep the lights off when there are no occupants, or when there is enough daylight so that lights aren't necessary. Again, these measures do not require smart grid. The addition of smart grid, two way communication and incorporation of lighting controls into a building management system may yield incremental benefit, but the benefit will be small compared to the gains already achieved from the measures above (probably not more than 5% to 10% additional savings). And the cost is significant. So the incremental benefits are small compared to the incremental smart grid costs, and the benefit-cost ratio is not attractive.

Information Feedback and Behavior Change—in the past several years, paper electricity bill inserts providing enhanced customer feedback—e.g., paper based home energy reports (HERs), have shown to be effective at reducing energy consumption. Many of these approaches do not require smart-grid, but can be based primarily on monthly billing data. These approaches do create behavior change that persists, at least for a few years. The incremental benefit of using smart grid—two way communications and automation—seems to be quite small relative to what is already being achieved. Thus, again, the benefit-cost ratio is unattractive.

Equipment Replacement and Maintenance—this would use smart grid generated information to understand the condition of end-use equipment, and allow timely maintenance or replacement to improve energy efficiency. This approach holds promise, but is considered to be many years in the future with a high degree of uncertainty. However, this approach may be able to leverage smart grid investment that is made for other reasons, and thus may be fairly low cost in the future once smart grid deployment is significant. Nevertheless, the benefits are also small in the analysis, and so do not significantly increase the overall benefit cost ratio.

Non-end-use Efficiency—analysis indicates that far the largest increase in efficiency is created by a electricity system distribution engineering technique called Conservation Voltage Reduction (CVR). This technique calls for lowering the distribution voltage to the lower levels of its acceptable safety margin, and thereby lowering energy consumption on end-loads. The benefit cost ratio for this investment is quite high (5 to 6 in the analysis). However, this approach falls into the T&D Optimization investment category in our analysis, since it is entirely under the control of the electricity distribution system, rather than end-use customers.

Initial Findings for Dynamic and Responsive Demand Investment Area

As shown in Figure 3 above, results indicate the potential for significant benefits from smart DR investments; however, results vary greatly by customer segment and end-use. Again, cost and benefit results for smart dynamic and responsive demand are *incremental to those generated by traditional DR programs* that do not require smart grid technology. Benefits and costs are examined in more detail below.

Smart DR Can Provide Flexible Response to Changing Grid Conditions.

The changing landscape of supply in the Pacific Northwest is driving a renewed interest in DR in the region. This change is due, in part, to expected limitations in available traditional regional generation capacity resources and an increasing penetration of renewable generation.

Many forms of DR are possible without smart grid, and these have been feasible for decades. Utility programs like Portland General Electric's interruptible contacts for industrial customers or Idaho Power's direct load control program for residential customers are examples of regional smart grid initiatives that have operated for years without smart grid.

However, smart grid can bring important benefits to DR programs that traditional DR mechanisms cannot provide, such as improved response rates, deeper curtailment, increased participation, and use of DR for ancillary services and oversupply mitigation that require more advanced communication and control capabilities than traditional DR can provide.

The investment characteristics for DR are driven by the type of end-use equipment under control and demand for its end-use service. Depending on the type of load, the equipment can be used to both curtail and/or absorb load when called upon. To capture the unique benefits of each end use, the study applied a breakout by seven end-use categories, four sectors, and three degrees of intelligence (curtailment events, real-time pricing,[7,8] and fast-acting ancillary services[9]). Generally, DR is more attractive when the load per control point is high.

Many of the costs associated with implementing a smart DR infrastructure in the region are common to the different end-use categories. The RBC considered the administrative overhead, operations, engineering, contracting, and other labor costs associated with establishing and maintaining the different types of DR asset systems. All of the end-use categories also have a set of common system costs associated with each. The RBC model shares equipment costs across all of the asset systems that utilize those pieces of equipment. For the seven different end-use categories, equipment costs associated with establishing and maintaining the two-way communications infrastructure are common. These include the AMI meters, broadband bandwidth, gateway devices, web portals or smart phone apps, meter data management systems, and demand response management systems. There are also unique costs associated with the different smart DR end-use categories that are discussed below.

