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14. ABSTRACT
Presents existing methodologies and third-party financing options from technology, and viable methods to supplement the lack of Congressional funding the \$3.6 billion to fix damaged structures in NC from Hurricane Florence in September 2018; currently underused by the U.S. Marine Corps. Core idea of resource stewardship and critical concepts of Deep Energy Retrofits (DER), holistic systems design methodologies, and unique structural additions to Energy Service Performance Contracts (ESPCs) and comprehensive use of third-party financing already used across the US Government. Recommend augmenting working groups developing plans and deliberate use of efficiency measures.

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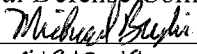
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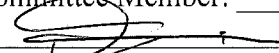
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Executive Summary

Title: Applying Deep Energy Retrofits and Radical Building Efficiencies through Deep Energy Retrofits and Zero-Energy Ready Homes to Rebuild after Hurricane Florence

Author: Major James S. McLean, United States Marine Corps

Thesis: Hurricane Florence's destruction of long neglected infrastructure at the three NC bases is an opportunity for the Marine Corps to apply updated and radical design efficiencies using existing energy efficient technologies for installations, housing, and infrastructure at a similar cost to achieve greater long term savings on operating expenses while increasing resilience, decreasing required maintenance, and increasing available funds for structures specific to warfighting capabilities across the Marine Corps.

Discussion: This project brings together methodologies and third-party financing options from existing technology, and viable methods to supplement the lack of Congressional funding the \$3.6 billion requested to fix damaged structures in NC from Hurricane Florence in September 2018. The core idea of resource stewardship and critical concepts delineating between renovations, retrofits, and Deep Energy Retrofits (DER); passive versus active measures; unique additions to Energy Service Performance Contracts (ESPCs) compared to Utility Energy Savings Contracts (UESC) as a third-party funding option as used by the General Services Administration (GSA) and US Army. The concepts of holistic systems versus whole structure design mentality; and critical contextual understanding of the unique Hot-humid climatic zone are explored on the outset. Commercial and other government DER case studies of the Empire State Building, Naval Air Station (NAS) Oceana, and Camps Lejeune, Johnson and Marine Corps Air Station (MCAS) New River are analyzed for applicable lessons and best practices that follow for implementation of DER. The methodology and fiscal case of Zero-Energy Ready Homes (ZERH) is presented and two frugal examples from the databases of examples are explored.

Conclusion: Through the case studies and the subject matter explored in this study makes the following recommendations in addition to the best practices for executing Marine Corps Deep Energy Retrofits and Zero-Energy Ready Homes at Installations across the service portfolio:

Recommendations:

1. Maximize use of Deep Energy Retrofits and Add structural envelope improvements to Energy Savings Performance Contracts.
2. Add expertise to the Florence Recovery Working Group (FRWG) and MCICOM wide Facilities, Restoration, Sustainment, and Maintenance (FRSM) managed projects to patch badly damaged infrastructure and working to update long neglected key infrastructure.
3. Direct Atlantic Marine Corps Communities (AMCC) to use the Zero-Energy Ready Home methodology as the proven system for maximizing utility in the 144 homes that need replacement after Hurricane Florence and as an executable model for housing needs across DoD installations.

The options presented here are important to the overall effort to manage impacts to operations, and to mission critical infrastructure in an increasingly competitive global situation. Unique Marine Corps leadership is required to advance these efforts and positively impact our future.

DISCLAIMER

THE OPINIONS AND CONCLUSIONS EXPRESSED HEREIN ARE THOSE OF THE INDIVIDUAL STUDENT AUTHOR AND DO NOT NECESSARILY REPRESENT THE VIEWS OF EITHER THE MARINE CORPS COMMAND AND STAFF COLLEGE OR ANY OTHER GOVERNMENTAL AGENCY. REFERENCES TO THIS STUDY SHOULD INCLUDE THE FOREGOING STATEMENT.

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Introduction

When Hurricane Florence hit the Marine Corps Bases in North Carolina (NC) in September 2018, its impact affected not only the lives of those residing and working in the area, but also the ability of II Marine Expeditionary Force (IIMEF) to meet operational and strategic commitments in Norway, the Middle East, and elsewhere.¹ The installations affected include Camp Lejeune, NC (CLNC); Marine Corps Air Station (MCAS) New River, NC (MCAS-NR); and MCAS Cherry Point, NC (MCAS-CP) which were reported to have more than 809 buildings severely damaged just between CLNC and MCAS-CP.² Atlantic Marine Corps Communities (AMCC) reported that the storm damaged 3,045 homes at the area bases and destroyed 144 more.³ Erosion to Onslow Beach degraded the primary amphibious training area for the east coast expeditionary forces.⁴ Coastal bases for an expeditionary amphibious force cannot be completely risk free, but rebuilding in a smart and efficient manner can mitigate those risks to operations and to resident forces and their families, preserving IIMEF's ability to project combat power abroad. Hurricane Florence's destruction of long neglected infrastructure at the three NC bases is an opportunity for the Marine Corps to apply updated and radical design efficiencies using existing energy efficient technologies for installations, housing, and infrastructure at a similar cost to achieve greater long term savings on operating expenses while increasing resilience, decreasing required maintenance, and increasing available funds for structures specific to warfighting capabilities across the Marine Corps.

In place of normal status quo renovations, the use of Deep Energy Retrofits, passive building techniques, and highly efficient current building technologies and techniques will enhance installation planning measures already underway, minimize maintenance, and help posture Marine Corps investments for the ambiguous future. These measures have the added

benefit of helping the Marine Corps Installations Command (MCICOM), and Naval Facilities and Engineering Command (NAVFAC) meet the mandatory, tri-service Unified Facilities Criteria (UFC), and holistic design requirements for high performance buildings. Applying Deep Energy Retrofits will also help meet the current needs of the Marine Corps and set the stage for better management of Marine Corps resources into the future. The systematic analyses, technology, and techniques are available now, and are at cost parity when accounting for the long-term savings. If applied aggressively, the cumulative future savings this course of action calls for aligns with wise and frugal Marine Corps ideology; and makes the case for similar investments to be used elsewhere.

Roadmap

The journey conducted herein addresses the context through some background and stating the problem succinctly. Defining the core idea and critical concepts are essential to understanding the progress that government, commercial, and private entities have made in the form of case studies with salient lessons identified in following sections. Although building types vary significantly, core best practices will be explained that crosscut the Hurricane Florence recovery and dovetail into resiliency and energy security benefits for the long-term. This includes recommendations for the homes and houses destroyed by Florence and concludes with extra emphasis on the core recommendations.

