<a> Tale of Two Sprawls: Energy Planning and Challenges for Smart Growth 2.0

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Abstract

Smart growth principles have focused on land use and transportation connections while ignoring the underlying energy infrastructure. In this chapter we explore ways to decrease energy consumption and increase renewable generation while upholding the goals of Smart Growth. Smart Growth policies promoting compact development can lessen transportation and building energy use. However, decarbonisation of the energy systems has the potential to create its own sprawl due to low energy density of renewables. In this chapter, we explore the challenges and opportunities associated with integrating energy planning principles into regional urban growth management. Land use guidelines can be used to lessen the institutional and physical barriers to reducing fossil fuel consumption and energy sprawl.

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<b> Introduction

Energy conservation was one of the 19 goals in Oregon's 1974 plan that was a harbinger to the Smart Growth movement (Oregon Department of Land Conservation and Development, 1974). While principles of sustainability and resilience have been embedded in Smart Growth principles, explicit acknowledgement of energy systems and their planning is surprisingly lacking in the literature (Lindseth, 2004).The compactness of urban form promoted by Smart Growth principles dovetails well with energy conservation efforts. Because consumption, conversion, production of energy and climate change are intrinsically linked, it is time to recognize energy systems as core infrastructure that constrains and directs urban growth rather than viewing them as ancillary planning issues handled by private firms, such as utilities.

Many principles of Smart Growth directly impact or are impacted by energy systems and their transitions. For example, mixing of land uses has implications for microgrids as they rely on renewable energy sources to account for time-of-day demand balancing. Creating walkable neighborhoods directly reduces the number of short trips taken by car and by public transit. However, electric cars and neighborhood electric vehicles are much more likely to be used for these trips (compared to intercity trips), because of current limitations on battery technology. Different housing types are shown to have differential energy consumption impacts; because of ownership structures and alignment of incentives, single family houses that are owned likely are more efficient on a per square foot basis, even when their total consumption is much higher than multi-family ones. The preservation of farmland and open spaces is as likely to be threatened by energy sprawl as it is by urban sprawl.

When considering the production end of the energy system, we ought to account for different stages of energy production and the implications on land uses. Kaza and Curtis (2014), identify these stages as 1) primary extraction of fuel 2) transmission/distribution of fuels or usable energy 3) siting conversion facilities 4) disposal of waste. Different technologies and fuels interact with urban development in different ways. For example, while rooftop solar converts its primary fuel into usable energy on-site, biomass must be collected and transported to a centralized facility before it can be converted. Utility scale renewables are likely to be located far from urban centers on pristine farmland and on ridgelines to maximize fuel extraction. The resulting transmission pipelines and corridors have been a cause of concern for impacting local (including Native American) lands. Disposal of fly ash from coal and permanent storage of nuclear waste have been perennial wicked planning problems.

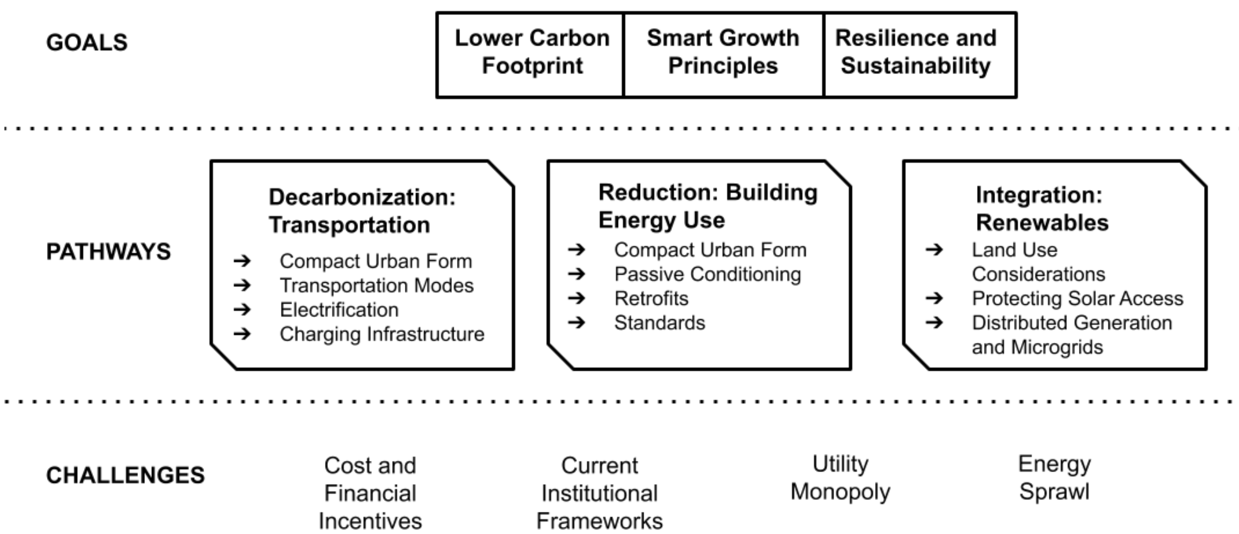
On the consumption end, urban form impacts energy through type, mix, size, and density of buildings. These features impact the level of energy demand and diurnal and seasonal variability privileging some forms of energy production over others. Furthermore, different climatic zones and different behavior patterns of households and organizations necessitate more nuanced approaches to sustainable and resilient urban form. Urban form also impacts transportation energy consumption through trip lengths, volumes, and mode shifts. Sprawling urban form allows for more on-site parking on single family residential lots and allows for electrification of personal automobiles. On the other hand, decarbonisation and, in particular, electrification of public transit systems are likely to be hastened by compact urban form.

