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ABSTRACT

Buildings account for more than 70% of U.S. electricity use and at least one-third of U.S. economy-wide CO_2 emissions. Changing the timing and overall amount of electricity consumption in buildings would significantly reduce energy costs to consumers and facilitate the transition to a decarbonized economy. Grid-interactive efficient buildings (GEBs) incorporate energy efficiency, smart technologies, and active use of distributed energy resources (DERs) to provide these benefits. As the link between the customer and the power system, utilities are central to widespread deployment of GEBs. Yet, despite the significant cost savings and operational benefits of GEBs for utilities, deployment has remained limited.

This paper explores emerging models for enabling utilities to facilitate GEB adoption. Building off foundational research conducted to develop the U.S. DOE's *A National Roadmap for Grid-Interactive Efficient Buildings*, we describe the most novel recent examples of ways in which utilities and regulators have made demand-side innovation a win for both the customer and the utility. Emerging concepts include: (1) performance incentive mechanisms to align GEB deployment with utility financial motivations, (2) the use of subscription pricing (i.e., fixed monthly bills) to promote load flexibility and energy efficiency, (3) rate-basing utility-controlled behind-the-meter assets, and (4) coupling energy efficiency and load flexibility with electrification proposals to ensure that customer benefits are maximized. The paper concludes with a discussion about prospects for widespread GEB deployment and utilization by utilities, and how to scale efforts.

Introduction

The power system is experiencing rapid transformation of electricity generation and consumption. Renewable energy, particularly wind and solar, accounted for about 20% of total US electricity generation in 2020 and more than either coal or nuclear generation sources (EIA, 2022a). Future projections of the US power system suggest that 80% of electricity demand in 2050 could be reliably served by renewable energy (NREL, 2012). On the electricity demand-side, electric vehicle (EV) sales have accelerated in recent years with plug-in EVs representing more than five percent of US light-duty vehicle sales in January, 2021 and more than 2.4 million plug-in vehicles sold in the US since 2010 (ANL, 2022). And, despite significant efficiency gains in certain end-uses (e.g., lighting), electricity is the fastest-growing source of energy in the US building sector as cooling demand and the proliferation of personal computing, smartphone, and commercial IT technologies increases (EIA, 2022b). Importantly, many states and electric utilities have established goals to reduce, or sometimes eliminate, electricity sector CO_2 emissions.

Buildings account for over 70% of all U.S. electricity consumption (EIA, 2019) and at least one-third of U.S. economy-wide emissions (Langevin et al., 2019). Reducing building consumption through improved efficiency and changing the timing of electricity use through demand flexibility (DF) strategies is an important opportunity to facilitate power system transformation (Frick and Schwartz, 2019). Additionally, consumer adoption of new energy technologies will introduce opportunities for improving the efficiency and flexibility of electricity consumption while better serving the needs of building owners and occupants, as well as benefiting the broader distribution system.

Grid-interactive efficient buildings (GEBs) are energy efficient buildings with smart technologies characterized by the active use of DERs to optimize energy use for grid services, occupant needs and preferences, climate mitigation, and cost reductions in a continuous and integrated way (US DOE, 2019).[1] Broad adoption of residential and commercial energy efficiency (EE) and DF measures could avoid 742 TWh of annual US electricity consumption and 181 GW of US summer peak demand by 2030 (Langevin et al., 2021). Additionally, GEBs could deliver $100-$200 billion in cumulative power system benefits by 2040 through avoided generation capacity costs, reduced energy costs, ancillary services, and avoided transmission capacity costs (US DOE, 2021). Furthermore, GEBs can provide significant environmental benefits and reduce about 6% of total annual power sector emissions by 2030 (US DOE, 2021). From the perspective of electricity customers, GEB power system benefits reduce system costs, in addition to lower electricity consumption, that can result in customer bill savings. GEBs also benefit customers through improved power system reliability, building comfort, and increased choice and capabilities in managing electricity consumption through advanced building technologies.

As the link between the customer and the power system, utilities are central to widespread deployment of GEBs. Yet, despite the significant cost savings and operational benefits of GEBs for utilities, deployment and utilization of this grid resource has remained limited due to several barriers. For example, investor-owned utilities lack a financial incentive to invest in and/or drive adoption of EE and DF resources because they may erode revenue between rate cases under current rate designs and reduce future earnings opportunities by avoiding new grid infrastructure investments (Satchwell et al., 2011). Utilities may also perceive EE and DF performance limitations compared to the resources that utilities and system operators have traditionally relied upon. EE and DF are also not typically considered in utility planning activities (e.g., integrated resource planning), because of data, modeling, policy, or other constraints (Frick et al., 2021). Furthermore, customer financial incentives, which are a primary motivation for GEB technology adoption, may be insufficient or lacking (US DOE, 2021). Also, the compartmentalized structure of utility management can result in lack of coordination between staff responsible for demand-side initiatives and those responsible for grid operations.

