



4th Annual

Grid Modernization Forum

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Grid Modernization: Policy, Market Trends and Directions Forward

PRESENTED TO

4th Annual Grid Modernization
Forum

PRESENTED BY

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THE **Brattle** GROUP

Background

Several utilities and commissions across the U.S. have made investments into new grid technologies over the past decade

There is now significant experience from grid modernization investments that can be used to develop trends and best practices

We reviewed 21 recent grid modernization investments and conducted 10 case studies to:

- Understand how grid modernization technologies have benefitted customers and utilities
- Document cost recovery mechanisms and business cases related to these investments

Grid Modernization Investments Reviewed in our Study

Grid modernization projects reviewed in our study span efforts in five areas

Grid Modernization Effort	Description
Distribution Infrastructure Hardening and Resiliency	Physical improvement of asset durability to prevent outages/damage or minimize the impact of events and improve the ability to recover
Transmission Infrastructure Hardening and Modernization	Transmission line upgrades, flood mitigation, storm resistance, and enhanced physical and cyber security
Smart Grid and Distribution System Modernization	Advanced grid technologies that enable two-way communication, self-healing, and autonomous restoration
Advanced Metering Infrastructure	Metering and communication infrastructure
Distributed-Energy Resources	Deployment or integration resources such as distributed solar and storage

Our Approach

We screened grid modernization projects from 21 utilities, representing a wide range of relevant utility characteristics, regulatory environment, and grid modernization activities

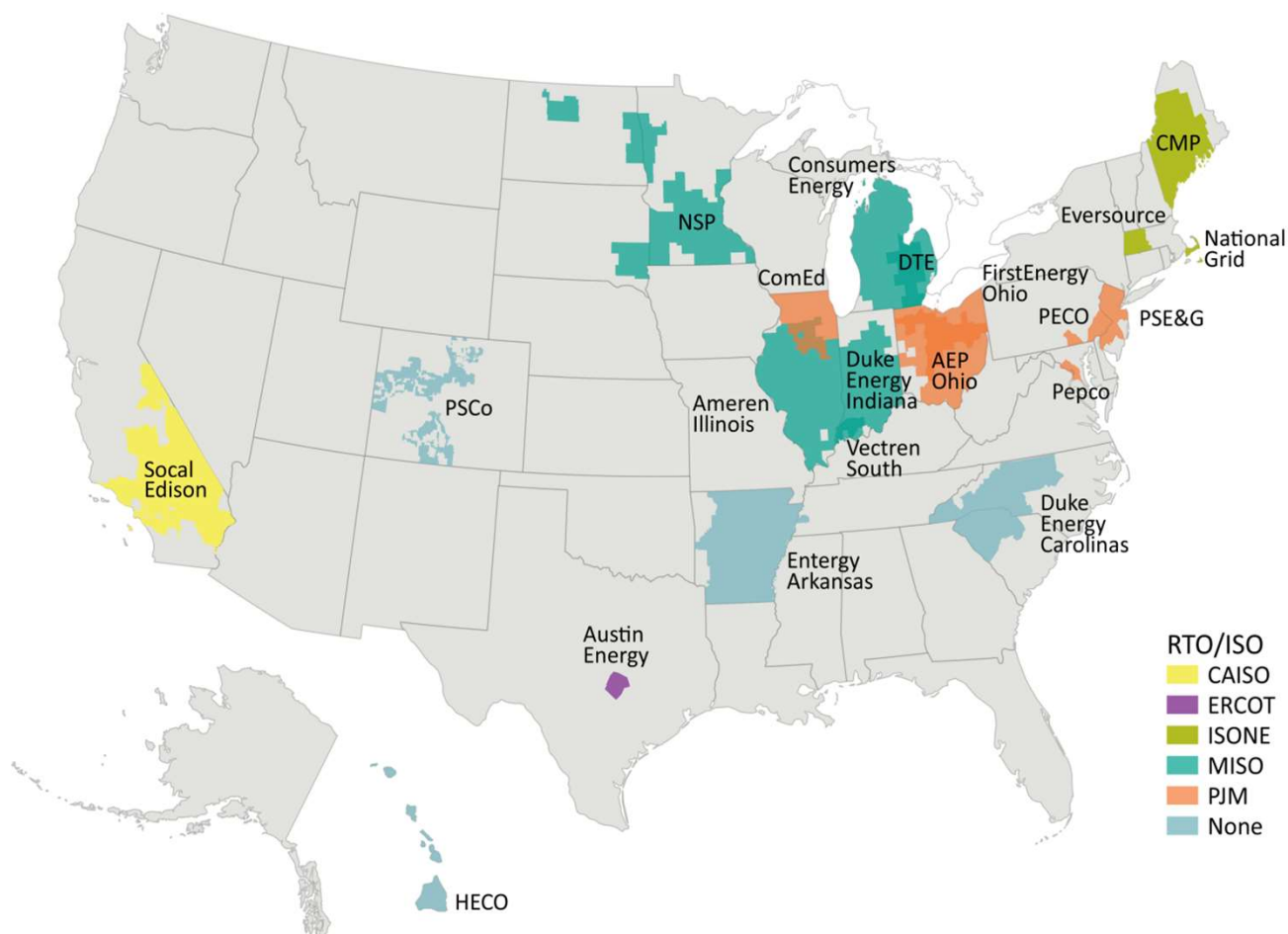
We selected ten of these projects, representing a cross-section of the 21 projects, to be studied in more detail

