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ADVANCED REVIEW

# Advancing transformative sustainability: A comparative analysis of electricity service and supply innovators in the United States

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The electricity sector is undergoing rapid and dramatic change. The momentum of sustainable energy technologies and business model innovation is giving rise to a "polycentric" framework of policy innovation and action organized by institutions that support customer choice and give customers the means to become electricity generators and service providers in their own right. These local experiments will have to deliver transformative change, flexibly address the electricity sector's legacy of political and administrative complexity, achieve scale and financial sustainability, and enable greater and wider stakeholder participation and choice. This article reviews the evidence to date of the importance of these experiments and examines three innovators—municipal utilities, community choice aggregators, and the sustainable energy utility—to gauge the capacity of pioneers to address climate-driven and other challenges in the electricity market.

This article is categorized under:
Energy Efficiency > Economics and Policy
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**KEYWORDS**

community choice aggregation (CCA), electric utility, electricity services, energy governance, energy innovation, institutional change, municipal utility, polycentricity, sustainable energy utility (SEU)

## 1 | INTRODUCTION

The electricity sector is undergoing a period of institutional change to address external and internal challenges. This review focuses on challenges emanating from demands by the sector's customers, including:

- An increasing desire by customers to have more choice in the types of energy supply and services (especially those focused on energy saving) they are provided;
- Concerns about climate change and other environmental problems traceable to the operation of the sector and the need for policies (such as de-carbonization) to address these concerns[1];
- Fears about the quality of electricity service, especially in light of climate-caused events or extreme weather[2]; and
- A desire to take advantage of new technologies and business models that enable customers to manage and reduce their own consumption and, in many cases, generate their own energy supply.

Incremental system evolution—solving these challenges one at a time—will likely be an insufficient response due to the highly interconnected nature and urgency of the problems. In recognition of this, our focus is on experiments underway in the electricity sector that seek to address the challenges simultaneously, rather than iteratively. Among these experiments, we further narrow our focus to new service and supply models that are intended to meet the combined pressure of these daunting challenges.

Table 1 provides a snapshot of the variety of models recently introduced and currently in operation in the United States. A classification of "traditional" and "innovator" models is included to distinguish new models from already established ones. In the case of investor-owned and municipal utilities, innovator candidates are defined as those reporting energy efficiency savings per customer (MWh saved/capita) and installed distributed solar capacity per customer ($W_p$/capita) that place them in the top 20% of municipal or investor-owned utilities (IOUs; see notes for Table 1).

Table 1 highlights "polycentric" patterns of the sector's development in which a range of different institutions compete with or complement each other (Ostrom, 2010). Hallmarks of this change process include: transformation of consumers to "prosumers" who generate their own power; the rise of markets and programs to save/not use electricity; introduction of a system of micro-grids; conversion of traditional electric utilities to grid managers; conversion of buildings and other physical infrastructure into "smart," automated, low-carbon energy service platforms. Perhaps most importantly, this process is enabling traditional and new stakeholders to customize a wider menu of energy choices to meet their specific energy service needs.

The experimental approaches represented by the "innovators" in Table 1 chart a course for future electricity sector development that is driven by customer choice. In response to changes occurring in and beyond the electricity sector, these innovators are undertaking customer engagement initiatives, forging technology partnerships, and exploring alternative regulatory and business models. We review three innovators that have launched their strategies without the protection of standard regulatory rate-basing treatment (Fox-Penner, 2010).

1. **Austin Energy**—to illustrate an emerging group of municipal utility pioneers focusing on reduced demand and low-carbon supply;
2. **Marin Clean Energy**—an example of Community Choice Aggregation (CCA), a rapidly expanding local initiative that enables electricity users to self-organize and choose the fuels used to produce their electricity; and
3. **Sustainable Energy Utility** (SEU)—an approach that enables community governance of electricity services on the demand and supply sides of the sector (represented here by the Pennsylvania Sustainable Energy Finance Program [PennSEF]).

**TABLE 1** Overview of experimentation in U.S. electricity services and supply models (2016 data)

| | Count | Customers served (millions) | Annual sales (thousand MWh) | Annual revenues (millions $) |
|---|---|---|---|---|
| Traditional | | | | |
| Investor owned utilities (except innovators, see below) | 247 | 84.94 | 2,162,883 | 192,118 |
| Power marketers | 871 | 17.80 | 767,413 | 55,336 |
| Cooperative | 929 | 19.64 | 432,402 | 44,504 |
| Municipal utilities (except innovators, see below) | 1,780 | 13.28 | 347,427 | 34,503 |
| Political subdivision | 108 | 3.97 | 110,608 | 10,041 |
| State | 13 | 1.36 | 50,280 | 5,091 |
| Federal | 26 | 0.04 | 30,029 | 1,068 |
| Innovators | | | | |
| Investor owned utilities innovators[a] | 29 | 18.70 | 394,232 | 41,338 |
| Municipal utility innovators[a] | 64 | 3.32 | 73,968 | 8,351 |
| Community choice aggregator[b] | 7 states | 3.30 | 8,738 | 385 |
| Third party renewable Energy operators | 202 | 0.47 | 4,974 | 673 |
| Community solar[c] | 223 | 0.02 | 258 | N.A. |
| Independent providers of electricity services[d] | 11 | 63.34 | 2,607 | 946 |

Primary sources: Energy Information Administration (EIA) electric power sales, revenue, and energy efficiency data from Form EIA-861 and EIA-861S (Energy Information Administration, 2017).

[a] Municipal and investor-owned utilities are classified as "innovators" when their reported energy efficiency savings per customer (MWh saved/capita) and installed distributed solar capacity per customer ($W_p$/capita) place them in the top 20% of municipal or investor-owned utilities. Ranking is determined by taking the mean of the two normalized variables. A detailed list of the selection of "innovators" is available as supplementary material at http://www.freefutures.org/research

[b] Community Choice Aggregator data from O'Shaughnessy, Heeter, Cook, & Volpi (O'Shaughnessy et al., 2017) for count, customers and sales. Revenue data from EIA (Energy Information Administration, 2017).

[c] Community solar data from (O'Shaughnessy et al., 2017).

[d] Independent providers of electricity services include NYSERDA, Energy Trust of Oregon, Efficiency Maine Trust, Vermont Energy Investment Corporation or Efficiency Vermont, Focus on Energy, Cape Light Compact, Hawaii Energy Efficiency Program, the NJ Clean Energy Program, the DC Sustainable Energy Utility (DC SEU), the Delaware Sustainable Energy Utility (DE SEU), and the Pennsylvania Sustainable Energy Finance Program (PennSEF). Data from EIA form 861 EIA (2017) and PennSEF's $15 million investment (see below).

Two of the models are emergent (CCA and SEU) while the other—the municipal utility—has had an institutional presence dating to the early 20th century. Nevertheless, all three models have a sufficient empirical record for evaluation. Strategic differences between the three models further supported their selection.

To assess each approach, an evaluation is conducted along four dimensions: (a) their capacity to deliver transformative change; (b) their responsiveness to political and administrative complexity; (c) their ability to achieve scale and financial sustainability; and (d) their ability to enable greater and wider stakeholder participation and choice. The article first highlights customer-driven innovation trends in electricity service and supply (Section 1). Next, Section 2 offers a brief comparative overview of the three selected innovators while Sections 3, 4 and 5 provide detailed case-by-case assessment of each model. An overview of the lessons learned closes the article.

## 2 | A REVIEW OFCUSTOMER-DRIVEN INNOVATION IN THE UNITED STATES

The range of innovations underway in the electricity sector is extensive. For example, the literature includes trends toward: greater community governance of electricity policy (in an effort to diminish reliance on conventional regulation); local policies that set environmental standards of service; community control over financial and operational decision-making; business models that advance local economic development (e.g., job creation, increased revenues for local jurisdictions); programs created to reduce exposure to volatile energy prices; and "prosumer" initiatives responding to community desires to decide the types of energy supplied, the amounts of energy used, and the goals of the electricity system, especially in terms of its sustainability and fairness (Byrne & Taminiau, 2016; DeShazo, Gattaciecca, & Trumbull, 2017; Stoner & Dalessi, 2009).

Table 2 summarizes trends found in the research literature that extend across a host of dimensions (including political, regulatory, market structure, program design, and stakeholder engagement dimensions), but they share an interest in overcoming the mostly passive and impersonal customer interface historically found in the electricity sector.

Four yardsticks for evaluating the efficacy and viability of customer-driven innovation stand out in discussions in the research literature:

1. Can innovators deliver transformative change, especially in the areas of environmental impact and governance?
2. Can these initiatives respond effectively to the sector's legacy of political and administrative complexity and opaqueness?
3. Can they achieve scale and financial sustainability?
4. Can they enable greater and wider stakeholder participation and choice?

Each of these yardsticks is discussed below.