This paper explores emerging models for enabling utilities to facilitate GEB adoption. We describe the most novel and recent examples of ways in which utilities and regulators have made demand-side innovation a win for both the customer and the utility through increased GEB deployment and achieving the significant power sector cost and emissions benefits described earlier. While not an exhaustive review of all programs or policy/regulatory initiatives currently offered in pilot or full-scale deployment, we particularly identify GEB-specific examples with EE *and* DF components (including a handful of examples of GEBs integrated with DERs). We focus on utility programs for residential and commercial building sectors where there are key deployment challenges due to high transaction costs and borderline customer economics. Finally,

[1] See US DOE (2019) and US DOE (2021) for more details on the technologies, controls, and communications that may be deployed in buildings for grid interactivity.

we focus our examples where there are opportunities for both utilities and customers, though the extent to which *all* customers and utilities are better off depends on overcoming certain implementation challenges (e.g., regulatory oversight). The remainder of the paper presents emerging models in three areas: utility business models, pricing, utility infrastructure investments. The paper concludes with a discussion about key challenges and opportunities for widespread GEB deployment.

Utility Business Models

Investor-owned utilities have a financial incentive under rate-of-return regulation to maximize earnings opportunities through new capital investments. Additionally, current rate designs that emphasize revenue collection via volumetric electricity sales discourage utility deployment of EE and other behind-the-meter DERs due to the risk of under-collecting fixed, or non-production, costs (Moskovitz, 2000). DF is a key feature of GEBs and may also produce financial impacts to utility shareholders. Concerns about reduced revenue collection from DF are somewhat less than EE because DF doesn't necessarily suggest lower total consumption (and DF may *increase* consumption through electrified end-uses); but, reductions in utility costs through improved system load factor reduces future utility earnings opportunities (e.g., deferred or avoided generation and transmission capital investments). Additionally, EE and DF investments may be an earnings opportunity for the utility under certain ownership models, but are much smaller scale (e.g., on the order of tens of millions of dollars) compared to much larger investments in grid infrastructure (e.g., on the order of hundreds of millions of dollars) (Kihm et al., 2016).

Alternative utility regulatory and business models can provide greater alignment between utility financial motivations and successful GEB deployment. Several successful alternative utility regulatory and business models have been implemented for EE, including targeted utility financial incentives (e.g., performance incentives, shared net benefits) and revenue decoupling. Key strategies to better align corporate and shareholder objectives with GEB deployment (thereby unlocking the value of GEBs to customers) can build on the success of EE utility business models, as well as exploit broader trends in utility regulatory and business models.

Utility financial performance incentives

Performance-based ratemaking (PBR) is a form of incentive regulation intended to more directly tie utility revenues to performance (Satchwell and Cappers, 2015). PBR has been implemented to varying degrees of "comprehensiveness" in many states and typically includes multi-year rate plans and/or performance incentive mechanisms (PIMs). PIMs can target improvements and outcomes in specific areas by tying financial earnings to specific goals and can benefit customers by mitigating the utility bias away from capital investments towards delivering more GEB program opportunities. PIMs also benefit utilities with new earnings opportunities and improved relationships with regulators and customers (Lowry and Woolf, 2016).

While PIMs have been used to encourage utilities to successfully administer EE programs, they can also be an effective tool for DF. For example, National Grid in Rhode Island has a PIM for "system efficiency" that is measured by annual capacity savings from residential, commercial, and industrial demand response (DR) programs (including a residential battery storage program). The utility's 2020 system efficiency goal was 25 MW and the utility delivered more than 32 MW. This resulted in $622,370 in additional utility revenue (collected from utility ratepayers) (National Grid, 2021). Notably, the Hawaii Public Utilities Commission (HIPUC) recently approved an extensive portfolio of PIMs to support the state's clean energy goals (HIPUC, 2021). Many of the HIPUC PIMs support GEB deployment and include:

- "DER Asset Effectiveness Metrics" that measure the enrollment, capabilities, and utilization of DERs to provide grid services, including load curtailment, which are a direct benefit of GEBs.
- "Cost Control Metrics" that measure revenue and cost (including separate accounting of rate base and O&M costs on a per-customer basis) growth, which can be managed through GEB deployment and its impacts on utility costs.
- "Customer Engagement Metrics" that measure enrollment in customer programs, including DER and DR programs, as well as number and percent of customers using and sharing hourly consumption data (i.e., Green Button Connect) that enables DER providers to target GEB technology solutions.
- "Affordability Metrics" that measure low-to-moderate income customer electricity bills relative to income, among other things, that can be better managed through GEB technologies.