- The selection of case studies was based on the availability of cost-benefit analyses and obtaining approvals by regulatory commission at the time of the writing of this report

For each case study, we systematically reviewed:

- Nature of the investment/ impetus for the project
- Regulatory process / stakeholder involvement
- Cost-effectiveness methodology used
- Cost recovery mechanism used

Overview of 21 Recent US Grid Modernization Investments



—Utilities of varying ownership structures (i.e., IOUs and municipalities) and sizes are undertaking grid modernization efforts in both regulated and deregulated states

—While most of these efforts cover multiple areas, the most common area is Smart Grid and Distribution Modernization investments

Ten case studies represent a diverse cross-section of initial 21 projects

Case studies were selected based on the diversity of the projects and the transparency of the cost-effectiveness

Utility	Project Reviewed	Case Name
Ameren Illinois	AMI	Ameren AMI
Austin Energy	Storage & DER Optimization	Austin SHINES
Central Maine Power	AMI	CMP AMI
Commonwealth Edison Company	AMI	ComEd AMI
Duke Energy Indiana	Integrated Volt-Var Optimization	DEI IVVO
Entergy Arkansas	AMI	EAI AMI
Hawaiian Electric Companies	Smart Grid, Distribution Modernization, and DER Integration	HECO GMS
Potomac Electric Power Company	Distribution Infrastructure Hardening/Resiliency	Pepco DC PLUG
Public Service Company of Colorado	Integrated Volt-Var Optimization and AMI	PSCo AGIS
Public Service Electric & Gas Company	Distribution and Transmission Infrastructure Hardening/Resiliency	PSE&G Energy Strong

1 - Trends in Impetus for Grid Modernization

Key Findings

- Grid modernization efforts are taking place in many states across the country, each starting with their own priorities
- Most grid modernization efforts were initiated in response to local/ state policy requirements; some were based on utility initiatives
- Many utilities have renewed their “customer engagement strategies” and these rely on capabilities enabled by grid modernization efforts
- Utilities typically combine grid hardening investments with investments that involve the modernization of infrastructure or service delivery

