The Costs and Benefits of Smart Meters for Residential Customers

IEE Whitepaper
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The Edison Foundation
Institute for Electric Efficiency

Advancing energy-efficiency and demand response among electric utilities.

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Prepared by

Ahmad Faruqui
Doug Mitarotonda

The Brattle Group

Lisa Wood
Adam Cooper

Institute for Electric Efficiency

Judith Schwartz

To the Point

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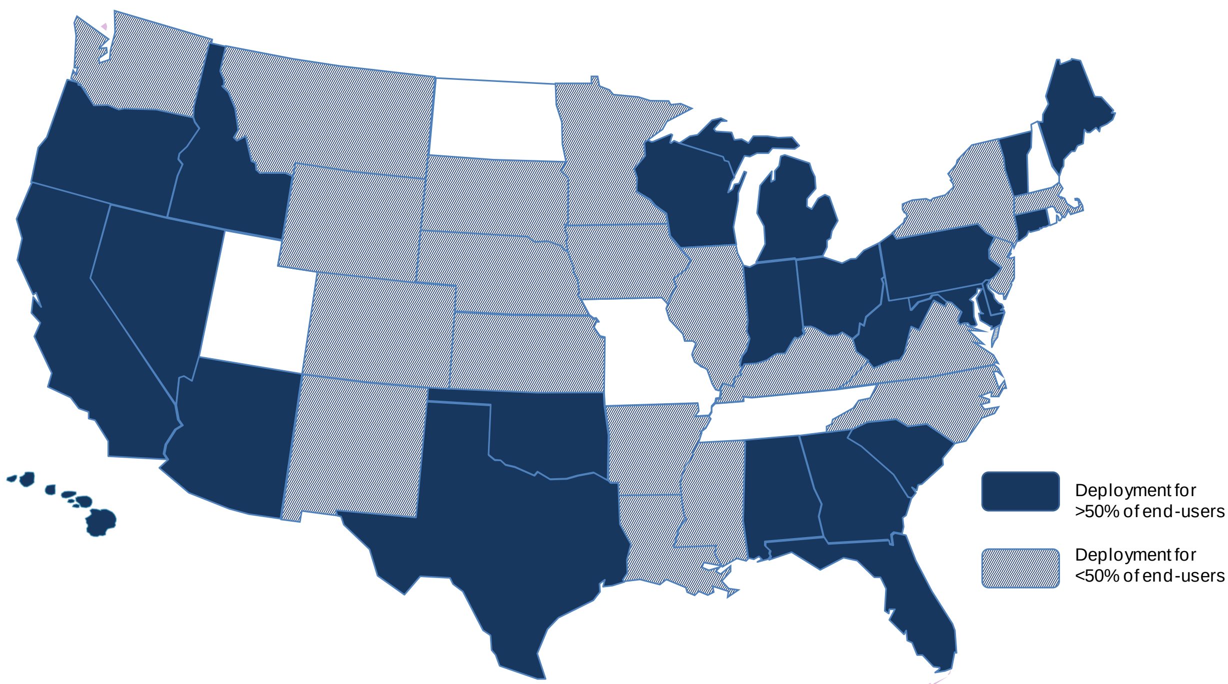
INTRODUCTION

Across the nation, electric utilities are deploying smart meters (technically termed advanced metering infrastructure or AMI) to their residential customers as the basic building block of the Smart Grid. In a few areas of the country, such as California and Texas, smart meters are almost fully deployed. As of June 2011, approximately 20 million smart meters had been deployed in the U.S. and it is likely that the number will rise to approximately 65 million meters by 2015.[1] This would represent approximately 50 percent of all U.S. households. By the end of this decade, smart meters may be deployed to almost all U.S. households. Another noteworthy trend is the growing number of home energy management devices. In a recent report, Greentech Media estimated that approximately 6 million U.S. households will have some type of home energy management device by 2015.[2] This represents about 10 percent of the expected 65 million households with smart meters and, in our view, is a realistic estimate of the size of the home energy management market.

Figure 1: Utility-Scale Smart Meter Deployments, Plans, & Proposals



Source: IEE 2010, www.edisonfoundation.net/IEE

1 Institute for Electric Efficiency, "Utility Scale Smart Meter Deployments, Plans, & Proposals." (September, 2010). www.edisonfoundation.net/IEE

2 Greentech Media report "Smart Grid HAN Strategy Report 2011: Technologies, Market Forecast, and Leading Players," 2011.

Despite this rapid growth in the home energy management space (almost 100 percent growth is expected over the next 3-4 years according to Greentech Media), and the significant energy management opportunity that is unleashed by the combination of smart meters and smart home energy management devices, concerns about the adverse effects of smart meters continue to dominate conversations among regulators, consumer advocates, and electric utilities.

With an eye toward resolving some of these controversies, this paper presents a framework for quantifying the costs and benefits of smart meters from a wide variety of perspectives across a range of electric utility and customer types. It shows how the magnitude of both costs and benefits might vary across different types of electric utilities and different types of customers. In the paper, we allow utility types to vary in terms of their load shapes; supply mix, including renewable energy and other energy sources; cost structures; current metering technology; and customer base. Furthermore, customers vary in terms of the level of their engagement in energy management.

Smart meters provide two-way digital communications between the utility and the customer, thereby enabling:

- customer energy management and demand response via both information and rate programs;
- utility operational advantages such as outage detection and management, remote meter reading, and remote customer (dis)connections;
- smart charging of plug-in electric vehicles; and
- integration of distributed generation resources.

Our main objective is to provide a framework that is general enough to be adapted by individual utilities and regulators in conducting their own analyses. In places, this whitepaper presents the same data in multiple ways to make the concepts behind the analysis more accessible to the range of stakeholders. Our results demonstrate that the benefits of smart meters exceed the costs under a variety of realistic assumptions. This whitepaper does not claim that AMI and the customer programs measured in this paper would be cost-effective for every utility, and results could vary using different assumptions.

For certain types of utilities, engaging customers in smart energy management programs is not necessary from a benefit perspective. Such utilities show positive net benefits whether or not customers engage in energy management programs. However, we believe that even those utilities that can justify investing in smart meters on operational cost savings alone can further enhance benefits to their customers by engaging with them in ways that are discussed in this whitepaper. Only then will the full power of the Smart Grid be unleashed for the greater good of society and for energy sustainability.

In estimating the consumer-driven benefits of smart meters, we took a very conservative approach by assuming fairly low participation rates by customers in different program offerings and in the use of enabling technologies, even after 20 years. We believe that if customers can choose their preferred rate plans, programs, and enabling technologies, adoption rates will be higher. If significant investment is made in customer engagement, this will enable the realization of more extensive financial benefits to individuals, utilities, and society.

KEY ISSUES NOT ADDRESSED IN THIS STUDY

In some areas of the country, utility customers are "opting out" of smart meters, resulting in a loss of operational savings that could have been realized with full deployment. Such losses in savings are borne by all customers in a utility service area. In addition, it is not clear how allowing small numbers of customers to "opt out" of the basic building block of the Smart Grid will impact the nation's ability to transition to a modernized grid. We do not address this issue in this study.

Given the very low penetration of distributed resources at this time, this paper does not integrate or quantify the incremental value and environmental benefits of integration of distributed renewable generation. However, distributed generation would only increase the benefits of smart meters.

STUDY FRAMEWORK

One question that continually arises in discussions of grid modernization is whether investment in smart meters (AMI) makes economic sense from a benefit and cost perspective. This study quantifies three categories of "benefits" from smart meters.