There are important implementation challenges for PIMs to consider. For example, designing and supervising PIMs can be a significant shift in the way utilities are regulated and there may be uncertainty and unintended consequences in their outcomes. Additionally, PIMs may be subject to gaming and manipulation and over-compensate utilities (either unintentionally by design or intentionally through data manipulation). Utilities and regulators should use incremental approaches, solicit stakeholder input (e.g., via collaboratives), establish transparent verification measures (e.g., independent third parties) and adjust metrics and targets overtime as they gain implementation experience (Lowry and Woolf, 2016).

Data services and other commercial opportunities

The electric utility business model was established on profit achievement through commodity sales and profit motivation through investments in assets (Satchwell and Cappers, 2015). Recently, electric utilities are transacting with customers and aggregators/service providers in ways that extend beyond providing commodity service. This is in part to generate profit from new revenue and earnings opportunities as electricity sales stagnate or decline, as well as in response to advances in energy technologies and the increasing adoption among customers. From the customer perspective, new commercial opportunities and services from the utility may increase choice among providers, and can drive the industry towards innovation and commercialization of advanced GEB technologies.

Utilities are promoting GEB deployment through several commercial opportunities. Beyond administering integrated EE and DF programs (which themselves may be a new revenue opportunity for the utility), utilities are partnering with service providers and technology companies to deploy, for example, smart thermostats (e.g., Georgia Power partnership with Vivint) or battery storage (e.g., Green Mountain Power partnership with Tesla). In addition, utilities are investing billions of dollars in networking and communications systems, which can support GEB technologies by enabling and integrating multiple energy technologies. For example, Burbank Water and Power offers customers free WiFi through its wireless metering network that can be used to manage in-home GEB technologies (Brooks et al., 2021).

Regulators must consider technical and policy issues associated with expanding the scope of utility commercial offerings. Two of the key issues for regulators to consider are market structure and competition that define what commercial activities is appropriate for the utility to engage in and whether and how the utility should directly compete with non-utility entities in some commercial activities (Brooks et al., 2021).

Pricing

Rate design has been a tool for advancing EE and DF for decades. Time-of-use (TOU) and dynamic pricing rates encourage the shifting of usage from higher-priced peak hours to lower-priced off-peak hours. More than 60 utility pilots and full-scale rate offerings over the past two decades have demonstrated that time-varying rates with strong price signals can result in average participant peak period usage reductions of 25 percent or more (Faruqui, 2017). Inclining block rates, in which the price of electricity increases with a customer's consumption over the billing period, can provide an incentive to conserve energy.

While these rate designs encourage EE and DF, their use is limited for many of the same reasons utilities have been hesitant to deploy EE and DF programs more broadly, as discussed in earlier in the paper. However, two emerging trends in rate design can help to overcome the barriers to EE and DF deployment while providing many of the same benefits to consumers, namely subscription pricing and innovations in DER rate designs.

Subscription pricing

Subscription pricing provides customers with a tailored and entirely fixed bill for their electricity service. Customers are offered a monthly fixed bill amount that is based on their historical usage, and that monthly bill remains unchanged for a specified term (typically one year). At the end of the term, customers do not face any true-ups or adjustment charges for that year. In this sense, subscription pricing is similar to the simple form of billing that consumers have become familiar with for services such as television and music streaming, gym memberships, and cell phone data plans.

Recently, the subscription pricing concept has emerged as a tool for promoting the achievement of EE and DF goals by packaging the fixed bill offer with other customer offers, such as EE and DF incentives. For example, the acceptance of a smart thermostat could be a prerequisite for enrolling in the subscription pricing offer, or it could be a voluntary add-on to draw more customers to the program.

With this approach, the customer benefits from a simple and entirely predictable bill, thereby improving their ability to budget for other expenditures. Additionally, if the packaged EE and DF measures significantly reduce the cost of serving the customer, it may be possible for the utility to offer the customer a fixed bill that is lower than the average bill that the customer otherwise would have paid. From the utility's perspective, the company may be able to earn a premium from participants by sharing in those cost savings with the customer, and by charging a premium for taking on the additional financial risk of providing an entirely fixed bill (Hledik et al., 2020).

