Reviewing Grid Modernization Investments

SUMMARY OF RECENT METHODS AND PROJECTS

PRESENTED TO

National Electrical Manufacturers Association (NEMA)

PRESENTED BY

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THE Brattle GROUP

Agenda

1. Background & Scope

2. Our Review Approach
   - Grid Modernization Investments
   - Common Cost/Benefit Assessment Mechanisms
   - Common Cost Recovery Mechanisms

3. Key Takeaways from Study

4. Overview of 10 Case Studies

5. Recap

Background and Scope

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

Brattle 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 investments

Grid Modernization Investments Reviewed in our Study

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

Grid Modernization Effort	Description
1) **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

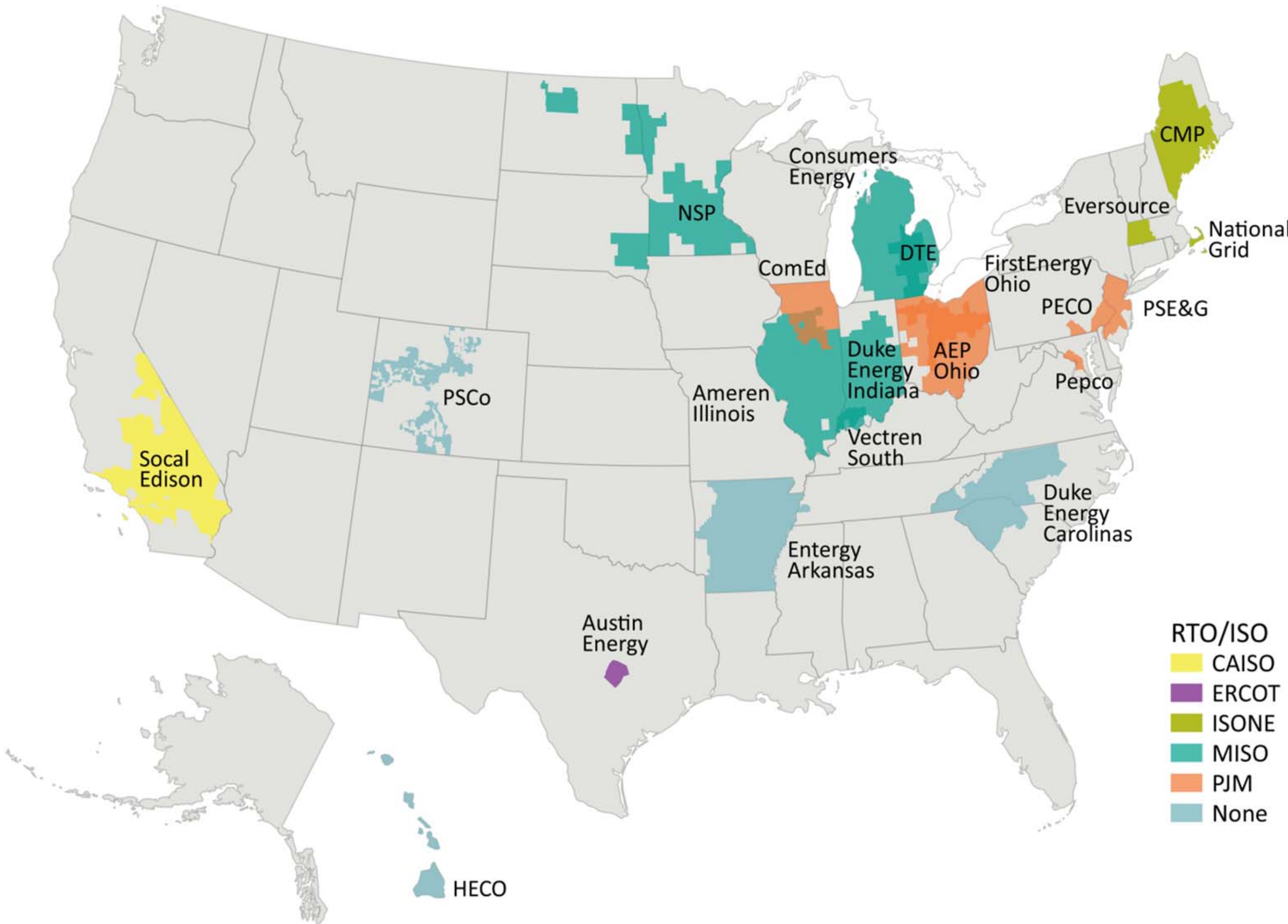
We selected ten of these projects, representing a cross-section of the 21 projects, to be studied in more detail