- **Operational benefits** allow the utility to deliver more reliable service, rapid remote (dis)connection, and better outage detection and recovery to its entire customer base at a lower overall cost.
- **Customer benefits** arise from engagement in energy management driven by information and/or price signals, which leads to electricity usage reduction or load shifting and the opportunity to lower bills or mitigate cost increases.
- **Societal benefits** arise from demand response and direct load control, enabling reduction of peak purchases, thereby applying downward pressure on energy prices in spot markets, offsetting the need for new generation and transmission and distribution (T&D) capacity, and potentially lowering carbon emissions through integration of cleaner distributed generation and household usage reductions.

We estimate these benefits for a range of different utility types using four prototypical "examples" at different stages of deployment of the Smart Grid. We define the profiles for the four utility prototypes based on real world factors that influence the overall business case for smart meters, including the current generation mix, the renewable energy portfolio, the regulatory environment, emphasis on efficiency and conservation, and other factors (see Tables 1 and 2).[3] Also, we include a utility prototype that currently has automated meter reading (AMR) and is therefore likely to have lower operational benefits from smart meters.

1. **Pioneer**: A utility that previously invested in AMR with very high energy prices and that purchases all power.
2. **Committed**: A utility with relatively high energy prices, primarily natural gas-fired generation, and a mandate to aggressively pursue renewable generation.
3. **Exploratory**: A utility with relatively low-cost generation available, high population density, and highest demand in winter months.
4. **Cautious**: A utility with low population density, high annual demand growth, and coal, nuclear, and natural gas dominant in its generation portfolio.

[3] The authors thank Cheryl Hindes of BGE and the AEIC Load Research Committee for making real world load shape data available for this study.

Table 1: Profiles of the Four Utility Prototypes

	Pioneer	Committed	Exploratory	Cautious
Current meter	AMR Operational	AMI in process	All analog	All analog
Direct load control	DLC 1.0 (< 1% customers)	DLC 1.0 (< 1% customers)	DLC 1.0 (< 1% customers)	DLC 1.0 (< 1% customers)
Generation profile	T&D only, all generation purchased (nuclear, gas, hydro)	Mix of generation owned by utility and purchased (hydro, gas, nuclear)	Bulk of generation owned by utility (gas, nuclear, coal)	Bulk of generation owned by utility (coal, nuclear, gas)
Regulatory environment	Approved to proceed	Mandates for SG/RPS	Approved to proceed	Conservative
Climate change attitude	Problem	Serious Problem	Problem	Skepticism
Regional climate	Moderate cold-hot	Fairly temperate	Extreme cold-hot	Temperate-hot
Emphasis on efficiency and conservation	High	High	Low	Low

Another factor included in the study is how customers vary in terms of their energy "worldview." Not only do these patterns vary regionally, households are also likely to exhibit variation in their use of in-home energy management devices, their willingness to engage in smart rate programs, the types of vehicles and appliances they purchase, and their overall engagement in the use of electricity.

Based on multiple studies as cited in the *2011 State of the Consumer Report*[4], we assume that consumer adoption patterns will align with their energy worldviews. We developed energy management participation plans to correspond with four dominant customer segments, described below.

1. **Basic**: For consumers who do not wish to engage at all.
2. **Comfort**: For those with large load homes with air conditioning, pool pumps, smart appliances, minimal interest in energy engagement, and limited concern about their bills.
3. **Saver**: For those primarily motivated by the opportunity to save money on their bills or mitigate potential bill increases.
4. **Green**: For those motivated by environmental concerns and willing to be more engaged.

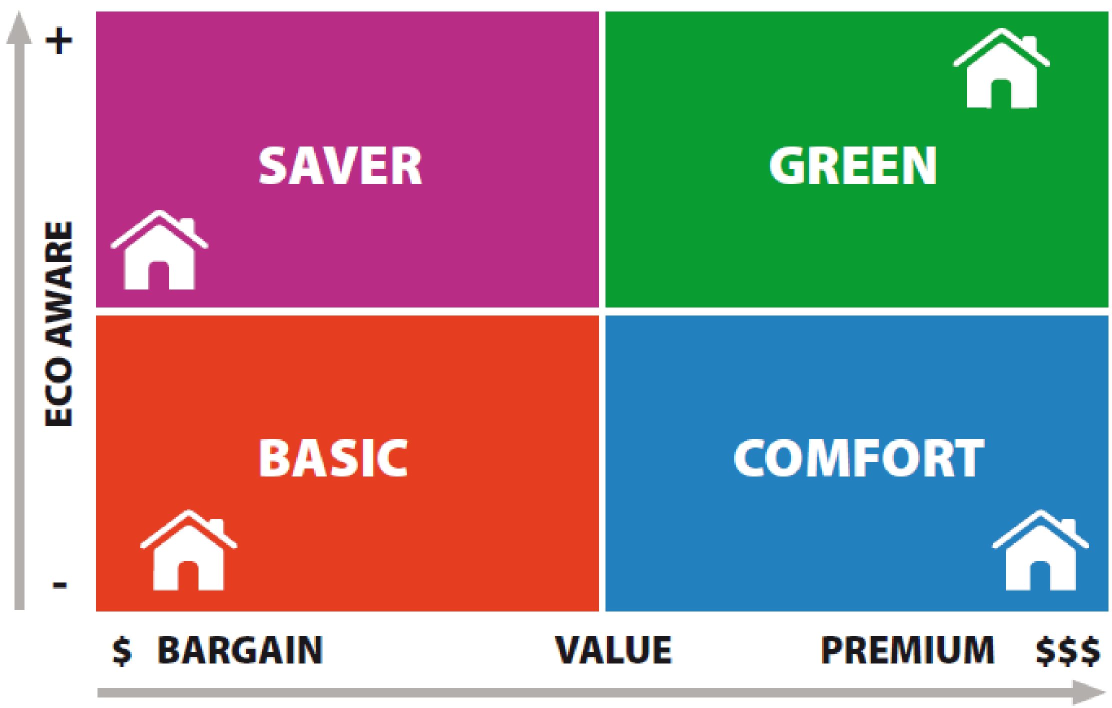
As shown in Figure 2, on the eco-awareness and value axes, the Comfort segment is environmentally and price insensitive when it comes to energy use. The Saver segment is the most bargain-conscious with some degree of eco-awareness. The Green segment has a higher level of eco-awareness and is willing to pay a premium for environmentally friendly energy

[4] *2011 State of the Consumer Report*, Smart Grid Consumer Collaborative (January 31, 2011). http://www.smartgridcc.org

solutions. Finally, the Basic segment is relatively indifferent to environmental concerns and, while wanting low bills, is less willing to take action than the Savers.

Using national studies of current consumer attitudes as a starting point; we assigned specific customer segment mixes to each utility based on the utility profile.

Figure 2: Four Customer Segments with Varying Levels of Eco-Awareness and Value Consciousness



POSITIVE NET BENEFITS USING REAL WORLD DATA

By leveraging real world utility load shapes, varied generation mixes, and capacity, T&D, and AMI installation costs based on composites of actual deployments, the study shows that positive net benefits flow to all ratepayers when utilities adopt AMI as part of their Smart Grid modernization plans.