Challenges to implementing “sustainable” energy policies primarily stem from institutional and financial barriers. The uncertainty and inconsistency associated with subsidies and tax rebates for renewable energy and electric vehicles have impacted investments in them. Retrofits could lower building energy use, but may not pay for themselves over a homeowners lifetime. The technology exists to build solar panels or wind turbines, but installing them at a large scale has a large capital cost. For a grid to run primarily on renewables, large investments in battery storage and grid modernization would be needed. Beyond direct costs, rooftop solar can run afoul of aesthetic codes, and land use codes may not take into account passive climate control.

Furthermore, energy planning in the United States has rarely been in the public domain, though such planning is widespread. Electric utilities are required to submit integrated energy management plans to the public utilities commission (PUC). Scenario planning approaches used in the public sector have been pioneered by Royal Dutch Shell, an oil and gas company. However, much of this private sector planning is directed within the firm or externally directed to engage with limited stakeholders, such as the PUCs, and rarely coordinated with other plans such as comprehensive or climate change adaptation plans of municipalities. Because of energy’s central role in maintaining economies, it is vital that public planning processes inform energy planning and vice versa. In particular, urban development plans, and by extension, Smart Growth principles should explicitly acknowledge the role of energy. In addition, very few of the procedural planning principles have been used in the energy planning realm. It is time to make energy a central component of urban development processes.

We assert that decarbonization can be accomplished without compromising on Smart Growth Principles. Figure 16.1 outlines the paths to a lower carbon future and the challenges that must be addressed to achieve Smart Growth Energy. Transportation and buildings are responsible for most US energy consumption; compact development can be crucial for lowering the energy intensity of both. Solar energy is the key renewable resource, and land use codes can empower buildings to harvest it for energy and climate control. Renewables, however, may lead to their own land sprawl without guiding codes of their own. Legislative, regulatory, and financial uncertainties can stand in the way of achieving all these goals; greater regional control, taking into account local conditions may prove to be necessary.

Figure 16.1 Pathways and challenges for incorporating energy planning principles in smart growth



<b> Decarbonisation: Transportation

Decarbonisation of the transportation system is usually conceptualized along two dimensions: mode substitution and fuel substitution. Different transportation modes have different energy efficiencies. Similar arguments can be made about fuels. In this section, we focus on decarbonisation through electrification of the transportation sector. However, it would be remiss not to mention the effect of Smart Growth principles (compactness, diversity of land uses) on mode switching.

<c> Compact Urban Form, Transportation Modes and Energy Efficiency

The connection between land use and transportation is unassailable. Dense cities, in general, consume less per capita transportation energy (Baker & Steemers, 2003), even though there is some disagreement about the magnitude of this correlation (Echenique, Hargreaves, Mitchell, & Namdeo, 2012; Handy, 2005; TRB & BEES, 2009). Nonetheless, transportation volumes and modes are intricately tied to land use characteristics (Kaza, 2020). Compact development enables biking, walking, and mass transit systems (Filion & McSpurren, 2007). These modes, in general, consume less per capita energy than gasoline powered automobiles. However, in the United States, per passenger mile energy consumption of transit motor buses in 2017, is 7% higher than that of passenger cars (Bureau of Transportation Statistics, 2019). This is largely driven by low load factors of buses in a large number of urban areas (Randolph & Masters, 2008). Compact development, coupled with context sensitive design can significantly increase the number of people using the transit system.

