Advanced Review

A review of sustainable energy utility and energy service utility concepts and applications: realizing ecological and social sustainability with a community utility

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Strategies that guided development throughout the 20th century relied heavily on economic optimality as a chief guiding principle in the design of energy, technology, markets, and policy. A review of the record of performance of this decision-making process is followed by a review of proposals to redefine energy progress on sustainability principles. An emerging 21st sustainability paradigm is described which relies on commons-based economics and long-term ecological viability. An existing operational expression of the new paradigm—the Sustainable Energy Utility (SEU)—is analyzed as a practical means to arrive at the New Economics and New Policy which might guide the sector. It is compared to the Energy Service Utility and its applications in order to gauge the transformative potential of the SEU.

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INTRODUCTION

A defining challenge for social and ecological progress in the 21st century is balancing the interplay between our planet's climate and society's energy throughput. On the one hand, nearly one third of humanity is unable to affordably access modern society's energy-driven development process,[1,2] and significant effort is urged to lift the 'bottom billion'[3] out of their 'energy poverty trap'.[4,5] On the other hand, those fortunate enough to live in the modern enclave enjoy services and benefits brought about by increasing levels of 'energy obesity'.[6,7]

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Spreading the high-carbon lifestyle as the epitome of what it means to live well is cited by many as a key cause of global unsustainability, straining the world's planetary boundaries.[7,8] In its most recent assessment, the Intergovernmental Panel on Climate Change (IPCC)[9] concludes that unless humanity changes course, ecosystem health is at serious risk. Indeed, the IPCC finds that continued development along the path followed in the 20th century could result in food, economic, and social insecurity on a scale not seen before (Ref 9, p. 11–14).

While the provision of electricity and other energy services can be critical to social development and poverty alleviation,[10,11] environmental sustainability threats—not only climate change, but also, among others, widespread deforestation, ocean acidification, biodiversity loss, habitat destruction, and air pollution—underscore the need to provide energy services under a paradigm-shifting development regime which can deliver broad energy access, poverty alleviation, and the pursuit of quality of life improvement *without* further risk of environmental crisis.[12–14]

Two efforts to reconstruct energy policy consistent with this objective are reviewed: the Energy Service Utility[15,16] and the Sustainable Energy Utility (SEU).[7,17] The theoretical basis for each model replacing optimality thinking with sustainability principles is assessed. Empirical use in several applications in and beyond the U.S. to deliver *sustainable* energy, materials, and water services is also examined.

OPTIMALITY'S APPROACH TO CLIMATE AND ENERGY CHALLENGES

Modernity's successes have given rise to the idea that improved human welfare and, eventually, an end to poverty can be realized when technological and economic criteria guide development.[18–20] The optimality goal of 'the greatest benefit for the greatest number' is believed to be reachable through reliance on the so-called 'bottomless well' of human ingenuity expressed particularly in scientific and technological innovation.[20] Throughout the 20th century, modern energy invention clearly preferred increasingly large-scale and centralized technologies that could deliver enormous amounts of light, heat, motion, and so on, or what Byrne and Rich[21] characterized as 'abundant energy machines' and Lovins depicted as the 'hard path' of development.[22,23]

Measured on its own terms, the hard path worked and its proponents argue that continued technological and scientific advancements are available which can maintain economic momentum while reducing overall burdens on the environment.[a,19,20,28–30] Significant advances would be needed as the U.S. Energy Information Administration (EIA), e.g., projects a 56% increase in global energy consumption by 2040.[31] To fuel fast-growing demand and simultaneously address concerns of air pollution, climate change, and other forms of environmental degradation, hard path infrastructure ideals are advocated by some in the build-out of a renewable energy subsector[20,28,30] and one researcher's study of the recent history of renewable energy development suggests that energy abundance and technical and economic optimality have often trumped sustainability.[32] In essence, in an attempt to drive modernity's expansion while mitigating negative ecological consequences, a 'bigger is greener' mentality[33] is proposed to power ever larger renewable or low-carbon energy installations.[34–36] Repeated calls for 'Manhattan Project' type programs for renewable energy[37] foster optimality thinking for our future existence.

DOUBTING THE EFFECTIVENESS OF SUSTAINABILITY AS A MODIFIED FORM OF OPTIMALITY

But research on growing environmental problems doubts the validity of this ideal view of the future. So-called 'Green Giantism' is challenged by an increasing number of researchers who regard the proposition as tantamount to an oxymoronic appeal for transformation without change.[38] Potentially irreversible decline in biodiversity,[39] sudden permafrost melt,[40] and unexpected speed of ocean warming and acidification[11] complicate global efforts to address persistent patterns of inequality and endemic poverty by 'more-of-the-same' development planning.[41,42] It appears that modern society's 'Great Acceleration'[43] and rise into the 'Anthropocene',[44] both made possible due to the supply of abundant energy, may produce ecological and social consequences of unprecedented proportions.

Faced with such risks, a modified optimality response has been proposed in line with what has been termed a 'weak' notion of sustainability.[45,46] The aim is to sensitize market participants and reshape economic decision-making, so that no- or low-carbon products are favored. A carbon credit commodity is advocated to intensify competition between energy technologies and sources by elevating prices for carbon intensive energy sources and, thereby, improving the competitive position of low-carbon energy sources.[47,48]

In sum, economic optimality's response to the dual challenge in the 21st century of greater energy access *and* sustainable development is to rely on self-directing market forces. Natural limitations are answered with a 'governance by capital' approach that aims to attenuate ecological repercussions but simultaneously allow for continued maximization of economic growth.[49,50] Public policy is tasked with facilitation of the search for economies of scale, the creation of new markets, and better management of existing markets.[48,51,52] Under the optimality paradigm, future energy development and its ecological footprint are to be decided by this 'governance by capital' approach, with citizens exercising control through their decisions as end-use consumers of energy. Social agency is confined to a form of 'consumer democracy' and an optimistic belief in technological cures.[50,53–56]

The two-pronged policy proposal of promoting green technology giantism and governance by capital intends to lower a society's carbon intensity while sustaining economic growth, a strategy which has been coined by several organizations and researchers as 'green growth'.[57–61] In this regard, optimality's