Deployment Assumptions

Figure 4 shows the assumptions used in the RBC model for deployment of smart DR. As there is limited deployment of DR throughout much of the Region, deployment of future DR is likely to be *smart* DR. Also, the deployment assumptions used were considered to be relatively

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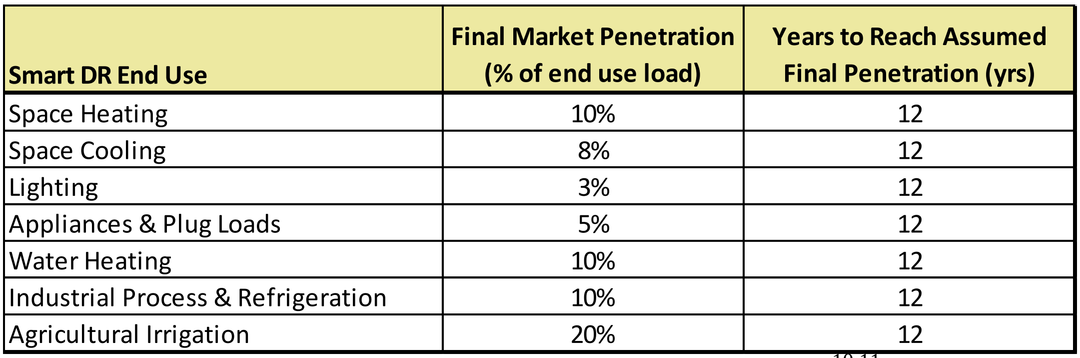
[7] There is certainly no consensus on the viability of pricing programs in the foreseeable future in the Pacific Northwest. One theory is that smart DR can and should be accomplished via direct load control programs. Another theory allows for both direct load control and pricing programs.

[8] While advanced pricing options such as TOU are technically feasible without AMI and 2-way communications, the preferred implementation typically includes this digital infrastructure to enable much greater flexibility at only a moderate incremental cost as compared to the most basic implementation without AMI.

[9] For the purposes of the RBC, the ancillary services modeled include non-spinning reserves to increase load (DEC) and decrease load (INC). Fast acting services could also be used for other services such as spinning reserves and regulation, but those services were not included in the RBC.

conservative, in keeping with the overall estimation approach used for the RBC. Thus, these deployment assumptions for smart DR are considered to be incremental to the existing traditional DR that has been deployed.



Smart DR End Use	Final Market Penetration (% of end use load)	Years to Reach Assumed Final Penetration (yrs)
Space Heating	10%	12
Space Cooling	8%	12
Lighting	3%	12
Appliances & Plug Loads	5%	12
Water Heating	10%	12
Industrial Process & Refrigeration	10%	12
Agricultural Irrigation	20%	12

Figure 4. Regional Smart DR Deployment Assumptions in RBC[10,11]

Although the timeframe for a regional deployment may take longer than a decade, individual utilities may deploy DR very quickly. For example, large traditional DR programs have been deployed at Ohop Mutual, Milton-Freewater, Snohomish County PUD, Seattle City Light, Orcas Power & Light, PacifiCorp, and Idaho Power each within the timeframe of a year or two.

Benefit Cost Results

Figure 5 presents the range of benefits and costs for smart DR in seven end-use categories. The figure represents a breakout view of the Dynamic & Responsive Demand benefit-cost bars in Figure 3. The vast majority of benefits from smart DR are capacity benefits rather than ancillary service benefits.[12] There are two important caveats to this finding, however. There is some disagreement among regional stakeholders on the link between peak load reductions and actual deferment of planned generation, transmission, and distribution infrastructure investments. The RBC applies avoided capacity cost values provided by BPA and treats them deterministically.

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[10] The Final Market Penetration assumption values for smart DR by end use and the number of years it takes to reach this penetration level are for the entire region. This penetration level comprises the rollout of many utility smart DR programs throughout the region. Note that a single utility, once it decides to implement a smart DR program, could roll-out a program to its own service territory in one to two years, and in doing so might reach a saturation level higher than what is shown in the table. Depending on developing circumstances that drive the need for capacity resources, the market penetration could be driven faster—or slower—than what is assumed here. But this timeframe was considered to be a reasonable compromise.