Shared automobility (for example ride-hailing services such as Uber, Lyft) poses a peculiar problem for land use patterns. Shared automobility might affect personal vehicle ownership and usage (Hampshire, Simek, Fabusuyi, Di, & Chen, 2018). The deadhead losses in these systems are around 42 percent (Henao & Marshall, 2019). This effectively means that these systems are likely to reduce the need for parking and increase congestion on the road, because of increases in Vehicle Miles Travelled (Erhardt et al., 2019). Thus, ride-hailing trips are likely to use vehicles that rely on conventional liquid fuels, slowing the adoption of (fully) electric vehicles. Congestion in parking lots is more likely to be offset by congestion on roadways, because of these ride hailing services. The deadhead losses are likely to be lower in denser urban environments.

<c> Electrification & Charging Infrastructure

In 2018, the transportation sector accounted for 28 percent of the energy consumption in the United States. 92 percent is derived from petroleum based liquid fuels, while less than 1 percent comes from electricity. Much of the electricity used in transportation is in mass transit systems (US Energy Information Administration, 2019b). With the advances in battery technology, the range anxiety associated with electric vehicles is starting to decrease, spurring increasing adoption of electric vehicles. According to some projections, 55 percent of new vehicle sales will be electric by 2040 (Jones, Levy, Bosco, Howat, & Van Alst, 2018). The electrification of personal transport, with the continuing adoption of electricity for mass transit systems will impact land use planning processes and Smart Growth principles.

The key land use issue for the electrification of personal automobiles is the ubiquity of the charging infrastructure. Current refueling efforts with liquid fuels require strategically located gasoline stations in addition to robust transmission and distribution infrastructure associated with petroleum products (e.g. pipelines and tankers). To hasten transportation electrification, similar infrastructure should be created for electricity. While transmission and distribution of electricity are not a major concern in the United States, the location and availability of the charging stations are a key factor in adoption of electric vehicles. Furthermore, because gasoline refueling times are shorter than electric vehicle charging times, the throughput of gasoline stations is higher. Charging infrastructure will thus need to be available at places where vehicles are stationed for a longer duration (parking lots, driveways). Thus, electrification of personal transport may substantially increase the number of required parking spaces because of higher occupancy rates and lower throughput rates. On the other hand, battery swap or wireless refueling systems will have lower land use impact. Housing type also interacts with adoption of electric vehicles. Households in single family houses with off-street parking are more likely to adopt electric vehicles because of ease of charging infrastructure (level 1). The impact of charging infrastructure on the electrical grid may have diurnal effects. Charging during the day, when ‘peakers’ are operational in producing electricity, is less ideal than charging at night when electrical demand is met by base load power plants. Simulation studies that quantify this total effect of electrification of transport on land use are lacking.

<b> Reduction: Energy Addiction in Buildings Through Smart Policies

Residential and commercial buildings were responsible for 40 percent of all energy consumption in 2018 (US Energy Information Administration, 2019a). Single-family detached homes make up a disproportionate fraction of residential energy use. Residential buildings overall consume 41 percent of energy for space conditioning. Because energy use is correlated to building size, promoting compact building design through density will lead to energy savings.

<c> Compact Urban Form

The value of density and compact development is discussed in other chapters, but we would be remiss to not touch upon the role density can play in lowering building energy consumption. Density is achieved usually through housing type (single family vs. multi-family) or land use efficiency (e.g. smaller lots). With increased density comes increased sharing of energy infrastructure and increased viability of district-wide heating and cooling systems (Güneralp et al., 2017). Multi family units typically are smaller in floor area and share walls contributing to the shared space conditioning loads (Ewing & Rong, 2008). However, on a per square foot basis, single family houses are more energy efficient than multi-family units (Kaza, 2010).

Urban form affects residential energy use primarily by affecting the housing stock and urban heat islands. Areas with constrained land supply (as seen in compact counties) tend to favor more efficient multifamily and attached housing, though the exact mechanism of the effect is unclear (Ewing & Rong, 2008). Urban heat islands are caused by constructed surfaces, lack of plant canopy, vehicle travel, and waste heat from electricity use. The urban heat island creates a greater need for energy consumption in hot seasons. Compact development does increase this heat island, nevertheless counties with compact development consume less energy than those with sprawling development.