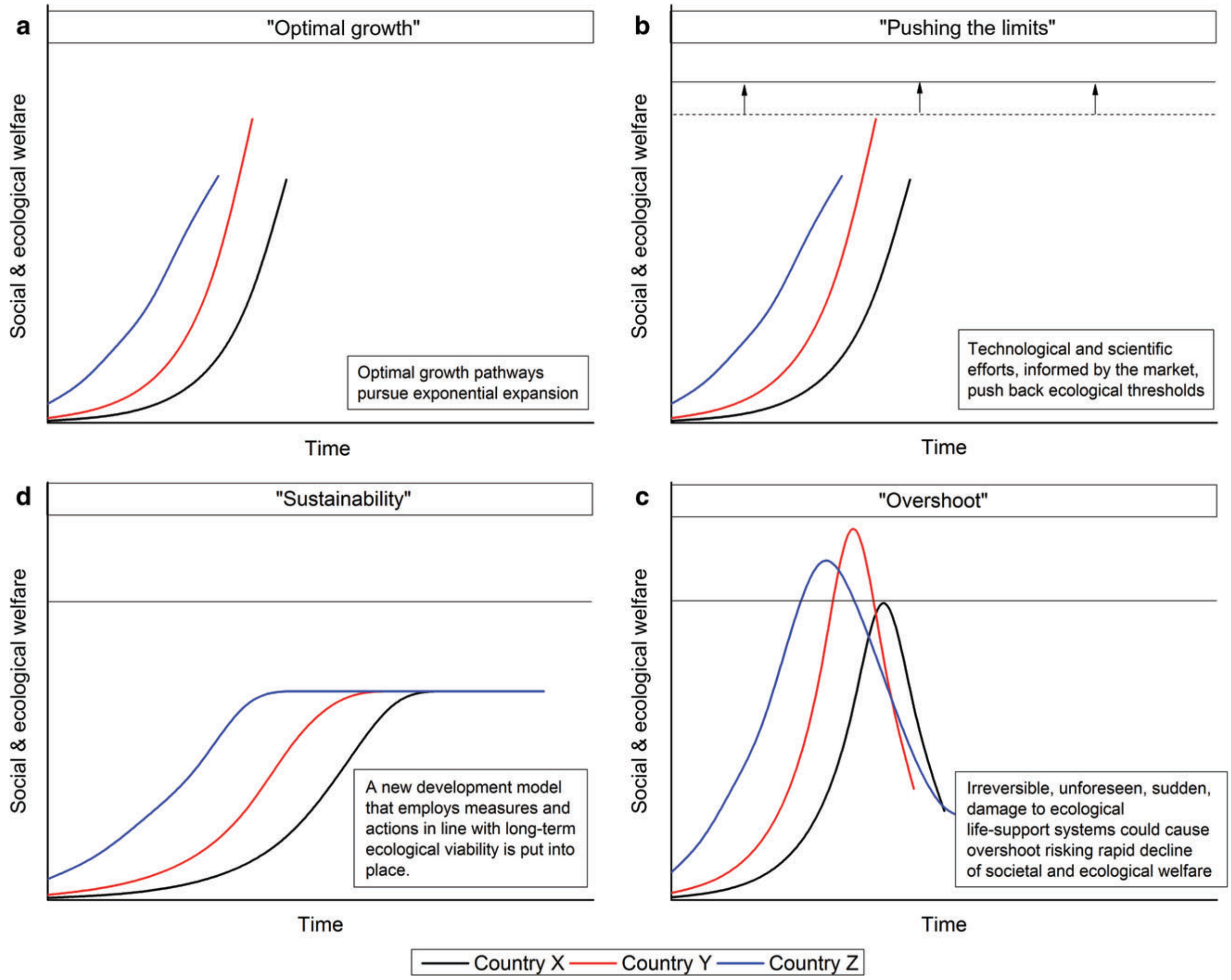

FIGURE 1 | (a)–(d) A hypothetical depiction of optimality's economic pursuit contrasted with the New Economics of Ecological Sustainability. Source: Adapted from Refs 45, 46.

response rationalizes unbroken economic growth,[62] translating sustainability into an economic principle of, hopefully, ecologically sensitive expansion. And it addresses social concerns with a 'cornucopian principle'[50] which posits an egalitarian promise for those who agree to support governance by capital. Indeed, this paradigm typically combines the promise with a warning[b] which, in the case of energy policy, often means that any serious effort to reduce its use is criticized as risking a future of 'de-growth'.[64] Under such a conceptualization, the only viable goal for society is continued expansion,[62] complicating adherence to sustainability constraints.

The suitability of optimality-based decision-making processes to the task of 'strong' sustainability goals in which environmental constraints are intentionally regarded as 'stop signs' rather than 'speed bumps' is concerning to many. Observations of thresholds, tipping points, and planetary boundaries[8] are difficult, if not impossible, to translate into marginal 'governance by capital' decision-making. Moreover, key natural resource stocks that provide critical life-support functions[65–67] might be unavailable for substitution and green technology giantism may actually deflect attention in the false belief that boundaries are being addressed by technological innovations.[38]

Figure 1(a)–(d) illustrates the resulting dilemma associated with the optimality response and outlines how a new development model could prevent fundamental damage to ecological life-support systems. Optimality's original pursuit of prosperity seeks realization through exponential economic growth without much attention to environmental consequence (Figure 1(a)). But, with time, potential and actual ecological externalities are recognized. A revision of optimality is then made to address problems by concerted efforts to improve technological and scientific know-how, supported by a market-development process that captures ecological value vectors and transmutes them to fungible alternatives stimulated by economic exchange (Figure 1(b)). Optimality's expansionist drive and preference for 'more and bigger' in the belief that things will be 'better' breeds risk-taking until, for example, higher energy throughput and increased levels of consumption *in themselves* produce harm. When natural limitations are overshot, ecological damage could be at scales and intensities that threaten to undo welfare gains (Figure 1(c)). Mounting evidence points not only to the existence of such conflict but increasingly also suggests the high risk of crises if boundaries are crossed.[9]

A development model built to be consistent with long-term ecological viability would appear to require a paradigm shift in economics and governance such that prosperity is sought expressly from activities which reduce pressure on the environment while enhancing living conditions and establishing equity (Figure 1(d)). It is this model which we next review in terms of its theory and application.