**TABLE 2** Emerging and historical trends characterizing the electricity sector

| Electricity service and supply requirements | Timing | Traditional view | General innovation challenge |
|---|---|---|---|
| Supply low cost power | Historical | Aggregate supply through centralized, large-scale generation | Aggregate demand in a decentralized market |
| Meeting (projected) increases in demand | Historical | Build sources of supply to meet projections | Operate programs that reduce demand |
| Operate service and supply without ecosystem carrying capacity overshoot | Historical | Use technology to overcome resource constraints | Use conservation and renewable energy to reduce energy's eco-footprint |
| Rising demand for electricity service choice | Emerging | Technical expert and bureaucratic decision-making in response to regulatory mandates and incentives | Empower individual and community decisions and treat energy as services |
| Ensure that customers receive accurate price signals connected with their consumption (especially to save/not use electricity) | Emerging | Operate ratepayer-funded demand-side management (DSM) to reduce electricity growth rate | Devise new service and supply pricing to reflect a goal of declining electricity demand |
| Rapid transition to low-carbon sources | Emerging | Own and operate utility-scale renewable energy power plants | Rely on distributed energy sources "behind the meter" at scale |
| Access to low-cost capital for sustainable energy development | Emerging | Operate under protection of regulatory rate-basing treatment | Remove barriers to capital not based on regulatory rate-basing treatment |
| Enable local control by:<br>• Promoting system-wide decentralization<br>• Applying sustainability criteria to electricity market development | Emerging | Increase share of renewable electricity in energy mix (often by purchasing output shares of renewable energy projects thereby fostering passive "green consumption") | Enable "green citizenship" by:<br>• Aligning service and supply with local conditions (e.g., microgrids)<br>• Aligning development with local values<br>• Relying on local resources |

*Note.* Source: Authors. Also see Braun & Hazelroth (2015), Sovacool (2011), and Byrne et al. (2009) for a discussion on the topic.

Transformative changes coming to the electricity sector include the pressing need to reduce the electricity system's greenhouse gas emissions through decarbonization and system-wide efficiency improvements (IPCC, 2014). To illustrate, the U.S. electric end-use energy efficiency potential for single-family detached housing, according to one estimate, stands at 245 terawatt-hours (TWh) per year (Wilson, Christensen, Horowitz, Robertson, & Maguire, 2017). However, actual investment in energy efficiency in this market segment is far below necessary levels. Ratepayer funded U.S. demand-side management (DSM) programs for the entire sector saved about 30.2 TWh of electricity in 2016 (Consortium for Energy Efficiency, 2017). Renewable energy deployment potentials similarly signal a large opportunity for decarbonization: estimated U.S. rooftop solar energy potential alone is 1.12 terawatt (TW), which could generate 1,432 TWh of electricity per year—equal to ~39% of the electricity sold in the contiguous United States (Gagnon, Margolis, Melius, Phillips, & Elmore, 2018). While growing, annual utility-installed renewable capacity and generation are at the low-end of the GW and GWh scales. The current electricity market and policy regime is failing the test of decarbonization. How can community-governed initiatives do any better? Initial evidence gained from evaluation of local action is promising (Byrne, Taminiau, Seo, Lee, & Shin, 2017; Kona et al., 2016). For instance, climate change commitments and action by U.S. cities outpace national achievements (Kuramochi, Höhne, Sterl, Lütkehermöller, & Seghers, 2017; Roelfsema, 2017).

Political and administrative complexity characterizes and continually shapes the electricity sector (Bartos & Chester, 2015; Hess, 2013). For example, the 1970s energy crises and the late 1990s deregulation initiatives generated political and institutional reform. Yet, it is far from clear if the vulnerability of the American electricity market to volatile energy prices has been removed. And in any case, past reforms do not appear to prepare the sector for new fuel-related concerns (to address looming environmental problems). Nonetheless, regulatory and administrative solutions to previous challenges have created a complex policy system that poses significant barriers to the entry of new approaches and organizations (observed by analyses from Kahn, 1990 to Fox-Penner, 2010). Community experiments may have an advantage as they align with local stakeholders demanding solutions to local problems (Carlisle & Gruby, 2017) but they will conflict with this complex regulatory environment.

An innovating institution's capacity to maintain long-term financial sustainability or expand into different settings with varying contextual attributes is an important determinant of efficacy and viability. Innovators commonly encounter difficulties in maintaining long-term financial health (Negro, Alkemade, & Hekkert, 2012; Richter, 2012). Learning from risks and threats to their survival will be a key factor in the survivability of local experiments in transformative change (Carlisle & Gruby, 2017).

Finally, consumer-driven demands for different relationships with their electricity provider and each other (as evidenced, e.g., by the rise of peer-to-peer models or "prosumer" community groups (Parag & Sovacool, 2016)) will conflict with other stakeholders (including some business consumers and nearly always, the utilities themselves). Addressing these conflicting interests will represent a critical test for consumer-driven innovation.

## 3 | COMPARATIVE OVERVIEW OF THE THREE INNOVATORS

Before presenting our case-by-case evaluations of the three innovators, we provide a comparative overview of the distinctive institutional and programmatic features of each innovator and the distinguishing economics that underpin them (Table 3).

Critical distinctions include the policy and market rules governing investment, cost recovery, and procurement. The traditional utility uses system-wide revenues (delivered by regulated rates that guarantee a rate of return) to underwrite investments. Shareholders play a central role in deciding investment portfolios. Municipal utilities also use system-wide revenues from sales to underwrite investments but serve the objectives and goals laid out by the communities they serve, not shareholders. The municipal utility effectively leverages electricity *sales* to the customer base to operate, design, and innovate programs in service to customers. The CCA model leverages community-wide *purchasing power*, not revenue from sales, to contract for lower future prices and other benefits. Effectively, the CCA model pools system-wide *use* to extract negotiation concessions from energy or technology suppliers leading to lower prices for future consumption. The SEU focuses on existing levels of inefficient energy use by monetizing the savings occurring from energy efficiency and renewable energy investment—thus leveraging community-wide *savings potential* to underwrite sustainability investments. In the case of Delaware, payment by utilities to purchase $CO_2$ emission permits are an additional source of leverage, in this case of *environmental prevention potential.*

## 4 | INNOVATIVE APPLICATIONS OF THE MUNICIPAL UTILITY MODEL: THE CASE OF AUSTIN ENERGY

In the United States, municipal utilities are non-profit, community-owned companies operated as part of local or state government (American Public Power Association, 2016). Generally, governance takes one of two forms: (a) utility services

**TABLE 3** Dimensions of the three 'innovator' models compared with the traditional utility

| | Traditional Utility (IOU) | Municipal Utility innovators (see Table 1) | CCA | SEU |
|---|---|---|---|---|
| Primary focus | Privately owned infrastructure – goal is expansion | Owns infrastructure for community purposes | Aggregated procurement to secure better terms | System-wide cuts in energy losses using "asymmetry principle"[a] and pooled investment to lower capital cost |
| Infrastructure | Large-scale, centralized generation | Distributed, renewable energy and energy efficiency. Customer oriented. | | |
| Relationship with investors | Maximize shareholder value | Use sustainability assets (e.g., free sunlight) to secure low-cost private capital to implement sustainability-focused programs | | |
| Customer interface | Supplier-consumer relationship (passive, short-term, distant) | Service provider-customer relationship (active, long-term, close) | | |
| Institutional structure | Investor-owned corporations operated under regulatory supervision | Community-owned company, run as part of local or state government | Community partnerships to buy renewable generation | Community utility, independent from IOU – any community can establish an SEU |
| Value creation | Leverages electricity sales to generate attractive rate of return for investors | Leverages sales to raise revenue for investment to meet community-established objectives. | Uses community-wide purchasing power to buy low-carbon energy | Uses community-wide energy savings to buy infrastructure-scale low-carbon options |
| Program design | Asset expansion to secure guaranteed rate of return | Administration of energy programs open to customers of the municipality | Aggregation to buy bulk, low-carbon power for participants | Community low-carbon energy services bought through guaranteed energy savings agreements |
| Target customers | Consumers of the jurisdiction served by the investor-owned company | Citizens of the municipality served by the public power company | Automatic enrollment for customers within jurisdiction | Open to participation by residential, commercial, industrial, and public sectors |

[a] *Note.* the asymmetry principle (Tertzakian & Hollihan, 2009) states that a unit of energy saved or generated at the end-use level cascades into multiple units of energy saved at the source.
[b] *Source*: Authors. Also see Byrne & Taminiau (2016), Helms (2016), and Taminiau et al. (2017) for a discussion on the topic.

established as part of the municipal government with management reporting to the city council or mayor; or (b) an independent authority with board members elected or appointed by the mayor and city council (American Public Power Association, 2016).

Similar to investor-owned utilities, municipal utilities raise revenue through electricity sales. However, municipal utilities have access to low-cost capital through the U.S. municipal bond market, have lower debt interest rates, are exempt from federal taxes, and do not pay dividends to investors—all benefits that can be passed on to customers. For example, 2016 data from EIA Form 861 indicates that average residential electricity retail rates for customers served by investor-owned utilities is about 14.8% higher than for customers served by municipal utilities (Energy Information Administration, 2017; Homsy, 2016).

Community ownership and oversight of municipal utilities enables a high degree of responsiveness in meeting community-established objectives. The model can offer "democratic participation in energy provision" and "green citizenship in place of merely green consumption" (Heiman & Solomon, 2004).

Innovative efforts by some municipal utilities include the deployment of renewable energy, battery storage, advanced metering infrastructure, electric vehicles, micro-grids, and energy efficiency (Kushler, Baatz, Nowak, & Witte, 2015). The model's capacity to align with community objectives, deliver enhanced environmental performance, provide local economic benefits, and improve service delivery motivates renewed interest in municipalization of electric service (Crandall, Bailey, Gichon, & Koehn, 2014; Homsy, 2016).