2- Trends in Cost/Benefit Assessment

Common Cost/Benefit Assessment Mechanisms

Test	Perspective	Description
Total Resource Cost Test (TRC)	Utility and Customers	<ul style="list-style-type: none"> Measures overall effectiveness of a project from the perspective of utility and its customers Answers the question of “whether the resource efficiency is improved with this project”
Societal Cost Test (SCT)	Society	<ul style="list-style-type: none"> Determines whether a project represents a good allocation of societal resources irrespective of the distribution of benefits Captures positive and/or negative externalities
Utility Cost Test	Utility	<ul style="list-style-type: none"> Determines whether utility net costs are increasing as a result of undertaking the project
Participant Cost Test	Participants/ direct beneficiaries	<ul style="list-style-type: none"> Determines whether the participants of the project/program achieve net positive benefits
Ratepayer Impact Measure (RIM) Test	Ratepayers	<ul style="list-style-type: none"> Determines whether the rates will increase as a result of undertaking the project Typically used to protect the interests of non-participants
Resource Value Test	Public interest	<ul style="list-style-type: none"> Measures the cost effectiveness of a project from the perspective of the public and has a special emphasis on public policy goals

2- Trends in Cost/Benefit Assessment

Key Findings

Strong cost-benefit analyses emerge as the most important determinants of the success of the efforts and eventual regulatory approval

- Based on our review, projects motivated by legislation or regulatory orders did not necessarily have a much smoother approval processes

In most cases regulatory approvals were based on standardized benefit-cost tests, such as the Total Resource Cost (TRC) test

- New methods such as Resource Value Test is starting to be used to incorporate the emphasis of public policy goals

Some notable examples received approvals based on less standard approaches

- Break-even analysis
- Proof of cost prudence
- Foundational nature of investments advancing other utility initiatives

3- Trends in Cost Recovery Mechanisms

Key findings

The traditional general rate case approach can result in significant regulatory lag and associated uncertainties with the cost recovery of large capital investments

- If not addressed, this can slow down the pace of innovation and grid modernization initiatives
- In addition, the incentives embedded in rate of return regulation may run counter to evolving and important policy goals (such as DER integration)

While the majority of cost recovery still utilizes general rate case filings, a number of cost recovery mechanisms rely on formula rates and trackers to address regulatory lag (i.e., ComEd's Annual Performance Based Formula Rate Plan, Pepco DC's Underground Project Charge)

Some jurisdictions introduced performance-based rates and performance incentive mechanisms, a trend we expect to continue