The impact of compact urban form on passive heating and cooling is less clear. Density that does not take into account solar irradiation could lead to a greater need for electric heating or lighting. An analysis of the UK showed that the drawbacks outweigh the benefits for residential development at densities greater than 200 dwelling per hectare (Steemers, 2003). In areas where air conditioning is only required due to building depth, large office or apartment buildings could limit the ability of residents to use natural ventilation and increase the need for air conditioning (Steemers, 2003). This key point will be addressed later: the importance of regional climate and conditions when determining energy use. In areas where natural ventilation is a viable option year-round for cooling, the effect of density on ventilation is a key factor, while in areas where air conditioning is the only means to effectively cool (such as Houston, Texas, where you would be unwise to crack a window to cool down in July) this is not an issue. There is no one size fits all prescription.

<c> Passive Conditioning

While much of the work in passive heating and cooling will be the result of building specific technologies (such as double-glazed windows and natural ventilation), shaded, and sunlight hours will be determined by building orientation and the surrounding landscape. The urban heat island effect can be reduced with greenscape. Deciduous trees provide shade to facades in summer and allow sunlight through in winter (van Esch, Looman, & de Bruin-Hordijk, 2012). Specific setback requirements can encourage or discourage shading. Equator-facing windows and walls give a greater opportunity for passive cooling and heating. Buildings that use passive cooling/heating could have expedited permitting processes. Several American cities have already adopted such guidelines, and a list of many of them can be found in the American Planning Association's "Planning and Zoning for Solar Energy" Packet (Planning Advisory Service, 2011). Land use and building guidelines regarding solar access for passive heating can also be applied to distributed solar generation, which is covered later.

Cities that use standard grid layouts with tall buildings flanking a street create an "urban canyon" microclimate, with different wind, temperature, and shading patterns compared to an open area. This usually leads to an increased urban heat island effect, especially for north/south oriented canyons. Wide streets allow for more heat capture in east/west oriented canyons. Therefore, narrow streets are better at mitigating the heat island effect in canyons, and wider east/west oriented streets may help areas hoping to use the canyon's solar gain as passive winter heating (van Esch et al., 2012). North/south canyons provide more sun in the dead of winter, while east-west canyons provide midday shade on the streets (van Esch et al., 2012). Roof pitch and awning size also play a role in where and to what degree the canyon affects solar access.

<c> Retrofits

At an individual building level, energy efficiency retrofits are one of the simplest methods to reduce energy consumption by targeting space conditioning (Güneralp et al. 2017)**.** These retrofits can be accomplished directly by municipalities and by providing financial incentives to homeowners and businesses. Efficiency doesn't end at the building itself, but includes internal appliances and patterns of use. More efficient refrigerators, light bulbs, washing machines, windows, and more can save 30-75 percent over the standard (Brown & Southworth, 2008). Retrofits can include better insulation, weatherization, solar water heating, replacing natural gas burning equipment with electric and installing energy efficient lighting and appliances. As renewable penetration increases, time-of-use plays a larger role in lowering the carbon footprint of energy consumption, increasing the importance of smart appliances and timed energy use (including EV charging). Storage is expensive, and while the sun is highest at noon, energy use often peaks right after work in the early evening (US Energy Information Administration, 2011)**.**

Attaching a price signal to time of day energy use can promote adoption of these technologies and encourage manual smart energy use. There is also a need to electrify heating and cooking systems rather than expand natural gas infrastructure. A recent study shows that methane emissions of four major US cities due to natural gas alone add up to 827 000 tons per year, the same warming effect as 26.5 million tons of CO_2 (Plant et al., 2019). Propane heating also causes warming out of scale with electric heat.

<c> Setting a Standard for Standards

Green building standards have been used to promote sustainable building and energy efficiency in various places. In the United States, standards such as Leadership in Energy and Environmental Design (LEED), Energy Star are useful starting points for reducing building energy use. In one study an average LEED building used 18-39 percent less energy per floor area than an average non-certified building, but the levels of certification are not found to correlate with energy conservation (Newsham, Mancini, & Birt, 2009). Another study in New York City found no savings in LEED office buildings and in fact higher energy use in Silver and Certified buildings, even though ENERGY STAR certification showed better energy performance (Scofield, 2013). LEED certified buildings command a premium as markets place increasing value on “green” (Kahn & Kok, 2014). It should also be noted that while LEED and Energy Star (for residences) are design and building standards, whereas Energy Star for commercial buildings is a performance standard and certification has to be renewed periodically.

