Advanced Metering Infrastructure: Utility Trends and Cost-Benefit Analyses in the NEEP Region

February 2017

Table of Contents

Acknowledgements

This report reflects the invaluable contributions of multiple individuals. Samantha Caputo, NEEP's Research Associate, served as the brief's lead author. The following NEEP staff provided feedback, input, and edits: Brian Buckley, Public Policy Manager; Claire Miziolek, Technology & Market Solutions Manager; and Elizabeth Titus, Regional EM&V Forum Acting Director. Formatting and edits were provided by Lisa Cascio, Public Relations Manager; and Chris Tanner, Senior Digital Marketing Associate. This report is a product of NEEP policy-related and EM&V Forum research and products.

About NEEP

NEEP was founded in 1996 as a non-profit whose mission is to serve the Northeast and Mid-Atlantic to accelerate energy efficiency as an essential part of demand-side solutions that enable a sustainable regional energy system. Our vision is that the region will fully embrace next generation energy efficiency as a core strategy to meet energy needs in a carbon-constrained world.

Introduction

Within the Northeast and Mid-Atlantic states, the recent deployment of advanced metering infrastructure (AMI) has opened a door of opportunity, enabling some states to advance innovative energy efficiency and demand response programs.[1] Deploying AMI opens the door for the electric grid to step into the twenty-first century. AMI provides two-way communication that enables the growth of a smart grid with the integration of distributed energy resources and provides a stronger, more resilient electric grid. Each utility has embarked on a different path towards AMI implementation, and some programs are further along than others. Many utilities within the NEEP region[2] are integrating AMI into their grid modernization efforts as a way to increase system efficiency and gain better understanding of the way customers use energy. Others are harnessing AMI to offer customers access to more granular energy usage data and time varying rate designs.

As utilities present their business plans, the major question facing Public Utility Commissions (PUCs) is whether the upfront cost of AMI is justified by the benefits of deployment. This is because full benefits may only be realized after programs that take full advantage of AMI functionality are implemented, and many of the benefits depend on customer acceptance and adoption of AMI. There is rarely a straightforward answer to the question of whether the benefits of AMI outweigh the costs or vice versa. This is due to the different types of available metering systems and functionality, as well as program-specific deployment drivers, market structure, and methodology used in analyzing the costs and benefits.[3] When evaluating the benefits of AMI, it is crucial to use the most accurate information to determine the value of benefits that are hard to monetize.

There is rarely a straightforward answer to the question of whether the benefits of AMI outweigh the costs or vice versa. This is due to the different types of available metering systems and functionality, as well as program-specific deployment drivers, market structure, and methodology used in analyzing the costs and benefits.

Utilities in the NEEP region are including capital costs and operations and maintenance (O&M) costs in their analysis, and for benefits, the avoided capital costs and O&M expense. Beyond these initial buckets, there is some variance. In addition, there are benefits that can be categorized as quantitative or qualitative, and there are inconsistencies in whether the utilities have monetized certain benefits or included them as qualitative benefits, particularly in the environmental and customer categories of costs and benefits. In the cost benefit analysis, utilities also need to make the decision whether or not to include stranded costs of legacy meters, or implement time-varying rates (TVR), both of which can have a significant impact on an AMI cost-benefit analysis.

---

[1] M&V 2.0 provides advanced data analytics through automated measurement and verification. M&V provides improved data collection tools via smart meters, nonintrusive load monitoring, smart thermostats, and home energy management. More information available at: http://www.neep.org/sites/default/files/WorkshopIntroMasterFramework_NEEP_pt2.pdf

[2] This includes Connecticut, Delaware, District of Columbia, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont

[3] Haney, A. et al., *Smart Metering and Electricity Demand: Technology, Economics and International Experience*, University of Cambridge, Electricity Policy Research Group, (February 2009), Available at: http://www.econ.cam.ac.uk/dae/repec/cam/pdf/cwpe0905.pdf

The magnitude of benefits that will be realized is influenced by the level of performance, deployment speed, and behavioral change. Deployment speed is important because slow deployment can have adverse effects on efficiency and total benefits. Demand response is one of the main benefits that can be achieved with AMI because it can influence customer demand at times of peak load when capacity is expensive. AMI functionality can be a prerequisite for some behavioral demand response (BDR), peak time rebate (PTR), or other TVR offerings. AMI may also provide additional consumption information either via the meter, external display, or directly from the supplier, which has the potential to benefit pay-for-performance programs and other energy efficiency programs. Reductions in carbon emissions resulting from these load-reducing customer engagement strategies are ingrained in most AMI systems, but are harder to predict because of the need for customer acceptance and behavioral change.[4] Therefore, with any pending embrace of AMI, customer education will be vital to achieve real change in how customers use electricity and think about energy pricing in order to accomplish maximum peak load reduction benefits.

The purpose of this report is to provide insight into utility trends regarding AMI deployment costs and benefits within the NEEP region. The report reviews the costs and benefits evaluated in both retrospective and prospective AMI deployment proposals, highlighting any outlying factors included in each proposal. There are a wide range of functions offered by an AMI system that enhance the information available to the customer, increasing the potential for interaction between the customer and utility. The customer is able to become a more active participant in the market for electricity and can change the way they use electricity. The utility is able to provide new programs and rate designs that incentivize more efficient use of electricity. The economic and social benefits of these changes are widespread and differ according to the functionality proposed in various AMI deployments.

General Definitions

Advanced Distribution Automation (ADA): The layered control and automation to coordinate protective sectionalizing devices to minimize the impact of outages for customers.
Advanced Metering Infrastructure (AMI): An integrated system of smart meters, communications networks, and data management systems that enables two-way communication between utilities and customers.
Avoided Capital Expense: A benefit that can be realized due to actions taken to reduce future capital costs. It is a cost not yet incurred.
Cost- Benefit Ratio: The ratio between discounted economic benefits and costs that attempts to summarize whether a project or proposal provides a net benefit to ratepayers.
Distributed Energy Resources (DERs): Small-scale power sources that can be aggregated to provide power necessary to meet regular demand. DERs include distributed generation systems (such as high-efficiency combined heat and power and solar photovoltaic systems), distributed storage, battery electric vehicles, demand response and energy efficiency.
Net Present Value: The difference between the present value of cash inflows and the present value of cash outflows. A positive NPV indicates the projected earnings generated by a project or investment (in present dollars) exceeds the anticipated cost (in present dollars). A negative NPV generally results in a net loss.
Nominal dollars: “Current year dollars”, they are the dollar value in the year being presented.

---

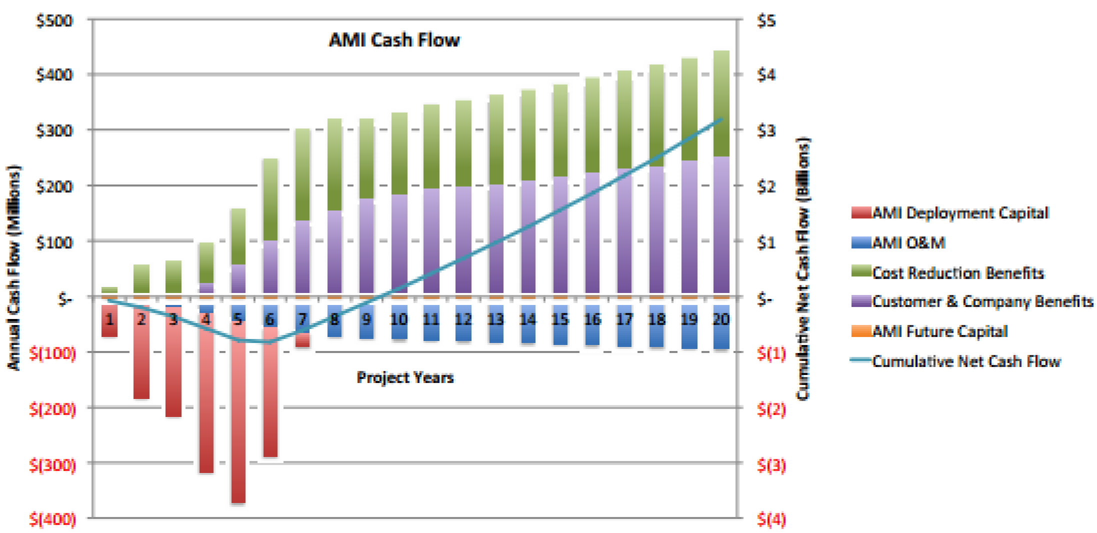
[4] *Id.* at 41

Stranded Cost: A public utility's existing infrastructure investment that may become no longer "used and useful" before the end of its projected lifecycle due to substantial changes in regulatory or market conditions. For example, when a meter is replaced before replacement is required, the value inherent in the meter is lost as it is unlikely to be reused elsewhere.

Volt VAR Optimization and Conservation Voltage Reduction (VVO/ CVR): The layered control and automation necessary to optimize the voltage and power factor of the distribution circuits in real time to reduce system losses and customer consumption. VVO/CVR is also known as conservation voltage optimization (CVO).

Cost-Benefit Analysis

The trending model to determine if an investment in AMI is a prudent investment of ratepayer dollars is a cost benefit analysis.[5] All cost and benefit categories are calculated as financial flows over the course of a project lifetime using a discount rate based on the cost of capital appropriate for the company in question.[6] These values are expressed in net present value terms. The cost-benefit analysis is crucial in showing that, despite the initial capital investment, the long-term benefits from AMI will provide a net benefit that outweighs the costs. This graph from ConEdison illustrates the cost and benefit (revenues and avoided costs) patterns of the AMI investment.



Source: ConEdison Capital Investment and Ongoing Cost-Benefit Comparison

When conducting a cost-benefit analysis, the economic analysis takes into account all costs and all benefits that can be expressed in monetary terms.[7] Depending on which cost-effectiveness test is used, this analysis can include a societal perspective. This may include costs and benefits that expand beyond the AMI system to the overall grid, such as the integration of DERs, the impact on electricity prices and tariffs, as well environmental

---

[5] In 2013, the NEEP EM&V Forum produced a white paper and guidance on cost-effectiveness for energy efficiency programs that includes a set of core principles that may be transferable to AMI investment decisions. Available at: http://www.neep.org/sites/default/files/resources/EMV_Forum_C-E-Testing_Report_Synapse_2013%2010%2002%20Final.pdf

[6] *Id.* at 50

[7] For some elements that cannot easily be quantified in monetary terms directly, other strategies may be used – for example "adders" or setting thresholds different from 1.0 for the c/e ratio.

costs or customer benefits.[8] While some of these societal benefits can be monetized, they are not always included in the economic analysis, and are instead considered on a qualitative basis. Benefits that are considered in a qualitative manner are often included in the analysis surrounding the economic assessment, or in a sensitivity analysis. In the Northeast and Mid-Atlantic states, there has been a variation between the inclusions of benefits that accrue to stakeholders other than the company implementing the AMI system. In the case of Con Edison, it can be seen in the graph above that both customer and company benefits are included in the analysis.