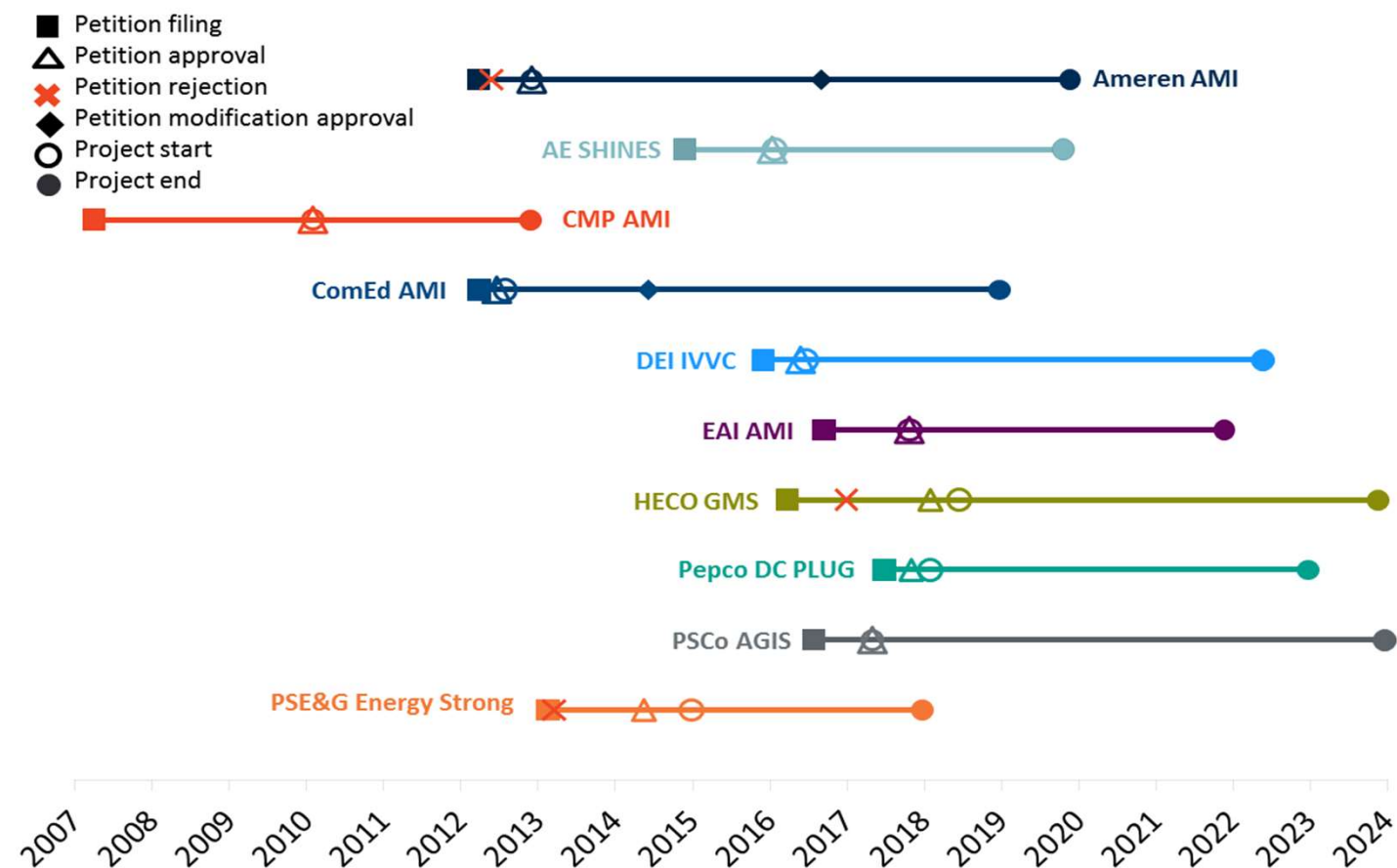
3- Trends in Cost Recovery Mechanisms

Common Cost Recovery Mechanisms

Mechanism	Description
Rate-basing	<ul style="list-style-type: none">• Recovery of the investment cost plus an authorized return over the life of the assets• Subject to regulatory lag, which provides an incentive for utilities to control costs as utilities but may prevent them from achieving timely recovery of new investment
Formula Rates	<ul style="list-style-type: none">• Rates are adjusted to true-up past under- or over-earnings on a forward looking basis• Prevents utilities from under- or over-earning• Application has increased, especially in jurisdictions where large grid modernization efforts are driven by the regulatory bodies
Trackers/Riders	<ul style="list-style-type: none">• Rate mechanisms used for recovering certain operating expenses and capital investments.• Typically designed to address specific areas of expenditure• Typically recovered through adjustments to revenue requirements and rates (outside of a rate case) or through a separate line item on customer bills

4- Trends in Regulatory/Stakeholder Process

Timeline of Reviewed Grid Modernization Efforts



4- Trends in Regulatory/Stakeholder Process

Key Findings

Obtaining regulatory approvals took 13 months on average

Significant delays associated with incomplete benefit-cost analysis and strong stakeholder opposition

Grid modernization projects driven by state initiatives did not necessarily face fewer hurdles in the regulatory process

Projects that faced lengthier times of approval were generally unpopular with stakeholders

Projects that faced initial rejection were typically approved after scaling back costs

Direction Forward

“Utility of the Future” will not be possible with an antiquated grid

More utilities are proposing smart grid and distribution system modernization plans and regulators are more enthusiastic about enabling these proposals

Alternative regulatory mechanisms are key to aligning revenue recovery to utility costs and addressing potential disincentives for engaging in grid modernization activities

