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Urban Smart Microgrids: A Political Technology of Emergency-Normalcy

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Urban Smart Microgrids: A Political Technology of Emergency-Normalcy

Abstract

Increasing threats to the electrical grid are generating responses that seek to secure selected 'mission critical' assets essential to the functioning and continuity of life. Focusing on military and urban domains in the US that use the smart microgrid as a technique for securing 'always-on' power during grid failure, we explore the core rationales, socio-technical configurations and wider implications of these projects to interrogate their novelty and urban significance. The threefold argument of the paper is that smart microgrid systems constitute: i) a mode of grid expansion that utilises the off-grid 'islanding' and grid-tied functionalities of microgrids to secure urban operational continuity, ii) a relational systemic reconfiguration that draws on, develops and holds together expertise and interdependencies across military, urban and community domains as a means of constructing an integrated response to grid vulnerability, and iii) an adaptive response that manages future turbulence by enabling seamless switching between normal and emergency modes. Critically for urban geography, smart microgrids bring into view an emerging set of spatial-temporal dynamics and implications through which the interval of disruption is eliminated and power maintained albeit for selected designated critical assets. Tracking the highly uneven consequences of this selective infrastructural reconfiguration will be a key task for urban research.

Keywords

Urban smart microgrids, electricity networks, operational continuity, vital systems, adaptive systems

Introduction

In October 2012, Hurricane Sandy knocked out much of the energy grid infrastructure of the north east of the US leaving more than 8 million people including most of New York without power for up to two weeks, the longest outage in the Con Ed utility's long history (IDEA & OBG, 2015, p. 5; Jones et al., 2016, p. 1719). There were, however, some notable exceptions at commercial, university and hospital sites with their own power generation systems (IDEA & MRC, 2016). The Goldman Sachs building in lower Manhattan was able to keep the lights on and its operations going because the bank had, following 9/11, constructed its own purpose-built off-grid electricity microgrid, for just such an event (see Folkers, 2017).

In April 2013, Pacific Gas and Electric's Metcalf electricity substation outside of San Jose in California came under sustained, organised attack from sniper bullets of unknown assailants targeting the cooling tanks on top of the substation's transformers. Thousands of gallons of oil in the tanks leaked leading to overheating of the transformers which then shut down. A complete blackout of Silicon Valley was narrowly avoided by electricity grid officials increasing production from other local power plants and rerouting electricity flows around the Metcalf substation (Alford, 2017, pp. 97-98; Smith, 2014; Madrigal, 2014; CNA, 2015, p. 7). This attack, combined with the stress placed on California's electricity system by recent wildfires and heatwaves, has led to increasing deployment of local microgrids to make the power system more resilient for both specific facilities and the wider community. The microgrid of the Marine Corps base at Miramar, for example, was used during the 2020 Californian heatwave to provide 6 MW of power to the San Diego Gas & Electric grid to avoid rolling blackouts in residential areas (Balocki, 2021; Carlisle, 2020).

These separate and unrelated events, on the east and west coasts of the US, demonstrated the fundamental vulnerability of US energy grids to extreme weather and organised attack, among other threats. For many observers, it signals "alignment" or "overlapping interest" between national security and environmental resilience (Alford, 2017, p. 99; see Davoudi, 2014, pp. 367-368). This was made manifest by Biden signing off early in his presidency an executive order making the climate crisis a national security issue (see also Belcher et al., 2020). A key strategic response has been systemic programmes that seek to deliver increased resilience and security of US energy systems, through major investment in smart microgrids (Suit, 2016, pp. 5-6; Jones et al., 2016, p. 1725). At the centre of this response are the US Departments of Defense and Homeland Security, who provide substantial funding, resources and expertise in the military application of microgrid systems. Smart microgrids are energy systems of varying sizes/scales within specific territories that draw on local sources of energy production, increasingly focused on renewables. The critical functional capacity of smart microgrids is to automatically 'self-disconnect' from the grid to operate as stand-alone – 'island' – facilities in *emergencies*, but also to be connected to national grids for the mutually beneficial import/export of power during *normal* operations (IDEA & OBG, 2015, p. 4). Smart microgrids are being developed in multiple contexts, within the military domain for domestic bases at 'home' and operations in the 'battlefield', and at the same time in cities and communities promoting decentralised energy solutions (Maron, 2010; DSB, 2016, p. 55). There are important relational connections across military and urban contexts, with microgrids cited by Army, Navy and Air Force representatives as a critical part of building infrastructure resilience (US Senate Committee on Appropriations, 2021). As in the above Miramar example, microgrids can be used to link bases to their wider local community contexts with mutually beneficial implications. Consequently, in the US

context it is argued that "the military is leading the charge in microgrids" (St John, 2013), and producing new understandings and configurations of crucial energy resource flows more widely (Gardner, 2017). Furthermore, the 'energy security' expertise of the 'military-environmental complex' (Light, 2014) is closely involved in the civil domain – both in cities and communities where military bases are located and in other urban contexts – to create microgrids that provide enhanced resilience and flexibility in the face of threats to grid-reliant urban life (ENEA, 2017; see Wilson & Jonas, 2018 on the urban resilience agenda).