[11] Although the total benefits and costs are largely driven by these deployment assumptions, the B/C ratios are largely independent of these assumptions.

[12] The renewable integration benefits of smart DR occur primarily through avoided ancillary services.

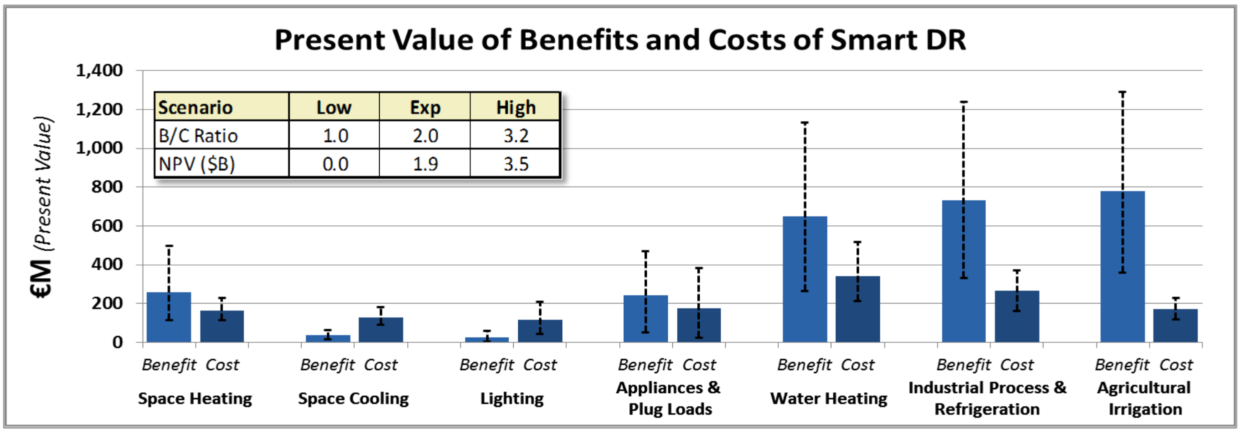

Figure 5. Smart DR Investment Returns Vary Widely by Target End Use.

Second, there is currently no consensus value of ancillary services (i.e., for regulation and balancing reserves) in the region. The costs of such services are absorbed by the system, and are not exposed externally as they are in organized wholesale markets. There is, however, an emerging consensus by regional stakeholders that there is value and that this value will be more evident as installed renewable capacity increases and the need for balancing services grows. The RBC effort applied best estimates for future ancillary service values (i.e., beyond 2015)[13] based on BPA research and held them constant for future projections. There is a possibility that growing renewable generation installations beyond 2020 could reach a point to where the value of ancillary services rises dramatically, increasing the benefit of smart DR; however there are a number of factors that could mitigate this rise as well.

Results for the various categories shown in Figure 5 are discussed below.

Space Heating—Electric resistance space heating accounts for about 31 percent of residential and about 7 percent of commercial end-use regional energy consumption. The load per control point for electric space heating is higher than space cooling in the Pacific Northwest due to higher heating loads than cooling loads as well as the relative efficiency of each equipment type. There are less impact data available (and fewer programs) for space heating DR programs than space cooling because most regions are summer-peaking when space heating load is not available to curtail. There are few traditional space heating DR programs in the region currently. In addition to the two-way communication system costs, the RBC assumes the installation and programming of a smart thermostat to realize the benefits of a space heating smart DR program. Space heating can be used to either decrease load for balancing purposes or peak shifting.

Space Cooling—Electric cooling accounts for just over 1 percent of residential and about 30 percent of commercial end-use regional energy consumption. Space cooling accounts for less end use in this region than in other parts of the US, but there is still some potential for DR with air conditioners. Air conditioning DR programs are common; they typically equip A/C units with a switch that can receive a signal to turn off the unit during a DR event.