Currently, at least 11 electric utilities offer subscription pricing on a pilot or full-scale basis, as well as several competitive electricity retailers. Figure 1 summarizes the utilities currently offering some form of subscription pricing. Although several of the utilities listed in Figure 1 offer standard subscription pricing products which have not been coupled with EE or DF, a number of utilities have begun to test the concept of coupling subscription pricing with other services that will advance progress toward clean energy goals. Several pilots or recent proposals are discussed below.

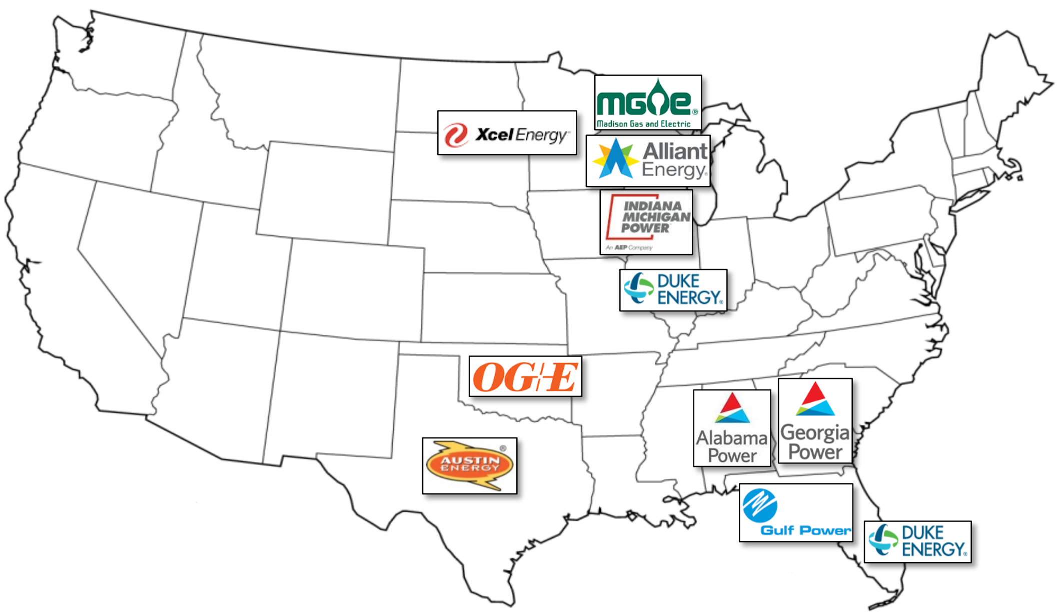

Figure 1: Electricity Subscription Pricing Offerings in the U.S.

Evergy subscription pricing proposal with efficiency incentives

In Evergy's January 2022 Missouri rate case filling, the utility included a proposal for a residential subscription pricing pilot. A unique feature of Evergy's proposal is that it includes an "efficiency incentive" which provides customers with a rebate payment if their usage does not increase after they enroll in subscription pricing. Additionally, Evergy offers subscription pricing participants a smart thermostat "add-on." With the smart thermostat add-on, participants can include the purchase of a smart thermostat in their monthly subscription pricing fee. Evergy will provide the smart thermostat to the customer at cost. The add-on provides additional energy savings and, in the future, could be enhanced to facilitate thermostat-based DR.[2]

Xcel Energy EV subscription pricing pilot

In its Minnesota service territory, Xcel Energy offers an EV subscription charging pilot rate. For a fixed monthly fee, participants lease a home charger and can charge their EV at no additional cost between the hours of 9 pm and 9 am on weekdays, or all day on weekends and

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[2] For more detail, see Evergy rate case filing: https://www.efis.psc.mo.gov/mpsc/filing_submission/DocketSheet/docket_sheet.asp?caseno=ER-2022-0129&pagename=docket_sheet.asp.

holidays. Participants also have the option to combine the offer with participation in Xcel Energy's Windsource program and match their expected EV charging load with clean energy.[3]

Austin Energy EV subscription pricing

Similar to Xcel Energy, Austin Energy offers a fixed fee for unlimited off-peak home EV charging. EV charging must occur outside the 2 pm to 7 pm window on weekdays; otherwise, participants could be charged up to 40 cents/kWh for charging during the peak window.[4] Additionally, to promote EV uptake, Austin Energy offers its Plug-In Everywhere program, which includes access to more than 1,000 Level 2 charging stations around the city for a fee of around $4/month.