Our aim in this paper is to examine the emerging spatial-temporal dynamics and implications of the smart microgrid as a technology of emergency *and* normalcy. We examine the potential distinctiveness of the smart microgrid in extending existing logics of infrastructural preparedness through a configuration that can use the capacities of digital technologies to switch seamlessly between normal and emergency modes. In this way, the interval of disruption is minimised to micro-seconds enabling mission critical assets to function continuously and rendering turbulence manageable. Our focus is on understanding the core rationales, socio-technical configurations and emerging spatial and temporal consequences of smart microgrids in the US context. We explore the systemic and *relational* effects of smart microgrids *in and across* military, urban and community contexts. This involves tracing evolving logics, expertise and practice that seek to develop 'mission critical' operational continuity whether the security threat/challenge is ecological/climate or human/military. The paper thus contributes to urban geographical scholarship by extending recent work on smart grids and evolving urban infrastructure configurations into urban security debates, by showing how reconfigured energy systems are a core instrument for the strategic securing of the urban.

The research draws on interviews with energy strategy consultants, researchers in national and Massachusetts state energy agencies, and relevant stakeholder actors in urban policy and local community initiatives in Boston, in-depth reviews of grey and secondary materials produced by national agencies (military, energy) and consultants, as well as technical academic literature and reports on legal, regulatory and energy system aspects to smart microgrid development. We used a 'snowballing' method throughout where interviewees were asked to suggest other relevant contacts in the field, and our reviews of reports produced by some organisations led to identification of other pertinent documents by the same or other organisations, thus building up a thorough understanding of the relevant issues from the diverse positions of the actors involved.

The rest of the paper is organised into five further sections. Section 2 constructs an analytical framework for understanding the emergence of smart microgrids as an infrastructural configuration designed to render turbulent events manageable by selectively maintaining services in an emergency. Section 3 tracks the emergence and practices of smart microgrid development in US military contexts focusing on military bases and their links 'beyond the fence' to urban defense communities. Section 4 then examines how microgrid projects are emerging in the wider urban context through an analysis of smart community microgrid development in the Boston city-region. Section 5 draws out the key processes and interrelations that emerge through these smart microgrid initiatives across differing contexts, and highlights the critical socio-spatial implications. Finally, the conclusion summarises the main contribution of the paper and the future research implications.

Smart Microgrids: Operational Continuity in Disruption

Smart grids can be seen on a first level as a straightforward *response* to grid fragility and constraints. Long-standing energy infrastructures in Europe and North America are reaching an age where they require urgent renewal and investment. Smart technologies can allow interconnection of more distributed energy resources, and new means of transmission and storage of energy, thereby avoiding the wholesale rebuilding of national grids. But smart infrastructure systems and their capacity for near real-time adjustments and modulations are also a technique of dealing *pre-emptively* with increasingly uncertain urban futures – what Collier and Lakoff (2015, p. 33) term 'a political technology of emergency'. Our argument is that there is an important, albeit selective, extension of the logic of preparedness to a focus on particular mission critical assets that must be guaranteed continuity of supply during an emergency. Below we set out in three steps the importance of this intensified logic by focusing on why the city and military base have emerged as critical sites for the management of multiple modes of disruption, how the new logic stresses the importance of continuity management in the provision of infrastructure services, and what is distinctive about the capacities of smart grids that enable turbulence to be modulated.

First, our starting point is the ways in which different forms of turbulence – political, technological, climate, environmental – are viewed as systemic threats to the continued operational effectiveness of infrastructure systems across urban and military domains. Recognition that the urban context is now the key site of societal vulnerability and (thus) of its management through infrastructural interventions at the nexus of climate, ecological, population, technological and other security concerns is claimed to be the "hegemonic discourse of our time" (Davoudi, 2014, p. 371; see also Braun, 2014; Bulkeley, 2021; Derickson, 2018). Within the military domain there is now widespread acknowledgement that key operational defence bases and facilities are also vulnerable to multiple forms of turbulence because they are reliant on the same centralised electrical grids as cities and communities. Consequently, there is an emerging commensurability between urban resilience and military security where constituting secure enclaves of critical assets with bespoke infrastructure configurations appears to offer protection against both human and climatic threats (Davoudi, 2014, pp. 367-368). On the one hand, military techniques are reconfiguring the infrastructures of the resilient city (see Graham, 2011; Tironi & Valderrama, 2021), and on the other hand, civilian innovations are reshaping military organisation and operations (see Belcher et al., 2020; Linkov, 2014; Merad et al., 2013). This intertwining is consistent with 'shared understanding' and 'common techniques' across civilian and military policy domains of vulnerability and the need for organised preparedness (Collier & Lakoff, 2015, pp. 20, 36). But this ostensible convergence of otherwise distinct forms of resilience goes to highlight the inherent interpretative flexibility of the resilience concept as more than a readily identifiable singular 'thing' (Anderson, 2015). The discursive common ground between military and urban understandings of resilience needs therefore to be subject to critical analysis in how it plays out materially in developments on the ground. As Anderson, Braun and others make clear, any notion of resilience does not pre-exist the ad hoc making of stabilised relations through which particular objectives are implemented or sought. Wakefield (2021) problematises for example the notion that enclaves, secession and delinking/disentanglement are always necessarily regressive responses to social and ecological processes viewed as harmful. She highlights as well the potentially positive and generative aspects of 'islands' that "can be a liberatory process of subjects detaching from structures and situations that strangle them, to reweave others according to other priorities" (p. 3). We need then to be attentive to how in any particular context

very specific and contingent or competing understandings of resilience are formed that may lead to quite different or differently experienced outcomes in situ.