However, the methods to achieve energy efficiency must vary by location. Installing Energy Star air conditioning units in Alaska should not be valued as highly as doing the same in Ecuador. LEED currently uses essentially the same criteria to certify buildings worldwide, with only 3.6 percent of the points value used for assigning a certification reserved for “Regional Priority”. “Energy and Atmosphere” is the only category that is directly related to energy consumption, and it only constitutes 31.8 percent of the ranking (Suzer, 2015). If different regions created their own certifications or if existing certifications placed more weight on local environmental concerns, the certifications would have more relevance. In the American Southwest, standards should prioritize water conservation, air conditioning efficiency, building insulation and shade usage, whereas in Sweden standards might value the ability to passively heat the building.

In addition to building scale standards, neighborhood scale standards have also been in play. Prominent among those is LEED for Neighborhood Development (LEED ND), a neighborhood-wide certification given by the US Green Building Council. This standard faces similar drawbacks to LEED’s building standards. Because of its wide range of criteria, it is impossible to generalize about the efficacy of these standards. There are valuable considerations in the LEED ND criteria from an energy perspective, such as giving points for reducing heat island, solar orientation, district heating/cooling, and renewable energy production. Regional priorities make up at most four points (of 110) of certification criteria (US

Green Building Council, 2014). However, we are unaware of any systematic post-hoc analysis of the actual energy impact of LEED ND certification on communities.

The lack of efficacy of LEED standards highlights the importance of the human factor in energy conservation. A more efficient building could lead to less efficient practices, commonly known as the rebound effect. Knowing one's building is LEED certified could lead to fewer conservation actions by the humans using the building, as they trust the building to do most of the work. Without post-construction efficiency metrics and certifications, there is no guarantee of actual reductions in consumption. Repeated energy audits tracking the actual energy use are the best way to truly evaluate the effectiveness of efficiency measures

This presents an additional marketing challenge over construction certifications: transfer of ownership of buildings does not usually include transfer of conservation practices. To counteract these issues, new building benchmarking and disclosure laws are being adopted in various cities in the US (Hsu, 2014). These laws are designed to reduce the information gap that limits investments in energy efficiency and conservation. The process of collecting information for disclosure also spurs individual and organizational action (Hsu, 2014). Different policies can be tailored to commercial buildings and multi-family units. Utility-based programs that compare a household's energy consumption to that of their neighbors have been shown to reduce energy consumption (Allcott & Mullainathan, 2010).

We stop short of offering many specific, generalizable recommendations because the ideal guidelines are context sensitive. Street orientation, lot setbacks, density, passive climate control, and canyons all play a role in energy consumption from space conditioning. However, shade might be desired year-round in Mali, but not in northern Finland. Most building energy is used for heating and cooling, so controlling how the space interacts with the sun is key to reducing energy use. Beyond temperature, optimizing energy use to coincide with the availability of renewables on the grid will lower energy costs and carbon footprints. Specific policies, guidelines and standards must be context sensitive to be effective at conserving energy.

<b> Integration: Renewables and Energy Sprawl

Smart Growth grew out of the need to curb sprawling development, as sprawl led to destruction of open space and degradation of environmental quality. Smart Growth literature often expounds on the problems caused by urban sprawl, but less is written on the land use impacts of energy infrastructure. Much of the infrastructure required for energy generation and transmission has a large land use footprint, and energy sources that rely on burning liquid or solid fuel have the additional environmental impact of extraction. Renewables may take up vital open space, locations historically used for agriculture and wildlife habitats without land use regulations. This "Energy Sprawl" can already be seen in areas that have committed to renewables without a coupled commitment to preserving open space (McDonald, Fargione, Kiesecker, Miller, & Powell, 2009). Smart Growth principles such as redeveloping areas within the urban core, promoting infill development and preserving open and natural areas can be applied to the siting of renewable energy generation.

<c> Land Use Considerations

Renewables tend to be less energy dense than conventional fuels. Direct footprints (on unusable land) are approximately 15 square kilometers per terawatt-hour (km^2/TWhr) for solar PV and closer to 127 km^2/TWhr for wind. A terawatt is 10^{12} Watts: for reference the US consumed 29 688 TWhrs of electricity in 2018 (US Energy Information Administration, 2019a). Conventional energy production, on the other hand, has a total footprint of 0.64-8.19 km^2/TWhr on average. Nuclear power has the lowest land use impact of 0.13 km^2/TWhr, though this does not take into account disposal sites (Trainor, McDonald, & Fargione, 2016). One study estimates that if cap and trade were implemented, decarbonizing conventional energy systems with utility scale renewables in the United States would require 206 000-290 000 km^2 of new land by 2030 (McDonald et al., 2009).