Duke Florida subscription pricing smart thermostat pilot

In its Florida service territory, Duke Energy recently received approval to pilot the inclusion of demand response in its subscription pricing offer. Subscription pricing participants with an eligible smart thermostat will receive a gift card in return for allowing the utility to manage the thermostat year-round (subject to limitations) to reduce system costs.[5]

In order to advance subscription pricing, utilities will need to be willing to accept additional financial risk associated with offering an entirely fixed bill; in years with unusually hot or cold weather, or with unanticipated changes in costs, utilities could under-recover costs from subscription pricing participants. The inclusion of a risk premium in the fixed bill offer may help to offset this risk, and the fixed bill could similarly act as a "hedge" against utility revenue fluctuations associated with the largely volumetric rates that most customers are enrolled in today. From the customer's perspective, if that risk premium is not offset by cost savings associated with EE and DR bundles, then participants will need to be willing to accept a subscription pricing offer that is higher than what the customer's average may be otherwise. From a regulator's perspective, subscription pricing is in some ways still an emerging concept, and there has been hesitancy to approve some utility proposals due to environmental or financial concerns. Pilots can help to alleviate these concerns before moving to full-scale rollouts.

Innovations in DER rate design

Traditional rate designs have not kept up with consumer adoption of new technologies. Most residential electricity customers today remain on a flat volumetric rate design and, in some cases, this rate design overcompensates customers and provides distorted incentives. For example, when coupled with net energy metering (NEM)[6], flat rates provide a significant non-transparent subsidy to customers with rooftop solar PV and encourage them to install south-

[3] Xcel Energy tariff. See Section No. 5, Sheet No. 8.1-8.3: https://www.xcelenergy.com/staticfiles/xe-responsive/Company/Rates%20&%20Regulations/Me_Section_5.pdf.
[4] Austin Energy Tariff, pages 34-35. https://austinenergy.com/wcm/connect/bca7e254-aaf2-4f4c-ae38-070288f4e94e/Residential-PilotPrograms.pdf?MOD=AJPERES&CVID=nPpTRi7.
[5] Florida PSC Docket No. 20200222-El. http://www.psc.state.fl.us/library/filings/2021/01449-2021/01449-2021.pdf.
[6] Net energy metering (NEM) is a billing method that applies specifically to electricity exported from customer-sited distributed generation (DG) systems, allowing that exported generation to be netted against consumption from the grid at other times (Satchwell et al., 2019).

facing solar panels (to maximize solar output) rather than west-facing panels (to maximize the value of the output) (Borenstein et al., 2021). In other cases, current traditional rates may financially penalize customers. For example, rates which recover fixed or demand-driven infrastructure costs through a volumetric charge can discourage the adoption of electric end-uses (e.g., electric heating, EVs) which otherwise may provide significant economic and environmental benefits.

Utilities, regulators, and their stakeholders are continuing to explore new designs that address these challenges (Satchwell et al., 2019). Specifically, new approaches to DER rate design that benefit both utilities and consumers can incentivize adoption of beneficial emerging technologies and optimize their use by aligning the compensation of owners with the real system cost savings that those technologies provide. Examples of new rate designs for DER customers that are consistent with this approach include the following.

Duke's Solar Choice Net Metering tariff

Duke has proposed a new compensation model for residential customers with rooftop solar. While the model retains NEM at the full retail rate, it includes a time-varying volumetric rate with a strong price signal and significantly discounted mid-day price, which incentivizes the shifting of load to hours when electricity is cheapest to produce. As an additional incentive for DR, the model includes a financial incentive per-watt of installed solar PV capacity if customers agree to participate in a smart thermostat DR program.[7] With this type of approach, if the incentive payments count toward a utility's existing EE or DR goals, utilities could effectively improve their earnings through rooftop solar adoption (e.g., through decoupling or other EE-related financial incentives).[8] Duke's proposal has support among several environmental advocates and is currently under review in North and South Carolina.