In the analysis, for all of the prototypical "example" utilities, we assume:

- One million customers within the service area;
- AMI is phased in gradually over a five-year time horizon;

- A web portal for feedback, plus the option to add a simple in-home display, are available to everyone that has AMI installed;
- Every customer with a new AMI meter is defaulted to a no risk, peak time rebate rate offered on 12-15 event days per year;
- Customers will choose one of four plans that include pricing options of no risk (i.e., peak time) rebates (the default for everyone), heat wave (i.e., critical peak) pricing, or time of use for households with electric vehicles;
- Direct load control is available and is measurable and verifiable (in contrast to legacy DLC 1.0 programs, which are not measurable and verifiable today);
- A small percentage of customers have electric vehicles with a time of use rate plan applied on a daily basis for the entire household; and
- Energy management automation may be selected by individual consumers.

We based the cost of devices on actual prices and projections provided by manufacturers and assumed that, over the next 20 years, prices will decline significantly as innovations occur, economies of scale take hold, and manufacturing costs decline. We also recognize that technology innovations not known today are likely to appear in the market.

CONSUMER CHOICE

All customers have access to a web portal with simple energy-use feedback information and all customers receive the operational benefits and the avoided costs of AMI whether they choose to engage in energy management or not.

Customers have access to a variety of technologies such as displays, programmable communicating thermostats, and home energy management systems, as well as smart rate and program options including no risk (i.e., peak time) rebates, heat wave (i.e., critical peak) pricing, time of use rates for electric vehicles, and direct load control. We assume customers will choose their own preferred technologies and program options. The model accounts for the technology cost independent of whether it is paid for by the customer, the utility, or a subsidy.

The technology and program/rate options are:

- **Web portal**: An online site the customer can visit to monitor the aggregated electricity usage for the home on a one-day lag basis;
- **Display**: A visual feedback device or application that lets the customer know whether the price of electricity is expensive, moderate, or cheap in real time;

- **Programmable Communicating Thermostat** (PCT): A programmable thermostat that includes an in-home feedback display plus applications that can monitor and control temperature remotely as set by the customer;

- **Home Energy Management System** (HEMS): A device and application that allows the resident to monitor and control a broad range of electrical devices and appliances within the home;

- **Electric Vehicle** (EV): An electric car and charging system that are purchased by the customer;

- **No Risk Rebates**: Peak time rebates (PTR) are the default rate wherever meters have been installed. A customer that reduces usage during event hours will receive a rebate. Otherwise the consumer remains on their current rate;

- **Heat Wave Pricing**: Critical peak pricing (CPP) is available and the percentage of customers that choose it varies by market segment;

- **Direct Load Control 2.0** (DLC 2.0): Customers who choose DLC have a device provided by the utility or a third party that includes monitoring and verification capabilities. Note: load control equipment in use today generally cannot measure and verify usage during a load control event. Hence, we use the term DLC 2.0 to signify a new generation of load control equipment that measures and verifies the change in usage; and

- **Time of Use** (TOU): Time variable pricing on a daily basis is the default rate for EV owners and applies to the entire residence.

Even within a market segment, we anticipate customers will manage their energy usage in a variety of different ways from passive behaviors to active energy management to investing in more elaborate automation. We assume customers will choose different technologies, programs, and rates depending on their style of energy management.

The five customer engagement pathways quantified in the analysis are:

- **Passive**: Unengaged households that benefit indirectly from operational improvements due to smart meters and incrementally if they coincidentally defer usage on demand response event days;

- **Active**: Engaged households that make conscious and <u>manual</u> adjustments to their electricity use based on energy information and price signals from peak rate plans (either no risk PTR or heat wave CPP) obtained via a web portal, a display, or other communications methods (e.g., email, text, or phone);

- **Set and forget**: Engaged households that use <u>automation</u> to adjust their electricity use via technologies such as programmable communicating thermostats (PCT) or home energy management systems (HEMS) based on energy information and price signals from peak rate plans (either no risk PTR or heat wave CPP);

- **Utility automation**: Households that allow the utility or a third party to directly control their central air conditioning via a signal sent to their smart thermostat or to a switch on their air conditioner. Customers retain the ability to override; and
- **Energy partners**: Highly interested and engaged households that have electric vehicles and home energy management systems to automatically control electricity usage. The time of use rate applies to the entire household on a daily basis, not just on event days.

The model assumes, as illustrated in Figure 3, that customers will choose an engagement pathway that resonates with their worldview but will select different technology and rate options based on whether they have central air conditioning, smart appliances, and home energy management systems, or electric vehicles. Attentive customers without automation will be able to save energy, shift tasks, and realize savings, although those with the ability to automate will likely realize the largest customer-driven savings.

Figure 3: The Four Customer Market Segments Choose Different Engagement Pathways

Customer Engagement

Customer Segments	PASSIVE	ACTIVE	SET & FORGET	UTILITY AUTOMATION	ENERGY PARTNERS
BASIC	●	●			
COMFORT	●	●	●	●	
SAVER		●	●	●	
GREEN		●	●	●	●

As shown in Figure 4, customers choose different technologies, programs, and rates depending on their energy worldview, willingness to take action, purchase of smart appliances, etc.

Figure 4: The Five Customer Engagement Pathways range from "Passive" to "Energy Partners"

	PASSIVE	ACTIVE	SET & FORGET	UTILITY AUTOMATION	ENERGY PARTNERS
BASIC		Display/no display No risk rebate			
COMFORT		Display/no display No risk rebate	Programmable Communicating Thermostat No risk rebate	Direct load control Programmable Communicating Thermostat or Switch No risk rebate	
SAVER		Display/no display No risk rebate	Programmable Communicating Thermostat No risk rebate or Heat wave pricing	Direct load control Programmable Communicating Thermostat or Switch No risk rebate	
GREEN		Display/no display No risk rebate or Heat wave pricing	Programmable Communicating Thermostat Home Energy Management System Heat wave pricing	Direct load control Programmable Communicating Thermostat or Switch No risk rebate	Electric Vehicle Home Energy Management System Time of use rate

METHODOLOGY

The net benefits of smart meters were calculated using *The Brattle Group*'s *iGrid* numerical simulation model. In addition to the operational costs and benefits of smart meters, the *iGrid* model calculates the costs and benefits of smart meters for the four utility prototypes based on customer programs that vary in terms of customer engagement levels and adoption of enabling technologies and smart rates.

We modeled the net benefits of the following:

- The operational benefits to all customers (including passive customers) that are enabled by smart meters, such as outage detection and restoration, rapid remote connects and disconnects, and automated meter reading;
- Customer response to increased information through web portals, with and without a real time information display;
- Customer response to no risk (i.e., peak time) rebates with a varying mix of enabling technologies, including web portals, displays, home energy management systems, and programmable communicating thermostats;
- Customer response to heat wave (i.e., critical peak) pricing with a varying mix of enabling technologies including: web portals; displays; home energy management systems, and programmable communicating thermostats;
- Customers shifting load via direct load control with measurement and verification (DLC 2.0); and
- Customers with electric vehicles (that substitute electricity for gasoline usage), a home energy management system, and a time of use rate in effect.

COSTS AND BENEFITS

The model includes costs, direct smart meter operational benefits, and customer-driven benefits based upon the mix of technologies and rate plans adopted by the consumer. Table 2 shows model input assumptions for the four utility prototypes.

Costs are associated with the AMI installation as well as the purchase of enabling technologies.

- **AMI costs**: Our review of AMI business cases indicates a range of costs, primarily due to differences between AMI vendors, the features of each AMI installation, and the quantity of AMI meters installed. We chose values that fall within these ranges for each of the utility prototypes.