Scope

The scope of this research project will be limited to making the case for Deep Energy Retrofits and high-performance housing options instead of normal scheduled renovations or Florence recovery projects just getting back to the *minimum* levels required by International Building Code. With the impacts to the CLNC area so fresh, baseline recommendations will also

be proposed relating to efforts to rebuild CLNC and the two associated bases. The intended audience is Marine Corps Installations Command (MCICOM), Marine Corps Installations – East (MCI-East), and Naval Facilities Command (NAVFAC) due to their influence on the contracting processes and management of installations. MCICOM and subsidiaries are the primary advocates for installations budgetary planning, but also control the military construction (MILCON) specifications within the wider Naval Facilities (NAVFAC) command construct and approval authority. Impacting both leaders in positions to direct these changes, and those incorporating the more precise written requirements at the MCICOM and MCI-East level, will do the most for the CLNC recovery but also provide introduction of benefits to future requirements for the entirety of MCICOM.

This writing is not a technical paper nor laden with specific procedural solutions as the variance across building type and specific environmental context cannot be captured in this one product; merely introduced. Recommendations will be limited to policy and processes but touch on the technical aspects that have pertinence. Recommendations will also focus on processes and policy associated with installations and on resource consumption; working towards increased resiliency, and future operations at a lower cost. Another limitation to this writing is the sensitivity of the ongoing Hurricane Florence Recovery Working Group (FRWG) activities; specifically, its composition and internal workings. Where applicable, specifics of the MCICOM actions taken and reconstruction activities that can be provided, will be.

Marine Corps Installations – East (MCI-East) and CLNC efforts in holistic planning,⁵ resource stewardship, and implementation of efficient building practices⁶ have made similar steps towards resiliency and efficiency *ends* like those proposed below in MCICOM's Facilities, Sustainment, Restoration, and Modernization (FRSM) plan. However, the FRSM effort can be

augmented in key areas that will be emphasized throughout. Where MCI-East and CLNC efforts are applicable, a case study has been written in collaboration with CLNC design engineers and energy managers. The FRSM division and CLNC regional efforts by the engineers and managers at the installation level need support and sponsorship from leaders to recruit partners in the federal and private ecosystems to supplement their expertise and capacity. MCICOM, Deputy Commandant for Installations and Logistics (DC I&L), Commandant of the Marine Corps (CMC) and Chief of Naval Operations (CNO) are leaders that have the influence, authority, and experience to communicate the need to future government, private, and industry partners. Reducing consumption of government resources and establishing solid ground for future savings will increase resiliency of units on installations and surrounding communities and ensure that Marines are focused on the fight.

Adding urgency to the need for awareness and sponsored application of these innovative methods is the fact that Americans at large need to close a gap from which we are hemorrhaging resources: more than 40% of all energy consumption in the United States occurs in infrastructure and buildings.⁷ In a similar fashion, the improvements provided herein are not just about Operations or Energy but about *both*, as energy is one of the biggest drivers of cost for structures over the entire lifecycle, and of increasing importance as budgets are trimmed and access to resources reduced.

If the problem – let alone a solution – were well known and the decision easy, there would be no need for advocacy or corrective action. The certifications in themselves are important relative to **what** the efficiency measures collectively **do** to increase capacity across Marine Corps installations and what they will accomplish for Camp Lejeune's ability to focus installations operations and maintenance funding towards investing savings in future warfighting

capabilities. By updating long neglected areas that drain resources with ultra-efficient operational workspaces and housing, long term savings ensure more funding for the operational generation of combat power and resilience is attained.

Statement of the Problem

The immediate problem that arose in September 2018 when Camp Lejeune, NC (CLNC) was hit by Hurricane Florence was first that of immediate safety to the Marines and their families during the storm, the flood damage that followed, and the long term respiratory and mental health impacts from the wide range of storm related events. In the mid-term, storm damage led to the onset of mold and included added stress accrued while living and working in the aftermath.⁸ Implemented comprehensively as a whole system that will be explained, Deep Energy Retrofits (DER) and construct Zero-Energy Ready Homes (ZERH) improve air quality and manage moisture to directly mitigate these problems.

Through all of this disruption, Marines' split their attention between the job of preparing for combat and the urgency of taking care of themselves and their families. Impacts to operational commitments like rotational forces, crisis response forces, and exercise deployments to Norway in fall 2018 were just a portion most immediately impacted by Hurricane Florence damage in NC.⁹ While its request to Congress for recovery funds goes unanswered, MCICOM has shifted more than \$279 million from the FRSM budget, and proposed 31 MILCON projects totaling \$1.98 billion to help with the worst of the damage and health issues.¹⁰ As recovery efforts continue, operational readiness suffers in ways that are hard to quantify, but the projects identified number in the hundreds,¹¹ for which volume provides its own gravity.

The wider context to the Marine Corps' difficulty – and the deeper nature of the problem – stems from the interconnected twin challenges of resource competition and climate change in a

tumultuous global environment. These challenges are not ones that increased spending or production (energy or materiel) will correct. Steeply increasing consumption rates are exacerbating resource shortfalls.¹² As resource competition intensifies, the need to reduce fossil fuel energy consumption becomes more urgent.¹³ Increasing portions of the world's population reside in vulnerable littoral areas and are expected to rise, with 14 of the largest 17 cities already near coastlines.¹⁴ With them, Marine Corps coastal bases, and units deploying to vulnerable areas across the globe, will be pulled in to this operating environment.¹⁵ Failure to address this problem in areas that can be *and already make fiscal sense* will continue to affect Marine Corps communities and mission accomplishment.

The Intelligence Community's 2012 and 2017 U.S. *Global Trends* assessments, and U.S. Global Change Research Program's (USGCRP)¹⁶ *2018 Fourth National Climate Assessment* (NCA4) speak to an approaching future neither desirable, nor ideal for American or global prosperity as regional crises continue to rise in frequency and effect. All three of these major assessments point to unavoidable natural catastrophic events surrounding the Marine Corps' coastal bases and include increasingly dire forecasts outstripping the service's present resources. These catastrophes and the resulting effects to regional stability only get worse without decisive action by a worldwide collective effort. Impacts are already apparent now to Americans' health and welfare, livelihoods, and the local economies across the nation. These same impacts apply, in varying degrees by locale, to the rest of the globe. Individual events will be devastating to those directly impacted by a catastrophic event, but the aggregate effects and frequency will increasingly threaten everyone.¹⁷ The Department of Defense (DoD) has been planning formally since at least 2014 for the associated operational and strategic effects from the changing global condition across the spectrum of military operations.¹⁸ This proposed policy shift assists this

combined effort to curb national appetites by starting within the Marine Corps service-sphere of influence.