ESTABLISHING SUSTAINABILITY AS A PRINCIPLE OF THE COMMONS

Garret Hardin´s famous argument on the 'tragedy of the commons'[68] cited management structures that fail to recognize the conflict between rational private wealth maximization and the frailty of the common good. He urged the replacement of commons management schemes with property-based ones in the hope that wealth maximization could be re-dimensioned to include valuation of ecological risk by those who have an interest in worrying about this dimension—allegedly, property owners. In this way, Hardin's thesis was a precursor of contemporary efforts to conceive sustainability as a refinement of market-based rules placed on shared resources such as the atmosphere in order to harness optimization as an environmental improvement, or more aptly, to modernize nature.[7,48,50,69–71] Importantly, the sustainability case is captured by the 'governance by capital' approach and weakens any commitment to sustainability constraints.[51,72–75]

Despite worldwide commitment to elaborate commodity-based carbon management schemes,[76,77] only economic recession has been able to materially affect (but not reverse) the rising global atmospheric saturation of greenhouse gases.[57,78,79] A 'reality gap' between sustainability rhetoric and actual performance is apparent.[80]

Many have challenged Hardin's premise that commons-based management is destined to end in tragedy. Ostrom[81] and several others[82–85] have documented the opposite—well-functioning governance institutions and strategies, built on commons principles that have stewarded ecosystems to healthy coexistence with human communities in defiance of the prediction of tragedy. In many documented cases, the success of the commons is several centuries in length.[7,84,86] Commons-based economics and governance offer a critical distinction, whereas sustainability as a proposal to refine optimality translates as 'growth within limits'[87] 'singularizing' social and ecological values into economic terms[88]; sustainability as a proposal of the commons works to restore social institutions grounded in shared obligations to observe and adapt to limits defined in natural terms (e.g., untradeable carbon constraints) and in social terms (i.e., the obligation of equitable burden sharing rather than equity-dismissive burden shifting schemes (see Refs 7, 89, 90). An opposite diagnosis to Hardin's would appear to be supported by this empirical record: 'moderns cannot be trusted in the commons' but this only reinforces the need to recover commons-based economics as a possible strategy to undo harms that modernity has persistently failed to resolve.[7]

Finally, optimality's market rationality reduces community members to anonymous end-use consumers.[50,53] A shift away from that approach could reconstitute the social relations of energy in a manner which enables all of us to act in the wider public landscape of sustainable futures.[7,38,91] In contrast to 'consumer democracies',[56] alternative governance structures focused on 'energy democracy'[92] and alternative political economies like those embedded in 'sustainable energy utilities' can repurpose policy, economics and engineering to the search for sustainable public benefits.[7,38,93–95]

Community Sustainability's Promise for the Energy Sector

In the energy space, significant promise exists in practical form to pursue a commons-based sustainability transition. In fact, the capital to launch the transition already exists: it is found in the one energy option routinely neglected by the optimality model—conserving energy, or more precisely reducing energy needs. Whereas the long-traveled optimality path fears the de-growth risks of energy reduction, sustainability models can harness the economic savings of reduced use of energy commodities as the means to capitalize the *public* benefit of the new approach. By redirecting economic capital from the singular purpose of growth in private wealth (e.g., gross national product) to the public purpose of building an infrastructure anchored in sustainable energy (namely, conservation, and renewable sources), society possesses the ready ability to prosper and, at the same time, observe natural boundaries and achieve public purposes of fair and just prosperity. In this respect, an economics of public benefit, governance in the interest of that benefit, and a commons culture of socially appreciated natural limits and public purposes can act synergistically to enable the *practical* pursuit of sustainability.

Substantial volumes of re-directable economic value are widely recognized in the energy sector. In the United States, e.g., building energy performance options are estimated to cost $279 billion in investments that would yield over $1 trillion in energy savings across a 10-year period.[96] Another report finds that *annual* U.S. nontransportation energy efficiency potential is approximately $1.2 trillion in savings volume against an initial $520 billion investment.[97] Studies at the global scale find similar energy savings potentials.[98–105] A global estimate by the World Business Council on Sustainable Development (WBCSD) reports a 60% energy savings potential by 2050.[106] Using *less* energy will produce significant environmental and economic benefits in terms of climate change mitigation, green job creation, and pollution reduction. The adequate capture of energy efficiency in load forecasts, furthermore, can substantially reduce short- and long-term customer costs primarily due to reductions in capacity procurement costs.[107] The pursuit of all of these benefits can, together, improve energy access and social participation (by making this critical service affordable).

The relevant conservation options to initiate a commons-based sustainability path would need to be self-funding, delivering more savings than their original investment cost. In fact, worldwide self-funding conservation potential is estimated at a significant US $30 trillion.[108] However, as the Consortium for Energy Efficiency (CEE) shows, much of this potential remains untapped. At a 2011 combined U.S. and Canadian expenditure for gas and electric demand-side management of $7.6 billion, the United States and Canada are nowhere near fully exploiting their energy efficiency and conservation potential.[109,110] Similar self-funding investment potential in onsite renewable energy generation and microgrids exists,[111,112] raising the prospect of society's members affecting consumption *and* supply—creating not simply 'prosumers'[113] but sustainable citizens.[114]

The explanation of why this potential has not been realized increasingly appears to be paradigmatic: optimality (including its 'green growth' version[c]) versus sustainability as the guiding principle for energy investment. Amory Lovins noted in 1977 that it would be 'spherical nonsense' to believe one can pursue hard and soft paths as complementary options.[23] The same appears to apply for optimality and 'strong' sustainability.

ENERGY SERVICE UTILITIES—MOVING AWAY FROM OPTIMALITY

The practice of energy sustainability on an infrastructure level will inescapably produce conflict. Importantly, sustainability-inspired conservation and decentralized renewable energy use, from an optimality perspective, are actually threats to the status quo and will attract resistance; what in an earlier publication by one of the authors was called the 'dynamic conservatism' of political economy.[115] Naturally, current investor-owned energy companies and their political supporters argue the importance of these threats:

1. Sustainable energy programs essentially represent a financial loss that requires conventional utility cost recovery mechanisms to offset decreased utility revenues and the cost of 'stranded assets'.[116,117]
2. Successful energy efficiency programs decrease conventional utility financial returns, thereby increasing the long-term cost of capital to owners of the existing energy infrastructure.[118,119]
3. Unless integrated on the terms and conditions of profitability of current energy companies, renewable energy development threatens the viability of the energy sector.[120,121]
4. Integrating onsite renewable energy generation and microgrids into the existing energy sector is expensive and contradicts the architectural logic of modern utility systems.[54]

As sustainable energy program spending increases,[122,123] (due, in part, to states' and municipalities' increasingly aggressive energy efficiency policies[124]), inherent conflicts between the optimality-based energy utility business model and sustainable energy development have escalated. While several mechanisms have been proposed to overcome such conflict,[125] efforts to establish 'regulatory' energy efficiency or renewable energy frameworks—ones that incentivize or force energy utilities to overcome their inherent business model complications—might well be replaced by models that excel in the direct delivery of sustainable energy. In the latter case, conflict is recognized but there is no compulsion for either party to overcome it. Instead, competition sets in (politically and economically). The need for a new 'governor' of energy is apparent[126,127] and the likelihood grows that the new governor will emerge from political and economic competition.