The Electric Power Institute (EPRI) has defined a framework used by many utilities in California to determine benefits in its analysis of the cost effectiveness of AMI.[9] These categories include economic, reliability, environmental, and other benefits. This framework has been used by Pacific Gas & Electric and San Diego Gas and Electric,[10] but has not been used explicitly by utilities in the Northeast and Mid-Atlantic. The approach utilities have taken to complete a cost-benefit analysis differs, but there are underlying trends in the types of economic and qualitative benefits and costs that are included. The economic and qualitative benefits tables below show there is an overlap between the EPRI categories and the types of benefits utilities have included in their cost-benefit analyses. These tables were created based on the commonalities and differences between the utilities in the Northeast and Mid-Atlantic states to provide a framework for the types of costs and benefits included in a cost-benefit analysis of AMI.

Economic Benefits

When conducting a cost-benefit analysis, most utilities in the region have included the benefits of avoided capital expense and avoided operations and maintenance, but environmental benefits are not always included because some utilities do not monetize them. The outcome of the economic analysis can be expressed as a net present value, internal rate of return, or a benefit-cost ratio.[11] EPRI provides an approach to quantify and monetize various benefits, including the calculations to do so.[12] The table below summarizes the type of economic benefits that can be included in an analysis.

Economic Benefits		
Category	**Benefit**	**Description**
Avoided Capital Expense	Reliability	AMI is expected to reduce the storm system average interruption duration index (SAIDI) through increased outage notification accuracy. This will provide the utility the ability to detect, isolate, and respond to outages quicker than current capabilities

[8] Fulli, G., *Guidelines for Cost Benefit Analysis of Smart Metering Deployment*, European Commission Joint Research Centre: Institute for Energy and Transport, (2012), Pg. 12, Available at: https://ses.jrc.ec.europa.eu/sites/ses/files/documents/guidelines_for_cost_benefit_analysis_of_smart_metering_deployment.pdf
[9] *Methodological Approach for Estimating the Benefits and Costs of Smart Grid Demonstration Projects*. EPRI, Palo Alto, CA: (January 2010). 1020342, Available at: https://www.smartgrid.gov/files/methodological_approach_for_estimating_the_benefits_and_costs_of_sgdp.pdf
[10] Smith, A. *Survey of Smart Grid Implementation in New England: Including Opt Out Programs, the Importance of Customer Education & an Early Look at Benefit Evaluation Approaches in Other States,* New England States Committee on Electricity, (Spring 2012), Pgs. 22-26, Available at: http://magrid.raabassociates.org/Articles/nescoe-Smart_Grid_Final_May_2012.pdf
[11] Fulli, G., *supra* note 8, at 13
[12] EPRI, *supra* note 9, at 149-175

	Avoided Transmission & Distribution	Avoided generation and capacity investments
Operations & Maintenance	Reduction in meter reading and operation costs	AMI will provide more accurate metering and enable reduction of costs accrued due to meter inaccuracy, theft of service, consumption on inactive meters, and bad debt, resulting in reduced billing costs and call center costs.
	Engineering	The ongoing O&M costs for physical assets necessary for grid modernization investments
	Field service operations	Meter services including meter reading and fuel costs
Environmental	Peak load reduction	Capacity revenue and capacity price mitigation - Shift consumption timing from peak to off-peak and provide opportunities to reduce consumption
	Reduced GHG emissions	Avoided GHG emissions through reduced energy consumption and reduced peak demand, resulting in reduced dispatch of dirtier fuels.
	Energy Conservation	Avoided energy costs, energy procurement, and energy price mitigation.

Qualitative Benefits

The table below illustrates that a majority of the qualitative benefits associated with AMI accrue to society. The qualitative benefits in the cost-benefit analysis consider the impact the AMI project may have on the entire electricity system and society at large. Qualitative benefits are often expressed in physical terms or through a description to provide decision makers a broader picture beyond monetized benefits. There are key benefits from AMI that have not been monetized yet, such as demand response and energy efficiency. Many utilities consider these in the business cases for AMI that they present to state commissions. These benefits often align with the policy objectives of AMI deployment.

Qualitative Benefits		
Category	**Benefit**	**Description**
Safety	Risk reduction	Sensors provide the opportunity for detection and reporting of methane leaks, corrosion potential, arc fault, and stray voltage
		Utilities with have the ability to remotely control the meter service switches, which allows the operators to respond more effectively to system emergencies, reducing workplace injury
	Improved compliance with safety standards	Automated data collection and logging for regulatory reporting
	Data Privacy	Encrypted communication of meter data information to the utility
Reliability	Efficiency	AMI could provide improved system efficiency, resiliency, and provide energy security

		Accessibility to program strategies that require more granular data, such as "virtual audits, or M&V 2.0
	System planning	Avoided investment in peak generation capacity, and T&D; as well as proactive preventative maintenance
	Crew productivity	The value of increased productivity associated with shorter outages and field service calls is considered a societal benefit
Customer	Customer satisfaction	Accurate information for billing purposes and fewer complaints, reduction in unpaid bills
		Provides new abilities to engage low income customer to help manage their usage and costs
	Customer convenience	Customer portals to monitor energy usage in near real time- Assuming that the more customers know about and understand their electricity use, the more likely they are to conserve energy
	Demand Response	Facilitates the introduction of behavioral demand response, peak time rebates, and other time-varying rate designs. Can provide consumption information via the meter, external display or from the supplier.
Environmental	Conservation Voltage Reduction	Reduction of energy usage and peak demand through reduced voltage
	Priority pollutant reduction	Particulate matters, NOx, SO_2, leading to health and environmental benefits. Reduced air pollutants due to reduced line losses, as well as reduced air pollutants emissions due to wider diffusion of low carbon generation sources
	Energy conservation	Decreased pollution and use of fossil fuels to combat climate change and create a healthier environment

Some qualitative benefits can also have an impact on the quantitative analysis. For instance, the energy conservation benefit impacts the energy price mitigation benefit. Therefore, even though conservation is qualitative, it can have indirect monetized effects in the cost-benefit analysis. In the case of Baltimore Gas & Electric's (BG&E) AMI deployment, regulators determined that energy conservation should be quantified and found a $123 million benefit for energy conservation accounting for load shifting.[13] Other qualitative benefits can be quantified, but some utilities may refrain from quantifying them because too many assumptions must be made. One example is theft reduction. Even though it may provide better cost allocation for customers and reduce unaccounted for electricity in billing, it can become unreliable due to the number of assumptions required to quantify this benefit.[14] In addition, the reduction of unpaid bills has a monetary benefit, but it is

[13] ML 192110, Order No. 87591, Case No. 9406, *In the Matter of Application of Baltimore Gas and Electric Company for Adjustments to its Electric and Gas Base Rates*, (June 3, 2016), Pg. 67 Available at: http://www.psc.state.md.us/wp-content/uploads/Order-No.-87591-Case-No.-9406-BGE-Rate-Case.pdf
[14] *Id.* at 41

difficult to estimate what this value will be before implementation. To account for these variations, some benefits appear in both the qualitative and monetized economic tables.

In order to maximize the customer benefits derived from AMI deployment, regulators in several states have required utilities to propose customer engagement and education strategies in tandem with their AMI proposals. For example, to increase the likelihood of achieving maximum benefits, the Maryland Public Service Commission required BG&E to file a customer education plan.[15] Other commissions within the region have required similar plans. With engagement and education strategies for AMI, customers gain insights into their energy usage, which can turn into customers taking their own actions.

Several utilities have introduced programs and product offerings to empower customers to make changes and improve their energy experience. Data from AMI can be analyzed by Home Energy Management Systems (HEMS), online portals, or in-home displays; this can solve the "out of sight, out of mind" issue, and is useful because it allows customers to interact with their energy usage on a more granular level. The data collected by AMI systems opens the door for greater integration of new resources and new energy services for customers. The AMI system may enable customer-derived benefits that could lead to more choices regarding energy efficiency, conservation and rate incentives. These demand response benefits are subject to more uncertainty because there is a need for customer acceptance and behavior change. When customers begin to recognize the advantages AMI may provide, customers and the utilities may be able to take full advantage of the benefits of AMI.

Costs

Utilities in the region generally consider two main categories of costs in their AMI proposals: (1) capital expenses and (2) operations and maintenance costs. The costs of customer engagement are not always included in the cost-benefit analysis. The capital cost is expensed during the initial deployment phase because it is the cost of the AMI infrastructure as well as the supporting network and communications infrastructure. The cost or replacing legacy meters before the end of their lifecycle, known as stranded costs, are sometimes also considered in an analysis when AMI systems are deployed before the legacy metering technology has fully depreciated, although not all utilities include this cost in their analysis. The operations and maintenance costs are the costs the utility will pay throughout the lifecycle of the AMI system. The table below provides a description of the various types of costs that are often included in utilities' cost-benefit analysis.

[15] Smith, A., *supra* note 10, at 17

Costs		
Bucket	**Cost**	**Description**
Capital Expense	Metering equipment	The physical hardware cost, labor cost for installation, project and change management
	Network and communications infrastructure	Communications, metering and telecom network infrastructure hardware and installation
	Stranded costs	The lost value of existing infrastructure replaced before its lifecycle is over
Operations and Maintenance	Infrastructure procurement	Vendor management, a significant cost factor in this category is expected life of the assets.
	Project Management	Management of the project during deployment and on-going AMI operations
	IT systems	Procurement, development and integration of the meter data management system and data center aggregator system, as well as a web portal, load control systems, and quality control processes
	Field services	Including meter operations, communication, customer service O&M, as well as project administration, organizational readiness, and quality assurance
	Revenue reduction	Reduction in revenue through more efficient consumption
Customer Engagement	Marketing	Development of marketing materials and allowing IT systems to handle the letter mailing, as well as price signaling
	Customer education	Educating customers on pricing programs and benefits of AMI

Utility Trends and Case Studies

A majority of the AMI projects examined in this report were proposed in 2015, with a few in 2007 and 2010. The 2015 projects are examined from a prospective point of view, whereas the others are retrospective. The following table provides an overview of the cost-benefit analysis conducted by each utility.[16]

Utility	Year Proposed	Meters	Costs		Benefits			
			Physical Hardware	O&M	O&M	Peak reduction (DR/TVR)	CVR	Lifecycle
CMP (ME)	2007	622,000 (Deployed)	$78.4M	$48.8M	$67.8 M	Included, but unquantified		20
GMP (VT)	2010	260,600 (Deployed)	104.8M	19.64M	19.32 M	No	vvo	20
CL&P (CT)	2007	3,000[17] (Deployed)	294M	197M	211M	Included, but unquantified		20
NGrid (MA)	2015	1.3M (Proposed)	300.65 M	x	x	Included, but unquantified	x	15
Con Edison (NY)	2015	4.7M[18] (Approved)	777M/ 1,026M	634M	1,383 M	Included, but unquantified	cvo	20
BG&E (MD)	2010	1.23M (Deployed)	$653.6M		436M	$123M	cvr	15
Unitil (MA)	2015	103,000 (Deployed, to be upgraded)	x	x	x	Included, but unquantified	x	15
Eversource (MA)	2015	5 percent (Proposed)	140-450 $/unit[19]	$21 ($/unit/yr)	x	33.4M	vvo	15

The table above shows that all the utilities, besides GMP, included peak reduction benefits through demand response or time-varying rates, though only Eversource MA has quantified those benefits. The Massachusetts Department of Public Utilities recommended the utilities (National Grid, Unitil, and Eversource) collaborate on their approach to TVR. [20] Eversource MA provides a monetized benefit for including TVR. The O&M benefits are

---

[16] An "x" indicates the metric was included in the analysis, but a monetized number was not identified, where there is a blank space, the metric was not included.