HECO NEM reform

Due to in part to HECO's high volumetric residential rate coupled with NEM, the utility reached rooftop solar penetration levels that were beginning to create operational challenges on its power system. Initially, the company had to impose restrictions such as limiting a customer's ability to modify or expand existing systems. HECO has subsequently implemented several options that are designed to encourage the coupling of batteries with rooftop solar and mitigate these challenges. For example, HECO's Smart Export option incentivizes customers to charge batteries from rooftop solar during daytime hours and discharge during other hours when the output is more valuable to the utility, by providing an export credit that is only applicable outside the hours of 9 am to 4 pm. HECO's NEM Plus program allows customers to modify their rooftop solar systems – including through the addition of a battery – if the added resources are designed to facilitate on-site consumption and do not export to the grid. HECO's Grid Supply Plus option

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[7] The program includes an additional up-front incentive for the purchase of a thermostat. Customers must agree to enroll in the smart thermostat program for a 25-year contract period.
[8] Public Service Commission of South Carolina Docket No. 2020-264-E/2020-265-E. https://dms.psc.sc.gov/Attachments/Matter/c0ad5520-13f4-4e05-865d-2db12f164d36.

pays customers for exports to the grid, but allows HECO to curtail that output when needed, under certain conditions.[9]

BGE EVSmart TOU rate

Roughly 25% of residential utility customers in the U.S. had access to a TOU rate specifically designed for EV charging as of 2019, and the number surely has increased since then (SEPA, 2019). EV TOU rates benefit the customer by providing an opportunity to reduce their electricity bill by shifting a discretionary and flexible source of load by just a few hours. From the utility's perspective, shifting charging load to off-peak hours increases utilization of existing infrastructure, spreads the recovery of fixed costs over a larger sales base, and improves system reliability. Among many utility EV TOU offerings, BGE's EV Smart rate is notable because the utility "meters" the EV's charging load through the charger itself. This avoids the need to install a second meter, the cost of which otherwise would be passed on to the participant and may discourage enrollment. BGE promotes the adoption of eligible chargers to its customers through an annual rebate payment and encourages management and scheduling of the charger through a smartphone app.[10]

Retail rate design is a highly contentious issue, because most rate design changes typically result in some customers experiencing automatic bill increases (though other customers experiencing bill decreases). The politics of removing subsidies embedded in existing rates are particularly challenging. Utilities and regulators will need to be aware of potential bill increases for vulnerable segments of the population, and the impact of rate changes on industries that are aligned with other policy objectives such as clean energy goals. Ultimately, rate design changes like those described in this paper will need to find the appropriate balance between incentivizing the adoption of clean technologies and remaining consistent with the principles of cost-reflective rate design.

Utility infrastructure investments

The transition to a decarbonized and distributed power system will require new investments in enabling infrastructure in order to maintain system reliability. From the utility's perspective, these investments represent a financial growth opportunity, as well as an opportunity to play a significant and critical role in achieving global decarbonization goals. In order to make these investments, utilities will need to demonstrate that the investments are prudent, and EE and DF can be an important element of that determination. In this sense, EE and DF can be an enabler of utility capital investment in infrastructure, rather than "compete" with it. Customers will benefit from the new opportunities to reduce electricity bills through EE and DF participation by leveraging smart technologies that are being rapidly adopted behind the meter.

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[9] HECO website: https://www.hawaiianelectric.com/products-and-services/customer-renewable-programs/private-rooftop-solar/customer-grid-supply-plus.
[10] BGE website: https://www.bge.com/SmartEnergy/InnovationTechnology/Pages/EVTOURate.aspx.

Facilitating electrification through EE and DF

Electrification is a cornerstone of most decarbonization initiatives. However, electrification potentially can pose new affordability and equity challenges if load growth is inefficient and inflexible. The utility infrastructure investment needed to support the load growth from transportation electrification alone through 2030 could be $100 billion (Hagerty et al., 2020). While this investment presents utilities with an opportunity to expand their rate base, regulators are likely to be skeptical of proposals requiring significant rate increases. Utility proposals for new electrification-related investments will need to be coupled with new EE and DF initiatives in order to mitigate these cost increases and demonstrate to stakeholders that the investments are the most cost-effective path to decarbonization. Recent utility proposals illustrate this concept and are described below.

Pepco's Climate Solutions Plan

In 2021, Pepco proposed its Climate Solutions Plan ("the Plan"), consisting of 62 programs designed to facilitate achievement of Washington, D.C.'s ambitious goal of net-zero economy-wide emissions by 2050. Incentives and investments in transportation and building electrification infrastructure are key elements of the Plan. Additionally, the Plan also includes a proposal for very significant investments in residential and commercial building EE and DF. The EE and DF portfolio consists of traditional measures as well as emerging options that leverage smart thermostats, behind-the-meter batteries, distributed generation, and flexible EV charging. Recent analysis of the Plan indicates that every $1 spent by Pepco through the Plan would produce roughly $1.70 in environmental and energy system benefits, with EE and DF playing a large role in the Plan's cost-effectiveness (Hledik et al., 2022).