- 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



Reviewed Utilities Demonstrate Diversity of Characteristics

Utility Name	Ownership Structure		State Regulatory Status*		Utility Functions		Customers
	Investor	Muncipal	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

Utilities of varying ownership structures and sizes are undertaking grid modernization efforts in both regulated and deregulated states

Reviewed Utilities Engaged in a Variety of Grid Modernization Efforts

	Investment Type				
Utility Name	**Distribution Infrastructure Hardening/ Resiliency**	**Smart Grid and Distribution Modernization**	**Transmission Infrastructure Hardening and Modernization**	**AMI**	**DERs**
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	✓	✓			✓

10 Case Studies Represent a Diverse Cross-section of Initial 21 projects

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

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

Cost Effectiveness Assessment

Regulators often require utilities to provide a quantitative cost-effectiveness or Cost/Benefit (C/B) analysis of a proposed grid modernization project to justify cost of investment

Each C/B test uses the same approach in which net present values of benefit and cost streams are compared to each other over the lifetime of the project or investment

- Benefit-to-Cost Ratio > 1 indicates a project is cost-effective

C/B tests differ in perspective, driven by the policy emphasis of a given jurisdiction

- Range from a broad societal view to a narrow, private view of these benefits and costs

Common Cost/Benefit Assessment Mechanisms

Test	Perspective	Description
Total Resource Cost Test (TRC)	Utility and Customers	• 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	• 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	• Determines whether **utility net costs are increasing** as a result of undertaking the project
Participant Cost Test	Participants/ direct beneficiaries	• Determines whether the **participants of the project/program achieve net positive benefits**
Ratepayer Impact Measure (RIM) Test	Ratepayers	• 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	• Measures the cost effectiveness of a project from the **perspective of the public** and has a special emphasis on public policy goals

Common Cost Recovery Mechanisms

The traditional approach of recovering costs of large capital investments involves "rate-basing" of the assets

- This involves recovering the investment cost plus an authorized return over the life of the assets
- Even though cost recovery is certain, timing of recovery may be unpredictable due to regulatory lag

"Formula rates" and "trackers/riders" are designed to deal with regulatory lag

More recently, several states have called for the review and consideration of alternative regulatory models such as performance-based regulation

Common Cost Recovery Mechanisms
(cont'd)

Mechanism	Description
Rate-basing	• 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	• 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	• 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

Key Takeaways

Trends in Impetus for Grid Modernization

- 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

Key Takeaways (cont'd)