Second, there have been significant extensions in how vital systems security is now being understood in the urban and military domains. Across these contexts there has been long-standing recognition of the critical importance of reliable functioning infrastructures for the maintenance of life and operations. Vital systems security conceptualised the management of emergency as an increasingly central part of governing as knowledge and techniques for preparedness developed in the Cold War conflict transmuted into wider civil domains susceptible to disruptions (Collier & Lakoff, 2015). Particular security mechanisms were developed and extended to reduce the vulnerability and increase capacities of control of vital infrastructure systems within emergency management (also Mayer & Acuto, 2015). In the urban and military context these primarily focused on three techniques: first, developing systemic understanding of the vulnerability of critical infrastructure systems; second, preparing for emergencies through plans, protocols and systems designed to minimise the interval between emergency and recovery; and third, investments that sought to reduce the vulnerability of infrastructures including back-up generation, decentralised systems, etc (see Gissen, 2014; Hodson & Marvin, 2009; Luque-Ayala & Marvin, 2016; Whitington, 2016). While all these techniques are still relevant and utilised they had an important limitation during grid failure as key military and civilian functions would remain inoperable until the whole system was recovered. Such approaches also frequently failed to consider the complexity and prospective nonlinearity of climate impacts on vulnerable grids and their impacts on urban and military sites. The critical challenge was how to maintain critical functions during disruption – how the interval between the emergency starting and recovery being completed could be eradicated or minimised. Critical infrastructure security thus became bound up with continuity management. The emergence of 'business continuity management' as a mode of organising in the face of immanent risk and disruption in the financial sector (Folkers, 2017; also Cooper, 2010) is becoming pertinent for wider urban and military domains. In this context of uncertainty and turbulence, key military and urban operations need the guarantee of not being disturbed due to the vulnerability of the grid. Rather than focusing on the mitigation of vulnerability or future 'preparedness', this extended technique foregrounds operational continuity through management of infrastructure in the present across normal and emergency modes.

Third, smart microgrids are a key instance of the novel adaptive systems that are being put to work in the urban context at the juncture of smart and resilient urbanism (Derickson, 2018). Facing immanent uncertainty and serious disruption, spatially and temporally adaptive infrastructure reconfigurations can be rolled out to secure urban systems and activities from multiple grid-based vulnerabilities and threats. Smart microgrid projects often cover large single users such as universities or hospitals, or they can be larger-scale community initiatives serving whole districts or neighbourhoods (see case studies in Levenda, 2019; McGuirk et al., 2019; McLean et al., 2015). As well as being located in cities and on military bases, microgrids are also important urban technologies because, in contrast to most wider energy systems reliant on distant generation facilities and long-distance distribution networks, they concentrate energy production, storage and usage in close proximity within the city and can function autonomously in an emergency. They are thus an important part of a wider evolving form of infrastructure change that draws on relocalised resource flows and/or partially decentralised technological components that, it is claimed, render socio-technical systems more sustainable and adaptive to emerging and future needs and uncertainties

(Coutard & Rutherford, 2016). 'Smart' technology is thus increasingly incorporated into projects to allow coordination of components and rapid switching between grid-connected and island modes. The close interplay of these two modes highlights that rationales of energy autonomy and redundancy through smart grids must be seen to fold into, rather than oppose, logics of centralised grid renewal. It is thus recognised that smart microgrids and traditional centralised grids *co-exist* and are increasingly mutually constitutive (Lopez, 2019; Yu et al., 2018; for an early review see Luque, 2014).[1] The outcome is a kind of 'self-healing' infrastructure system preventing power loss by diverting loads or switching between sources, or reducing the time taken to restore power through automated systems of recovery that do not require human intervention (see Amin, 2001; Tomyak, 2003).[2] However, as in the resilience discussion above, a key issue here is understanding often divergent purposes and interests behind smart microgrids and their variegated capacities (see McLean et al., 2015; Wiig & Wyly, 2016) as tracking its multiple applications can contribute to "a theoretical and material 'debate' over entanglement or disentanglement, interlinking or delinking, and the ethical, political, and infrastructural dimensions of each" (Wakefield, 2021, p. 4).

In sections 3 and 4 we focus on the relational development of smart microgrids in the US. Smart microgrid projects are being developed in and across a variety of contexts through military, urban and conjoined military-community partnerships. Drawing on the framing set out above, we argue that this military and urban focus and approach is attuned to the systemic nature of the overarching challenges, and the relational development of techniques and reconfigurations through which vital energy systems are secured. Consequently, we explore in the next section the way that military bases and their host communities relationally construct smart microgrids. We then go on to examine the application of smart microgrid planning techniques in projects in the city region of Boston.

Military – Community Partnerships for Energy Security

The interrelationships between US domestic military bases and their host communities have become an increasing focus of attention both for the Department of Defense (DoD) and the municipalities and states where bases are located (ADC & CSL, 2018; CNA, 2015; DSB, 2018). Both the base and the community frequently share dependence on the same infrastructure networks including transport, waste, water and the focus of our concern – electricity. An emerging coalition of military and urban/state societal interests has drawn increasing attention to the vulnerability of national energy grids to technological failure, deliberate disruption and interruption due to weather related events. The development of 'partnership' models has been proposed to accelerate the implementation of smart microgrids on and beyond military bases to reinforce energy security.

'Beyond the fence line'? Vulnerability of the community grid

[1] For the US Department of Energy, for example, microgrids "strengthen grid resilience" and "support a flexible and efficient electric grid" by integrating renewables and reducing transmission losses, which offer a threefold benefit: "improve reliability and resiliency of the grid, help communities better prepare for future weather events, and keep the nation moving toward a clean energy future" (DoE, n.d.).

[2] Extensive work in the US on the development of self-healing power systems in the early 2000s was built on the "conceptual foundations" of work undertaken on the F15 fighter sponsored by the Department of Defense to automatically reconfigure flight surfaces following a failure or battle damage to increase the probability of mission success (Amin & Wollenberg, 2005).