- **Enabling technology costs**: The costs of enabling technologies are based on conversations with industry experts and device vendors.

For the smart meter benefits, we include three operational benefits:

- **Avoided metering costs**: This is broken into fixed and variable avoided costs. In all years smart meters are installed the fixed cost is calculated as the assumed avoided cost times the fraction of fixed avoided metering cost eliminated by smart meters. The variable cost is calculated as the number of smart meters installed times the variable avoided metering costs times the fraction of variable cost eliminated by smart meters;

- **Value of outage avoidance**: This is calculated by first measuring a customer's value of lost load, which is the number of outage hours per year times the cost per kWh of the outage. Second, the total benefit is calculated as the value of lost load times the customer's average annual demand times the fraction of the outages avoided by smart meters; and

- **Remote connection and disconnection of service**: This is calculated as the number of (dis)connections per year times the avoided cost per (dis)connection due to smart meters times the fraction of (dis)connection costs that are avoided due to smart meters. Based on our review of utility business cases, we assume that 20 percent of customers per year require a connection or disconnection of service.

For the customer related benefits, we calculate five benefits:

- **Avoided generation capacity costs**: This is calculated as the change in peak demand times the avoided cost of generation capacity, and then scaled due to system line losses (assumed to be eight percent) and reserve margin (assumed to be 15 percent). The avoided cost of generation is $50 per kW-year and is based on *Brattle*'s previous experience working on this topic;[5]

- **Avoided transmission and distribution capacity costs**: This is calculated as the change in peak demand times the avoided cost of transmission and distribution, and then scaled due to system line losses and reserve margin. The avoided transmission and distribution capacity cost is assumed to be $10 per kW-year and is based on *Brattle*'s previous experience working on this topic;[6]

- **Avoided energy costs**: This is calculated as the change in energy in each time period (off-peak, peak, and critical peak) times the cost of energy in the respective time period, and then scaled due to system line losses. The avoided energy costs vary by region and are based on reviews of energy market data as well as *Brattle*'s prior experience;

- **Avoided carbon dioxide costs**: This is calculated as the change in energy use in each time period (off-peak, peak, and critical peak) times the carbon dioxide emissions rate in the respective time period times the value of each ton of carbon dioxide emissions. The emissions rate for each utility differs based on the assumed fuel mix. Furthermore, the value

[5] Ahmad Faruqui, Ryan Hledik, Sam Newell, and Hannes Pfeifenberger. "The Power of 5 Percent." *The Electricity Journal*. October 2007.

[6] Ibid.

of carbon dioxide emissions is the same for each utility but changes over time with a value of zero until 2016. The value of carbon dioxide emissions is $15 per metric ton in 2017 and increases linearly until 2030 when it reaches a price of $60 per metric ton. This assumes no national carbon legislation will be in place until after the 2016 Presidential election; and

- **Avoided gasoline costs**: This is calculated as the change in gallons of gasoline consumed times the price of gasoline (assumed to be $3 per gallon [2011 dollars], a conservative approximation for the national average gas price). This benefit is only applicable to the customers with electric vehicles. Many conventional vehicle estimates are from a recent EPRI report and electric vehicle assumptions are based on data published by Nissan about the LEAF models.[7]

Table 2: Model Input Assumptions

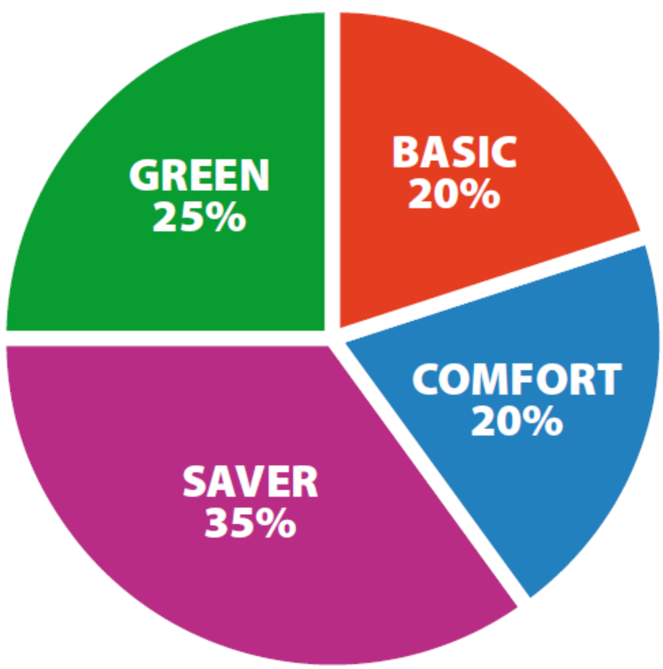
Input	Utility			
	Pioneer	Committed	Exploratory	Cautious
AMI installation cost ($/meter)	150	225	200	250
Avoided meter reading cost ($/meter)	5.00	12.50	10.00	15.00
Cost of generation capacity ($/kW-year)	50	50	50	50
Cost of transmission & distribution capacity ($/kW-year)	10	10	10	10
Energy price: critical peak ($/MWh)	300	240	180	120
Energy price: peak ($/MWh)	90	80	70	60
Energy price: off-peak ($/MWh)	50	40	30	20
Carbon dioxide emissions rate: critical peak (tons/MWh)	0.57	0.57	0.57	0.57
Carbon dioxide emissions rate: peak (tons/MWh)	0.57	0.57	0.57	0.57
Carbon dioxide emissions rate: off-peak (tons/MWh)	0.57	0.57	0.28	1.12
Maximum annual peak demand, per customer (kW) in 2011	2.1	1.8	4.5	3.8
Demand forecast (annual growth rate)	0.6%	0.8%	1.0%	1.2%
Central A/C saturation (% of customers)	15%	40%	71%	80%

[7] Electric Power Research Institute, Natural Resources Defense Council, and Charles Clark Group. "Environmental Assessment of Plug-In Hybrid Electric Vehicles, Volume 1: Nationwide Greenhouse Gas Emissions." July 2007

PIONEER RESULTS:

For the Pioneer utility, we are assuming a region with a strong social norm of frugality (35 percent of consumers are in the Saver segment) and a general belief that climate change is a problem that needs to be addressed (25 percent in the Green segment). Communities here see the connection between a green mindset and economic vitality. The balance of households less interested in action are divided between those who are indifferent to energy (20 percent Basic) and those who are price insensitive but would be willing to invest in technology if it makes their lives easier and better (20 percent Comfort). Figure 5 shows the Pioneer utility customer segment mix.