[17] While the AMI proposal was put on hold, CL&P had deployed 3,000 meters during a pilot program that went along with the proposal, More information available at: http://nuwnotes1.nu.com/apps/clp/clpwebcontent.nsf/AR/recommendations/$File/recommendations.pdf

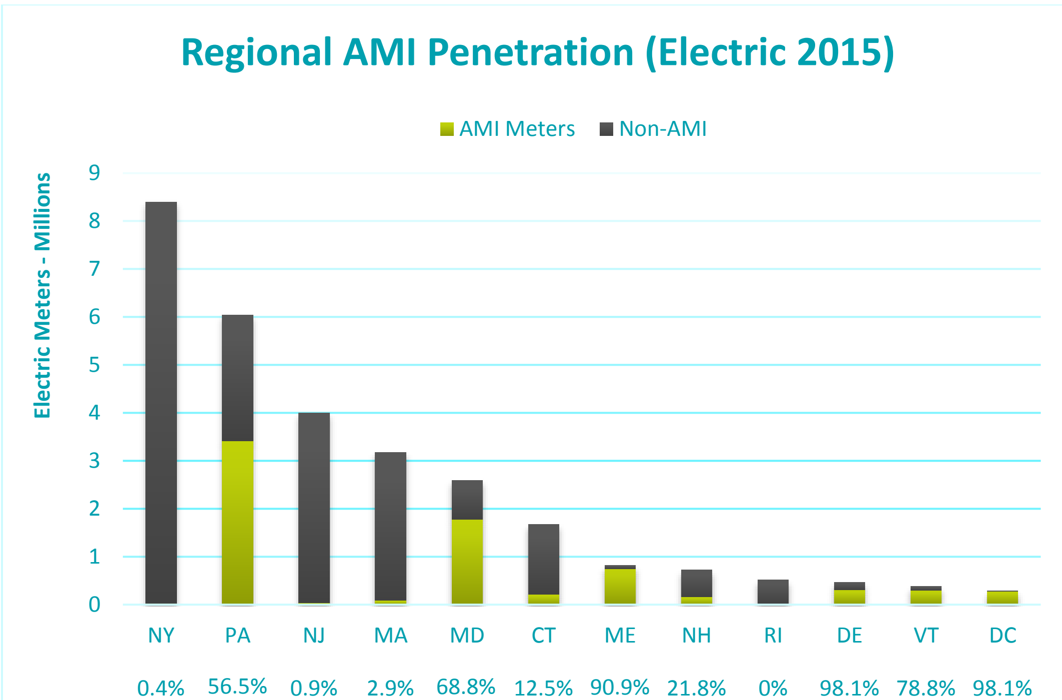
[18] 3.6M electric and about 1.2M gas meters

[19] Variation in range represents the different deployment strategies, such as opt-in and TVR

[20] Per D.P.U. 14-04-B, Available at: http://web1.env.state.ma.us/DPU/FileRoomAPI/api/Attachments/Get/?path=14-04%2fOrder_1404B.pdf

included in Eversource's analysis under economic benefits of TVR and VVO with AMI, but the benefits are not broken down to pull out what portion of the benefit comes from O&M.[21] Another benefit that is included by a majority of the utilities is CVR/VVO. National Grid and Eversource provide the monetized benefits for VVO under different deployment scenarios.

The lifetime costs of meters are sensitive to the discount rate chosen and the assumed lifecycle of the meter. Traditional meters typically assume a 20-year lifetime, but with AMI meters, some states assume a 15-year lifetime, while others assume a 20-year lifetime.



The graph above compares the number of AMI meters to non-AMI meters within each state. New Jersey and New York have less than one percent. This graph puts the table below in perspective, which shows the level of AMI penetration in the NEEP region. As a result of investments made by the federal government during the American Recovery and Reinvestment Act, many of the smaller states in the region already have significant AMI penetration.

The table below[22] shows the level of AMI deployment by state within the NEEP region through 2015. The District of Columbia has the highest percent of AMI at 98 percent. New Jersey, New York, and Rhode Island have the least at less than one percent penetration. Massachusetts only had 2.7 percent AMI in 2015, but this is the same year that the utilities in Massachusetts filed grid modernization plans, which include the business cases for AMI

---

[21] Eversource Energy, *NSTAR Electric Company and Western Massachusetts Electric Company (each d/b/a Eversource Energy) Petition for Approval of Grid Modernization Plan*, D.P.U. 15-122/15-123, Submitted to: Massachusetts Department of Public Utilities, (August 19, 2015), Pgs. 209-210, Available at: http://web1.env.state.ma.us/DPU/FileRoomAPI/api/Attachments/Get/?path=15-122%2fInitial_Filing_Petition.pdf
[22] Data for this table was taken from the EIA 861 form, available at : https://www.eia.gov/electricity/data/eia861/

deployment. National Grid MA plans to have 1.3 million meters installed by 2020. As far as actual number of AMI meters deployed, Pennsylvania leads with over three million meters, Maryland follows with 1.7 million. Of the 1.7 million AMI meters in Maryland, BG&E deployed 1.23 million of them.

AMI Penetration in the NEEP Region in 2015				
State	AMI Meters	Non-AMI	Total Meters	Percent of AMI
CT	209,922	1,463,530	1,673,452	12.5%
DC	277,998	5,504	283,502	98.1%
DE	308,685	156,744	465,429	66.3%
MA	86,544	3,092,547	3,205,736	2.7%
MD	1,780,499	806,289	2,586,788	68.8%
ME	746,599	74,601	821,200	90.9%
NH	158,377	567,430	725,807	21.8%
NJ	36,800	3,964,717	4,001,517	0.9%
NY	32,091	8,368,783	8,400,874	0.4%
PA	3,412,095	2,626,099	6,038,194	56.5%
RI	249	515,824	516,073	0.0%
VT	297,116	79,944	377,060	78.8%

Baltimore Gas & Electric

In 2009, BG&E filed a petition (Case 9208)[23] to deploy AMI, but the commission identified a number of concerns about the cost-benefit analysis and rejected the initial petition. Subsequently, the commission gave BG&E the opportunity to resubmit its application. BG&E filed a petition to reconsider its smart grid initiative in 2010.[24] The commission approved BG&E's revised proposal, which: 1) did not require mandatory time-of-use pricing; 2) included a consumer education and communication plan;[25] and 3) adopted measures to mitigate risk to ratepayers.[26] The Total Resource Cost (TRC) test is used consistently throughout the different cases covering BG&E's AMI project as the company saw this as the best way to evaluate total costs and benefits.

---

[23] Curry, K., *Application of Baltimore Gas and Electric Company for Authorization to Deploy a Smart Grid Initiative and to Establish a Surcharge Mechanism for the Recovery of Costs*, Baltimore Gas & Electric, Case No. 9208, (July 2009), Pg. 147, Available at: http://webapp.psc.state.md.us/intranet/casenum/NewIndex3_VOpenFile.cfm?ServerFilePath=C:\Casenum\9200-9299\9208\\59.pdf

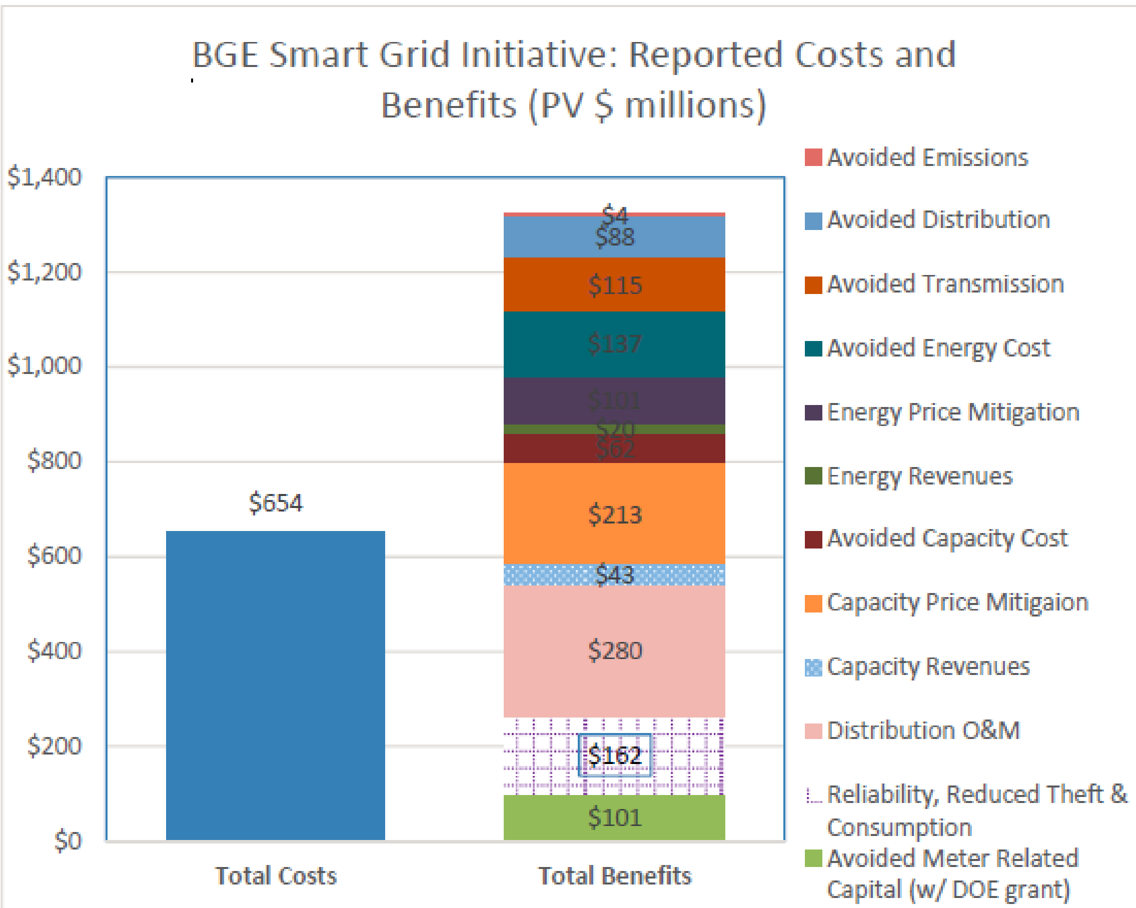
[24] Chang, M., *Direct Testimony of Maximilian Change on Behalf of the Maryland Office of People's Counsel*, Case No 9406, Public Service Commission of Maryland, (February 2016), Pg. 6-7, Available at: http://www.synapse-energy.com/sites/default/files/Testimony-of-M-Chang-BGE-Rate-Case-15-120.pdf