Opposition to implementing efficiency measures focuses on the status quo. Opponents hold efficiency certifications like the Leadership in Energy and Environmental Design (LEED), Energy Star®, and others as empty frameworks that divert funding away from function and into aesthetics. Another way to look at the certifications is that the name increases access to resources, and opens funding not currently used to maximum utility for Facilities Sustainment, Restoration, and Modernization (FRSM) within MCICOM.¹⁹ The Commandant of the Marine Corps has said multiple times, “the current and future operating environment requires an expeditionary mindset geared toward increased efficiency and reduced consumption.”²⁰

Irrespective of long-term impact on climate change, the DoD must cope with increasing competition for budget share. The Marine Corps can expect neither funding nor capacity increases without first curbing appetite and consumption, a traditional Marine Corps tenet that has fallen by the wayside. Intentional and intelligent investment for installations improvements supporting the operational needs of the tenant units can allow the Marine Corps to curtail one significant aspect of its consumption of resources, through Marine Corps installations and infrastructure. Investing wisely in improvements to installations at crucial times for maximum impact will allow more capital resources for the overall contribution of that site by re-investing that savings back into training capabilities.²¹

Radical Efficiencies: Central Idea and Supporting Concepts.

The specific challenges associated with retrofitting existing building stock are intricate and specific to building type. As that detailed information is limited in access or distribution and

very technical in nature this writing will focus on the general research, concepts, and through case studies, come to recommendations for CLNC recovery and possible applications beyond. Measures that align with this thesis by specific building types are a great option for future research (i.e. hangars, warehouses, housing specific).

Renovation or Retrofit versus Deep Energy Retrofit. Before discussing the use cases applicable to North Carolina, a clarification in terms and methods is necessary. A *renovation* is a planned or unplanned construction project returning a structure to a “good state of repair” using the most recent International Building Code standards (i.e. back to Code). A refurbishment is similar in that it improves by cleaning, decorating and re-equipping “like material or mechanical systems” to maintain function of the structure. As needed, refurbishment may include some retrofitting. Although sometimes used synonymously, a *retrofit* differs slightly from a renovation in that it is a construction project to a structure well past the original outfitting period requiring installation of some or all new architectural, structural, or mechanical active measures that have no equable replacement (i.e. a coal furnace for a modern heat element).²² Both a renovation and retrofit typically only fix what absolutely needs to be fixed to return to usable, ‘like new’ status, or “good state of repair.” Renovations generally reduce energy consumption by 15-30% for the structure.²³

A *deep retrofit* is a comprehensive strategy, a “whole building” approach that recognizes the interrelated nature of systems, structure, and usage as the basis for an aggressive and deliberate redesign of how a structure uses and sometimes creates energy. It holistically retrofits 30-50% of the facility with as many complementary refinements as possible to generate more dividends than possible with a distributed piecemeal process. For example, collecting incremental improvements over a dozen efficiency improvements to mechanical systems and prior structural envelope improvements allows a planned major equipment HVAC overhaul to be downsized instead of

upgraded and complimentary conservation measures to accumulate and assist each other.²⁴ The preferred term by professionals in Europe is Deep Renovation, but the term Deep Retrofit or Deep Energy Retrofit will be the one used herein.²⁵

Passive or Active Measures Defined. Principles of architecture, structural design, and construction have undergone an evolutionary period beyond pure brick, cinder block, or stick frame building techniques. Technologies that will be discussed later have led to a more comprehensive simulations models and revisions to the ideal construction systems to fully account for the thermodynamics of the structure in question; the heat gained or lost by the construction and the active changes that are mechanically driven to reach the operating parameters for the space.²⁶ Improvement of the envelope increases energy retention and limits the thermal losses. This allows for an accounting of the heat gained or lost through the changes occupants bring (i.e. human body heat), appliances added heat (i.e. water heater and refrigerator expend waste heat internally) and energy gained-lost throughout the annual seasonal cycle (i.e. passive solar heat gains).

Passive measures are design principles that are incorporated into the characteristics of the structure and function with minimal additional energy expended, modification to the structure before resorting to minimal mechanical assistance (i.e. opening windows, vents, or flues).²⁷ Examples include super-insulation, airtight building envelopes that eliminate thermal bridging (heat loss through junctions and building materials), deliberate use of building orientation within the climatic zone, and control moisture (i.e. relative humidity).²⁸ Active measures are the opposite: they actively work to change the state of the structural system using mechanical systems with the intent of overcoming the shortfalls of the structure or environment to get to the ideal conditioned state required for the space. For instance, a house or office building with human occupants requires different means to achieve the optimum parameters of a useable state than a warehouse, garage,

armory, or aircraft hangar. Overcoming the relative humidity of a hot-humid sub-tropical climate like that of North Carolina is another such environmental attribute.

The most comprehensive programs for making the structure work “as-is” or passively are the Passivhaus/Passive House and the Zero-Energy Ready Home (ZER or ZERH) standards and can be pursued to a certification level as desired.²⁹ As stated above, the intent here is not to pursue the certification so much as to incorporate the functional aspects of the designs into the recovery plan of the CLNC area bases. Recommended measures will be discussed in the case studies and best practices sections.

Energy Service Performance Contracts and Utility Energy Savings Contracts. Hurricane Florence caused enough damage above and beyond the Fiscal Year 2019 budget because hurricane recovery repairs cannot be accounted for in the course of normal operations and maintenance funding lines. An appropriated funding increase, requested from Congress for the Florence recovery effort has yet to be approved despite the request of \$3.6 billion from December 2018.³⁰ Without this funding the Marine Corps will need to use all funding vehicles available, appropriated and third party alike, to repair, let alone prepare, for the next storms.

One of the primary vehicles for financing Deep Energy Retrofits is partnering under Energy Service Performance Contracts (ESPCs) where an Energy Service Company (ESCO) competes for a contract to design, acquire, install, and finance the improvement of a specific property and provides the capital for the retrofit and efficiency conservation measures (ECMs). This process can be complicated with multiple awardings and different service providers. Since ESPCs became a third-party financing option, their use has proliferated across the United States (see Figure 1). ESPCs average anywhere from 12-24 years, with the ESCO paid in dividends from the energy saved over the contract period by the energy conservation measures (ECMs) emplaced. The more improvements

made, the higher return. Alternately, if the improvements do not work as advertised, the contract guarantees the government does not pay more. If the energy costs go past the estimated costs of the contract period, the ESCO still gets the contracted amount.³¹ Similarly, but usually for amounts between \$10-30 million, Utility Energy Savings Contracts (UESCs) are competed for among the local utilities, single sourced, and are for a maximum of 24 years by statute. The utility company arranges for the design, installation, and financing of the *equipment* or ECMs. Monitoring and validation are not required nor is there a guarantee on the savings realized, usually just on the operation and performance of the equipment.³²