Great River Energy's Community Storage Program

Energy storage comes in many forms, including thermal energy storage in buildings. Great River Energy (GRE) operates a Community Storage program which leverages the thermal energy storage capabilities of residential electric water heaters to provide flexibility to the power system.[11] Specifically, the utility has 110,000 residential electric resistance water heaters enrolled in the program. Roughly half are used to provide daily load shifting, which helps to absorb excess wind generation during nighttime hours. The other half provide "peak clipping" benefits which are controlled selectively in order to reduce the utility's capacity costs (Podorson, 2016). In both cases, the programs benefit consumers through financial incentives and a more stable power grid. GRE additionally benefits by improving the economics of electric water heating relative to other non-electric options the customer may consider.

For EE and DF to play a meaningful role in utility electrification plans, both utilities and regulators will need to develop confidence that the EE and DF resources can reliably provide infrastructure investment deferral benefits. While EE and DF have been used to avoid bulk system investments for decades, additional experience may be needed before EE and DF have the same level of confidence for providing location-specific distribution benefits on a smaller geographic scale. It also will be critical to ensure that the benefits of EE and DF are fully

[11] GRE website: https://greatriverenergy.com/smart-energy-use/beneficial-electrification/community-storage/.

considered in integrated resource planning and distribution resource planning processes (Satchwell and Hledik, 2014).

Investing in smart technology

Traditionally, most utility infrastructure investment has been in utility-scale generation and in building out and upgrading the transmission and distribution system. However, as the grid becomes more decentralized, utilities also may be able to earn a return on investments in distributed smart technologies, or in leveraging customer-owned technologies as a low-cost opportunity to improve system operations.

Green Mountain Power (GMP) Energy Storage System Service program

In Vermont, GMP offers a program through which customers pay the utility a monthly payment to lease Tesla Powerwall batteries for 10 years. The lease payment includes the cost of installation and is discounted relative to the full cost of the batteries. GMP owns the battery for the duration of the 10 year lease and is able to manage the battery during a limited number of events per year in order to reduce system costs. The customer has access to the battery on all other hours and can use it as backup generation or for bill reduction purposes. This program illustrates the opportunity for utilities to own and rate base DERs, and allows the utility to provide the customer with resilience benefits in addition to capturing system cost savings.[12]

Arizona Public Service (APS) Cool Rewards program

APS is one of many utilities offering a "bring-your-own-thermostat" (BYOT) program, which provides customers who own a smart thermostat with the opportunity to enroll it in a DR program and earn a financial incentive in return. APS's program is being expanded to include the management of other DERs such as behind-the-meter-batteries and grid-interactive water heaters to provide renewables integration benefits. In addition to providing APS with a low-cost option for meeting its DF goals (since the customer has already paid for the equipment), the program will enable investment in renewable generation by reducing mid-day solar curtailment and improving the economics of investments in utility-scale solar projects.[13] From the customer's perspective, the program is an opportunity to "unlock" an additional feature of their thermostat or other behind-the-meter device.

National Grid Partnership with Sense

National Grid recently received regulatory approval to deploy "second generation" smart meters across its Upstate New York service territory.[14] Second generation smart meters have improved processing power and the ability to measure meter data at a much more granular level than first generation smart meters. This added functionality has allowed National Grid to partner

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[12] Green Mountain Power website: https://greenmountainpower.com/wp-content/uploads/2020/06/GMP-Powerwall-Program-Tariff-and-Lease-2020.pdf.
[13] EnergyHub website: https://info.energyhub.com/blog/arizona-public-service-energyhub-mercury-derms.
[14] NYPSC Case 17-E-0238. https://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId={7F47DEF5-3F7F-4191-9A2A-FE0803682FDD}.

with Sense, a meter data disaggregation company, to provide customers with real-time appliance-level usage information through the Sense app. Access to this information and accompanying tailored energy efficiency advice is expected to result in overall usage reductions among app users, and could eventually facilitate the deployment of new "behavioral demand response" programs.[15] Providing customers with these services to fully leverage the functionality of the meters could become a prerequisite for regulatory approval of large scale utility investments in second generation smart meters.

Successful models of utility ownership of DERs will require that utilities, stakeholders, and regulators address concerns over competition from utilities in the private sector. Often, regulators and advocates favorably view these investments in cases where the market is not otherwise offering a solution (e.g., targeting underserved communities). But, other issues must be considered including how financial and operational risks are allocated between utilities and ratepayers.