Security is paramount to the emergence of microgrid technologies and systems in the US context. As the Military Advisory Board – an 'elite group' of former officers who advise on key contemporary issues – stated: "Failure to address known vulnerabilities and unwillingness to improve the grid aggressively – into one that is more adaptable, resilient, and reliable – hold the nation's security at risk" (CAN, 2015, p. iii). The US national electricity grid is widely viewed to be old, increasingly unreliable and vulnerable to disruption – there were over 360 'targeted attacks' leading to disruptions in energy provision reported by utilities between 2011 and 2014 (CNA, 2015, p. 1). The US grid is a 'patchwork' architecture of individual systems that were joined up incrementally over time, subdivided into three geographical zones but operated and owned by dozens of separate authorities and entities (Suit, 2016, p. 2; state energy agency interview, November 2019). The energy infrastructure upon which DoD bases and installations depend is therefore primarily commercially owned, and 99% of the electrical energy installations consume originates "outside the fence" (DSB, 2016). Although many installations have fossil fuel based backup generators these are extremely unreliable, only designed to function for a few days, and are dependent on fuel supplies (Marqusee et al., 2017, p. vi).

Consequently, there are increasing arguments within the military in favour of "a more reliable and resilient system, which would allow the DoD's critical assets to function in the event of a catastrophic failure of the commercial grid" (Alford, 2017, p. 98). The Pentagon has recently run a series of 'black-start' exercises to test the resilience of military installation energy infrastructure in case of outage or massive failure (Cohen, 2019). There has been serious concern that the "traditional approach to energy security on bases just doesn't work" with inefficient and unreliable diesel generators and a lack of planning for what happens if critical facilities are turned off (energy security consultant interview, November 2019). There has thus been increasing focus on the benefits of microgrid technologies for on-site energy generation at military bases and DoD facilities (Pearce, 2017; St John, 2013; Van Broekhoven et al., 2012). The defense-military-security complex is thus absolutely central to US microgrid development, pinpointing the most serious challenges – grid vulnerability notably – and offering a series of contexts at home for trialing and deploying alternative energy configurations (Van Broekhoven et al., 2013) that serve more widely as the "test bed for the new grid" (CNA, 2015, p. 16).

A systemic programme of microgrid research and project development has been initiated involving the US military (Army, Navy and Airforce), homeland security, Department of Energy (DoE), big technology and security companies and key partners in universities and consultancies (see DoE, n.d.). As a result, "more than 40 bases have either installed a microgrid, have plans to develop one, or have carried out a preliminary microgrid study" (Alford, 2017, p. 108). While current microgrid capacity is still small, increasing military focused projects have led market analysts to forecast the military sector to be the fastest growing microgrid market in North America (Burger, 2016).

>> Figure 1 here

Figure 1 illustrates the configuration of a typical base microgrid showing the location of "critical mission" assets and their ability to secure power both in grid-linked and "islanded mode" when disengaged from the utility grid during an interruption. Fort Bliss located near the city of El Paso in Texas became the first DoD microgrid to be connected to the grid in 2013. The demonstration project, a collaboration between the Army and Lockheed Martin, comprised a modest 120 KW solar

array, a 300 KW battery storage system and existing backup generators managed by an Intelligent Microgrid Control System. An automatic transfer switch connected up the local production and storage equipment and base critical loads to allow continuous power supply to the latter in the event of the switch sensing a grid outage. Distributed controllers present at critical loads throughout the microgrid configuration could operate autonomously if communication was lost with the centralized controller. The same automatic transfer switch could also revert supply back to the grid when the outage came to an end. The project serviced one of the dining complexes of the base as its primary aim was to test and demonstrate the capability for the continuation of operations through the "near seamless transition between Grid Tied and Grid Independent modes (Islanding)" (Hall & Fischer, 2014, p. xii). As a Fort Bliss official stated: "the tactical utility of this technology is its ability to allow us to operate off the grid. This project represents the future of military energy security" (quoted in PR Newswire, 2013).

To continue to build energy security and affranchise itself of reliance on backup generators, the base planned to construct a 20 MW solar PV plant at a cost of $120 million with the local utility El Paso Electric (St John, 2013). However, the project was cancelled in 2015 because the utility was not able to reach an agreement with the Army over the terms of access to the 218 acres needed for the plant (Kolenc, 2015). Although this project failed, the military often supplies unused land – known as "'want-it-in-my-backyard' or WIMBY land" – and partners with local utilities or 'energy developers' (Danigelis, 2018). Reconfiguring connections with the local grid also requires protracted negotiations between the military and relevant urban and state governments focused on procurement systems, environmental assessment and other regulatory processes, which complicates the process of upscaling the roll-out of smart microgrids across the 2000 domestic military bases (Alford, 2017, pp. 111-117).

Building community resilience through energy partnerships with the military

Consequently, the relational interface between the military base and the local community has become subject to more intense and organised analysis by the 'Association of Defense Communities'. The ADC is a 300-member organisation representing every major community that hosts military bases including "small towns, cities, regions and entire states" and seeks to "build resilient communities" by forming "community-military partnerships" (ADC, n.d.). The strategic interest of the military in microgrids has become a focus for the ADC and their 2018 report entitled 'Beyond the Fence Line' maintained that "military installations are only *as secure as the communities that neighbour* them" (ADC & CSL, 2018, p. 17, emphasis added). Military base projects, it is claimed, can benefit wider communities and states, by addressing energy security for military operations and locations, while the grid and local communities are "at the same time made more resilient" (energy policy consultant interview, November 2019). The ADC sought to develop 'defense community partnerships' that are designed to underpin "policy, planning and resourcing efforts by state and local governments to support energy resilience projects at military bases" (ADC & CSL, 2018, p. 8).