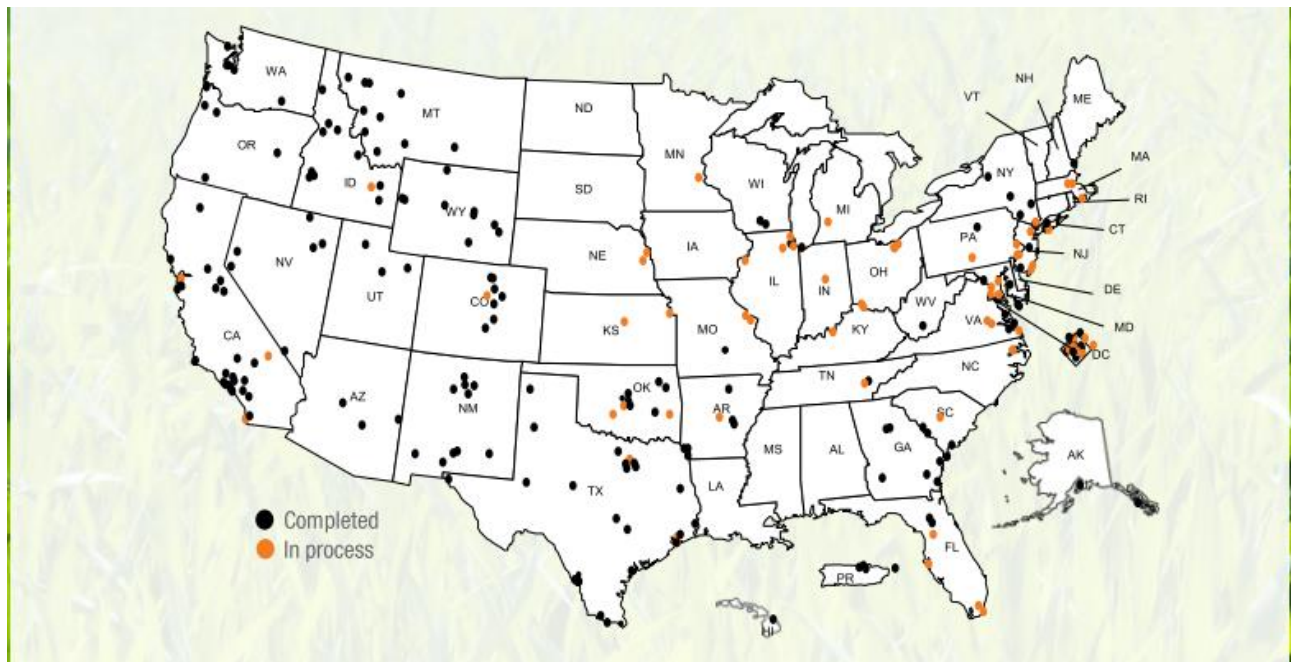


Figure 1. Federal ESPC Projects in the United States (2009-2013)

Source: “Improving Federal Energy Savings Through Performance Contracting.” *National Association of Manufacturers Webpage Nam.Org*. Washington, D.C., 2013.
<https://www.nam.org/Issues/Energy-and-Environment/Affordable-Energy/Domestic-Energy/Improving-Federal-Energy-Savings-Through-Performance-Contracting--Full-Report/>.

Holistic System and Whole Structure. Deep Energy Retrofits best practices and building science basic approaches use an updated view of the entire building as a system in its entirety. Both the design approach by the collaborative team of experts, and the technical or architectural design,

use similar ‘holistic’ terms as changes to one area affect another niche or system attribute. On the design team, the architect may make changes to the composition of the structure that affect the amount of cooling or heating load the mechanical engineer needs to account for in the design of active measure HVAC or ventilation systems. The lawyer may also limit or work an exception to policy that may allow variance to the design of both and all affect the bottom line of cost to the leadership team.³³ More will be discussed in the best practices section later.

Holistic also applies to the technical design of any structures, as building science also views the technical aspects of the interactions between structure characteristics and the forces included: water, vapor, air flow, heat transfer, occupants, and how it will be used.³⁴

Hot and Humid Climate Zones and NC Site Specific Challenges. With the genesis of this thesis being tied to vulnerabilities of the NC Marine bases highlighted during Hurricane Florence, discussing climatic planning factors unique to the area increases contextual knowledge important to the discussion and the whole Deep Retrofit process. CLNC, in the hot and humid coastal North Carolina area, presents challenges that require addressing regardless of recovery or long-term planning.

The overall age and wear on many of the buildings on the three NC Marine Corps bases dates back to World War II (WWII). Amplify the age-based wear with the wide range of type of buildings tailored to support specific military or organization mission sets that are not easily found in the corporate, public, or private sectors that are leading the way on solutions to this problem-solution set. Additionally, there is a wide variance in damage to the buildings at the three NC Marine Corps bases due specifically to conditions around Hurricane Florence in September 2018. Generally, the older buildings fared worse, but especially the historically preserved structures that employed legacy building methods that were less resistant to hurricane

level winds (i.e. shingled roofing materials vice metal roofing secured and rated to withstand hurricane winds).³⁵ Once building interiors were exposed to the accompanying rain (in excess of 30 inches in 3 days); mold, mildew, water damage to interior materials, and flooding caused the most damage.³⁶

Of key contextual importance emphasized during initial collaboration with MCICOM staff members, CLNC energy managers and design staff was the operational function of any structure that would not be sacrificed for efficiency's sake. This yielded insight into specific challenges to the recovery from Hurricane Florence and during normal updates for a hot-humid sub-climatic zone and regional challenges. The hot-humid climate zone is one of the hardest to plan for because of the high change (delta Δ) between extremes and the amount of moisture that is present, either in raw precipitation or via relative humidity from saturated air. Complications for both present design challenges requiring multi-disciplinary knowledge; from engineering to architecture to climatological. Moisture and heat lead to complications like mold and mildew that have severe implications to the operational function of the structure as designed and the health of occupants. Those inputs are extremely important and have re-directed some of the research efforts midway through the thesis process.

The International Energy Conservation Code (IECC) and the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) subdivide climate regions, or dominant meteorological conditions in to different climate zones (CZ) of which the United States has more nine thermal zones and three moisture regimes (East-to-West: Moist, Dry, Marine) that equate to 16 climate/moisture zones (see Figure 2 below).³⁷ The dominant Climate Zone across Pender, New Hanover, Carteret, and Brunswick counties encompassing the NC Marine Corps bases qualify as the 'hot-humid' CZ3A.³⁸