[25] BG&E, BG&E Smart Meter Customer Education and Communication Plan, (June 2011), Available at: https://www.smartgrid.gov/files/060111-BGESmartMeterCommPlanFINAL.pdf

[26] Smith, A., *supra* note 10 , at 18

Actual costs associated with AMI deployment were $653.6 million. This amount does not include the unamortized balance of the legacy meter assets, which was constituted as a sunk cost that is not appropriately included in the cost-benefit analysis for this new initiative. [27]

BG&E divided its benefits into two main categories, core benefits and additional benefits. BG&E calculated its conservative benefit-cost ratio based on the core benefits to show cost-effectiveness without including supplementary benefits.[28] Core benefits include market side and operational benefits. The graph below shows the reported costs and benefits of BG&E's AMI initiative; BG&E originally calculated a benefit-cost ratio of 1.37, indicating that the AMI project was cost-effective using the core benefits alone. After further analysis, the energy price mitigation benefit was reduced from $101 million to $18 million, which lowered the benefit cost ratio to 1.26.[29]



Source: Chang, M. Testimony in support of BGE's proposal

The market-side benefits of these core benefits include capacity revenue, capacity price mitigation, energy revenue, energy price mitigation, and energy conservation. These benefits were valued at $353.6 million NPV. This figure does not include avoided capacity costs or avoided emissions because these benefits were not

[27] ML 192110, *supra* note 13, at 68

[28] Core operational benefits include avoided capital expense, avoided T&D, and the DOE grant benefit. Core supply side benefits include operational savings, capacity revenue, capacity price mitigation, energy revenue, energy price mitigation and energy conservation.

[29] ML 192110, *supra* note 13, at 40-41

quantified and instead designated as additional benefits.[30] The Office of People's Counsel (OPC) attempted to quantify these benefits, and found avoided capacity costs to be valued at $9 million and avoided emissions at $3.9 million, but in the end the commission—while agreeing the value of the avoided capacity and avoided emissions were not zero dollars—declined to asses a value, especially in light of the fact that the investment was found to provide a net benefit to ratepayers regardless.[31]

Operational benefits attributable to the AMI initiative were valued at $485.8 million. This included Operational Savings ($174M) + Avoided T&D ($166M) + Avoided Capital Expenditures ($36M) + CVR Avoided Costs ($49.6M) + DOE Grant Benefit ($60.2M) = $485.8M. This did not include any amount for Reduction in Uncollectible Write Offs.[32] Commission staff contemplated eliminating the CVR benefit from the core analysis because it was unclear whether BG&E would have attempted to achieve the same amount of savings with a non-AMI CVR solution,[33] however, the OPC did not challenge BG&E's CVR benefit of $49.6 million NPV avoided costs, and therefore the commission included the quantified benefit in its analysis.[34]

Additional benefits were not assigned a value, but they are still considered important when demonstrating that the AMI system is cost-effective.[35] While these benefits were not assigned a value, the commission agreed with BG&E that these benefits were not valued at zero. In an exception of the non-valuation of additional benefits, the additional benefits associated with increased customer reliability, reduced theft, and reduced consumption on inactive meters were valued at $161.6 million.[36] The benefits of customer reliability, reduced theft, and storms were eliminated from the core analysis because many of the assumptions built into the calculations are uncertain, making the analysis unreliable.

Central Maine Power Company

Central Maine Power Company (CMP) received Recovery Act funding from the DOE for a Smart Grid Investment Grant of $95,858,307 to install a smart meter network for all residential, commercial and industrial customers within the service territory.[37] CMP completed its AMI deployment in 2012 and currently has 626,000 meters installed.[38] The deployment of AMI in CMP's territory was part of an opt-out program that gave customers the option to retain the legacy meter or receive a new meter with the transmitter turned off. Since the Maine

---

[30] ML 192110, *supra* note13, at 67
[31] *Id.* at 68
[32] *Id.* at 69
[33] *Id.* at 41
[34] *Id.* at 63
[35] Additional benefits include operational savings associated with storms, customer reliability, reduced theft, reduced consumption on inactive meters, conservation voltage reduction, avoided capacity costs, and avoided emissions.
[36] ML 192110, *supra* note 13, at 64
[37] Energy.gov, Recovery Act Selections for Smart Grid Investment Grand Awards- By Category, November 2011 Update, Available at: https://www.energy.gov/sites/prod/files/SGIG%20Awards%20by%20Category%202011%2011%2015.pdf
[38] Cooper, A., Electric Company Smart Meter Deployments: Foundation for A Smart Grid, IEI Report, The Edison Foundation Institute for Electric Innovation, (October 2016), Pg. 9, Available at: http://www.edisonfoundation.net/iei/publications/Documents/Final%20Electric%20Company%20Smart%20Meter%20Deployments-%20Foundation%20for%20A%20Smart%20Energy%20Grid.pdf

commission determined the smart meter would be standard service, customers who opt-out are electing to pay the incremental cost of non-standard service.[39]

Maine included the net book value of existing legacy meters in the capital cost. The net book value (NBV) of the legacy meters was $27.9 million. This represented the un-depreciated value of the legacy meters that were replaced with AMI meters. The total project cost was approximately $191.7 million with the legacy meters included, therefore the total unreimbursed cost after the DOE grant was approximately $94.4 million.[40] The cost of the AMI meters totaled at $78.4 million, with the meter and network installation totaling an additional $20.6 million. The breakdown of the capital costs can be seen in the table below.[41]

Capital Component	Costs ($ in millions)
AMI Meters	$78.4
IT	$31.6
Meter and Network Installation	$20.6
AMI System Network	$9.6
Project Management	$7.1
MDMS	$3.5
Research	$1.5
Legacy Meters	$27.9
Contingency	$11.5
Total	**$191.7**

Source: CMP

When looking at the operations and maintenance costs, CMP divided costs between deployment and post-deployment. CMP expected to spend approximately $1.97 million per year on average in operations and maintenance costs between 2009-2012 and then approximately $2.15 million per year on average for the post-implementation period from 2013-2031.[42] These costs included various software and communications maintenance costs, as well as operations labor.

The expected savings were provided for the AMI project for the years 2009-2013 and for savings beginning in 2014. Areas where CMP expected savings included meter reading, off-cycle reads, meter services, customer

[39] Friedman, E. et al., *Request for Commission Investigation into Smart Meters and Mart Meter Opt-Out*, Order Dismissing Complaint, Docket No. 2011-262, State of Maine Public Utilities Commission, (August 2011), Available at: http://stopsmartmeters.org/wp-content/uploads/2012/06/Sept-2-2011-Order-Dismissing-Friedman-et-al-complaint.pdf

[40] Blue Ridge Consulting Services, Inc., *Audit of Central Maine Power Company's Management of its Advanced Metering Infrastructure Program*, Report for the Office of the Maine Public Utilities Commission, (February 2014) Pages 42-117 *of Cases 14-E-0493 and 14-G-0494 In the Matter Of Orange & Rockland Utilities, Inc. Electric and Gas Rates*, (March 2015), Pg. 60, Available at: http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7BB1206B7A-0C98-478C-9EE1-9196EBF99291%7D

[41] *Id.* at 71

[42] *Id.* at 72

relations, remote reconnect/disconnects, cash flow savings, storm costs, and billing. The projected net operational savings over a 20-year period were $25 million, excluding supply side benefits.[43]

Benefit	2009-2013	Beginning 2014
Meter Reading Savings	$4,801,727	$5,096,065
Off-Cycle Reads	$663,914	$704,668
Meter Services	$292,825	$262,935
Customer Relations Center	$454,368	$511,808
Remote Reconnect/Disconnect	$921,540	$978,108
Cash Flow Savings	$207,946	$214,544
Storm Costs Savings	$165,865	$136,302
Billing	$46,475	$48,725
Total	**$7,554,660**	**$7,953,155**

Source: CMP

The commission premised approval of CMP's AMI plan on CMP developing the capability to measure and store TOU peak demands for each customer as necessary for billing and settling ICAP tags, as well as customers' daily peak demand.[44,45] In 2012, The Maine Public Utilities Commission (PUC) approved a time-of-use pricing option for customers within the CMP service territory,[46] but the PUC did not select a TOU option in 2015, ending the TOU program in February 2015.[47]

The main benefits that CMP has realized include improved electric service reliability and power quality, fewer estimated bills (from 300,000 to 30,000 annually), reduced service order costs, fewer greenhouse gas emissions, and reduced equipment failures and theft. Through May 2015, the project has avoided 346,000 truck rolls, which equals 623 metric tons of CO_2.[48]

CMP is leveraging its AMI network for distribution automation with a plan to achieve fully optimized automation by 2019. CMP plans to investigate potential applications for conservation voltage reduction (CVR) and the resulting business impacts.[49]

---

[43] *Id.* at, 58-59
[44] *Id.* at 84
[45] The reported ICAP is based on the aggregate of each Supplier's customers' contribution to the ISO-NE peak load during the preceding year. The individual customers' contributions (tags) are estimated annually. Customers' contributions to ICAP are estimated from either their actual peak hour use, if interval data are available, or load profiles.
[46] Maine PUC, Standard Offers Prices Set for CMP and EMERA Maine (BHE) Customers, available at: http://maine.gov/tools/whatsnew/index.php?topic=puc-pressreleases&id=612925&v=article08
[47] Central Maine Power Company, Time-of-use supply option, Available at: http://www.cmpco.com/YourHome/pricing/pricingSchedules/TOUSupplyOption.html
[48] Benner, B., *Central Maine Power Company Advanced Metering Infrastructure Project*, (May 2015), Pg. 2, Available at: https://www.smartgrid.gov/files/Central_Maine_Power_Co_PD_FINAL.pdf
[49] *Id.* at 1

Connecticut Light & Power

In 2007, Connecticut Light & Power (CL&P) now Eversource CT, proposed a cost-benefit analysis that monetized several benefits which others had yet to do. The attorney general indicated that the $492 million cost of the project was too high considering the project benefits are still unknown, with the estimated $600 million in savings depending heavily on customer response to the programs. It was unclear if the benefits actually outweighed the costs. The attorney general asked the Department of Public Utilities Commission (now Public Utilities Regulatory Authority) to deny the AMI proposal, arguing that the upgrade should be postponed until the existing mechanical meters require replacement. PURA suspended further action while the Department of Energy and Environmental Protection (DEEP) establishes state energy policy and implements a variety of new clean energy and energy efficiency programs.[50]Prior to the full scale AMI deployment proposal by CL&P, 3,000 meters were deployed during an AMI pilot program. Since the proposal has been tabled, no new actions have been taken to move the proposal forward.