The case of the Naval Submarine Base in New London (SUBASE) was offered by the ADC as an exemplar of the mutual interest of military, state and urban stakeholders in the development of a microgrid. In 2005 the base was selected for closure partly because of the vulnerability of "the commercial electricity system", with the existing diesel backup generators considered insufficient and a "high operational risk" (ADC & CSL, 2018, pp. 13-14). Located on a 700 acre site in the city of Groton, Connecticut, the base employed nearly 10,000 personnel and a successful campaign was mounted to prevent its closure. In 2007 the State of Connecticut established the Office of Military

Affairs (OMA) and approved a $50M bond fund for infrastructure upgrades of military value – initiatives designed to retain SUBASE. Furthermore, in 2015 the State authorized the OMA to provide a $1.1M grant to SUBASE for microgrid design and infrastructure upgrades. This involved SUBASE leasing part of its land for a 7.4 MW fuel cell project that will, under normal conditions, partly supply the power needs of the Connecticut Municipal Electricity Energy Cooperative – displacing power currently purchased on the wholesale market. The agreement is that, in exchange for the lease, SUBASE will receive power from the fuel cells during power outages, with the system also designed to remotely shed load in order to maintain critical facilities. More recently, the municipally owned Groton Utilities has been funded to work on energy resilience planning and microgrid development for its own infrastructure in collaboration with SUBASE (ADC & CSL, 2018, p. 13).

SUBASE provides critical insight into the increasing depth of the policy, planning, and resourcing of interrelationships supporting military microgrid development of wider import through supportive partnerships involving states, urban governments and localities. The ADC argues that states and cities should "support military energy resilience" and "bring their energy strategies, policies, programs and resources into alignment with DoD's", (ADC & CSL, 2018, p. 17). Specific examples include opportunities to "integrate the military into ongoing planning efforts related to energy assurance or extreme weather resilience" and identifying state and urban policy priorities that "specifically align with military energy reliance objectives" (ADC & CSL, 2018, pp. 17-18). Furthermore, although it is challenging for the military to directly accept state funds, the Defense Authorisation Act of 2019 permitted installations to accept state and local government funding if it improved wider energy security and resilience as a result (energy policy consultant interview, November 2019). Since the Act was passed, the US Congress has held nine hearings focused on updates from the DoD and army, navy and airforce officials on protecting national security and military installations from climate change.

Policy analysts have expressed concern that this suggests that Congress has prioritised military climate readiness over other types of publicly funded infrastructure (see Brown, 2021). There is concern that looking at climate change through a military framework "misdirects resources away from the programs that we need to mitigate and adapt to a warming climate" (Lorah Steichen, Institute for Policy Studies, quoted in Brown, 2021). These smart microgrid strategies are represented as being mutually beneficial to all – certainly they enable urban utilities to develop local energy production facilities that displace wholesale purchasers from the grid. Yet, during any emergency, the military base is nonetheless given priority over schools, health facilities and residential areas in the hierarchy of mission critical assets. The development of smart microgrids thereby constitutes an important shift in grid expansion strategy, focused now on developing off-grid capacities (islanding and the integration of renewables and storage) in particularly strategic areas and that can be enabled in microseconds rather than sustained grid investment over a number of years. Smart microgrids materialise an extended and deepening, but selective, mode of vital systems security, offering real-time management of everyday and emergency with fast switching between modes. This is nonetheless more about safeguarding connection for and continued functioning of specific critical assets than getting the whole grid working again.

Urban microgrids in Boston

Rapid progress in the military microgrid domain has been viewed as a spur to the energy industry and the wider development of microgrid systems. It is claimed that the "DOD serves as a microcosm of the grid challenges facing our entire nation, while at the same time it provides insights into possible

solutions" (CNA, 2015, p. iii). Defense and security actors and urban authorities are frequently assumed to share common interests in microgrid projects:

> it makes sense that today's movement to improve urban resilience – and add microgrids – looks to the military as a natural ally… Microgrids are a natural fit for this kind of partnership. It's a technology being pursued separately by both cities and the military, but for similar reasons. Both desperately need power to restore normalcy and protect the citizenry in a disaster. And both are leaders in greening U.S. energy supply. (Wood, 2018; for a similar perspective see Rockefeller Foundation, 2018).

Urban microgrid initiatives are emerging in parallel with military microgrid projects and activities as 'energy security' and 'resilience' take on new meanings and salience in the wake of blackouts and extreme weather events such as Sandy (Pyper, 2013; Yu et al., 2018). A 2018 Homeland Security report calls for the creation of microgrid-driven community enclaves as part of a larger security strategy should the United States experience a catastrophic power failure (NIAC, 2018). Microgrid deployment in US cities is clearly being sought by a number of actors to boost 'community resilience' (Asmus, 2017; Vine & Morsch, 2017; for a critique see Wakefield, 2020). Consequently, it is important to consider how microgrids are being framed and put to work locally towards ostensibly quite distinct forms of resilience.

Exploratory community energy study

Boston is widely recognised as one of the most active cities in the US in the energy domain (Puerto, 2015), and is a C40 member city aiming for carbon neutrality by 2050. It has developed a particularly dynamic and diverse 'energy ecosystem' (Sheehan, 2015) which has specifically come to engage with microgrids as a response to energy, climate and community resilience and security concerns and for creating flexibility and adaptability in the wider grid (planning official interview, Boston, November 2019). 'Imagine Boston 2030', the citywide plan finalised in 2017, specifically focuses on the potential of microgrids to "enhance resiliency", "make energy more affordable" and provide social and economic development benefits (City of Boston, 2017, pp. 346-347). A key element of the City's 'Climate Ready' action plan is to "develop district-level energy solutions to increase decentralization and redundancy" (City of Boston, 2016). The aim of the city's energy planners is to create 'self-sustaining' areas of the grid that could be specifically focused on areas of affordable housing and critical infrastructure facilities (City of Boston, 2016).