Even more acutely, biomass and biofuel crops have land use requirements far greater than those of any other energy source, requiring an average of 809 km^2/TWhr, more than 53 times that required for solar PV (Trainor et al., 2016). Thus, decarbonisation of energy systems requires substantial land use footprint and directly contravenes the compact land use development that underlie Smart Growth principles. Furthermore, the effect of this decarbonisation is geographically differentiated. In the US, the West has both rich energy resources and wild lands important for unique threatened species. Projections put the potential land use footprint at 20.6 million hectares by 2030, primarily in boreal forests, shrublands, and grasslands (Copeland, Pocewicz, & Kiesecker, 2011). None of this should be seen as an argument against renewables, as climate change is still the greater threat.

Spain's initial renewable boom, where land use planning and energy planning were detached, provides a useful case study of pitfalls of rapidly expanding clean energy without considering ancillary impacts. Over 20 gigawatts of solar and wind generation were installed since 1993, enough to power between 3.3 and 6.7 million households. However, these systems are often sited on agricultural land, precipitating the decline of Spanish agriculture (Prados, 2010). These areas also allow renewables to take advantage of the preexisting irrigation infrastructure, potentially leading to conflicts over water rights. The lack of regulatory clarity in terms of siting has also led to conflicts between local government, regional governments, and environmental groups. This lack of coordinated planning has led to large numbers of small-scale plants, increasing the transmission burden (Prados, 2010). Without incorporating Smart Growth principles in energy planning, agricultural land could disappear and water resources could be strained.

PV or solar water heaters installed on rooftops and building facades is the gold standard of renewable siting, as there are few if any land use impacts. Parking lots and brownfields could also be used as solar farm sites with minimal environmental impacts. Use of these desirable sites could be promoted through an expedited permitting process. Conversely, planners can also place restrictions on renewable development in floodplains, areas of high biodiversity, areas important for natural beauty, usable farmland, and wildlife corridors. Farmland should not be written off entirely for PV development, and solar panels can provide shade and have a synergistic effect on crop yields (Dupraz et al., 2011). While not all crops could work in these schemes and the field is still young, agrovoltaics are one of the best ways outside of distributed PV to preserve open space.

<c> Protecting Solar Access

In general, land use plans should consider insolation as a valuable resource. Sunlight can be obstructed by nearby buildings, which increase in number with density. Land use guidelines should consider this effect, and impact fees or PV requirements on the shade-casting building could offset some of the downsides of losing solar resources. Shadows vary by time of year; lands use plans can take this into account based on the local seasonal energy use and generation potential. Care should be afforded to tradeoffs between passive techniques such as mutual shading of buildings and PV generation.

Solar rights can be codified into law as part of property and land use rights (S. C Bronin, 2009). Code could also allow variances for developments which have the capacity to make use of passive heating or solar generation. This would serve to protect and encourage development that can use solar energy or heating. A certain number of unshaded sunlight hours could be guaranteed. Alternatively, protection of solar rights could come in the form of compensation for impeding solar access.

Many codes fail to assess the impact on extant PV for new construction (Strømann-Andersen & Sattrup, 2011). This is especially important in latitudes far from the equator where shadows are longer. Here again, density can play a negative role in the energy transition by creating shadowy canyons. Buildings with reflective surfaces could increase insolation in dense areas. Planners should consider not only the energy impacts of and on already existing building when considering new construction, but also estimate the effects of the maximum density and density changes on said solar resources (Strømann-Andersen & Sattrup, 2011).

Renewables can allow distributed systems to thrive and add to the mix of uses promoted by smart growth. Beyond that, planners can create land use guidelines for siting utility scale projects, so as to minimize environmental impact and preserve farmland and open space. This would allow a large portion of electricity to be generated within cities, reducing the need to use open space, farmland, or other natural areas as utility scale renewable generation sites.