Emerging performance incentive mechanisms (PIMs) reward utilities for projects that might lead to earning losses in the SR but lead to overall costs savings and lower rates for customers in the LR (i.e. various DER PIMs in NY)

Customer engagement is an essential component of a successful grid modernization effort

Appendix

Reviewed Utilities Demonstrate Diversity of Characteristics


Utility Name	Ownership Structure		State Regulatory Status*		Utility Functions		Customers
	Investor	Municipal	Regulated	Deregulated	T&D	Generation	
Midwest							
Ameren Illinois	✓			✓	✓		1,200,000
Commonwealth Edison Company	✓			✓	✓		4,000,000
Consumers Energy	✓			✓	✓	✓	1,800,000
DTE Electric Company	✓			✓	✓	✓	2,200,000
Duke Energy Indiana	✓		✓		✓	✓	820,000
FirstEnergy Ohio**	✓			✓	✓	✓	2,000,000
Northern States Power Company	✓		✓		✓	✓	1,500,000
Ohio Power Company	✓			✓	✓	✓	1,500,000
Vectren South	✓		✓		✓	✓	144,000
Northeast							
Central Maine Power	✓			✓	✓		600,000
Eversource Energy	✓			✓	✓		1,400,000
National Grid	✓			✓	✓		1,300,000
PECO Energy Company	✓			✓	✓		1,600,000
Public Service Electric & Gas Company	✓			✓	✓		2,200,000
Southeast							
Duke Energy Carolinas	✓		✓		✓	✓	2,500,000
Entergy Arkansas	✓		✓		✓	✓	700,000
Potomac Electric Power Company	✓			✓	✓		842,000
Austin Energy		✓		✓	✓	✓	448,000
West							
Hawaiian Electric Companies	✓		✓		✓	✓	462,000
Public Service Company of Colorado	✓		✓		✓	✓	1,500,000
Southern California Edison	✓			✓	✓	✓	15,000,000

Reviewed Utilities Engaged in a Variety of Grid Modernization Efforts

Utility Name	Distribution	Smart Grid and	Investment Type	AMI	DERs
	Infrastructure	Distribution	Transmission		
	Hardening/ Resiliency	Modernization	Infrastructure Hardening and Modernization		
Midwest					
Ameren Illinois	✓	✓		✓	
Commonwealth Edison Company	✓	✓		✓	
Consumers Energy	✓	✓	✓		✓
DTE Electric Company	✓	✓		✓	✓
Duke Energy Indiana	✓	✓	✓		
FirstEnergy Ohio	✓		✓		
Northern States Power Company		✓			✓
Ohio Power Company	✓				✓
Vectren South	✓	✓	✓		✓
Northeast					
Central Maine Power		✓		✓	
Eversource Energy		✓			✓
National Grid		✓		✓	✓
PECO Energy Company	✓				✓
Public Service Electric & Gas Company	✓	✓	✓		
Southeast					
Duke Energy Carolinas	✓	✓	✓	✓	✓
Entergy Arkansas				✓	
Potomac Electric Power Company	✓				
Austin Energy		✓		✓	✓
West					
Hawaiian Electric Companies		✓		✓	✓
Public Service Company of Colorado		✓		✓	
Southern California Edison	✓	✓			✓

Ameren Illinois: Advanced Metering Infrastructure (AMI) Plan


Ameren
Investor Owned
Deregulated
Transmission & Distribution



Summary of Costs and Benefits (millions)

	O&M	Capital	Total
Total Costs	\$207	\$313	\$520
Total Direct Operational Benefits	\$570	\$60	\$630
Total Customer/Societal Benefits			\$986
Terminal Value			\$456

AMI Plan (2012-2019)

- Launched in response to Illinois' Energy Infrastructure Modernization Act (EIMA)
 - **AMI**
 - **Other Functionality tied to AMI**
 - Goal of 100% Deployment by 2019
- 