The major benefit categories included were O&M, avoided capital costs, peak load reduction, energy conservation and social benefits. Many of these benefits are either qualitative or quantitative according to utility trends in the Northeast. The only benefits not quantified in this analysis were number of temporary jobs, improved safety, and improved energy security. CL&P did not consider CVO in its analysis, nor did it mention stranded costs.

CL&P applied a general annual inflation rate of 2.5 percent to capital costs, operational expenses, and forecast energy prices to keep the costs and benefits in nominal dollars. The tables illustrate the costs and benefits included in the cost-benefit analysis.[51]

Base, Worst and Best Case Scenario Costs (NPV $) in Millions			
Cost Category	**Base case scenario**	**Best case scenario**	**Worst case scenario**
Capital	$296	$247	$385
O&M	$153	$129	$175
Customer Engagement	$44	$76	$21
Total	**$493**	**$452**	**$581**

Source: Connecticut Light & Power

AMI Benefit Summary (NPV $) in Millions			
Benefits category	**Base case scenario**	**Best case scenario**	**Worst case scenario**
O&M benefits	$211	$278	$113
Capital Avoidance	$82	$194	$49
Peak reduction	$66	$353	$2

[50] McCarthy, K., & Hansen, L., Smart Grids/Smart Meters, OLR Research Report, (October 2012), Available at: https://www.cga.ct.gov/2012/rpt/2012-R-0392.htm

[51] Connecticut Light and Power (CL&P), *Appendix A- Detailed Cost Benefit Analysis and Assumption*, Docket No. 05-10-03RE01, Compliance Order No. 4, (March 31, 2010), Pgs. 6-17, Available at: http://nuwnotes1.nu.com/apps/clp/clpwebcontent.nsf/AR/appendices/$File/appendices.pdf

Energy reduction	$144	$277	$0
Reliability	$59	$110	$25
Environmental	$18	$31	<$1
Total	**$580**	**$1,243**	**$189**

Source: Connecticut Light & Power

CL&P's approach included a base, best, and worst case scenario. The only case where AMI would not be cost-effective was the worst case scenario where the results were a negative $392 million NPV. The base case scenario results came in at positive $87 million NPV, and the best case at a positive $392 million NPV.

In order to fully realize the benefits of an AMI investment, CL&P proposed investments in customer engagement through a customer outreach plan. The customer engagement included costs related to customers' energy conservation. This is because CL&P made the assumption that when customers are educated about the energy savings opportunities available with dynamic pricing plans, customers will leverage this to make better energy usage decisions, leading to energy conservation. [52] CL&P also monetized the emissions reduction benefit. The emissions reduction benefit resulting from less energy usage can be monetized due to the value attributed to a ton of CO_2 in the marketplace.

Con Edison

The New York utilities each proposed AMI deployment as a part of the distributed system implementation plans (DSIPs).[53] Con Edison included its cost-benefit analysis for the proposed AMI investment in its 2015 AMI business plan and the commission approved Con Edison's AMI deployment plan in March of 2016.[54] The company found that customers would realize significant benefits through service enhancements made possible by AMI. In the business plan, Con Edison emphasizes that AMI will enable the installation of demand response, energy efficiency and other Distributed Energy Resources (DERs) for customers, as well as encourage behavioral changes.[55] The results of the analysis found a net benefit of $1,149 million with customer, operational, environmental, and financial benefits.[56] The table below summarizes the business case;[57] the NPV and payback are calculated with a discount rate of 6.1 percent. The analysis is based on a six-year project life with a five-year meter deployment schedule.

Business Case Component	Costs & Benefits ($ in millions)
Costs (20 Year NPV)	
O&M Expense for AMI System	$634
New Capital Investment for AMI System	$1,026

---

[52] *Id.* at 10
[53] NY- Docket 16-M-0411 under the NY PSC contains the Initial DSIPs filed by each of the investor owned utilities (filed 7/28/16), Available at: http://documents.dps.ny.gov/public/MatterManagement/CaseMaster.aspx?MatterCaseNo=16-M-0411
[54] State of New York Public Service Commission, *Order Approving Advanced Metering Infrastructure Business Plan Subject to Conditions,* (March 2016), Available at: http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7B8C26CF58-5669-4A16-85BC-7D4AE21BFF8D%7D
[55] Con Edison, *Advanced Metering Infrastructure Business Plan*, (October 15, 2015), Pg. 19, Available at: http://nyssmartgrid.com/wp-content/uploads/Con-Ed-AMI-Business-Plan.pdf
[56] *Id.* at 43-66
[57] *Id.* at 60

Sub-Total	***$1,660***
AMI Benefits (20 Year NPV)	
AMI Cost Reduction Benefits	$1,383
Customer and Company Benefits	$1,426
Sub-Total	***$2,809***
Total (20 Year Net NPV)	
Benefits Less Costs	**$1,149**
Discounted Payback Period	***10***

Source: Con Edison

Con Edison did not include the remaining unrecovered cost of existing meters in its benefit cost analysis. It is standard practice for Con Edison to exclude previously-incurred sunk costs because they have no effect on evaluating the net benefits of new investment. Including such costs within the project's BCA inputs would have significantly limited the business case for AMI deployment.[58]

In support of its proposal, Con Edison consulted with Nexant to develop a report identifying the costs and benefits of time-varying rates in the Con Edison service area. The Nexant report is meant to illustrate what demand reduction could achieve in the service territory, but it is limited to time-varying pricing and does not include all the potential rate designs enabled by AMI.[59] The cost-effectiveness results calculated by Nexant include the five different enrollment scenarios resulting from the implementation of TVR. The total resource cost test was used to determine the net benefits associated with each scenario. The benefit-cost ratios range from 1.26 to 3.24. The analysis does not include the potential impacts from non-residential customers, nor does it factor in the potential increases in load reductions that can be achieved when TVR is combined with enabling technology such as smart thermostats and energy management systems.[60]

Con Edison divided its benefits between financial benefits and other benefits[61]. Each category was then divided into sub-categories, further dividing financial and 'other' benefits. 'Other' benefits were not included in the financial analysis. The financial benefits include customer and company benefits, and cost reduction benefits. The two main categories of costs included in the analysis are O&M expenses for AMI system and the new capital investment for AMI.

Financial Benefits	
Customer and Company	AMI will provide more accurate meter reading capabilities and reduce the costs associated with meter inaccuracy, theft of service, consumption on inactive meters, and bad debt. CVO will also lead to energy savings for customers and reduced emission levels. Outage

[58] *Id.* at 44
[59] George, S., et al., *Cost Effectiveness of Time-Varying Pricing with Advanced Metering Infrastructure in CECONY Territory*, Appendix D of Con Edison, Nexant, Inc, (June 2015), pgs. 75-122, Available at: http://nyssmartgrid.com/wp-content/uploads/Con-Ed-AMI-Business-Plan.pdf
[60] Con Edison, *supra* note 54, at 77
[61] *Id.* at 47

	management will improve with the capability to identify outages more quickly, reducing customer costs and lost revenue for the company due to outages.
Cost reduction	There will be reduced manual billing activities, reduced contractor and company outage resource requirements, increasing efficiency
Other Benefits	
Operation and maintenance	Cost reductions related to meter reading, field services, call center, outage management, interval metering, meter replacement avoided costs, solar site metering, and system retirement and discounted AMR installation program
Risk reduction	Remote control of meter service switches will allow operators to respond in a more efficient manner to system emergencies
Environmental and societal	Reduced emissions from CVO and customer participation in demand response, and strategic electrification
Future	The AMI network will allow new sensor function to improve O&M of system conditions and support the development of future billing and marketing programs

Source: Con Edison

Con Edison's report provided the cost per meter, which is listed at $97.99. Based on estimates, Con Edison was also able to determine the installation costs of $35 per electric meter, based on $20 per meter for favorable, and $50 for unfavorable conditions. The network communications equipment needed for each electric meter is valued at $10, which was validated by pricing from AMI vendors. [62]

Conservation voltage optimization (CVO) is included in the company's discussion of its cost-benefit analysis. CVO allows Con Edison to adjust the line voltage to a lower value, which will reduce the amount of energy consumed by customers to power a given load. CVO is considered an "other" benefit in the analysis and is not given a monetized benefit because the projected benefit is based on detailed long term projects. Although, the analysis shows that by using CVO, the AMI system can be leveraged to reduce energy usage across Con Edison's service territory by approximately 1.5 percent, decreasing associated fuel use for committed generation resources. This may result in an environmental impact of 1.9 percent fewer total CO_2 emissions due to the reduction of power generated by fossil fuel plants annually across the service territory and a one percent total reduction in New York State.[63]

Con Edison will begin reporting on AMI scorecard metrics on a semiannual or annual basis in 2018 and 2019.[64] Twelve months after AMI installation has been completed in each neighborhood, a survey will be conducted to

[62] Con Edison, *supra* note 54, at 61-62
[63] *Id.* at 16
[64] Consolidated Edison Company of New York Inc., *Appendix 18*, Cases 16-E-0060 and 16-G-0061, Index of Appendices, (2016), Pg. 126-130, Available at:
https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=3&cad=rja&uact=8&ved=0ahUKEwj6x4qOxbXRAhVLRCYKHauZBEAQFgg2MAI&url=http%3A%2F%2Fdocuments.dps.ny.gov%2Fpublic%2FCommon%2FViewDoc.aspx%3FDocRefId%3D%257B6B65D4E9-EB0A-4129-9BAE-C567EE242998%257D&usg=AFQjCNEuh1P7m8TO-D-Kx8SUsYo43gjSVA&sig2=KPqgSsWkA1kqHYVbSSS7WA

examine the extent to which a link may be present between AMI deployment and distributed energy resource adoption. Results of this study will be included in the following scheduled report.