The Boston Community Energy Study was commissioned to take this work forward and funded by the Massachusetts Clean Energy Center, DoE and DHS using an 'Air Force Contract' (Morgan et al., 2016, p. i). This project involved mapping energy demand in the city and the application of the Distributed Energy Resources Customer Adoption Model (DER-CAM) software model, previously developed by Berkeley Lab to evaluate optimal energy solutions for military bases, to identify sites for new local energy provision in Boston (researcher interview, November 2019). This work identified 42 areas across the city where community energy microgrids could be rolled out in three different configurations – focused on multi-user sites, energy justice areas, and emergency facilities – with scenarios demonstrating significant cost and CO_2 savings over a 25-year period (Morgan et al., 2016, Boston Redevelopment Authority, 2016).

Microgrids from the ground up: "evening the playing field"?

The Boston Community Energy study's focus on 'energy justice' areas inspired further thinking and action towards expanding microgrids at these sites and across the wider metropolitan area (planning official interview, Boston, November 2019). Multiple organisations campaigning around energy, climate and environmental issues and initiatives, have pushed forward "community controlled clean energy microgrids" as a potential bottom up intervention into creating community resilience and affordable and ecological energy access (project technical leader interview, Boston, November 2019). An exemplar such project in the Boston area is being developed in the city's Chinatown area and in Chelsea, a small dense municipality of only around 2 square miles located just across the Mystic River from Boston. GreenRoots is an independent community organization that works on environmental justice within Chelsea. It became involved in the Resilient Urban Neighborhoods (RUN) and Green Justice Coalition (GJC) microgrid feasibility project, supporting it for climate resiliency and energy democracy/justice priorities. A project partner explained: "Building a microgrid is not the problem. There're plenty of microgrids out there. It's just, how do you do it in a democratic and accountable way?" (interview, November 2019). The mobilisation of prior experience and transfer of expertise is adapted to the local context by the coalition's three principles of community control, virtual organisation and rollout, and cloud-based aggregation possibilities (project technical leader interview, Boston, November 2019).

There is then, first, the active involvement of community partners (GJC) who have local knowledge and outreach possibilities to enable community buy-in: "Our model is very different. … it really has been a grassroots project, where the community folks in Chelsea and in Chinatown have said these are the critical infrastructures that we think need to be powered on" (partner interviews, November 2019). The choice of key sites to be connected by the microgrid as critical infrastructure was taken in collaboration with the local community and the Chelsea municipality which will own the microgrid. Three buildings – a medical center, the city hall and a public housing unit – were initially chosen to be integrated into the system, and the plan is that more buildings will be connected up gradually as finance and the technical configuration permit (project interviews, November 2019).

Secondly, this is a virtual microgrid in which buildings are not connected by physical wires but through internet-based aggregation of loads. Each building has a source of local energy production (solar panels) and a battery storage facility adapted to the building's total peak load. These resources offer value to the project in grid-connected mode by creating the possibility of selling to the grid: "as markets change over the course of a day, we can assign the resources to different needs, different grid attributes or the local demand response or whatever pays the most money at the instant" (project technical leader interview, Boston, November 2019). As well as bypassing the limits of geographical contiguity and joining up sites in different areas, this 'smart' configuration allows the project to get past the constraints of current Massachusetts electricity regulation which forbids any physical connection of buildings across a public way not done by the distribution utility companies (partner interviews, November 2019).

Third, the advantage of cloud microgrids is that they can be grown quickly – "we call it a microgrid without borders" – so the Chelsea project should expand rapidly from the initial three connected sites (project technical leader interview, Boston, November 2019). In non-emergency, normal functioning, users are connected to the grid, and the aim is to share information among buildings about usage and the business model is to sell back to the grid aggregated unused local energy and load reductions at a beneficial price through net metering. In an emergency, when the grid is down,

the local energy production and battery storage provide for basic electricity needs separately in each building (figure 2). Switching between the two modes is done “automatically and seamlessly” through the smart microgrid controllers present in each building that monitor grid voltage and frequency. In an outage, these controllers route the electricity produced from the solar panels and stored in the batteries to building loads. A standby clean fuel-run DC generator can supplement this system if necessary, thereby creating capacity to maintain and manage power during “prolonged” periods of disruption. A satellite hotspot system installed at these critical sites also allows communications to continue independently of the mobile telecommunications and electricity grids (Clean Energy Solutions, 2020, pp. 16-18). Each building thus becomes “its own island. We install enough capacity to carry the full load. We want people to what we call ‘prosper in place’ so they don’t have to be evacuated… In this way, ensuring energy reliability becomes a form of resilience” (project technical leader interview, Boston, November 2019). Project leaders set out here what they call the democratic element to the project, that anybody could join and the importance of active community involvement. The GJC on their side canvassed local residents and businesses about key features and criteria that should be incorporated into the system. While there were for instance concerns about costs for participants and minimising fossil fuel use, people also mentioned core system design capabilities such as the need for buildings to have resilience of their full loads not just selected emergency functions, and backup capacity for people to be able to use and charge cell phones (project interviews, November 2019).