Figure 5: Pioneer Utility – Customer Mix

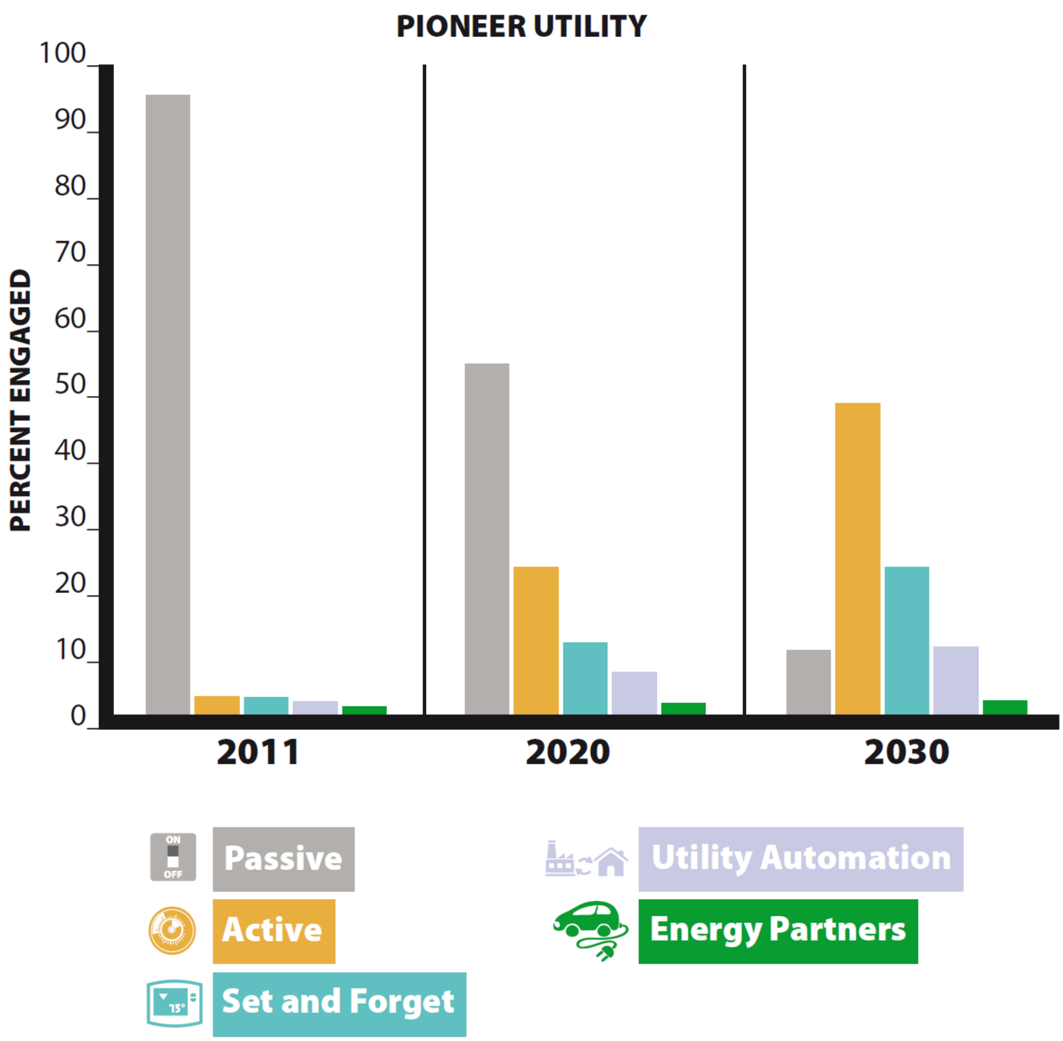


Household characteristics and the path towards energy management are described in Figures 6 and 7. In Figure 6, all four customer market segments begin with minimal engagement in 2011. By 2030, all of the Saver and Green customers are actively engaged. Figure 7 shows the migration of all customers across the five engagement pathways over time; by 2030, most customers have migrated from "passive" to another engagement pathway even among those who are indifferent today. An appropriate analogy is that 50 years ago, most people did not recycle. Today, almost everyone does.

Figure 6: Pioneer Utility – Customer Engagement by Market Segment

Pioneer Utility	Customer Types-2011					Customer Types-2030				
Customer Engagement Pathways	Basic	Comfort	Saver	Green	Total	Basic	Comfort	Saver	Green	Total
Passive	19.70%	19.24%	32.90%	22.88%	94.72%	8.00%	4.00%	0.00%	0.00%	12.00%
Active	0.30%	0.54%	1.40%	0.00%	2.24%	12.00%	11.00%	21.00%	5.00%	49.00%
Set and forget	0.00%	0.02%	0.35%	1.75%	2.12%	0.00%	1.00%	7.00%	16.25%	24.25%
Utility automation	0.00%	0.20%	0.35%	0.25%	0.80%	0.00%	4.00%	7.00%	2.50%	13.50%
Energy partners	0.00%	0.00%	0.00%	0.13%	0.13%	0.00%	0.00%	0.00%	1.25%	1.25%
Total	20%	20%	35%	25%	100%	20%	20%	35%	25%	100%

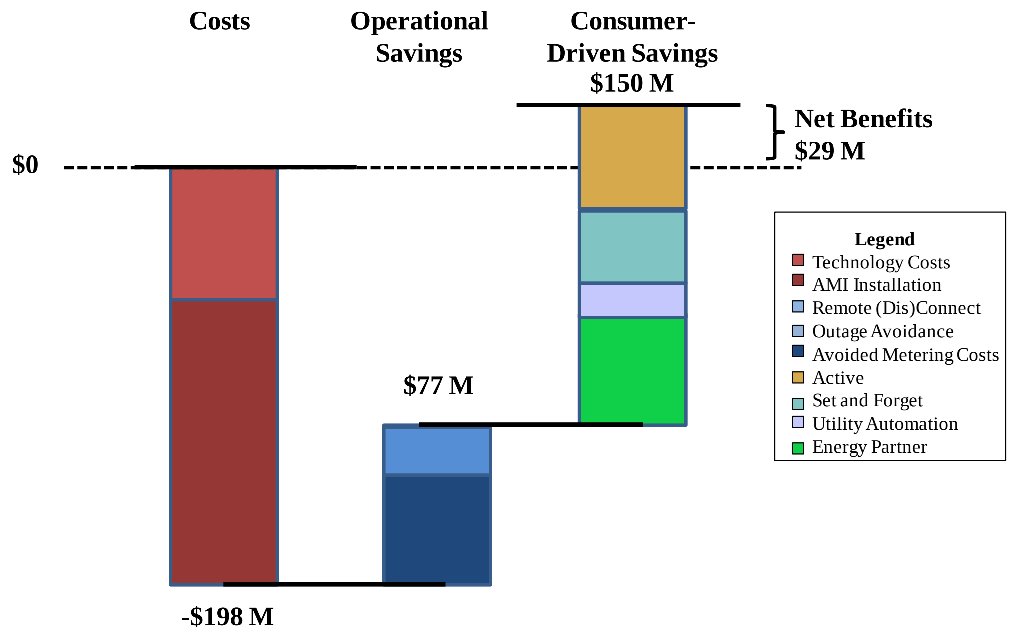
Figure 7: Pioneer Utility – Customer Engagement Pathways over Time (2011-2030)



The Pioneer utility is assumed to have installed AMR prior to the deployment of AMI. For this utility, the total costs associated with meter installation plus any devices/technologies in customer homes are $198 million over the 20 year forecast horizon. The total costs include the costs of meter installation as well as the costs of any devices, equipment, or technologies that customers install (see Figure A-5 in the Appendix for a detailed list of costs and benefits). As shown in Figure 8, the total costs are $198 million and the total operational benefits for this utility are $77 million. The operational benefits are dominated by avoided metering costs ($52 million), followed by improved outage detection and avoidance ($24 million) and remote rapid connections ($1 million).

Due to the customer mix, the regulatory environment, and other factors, this utility has customers that are reasonably engaged (i.e., 60 percent are in the Green or Saver market segments) and high customer benefits totaling $150 million (the largest customer benefits of the four utilities examined). Note the significant contribution of the Energy Partners engagement pathway to consumer-driven savings despite the fact that this pathway includes only 1.25 percent of customers. This demonstrates the large benefit contribution potential of electric vehicles. Total benefits for the Pioneer utility (both operational and customer-driven) are $227 million, indicating a net benefit of approximately $29 million over the 20 year forecast horizon, 2011 to 2030. So, in this case, even with a utility that has already deployed AMR, smart meter deployment still makes economic sense for residential customers.