Eversource MA

Eversource retained Navigant to perform a cost-benefit analysis of the grid modernization investments proposed in its Grid Modernization Plan.[65] The approach taken by Eversource divides benefits between monetized, quantitative, and qualitative benefits. Eversource identified the two main benefits associated with moving from manual meters to an AMI system as: (1) the reduction of bad debt; and (2) a reduction in field operations due to the ability to remotely disconnect customers due to non-payment, as well as remotely generating monthly bills. The most significant benefit that is described qualitatively is the integration of DER. The following table shows the capital costs included in the cost-benefit analysis.[66] The costs include direct and indirect capital costs.

Capital Cost Category	Nominal cost (millions)
Meters and Communications	$281
Information Technology	$634
Stranded Costs	$165
Total	***$946***

Source: Eversource

O&M Category	Annual O&M costs (deployed)
Meter and Communications	$3M
Back-office Support	$3M
IT & Cyber Security	$3M
Customer Education	$4M
Total	***$13M***

Source: Eversource

The capital costs far exceed the ongoing operations and maintenance costs to support AMI deployment within Eversource service territory with the annual O&M costs totaling at $13 million. [67] In addition, the above table

[65] Navigant Consulting, Inc., *Petition for Approval of Grid Modernization Plan*, *Appendix 7, Cost/Benefit Analysis*, D.P.U. 15-122/15-123, Submitted to: Massachusetts Department of Public Utilities, (August 2015), Pgs. 195-268, Available at: http://web1.env.state.ma.us/DPU/FileRoomAPI/api/Attachments/Get/?path=15-122%2fInitial_Filing_Petition.pdf

[66] Eversource Energy, *NSTAR Electric Company and Western Massachusetts Electric Company (each d/b/a Eversource Energy) Petition for Approval of Grid Modernization Plan*, D.P.U. 15-122/15-123, Submitted to: Massachusetts Department of Public Utilities, (August 19, 2015), Pgs. 105-107, Available at: http://web1.env.state.ma.us/DPU/FileRoomAPI/api/Attachments/Get/?path=15-122%2fInitial_Filing_Petition.pdf

[67] *Id.* at 108

shows that Eversource included stranded costs in its cost-benefit analysis. When considering stranded costs, the Department of Public Utilities instructed distribution companies to include a narrative regarding how estimated stranded costs impact the overall business case. Eversource began its initial deployment of 300,000 AMR meters between 1994 and 1999 for hard-to-read locations. From 2003 through 2007, the remaining 800,000 meters were deployed to complete the entire territory. Replacing existing AMR meters before the end of their projected useful life will result in $165 million of stranded costs.[68]

In its grid modernization plan, Eversource exhibited how the costs differ by program and location (western MA vs. eastern MA). Eversource provides the cost per meter. For instance, in Western MA the direct cost is $265 (excluding TVR), whereas in Eastern MA the direct cost is $360 per meter (excluding TVR).[69] The capital cost for an AMI meter under the TVR program ranges from $140-$450.[70] The programs in which Eversource evaluated the costs include AMI meters –excluding TVR, assets and costs with TVR, assets and costs-VVO, and assets and costs-advanced load flow model.

Eversource only attempted to monetize costs and benefits for TVR and VVO, and did not monetize any reliability benefits. The TVR programs, which include the costs of metering, have a benefit-cost ratio lower than one. The VVO programs will find a benefit-cost ratio of 2.15.[71] The remaining grid modernization plan investments were evaluated on a quantified or qualitative basis.[72] To realize maximum benefits, Eversource proposed an opt-in TVR program, which can be seen in the table below.

Cost-Benefit Analysis Opt-in vs. Opt-out ($ Millions in NPV)[73]			
	Opt-in, 20% participation	**Opt-in, 5% participation**	**Opt-out**
15-year Benefits	$83.4	$33.4	$42.6
15-year Costs	$207.1	$124	$857
15-year Net Costs	($123.7)	($90.6)	($814.4)
Benefit to Cost Ratio	***0.4***	***0.3***	***<0.1***

Source: Eversource

Since Eversource began investing in automated meter reading (AMR) in the early 2000's, Eversource proposed replacing meters only if the customer elects to opt-in.[74] The program includes time-of-use and critical peak pricing.[75] Eversource highlights the value in freedom of choice, stating that net benefits increase if the households retain the freedom to decide to implement AMI improving customer experience and satisfaction.[76] Eversource's analysis evaluated economic, environmental, and reliability benefits of each scenario. Examples of

[68] *Id.* at 106
[69] Navigant Consulting, *supra* note 64*,* at 214-215
[70] *Id.* at 222
[71] Acadia Center, Massachusetts Grid Modernization: Detailed Review of Utility Proposals, (December 2015), Pg. 4, Available at: http://acadiacenter.org/wp-content/uploads/2015/12/Acadia-Center_MA-Grid-Mod-Plans_Review-of-Utility-Proposals.pdf
[72] Navigant Consulting, *supra* note 64. at 209
[73] Eversource, *supra* note 65, at 140
[74] *Id.*at 435
[75] *Id.* at 88
[76] *Id.* at 114

specific benefits within these categories include project revenue, meter maintenance and replacement, conservation, and meter reading.

The plan also identified TVR-related benefits such as peak demand reduction, energy consumption reduction, demand reduction induced price effect in the wholesale market, and avoided investment in T&D infrastructure. In an opt-in TVR approach, Eversource is able to gain 78 percent of the benefits, with just 15 percent of the costs providing for a more cost effective deployment for customers in the service territory.[77]

The benefits of customer education and outreach were not quantified in the analysis, but were considered one of the cornerstones of the grid modernization plan in order to assist customers in managing energy costs and new technologies prior to deploying AMI with TVR. [78] On the other hand, the costs of customer education is included in the annual O&M costs of AMI at $4 million. Customer education included a comprehensive outreach, marketing, and education plan to inform customers about the potential of AMI and TVR.

Eversource considered monetized VVO benefits derived from reductions in end-use energy consumption and line loss reduction based on results from similar efforts in the utility industry. The potential energy savings have a monetary value in the marketplace that can be estimated based on forecasted prices over the 15-year timeline of the analysis.[79] Eversource projects avoided energy consumption will result in annual benefits of roughly $9 million nominal dollars. The table below shows the cost-benefit analysis of VVO done by Navigant Consulting.[80] VVO also accounts for 80 percent of the cost allocation of AMI meters.

Net Present Value (2015 $)- VVO (Millions)	
Benefits	$43.8
Costs	$20.3
NPV	$23.4
B/C Ratio	***2.15***

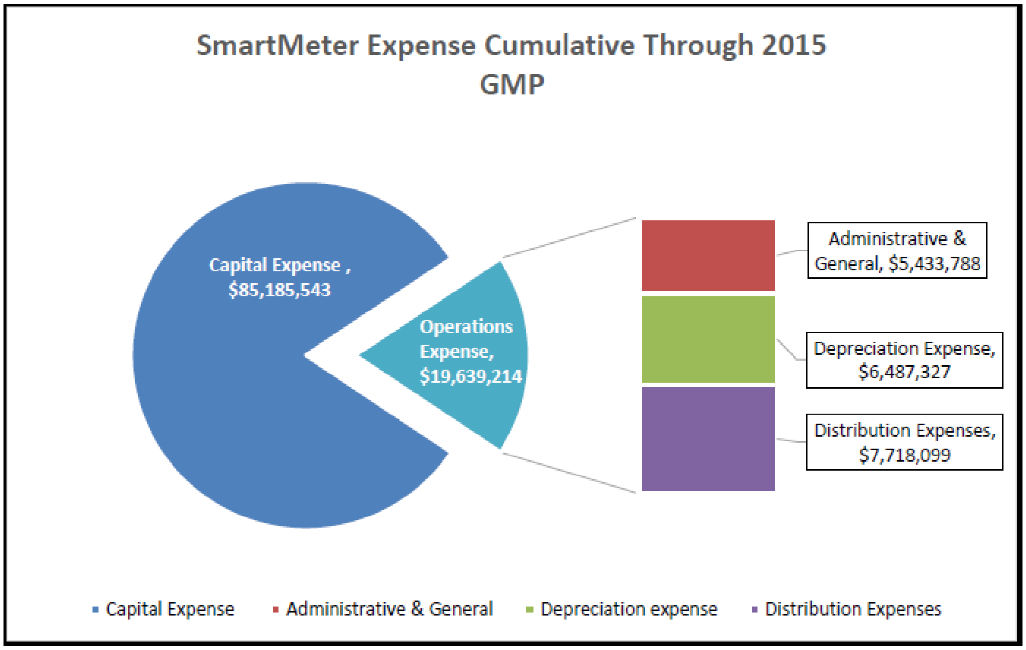
Source: Navigant Consulting

Green Mountain Power

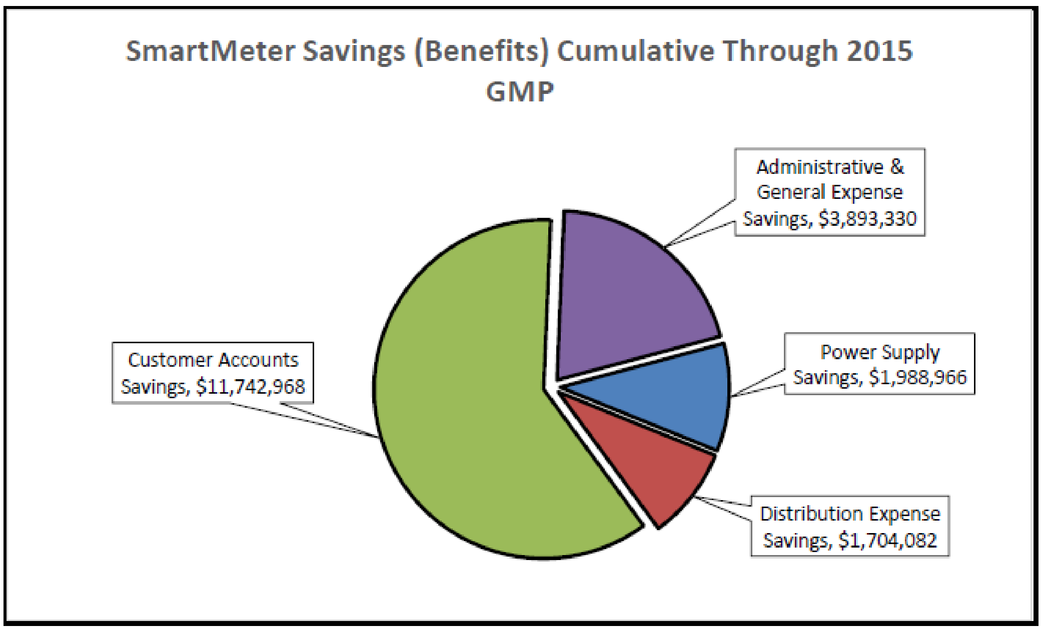
Each utility in Vermont has deployed an AMI system within its service territory and has begun reporting on its costs and benefits. For the utilities combined, AMI capital spending was 83 percent of total AMI spending. This consisted of $107.6 million in capital expenditures for AMI meters which includes AMI meters, spare parts, test equipment, line, and station improvements. Participating utilities spent $21.5 million on operational activities. This accounted for 17 percent of total AMI spending.[81] Green Mountain Power's (GMP) AMI expense through September 30, 2015 is $104.8 million, with benefits reaching $19.3 million thus far. The pie charts below illustrate the costs and benefits Green Mountain Power has experienced through 2015.