>> Figure 2 here

In both the Chelsea and Chinatown communities, the microgrid project created a meaningful link to other places where the local population has family and friends who suffered from major climatic events that knocked out electricity lines for many days. Boston’s Chinese population observed how the Chinatown district in New York was heavily affected by Hurricane Sandy - “one of the last communities to get power back on” (partner interview, November 2019) - while the large Puerto Rican diaspora in Chelsea was terribly affected by Hurricane Maria in Puerto Rico:

> There is a deep connection between what happens to these communities that are vulnerable. Those two stories, it's just very relevant. A lot of folks might think, and that’s what we thought at the beginning, that microgrids are so techy and wonky and complicated, how would people ever connect to this project? It turns out it's very relevant to people's lives. (partner interview, November 2019).

These kinds of community microgrid projects open up and re-problematize any notion of a homogeneous application of microgrids and a singular logic of infrastructure security as they seek to configure capacities of connection to energy for multi-user low income and climate risk areas. As a project leader stated “There are many microgrids in the world. I don’t think there's any quite like this that is yet operating…” (project technical leader interview, Boston, November 2019). The openness with multiple users and selection of the key buildings to be connected - “evening the playing field” (partner interview, November 2019) - are presented as the urban components of microgrids that seek to foster resilience and security for vulnerable communities and citizens. The orientation of the project around local benefits (‘prospering in place’) and its inclusive nature (‘configuring’ rather than ‘configured by’) does therefore, so far and at the very least, offer another way of responding to urban and infrastructure vulnerability. Community organisers spoke, for example, of their desire for

"trying to carve out some alternatives to the stranglehold of unaccountable utilities" (community organisation member interview, November 2019). So for all the technical convergence and shared knowledge and expertise across projects in different urban and military domains, there remains at the same time a fundamentally contingent and situated dimension to the development of smart microgrids, whereby similar configurations can be put to use for diverging rationales and interests.

It is important though to recognise the limits of community initiatives that sometimes constitute merely constrained local responses to disruption wrought by political and economic activities and choices elsewhere (see Grove, 2014). This is an infrastructure configuration that does not seek to deal with the fundamental issue of why the wider grid fails or is increasingly vulnerable. Responsibility for grid renewal and resilience is passed to communities which are asked to choose between and prioritise assets according to a particular local understanding of 'mission criticality'. Different parts of the community/city are becoming imbued with differing capacity to function in a crisis – thus the operational continuity in disruption afforded by the microgrid is prospectively highly uneven and selective. We discuss these issues further in the next section.

Infrastructure always on alert

Interrogating the application of smart microgrids has revealed their utilization as an increasingly emblematic response to both uncertainties and securitization rationales across military – community and urban domains. These microgrid focused initiatives are specific spatial-temporally differentiated forms of resilience response that sit distinctively and contingently in relation to other parallel efforts at governing and securing urban life (cf. Anderson, 2015). The smart microgrid is an example of a technology of 'event suppression' (Zebrowski, 2019) – it does not prevent a disruptive event from occurring but it works to close down the time of its disruptive effects – albeit only in those spaces endowed with the capacity to do so. It is in this sense that we argue that smart microgrid configurations constitute an emerging political technology that can hold together differing spatial-temporal capacities, relations and modes of operation that, together, fuse emergency and normal but in a selective way according to contingent framings of mission critical assets. We draw out three crucial socio-spatial implications of these emerging capacities and configurations.

First, the overarching importance of smart microgrid systems, we have shown, is in constituting an emerging socio-technical infrastructural capacity through which urban operational continuity is sought and secured through a particular mode of grid expansion/renewal. This mode utilises the off-grid 'islanding' capabilities of microgrids and their integration of local renewable energy production and storage to manage both local demands and requirements and the continued functioning of the wider grid in contexts of uncertainty. In the base-community and local Boston projects, adaptive system functionalities are developed that combine both grid/off-grid and normal/emergency modes. This involves a redefinition of what vital infrastructure is *in situ* – the contingent nature of 'mission critical' assets in particular places – and the role of the smart microgrid not in mitigation or reduction of vulnerabilities but their real-time management. A suite of technological functions is then established involving real-time modulation, islanding and grid-tied capability, and constant monitoring and feedback to produce a form of self-healing capability that notably eliminates the interval of disruption. There is a quite fundamental contradiction at work here whereby the resilience of power supply is enabled by creating the possibility of disconnection from the national

grid in 'island' enclaves. For urban infrastructure studies then, these systems come to represent a key emerging modality of infrastructure change 'beyond the network' that contributes to further understanding of the wider social significance of heterogeneous configurations of grid/off-grid components, renewable and traditional energy resources, smart and analogue control features, and their actual or potential regulation.

Second, but the smart microgrids we have studied here also, crucially, represent an extension and subtle shift in the logics of infrastructure security. Vital systems security held a clear distinction between the normal and the emergency. This was reflected in both a temporal and an infrastructural divide between normal and emergency modes. It required time and effort to switch from one to the other, and there tended to be a separate technical system configuration for each – centralised grid vs standby generators – thus also leading to substantial costs for extra equipment, infrastructure, maintenance, labour etc. Smart microgrids signify a distinctive technological constituent of, and response to, an imperative of urban resilience that is no longer solely focused on seeking to mitigate threats and prepare for future turbulence, but is a strategy of pursuing adaptive management and immanent securing of continuity of operations in an already disrupted now. Emergency becomes "positioned as a mode of urban existence" (Luque-Ayala & Marvin, 2016, p. 204) that is already here, and measures to reduce vulnerability and to improve 'preparedness' increasingly give way to letting ecological vulnerabilities play out (cf. Braun, 2014, p. 59), to the continuity management of the constantly uncertain and unpredictable now, and to the selective privileging of certain assets, spaces and circulations over others. Thus, with the smart microgrid, the logic of infrastructure security evolves and now works through the conflation of normal and emergency in three ways. First, by drastically reducing the interval between the two using smart modulation and control techniques and decentralised energy for near real-time switching from one to the other, as vaunted by both base microgrid technicians and the engineers in the local Boston projects. Second, by actually reworking normal practices through preparation for emergency mode. For example, the RUN Boston project seeks financial gain from selling power to the grid during normal times, developed from the partnership's thinking about how to do a smart microgrid for community resilience in emergency. Thus, normal becomes 'vital' too to the wider rationale and functioning. Third, by bringing together actors, knowledge and expertise that were previously otherwise separate. Planners, energy utilities and regulators and community development groups in the Boston region, as elsewhere, now have to think about strategies for managing ongoing disruption, leading to designation for example of critical community assets. Meanwhile, military technicians and engineers are thinking through the 'normal' implications 'beyond the fence' of their emergency mode planning.