<c> Distributed Generation and Microgrids

The utility of Smart Growth principles in energy planning is clear: by considering the land use-energy connection, planners can encourage thoughtful siting of renewables while mitigating the impacts on the environment and agricultural lands. Generating electricity within cities as part of mixed-use developments directly protects farmland, open space, and natural areas from being used as utility scale renewable plants. Planners could prioritize smaller scale and brownfield renewables siting and promote decentralized energy systems, such as microgrids.

Studies have shown that many cities could satisfy a significant portion of their energy demand with current technology rooftop PV alone. Oeras, Portugal and Bardejov, Slovakia could cover over 60 percent of their energy needs within city PV (Amado & Poggi, 2014; Hofierka & Kaňuk, 2009). Rooftop only PV could satisfy up to 30 percent of Mumbai, India's daily demand and exceed the peak midday demand requirements of Cambridge, USA (Halu, Scala, Khiyami, & González, 2016; Singh & Banerjee, 2015).

Distributed energy systems can involve local generation, distribution, and storage. These systems can be connected into the existing larger grid, or be used to create a semi- or completely independent microgrid system. Local control can save energy by making more nuanced decisions on which receptors get high vs low quality power, as many end uses do not require high quality power with no noise and extremely stable voltages and currents (Marnay, Asano, Papathanassiou, & Strbac, 2008). Total energy savings possible through microgrid optimization are estimated to be around 20-30 percent (Guan, Xu, & Jia, 2010). Natural disasters can cause traditional grid to go down, causing large scale power outages that can last for weeks. Microgrids would be able to disconnect from the traditional grid and act autonomously, acting to smooth out issues in the grid or acting completely independently to provide electricity until the macrogrid is restored (Strbac et al., 2015). For example, the Mississippi Baptist Medical Center was able to operate at full service during Hurricane Katrina using its on-site energy generation (Marnay et al., 2008).

The technical details of microgrids are beyond the scope of this chapter, but various models have been developed to optimize PV siting, evaluate the economics of microgrids, determine optimal storage capacity and create optimal schedules (Chen, Gooi, & Wang, 2012; Marnay et al., 2008). These models can be used in conjunction with different load profiles implied by different neighborhood land use mix and density to make appropriate design decisions. Mixing uses can be beneficial to distributed systems by spreading out the timing of peak demands for various uses. At least one study has found load-mixing reduces costs in microgrids, both with and without the presence of a fossil fuel backup (Aldaouab, Daniels, & Hallinan, 2017). The size of the mixed-use benefit was found to correlate positively with renewable penetration, as mixing uses decreases the difference between peak load and average consumption, which decreases the cost for utilities.

Technical concerns can be overcome with proper investments and planning, but the current US utility model poses challenges that require policy solutions. Due to the increased potential for and benefits of distributed energy, electric utilities are no longer a natural monopoly requiring massive economies of scale. In over half of US states, consumers do not have a choice between electricity suppliers and are subject to the monopoly of a privately controlled company. In North Carolina, courts upheld regulations on who can sell electricity, preventing an African-American church from installing rooftop solar panels and selling their own cheap energy to power the church. Third party solar, and therefore distributed generation without consent of the utilities, is banned in nine states, while 15 states have no clear policy guidelines. Leasing solar panels with a power purchase agreement is allowed in some states, but at rates set by the utility which may not be conducive to installing solar without further grants or tax credits (Gearino, 2018). Utilities lack incentives to build distributed systems or limit greenfield development.

<c> Institutional Challenges to Curbing Energy Sprawl

Smart Growth aims to increase community and stakeholder collaboration, remove barriers to urban design innovation and achieve a greater recognition of regional interdependence and solidarity (Downs, 2001). Regional distributed renewable energy can be more local than traditional energy infrastructure and thus are amenable to local stakeholder involvement. National and State level bodies such as the Federal Energy Regulatory Commission and Public Utilities Commissions regulate much of transmission and distribution infrastructure, leaving local governments a little say in energy planning (Goldthau, 2014). Decision making in centralized systems is often controlled by utilities or requires coordination between utilities, state, local, and federal governments.

Permitting processes add to the cost and time burden of developing distributed systems or creating small power plants (Bronin, 2010). Zoning laws, form-based codes and building regulations also limit the ability to install rooftop PV in many areas. Aesthetic codes in particular can be barriers for rooftop solar, so governments should allow exceptions or alternative compliance provisions for energy generation (White, 2008). Governments could require a percentage of solar oriented lots in new development, and require variation in lot width to avoid the urban canyon effect (White, 2008). Additional barriers often include requiring a direct connection from the individual to the grid, limiting the ability of those in the same building who receive separate bills from selling power and lack of legal certainty (Moroni, Antoniucci, & Bisello, 2016).