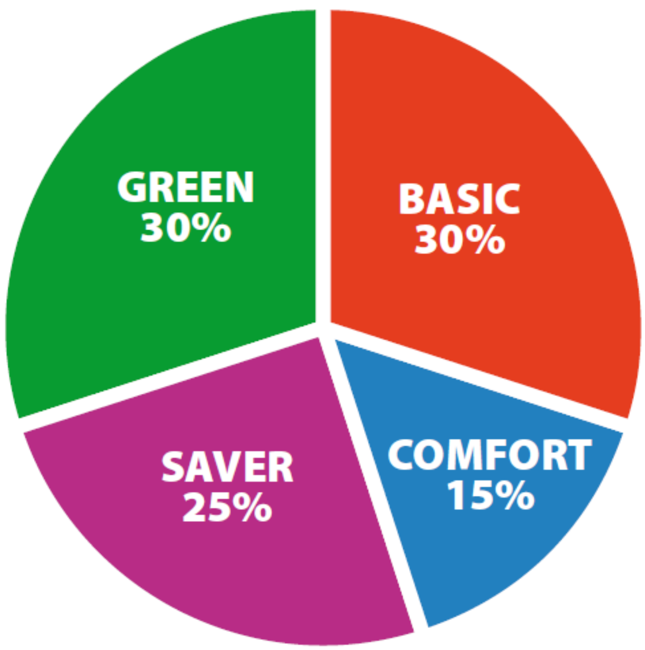
Figure 8: Pioneer Utility – Components of Costs and Benefits



RESULTS: COMMITTED

For the Committed utility, we are assuming a region with relatively high energy prices, a strong social norm of energy awareness, and a widespread belief that climate change is a serious problem that needs to be addressed. Figure 9 shows the Committed utility customer segment mix. The Committed utility services many affluent households willing to invest in green behaviors and technologies (30 percent Green) and a relatively small number of price insensitive customers unconcerned with conserving energy (15 percent Comfort). Savers in this region are likely to be tuned into their energy costs as well as concerned with climate change issues (25 percent). Those customers who are indifferent to environmental issues (30 percent in Basic segment) are likely to become more responsive with financial incentives (see Figure 9).

Figure 9: Committed Utility – Customer Mix

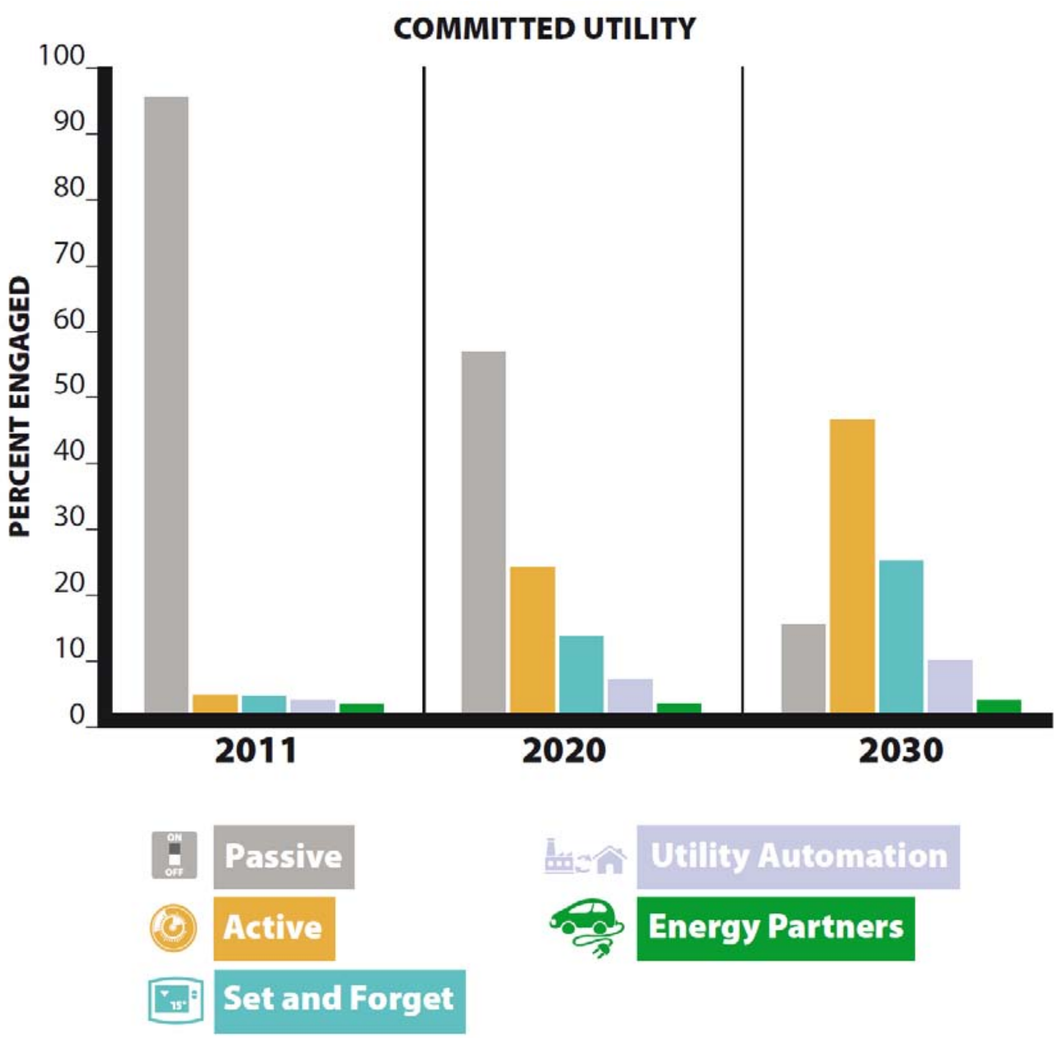


Household characteristics and the path towards energy management are described in Figures 10 and 11. In Figure 10, the four different customer market segments start at different engagement points in 2011. For example, Green and Saver customers are more engaged in energy management than the Comfort customers, while Basic customers are almost totally passive. By 2030, all of the Saver and Green customers are actively engaged in a range of technologies, price signals, and programs. Figure 11 shows the migration of all customers across the five engagement pathways over time; by 2030, most customers have migrated from "passive" to another engagement pathway. For this prototype utility we show very modest penetration of electric vehicles (i.e., 1.5 percent of customers are Energy Partners with EVs), although this type of utility service area is likely to be an epicenter of EV adoption.