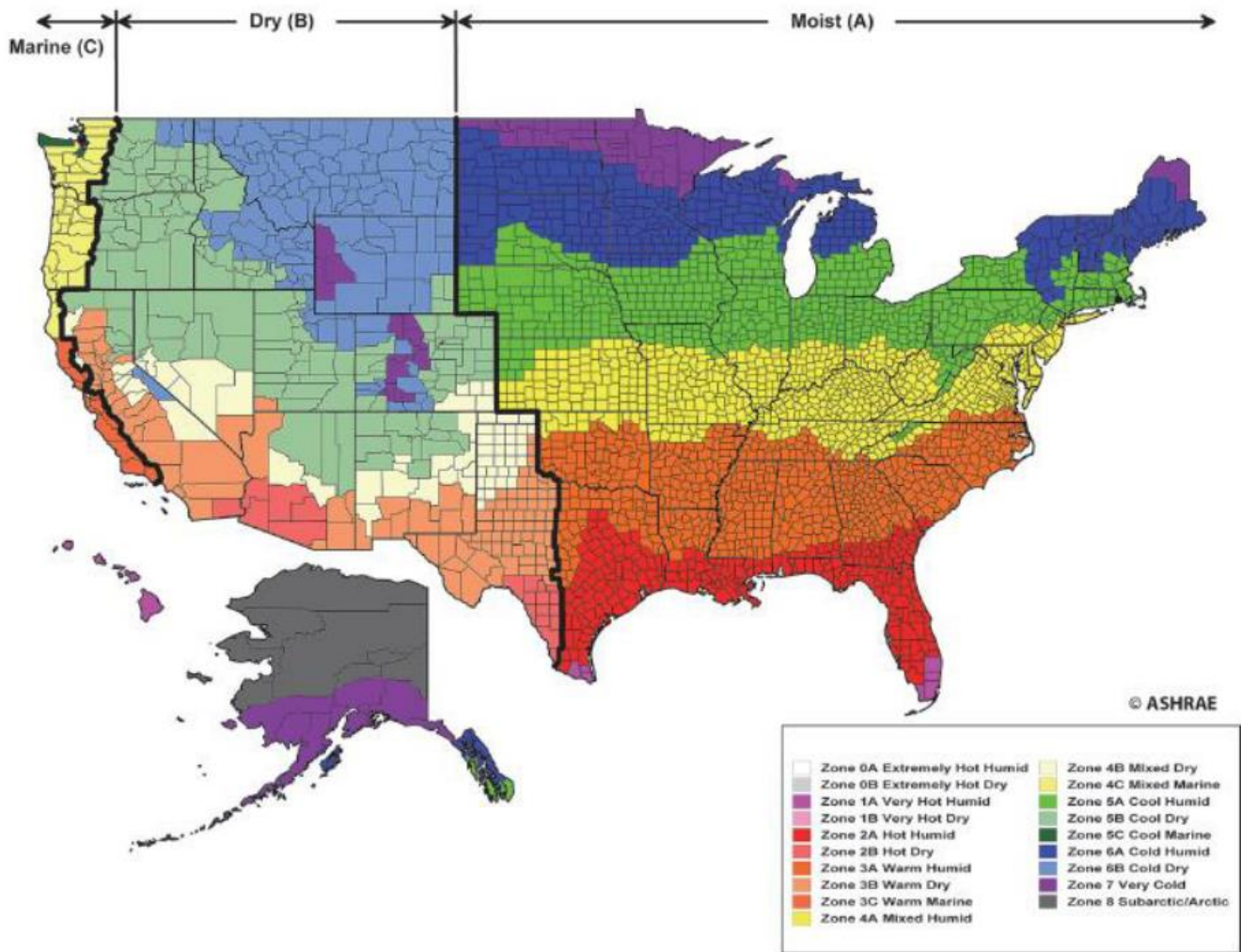


Figure 2. ASHRAE 90.1-2013 and IECC United States Climate Zone Map

Source: DOE Office of Energy Efficiency and Renewable Energy, “Preliminary Energy Savings Analysis ANSI/ASHRAE/IES Standard 90.1-2016” (Washington, D.C., 2017), 6, https://www.energy.gov/sites/prod/files/2017/07/f35/Preliminary_90.12016_Energy_Savings_Analysis.pdf.

The military mission specific infrastructure (like warehouses, garages, armories, and hangars) and requirements imposed by the sub-tropical “hot-humid” climate zone (CZ) for coastal North Carolina, CZ 3A, have been the most challenging to finding solutions. Initial research with the New Building Initiative in collaboration with the Rocky Mountain Institute (RMI), shows possible improvements to five types of buildings seen below in Table 1 show some (but not all) similarities to the complex portfolio on the NC bases. This table also helps illustrate how complex projects can be with so many

aspects that can be modified and the importance of designing improvements specific to the building. Improvements that work elsewhere in the continent often have issues in the hot-humid sub-tropical climates of the Coastal Carolinas. Moisture control (condensation, mold, and mildew from relative humidity differences between), active mechanical cooling requirements, and heat gained through sun angle and intensity at the global latitude all work to complicate the structural solutions that are viable.³⁹ Similar projects have been used to assess hundreds of ultra-efficient structures across the hot-humid climate zones in the Southern United States and Gulf Coast that apply some or all of the concepts discussed here.⁴⁰ The research on specifics for each building or structure is beyond the scope of this particular writing but well worth the time and effort to do so and should be utilized by MCICOM and MCI-East leadership.

Package	Office	Warehouse	Retail	School	Multifamily
Base Requirements	Tier 2 Bundle and Criteria 3.8: Plug Loads				
	PLUS				
25% Renewable Energy Requirement	3.7 W OR 12.8 Btu per sq ft of conditioned space*	2.4 W OR 8.2 Btu per sq ft of conditioned space	4.8 W OR 16.4 Btu per sq ft of conditioned space	5.4 W OR 18.5 Btu per sq ft of conditioned space*	5.6 W OR 19.3 Btu per sq ft of conditioned space
	PLUS ONE OF THE FOLLOWING OPTIONS				
Advanced Envelope Option	Criteria 3.2: Advanced Envelope	Criteria 3.2: Advanced Envelope PLUS Criteria 2.20: Enhanced LPD PLUS Criteria 3.3 Advanced Daylighting	Criteria 3.2: Advanced Envelope	Criteria 3.2: Advanced Envelope	NA
Advanced Daylighting Option	Criteria 3.3: Advanced Daylighting	Criteria 3.3 Advanced Daylighting PLUS Criteria 2.20: Enhanced LPD PLUS Criteria 3.2: Advanced Envelope	Criteria 3.3: Advanced Daylighting	Criteria 3.3 Advanced Daylighting PLUS Criteria 2.18: Enhanced Opaque Wall PLUS Criteria 2.20: Enhanced LPD	NA
Energy Recovery Ventilation Option	NA	NA	Criteria 2.22: Energy Recovery Ventilation	Criteria 2.22: Energy Recovery Ventilation PLUS Criteria 2.20: Enhanced LPD	NA
Demand Control Ventilation Option	Criteria 2.23: Demand Control Ventilation	NA	NA	Criteria 2.23: Demand Control Ventilation	NA
Advanced Office Lighting Option	Criteria 3.4: Advanced Office Lighting	NA	NA	NA	NA
Advanced HVAC Option	Criteria 3.6: Variable Capacity Heat Pump OR Criteria 3.7: Radiant Heating & Cooling	NA	NA	Criteria 3.6 Variable Capacity Heat Pump	NA
2% Additional Renewable Energy Option	0.5 W OR 1.7 Btu per sq ft of conditioned space	0.9 W OR 2.9 Btu per sq ft of conditioned space	0.7 W OR 2.4 Btu per sq ft of conditioned space	0.7 W OR 2.4 Btu per sq ft of conditioned space	0.8 W OR 2.8 Btu per sq ft of conditioned space

* If pursuing the Advanced HVAC option with Criteria 3.6: VCHP, the 25% Renewable Energy requirement is reduced to 19% (2.8 W OR 9.7 Btu per sq ft of conditioned space).