Cost Recovery through Performance-based Formula Rate Tariff

- Demonstrated cost effectiveness through **Total Resource Cost** test
- Determined **Benefit-to-Cost Ratio of 2.7**

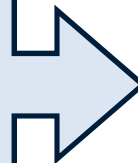
Austin Energy: Austin Sustainable and Holistic Integration of Energy Storage and Solar Photovoltaics (SHINES)

Austin Energy
Municipal
Vertically Integrated



Austin SHINES (2016-2019)

- Launched to support Austin's 2025 climate protection plan
- DOE SHINES program supported renewable energy + storage projects
- **Utility Scale Energy Storage + Solar PV**
- **Commercial Energy Storage + Solar PV**
- **Residential Energy Storage + Solar PV**
- **DER Management Platform**



At Present, No Quantification of Expected Benefits

- Expected benefits realizing Austin's renewable energy goals consistent with the metrics of a **Resource Value Test**
- Will inform how to lower overall LCOE for solar + storage system



Federal, State, and Utility Program Funding


- \$4.3 Million from DOE
- \$1 million from Texas Commission on Environmental Quality
- Austin Energy's Capital Improvements Program

Central Maine Power: Advanced Metering Infrastructure (AMI) Project

CMP
Investor Owned
Deregulated
Transmission & Distribution



AMI Project (2010-2012)

- Launched to support the CMP's Smart Grid Vision
 - Supported by DOE through the American Recovery and Reinvestment Act (2009)
 - **AMI**
 - **Communications Infrastructure**
- 

Cost Recovery through Rate Base and DOE Funding

- Project approved contingent on receiving DOE funding
- Demonstrated cost effectiveness through **Utility Cost Test**
- Initially estimated \$25 million in net operational savings over 20 years.

AMI Project Net Savings (millions)


Component		Costs
Total Costs	[1]	\$163.8
Cost to CMP	[2]	\$81.9
Expected Operational and Avoided Cost Savings	[3]	\$107
Net Savings	[4]	\$25.1

Commonwealth Edison: Advanced Metering Infrastructure (AMI) Plan

ComEd
Investor Owned
Deregulated
Transmission & Distribution



AMI Plan (2012-2019)

- Launched in response to Illinois' Energy Infrastructure Modernization Act (EIMA)
 - **AMI**
 - **AMI Functionality**
 - Goal of 100% Deployment by 2019
- 

Cost Recovery through Performance-based Formula Rate Tariff

- Demonstrated cost effectiveness through **Total Resource Cost** test
- Determined **Benefit-to-Cost Ratio of 2.0**


Summary of Costs and Benefits (millions)

	O&M	Capital	Total
Total Costs	\$999	\$1,116	\$2,115
Operational Benefits	\$1,906	\$2	\$1,908
Additional Benefits			\$2,313
Benefit to Cost Ratio			2.00

Duke Energy Indiana: Integrated Volt-VAR Controls (IVVC) Project

DEI


Investor Owned
Regulated
Vertically Integrated



Summary of Costs and Benefits (millions)

	2016	2017	2018	2019	2020	2021	2022	Total Deployment	Total 20 Year	PVRR 20 Year
Capital Costs	\$0.4	\$4.4	\$8.9	\$12.7	\$16.7	\$19.9	\$22.5	\$85.5	\$395.1	\$183.6
O&M Costs	\$0.4	\$0.7	\$0.9	\$1.0	\$1.2	\$1.3	\$1.4	\$7.0	\$41.6	\$18.9
Total Costs	\$0.8	\$5.1	\$9.8	\$13.7	\$17.9	\$21.2	\$23.9	\$92.5	\$436.7	\$202.5
Total IVVC Benefits	-	-	\$3.9	\$7.0	\$10.6	\$15.1	\$22.3	\$58.9	\$522.4	\$219.1
Net Present Value (NPV)									\$16.6	
Benefit / Cost Ratio (20 yr NPV)									1.08	

IVVC Project (2016-2022)