One business model in the evolving energy sector is the energy service utility model[15,128–130] that, unlike conventional investor-owned energy utilities, provides services such as hot water, clean electricity, or sustainable materials rather than commodities like kilowatt-hours, therms, and so on. While several distinctions between the two models can be made (see Ref 128, p. 1036, table 2), two stand out:

1. Energy service contracts establish long-term, close, and comprehensive relationships between the energy service utility and the customer unlike the standard, billing-based, and distant relationship [d]between the conventional energy utility and the consumer.
2. While the optimality-based utility business case couples revenue to energy consumption, the energy service utility couples revenue to energy conservation. In other words, unlike conventional energy utilities, energy service utilities are actively incentivized to reduce energy consumption (and associated greenhouse gas emissions).

The distinctions between conventional investor-owned energy utilities and energy service utilities lead some to reserve significant space for the new model in a transition to a low-carbon economy.[131,132] The most widely cited U.S. energy service utilities are Efficiency Vermont and Energy Trust of Oregon (see, e.g., Refs 15, 16) and both have outperformed the energy saving efforts of conventional utilities. The record of performance, documenting the energy savings portfolio of the two models over a 12-year period is calculated in Figure 2.

The success of energy service utilities within an overarching framework of investor-owned utilities has led some to characterize the problem as evolving the sector to a 'utility 2.0' platform. In this case, investor-owned utilities 'would be akin to traffic cops, coordinating the flow of electricity instead of functioning as a monopoly'.[135,132] The platform would allow energy service utilities to operate competitively in the energy market, compensated by conventional utilities for their delivery of decongestion and other ancillary services and their lower-cost energy services to the customers of the conventional utilities.

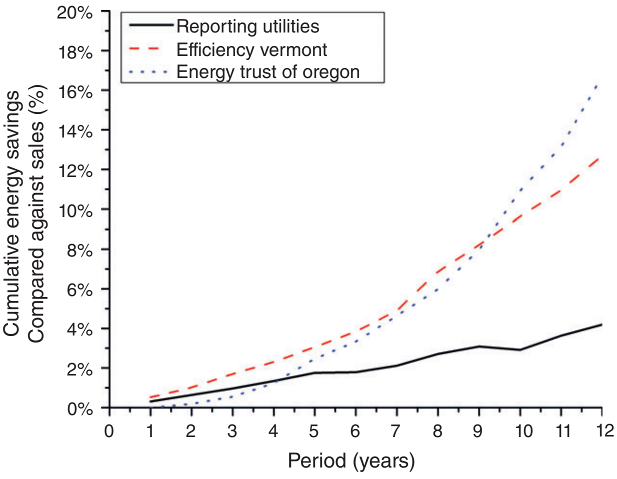

FIGURE 2 | Cumulative energy savings as a percent of sales: comparing U.S. investor-owned energy utilities and energy service utilities (Efficiency Vermont and Energy Trust of Oregon). *Notes:* Energy savings for Efficiency Vermont and Energy Trust of Oregon are extracted from their annual reports (see, e.g., the most recent reports for Efficiency Vermont[133] and Energy Trust of Oregon[134]) for the 2001–2012 period. Energy sales data are obtained from EIA Form 861 (electricity) and Form 176 (natural gas).[162] The 'reporting utilities' are the conventional utilities that have communicated energy savings to the EIA, but data are restricted to electricity savings and sales. However, the essential message of Figure 1, that the energy services utilities significantly outperform the conventional utilities, remains unchanged when the savings profile for both efficiency utilities is also restricted to electricity sales and savings.

SOCIAL CHANGE 2.0: A SUSTAINABLE ENERGY UTILITY

Energy efficiency markets continue to face persistent barriers like high initial upfront costs for installations, limited capital availability, and negative perceptions of risk and securitization that will need to be overcome to establish a workable strategy at the infrastructure level. In particular, energy services utilities, due to their relatively recent introduction and unfamiliarity, are perceived by financial organizations as higher risk models compared with conventional energy utility models,[128] further restraining capital availability.

But there is also an important conceptual constraint which needs to be recognized. By design, energy service utilities are intended to carve out markets for efficiency *without* shifting the energy paradigm. Specifically, the model and its applications anticipate parallel operations without a clear path for replacing optimality economics with a commons alternative. Moreover, the model often relies on funds from conventional utilities to underwrite energy efficiency investment. If conventional utilities did not exist, energy efficiency utilities would cease operations.

To facilitate infrastructure-level change in the energy sector, more may be needed. The search for a more complete model of transformation has recently begun – to conceive and implement an institutional strategy which no longer depends for its implementation on its 'fit' with the utility model built in the 20th century; i.e., the search for what one could call 'Social Change 2.0'. Here, the SEU model is reviewed as one example that could successfully overcome prevailing barriers, realize a substantial dial-back in energy use, dramatically enlarge the role of renewable energy, *and* empower a shift in social, economic, and ecological paradigms.

Positioned as a new governor of energy–economy–environment relations, an SEU was first conceived in a series of policy papers published in 2006–2007.[17,38] This led to the enactment of the idea by statute in the U.S. state of Delaware in 2007. Versions of the strategy have subsequently been created in several U.S. jurisdictions and the model is under active consideration in Asia and Europe (see Section *Diffusion of New Energy Economics and Governance*).

An SEU aims to redefine social and market forces to realize a fundamental transition to sustainability. Departing from the supply-side approach of conventional energy utilities, the SEU offers a comprehensive approach to deliver on-site energy services.[7,17,136] It pursues a carbon-free energy economy, providing energy services rather than energy commodities, accelerating a transition to a decentralized energy service and governance geography, and directly involving the wider community in the decision-making process.[7,17,136] An SEU functions as a central clearing house for comprehensive programs (efficiency, conservation, renewable energy; materials, water, and energy) and is authorized to leverage private capital markets and deploy self-financing strategies in its efforts to deliver energy services to the community it serves.[7,17,136]

The typical barriers to energy efficiency measures—high upfront costs, limited capital availability, and the need to charge ratepayers for using less—are overcome through a reliance on New Energy Economics that draws its power from the commonly held wealth of the community.[7] 'Commonwealth economics'[7] lead to a sharing of investment costs to reach energy dial-back, a deployment of local and renewable energy sources to fulfill any remaining energy needs, and a sharing of the benefits of such an energy future. As such, an SEU operates in a state of community trust: its performance to realize public benefits is evaluated directly by the community—does participation in an SEU enable the pursuit of social, economic, and ecological progress? If yes, an SEU attracts civil engagement. If it fails this test, it loses the trust of the community.[7] The state of community trust created by the SEU thus sets the conditions for social acceptance *and* social engagement, elements that can substantially hinder the implementation of any innovative approach, such as a Social Change 2.0 strategy, as their absence often evokes opposition.[137]