Trends in Cost/Benefit Assessment & Cost Recovery

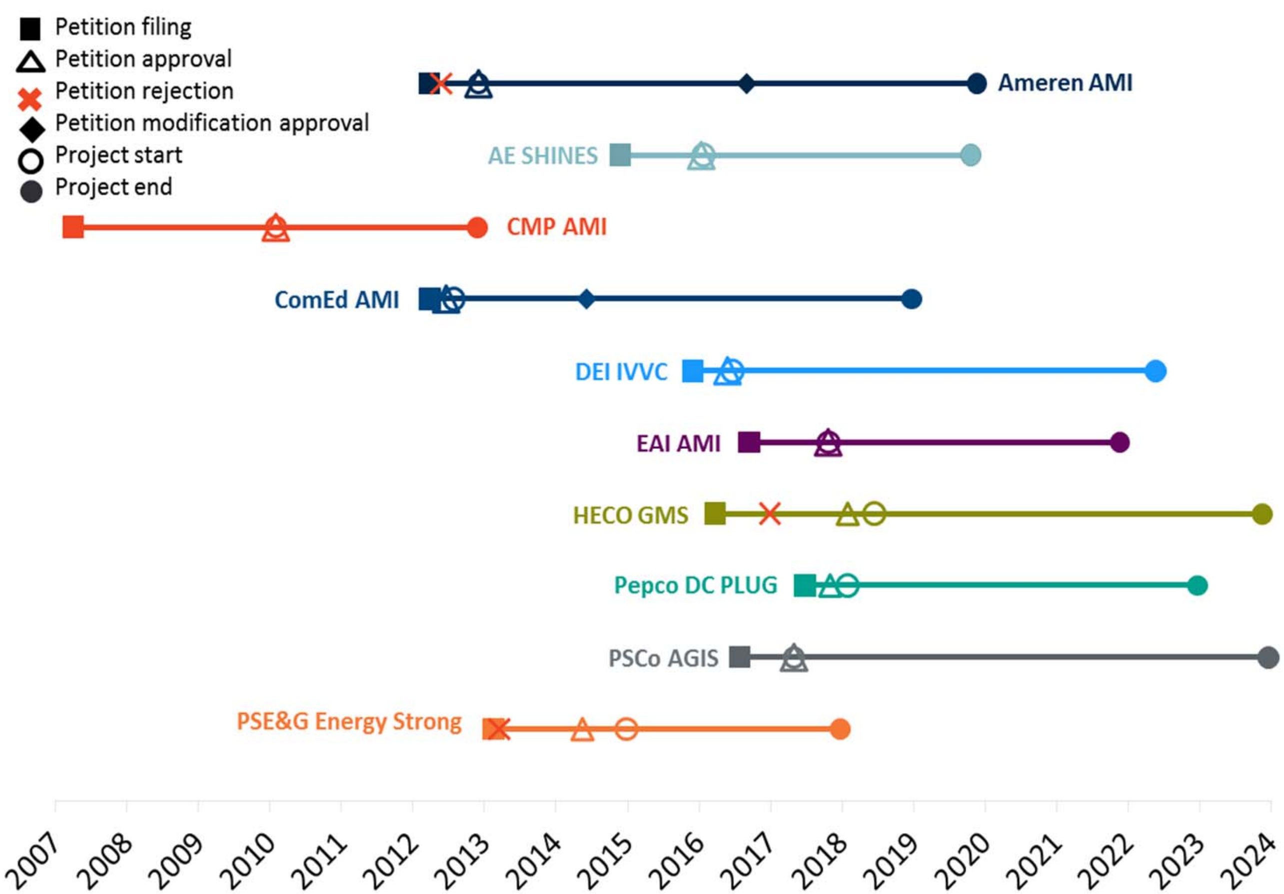
- In most cases regulatory approvals were based on standardized benefit-cost tests, such as the Total Resource Cost (TRC) test
- Some notable examples received approvals based on less standard approaches
  - Break-even analysis
  - Proof of cost prudency
  - Foundational nature of investments advancing other utility initiatives
- The majority of cost recovery utilizes general rate case filings, but a number of cost recovery mechanisms rely on formula rates and rate riders to address regulatory lag
- Some jurisdictions introduced performance-based rates and performance incentive mechanisms, a trend we expect to continue

Key Takeaways (cont'd)

Regulatory Process

- 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 face fewer hurdles in the regulatory process
- General rate case filings the most common, but a number of cost recovery mechanisms rely on formula rates and rate riders to address regulatory lag

Timeline of Reviewed Grid Modernization Efforts



- Projects that faced lengthier times of approval were generally unpopular with stakeholders
- Projects that faced initial rejection were approved after scaling back costs

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**

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

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

Central Maine Power: Advanced Metering Infrastructure (AMI) Project

CMP
Investor Owned
Deregulated
Transmission & Distribution

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**

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.

Commonwealth Edison: Advanced Metering Infrastructure (AMI) Plan

ComEd
Investor Owned
Deregulated
Transmission & Distribution

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**

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**

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 Costs and 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 prudency"

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**

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**

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

Public Service Electric & Gas Company:
Energy Strong

PSE&G
Investor Owned
Deregulated
Transmission & Distribution

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

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**

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

Recap of Key Findings

Driver

- Most grid modernization efforts were initiated in response to local or state policy requirements;
- Some were based on utility initiatives

Regulatory Approval

- Regulatory approvals were mostly based on standardized benefit-cost tests, such as the Total Resource Cost (TRC) test
- Some received approvals based on break-even analysis; proof of cost prudency and foundational nature of investments for other utility initiatives to move forward

Process

- Obtaining regulatory approvals took 13 months on average
- Significant delays were due to incomplete benefit-cost analysis and strong stakeholder oppositions

Cost Recovery

- The majority of utilities go through general rate case filings for cost recovery
- However, there are a number of utilities that rely on formula rates and rate riders to address regulatory lag.
- Some jurisdictions used PBR and performance incentive mechanisms in combination with the cost recovery of grid modernization investments

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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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