Distributed systems also lack the standardized funding and investment mechanisms that support utility scale development. Mercurial political support in tax credits has led to uncertainty in how safe clean energy investments are and discouraged large scale private investment (Sovacool, 2009). Private financing with distributed systems has picked up in recent years, but still falls behind that for utility scale developments. Homeowners can also be given financial incentive to invest in PV, making net metering, tax breaks, or value of solar tariff good incentives (Hess, 2016).

State and local governments have directly financed rooftop solar installations in several US states, and partnerships can expedite the process of creating distributed systems (Hess, 2016). Utility Sponsored Community scale solar (such as they have in Sacramento), a system where utilities sponsor distributed solar generation while maintaining control over the electrical system, is another promising model. By letting the utilities maintain control and develop multiple community scale projects, demand can be stabilized across the region they operate in and the traditional economies of scale and investor portfolio utilities rely on can be leveraged. Utilities can also leverage their existing revenue to finance building new solar panels. However, privately owned utilities usually find it more profitable to invest in utility scale projects (Funkhouser, Blackburn, Magee, & Rai, 2015). In order to make sponsored community scale solar appealing, regulatory incentives would be needed to make rooftops a more alluring option.

Without federal subsidies or an increased cost for fossil fuel electricity, local and state governments can promote solar growth by implementing binding renewable portfolio standards for utilities or by providing subsidies to homeowners. New developments could be given incentives to install rooftop solar, such as greater floor area ratios or expedited permitting. Capital cost is often the largest hurdle to rooftop solar, and so may require a direct financial benefit or be made into a legal requirement. Local governments and neighborhoods can partner with other entities such as nearby local governments, non-profits (such as Shine^{TM}) or private firms (such as University Park Solar LLC) to tap into existing expertise. These relationships can help leverage potential investors, lessening the major hurdle of covering capital costs (Coughlin et al., 2010). Distributed systems can also benefit from cooperation among municipalities.

Planning at a regional scale may be necessary for smaller communities trying to develop renewable systems (Funkhouser et al., 2015). Along with economic benefits, the more communities involved in a distributed solar project, the more siting options become available (Coughlin et al., 2010). Covering a broader area also increases the reliability and resilience of a solar grid, as energy production will not be at the whim of a single weather system. This is where Smart Growth's emphasis on innovative design and greater recognition of interdependence overlap most with energy planning. Regional planning bodies could oversee energy planning in conjunction with coordinating land uses.

<b> Conclusions

An example of non-profit sponsored community scale Smart Growth Energy done right is a low-income housing development in Denver, Colorado. First, energy retrofits were done to each of the houses in the program, greatly reducing their overall energy needs. These homes were also smaller than the average American home to begin with, a clear example of energy's synergy with other smart growth principles. PV related job training opportunities were created as part of this project as well. This project required collaboration between several affordable housing non-profits, the local utility (who provided clean energy incentives and agreed to purchase renewable energy certificates), Denver's Energy Office (who provided a $107,500 grant), the National Renewable Energy Laboratory and private investors (who would reap tax benefits) (Schwabe, 2012). Another example is University Park Community Solar LLC, a for-profit solar company owned by those that use the energy that has installed 22 kilowatts of solar capacity on a local church rooftop. Revenue comes from selling electricity to the grid, renewable energy credits, and tax incentives (Coughlin et al., 2010).

These examples emphasize the key point that smart energy planning requires coordination among different types of actors. Local grants were required as initial capital. Utility, federal, and state programs made renewables more affordable and attractive to investors. These groups and non-profits can provide the initial capital investment or grant to provide energy retrofits that pay for themselves over time as well. Renewable energy cannot be made the norm without deliberate, supportive and coordinated programs and policies. Distributed energy systems are the most effective way to curb energy sprawl, and regional land use guidelines and incentives are crucial to the development of these systems. These should be paired with standards to reduce energy consumption based on the key context sensitive factors.

Many extant Smart Growth Principles can be used to achieve resilient and sustainable energy systems. Energy should be considered part of the mix of land uses for smart growth communities. The potential conflict of renewable energy with preservation of open space, farmland, and natural areas can be mitigated with thoughtful planning. Planners can ensure land use guidelines promote access to solar resources for generation and climate control. Smart Growth can incorporate sustainability and resilience through making decarbonization an integral part of its goals.

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