---

77 *Id.* at 140
78 *Id* at 122-135
79 *Id.* at 137
80 Navigant Consulting, *supra* note 64, at 228-230
81 Vermont Dept. of Public Service, *Report on Savings Realized Through the Use of Smart Meters Pursuant to 30 V.S.A. § 2811(c)*, (March 8, 2016), Pg. 3, Available at: http://publicservice.vermont.gov/sites/dps/files/documents/Pubs_Plans_Reports/Legislative_Reports/2016%20Report%20on%20Savings%20Realized%20Through%20the%20Use%20of%20Smart%20Meters.pdf



Source: Vermont Department of Public Service



Source: Vermont Department of Public Service

The monetized benefits considered include power supply, administrative, distribution expense reduction, and customer accounts and meter reading. These operational and energy savings are captured through measurement and verification (M&V).[82] There are also societal benefits that are not measured in financial terms, but considered qualitatively. This includes commercial and industrial outage cost reduction, carbon reduction, decreased energy costs, and customer conservation associated with AMI- based web portals.

[82] *Id.* at 9

Green Mountain Power is the largest utility in Vermont and makes up 75.4 percent of AMI deployment between the five utilities, at 260,600 of 345,587 meters. The AMI system has enabled GMP to confirm outages and restorations in a faster manner, as well as offer customers lower rates from cost savings. GMP has an enterprise security program in place that includes protection, detection, change management, verification and vulnerability testing.[83]

Based on call center interactions between customers and customer service representative, GMP believes the investment in AMI has led to improved customer understanding of energy usage. Customers have access to energy usage data at a more granular level.[84] With the deployment of AMI, GMP conducted a consumer behavior study during the fall of 2012 and summer of 2013. The study compared the results of two different electricity-pricing structures: CPP and critical peak rebate (CPR). The project, including over 18,000 customers, resulted in the average CPP customer reducing his or her energy usage by 5.3-15 percent during peak events and the average CPR customer reducing his or her energy usage by 3.8-8.1 percent during peak events. [85]

National Grid MA

National Grid includes the cost and benefits of AMI as a part of its Short Term Investment Plans (STIP) within the grid modernization plan.[86] The costs and benefits are laid out within four different scenarios, as well as by monetized, quantified, and qualitative benefits. Monetized benefits from the STIP stem from avoided wholesale energy and capacity market costs, improved reliability, avoided or deferred O&M costs, reductions in unaccounted for electricity and enhanced revenue. Benefits evaluated in this STIP also include the avoided costs of replacing current technologies with like technologies for those investments that will reach the end of their useful lives within the benefit-cost analysis time horizon. Stranded costs are excluded from the main cost-benefit analysis and business case because they are not going-forward costs. This includes the costs for AMR meters that are not yet fully depreciated and that would be removed from service in order to install AMI meters.[87] In addition, National Grid did not monetize customer benefits, including convenience and satisfaction, but highlights the importance of customer education and outreach to maximize overall benefits. Benefits from avoided T&D capacity investments were also considered on a qualitative basis, which is a benefit that is typically considered on a monetized basis.[88]

National Grid includes the quantified benefit of reduced greenhouse gas (GHG) emissions of about 950,000 tons over 15 years due to anticipated energy reduction associated with customer load management, CVR/VVO, and TVR. The value of those GHG reductions are incorporated into the avoided costs developed by TCR.[89] While National Grid acknowledges that GHG reductions can be monetized by the values forecasted by the Regional Greenhouse Gas Initiative (RGGI), the cost of compliance with the Global Warming Solutions Act cannot be

---

[83] *Id.* at 21
[84] *Id.* at 12
[85] Blumsack, S., Hines, P., *Load Impact Analysis of Green Mountain Power Critical Peak events, 2012 and 2013,* Green Mountain Power Interim report, Green Mountain Power, (March 2015), Pg. 7, Available at: https://www.smartgrid.gov/files/GMP-CBS-Final-20150305.pdf
[86] National Grid, *Grid Modernization Plan*, Docket D.P.U. 15-120, Submitted to: Massachusetts Department of Public Utilities, (August 19, 2015), Pgs. 16-20, Available at: http://web1.env.state.ma.us/DPU/FileRoomAPI/api/Attachments/Get/?path=15-120%2fGrid_Mod_PlanFinalRedacted_Boo.pdf
[87] *Id*. at 124-125
[88] *Id.* at 114
[89] Hornby, R., et al., *Avoided Energy Supply Costs in New England: 2015 Report*, TCR, (March 27, 2015), Available at: http://www.tcr-us.com/uploads/3/9/7/2/3972068/aesc_2015__w_app_rev_2016_03_25.pdf

estimated, and therefore do not include the avoided cost beyond that anticipated by the TCR avoided costs in the monetized analysis.[90] The table below shows the overall costs and benefits of each scenario under the grid modernization plan. These costs and benefits show the ratio under the 15-year analysis period.

National Grid Overall Benefits and Costs in NPV ($ in millions)[91]			
Scenario	Benefits	Costs	Benefit Cost Ratio
Balanced Plan	$956.45	$1,066.49	.9
AMI-Focused Plan	$801.16	$784.27	1.02
Grid-Focused Plan	$463.33	$811.73	.57
Opt-in Focused Plan	$228.78	$408.76	.56

Source: National Grid

National Grid presents different scenarios for its STIP, including a balanced plan, AMI- focused, grid-focused, and opt-in focused. The estimated benefit-cost ratios for each scenario are as follows: 0.9 for the balanced scenario, 1.02 for the AMI-focused scenario, 0.57 for the grid-focused scenario, and 0.56 for the opt-in scenario.[92] Under the balanced plan and the AMI-focused scenario, AMI meters with 100 percent opt-out will be deployed in five years. The grid-focused scenario will deploy AMI meters in 10 years with 30 percent opt-out and 70 percent opt-in. The opt-in scenario will be 100 percent opt-in in full territory in 10 years. The table below shows the AMI meter monetized benefits by scenario.

Present Value of AMI Meter Monetized Benefits by Scenario ($ in millions)				
Monetized Benefit	**Balanced Plan**	**AMI-Focused**	**Grid-Focused**	**Opt-in**
T&D Capital Savings	$17.9	$17.9	$5.6	$.7
Distribution O&M Savings	$110.1	$110.1	$34.6	$2.2
Theft Reduction	$94.6	$94.6	$29.7	$1.9
Total	**$222.6**	**$222.6**	**$69.9**	**$4.8**

Source: National Grid

The cost-benefit analysis includes the implementation of a TVR framework. For the TVR framework, National Grid proposed to use the Smart Energy Pricing option from the Smart Energy Solutions Pilot that offered critical peak pricing or a peak time rebate. The methodology used in this framework is subject to adjustments based on customer experience in the pilot, and changes may result from customer feedback and the ability to reduce costs. The TVR would be offered to residential and small to medium commercial and industrial customers.[93]

---

[90] National Grid, *supra* note 85, at 113
[91] *Id.* at 122
[92] *Id.* at *13*
[93] *Id.* at 108, 209-210

National Grid also plans to deploy VVO within each of the plan scenarios, and provides monetized benefits. Under the balanced plan, grid-focused scenario, and the opt-in scenario, advanced distribution automation (ADA)/VVO will be deployed to 30 percent of customers, with feeder monitors. In these scenarios, VVO is grouped with ADA and feeder monitors. The AMI-focused scenario will set VVO to 10 percent of customers. These benefits can be seen in the table below.

Present Value of Monetized Benefits by Scenario of VVO/ADA, Feeder Monitors ($ in millions)				
Monetized Benefit	**Balanced Plan**	**AMI-Focused**	**Grid-Focused**	**Opt-in**
System Optimization	$68.4	$51.3	$68.4	$68.4
Distribution O&M Savings	$81.6	$53.3	$81.6	$81.6
Theft Reduction	$36	$0	$36	$36
Total	**$186**	**$104.5**	**$186**	**$186**

Source: National Grid

The AMI focused plan STIP costs include $300.35 million in capital expenses and $63.37 million in operation and maintenance expenses. Ninety-eight percent of the capital expenses will be spent during the first five years of the plan, with the remaining two percent during the second five years, whereas 80 percent of operations and maintenance expenses will be spent during the second half. [94] This plan also achieves an estimated 1.02 monetized benefit-cost ratio over 15 years with an estimated 10-year investment of $954 million. Of the four scenarios, this provides the highest monetized benefit-cost ratio, but because this scenario has significantly lower unquantified benefits, it may become difficult for National Grid to effectively maximize system benefits beyond year 10.[95] For example, CVR/VVO will be deployed to 10 percent of customers under this plan, but the utility expects it to be challenging after year ten to expand beyond that. The table below shows the capital expense and the O&M expense for each scenario under the 10-year grid modernization plan.[96]

Capital and O&M Costs by Scenario ($ in millions)[97]				
Scenario	CAPEX/OPEX	Years 1-5	Years 6-10	Total
Balanced Plan	CAPEX	$708.12	$261.11	**$969.23**
	OPEX	$122.36	$223.67	**$346.03**
AMI-Focused Plan	CAPEX	$558.89	$131.46	**$690.35**
	OPEX	$98.29	$165.52	**$263.81**
Grid-Focused Plan	CAPEX	$493.72	$249.02	**$742.74**
	OPEX	$79.39	$171.93	**$251.32**
Opt-in Focused Plan	CAPEX	$182.69	$204.4	**$387.09**

[94] *Id.* at 33-34
[95] *Id.* at 32
[96] *Id.* at 31-36
[97] The costs include: smart meters/AMI back office, customer load management, CVR/VVO, ADA, feeder monitors, telecommunications IT, cyber security, DSCADA/ADMS, training and asset management, and marketing/outreach/education