Table 1. New Building Initiative Construction Guide Options by Building Type

Source: RMI New Building Initiative, and The Advanced Buildings. “New Construction Guide and the 2030 Challenge.” Advanced Buildings Factsheet. Boulder, Colorado, 2015. http://newbuildings.org/wp-content/uploads/2015/11/nbi_ab_2030_Factsheet2.pdf.

Deep Energy Retrofits: Government, Commercial & Private Sector Progress

The Marine Corps can learn a lot about energy security and resiliency from government agencies, adjacent services, and commercial organizations. The largest and most capable is the General Services Administration (GSA) which started its National Deep Energy Retrofits (NDER) in 2012; and has collaborated with an ecosystem of ESCOs and other partners. The NDER originally began with 16 energy service companies (ESCOs) that the Department of Energy (DOE) recruited to retrofit government spaces to comply with stated federal goals and congressional mandates.⁴¹ The initial 2012 listing opened 30 GSA properties in 29 states for more than 16.9 million square feet.⁴² The program has since expanded to more than 102 ESCOs⁴³ and a plethora of projects all across the United States and the many climate zones already discussed above in Figure 1.

GSA continued expanding on the beginning partnership with the DOE, it's DOE National Laboratories, and the Department of Defense (DOD) among others.⁴⁴ The ten projects under the starting NDER experiment reached an average of 38% reduction in energy usage compared to the 21% reduction achieved by the 33 projects used by other federal agencies in the study. Continued collaboration between GSA, the DOE Federal Energy Management Program (FEMP), Oak Ridge National Laboratory (ORNL) and Rocky Mountain Institute (RMI) has helped the ESCOs understand more of the need for increased energy savings in federal buildings.⁴⁵ The third and most recent collaboration, or design charette from 2015, resulted in the Commissioner of GSA's Public Buildings Service issuing a memorandum re-directing the GSA force to maximize the impact of funding vehicles, like ESPCs and Utility Energy Services Contracts (UESCs), as the primary contracting vehicles to maximize each structure and investment returns over a 25-year cycle.⁴⁶

The GSA NDER has combined the short-term payback with an additional time for longer payback measures in order to find and using more ECMs that allow for a greater flexibility and projected at least 38% energy reduction across all GSA NDER projects as of 2017.⁴⁷ Another ORNL study from 2013 reviewed savings research and found that typically the government receives nearly twice the level of cost savings guaranteed by the ESCO in the contract and factors not typically captured in the monitoring and verification stage were found. The ESCOs are then contractually responsible for the maintenance on the installed hardware, which enables the equipment to last past the average performance period with the ESCOs taking consistent upkeep, and using very conservative energy prices estimates since 1998.⁴⁸

The Marine Corps' fellow services have capitalized on far more of GSA's NDER and the third-party contracting vehicles presented here. Just as an example of one fellow service, the US Army manages more than 1 billion square feet of structures in their portfolio and has been a longtime advocate of third-party financing since the 1990's that has been supported by many in the highest echelons of their leadership. As of 2017, the US Army program had used orders and modifications for ESPC over 245 times and UESC more than 375 times; totaling more than \$2.5 billion in the life of the program and over \$1 billion in the previous 5 years.⁴⁹

MCICOM is currently capitalizing on ESPCs for other projects as exemplified with the MCAS Beaufort energy reduction project in 2012⁵⁰ and the CLNC steam plant decentralization project completed in 2017.⁵¹ Although not technically a Deep Energy Retrofit by the definition here, MCAS Beaufort used an ESPC contracting vehicle to finance a 30% reduction in its energy intensity compared to a 2003 baseline through a combination of water efficiency measures, high-efficiency geothermal heat pump heating, ventilation, and air conditioning (HVAC) systems, a cogeneration plant for heating water and 1 MW of electricity, photovoltaic systems and more.

This ESPC was specifically nested under the DOE umbrella ESPC.⁵² Although MCICOM is using ESPCs and UESCs there remain areas for improvement that will be discussed later.

Another key organization that holds considerable weight in the commercial and private sector regarding resource efficiency is the Rocky Mountain Institute (RMI), led by Amory Lovins. Their 2011 book *Reinventing Fire* makes a convincing case for changing the way private citizens, businesses, and government look at energy consumption within their business models and charts a realistic course for moving beyond fossil fuels and operating at levels \$5 trillion less than in 2010 if utilized fully. More than 60 scientists, engineers, and business experts collaborated on the roadmap and action portfolio. The RMI research team's analysis was exhaustively contributed to, critiqued, and verified by experts outside RMI from industry, military, and government.⁵³

The RMI Re-Inventing Fire proposition and strategy focus on telling the story behind the true cost of using fossil fuels and transitioning energy infrastructure beyond oil to other sources⁵⁴ over four main lines of effort. These focus areas include improvements for energy consumed by industry, buildings, power production, and transportation, and match the main action areas also deemed crucial by the World Business Council for Sustainable Development (WBCSD) below in Figure 3. All business cases/models aimed at the bottom line - *cost*; and initial investments in the transition are offset by the return from the continued accrual of savings beyond the threshold of the initial investment.⁵⁵ The third line of effort applies to MCICOM installations: designing new buildings and retrofitting the old for maximum efficiency.⁵⁶ RMI.org continues to assist industry,

builders, town planners, engineers, and government organizations in these efforts to prepare society to meet this and future resource challenges.