### 4.1 | Case study: Austin Energy, TX

The city of Austin, Texas and Austin Energy, the city-owned utility, have long had a reputation as leaders in the energy sector (Smeloff & Asmus, 1997). The city and municipal utility actively participate in national and global city-led efforts (e.g., they are a part of the U.S. Conference of Mayors and the global C40 Cities initiative). Austin Energy's early efforts to enable comprehensive sustainable building design, initiated in the 1980s, has been widely seen as igniting the green building movement in the United States and later laid the foundation of the U.S. Department of Energy's zero energy homes program (Prindle, Eldrige, Eckhardt, & Frederick, 2007). Recognized as 2017 Energy STAR Partner of the Year and 2017 Smart Cities Dive

"Utility of the Year" for its disruptive innovation, Austin Energy continues to be at the forefront of policy and technology innovation in the electricity sector (Musulin, 2017; Ribeiro et al., 2017).

Formed in 1895, Austin Energy is the eighth largest municipal utility in the United States by customers served (448,000). It functions as a department within the City: the city manager appoints a utility general manager who then hires the management team that reports directly to the city council. Austin Energy meets its needs through a combination of its own generation capacity as well as buying electricity in the open market managed by the Electric Reliability Council of Texas (ERCOT). Austin Energy has about 12,000 miles of transmission and distribution lines and owns over 3 GW of generation capacity. Its generation mix consists of solar (5%), biomass (1%), wind (30%), and non-renewables (64%) (Austin Energy, 2017a).

#### 4.1.1 | Austin Energy and transformative change

The 2007 Austin Climate Protection Plan passed by the city of Austin designated Austin Energy as the primary administrator of the overall plan (City of Austin, 2007).

In 2010 Austin Energy developed a revised "Resource, Generation, and Climate Protection Plan," updating it twice, in 2014 and 2017 (Austin Energy, 2017b). The current goals for Austin Energy are to:

- Meet 35% energy needs from renewables by 2020, 55% by 2025, and 65% by 2027;
- Achieve 75% carbon-free energy by 2025;
- Implement 900 MW of energy efficiency and demand side management;
- Deploy 200 MW of solar (including 100 MW of customer-sited local solar);
- Realize 30 MW of storage;
- Achieve net zero $CO_2$ emissions from all Austin Energy-controlled generation by 2030;
- Limit rate increases to no more than 2% per year and keep rates in the lower 50th percentile statewide; and
- Retire a 927 MW gas-fired power plant (Decker Creek Power Station) by 2022.

To achieve these targets, Austin Energy operates several sustainable energy programs focusing on deployment of wind and solar resources, energy efficiency, storage, and electric vehicles (EVs) (Austin Energy, 2017a; Hughes, 2009), including: "Plug-in Austin" which offers a public charging network; and Austin SHINES (Sustainable and Holistic Integration of Energy Storage and Solar Photovoltaics), which develops solar plus storage pilot projects.

#### 4.1.2 | Austin Energy and community engagement

Austin Energy offers a range of choices to improve customer experience. The Green Choice program enables residential and business customers to select Texas wind energy for their electricity supply. Austin Energy also offers capacity-based solar incentives for customers, and is in the process of developing multiple community solar installations, offering additional customer choice (Austin Energy, 2017a).

Future stakeholder participation and experimentation could flow from Austin Energy's collaboration on the Pecan Street Project (Rhodes et al., 2014). The Pecan Street Project, a public-private partnership that includes Austin Energy, has set itself the goal of "reinventing the energy system of the United States" (McLean, Bulkeley, & Crang, 2016). Of critical importance in this process is the consideration of the customer: "customer value can't be an after-thought. Instead of imposing solutions on customers, smart grids must address these challenges by creating products and services that customers will value and voluntarily adopt" (McLean et al., 2016).

Another innovative endeavor has been the development of the country's first value of solar (VoS) electricity rate, replacing net metering to compensate owners of residential rooftop solar (Blackburn, Magee, & Rai, 2014). Since October 2012, customers installing rooftop solar PV are automatically signed up for the VoS, continue to pay a monthly energy bill based on how many kWhs they use, but are also credited for all kWhs their solar system generates. Initial VoS rates were set at 12.8 cents/kWh on a levelized basis but are annually adjusted—the 2017 value of the credit is 10.6 cents per kWh (Austin Energy, 2017a; Blackburn et al., 2014). Some contend that municipal utilities are better able to craft innovative mechanisms such as the VoS and that this type of rate structure would be much more difficult to implement in the rate-of-return model governing investor owned utilities (Phung et al., 2017).

Connection of the 2.6 MW community solar rooftop project at La Loma (largest community solar project in ERCOT system), and at least 43.4 MW of utility-supported, customer-sited rooftop solar are evidence of Austin Energy's intent to shift to customer-driven sustainable energy development (Austin Energy, 2017a; Austin Energy, 2018a). The La Loma solar project offers additional evidence of the utility's customer-driven focus, with one-half of the La Loma project's output set aside for low-income customers (who are charged a discounted rate (Austin Energy, 2017a, 2018b).

#### 4.1.3 | Austin Energy and long-term viability

Transformational sustainable energy programs can reduce the revenue base of the municipal utility (Homsy, 2016). The American Public Power Association (APPA) itself warns, "publicly owned electric utilities may face pressure to encourage development of distributed resources even at the expense of revenue and operational stability" (American Public Power Association, 2013). Municipal utilities share this limitation with investor owned utilities, but publicly owned utilities, under oversight locally, have flexibility in developing new mechanisms, as evidenced above by Austin Energy's experience with the VoS.

Nevertheless, financial pressures can emerge as municipal utilities consider innovative programs. Austin Energy faced this challenge several times in recent years. In 2009, it informed the City Council of the need for rate increases to restore financial health—deficits reached $86 million in 2010 and the utility stated it needed $71 million to cover costs (Toohey, 2012). At that time, Austin Energy had not raised rates since 1994. In 2012, the municipal utility commissioned a cost-of-service study to support its rate increase request and the City Council approved a five-year rate review cycle (Austin Energy, 2016). As a result, a 7% system-wide rate increase went into effect in late 2012 (Austin Energy, 2016).

Austin Energy's Vice President for Regulatory Affairs and Corporate Communications said in 2016 that "we're on an unsustainable path" referring to a $56 million gap in what it costs to serve customers coupled with declines in use due to energy efficiency, more rooftop solar, and denser and smaller housing (Rockwell, 2015a). These tensions also surfaced regarding the acquisition of long-term power purchase agreements, with environmental advocates pushing for higher capacity while Austin Energy and large customers, wary of rate impacts, advocated for lower capacity purchases (Rockwell, 2015b). These issues and decisions take place against a backdrop of Austin Energy's commitment to limit rate increases to 2% per year, and maintain rates in the lower 50th percentile statewide.

To date, Austin Energy's customer energy solutions have realized ~660 MW of the 900 MW energy efficiency objective (on track to achieve the utility's 2025 goal) and have offset 35% of its load with utility-and customer-purchased renewable energy systems, which places Austin Energy 3 years ahead of its target (Austin Energy, 2017a).

#### 4.1.4 | Austin Energy and political and administrative complexity

Austin Energy's rate increase request directed renewed attention to a proposal that has surfaced several times since 1996 to change its governance structure to an independent board. In 2013, members of the Electric Utility Commission (an advisory body to Austin energy) argued that the existing structure is inefficient, insufficiently transparent, poses financial risks, and lacks the expertise required to handle the increased complexity of the electricity business (Rockwell, 2016). The Commission declared: "the needs of a utility company in today's rapidly changing electricity and energy markets are too specialized to be run as another city department."

A more aggressive proposal to alter Austin Energy's business model has also emerged, involving deregulation and opening the municipal utility to competition. In April 2015, State Sen. Troy Fraser introduced SB 1945, calling for allowing Austin Energy's customers to appeal rate decisions to the Texas Public Utility Commission (PUC). In the event rates are found to fail the "just and reasonable" principle, the PUC would set rates and allow retail choice for Austin Energy's customers, in effect dismantling the municipal model.

The utility's annual general fund transfer also attracts heavy criticism (Toohey, 2015). Austin Energy transfers ~$150 million to the city annually, which is in turn used for a variety of items in the city budget. Sen. Fraser commented that Austin Energy is in effect supporting city services not connected to electricity and that "This is like a drug addict…Austin is addicted to that $156 million they take for the (municipal) budget. That really is the core of the problem" (Toohey, 2015). The Mayor of Austin highlighted Austin Energy's business model in his State of the City speeches in 2015 and 2016 (Adler, 2016). He declared "If we do not reform our utility's business model, we face the threat of the legislature taking control of our utility away from us…One problem we have is with the murky transfers of funds from the utility to the city's general fund. No one seems to understand, trust, or particularly like this model" (Adler, 2016).

Some of this pressure has abated since Austin Energy was able to reduce rates starting in 2017, largely owing to declining costs of energy purchases.

## 5 | THE COMMUNITY CHOICE AGGREGATION MODEL

The CCA model enables communities to aggregate electrical loads (both non-residential and residential) and purchase power (O'Shaughnessy, Heeter, Cook, & Volpi, 2017). CCAs are public agencies, established by local ordinance, and overseen by a board of directors, city council or a commission.

Several management options are available to administer a CCA (DeShazo et al., 2017). The most commonly deployed approach is an inter-jurisdictional joint powers agency (JPA) that operates as a public, non-profit authority on behalf of participating cities and counties (DeShazo et al. 2017).

Initially, CCAs were created to address impacts of electricity deregulation: price volatility, anti-competitive behavior and market manipulation (Local Power Inc, 2009). While customer choice and lower cost rationales remain, an increasingly strong driver for CCAs is the deployment of clean energy and combatting climate change.