Figure 10: Committed Utility – Customer Engagement by Market Segment

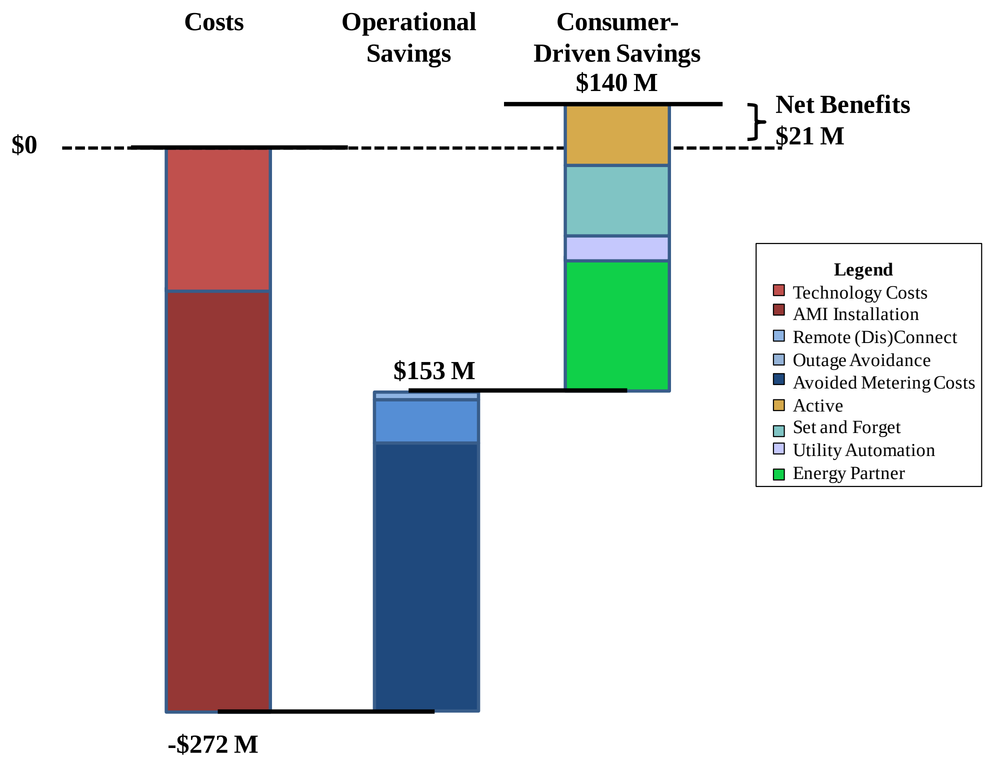
Committed Utility	Customer Types-2011					Customer Types-2030				
Customer Engagement Pathways	Basic	Comfort	Saver	Green	Total	Basic	Comfort	Saver	Green	Total
Passive	29.55%	14.43%	23.50%	27.45%	94.93%	12.00%	3.00%	0.00%	0.00%	15.00%
Active	0.45%	0.41%	1.00%	0.00%	1.86%	18.00%	8.25%	15.00%	6.00%	47.25%
Set and forget	0.00%	0.02%	0.25%	2.10%	2.37%	0.00%	0.75%	5.00%	19.50%	25.25%
Utility automation	0.00%	0.15%	0.25%	0.30%	0.70%	0.00%	3.00%	5.00%	3.00%	11.00%
Energy partners	0.00%	0.00%	0.00%	0.15%	0.15%	0.00%	0.00%	0.00%	1.50%	1.50%
Total	30%	15%	25%	30%	100%	30%	15%	25%	30%	100%

Figure 11: Committed Utility – Customer Engagement Pathways over Time (2011-2030)



For the Committed utility, the total costs associated with meter installation plus devices and technologies in the customers' homes are $272 million over the 20 year forecast. The total costs include the costs of the meter installation as well as the costs of any devices, equipment, or technologies that are installed in the home (see Figure A-6 in the Appendix for a detailed list of costs and benefits). As shown in Figure 12, the total operational benefits stemming from the utility investing in smart meters are $153 million. The operational benefits are dominated by avoided metering costs ($128 million), followed by improved outage detection and avoidance ($21 million) and remote rapid connections ($4 million).

Figure 12: Committed Utility – Components of Costs and Benefits

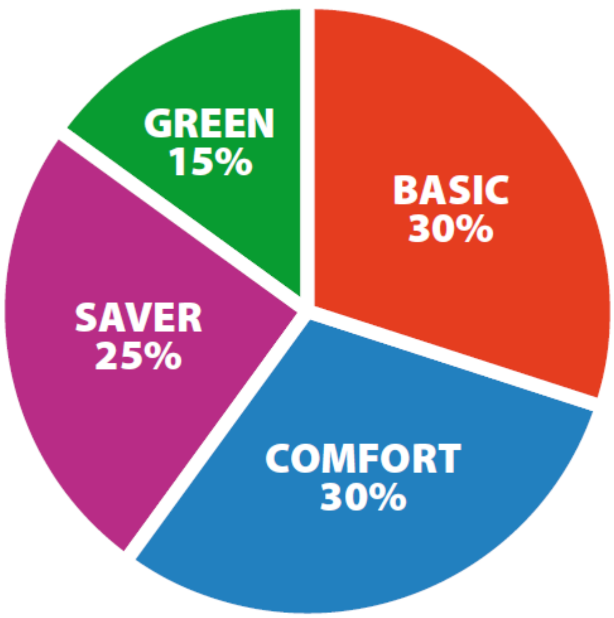


Over a 20 year period (2011-2030), customers migrate towards technology offerings and rate plans that fit their lifestyles and budgets, leading to customer-driven savings totaling $140 million. The consumer-driven savings are dominated by the Energy Partners pathway, demonstrating again the huge benefits contribution of EVs. Total benefits for the Committed utility (both operational and customer-driven) are $293 million, indicating a net benefit of approximately $21 million over the 20 year forecast horizon.

RESULTS: EXPLORATORY

Figure 13 shows the Exploratory utility customer segment mix. For the Exploratory utility, we are assuming a customer base that supports energy use management due to a desire to save money (25 percent Saver) and a concern about energy independence (15 percent Green). The balance of households less interested in action hold a slight majority, and they are divided between those who are indifferent (30 percent Basic) and those who are price insensitive though willing to invest in technology if it makes their lives easier and better (30 percent Comfort).