- Launched under the provisions of Indiana Senate Enrolled Act 560, which provided cost recovery opportunities for infrastructure improvement projects
 - **IVVC** supports efficient operation of distribution system by optimizing voltage levels
- 


Cost Recovery through Rider

- Authorized to recover costs through Transmission, Distribution, and Storage System Improvement Charge
- Demonstrated cost effectiveness through **Societal Cost** test
- Determined **Benefit-to-Cost Ratio of 1.08**

Entergy Arkansas: Advanced Metering Infrastructure (AMI) Plan

EAI

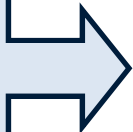
Investor Owned
Regulated
Vertically Integrated



Summary of Costs and Benefits (millions)

	Nominal	Present Value (2016)
Total AMI Lifetime Costs to Customers	\$415	\$270
Total Quantified Operational Benefits	\$270	\$162
Total Other Benefits	\$577	\$340
Net AMI Benefit	\$431	\$232

AMI Plan (2017-2021)

- Launched to support EAI's goal to move beyond traditional grid
 - **AMI**
 - **Communications Infrastructure**
 - **Meter Data Management System**
 - **Outage Management Support**
 - Business case was initially rejected to be approved subsequently
- 

Cost Recovery through Formula Rates

- Authorized to recover costs "formula rate plan rider"
- Demonstrated cost effectiveness through **Total Resource Cost** test
- Estimated **\$232 million** in NPV benefits 15-year lifetime period

Hawaiian Electric Companies: Grid Modernization Strategy

HECO

Investor Owned
Regulated
Vertically Integrated



Summary of Net Benefits (millions)

	2018	2019	2020	2021	2022	2023	Total
Customer-Facing Technology	\$1.3	\$22.5	\$21.0	\$31.9	\$7.7	\$8.6	\$93.0
Sensing and Measurement	\$2.0	\$2.0	\$2.0	\$2.0	\$2.0	\$2.0	\$12.0
Operational Communications	-	\$1.6	\$1.6	\$1.6	\$1.6	\$1.6	\$8.0
Adv. Operational Systems	-	\$17.7	-	\$24.6	\$8.7	-	\$51.0
Distribution Automation	-	\$1.8	\$4.5	\$4.9	\$4.9	\$4.9	\$21.0
Volt-Var Management	\$3.2	\$3.2	\$3.2	\$4.0	\$3.2	\$3.2	\$20.0
Annualized Total	\$6.5	\$48.8	\$32.3	\$69.0	\$28.1	\$20.3	\$205.0
Cumulative Total	\$6.5	\$55.3	\$87.6	\$156.6	\$184.7	\$205.0	\$205.0

GMS (2018-2023)

- HECO saw need to replace aging T&D infrastructure, better engage with smaller power plants and rooftop solar
- Initial Smart Grid plan rejected for lack of cost effectiveness
- Near term investments include **AMI, IVVC, Distribution Automation, Advanced Operational Systems, Sensing & Measurement, Advanced Communications** technologies



Cost Recovery through Rider

- Authorized to recover Phase I of its investments through “Major Project Interim Recovery Mechanism”
- Uses different tests depending on types of investment
- Estimated \$205 in savings from near term strategy

Potomac Electric Power Company: DC PLUG Initiative

Pepco
Investor Owned
Deregulated
Transmission & Distribution

DC PLUG (2018-2023)

- DC's Undergrounding Act requires Pepco and DDOT to file biennial Underground Infrastructure Improvement Projects Plan
- Pepco and DDOT identified 6 least reliable overhead electric distribution feeders for undergrounding over the next 6 years
- Education Plan

Summary of Costs (millions)

Feeder	Number of Customers Served	Estimated Pepco Cost	Estimated DDOT Cost	Estimated Total Cost
308	595	\$10	\$15	\$24
14900	1,371	\$3	\$4	\$7
368	697	\$9	\$10	\$18
14007	1,624	\$14	\$17	\$31
14758	2,165	\$10	\$11	\$22
15009	1,406	\$15	\$17	\$32
Total	7,858	\$62	\$72	\$134