The RBC assumes the installation of a smart thermostat to achieve smart DR space cooling, as well as two-way communications to respond to either price signals or a peak event. As building control systems evolve, strategies are also being developed to utilize the thermal mass of larger buildings through precooling. Using these strategies, smart thermostats may be used to cool the thermal mass of buildings during low demand periods, thus shifting some cooling load away from peak periods. The additional assets deployed are nearly identical to what would be required for a

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[13] The recently settled rate case for Variable Energy Resources Balancing Services concluded with mutually accepted values for all ancillary services through Sept. 20, 2015. There is no formal agreement on ancillary service values for the time period beyond that date.

space heating program, so there is additional opportunity to share asset costs while achieving benefits for both programs. Space cooling can be used either for decreasing load for balancing purposes or during peak DR events.

Lighting—Lighting accounts for about 22 percent of commercial end-use regional energy consumption. Smart DR can be achieved by curtailing lighting use but opportunities tend to be limited due to the relatively small amount of load controlled at a single point. Smart lighting DR becomes more attractive in facilities with a building management system, where lighting is controlled by a single system. For a variety of reasons, opportunities are also limited by areas where lighting can either be turned off completely or dimmed. A smart lighting DR system requires two-way enabled lighting control systems at the customer site. Lighting can be used either for decreasing load for balancing purposes or during peak DR events.

Appliances and Plug Loads--Appliances and plug loads account for about 24 percent of residential and about 13 percent of commercial end-use regional energy consumption. Relative to other end-use point loads, appliances and plug loads per control point are small. In the absence of an existing smart infrastructure (i.e., where costs can be shared across many asset systems), DR using appliance and plug loads may not be financially viable. If there is an existing smart DR infrastructure, smart appliance and plug loads could prove useful and supply some capacity for peak shifting. The ultimate role of appliances and plug loads as DR resources is uncertain.

Water Heating--Electric water heating accounts for about 26 percent of residential and about 2 percent of commercial end-use regional energy consumption. Water heating is generally a versatile end use for smart DR purposes because it can both absorb significant amounts of load as well as provide load curtailment, but it does have limitations. In all cases, smart DR using water heaters requires the same smart DR infrastructure as the other end-use categories as well as a switch on the water heater controller enabled with two-way communications. Water heating can be used both for decreasing and increasing load for balancing purposes, and for peak shifting and absorbing extra load during oversupply situations.

Industrial Process and Refrigeration—Industrial processes and refrigeration accounts for about 13 percent of commercial and about 49 percent of industrial end-use regional energy consumption. Relative to other end-use point loads, these processes are usually large, single-point end uses that represent an attractive opportunity for smart DR. For large-scale refrigeration (e.g., cold storage) the compressor motor and evaporator fans represent large end-use loads, similar to other industrial processes so these end uses were grouped together in the analysis. For this smart DR end use, there will either have to be custom, process-specific control grid interfaces or energy management system grid interfaces, depending on how the process is controlled at each individual site. The per-site costs for this smart DR end use are higher than for other end uses; however, the load controlled per site is also much higher. Smart DR using industrial processes and refrigeration can be used either for decreasing load for balancing purposes or peak shifting. Certain cold storage or other industrial sites will also be capable of absorbing load during both oversupply situations, as well as increasing load for balancing.

Agricultural Irrigation—Irrigation accounts for about 15 percent of industrial end-use regional energy consumption. Irrigation presents an attractive smart DR opportunity in that large loads are controlled at a relatively small number of control points. Essentially no one is affected by shifting irrigation pumping to different times of day. Thus, irrigation is an attractive and easy program to implement. There are already programs in the region with two-way enabled irrigation pumps that demonstrate the effectiveness of irrigation in smart DR. Irrigation can be used for either decreasing or increasing load for balancing purposes, as well as for peak shifting and absorbing extra load during oversupply situations.

Looking Forward

Regional stakeholders can leverage the results and information provided by the RBC on smart grid benefits, costs, and uncertainties to inform their decision-making processes and to help put the various smart grid capabilities into a context for decision making.

A primary objective of the RBC effort is to characterize the uncertainty and risk of smart grid investments in the Pacific Northwest. Most graphics in this white paper present results with explicit uncertainty bounds. Even with an understanding of the uncertainties, questions remain about how utilities should act on smart grid investments.