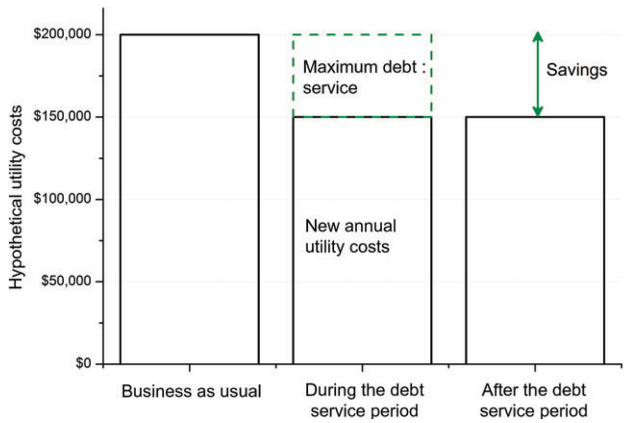

FIGURE 3 | SEU monetization of energy savings. Source: Ref 138.

In contrast to energy obesity economics where private producers decide and gain, SEU energy development decisions are based on the common interest of—and benefit for—the community as users *and* producers.[114] The resulting 'community utility' leverages community shared future savings to cover initial high upfront costs on its pathway away from energy obesity economics: the monetization of validated future community savings lowers investment risk and is used to attract capital investment (Figure 3).[e]

One of the signature innovations of the SEU model is its capitalization strategy and capabilities. The authority to deploy self-financing strategies, especially revenue-generating sustainable energy bonds, directs private investment capital towards public ends,[7] unlike energy obesity economics where public funds underwrite private financial gains.[139–141] This pathway to sustainable energy financing allows for infrastructure-level investment as a first key step to long-term capitalization of clean energy development.

The sustainable energy financing strategy of the SEU overcomes several well-known barriers. A prominent feature is the use of appropriation-backed bonds and revenue bonds[142] where, unlike general obligation bonds that are backed by a government's taxing authority, the public sector's appropriation process is employed to strengthen the investment's credit worthiness. This structure produced a stable and low-risk investment environment, winning an AA+ rating from Standard & Poor's Rating Service for a recent

TABLE 1 | Comparison of Investor-Owned, Energy Service, and Sustainable Energy Utilities

	IOUs	ESUs	SEUs
Key purpose	Expansion of supply and distribution infrastructure	Reducing utility costs by investing in the efficiency of end-use technology of energy services	Commons-based sustainability: cuts energy requirements based on sustainability-defined constraints
Business model	Increasing electricity sales and earning a guaranteed rate of return from investments	Supplements IOUs by taking over energy efficiency activities that conflict with the core business model of IOUs	Apply commonwealth economics (community savings potential) to fund Social Change 2.0 investments
Governance	Stockholders and utility regulators	Utility regulators	Community utility
Utility–client relationship	Producer–consumer	Service provider–customer	Seeks to empower sustainable citizens and communities

Delaware SEU bond investment.[138] The use of standardized and transparent contractual arrangements for all participants further strengthens credit worthiness. The SEU documents developed for Delaware are useable in a number of financing structures (as discussed in Ref 143), in this way guiding private market actors to address community-defined public benefit. Additionally, unlike metrics for conventional energy efficiency and on-site generation projects which measure performance in KWh or therms, the SEU deploys guaranteed grid energy savings contracts that outline contractually obligated *monetary* savings, further improving debt repayment assurance.

The SEU model can apply the same New Energy Economics principles to attract third-party financing, philanthropic grants, nonprofit sustainable energy funds, crowdfunding,[144] and carbon market auction proceeds. All can be harnessed by an SEU in its mission to deliver community benefits.[f] This capacity to draw on different funding sources allows the SEU to support a broad variety of programs targeting all community members and all energy service needs.

A summary of key differences between investor-owned utilities (IOUs), energy service utilities (ESUs), and Sustainable Energy Utilities (SEUs) is provided in Table 1. Importantly, operating as a community utility, the SEU model can be organized by communities of almost any scale (towns, cities, or regions) or by a variety of groups (e.g., churches, farms, business association, etc.) that seek to gain governing authority over their energy future.[g]

Impact of the Community Utility Approach

Consideration of the SEU performance record demonstrates the transformative promise of the community utility approach. In particular, the SEU's promise stands out when:

1. its actual use is extrapolated from its community context to national impact;
2. when it is compared against conventional energy economics; and
3. when its application to renewable energy markets is examined.

Each of these cases is analyzed in the following sections.

Extrapolation of Results to a National Context

The SEU's transformative power is revealed when actual outcomes of its practice are extrapolated. For example, if the United States adopted an SEU financing strategy based on the 2011 tax-exempt bond sale which received an S&P AA+ rating (noted above), it would unlock a $25 billion clean energy investment market in the municipality, university, schools, and hospitals (MUSH) sector alone. Using this market-tested strategy, the United States could expect this application to result in 300,000 construction, project management, engineering and finance jobs.[h] The avoided carbon dioxide emissions from a nationally equivalent investment in sustainable energy measures in the MUSH building sector is estimated to be more than 225 million metric tons, or a reduction in annual U.S. commercial sector emissions of more than 5% from just 4% of the MUSH building stock.[i] Such an application of the SEU model would outperform the U.S. Government's Energy Service Performance Contract Program by a factor of six and save taxpayers $500 million.[145] Annual replication of these impacts could readily continue for at least 20 years (by annually applying the capitalization strategy to 5% of the building unit area of the MUSH sector). Once the 20-year investment cycle would be completed, an SEU's original investments could be refreshed since equipment and envelope warranties typically expire in 10–25 years. For the United States, this raises the possibility of 20–25% reductions in commercial sector CO_2 emissions. Working through the credit enhancement needs for other building sectors and applying this one SEU program (there are many others) to all buildings could result in a 50% GHG reduction for the U.S. by use of *domestic* actions only.[j] These extrapolations underscore the significant potential and promise of the SEU.