Figure 13: Exploratory Utility – Customer Mix

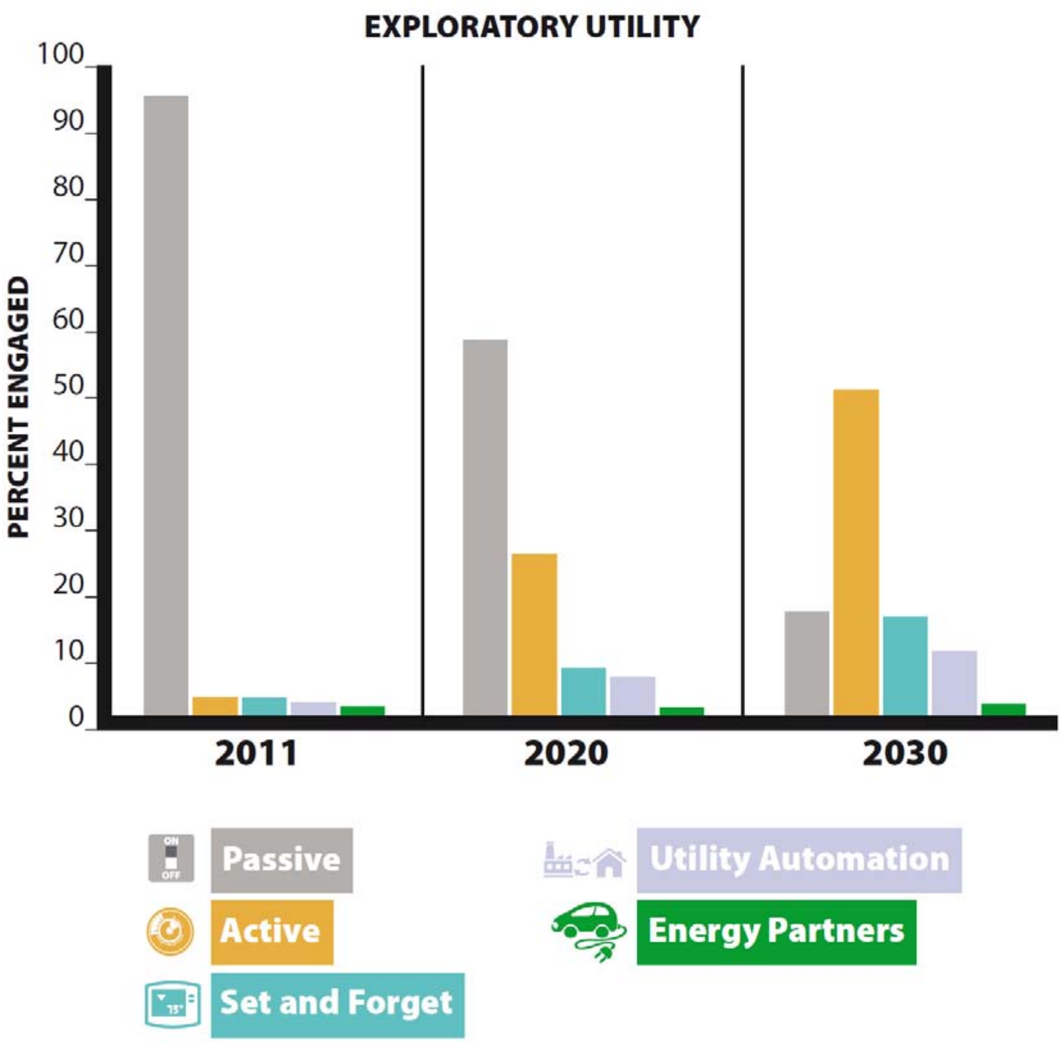


Household characteristics and the path towards energy management are described in Figures 14 and 15. In Figure 14, the four different customer market segments start at different engagement points in 2011. As in the other segments, initially very few customers are actively engaged in energy management. By 2030, all of the Saver and Green customers are either actively engaged or using automation. Figure 15 shows the migration of all customers across the five engagement pathways over time; by 2030, most customers have migrated from “passive” to another engagement pathway.

Figure 14: Exploratory Utility – Customer Engagement by Market Segment

Exploratory Utility	Customer Types-2011					Customer Types-2030				
Customer Engagement Pathways	**Basic**	**Comfort**	**Saver**	**Green**	**Total**	**Basic**	**Comfort**	**Saver**	**Green**	**Total**
Passive	29.55%	28.86%	23.50%	13.73%	95.64%	12.00%	6.00%	0.00%	0.00%	18.00%
Active	0.45%	0.81%	1.00%	0.00%	2.26%	18.00%	16.50%	15.00%	3.00%	52.50%
Set and forget	0.00%	0.03%	0.25%	1.05%	1.33%	0.00%	1.50%	5.00%	9.75%	16.25%
Utility automation	0.00%	0.30%	0.25%	0.15%	0.70%	0.00%	6.00%	5.00%	1.50%	12.50%
Energy partners	0.00%	0.00%	0.00%	0.08%	0.08%	0.00%	0.00%	0.00%	0.75%	0.75%
Total	30%	30%	25%	15%	100%	30%	30%	25%	15%	100%

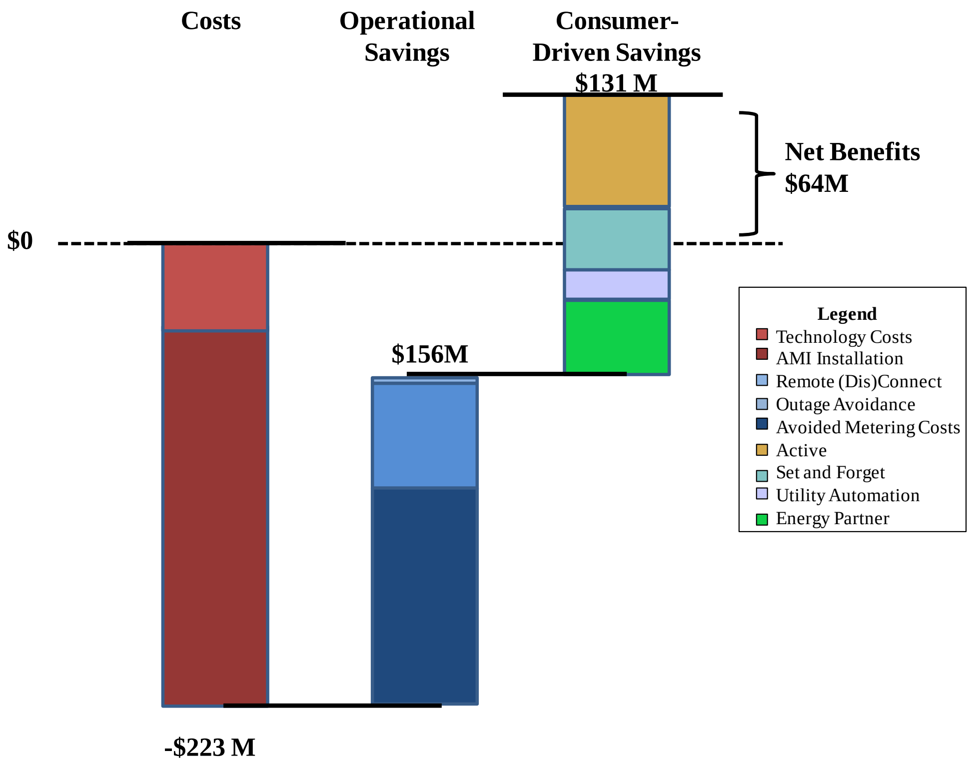
Figure 15: Exploratory Utility – Customer Engagement Pathways over Time (2011-2030)



For the Exploratory utility, the total costs associated with meter installation plus any devices or technologies in customer's homes are $223 million over the 20 year forecast horizon. The total costs include the costs of the meter installation as well as the costs of any devices, equipment, or technologies that are installed in the home (see Figure A-7 in the Appendix for a detailed list of costs and benefits). As shown in Figure 16, the total operational benefits stemming from the utility investing in smart meters are $156 million, which are dominated by avoided metering costs ($103 million), followed by improved outage detection and avoidance ($50 million) and remote rapid connections ($3 million).

Over a 20 year period (2011-2030), customers migrate towards technology offerings and rate plans that fit their lifestyles and budgets leading to customer-driven savings totaling $131 million, dominated by the Active engagement pathway. Total benefits for the Exploratory utility (both operational and customer-driven) are $287 million, indicating a net benefit of approximately $64 million over the 20 year horizon (2011-2030); this profile enjoys the largest net benefit of the four utility prototypes because their operational savings are relatively high relative to costs and their customer engagement is moderate. For the two utility prototypes with higher customer-driven savings (i.e., the Pioneer and Committed utilities), either the costs of installing and operating AMI are much higher (e.g., the Committed utility) or the associated operational savings are much lower (e.g., the Pioneer utility).

Figure 16: Exploratory Utility – Components of Costs and Benefits



For more information contact:
Institute for Electric Efficiency
701 Pennsylvania Avenue, N.W.
Washington, D.C. 20004-2696
1.202.508.5440
www.edisonfoundation.net/iee

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