Third, this highlights how smart microgrids also come to represent a relational systemic reconfiguration that draws on, develops and holds together expertise and interdependencies across military, urban and community domains as a means of constructing an integrated response to multiple challenges. It does so, however, in particular ways and often for quite different objectives. Local military installations seek to 'entangle' their base infrastructures with community grids and systems to increase resilience and benefit from funding opportunities, while safeguarding their priority access to 'always-on' power ahead of the community during disruption. At the same time, urban community microgrid projects are also emerging whose 'assets' may also become 'entangled' with energy markets but temporarily and in ways advantageous to local objectives, in order to sell locally produced power back to the grid to sustain their non-profit community microgrid model. It is here that the smart microgrid constitutes a relational, political technology that is never absolute or

definitive in what it allows or implies in terms of socio-spatial consequences, but that conveys particular selective spatial and temporal capacities of access to power in the making and stabilisation of any configuration.

Conclusion

This paper has focused on smart microgrids as a means of grid expansion/renewal and infrastructure security that mobilises the 'islanding' and grid-tied functionalities of microgrids to allow operational continuity in distinct contexts. We tracked the relational configuration of smart microgrid initiatives across military, community and urban domains as part of an emerging systemic spatial-temporal management of turbulence. Normal and emergency modes of energy provision are notably fused through automated seamless switching capabilities that enable continuous power for designated critical assets.

The key contribution of the paper has been to show that the systemic relational development of smart microgrids as a tool of infrastructure security across contexts is part of a broader change in urban resilience. This represents a shift toward a more active, but uneven, reconfiguration of the present in emergency/alert mode that can enable continuity of selected key operations in times of ongoing disruption. Smart infrastructure configurations here become an important political technology for the strategic securing of the urban, which raises critical issues around their wider socio-spatial implications. The increasing prevalence of smart microgrid projects prefigures an important evolution in grid security strategy, with a focus now on developing off-grid capacities in particularly strategic areas and that can be enabled in microseconds. It is not an attempt at getting the grid functioning again for all, but about keeping certain critical assets online across normal and emergency times irrespective of what happens elsewhere. Resilience capacity thus becomes unevenly distributed, while the underlying fundamental systemic issues – climate change, grid vulnerability and repair, security threats – remain largely unaddressed.

Our research thus identifies a key challenge that will require the attention of urban scholars. The paper shows how a particular asymmetrical form of resilience is applied in military communities through the smart microgrid and is increasingly transmuting into the urban arena as local communities attempt to reprioritise public infrastructure provision according to their own rationales and practices. It means understanding how there is an uneven distribution of exposure, capacity and resources to act, and level of protection from consequences between actors in and across contexts during, for example, a grid failure. Smart microgrids can be viewed then as a technique that offers fundamental and disproportionate advantage to some actors as they seek to defend themselves from turbulence of whatever sort. They are being used to diminish the case for general grid maintenance and upgrades, and to secede from responsibility for longer-term collective action aimed at addressing the original sources of turbulence and upheaval. The urban energy system thus runs the risk of becoming effectively fragmented into different types of grids instilled with different capacities to function across an increasingly integrated normal–crisis mode. In particular, the prioritisation of particular 'mission critical' assets points to a crucial new spatial-temporal division in urban infrastructure security between functions and spaces supported by infrastructure always on alert and those with vital systems subject to disruption and decay. If critical assets are protected, then we can question what level of service is provided to non-critical assets. If smart microgrids are

designed to cope with potential failures by switching to island mode automatically and in seconds, we can wonder what this means for those still reliant on vulnerable existing grids, or indeed whether this logic is likely to reinforce existing periurban or rural infrastructure vulnerabilities. Scholars will need to be attentive to the resistances and contestations that are associated with these processes. These are likely to vary at once within urban contexts, across military and civil relations, and more globally as technology companies and utilities seek to develop new markets for smart microgrids in communities of the Global South as well as the North.

This infrastructure differentiation has crucial socio-spatial consequences. It proceeds not just through the types of physical or geographical withdrawal and secession from centralized grids and services that have characterized much recent urban splintering (cf. Graham & Marvin, 2001), but through more or less intensified coexistence of grid and off-grid secure configurations. These configurations are modulated to differing extents by accelerated or deepened technological functionalities that eliminate the interval of disruption in any emergency. While the differentiation is still technological and spatial, it is, crucially, also now temporal with coexistence capacity coming to matter during disruption, but also through 'normal' grid-tied value creation from selling power to the grid. The implications of this kind of infrastructure fragmentation for urban life in a context of multiple uncertainties clearly merit further research and critical consideration.

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Figure 1: Typical Army base microgrid configuration (Source: Authors)

Figure 2: Chelsea community emergency microgrid configuration (Source: Climable)