Bond Capitalization Versus Conventional Rebate Programs

The SEU capitalization strategy introduces a savings potential for participating organizations which promises private investors a tax-free return on investment, backed by contractor performance guarantees. Benefits of the program include:

1. Program participants receive cost savings on their utility bills that are contractually guaranteed to cover the full cost of all energy saving measures (including the application of renewable energy options to reduce grid demand). Additional benefits can accrue from contractual monetary savings as future price volatility and perhaps unstable consumption patterns do not undermine the business case—unlike when energy service contracts are formulated in physical units (therms, kWhs, etc.) within a regulated utility environment (thereby invoking contradictions in the business model of the utility). For this reason, public investment planning may actually be less risky when an SEU approach is employed.
2. Contractors have an incentive to forecast conservative energy savings amounts to ensure compliance with contractual obligations. Any additional savings increase the public benefit.
3. Aggregating all participants under a single financing lowers transaction costs and borrowing costs thereby reducing the total cost of the investment—a benefit especially to medium- and small-size MUSH actors whose sustainable energy investments (considered on their individual merits) are too small to attract bond buyers.
4. Credit risk is low in the case of public agencies with strong credit histories which is rewarded with the lowest cost of capital in the marketplace.
5. Perhaps most important, the New Energy Economics applied here uses the public sector's normally superior credit rating to underwrite *public* infrastructure transformation as the leader in societal infrastructure change thereby positioning the public sector—and its far more transparent decision-making processes—to define sustainability. This commons leadership approach replaces commodity thinking as the governor of sustainability.

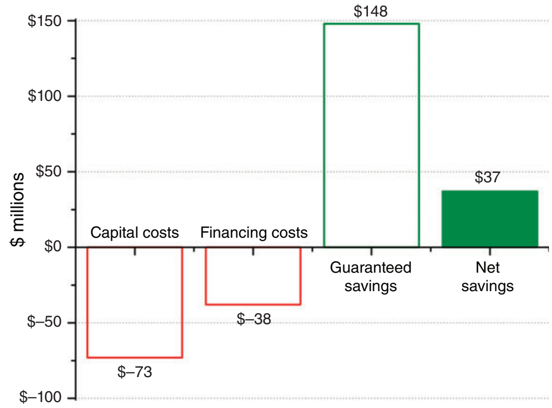

FIGURE 4 | Overview of the 2011 Delaware SEU energy efficiency bond issue. Source: Ref 138.

The first of its kind in the United States, the statewide tax-exempt bond issued in 2011 by the nonprofit Delaware SEU[k] attracted $72.5 million of investment from the private market.[138] The bond issue included contractual guarantees of $148 million in savings which cut energy use in participating buildings by more than 25% for 20 years (the 2011 bond issue average payback period was almost 14 years and the longest maturity was 20 years, while average performance guarantees were greater than 20 years) (see Figure 4).[138] No tax obligation to support the bond issue was given and no capital funds were required by the participants to realize its AA+ rating.

The Delaware SEU has operated its bond and other programs for 3 years. The transformative power of the novel SEU capitalization strategy is evident when contrasted against conventional utility energy efficiency programs such as rebates and loans (Table 2).

Table 2 documents how, over the 20-year lifetime of the bond program, energy use on the order of 7.2 million MMBTU is avoided, roughly corresponding to the total energy use of 33,000 Delawarean households[l] or, said another way, the realized energy savings in the public sector through the bond program are equivalent to establishing energy self-sufficiency for nearly 10% of the state's households. Notably, this *single* SEU application affected less than 5% of the building footprint of the public sector meaning that an ongoing investment process can be expected to

TABLE 2 | Delaware SEU Savings Profile—Energy Efficiency

Lifetime Savings	Sustainable Energy Bond[1]	Rebate Programs[2]
Avoided grid energy use (MMBTUs)[3]	7,253,592	1,139,157
Emissions avoided (metric tons of CO_2)[4]	661,687	122,646
Total capital costs[5]	$67,435,000	$17,295,143[6]
Costs/MMBTU avoided [7]	$2.05	$3.34
Costs/metric ton of CO_2 avoided [7]	$22.42	$31.02
Gross program bill savings [5]	$147,889,405 (guaranteed)	$5,179,935 (estimated)

[1]Savings data are sourced from Investment Grade Energy Audits.
[2]The Delaware SEU maintains several rebate programs. The programs, with the average rebate per participant in parentheses: Appliance Rebate ($68), Residential Lighting ($1.13 per bulb), Home Performance with Energy Star ($497), Green for Green ($3647), and Efficiency Plus Business ($1909).
[3]Electricity savings have been converted to primary energy savings to reflect avoided grid energy use.
[4]The emission factor for the PJM Interconnection for 2012 (0.510 ton CO_2/MWh) has been used. To reflect changes in the fuel mix of the grid due to policy factors (such renewable energy portfolio standards) and market factors (such as the improving competitiveness of renewables), this emission factor is assumed to decrease by 1.9% per year (based on analysis of recent PJM data). A 7-year lifetime is used for the rebate programs and a 20-year lifetime is used for the sustainable energy bond.
[5]The SEU bond covered all capital, operating and maintenance, and transaction costs. An all-in cost for the August 1, 2011 bond was $110 million, producing a net revenue stream of $38 million. Because rebate program costs cover only a portion of total capital and operating costs (e.g., recipients must pay the difference between the rebate and the device cost, and they must assume installation and maintenance cost themselves), it is not possible to report a net revenue stream with the accuracy of the bond program. It is important to note that the SEU bond covers all capital costs—not simply the incremental cost of the efficiency improvement. By contrast, rebates cover only incremental costs of efficiency improvements.
[6]The program cost is $9,403,826, of which $3,381,993 was used to offer rebates. The rebates, however, only cover 30% of the total capital cost of the equipment. Participants must cover the remaining 70% of the capital cost. These costs are included in the total capital cost reported here.
[7]In contrast to the total capital costs—which reflect all costs associated with the equipment—the costs illustrated here are limited to the additional cost associated with the energy efficiency equipment compared to a benchmark conventional energy unit. In this regard, the reported costs reflect the needed additional cost to go beyond 'business-as-usual' and to opt for the more efficient unit. Based on a review of the research literature and results from DOE-2 (a simulation software developed for the U.S. Department of Energy), it is assumed that, on average, the capital cost premium paid for a more efficient device is 22%. There is evidence that the premium in the residential sector is higher than in nonresidential applications. However, statistical variation around sector estimates can be large. Therefore, a composite value is used.

reproduce such results indefinitely. In terms of greenhouse gas emissions avoided, the sustainable energy bond lifetime savings correspond to about 9.2% of the state's 2010 nontransportation emissions. [m]

During 2009–2012, the Delaware SEU operated a suite of loan and rebate programs funded by federal programs. Its programs in content and implementation were nearly identical to those implemented by conventional utilities in the Mid-Atlantic region. The Delaware SEU's loan and rebate programs [n]offer a unique opportunity to compare the effects of the New Energy Economics and its conventional counterpart. Based on real-time performance of the two options, the New Economics of the bond program produced energy savings at 40% lower cost per unit of saved energy and avoided 25% more carbon per invested dollar (Table 2). In contrast to the SEU's rebate programs, the bill savings from the Sustainable Energy Bond are *guaranteed*. Its loan and rebate program savings, like those of conventional utilities, rely on estimates using average appliance lifetime, use, baselines, etc. and are not guaranteed. Finally, the new capitalization strategy generates self-financing investment (viz. $148 million in guaranteed savings on a capital investment of $67.4 million or all-in investment cost, including debt service, of $110 million) versus an expenditure program which requires combined program and participant investments of $17.3 million in order to realize projected (not guaranteed) benefits of only 30% of costs.