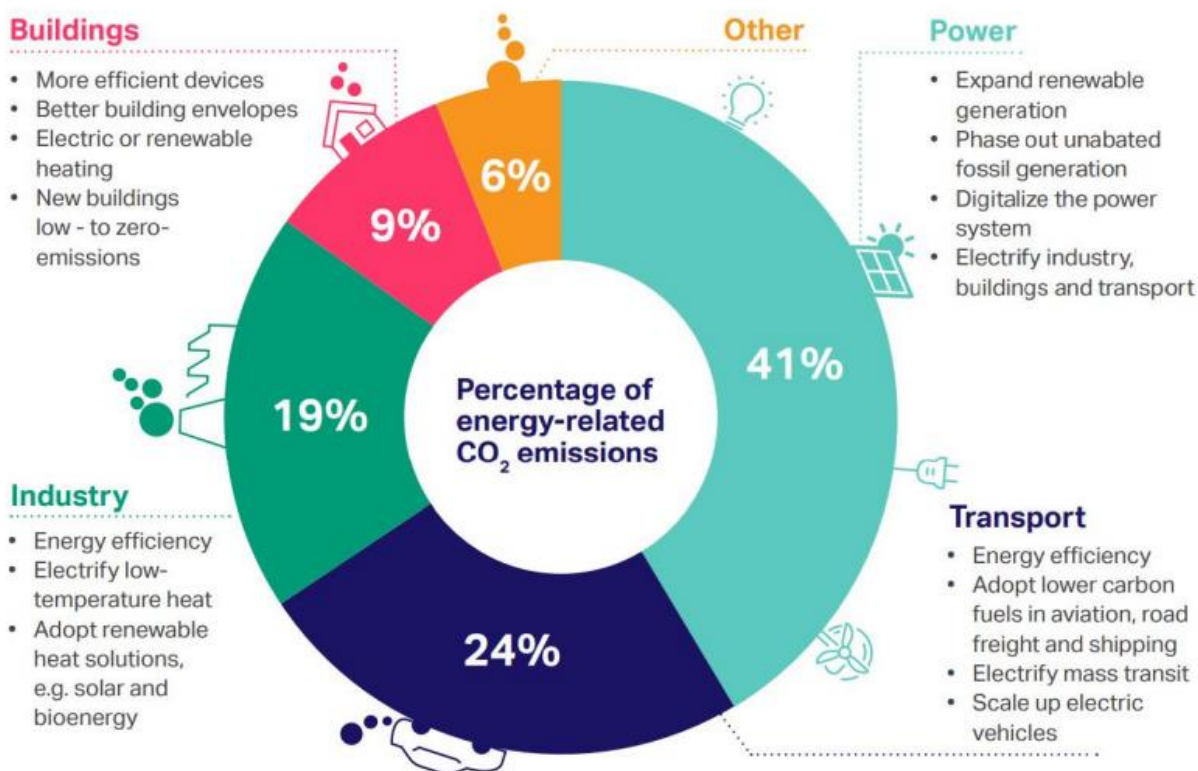


Figure 3. WBCSD Four Principle Areas of Effort for Sustainable Development

Source: Mariana Heinrich and Lindee Wong, “New Energy Solutions for 1.5°C Pathways and Technologies to Achieve the Paris Agreement” (Geneva, Switzerland, 2018), https://docs.wbcsd.org/2018/12/WBCSD_New_Energy_Solutions_for_1.5C.pdf.

RMI chose to focus improvements on building infrastructure because they are attributed with consuming nearly 3/4 of all electricity produced in the United States.⁵⁷ RMI continues to collaborate and execute plans across the industry as published via the RMI webpage, publish cooperative business models, document through case studies, and lead engagement projects applying technology towards the end state of decreasing U.S. energy consumption and shifting the economy to be the most competitive in future markets. RMI has been a driving force in bringing the ecosystem together on this issue and a key partner collaborating with players across government on many projects for over a decade.⁵⁸

Civilian corporate and academic institutions working on associated problem sets are far wider reaching than the apparatus currently being used by MCICOM staff, MCI Regional commands, and the individual installation staffs that have limited time and capacity to research and implement new ideas. They have generated experiences and tested improvements in the commercial and private sectors from which MCICOM can glean knowledge to make the case for using similar construction techniques, and contracting vehicles to decrease the current consumption models. Case studies in this work will highlight some of the problems the GSA NDER has already recognized and that MCICOM has yet to employ fully and incorporate in to future contracts. These case studies will get MCICOM and NAVFAC closer to solutions for some of the wide variety military use specific workspace requirements and are relevant to the Coastal Carolina specific challenges already discussed.

Case Study: Empire State Building “Deep Energy Retrofit”

Anthony Malkin, the Empire State Building (ESB) owner, led the effort and recruited a list of partners⁵⁹ to assist in the “deep retrofit” of the iconic landmark, which completed the first stage of its deep retrofit in September of 2010. The final stage is a progressive work as tenants change over or decide on specific needs to be incorporated in to their scheduled remodels on leased spaces inside the ESB. For this initiative, the RMI served as the design partner, and pushed the integrative design process. Key leadership and the hard work of the motivated group of experts gathered together for this effort led to a long-term plan that maximized energy efficiencies, and in doing so supplanted a chiller replacement project with a refurbishment; realizing a \$17.4 million reduction right at the outset. The measures chosen incurred minimal extra investment that was returned inside three years for most projects⁶⁰ (Figure 4 and Table 2).

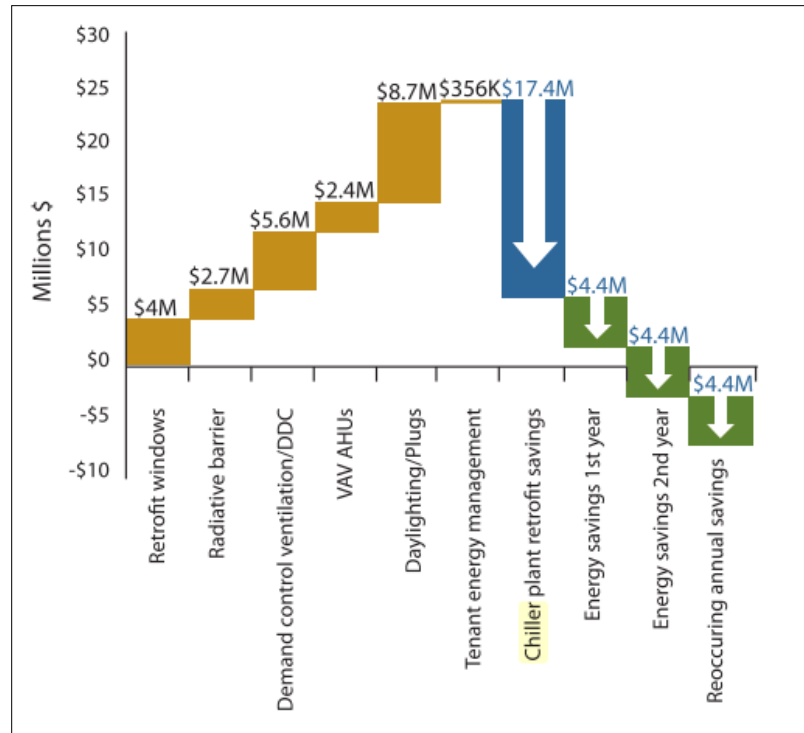


Figure 4. ESB Annual Energy Savings 4 Year Return on Investment

Source: Eric Harrington and Cara Carmichael, “RetroFit Project Case Study: Empire State Building,” Rocky Mountain Institute Case Study Database, 2009, 2, <http://www.rmi.org/Content/Files/ESBCaseStudy.pdf>.