The details of each program differ, but some common features characterize CCAs:

- Customers within the CCA service territory are automatically enrolled unless they opt out. Automatic enrollment of customers improves participation: the lowest CCA participation rate stands at about 75%, comparing favorably to the typical 20% seen in voluntary programs (Jones, Bennett, Ji, & Kazerooni, 2017);
- The aggregator selects power supply options and sets electricity rates;
- The incumbent utility remains responsible for transmission and distribution, including billing and collections (O'Shaughnessy et al., 2017; Stoner & Dalessi, 2009); and
- Many CCAs also implement energy efficiency and other demand side management programs (Local Power Inc., 2009).

There is growing interest in the CCA model: CCA sales in the United States increased by ~18% over 2015–2016 in particular due to expansions of CCA programs in California, Massachusetts and New York (O'Shaughnessy et al., 2017). Seven states have now passed CCA-supporting legislation (Jones et al., 2017; O'Shaughnessy et al., 2017).

## 5.1 | Case study: Marin Clean Energy, CA

California is a leading state in the implementation of CCAs, and Marin Clean Energy is the longest functioning CCA in the state. It was originally established in December 2008 as Marin Energy Authority to operate as "an independent public agency… to study, promote, develop, conduct, operate, and manage energy and energy-related climate change programs" (Marin Energy Authority, 2008). Total start-up costs between 2003 and 2010 were $3.3 million. The CCA effort became Marin Clean Energy in May 2010 with a budget of $500,000 (Marin Energy Authority, 2008).

Marin Clean Energy has since expanded to 24 jurisdictions as of mid-2016: Marin and Napa Counties, plus 16 cities and 6 towns[3] (Jones et al., 2017). The CCA operates as a JPA governed by a 19-member board of directors, comprising a council member or supervisor from each of the participating communities. Marin Clean Energy is a separate entity and does not derive any financial support from its member communities (Marin Clean Energy, 2017). Currently, Marin Clean Energy serves 255,000 customers with electricity sales revenues of $179.7 million (Marin Clean Energy, 2017).

### 5.1.1 | Marin Clean Energy and transformative change

Marin Clean Energy's foundational rationale is sustainability: its stated mission is "to address climate change by reducing energy related greenhouse gas emissions through renewable energy supply and energy efficiency at stable and competitive rates for customers while providing local economic and workforce benefits."

Marin Clean Energy provides customers several supply options to achieve this mission:

- Automatic enrollment in the "Light Green" program, guaranteeing that at least 55% of electricity is renewable.
- Customers can select from two additional options:
  - "Deep Green": 100% renewable energy.
  - "Local Sol": 100% locally produced solar electricity.

Marin clean energy also offers a net energy metering (NEM) program for owners of rooftop solar panels, a feed-in-tariff for development of small-scale renewable projects (up to 1 MW in size with at least 25,000 square feet of space), special rates for electric vehicle owners, and energy efficiency services.

In terms of performance, as per its website, the Marin Clean Energy portfolio now includes 19 MW of renewable energy projects—equivalent to 74 watts per capita of renewable energy for its 255,000 customers. In addition, one estimate indicates that, in 2016, Marin Clean Energy emitted 26% less greenhouse gas emissions for the same amount of electricity compared to the incumbent utility (DeShazo et al., 2017).[4]

Some concerns have been raised over "additionality"—how much *new* clean energy CCAs actually support—challenging the "greenness" of CCA efforts by arguing that renewable energy production is simply shifted from incumbent utilities to the CCA. In a related issue, in 2015 the union representing Pacific gas and electric (PG&E) electrical workers questioned Marin Clean Energy's use of unbundled RECs and its procedure for calculating its "greenness" (Halstead, 2015a). "Unbundled" RECs refer to the value or environmental attributes of renewable generation separate from the electrons produced. Marin Clean Energy responded that its use of unbundled RECs has decreased, representing a small part of its portfolio, and it is complying with all regulatory and reporting requirements (Halstead, 2015a).

#### 5.1.2 | Marin Clean Energy and community engagement

Similar to municipal utilities, the CCA model provides local control over decisions related to supply sources and rates, and allows the CCA to incorporate other community goals. Indeed, customer demand, grassroots movements, and a local "advocacy pioneer" initiated Marin Clean Energy (Ruppert-Winkel, Hussain, & Hauber, 2016). Heeter & McLaren (Heeter & McLaren, 2012) similarly note that residents of Marin County overwhelmingly supported increasing community use of renewable energy in a 2007 survey: over 90% of residents said that reducing greenhouse gases was important to them and 74% indicated willingness to support the local government in becoming a provider of greener energy. The customer choice options highlighted above are a response to this demand (Heeter & McLaren, 2012). This is a clear example of how CCAs can provide customers with greater decision-making input in their electricity supply and use. In short, enhanced customer choice is one of the chief selling points for joining a CCA (Heeter & McLaren, 2012).

#### 5.1.3 | Marin Clean Energy and long-term viability

There are a number of potential financial risks affecting the competitiveness of CCAs, specifically that increase the cost of CCA operations vis a vis the incumbent utility. In California, the California Public Utilities Commission (CPUC) requires investor-owned utilities to cooperate with CCAs. As part of that arrangement, the CPUC sets an "exit fee" (the "power charge indifference adjustment") which accounts for costs the investor owned utility incurred to serve customers that switch to the CCA, and prevents the utility from recovering lost revenues from its remaining bundled customers (Stoner & Dalessi, 2009). CCA model attractiveness directly correlates to the exit fee: higher exit fees could deter customer movement from the investor owned utility to the CCA (DeShazo et al., 2017).

In early 2015, incumbent utility PG&E requested approval from the CPUC to raise the exit fee charged to an average Marin Clean Energy customer from $6.70 to $13 per month, arguing that existing fees were insufficient to cover the investor owned utility's costs related to energy supply contracted years in advance (Halstead, 2015a). Marin Clean Energy argued that the request was anti-competitive and would significantly raise rates, especially for smaller and lower income customers of the CCA (Halstead, 2015b). Exit fee increases from $12.9 million in 2014 to $19.3 million in 2015 and to an estimated $30.6 million in 2016 are a major concern for Marin Clean Energy since the rate differential with PG&E has been narrow. The CPUC ultimately approved PG&E's request, arguing that it avoids undue burden on the utility's remaining customers, better aligns the rates of PG&E and Marin Clean Energy according to costs incurred, and helps pay for renewable energy purchases the investor owned utilities were mandated to make by state policy (Halstead, 2015a).

This issue continues to be contentious: in April 2017 the three investor-owned utilities in California submitted a joint proposal to the CPUC to eliminate the exit fee setting process altogether and institute a new methodology (Joint application of southern California Edison company, 2017). PG&E estimates that CCA customers pay only 65% of the costs for previous long-term purchases, and the associated cost shift could reach $180 million in 2017 (PG&E, 2018). The CPUC has initiated a proceeding to investigate alternatives to the exit fee, and the utilities and CCA supporters have each put forward proposals (Trabish, 2018).

The risk also works in reverse: customers leaving the CCA impose costs on both the CCA and the investor-owned utility. If customers leave the CCA too soon or too often, revenue streams will be affected (Local Power Inc, 2009). In California, CCAs are required to post a bonding fee of $100,000 to cover potential costs associated with the investor-owned utility reabsorbing customers who may later opt-out of a CCA. The City of Chicago, after operating a CCA for 2 years, returned 750,000 customers to the investor-owned utility because the latter was able to lower its prices (Penn, 2017). In some cases, cities assessing the feasibility of forming or joining a CCA have decided against this route owing to the inability to ensure competitive rates, or even rate parity (MRW, 2014).

#### 5.1.4 | Marin Clean Energy and political and administrative complexity

There are also political and administrative risks confronting CCAs. In California, institutional coordination vis-a-vis policy implementation and longer-term planning has emerged as a major concern. The CPUC has flagged several issues: resource adequacy, integrated resource planning, the renewable portfolio standard, and ensuring that California's policy goals are met regarding customer facing programs, in particular energy efficiency, transportation electrification, and implementing time of use rates (CPUC, 2017). In short, as more CCAs emerge, the investor owned utilities and the CPUC will have less visibility into what is happening in the markets in terms of amount and types of resources added, procurement methods to satisfy load (e.g., duration of contracts), and coordination and consistency in planning between the CPUC and CCAs (CPUC, 2017; DeShazo et al., 2017). As the CPUC recently summed up the concern: "Fewer and fewer customers are getting power from the traditional large regional utilities and the central decision making that we use for keeping the grid reliable, safe and affordable is splintering, becoming the task of dozens of decision makers […] we are deregulating electric markets through dozens of different decisions and legislative actions, but we do not have a plan" (CPUC, 2018). These concerns have led the CPUC to establish the California Customer Choice Project, designed to answer a basic question: "How does the increased customer choice occurring in the electric sector impact California's ability to achieve its policy objectives of affordability, de-carbonization, and reliability?" (CPUC, 2018).

There are also political risks, including opposition from incumbent investor owned utilities. For example, in California PG&E sponsored a ballot proposition in 2010 that mandated a statewide two-thirds vote to support CCAs instead of a simple majority, potentially making it much harder to implement CCA programs (Hess, 2013). A grassroots movement successfully defeated Proposition 16 and, in the process, unified previously split stakeholders (Ruppert-Winkel et al., 2016).