	OPEX	$52.7	$81.54	**$134.24**

Source: National Grid

Unitil MA

Unitil was an early adopter of AMI, therefore its cost-benefit analysis considerations include upgrades to existing capabilities and limitations. The grid modernization in Massachusetts that requires the utilities to develop business plans including AMI defines the capabilities that should be captured. These include 1) the collection of interval usage data in near real-time; 2) automated outage and restoration notification; 3) two-way communication between customers and the utility; and 4) with customers' permission, communication with and control of appliances. The current AMI meters in place in Unitil's territory have the first two capabilities of AMI.[98]

In the cost-benefit analysis, Unitil divided its benefits into grid benefits and customer benefits. Grid benefits are those that improve the operation of the grid and reduce cost, while customer benefits are those that lower cost for customers on their bills, or reduce the effects of outages.[99] The analysis shows an overall benefit-cost ratio of 1.5, with major net benefits from grid reliability and workforce management improvements, and major net costs from distribution automation.[100] CVR is considered a program metric under distribution automation with separate costs and benefits from the grid reliability program areas that contain AMI. By implementing an advanced distribution management system (ADMS), CVR will be able to reduce customer energy consumption by 2-3 percent and match peak demand reductions. This benefit will accrue directly to customers on their bills, and through utilities as reductions in demand charges.[101]

Prior to its grid modernization proposal, Unitil had already captured most of the traditional benefits of an AMI with a system-wide deployment in 2008 that consisted of 103,000 smart meters, as well as a pilot that included TVR. As a practical means to offer TVR pricing to customers, the company is proposing a project within the STIP that will provide TVR and in tandem AMF capability to customers on an opt-in basis. This would include the full functionality laid out by the grid modernization order. Customers that opt-in to the TVR program will pay for a meter upgrade upon enrollment they will not be added to the rate base. Unitil will also offer an Energy Information Web portal to encourage customer load management by providing a way for customers to better understand and manage their energy usage.[102]

Rollout of this program will begin in 2020 and continue through the rest of the grid modernization plan for a total cost of $2.13 million. By starting an opt-in program in 2020, Unitil will be able to incrementally spend capital on meter replacements. It is a more cost effective approach. The benefits of this program are estimated at $994,000. This will allow Unitil to avoid the $12 million cost of upgrading the current AMI system that will only deliver about $3.3 million in benefits. In addition, this will avoid the stranded costs of replacing the existing meters before they have reached the end of their useful life.

---

[98] Unitil*, Fitchburg Gas and Electric Light Company (d/b/a/Unitil) Grid Modernization Plan*, Docket D.P.U. 12-76 and Docket D.P.U. 14-04, Submitted to: Massachusetts Department of Public Utilities, (August 19, 2015), Pg. 66, Available at: http://web1.env.state.ma.us/DPU/FileRoomAPI/api/Attachments/Get/?path=15-121%2fUnitil_GMP_Report_81915.pdf
[99] *Id*. at 76
[100] Acadia Center, *supra* note 70, at 4
[101] *Id.* at 52
[102] Unitil, *supra* note 97, at 55

As a part of the investment in grid reliability, the proposal suggests integration of AMI with an outage management system (OMS). The benefit of this is that customers will experience shorter outages due to Unitil's ability to locate outages more quickly, and improve the detection of outages. The utility benefit is the reduction of time required to locate and restore outages. The integration of AMI to OMS will cost $59,000 over the 10-year grid modernization plan, with the initial capital expense of $50,000 in 2017, and a recurring $1,000 for the following nine years. There will be a recurring benefit of $117,000 after the initial deployment in 2017.

Conclusion

The level of AMI penetration in the NEEP region is relatively low, but this number is expected to increase as many utilities have recently proposed investing in advanced meters. Maryland and Pennsylvania have the highest percent of AMI, with states such as Vermont and Maine at over 70 percent penetration. Massachusetts and Rhode Island are late adopters of AMI. New York and New Jersey have less than one percent of AMI, but the energy served by AMI is rather high.

AMI enhances the efficiency of the electric grid and improves operations and maintenance. AMI has the potential to optimize the operation of distribution assets though enhanced automation, monitoring, security, and real-time operation. Consumers, utilities, generators, and suppliers may realize many benefits through the implementation of an AMI system. Utilities are tasked with showing that these benefits exceed the costs, particularly the capital costs of the system, to state commissions. The business case for AMI deployment depends on the elements and goals involved in the project given each utility's particular situation. Elements that are taken into consideration include the scale and dimension of the project, such as customers served and deployment timeframe, as well as the technological features. This includes the local characteristics of the grid, the types of technologies that will be deployed with the system, such as smart meters, communication infrastructure, and CVO/VVO.

The various perspectives included in a benefit-cost analysis will have an impact on the outcome because AMI costs and benefits will vary across different stakeholder groups. Some analyses go beyond the benefits and costs to the utility alone, and include benefits to customers, system operators, and society at large. There is no uniform methodology used for determining monetized, quantified, or qualitative benefits, nor do utilities include the same costs. For instance, Con Edison and Baltimore Gas & Electric used the total resource cost test to inform the cost-benefit analysis.

There are common benefits that can be seen between utilities' cost-benefit analyses due to improved functionality of the system. A majority of these benefits accrue to customers, either through electricity cost savings in the value of a kWh, or the value of reducing outage minutes. Customers benefit from more accurate billing, reduction of peak load, cost savings, and reduced outages. Customer gain more granular data access and direct communication of meter readings, which can also be used to achieve energy savings. Many utilities, such as National Grid, are providing an interface for the customer to receive secure delivery of individual consumption data.

Utility operators benefit from remotely reading meters and having the capability to communicate between the metering system and external networks for maintenance and control of the system. This capability will also assist in network planning. In addition, through the implementation of AMI, many utilities included a time-of-use rate structure in the analysis to assist in achieving maximum benefits by incentivizing customers to shift their energy usage to off-peak times. This has a positive impact on both the demand side and the supply side of the electric grid. Moreover, AMI will enable distributed generation, such as renewables, to interconnect with the grid. Utilities are also integrating CVO/VVO into the analysis because this will improve the efficiency of the electric grid and reduce the amount of energy consumed by customers. CVO/VVO is a relatively new concept that is receiving significant attention. National Grid, Eversource, and Con Edison provide a monetized benefit for CVO/VVO.

The costs included in an AMI business case generally fall into three categories: capital expenses, operations and maintenance, and customer engagement. While customer engagement costs are not always included, the clear costs of an AMI system include the capital expense and O&M. Customer engagement costs are often included if the utility plans to implement an extensive customer outreach and education program along with AMI. The purpose of the cost-benefit analysis is to justify the large upfront cost of the system by showing the benefits will exceed the costs over the lifetime of the system. The analyses done by utilities are not always symmetrical because in some instances utilities include the costs, but not all the benefits. The inclusion of stranded costs in the cost-benefit analysis different cases by case, for instance, National Grid does not include them in its analysis, whereas Eversource did. In addition, some utilities will monetize benefits such as GHG emissions reduction by taking the market value of CO_2, while others will not. This creates an overlap in the types of economic and qualitative benefits that can be included in a cost-benefit analysis.

It is essential to use the best-available information to determine the value of benefits that are hard to monetize. Con Edison made the point to clarify in the event of not monetizing a benefit that the utility was not implying the benefit did not have monetary value, nor was it a zero dollar benefit. This clarification is important for the analysis because there are benefits that can be categorized as qualitative or economic benefits. For instance, a benefit that stands out in this case is the cost savings of reducing CO_2 emissions. CO_s can be monetized by the cost per ton of CO_s in the market place, but various utilities elected to cite it as a qualitative benefit.

In Massachusetts, Eversource, National Grid, and Unitil included their AMI cost-benefit business plans as a part of their Short Term Investment Plans (STIP) within their grid modernization plans. Eversource and National Grid both used the monetized, quantitative, and qualitative approach to the cost-benefit analysis. The analysis done by Unitil was different from the others because Unitil was an early adopter of AMI, which made the analysis more about upgrades to the system to ensure the system had full capabilities.

The inclusion of different pricing designs also influences the outcome of the analysis. The utilities in Massachusetts include TVR in their analysis, which impacted the benefit cost ratio depending on the type of TVR program scenario. Eversource provided the cost of an AMI meter by geographic location and whether or not TVR was included. While many utilities are implementing TVR, the Maine PUC did not select a TOU option during the March 2015 bid period, ending the TOU program February 2015. This is significant because TVR can help maximize benefits since the rate structure engages customers and utilities can use this opportunity to educate consumers on ways to save energy and reduce the cost on electric bills. Baltimore Gas & Electric developed an entire customer education and engagement plan, and Massachusetts utilities also explored ways to market to and educate customers. GMP has also experience improved customer understanding of energy usage through call center interaction between customers and customer service representatives.

Customer education often includes community outreach strategies, and education covering the purpose and potential impacts the customer, the system, and environment may experience. This is frequently paired with ways to use the technology and adjust behavior to reduce the cost on customers' bills, such as Home Energy Management Systems. In doing so, utilities are able to realize more benefits. To achieve maximum benefits, technology has to be advanced to become more efficient, but there also has to be social change in the way consumers interact with their energy consumption. By changing the way consumers use and think about energy, and implementing an AMI system, the benefits substantially increase.

The benefits and costs attributed to each grid modernization investment determine the cost-effectiveness of the overall investment portfolio. The utilities account for cost and benefits in monetary terms and include a discussion of the qualitative benefits, but do not consider including the qualitative factors by assigning a weighting factor to combine the quantitative and qualitative analysis. Guidance on approaches to estimate non-energy benefits associated with AMI may improve cost-benefit analysis and could enhance penetration of AMI in the region. Where it is possible, qualitative benefits such as job creation, social acceptance, consumer inclusion, and environmental benefits may be expressed in physical units to provide a more objective basis for the project. In many instances, utilities do include a sensitivity analysis, but to ensure maximum benefits, these externalities should be weighted. The most common methods to compare costs and benefits once they have been estimated is either a cost-benefit ratio, the net present value, or a cumulative comparison that shows how the costs transition into savings as the lifetime of the project goes on.

Where it is possible, qualitative benefits such as job creation, social acceptance, consumer inclusion, and environmental benefits may be expressed in physical units to provide a more objective basis for the project.

As utilities begin upgrading the electric grid to account for distributed generation, aging infrastructure, and increased demand, it is important to capture as many costs and benefits as possible when evaluating AMI. Through this report, NEEP attempts to streamline this process by providing a resource with a regional perspective of the AMI landscape in the Northeast and Mid-Atlantic states. AMI is an essential stepping stone in modernizing the electric grid. Effectively evaluating the costs and benefits of AMI deployment will help ensure these projects meet the goals of energy efficient programs and policies within each state, therefore enabling the growth of smart grids. Shared experience and transparency between utilities will help inform the types of costs and benefits that should be included in an analysis, and moving forward towards a standardized practice.