Cost Recovery through Rider

- Authorized to up to \$250 million from authorized costs and charges through an "Underground Project Charge"
- No cost benefit analysis required through Undergrounding Act; must show "cost prudence"

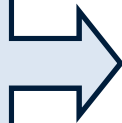
Public Service of Colorado: Advanced Grid Intelligence and Security (AGIS) Initiative

PSCo
Investor Owned
Regulated
Vertically Integrated



AGIS Plan (2017-2024)

- Launched by PSCo in response to customers interested in new energy technologies
- **AMI**
- **IVVO**
- **FAN and IT**



Rate Base Cost Recovery

- Relied on **Modified Total Resource Cost** test
- It was approved due to the foundational nature of investments and various other hard to quantify benefits, although $B/C < 1$

Summary of Benefits to Costs (\$M)

	AMI	IVVO	Total
O&M Savings & Customer Benefits	159	0	159
Avoided Energy and Capacity	241	144	385
Total Benefits	401	144	544
O&M Cost	115	47	162
Change in Cap Revenue Requirement	337	142	479
Total Costs	452	189	641
Benefit to Cost Ratio	0.89	0.76	0.85

Public Service Electric & Gas Company:

Energy Strong

PSE&G

Investor Owned
Deregulated
Transmission & Distribution



Energy Strong (2015-2018)

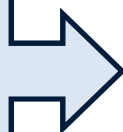
- New Jersey BPU Order for infrastructure hardening in response to major storm events
- Program initially rejected for high expenses
- **Electric Substation Flood Mitigation**
- **Contingency Reconfiguration Strategies**
- **Advanced Technologies**

Estimated Savings from Avoided Interruption

Coincidence Factor	Avoided Customer Minutes of Interruption (M)	Avoided Unserved GWhs	Total Benefit to Customers (M)	Outage Days to Break Even with Program Costs
Aggregate Non-Coincident	2,756	98.5	\$2,870	2.06
33%	1,847	66.0	\$1,923	3.08
50%	1,378	49.3	\$1,435	4.13

Rate Base and Rider Cost Recovery

- Original filing for \$2.7 billion cost recovery
- After initial rejection, PSE&G approved to recover \$600 million from an “Energy Strong Adjustment Mechanism” rider and \$220 million from rate base
- Break-Even Analysis estimated that mitigating 3.08 days of outages would produce a value to customers equal to the present value of PSE&G’s ES investment



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Dr. Sanem Sergici is a Principal in The Brattle Group's Boston, MA office specializing in program design, evaluation, and big data analytics in the areas of energy efficiency, demand response, smart grid and innovative pricing. She regularly supports electric utilities, regulators, law firms, and technology firms in their strategic and regulatory questions related to retail rate design and grid modernization investments.

Dr. Sergici has been at the forefront of the design and impact analysis of innovative retail pricing, enabling technology, and behavior-based energy efficiency pilots and programs in North America. She has led numerous studies in these areas that were instrumental in regulatory approvals of Advanced Metering Infrastructure (AMI) investments and smart rate offerings for electricity customers. She also has significant expertise in development of load forecasting models; ratemaking for electric utilities; and energy litigation. Most recently, in the context of the New York Reforming the Energy Vision (NYREV) Initiative, Dr. Sergici studied the incentives required for and the impacts of incorporating large quantities of Distributed Energy Resources (DERs) including energy efficiency, demand response, and solar PVs in New York.

Dr. Sergici is a frequent presenter on the economic analysis of DERs and regularly publishes in academic and industry journals. She received her Ph.D. in Applied Economics from Northeastern University in the fields of applied econometrics and industrial organization. She received her M.A. in Economics from Northeastern University, and B.S. in Economics from Middle East Technical University (METU), Ankara, Turkey.

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