## 6 | THE SUSTAINABLE ENERGY UTILITY MODEL

The SEU is a type of "community utility" focused on the development and delivery of sustainability rather than sales of kilowatt-hours (Byrne & Taminiau, 2016). A key feature of the model is its positioning as an organization exclusively interested in energy conservation and self-generation from renewable energy across all sections of the energy market irrespective of fuel, end-user, or end use (Byrne, Martinez, & Ruggero, 2009; McDowell III et al., 2007). The model reflects a trend toward "servitization" in the energy sector, increasingly making use of service-focused performance agreements and underwriting capital investments with operational savings.

Indeed, novel use of capital markets to fund sustainable energy investments is a signature component of the SEU model. Its 2011 bond financing in Delaware (rated AA+ by S&P) pooled $72.55 million in investments in energy reductions and onsite solar energy installation for six state agencies and two higher education institutions. Major energy service companies made contractual guarantees of savings of $148 million. After debt service and closing costs for the bond series are included, the participating government agencies and higher education institutions paid $110 million to participate in the program and realized a net benefit of $38 million (Byrne & Taminiau, 2016). Evaluation of the financing shows over-performance against guarantee: first-year savings exceeded the 25% savings obligation by 3% (Chu, Bruner, & Byrne, 2015).

Early evidence of performance suggests the SEU model provides economic value beyond what can be offered by traditional utilities (Byrne & Taminiau, 2016). It was recently recognized by the International Energy Agency for its innovative approach underwriting sustainability investments with guaranteed future energy savings, giving it the potential to drive transformation from 'the bottom up' (IEA, 2016).

### 6.1 | Case study: Pennsylvania Sustainable Energy Financing Program

Created in 2014, a recent application of the SEU model is the PennSEF. This partnership between the Pennsylvania Treasury Department and the Foundation for Renewable Energy and Environment (FREE) received financial start-up support from the West Penn Power Sustainable Energy Fund. The program aims to develop a prudent, market-based investment vehicle that delivers energy and water efficiency, on-site clean energy generation, economic development and environmental improvement across Pennsylvania. In particular, the program targets the so-called MUSH sector—municipalities (including counties and governmental agencies), universities, schools, and hospitals.

PennSEF (and other SEUs) aggregate and connect capital supply and demand to facilitate large-scale energy investment. The financial mechanism connecting supply and demand specifically focuses on self-financing principles: the energy savings generated through the installation of on-site renewable energy generation and energy efficiency measures underwrite the investment and cover all program costs (Houck & Rickerson, 2009). The PennSEF platform can organize multiple financing pools by bringing together the energy savings and on-site self-generation potential of Pennsylvanian MUSH actors.

#### 6.1.1 | PENNSEF and transformative change

The mission of the SEU model generally and PennSEF specifically is explicit: to redefine social and economic forces by stepping away from marginal adaptation of existing energy systems and towards infrastructure-scale deployment of sustainability efforts (Byrne & Taminiau, 2016). Two primary mechanisms support this pursuit. First, a signature innovation of the SEU model is its capitalization ability through aggregation of system-wide inefficiencies. Capable of capturing the energy efficiency and renewable energy value present in communities—what is considered the "commonwealth" of energy (Byrne et al., 2009; Houck & Rickerson, 2009)—the mechanism raises low-cost capital from the market and banks to cover initial investment costs to unlock these benefits (Schlein, Szum, Zhou, Ge, & He, 2017). A second distinguishing feature of the SEU model is its reliance on guaranteed energy saving contracts (GESAs). Critically, the SEU's capitalization strategy relies on a money guarantee of energy savings sufficient to cover all project costs, including debt service. To do so, the SEU pools together the community-wide energy savings and on-site generation potential prevalent in all communities in order to obtain attractive guarantees from the companies that deliver and install the hardware.

In 2017, PennSEF organized its first financing pool along these dimensions of "commonwealth" financing and guaranteed energy savings. Called the PennSEF Streetlight Program and brought to PennSEF by the Delaware Valley Regional Planning Commission (DVRPC), the pool brings together 35 municipalities around the city of Philadelphia in order to replace and retrofit 28,000 exterior lights, street lights, and traffic signals (Figure 1). Using GESAs, the project is able to guarantee gross energy savings of \$30.6 million and, after deduction of all costs, deliver \$15.6 million in net savings. In contrast to the Delaware SEU application, which used bond financing for its \$72.5 million investment round, the PennSEF Streetlight Program uses bank financing: 24 of the 35 municipalities financed the streetlight and exterior light retrofit while the remainder either paid using their own resources or found financing elsewhere.

#### 6.1.2 | PENNSEF and community engagement

In operation, the SEU can realize complementary change in relation to the investor-owned utility but, crucially, is not dependent on a "fit" with the investor-owned model (Byrne & Taminiau, 2016; Byrne, Wang, Taminiau, & Mach, 2014; Taminiau & Byrne, 2016). This position is considered as a key contributor to its ability to draft paradigmatically different energy governance strategies. In particular, the common interests and benefits of the community served by the SEU—in contrast to the interests and benefits represented by shareholders—shape decision-making (Byrne & Taminiau, 2016; Taminiau, Nyangon, Ariella, & Byrne, 2017). This concept has been described as a "community utility" in an attempt to differentiate it from both the investor-owned utility and from other local energy innovations (Byrne & Taminiau, 2016).

The "community utility" aspect of SEU operations fosters a critical commodity in any energy efficiency program: trust (Backlund & Eidenskog, 2013). Successful energy program oversight and management depends on garnering trust from all stakeholders that program operation will deliver the benefits it promised and avoid possible disadvantages. The Delaware SEU and the PennSEF program illustrate capability to overcome trust limitations across many relevant stakeholders. An important element in this capability is the SEU model's positioning as a "trusted advisor" for participating agencies—extant literature points to the challenge of bringing together deep energy service company (ESCO) expertise with relatively inexperienced clients and balancing the resulting power dynamic (Backlund & Eidenskog, 2013). Under conventional energy efficiency projects, a sense of the "fox guarding the henhouse" might surface—ESCO expertise and incentives are structured such that clients can mistrust that ESCOs operate in the client's interest. The SEU model seeks to overcome this challenge by guiding, advising, and representing the pool of clients and ensuring their objectives and priorities are satisfied (Byrne & Taminiau, 2016).

#### 6.1.3 | PENNSEF and long-term viability

The success of the investor-owned utility model stems, in part, from guaranteed rates of return provided by regulators. This enabled IOUs to reliably deliver financial returns to their investors. The SEU model changes the nature and source of the guarantee. Private companies compete in the market to guarantee savings to the SEU's clients. A combination of market competition and new business models ensure returns via guaranteed savings contracts, whose performance is annually verified by

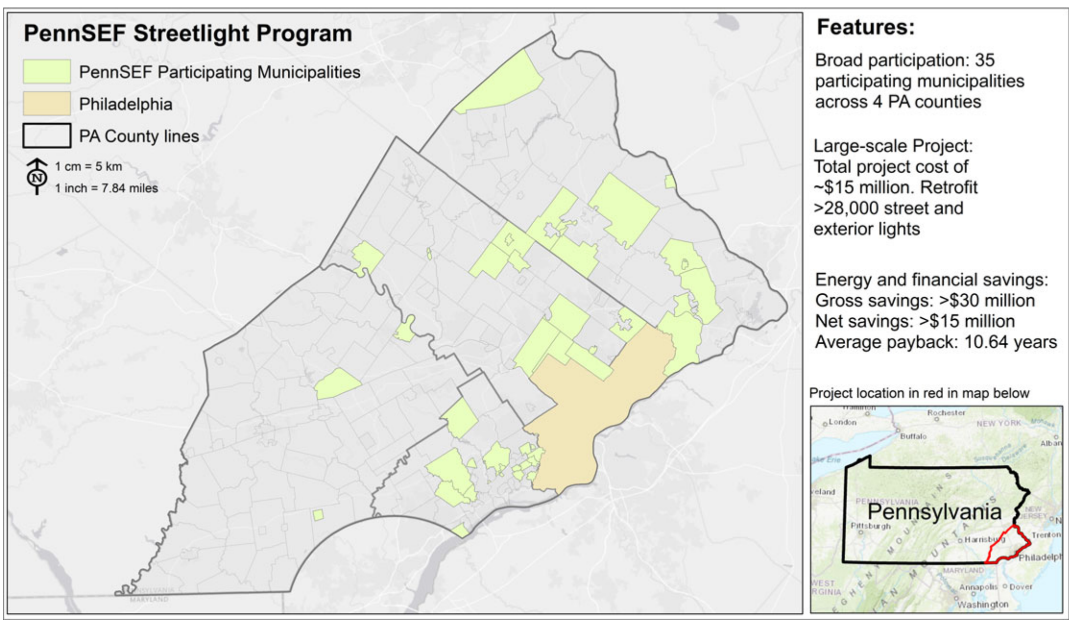


**FIGURE 1** Characteristics of the first financing round of PennSEF, the PennSEF Streetlight Program. Source: Authors

independent parties (including private companies and research agencies). The guarantee of savings is stated in a common contract format thereby allowing participants to be pooled for financing purposes. Aggregation of both capital providers and program participants in this way—as is also done under the CCA model but under a different mechanism—overcomes some of the limitations regarding local institutional capability. For instance, pooled finance strategies can avoid higher interest costs ordinarily charged for smaller jurisdictions and additionally enables access to bond markets that can offer lower interest charges and longer maturities larger markets (Bastida, Guillamon, & Benito, 2014). In addition, this strategy trains stakeholders to operate at this new scale, effectively priming the market for future, larger rounds of investment.