Advancing Renewable Energy Markets

The Delaware SEU also supports local renewable energy development. The United States renewable energy development is directed in 36 of its 50 states by a combined policy effort of mandatory or voluntary Renewable Portfolio Standards (RPS) and Renewable Energy Credits (RECs).[149,150] Delaware is among the 36 states employing these tools and has a high RPS mandate (25% of electricity sales from qualifying renewable sources by 2026), a solar 'carve out' (at least 3.5% of sales from solar electric power in 2026—second highest in the United States) and an obligation to comply with state standards by buying RECs in a competitive market organized by the SEU. In 2012, the Delaware SEU created an auction platform for spot and future solar REC trading. The SEU's involvement has positioned Delaware's solar market as seventh in the country on a per capita sales basis.[o34,151] The effects on local renewable energy generation are reported in Table 3.

The Transformative Potential of the SEU Concept

Combining the benefits presented in the previous sections, Figure 5 illustrates the transformative

TABLE 3 | Delaware SEU Savings Profile—Solar Energy Programs

	Dover Sun Park[1]	2012 SREC Auction[2]
Avoided grid energy use (MMBTUs)[3]	111,332	669,332
Emissions avoided (metric tons of CO_2)[4]	16,334	84,125
Program costs [5]	7,309,132	27,343,093

[1]At 10 MWp, the Dover SUN Park is one of the largest public sector installations on the U.S. east coast. As per the contract between the SEU and Delmarva Power, the SEU purchases 10,600 SRECs in year 1 and 2 and sells them back to Delmarva Power in year 4 and 5 of the 50-year program.
[2]The 2012 SREC program established a multi-tiered solicitation for long-term SRECs. Contracting with SRECTrade, the SEU awarded 20-year contracts to 166 PV systems with an estimated 7.7 MW of capacity.
[3]Electricity savings have been converted to primary energy savings to reflect avoided grid energy use. The total SRECs generated by the Dover SUN Park and the SREC Auction contain a 20% multiplier for in-state products. Here, this multiplier is subtracted. The Dover SUN Park displaces distribution (+3%) and the 2012 SREC Auction avoids both transmission and distribution losses (+7%). Additionally, it is expected that the PV panels will lose 0.5% per year of their rated power on average over 20 years and balance of system losses will average also 5% over the 20-year period.
[4]The PJM emission factor for 2012 (0.510 ton CO_2/MWh) has been used. To reflect changes in the grid, this emission factor decreases by 1.9% per year.
[5]In the case of the Dover SUN Park transaction, program costs reflect the cost to purchase the SRECs throughout the program lifetime and payment of SEU fees. For the SREC Auction, program costs include the purchase of SRECs for 20 years as well as the costs to contract with SRECTrade and payment of SEU fees.

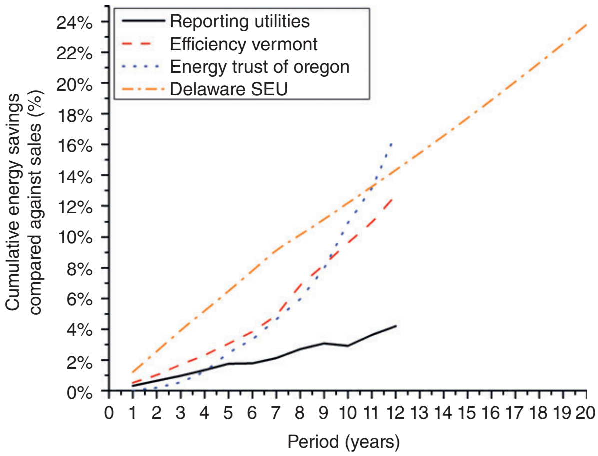

FIGURE 5 | Cumulative energy savings as a percent of sales: comparing investor-owned utilities, energy service utilities, and the Delaware sustainable energy utility. *Notes:* The Delaware SEU data include a single application of the bond issue calculated over the lifetime of the bond (20 years), the application of the loan and rebate programs (7 years), the Solar REC auction, and Dover SUN Park program. Like Figure 1, the data for Efficiency Vermont, Energy Trust of Oregon, and the Reporting Utilities, are drafted from reported savings and sales. The Delaware SEU data, however, draw from a combination of reported savings and expected future savings. To calculate expected future savings against future sales in the state of Delaware, sales growth rates are based on 2001–2012 growth patterns. Notably, bond issue savings are drawn from contractually guaranteed savings.

potential of the SEU concept. The cumulative natural gas and electricity savings of the DE SEU are contrasted with those reported above in Figure 2. Bearing in mind that these savings accumulate from only 3 years of DE SEU operations and a single application of the described innovative financing strategy, the Delaware SEU's rate of conversion of energy sales to energy savings is unprecedented.

With the community utility approach embodied in the SEU model, it is possible to realize the full meaning of infrastructure change. The sustainable energy technologies and markets it enables make long-lived changes to the energy sector and to society. Once the investments accumulate, energy dial-back, onsite renewable energy generation and deep carbon reductions are, effectively, irreversible. Equally important, societal decision-making and governance is embedded in sustainable citizenship and undoing this power would be akin to undoing social networks. Finally, the anchoring of economics in commons principles instead of commodity markets permanently changes the energy economy in a manner that is similar to the transformation of the communications sector – no one buys kWhs any more than communication markets sell 'minutes'.

Diffusion of New Energy Economics and Governance

Since its inception, the SEU model has gained significant traction across the United States and internationally. The model has been recognized by the U.S. White House[152] and the Asian Development Bank[153] and implementation of SEUs is being explored internationally.[b],91, 154–157 In 2014, the California Statewide Communities Development Authority (CSCDA) launched a Sustainable Energy Bond Program.[158] Like the bond issue in Delaware, the campaign in California will provide public agencies and nonprofits with access to tax-exempt capital to allow sustainable energy investments and to bring down energy costs. An innovation that will be deployed in California is an explicit inclusion of water conservation measures, contributing to the alleviation of a range of issues associated with the water-energy-climate nexus.[159] Similarly, the Pennsylvania Treasury launched a Sustainable Energy Bond Program with the aim of lowering public participants' utility costs by over 20%.[160] Organizers of the Pennsylvania program believe that routine bond investments in excess of $50 million are readily available.