Discussion and conclusion

We identified numerous examples of utility GEB deployment benefitting customers and utilities organized into three emerging concepts. Notwithstanding the success of the examples and the significant benefits, widespread GEBs are still a small component of utility resource and program portfolios. Drawing from the examples in our emerging concepts, we identify several strategies and themes that could be used by regulators, utilities, and/or DER providers to develop and deploy GEBs.

First, clearly defined and inclusive processes can overcome widely divergent stakeholder perspectives and the often highly litigious nature of utility regulation to design and implement novel regulatory models and pricing. For example, the HIPUC established its PIMs using a two-phase proceeding that first identified priority areas and outcomes and then designed PIMs to achieve the stated goals. The HIPUC proceeding included participation across a broad range of perspectives (e.g., workshop presentations by commission staff, utility, municipal government, and customer and clean energy advocates, testimony filed by at least 10 organizations). The HIPUC also established a working group to "continuously introduce, examine, and vet new Performance Mechanism proposals, as well as explore modifications to existing PIMs" (HIPUC, 2020). Similarly, the Minnesota PUC (MNPUC) utilizes an iterative process to design, implement, and improve PIMs (see Figure 2). Notably, changes to utility regulatory and business models in Minnesota were started by a stakeholder collaborative ("e21 Initiative") that included utility, consumer advocate, and clean energy advocate representation and the PIM process was proposed by the Attorney General.

[15] A Sense pilot with Alliant in Wisconsin found that customers reduced energy consumption by 9% when provided with this information (Kramer, 2019). Additionally, a Sense pilot with OhmConnect in California found that customers doubled peak period usage reductions during demand response events when equipped with the Sense app. Sense Press Release, November 2021: https://www.prnewswire.com/news-releases/sense-and-ohmconnect-partner-to-increase-participant-savings-by-160-301414758.html.

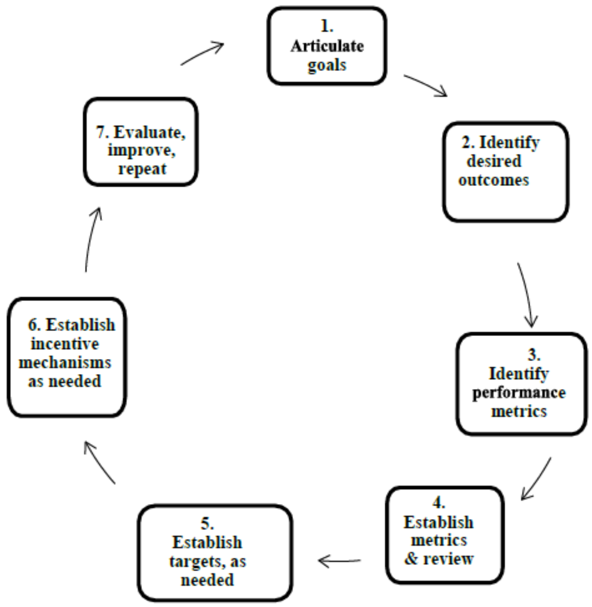

Figure 2. MNPUC process to design, implement, and improve PIMs. *Source*: MN PUC, 2019.

Second, the pricing examples particularly highlight the continued importance of pilots as a means to deploy novel approaches. While some industry stakeholders may perceive continuous use of pilots by utilities (i.e., "pilot-itis") without commitment to full-scale deployment, pilots serve an important and low risk mechanism to drive innovation and build implementation experience. Many states have "alternative regulatory plan" proceedings/dockets that can establish important regulatory and legal basis for pilots, while also allowing intervenors to review, evaluate, and build a record for regulators. For example, GMP's customer leasing programs were initiated under an alternative regulatory plan.

Third, utility partnerships, either with DER providers, technology developers, or customers, may unlock new profit opportunities, while sharing risk. Investments in smart technologies can be risky as technologies advance and develop leaving prior investments obsolete. Partnerships with technology developers may mitigate this risk (which is largely borne by ratepayers). Programs like BYOT leverage already existing customer technology investments, thereby reducing or mitigating the risk that customers may not enroll in and adopt certain programs.

Importantly, strong federal, state, local, and industry leadership is necessary to realize the opportunity of GEBs. The US DOE recently established a national goal of tripling the energy efficiency and demand flexibility of buildings by 2030 relative to 2020 levels (US DOE, 2021) and many of our examples are supported by state and utility leadership. Researchers and advocates also play a critical role in advancing GEBs.

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