The guaranteed energy savings contracts include stipulations that limit financial risk. In particular, the ESCO is responsible for ensuring the performance of the energy efficiency measures—any performance shortfall needs to be compensated by the ESCO. Such provisions were part of the reason why rating agencies rated the Delaware SEU 2011 bond offering at AA+. The capitalization of sustainability through multi-year contractual agreements and supported by patient investor capital further enables the SEU model to maintain a long-term perspective.

#### 6.1.4 | PENNSEF and political and administrative complexity

The innovative character of the pooled financing used in both Delaware and Pennsylvania can encounter political or administrative complexity due to its relatively unfamiliar and novel structure. One example of critical feedback comes from the Delaware State Auditor in 2016 commenting on the Delaware SEU program (Wagner, 2016). The Auditor raised several concerns from his assessment of the $72.5 million Delaware SEU program, including:

- Participating agencies are under no obligation to commit cost savings resulting from the program to further energy reduction efforts;
- The accounting processes used to determine energy and cost savings are complex leading to, according to the Auditor, an "inability to ever know the true cost savings";
- The process for determining the annual adjustments to the ESCO monitoring and verification (M&V) fee is unclear to the Auditor who raises the concern that the State's best interest might not be properly represented in this process;

Delaware SEU leadership as well as the Delaware Office of Management and Budget questioned the validity of the Auditor's conclusions. In particular, the program's use of internationally accepted industry quality standards and protocols for program measurement and practices were raised as rebuttal to the Auditor's assessment of unknowable cost savings (Walton, 2016). For example, the SEU executive director responded to the concern regarding program complexity by pointing out that the International Performance Measurement and Verification Protocol (IPMVP) used in the monitoring of Delaware SEU program operations guides the energy efficiency sector with best practices and is the industry standard for the $5.3 billion market (Stuart, Carvallo, Larsen, Goldman, & Gilligan, 2018). The executive director noted in an industry publication: "I don't think they understand the protocols or standards being used, especially since they didn't consult with any experts in the field of energy engineering" (Walton, 2016).

The Delaware SEU has recently received *Standards for Excellence* certification by the Standards for Excellence Institute for its ethics, accountability, and transparency and national recognition by the U.S. Environmental Protection Agency as *Energy STAR Partner of the Year* and was awarded the *Energy STAR Excellence Award.* The Delaware SEU has launched three new programs in 2017 and the start of a statewide energy savings database (Delaware Sustainable Energy Utility, 2017). In 2018, the Delaware SEU again received AA+ rating from Standard and Poors for a pooled financing of $16.5 million in energy efficiency retrofits and sustainable energy measures (Sustainable Energy Utility, 2019). This round of financing will reduce energy savings at several school districts and state agencies. For example, the Colonial School District received a bridge loan for $7.6 million for energy efficiency and sustainable energy capital improvements across sixteen of its buildings—this investment is projected to deliver $9.8 million in savings over 20 years (Delaware Sustainable Energy Utility, 2017).

## 7 | LESSONS LEARNED AND DISCUSSION

The comparative and case-by-case analysis of the three innovator models demonstrates how each model deals with the four primary challenges of community engagement, delivering transformative change, navigating political and administrative complexity, and achieving financial sustainability. Continued experimentation and recombination (as illustrated in Table 1 for 2016) supports the notion that future governance structures of the electricity sector could consist of a polycentric multiplicity of experiments. As such, the three innovator models represent potential future "governors" as they respond to *and* accelerate the system-wide challenges and changes in the electricity sector.

**TABLE 4** Lessons learned

| Challenge | Important considerations |
|---|---|
| Realize transformative change | • Support aggressive and comprehensive targets<br>• Regularly update targets to maintain high levels of ambition<br>• Operate cross-cutting sustainable energy programs<br>• Set a clear mission statement that prioritizes sustainability<br>• Redirect the available "commonwealth" (i.e., money flows that already exist) towards sustainability |
| Engage with stakeholder demand for choice | • Participate in innovative public-private partnerships (e.g., Pecan Street Project) that emphasize customer perspective from the start<br>• Nurture and mobilize local "advocacy pioneers"<br>• Operate as a "community utility" that serves the community directly |
| Achieve financial sustainability | • Launch innovative customer-focused compensation mechanisms for sustainable energy (e.g., VoS)<br>• Identify benefits to incumbent utility to elicit cooperation<br>• Use long-term contracts<br>• Monetize savings to underwrite investments<br>• Aggregate customers to achieve scale for financing and to realize long-term performance guarantees<br>• Redirect existing budgets |
| Addressing political and administrative complexity | • Interact with and support long-term policy planning<br>• Build local grassroots support<br>• Ensure transparency<br>• Incorporate a "trusted advisor"<br>• Receive independent evaluation of performance by third-party certifiers<br>• Use industry-wide and accepted standards for performance monitoring and verification |
| Cross-cutting<br>Trust-building | • Nurture local relationships with relevant stakeholders<br>• Rely on patient and gradual application of experimentation towards overarching vision |

Looking ahead, future experimental designs interested in responding to existing and expected challenges can draw valuable lessons from the innovations evaluated above (Table 4). Foremost, such efforts will need to invest heavily in developing and maintaining reciprocal and trust-focused relationships with relevant stakeholders in order to address the forms of resistance experienced by each of the case study initiatives.

The application of new experimental designs generates the need for further research. We offer a few agenda items for consideration. Analysis of other "innovators" beyond the three groups discussed here are needed. An expanded body of case studies will facilitate understanding of the innovation process while also offering aspirants analytical benchmarks for their own efforts. Additional investigation of each of the dimensions listed in Table 2 can identify strengths and shortcomings in innovation strategies. For instance, reviews of the financial viability of innovator institutions could look into the specific year-on-year budget changes of various institutions or the interaction with the (green) finance market (e.g., green bonds). Similarly, surveys and interviews with key actors in the design and operation of these innovator models could generate insight into the specific dynamics associated with polycentric innovation. Other expected energy system transformations (e.g., electrification of transportation or the built environment) and new technology options will pressure the evolution of electricity service and supply providers. Additional research is needed to investigate the character and direction of this evolution. While currently relatively small in impact (Table 1), the innovator models evaluated here hold substantial promise to respond to existing and projected changes in the electricity sector. Expanded pursuit of energy efficiency and sustainable energy could facilitate a "peak carbon" reality and help align (global) greenhouse gas emissions with necessary reduction trajectories. Realizing a low-carbon social order requires significant institutional transformation to accommodate a focus on contraction and sustainability. Fortunately, as discussed here, the process of significant institutional change is underway.

## CONFLICT OF INTEREST

John Byrne is an unpaid officer of and Job Taminiau is paid staff with the Foundation for Renewable Energy and Environment (FREE), a 501(c)3 non-profit dedicated, among other things, to accelerating the diffusion of the SEU model discussed here.

## ENDNOTES

[1]The electricity sector is the largest source of U.S. greenhouse gas emissions (Environmental Protection Agency, 2018)

[2]Recent resilience deficits include the Texas, Florida, and Puerto Rico experience with severe hurricanes (National Academies of Sciences, Engineering, and Medicine, 2017)

[3]The Cities of American Canyon, Belvedere, Benicia, Calistoga, EL Cerrito, Lafayette, Larkspur, Mill Valley, Napa, Novato, Richmond, San Pablo, San Rafael, Sausalito, St. Helena, and Walnut Creek; and the Towns of Corte Madera, Fairfax, Ross, San Anselmo, Tiburon, and Yountville.

[4]All CCAs in California together reduced $CO_2$ emissions by 590,000 metric ton CO2eq (about 1.3% of California's 2015 electric power $CO_2$ emissions) (DeShazo et al., 2017)

## RELATED WIREs ARTICLES

A review of sustainable energy utility and energy service utility concepts and applications: realizing ecological and social sustainability with a community utility
Designing electricity markets for a high penetration of variable renewables
Understanding constraints to the transformation rate of global energy infrastructure

## REFERENCES

Adler, S. (2016). *"Great cities do big things"—State of our city*. Retrieved from http://www.mayoradler.com/great-cities-do-big-things-state-of-our-city-feb-16-2016-austin-texas/

American Public Power Association. (2013). *Distributed generation: An overview of recent policy and market developments*. Washington, DC: American Public Power Association (APPA). Retrieved from https://sites.hks.harvard.edu/hepg/Papers/2013/APPA%20Distributed%20Generation%20Paper%2011%2013%20Final.pdf

American Public Power Association. (2016). *Public power for your community*. Arlington, VA: American Public Power Association (APPA). Retrieved from https://www.publicpower.org/system/files/documents/municipalization-public_power_for_your_community.pdf

Austin Energy. (2016). *Austin energy's tariff package: 2015 cost of service study and proposal to change base electric rates*. Austin, TX: Austin Energy. Retrieved from http://www.austintexas.gov/edims/document.cfm?id=246853

Austin Energy. (2017a). *Austin energy annual report fiscal year 2017*. Austin, TX: Austin Energy.