To reduce the uncertainties in these areas, several activities are important to the RBC effort going forward. For instance, a primary focus will be incorporation of test results from the Pacific Northwest Demonstration Project as they become available. These results will provide information from a range of smart grid technology tests being conducted by participating regional utilities, as well as a better understanding of the use of a transactive control signal for regional benefit.

Finally, continued outreach and stakeholder communication will be critical to achieving the goals of the RBC effort. This includes providing data-based, grounded analysis and information to regional decision makers, policy makers, utilities, investors, and planners.

References

The primary reference for this document is:

"Smart Grid Regional Business Case for the Pacific Northwest: Interim Results & Analysis," Bonneville Power Administration, December , 2013.

This white paper is available from the Bonneville Power Authority website at: http://www.bpa.gov/Projects/Initiatives/SmartGrid/Pages/default.aspx

An extensive bibliography of references used in the preparation of the analysis can be found in Appendix C of the white paper.

Applicability in Europe

Despite the fact integrated resource planning (IRP) isn't a requirement in most European countries [14,15], the introduction of policy instruments such as the European Directive of 2012 on energy efficiency and the EU-wide target of 20% reduction in energy consumption through energy efficiency by 2020 have effectively created a DSM requirement for Member States. This in turn has led to the introduction of various programs across Europe that focus on the reduction of energy and peak demand by DSM.

Specifically, energy efficiency obligation schemes are operated in some of the biggest European countries (UK, Denmark, France, Italy) for the last few decades with high levels of success [16]. Through these programs, energy suppliers and distributors are required to fulfill a specific annual quota of energy savings based on their energy sales, thus driving significant improvements in the building stock and the efficiency of appliances. Further to these programs, Member States have

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14 D'Sa A. 2011. Integrated Resource Planning (IRP) Part 1: Recent practice for the power sector. The International Energy Initiative. Bangalore, India.

15 Nilsson, LJ, S. Thomas, C. Lopes, and L. Pagliano. 2001. Energy efficiency policy in restructuring European electricity markets.

16 Bertoldi P. and S. Rezessy. 2009. Energy saving obligations and tradable white certificates.

introduced and are implementing an appliance labeling scheme and mandates around public sector building retrofits.

Additionally, demand response has been successfully introduced in some European systems in the last few years. In the UK, the TSO is responsible for the country's DR capacity, which is contributed by the large commercial and industrial customers, by requiring them to be able to curtail a minimum of 3 MW of load [17]. In Belgium, the local TSO has recently handed out the first contract to an aggregator to provide demand response that can meet the primary reserve requirements of the network [18], thus opening the door to the implementation of DR for ancillary services in Europe.

The above examples are further enhanced by the implementation of innovative programs that demonstrate the integration of DSM with the smart grid. In France, the Riviera DSM program (also referred to as Eco-Energy Plan by EDF Energy) was one of the first to trial the DSM with primary focus on energy efficiency and DR components to defer the need to upgrade a major transmission line in the east of France [19]. UK Power Network's Low Carbon London project, as part of the Low Carbon Network's Fund, is looking into predicting grid demand and adjusting power use at various commercial facilities across central London based on contractual arrangements and time-varying pricing [20].

With the growth of smart grid-enabled DSM programs in Europe in the last few years, it is clear that there is a need to quantify the potential benefits and costs of a wider roll out of similar initiatives across the continent. The results of the RBC analysis for the Pacific NW in the USA might not be applicable to Europe without adjustments to account for the regional differences in the characteristics of the electricity networks, but the overarching methodology could be a valuable tool in conducting a similar analysis.

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[17] http://www2.nationalgrid.com/uk/services/balancing-services/reserve-services/short-term-operating-reserve/

[18] Vandenbroucke H. 2013. Demand Response from the TSOs point of view. Presentation. Brussels, Belgium. Available at http://iet.jrc.ec.europa.eu/energyefficiency/sites/energyefficiency/files/files/documents/events/12_elia_15102013.pdf.

[19] Crossley D. 2010. Case Study - French Riviera DSM Program. IEA-DSM Task 15. Available at http://www.ieadsm.org/ViewArticle.aspx?id=6.

[20] http://innovation.ukpowernetworks.co.uk/innovation/en/research-area/demand-side-response/#LCL