In both states, the build-out would naturally rely on local engineering, equipment suppliers, and contractors, thereby engraining a sustainable energy future in the very communities that use *and* supply energy options. Again, transformation is possible because job creation multipliers for clean energy are typically 4–6 compared to conventional energy.[161]

Of course, the spread of this 'Social Change 2.0' thrust is hardly assured and will depend upon innovations in and across communities (virtual and geographical) to address ongoing problems and future challenges which cannot now be foreseen. Institutions inescapably face such issues in the present and future and their responsiveness and effectiveness are the tests of their viability.

A 21ST CENTURY SUSTAINABILITY PARADIGM

The optimality paradigm that guided 20th century energy development led to rapid growth in mostly fossil-fuel based energy production and a similar rise in energy intensive consumption. The paradigm succeeded in growing global income and wealth at rates unmatched in human history. But it also created an energy obese social condition with unacceptable social, climate, and other risks. Left to its own devices, the paradigm could only repair social and ecological harms at a pace consistent with economic growth. As the problem of climate change has made clear, however, this pace is far too slow to sustain a healthy future in human and ecological terms.

The proposal for sustainability as an economic principle has so far experienced difficulty in overriding optimality as the defining decision-making factor in human development, essentially reducing sustainability's translation to marginal costs or benefits affecting, without materially altering, the obesity defect of modern success. Transitioning away from the current energy intensive pathway of development will form a critical component of any development strategy that aims to enhance and maintain living conditions for the world's growing population without outpacing environmental carrying capacity or entrenching inequality in the human prospect.

Sustainability as a principle of commons development repositions the social dynamic away from singularizing individual gain and, instead, reconstitutes society as a matrix of community landscapes confronting the practical consequences of energy-environment-development interactions. The SEU appears to offer a promising practical strategy to deploy sustainability as an operational form of commonwealth economics.[7] SEUs can continuously organize investments creating significant potential for the model to substantially change the energy economy. At the same time, an SEU keeps value in the local context due to its bottom-up, polycentric governance and economic structure, thereby linking its viability to ongoing community trust.[7,95,144]

Business-as-usual scenarios clarify the untenable character of the 20th century's Great Acceleration as we move forward in the 21st century: when no action is taken, society will continue to push the limits and strain environmental boundaries. The range of concerns that modern society faces go well beyond the singular issue of energy, but abundant energy machines[21] are now a major part of the problem instead of a solution. The SEU model offers an opportunity to tackle modern dilemmas which have emerged from 20th century conventional utility performance. Building community trust and commonwealth economies, an SEU model may represent a Social Change 2.0 method to deliver transformation, rather than relying on incremental change of supply-side business-as-usual development to meet our dual challenge of social *and* ecological progress.

NOTES

[a] Notable exceptions are the work of Herman Daly[24,25] and Nicolas Georgescu-Roegen.[26,27]
[b] Sachs captured this warning in its broad form 15 years ago: "The [modern] development creed impedes any serious public debate on the moderation of growth. Under its shadow, any society that decides, at least in some areas, not to go beyond certain levels of commodity-intensity, technical performance, or speed appears to be backward" (Ref 63, p. 42).
[c] Elastic definitions of green growth, encapsulating a broad range of 'green' strategies, are unlikely to spur fundamental reorientation towards strong sustainability. While the degree of reliance on curative properties of efficiency-based growth clearly varies among the different 'tools' of green growth all versions remain dependent upon growth-without-end. Such dependence conflicts, finally, with the aspiration for long-term sustainability. In this respect, the problem is not an 'anti-growth' strain in thinking about sustainability but the ambivalence of green growth toward the 'stop sign' of long-term sustainability.
[d] This distance is partly created by the fiduciary obligation that conventional energy utilities have to their stakeholders—the owners of the company.

[e] It should be noted that an SEU can have no 'stranded assets' and cannot bill a community for nonuse of its programs and infrastructure, unlike the widespread practice of such billing in the conventional utility framework.

[f] Centralized energy regimes in the United States, Europe, Asia, or elsewhere may find the model threatening in some ways. But the loss of centralism in communications, computation, manufacturing or a host of other contemporary infrastructures should remind us that social, economic, and in some cases, environmental improvements have accompanied decentralization. China's recent experiments with economic restructuring as a means of poverty alleviation are a case in point.

[g] The Delaware SEU, e.g., serves as the administrator of 65% of Delaware's share of the Regional Greenhouse Gas Initiative (RGGI) auction proceeds. As well, the nonprofit focus of the SEU can enable injections of government funds and government-created incentives (e.g., public benefit charges).

[h] Based on an extrapolation of the results of the Delaware SEU bond offering in 2011. For details on the Delaware SEU bond offering, see Section *Bond Capitalization Versus Conventional Rebate Programs* of this article. For specific details, see Ref 138.

[i] The Delaware SEU financing (discussed in Section *Bond Capitalization Versus Conventional Rebate Programs* of this article) affected less than 5% of the state's MUSH building area and is guaranteed to save energy in participant buildings by 25% or more for 20 years.

[j] Authors' calculation.

[k] For more information on the Delaware Sustainable Energy Utility, see: http://www.energizedelaware.org/Sustainable-Energy/.

[l] To determine household energy consumption, EIA energy data[146] and U.S. census data were used.[147]

[m] Data on energy-related emissions were used for this calculation.[148] If the bond program is extended to residential, industrial and for-profit commercial buildings, the emission reduction quadruples.

[n] Such rebate programs provide access to sustainable energy services and technologies that are not otherwise available to some households and small businesses (where financing is not a realistic option). Embedding these programs in an SEU has the important institutional benefit of uncapping the volume of savings. Rebate programs funded and managed by conventional utilities (investor- and municipally owned) often struggle with the conflict of revenue redemption created by successful programs. The SEU has no conflict of this kind.

[o] The SEU solar energy market application is based on 20-year 'mirror' contracts between conventional utility SREC buyers and sellers of every type (i.e., institutional, residential, commercial, industrial, agricultural, and public properties). The SEU can sell SREC's over time at varying prices to conventional utilities with the goal of moderating boom-and-bust development cycles which have plagued U.S. SREC markets. Functionally, this turns the state's SREC market into a competitively established feed-in tariff. The hallmark of feed-in tariff policies has been rapid market growth, a feature now found in the SEU arranged SREC-market.

[p] One of the authors of this article, John Byrne, is involved in discussions about the future direction of the City of Seoul with the Seoul Metropolitan Government under the auspices of the Seoul International Energy Advisory Council.

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