Austin Energy. (2017b). *Austin energy resource, generation and climate protection plan to 2027*. Austin, TX: Austin Energy. Retrieved from https://austinenergy.com/wcm/connect/6dd1c1c7-77e4-43e4-8789-838eb9f0790d/2027+Austin+Energy+Resource+Plan+20171002.pdf?MOD=AJPERES&CVID=lXv4zHS

Austin Energy. (2018a). *Renewable resources*. Retrieved from https://data.austintexas.gov/Environment/Renewable-Resources/c2a6-efzi/data

Austin Energy. (2018b). *Community solabration marks grand opening of la Loma, largest community solar project in ERCOT*. Retrieved from https://austinenergy.com/ae/about/news/press-releases/2018/solabration-marks-grand-opening

Backlund, S., & Eidenskog, M. (2013). Energy service collaborations–It is a question of trust. *Energy Efficiency*, *6*(3), 511–521. https://doi.org/10.1007/s12053-012-9189-z

Bartos, M. D., & Chester, M. V. (2015). Impacts of climate change on electric power supply in the western United States. *Nature Climate Change*, *5*, 748–752. https://doi.org/10.1038/nclimate2648

Bastida, F., Guillamon, M., & Benito, B. (2014). Explaining interest rates in local government borrowing. *International Public Management Journal*, *17*(1), 45–73. https://doi.org/10.1080/10967494.2014.874257

Blackburn, G., Magee, C., & Rai, V. (2014). *Solar valuation and the modern utility's expansion into distributed generation*. https://doi.org/10.1016/j.tej.2013.12.002

Braun, G., & Hazelroth, S. (2015). *Energy infrastructure finance: Local dollars for local energy* https://doi.org/10.1016/j.tej.2015.05.008

Byrne, J., Martinez, C., & Ruggero, C. (2009). Relocating energy in the social commons. *Bulletin of Science, Technology & Society*, *29*(2), 81–94. https://doi.org/10.1177/0270467609332315

Byrne, J., & Taminiau, J. (2016). A review of sustainable energy utility and energy service utility concepts and applications: Realizing ecological and social sustainability with a community utility. *WIREs Energy and Environment*, *5*(2), 136–154. https://doi.org/10.1002/wene.171

Byrne, J., Taminiau, J., Seo, J., Lee, J., & Shin, S. (2017). Are solar cities feasible? A review of current research. *International Journal of Urban Sciences*, *21*, 1–18. https://doi.org/10.1080/12265934.2017.1331750

Byrne, J., Wang, Y., Taminiau, J., & Mach, L. (2014). The promise of the green energy economy. In J. Byrne & Y. Wang (Eds.), *Secure and green energy economies* (pp. 1–17). New Brunswick, NJ: Transaction.

Carlisle, K., & Gruby, R. L. (2017). Polycentric systems of governance: A theoretical model for the commons. *Policy Studies Journal*, 1–26. https://doi.org/10.1111/psj.12212

Chu, C., Bruner, A., & Byrne, J. (2015). *DESEU energy efficiency revenue bonds series 2011: Project savings analysis*. Newark, DE: Center for Energy and Environmental Policy.

City of Austin. (2007). *Resolution no. 20070215-023*. Austin, TX: City of Austin. Retrieved from http://austintexas.gov/sites/default/files/files/Sustainability/ACPP_resolution_20070215-023.pdf

Consortium for Energy Efficiency. (2017). *2017 state of the efficiency program industry - budgets, expenditures and impacts*. Boston, MA. Retrieved from https://library.cee1.org/system/files/library/13561/CEE_2017_AnnualIndustryReport.pdf

California Public Utilities Commission. (2017). *Community choice aggregation en banc background paper*. California Public Utilities Commission. Retrieved from http://www.cpuc.ca.gov/general.aspx?id=2567

California Public Utilities Commission. (2018). *California customer choice: An evaluation of regulatory framework options for an evolving electricity market*. California Public Utilities Commission. Retrieved from http://www.cpuc.ca.gov/customerchoice/

Crandall, K., Bailey, H., Gichon, Y., & Koehn, J. (2014). Chapter 22 - turning a vision to reality: Boulder's utility of the future. In F. P. Sioshansi (Ed.), *Distributed generation and its implications for the utility industry* (pp. 435–452). Boston, MA: Academic Press. https://doi.org/10.1016/B978-0-12-800240-7.00022-9

Delaware Sustainable Energy Utility. (2017). *Delaware sustainable energy utility - annual report 2017*. Delaware Sustainable Energy Utility. Retrieved from https://evogov.s3.amazonaws.com/50/media/127658.pdf

DeShazo, J. R., Gattaciecca, J., & Trumbull, K. (2017). *The promises and challenges of community choice aggregation in California*. Los Angeles, CA: Luskin Center for Innovation.

Energy Information Administration. (2017). *Electric power sales, revenue, and energy efficiency form EIA-861 detailed data files*. Washington, DC: Energy Information Administration. Retrieved from https://www.eia.gov/electricity/data/eia861/

Environmental Protection Agency. (2018). *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2016*. Washington, DC. Retrieved from https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2016

Fox-Penner, P. (2010). Smart power. *Climate Change, the Smart Grid and the Future of Electric Utilities*. Washington.

Gagnon, P., Margolis, R., Melius, J., Phillips, C., & Elmore, R. (2018). Estimating rooftop solar technical potential across the US using a combination of GIS-based methods, lidar data, and statistical modeling. *Environmental Research Letters*, *13*(2), 024027.

Halstead, R. (2015a). Critics: Marin clean energy not so clean and green. *Marin Independent Journal.* Retrieved from http://www.marinij.com/article/NO/20150711/NEWS/150719957

Halstead, R. (2015b). PG&E wants Marin Clean Energy customers to pay more for exit ticket. *Marin Independent Journal*. Retrieved from https://www.marinij.com/2015/12/05/pge-wants-marin-clean-energy-customers-to-pay-more-for-exit-ticket/

Heeter, J., & McLaren, J. (2012). *Innovations in voluntary renewable energy procurement: methods for expanding access and lowering cost for communities, governments, and businesses*. Golden, CO: National Renewable Energy Laboratory (NREL).

Heiman, M. K., & Solomon, B. D. (2004). Power to the people: Electric utility restructuring and the commitment to renewable energy. *Annals of the Association of American Geographers*, *94*(1), 94–116. https://doi.org/10.1111/j.1467-8306.2004.09401006.x

Helms, T. (2016). *Asset transformation and the challenges to servitize a utility business model.* https://doi.org/10.1016/j.enpol.2015.12.046

Hess, D. J. (2013). *Industrial fields and countervailing power: The transformation of distributed solar energy in the United States.* https://doi.org/10.1016/j.gloenvcha.2013.01.002

Homsy, G. C. (2016). Powering sustainability: Municipal utilities and local government policymaking. *Environment and Planning C Government and Policy*, *34*(6), 1076–1094. https://doi.org/10.1177/0263774X15596530

Houck, J., & Rickerson, W. (2009). The sustainable energy utility (SEU) model for energy service delivery. *Bulletin of Science, Technology & Society*, *29*(2), 95–107. https://doi.org/10.1177/0270467608330023

Hughes, K. (2009). An applied local sustainable energy model. *Bulletin of Science, Technology & Society*, *29*(2), 108–123. https://doi.org/10.1177/0270467608330022

IEA. (2016). *Energy technology perspectives—Toward sustainable urban energy systems*. Paris, France: International Energy Agency.

IPCC. (2014). *Climate change 2014: Impacts, adaptation, and vulnerability. part A: Global and sectoral aspects. Contribution of working group II to the fifth assessment report of the intergovernmental panel on climate change*. Cambridge, England: Cambridge University Press.

Joint application of southern California Edison company. (2017). *Joint application of southern California Edison company (U-338-E), pacific gas and electric company (U 39-E), and San Diego gas & electric company (U 902-E) for approval of the portfolio allocation methodology for all customers.* Retrieved from https://www.sdge.com/sites/default/files/PAM_Joint_IOU_Application.pdf

Jones, K. B., Bennett, E. C., Ji, F. W., & Kazerooni, B. (2017). Beyond community solar: Aggregating local distributed resources for resilience and sustainability. *Innovation and disruption at the Grid's Edge: How distributed energy resources are disrupting the utility business model,* 65.

Kahn, A. E. (1990). Deregulation: Looking backward and looking forward. *Yale Journal on Regulation*, *7*, 325.

Kona, A., Melica, G., Koffi, B., Iancu, A., Zancanella, P., Calvete, S. R., … Monforti-Ferrario, F. (2016). *Covenant of mayors: Greenhouse gas emissions achievements and projections.*

Kuramochi, T., Höhne, N., Sterl, S., Lütkehermöller, K., & Seghers, J. (2017). *States, cities and businesses leading the way: A first look at decentralized climate commitments in the US.* Retrieved from https://newclimate.org/wp-content/uploads/2017/09/states-cities-and-regions-leading-the-way.pdf

Kushler, M., Baatz, B., Nowak, S., & Witte, P. (2015). *Municipal utility energy efficiency: Successful examples around the nation.* Washington, DC: American Council for an Energy-Efficient Economy (ACEEE). Retrieved from http://aceee.org/sites/default/files/publications/researchreports/u1510.pdf

Local Power Inc. (2009). *Community choice aggregation program report.* San Francisco, CA: Local Power Inc. Retrieved from https://sfgov.org/lafco/sites/default/files/FileCenter/Documents/19045-local_power_report_Feb09.pdf

Marin Clean Energy. (2017). *Financial statements: Years ended March 31, 2017 & 2016 with report of independent auditors.* Marin County, CA: Marin Clean Energy. Retrieved from https://www.mcecleanenergy.org/wp-content/uploads/2017/08/MCE-Audited-Financial-Statements-2016-2017.pdf

Marin Energy Authority. (2008). *Marin energy authority - Joint powers agreement.* Marin County, CA: Marin Energy Authority. Retrieved from https://www.mcecleanenergy.org/wp-content/uploads/2016/06/JPA-Agreement-with-Amendment-10-on-4.21.16-24-Communities.pdf

McDowell III, H. B., Byrne, J., Houck, J., Walker, R., Schreiber, J., Kurdgelashvili, L., … Zhou, A. (2007). *The sustainable energy utility: A Delaware first.* Sustainable Energy Utility Task Force. Retrieved from http://www1.udel.edu/SEU-DE/docs/2007_DE%20Senate_SEU_Task_Force_final_report.pdf

McLean, A., Bulkeley, H., & Crang, M. (2016). Negotiating the urban smart grid: Socio-technical experimentation in the city of Austin. *Urban Studies*, *53*(15), 3246–3263. https://doi.org/10.1177/0042098015612984

MRW. (2014). *Risk assessment of participation in the Marin Clean Energy Community Choice Aggregation program: On behalf of the city of Benicia*. MRW & Associates. Retrieved from https://www.mcecleanenergy.org/wp-content/uploads/2016/01/Benicia-MRW-analysis-.pdf

Musulin, K. (2017, December 4). Utility of the year: Austin energy. *Smart Cities Dive.* Retrieved from https://www.smartcitiesdive.com/news/utility-of-the-year-austin-energy/511127/

Negro, S. O., Alkemade, F., & Hekkert, M. P. (2012). *Why does renewable energy diffuse so slowly? A review of innovation system problems.* https://doi.org/10.1016/j.rser.2012.03.043

O'Shaughnessy, E., Heeter, J., Cook, J., & Volpi, C. (2017). *Status and trends in the U.S. voluntary green power market (2016 data*). Golden, CO: National Renewable Energy Laboratory (NREL). Retrieved from https://www.nrel.gov/docs/fy18osti/70174.pdf

Ostrom, E. (2010). Polycentric systems for coping with collective action and global environmental change. *Global Environmental Change*, *20*(4), 550–557. https://doi.org/10.1016/j.gloenvcha.2010.07.004

Parag, Y., & Sovacool, B. K. (2016). Electricity market design for the prosumer era. *Nature Energy*, *1*, 16032. https://doi.org/10.1038/nenergy.2016.32

Penn, I. (2017, April 30). Public energy programs save customers money—At least in the beginning. *Los Angeles Times.* Retrieved from http://www.latimes.com/business/la-fi-public-energy-programs-20170430-story.html

PG&E. (2018). *PG&E proposes reforms to support the state's clean energy future.* Retrieved from https://www.pge.com/en/about/newsroom/newsdetails/index.page?title=20180403_pge_proposes_reforms_to_support_the_states_clean_energy_future

Phung, T., Riu, I., Kaufman, N., Kessler, L., Amodio, M., & De Silva, G. (2017). *The effect of Austin energy's value of solar tariff on solar installation rates.* Lawrence Berkeley National Laboratory. Retrieved from https://emp.lbl.gov/sites/default/files/1._austin_vos_paper_final_2017-06-16.pdf

Prindle, B., Eldrige, M., Eckhardt, M., & Frederick, A. (2007). *The twin pillars of sustainable energy: Synergies between energy efficiency and renewable energy technology and policy*. Washington, DC: American Council for an Energy-Efficient Economy (ACEEE).

Rhodes, J. D., Upshaw, C. R., Harris, C. B., Meehan, C. M., Walling, D. A., Navrátil, P. A., … Webber, M. E. (2014). *Experimental and data collection methods for a large-scale smart grid deployment: Methods and first results.* https://doi.org/10.1016/j.energy.2013.11.004

Ribeiro, D., Bailey, T., Drehobl, A., King, J., Samarripas, S., Shoemaker, M., … Castro-Alvarez, F. (2017). *The 2017 city energy efficiency scorecard.* (Report No. U1705). Washington, DC: American Council for an Energy Efficient Economy (ACEEE).

Richter, M. (2012). *Utilities' business models for renewable energy: A review.* https://doi.org/10.1016/j.rser.2012.01.072

Rockwell, L. (2015a). Coming in 2016: A debate over new electricity rates from Austin energy. *Austin-American Statesman.* Retrieved from https://www.mystatesman.com/news/local/coming-2016-debate-over-new-electricity-rates-from-austin-energy/j5oY41boyq8GU57KXcDNxM/

Rockwell, L. (2015b). Austin city council takes middle road on solar energy purchase. *Austin-American Statesman.* Retrieved from https://www.mystatesman.com/news/local/austin-city-council-takes-middle-road-solar-energy-purchase/09adlM24MkMl8nbSIA9PlM/

Rockwell, L. (2016). Austin energy chief gives candid assessment of utility, city politics. *Austin-American Statesman.* Retrieved from https://www.mystatesman.com/news/local/austin-energy-chief-gives-candid-assessment-utility-city-politics/u6ppzUlv6xJ3QJLHUiG4yK/

Roelfsema, M. (2017). *Assessment of US city reduction commitments, from a country perspective.* PBL Netherlands Environmental Assessment Agency. Retrieved from http://www.pbl.nl/sites/default/files/cms/publicaties/pbl-2017-assessment-of-us-city-reduction-commitments-from-a-country-perspective-1993.pdf

Ruppert-Winkel, C., Hussain, W., & Hauber, J. (2016). *Understanding the regional process of energy transition in Marin county, California: Applying a three-phase-model based on case studies from Germany.* https://doi.org/10.1016/j.erss.2016.01.003

Schlein, B., Szum, C., Zhou, N., Ge, J., & He, H. (2017). *Lessons from Europe, north America, and Asia: Financing models that are facilitating building energy efficiency at scale.* Berkeley, CA: Lawrence Berkeley National Laboratory (LBNL). Retrieved from https://eta.lbl.gov/sites/default/files/publications/eceee_6-146-17_schlein_final.pdf

Smeloff, E., & Asmus, P. (1997). *Reinventing electric utilities: Competition, citizen action, and clean power*. Washington, DC: Island Press.

Sovacool, B. K. (2011). National energy governance in the United States. *The Journal of World Energy Law & Business*, *4*(2), 97–123.

Stoner, P. G., & Dalessi, J. (2009). *Community choice aggregation pilot project.* Sacramento, CA: Public Interest Energy Research (PIER). Retrieved from http://www.energy.ca.gov/2008publications/CEC-500-2008-091/CEC-500-2008-091.PDF

Stuart, E., Carvallo, J. P., Larsen, P. H., Goldman, C. A., & Gilligan, D. (2018). Understanding recent market trends of the US ESCO industry. *Energy Efficiency*, *11*, 1303–1324. https://doi.org/10.1007/s12053-018-9633-9

Sustainable Energy Utility. (2019). Energy efficiency revenue bonds series 2019. *Energize Delaware*. Retrieved from https://emma.msrb.org/IssueView/Details/ER388643

Taminiau, J., & Byrne, J. (2016). Reconsidering growth in the greenhouse: The sustainable energy utility as a practical strategy for the 21st century. In G. Dale, M. V. Mathai, & J. A. Puppim De Oliveira (Eds.), *Green growth: Ideology, political economy and the alternatives* (pp. 233–252). London, England: Zed Books.

Taminiau, J., Nyangon, J., Ariella, S. L., & Byrne, J. (2017). Sustainable business model innovation: Using polycentric and creative climate change governance. In Z. Fields (Ed.), *Collective creativity for responsible and sustainable business practice* (pp. 140–159). Hershey, PA: IGI Global. https://doi.org/10.4018/978-1-5225-1823-5.ch008

Tertzakian, P., & Hollihan, K. (2009). *The end of energy obesity: Breaking today's energy addiction for a prosperous and secure tomorrow*. Hoboken, NJ: John Wiley & Sons.

Toohey, M. (2012). Austin city council approves electric rate hike. *Austin-American Statesman.* Retrieved from https://www.statesman.com/news/local/austin-city-council-approves-electric-rate-hike/Aw3zxUnQr66QA2Xm6jP3XP/

Toohey, M. (2015). Lawmakers give Austin energy a verbal beating. *Austin-American Statesman.* Retrieved from https://www.mystatesman.com/news/lawmakers-give-austin-energy-verbal-beating/uv7B7nORBnPWDfKcuwveOP/

Trabish, H. K. (2018). Exit fee: deciding the fate of California's utilities and customer choice movement. *Utility Dive*. Retrieved from https://www.utilitydive.com/news/exit-fee-deciding-the-fate-of-californias-utilities-and-customer-choice-m/529894/

Wagner, T. R. (2016). *Sustainable energy utility, inc.—Inspection.* State of delaware office of auditor of accounts. Retrieved from https://auditor.delaware.gov/wp-content/uploads/sites/40/2017/01/SEU-Inspection-Report.pdf

Walton, R. (2016). Delaware auditor criticizes energy efficiency program as 'inadequate'. *Utility Dive.* Retrieved from https://www.utilitydive.com/news/delaware-auditor-criticizes-energy-efficiency-program-as-inadequate/412200/

Wilson, E. J., Christensen, C. B., Horowitz, S. G., Robertson, J. J., & Maguire, J. B. (2017). *Energy efficiency potential in the U.S. single-family housing stock*, *US.* Retrieved from https://www.osti.gov/servlets/purl/1414819

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