Through innovative brainstorming, systems knowledge, and referencing other successful projects, the RMI ESB Deep Retrofit team came up with more than 70 feasible energy efficiency measures to implement with current technology, if unfettered by time, cost, material or other limitations. The team of experts used on the ESB DER collaborated and planned the possible solutions. They focused on performing “the right steps in the right order” by reducing the thermal loads to lower total heating or cooling requirements; installing and upgrading to the most efficient systems currently available; and ongoing adaptive control and monitoring of these energy systems (see Figure 5 below).⁶¹

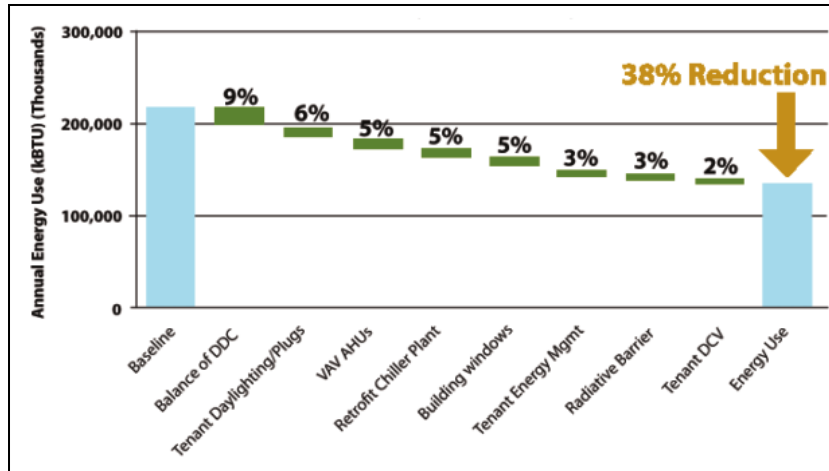


Figure 5. ESB Annual Savings by Energy Conservation Measure

Source: Eric Harrington and Cara Carmichael, “RetroFit Project Case Study: Empire State Building,” Rocky Mountain Institute Case Study Database, 2009, 2, <http://www.rmi.org/Content/Files/ESBCaseStudy.pdf>.

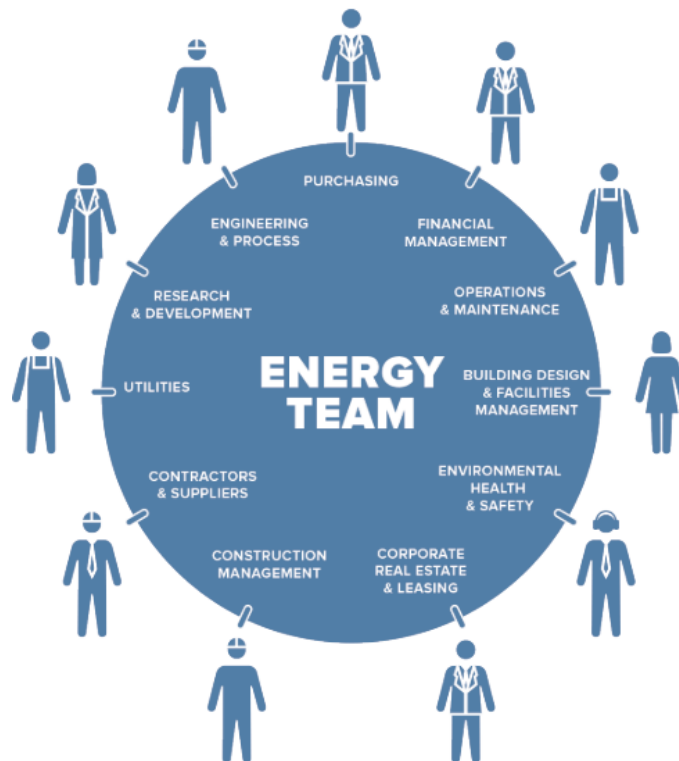


Figure 6. Working Group – Deep Energy Retrofit Team of Design Experts

Source: Thelen, et al. “Scaling the Circular Built Environment.” Geneva, Switzerland, 2018. https://docs.wbcsd.org/2018/12/Scaling_the_Circular_Built_Environment-pathways_for_business_and_government.pdf. and

The ESB Retrofit team composition itself was a crucial factor in the collaboration. The experts ranged from maintenance, construction, utilities, and building design experts to finance, legal and environmental health and safety (see Figure 6 above). Through this process all of them understood the combined effects of the interactions between measures and systems; and the resulting energy savings of the different bundled options allowed them to pick about twenty projects to implement in the Deep Retrofit, with the biggest items displayed in Figure 4 and Figure 5. These measures combined to achieve a 38% reduction in energy consumption and culminated in more than \$4.4 million annual cost savings per year above the \$17.4 million saved by installing a smaller chiller and forestalling street excavation that cumulated into a significant cost offset⁶² (see Figure 4 and

Table 2). In addition to maximizing the use of existing building stock this also proves that using a “deep retrofit” can help a scheduled large update come in on time; and on or under budget, while decreasing the overall operating costs throughout the life of the building.

Retrofit Technique Applied	Capital Cost	Annual Savings	Description
Radiator Insulation and Steam Trap Savings	\$2.7 million	\$491, 191	More than 6000 reflective barriers installed behind radiators
Windows Retrofit	\$4.5 million	\$410,000	6,500 existing double hung windows rebuilt onsite to include suspended coating film & gas fill (3x insulation value)
Direct Digital Controls and Demand Control Ventilation	\$24.5 million \$117,000	\$858, 305	Upgraded existing piecemeal and pneumatic control system to digital controls, CO2 sensors for occupancy cueing. Lower Cooling demand = smaller chiller plant needed.

Chiller Plant Retrofit	+\$17.5 million cost savings Cost \$5.1 million	\$675,714	The chiller plant retrofit project included the improvement of four industrial electric chillers in addition to upgrades to controls, variable speed drives, and primary loop bypasses. Smaller enabled by ECMs & mitigated tearing up 5 th Avenue.
Tenant Energy Management	\$365,000	\$386, 709	Education and collaboration with tenants to manage plug loads and access to online energy benchmark info
Tenant Daylighting, Lighting and Plug Loads	UNK	\$904,862	Biggest Energy Saver. Reduced lighting density in spaces; dimmable ballasts & sensors for workspaces; Cost w/ Window Retrofit & tenants turnover. Education!
VAV Air Handling Units	\$47.2 million Distributed cost at turnover	\$702, 507	As tenants turn over units upgraded to two variable air volume units per floor & more efficient distribution system. Greater occupant comfort & performance
TOTAL Annual Savings		\$4,393,796	

Table 2. Empire State Building DER Technique, Cost, Savings

Source: Vaughn, Kelly. “Empire State Building Retrofit Surpasses Energy Savings Expectations.” *Rocky Mountain Institute: Outlet Blog*. Boulder, CO: Rocky Mountain Institute online content, 2012. https://www.rmi.org/blog_empire_state_retrofit_surpasses_energy_savings_expectations/.

Another key consideration for the building owner was the bottom line of the investors and other stakeholders that were invested in the ESB itself, part of the economy, or the project as a contributor of material or labor. All of these external actors exert influence in some way or form on the DER project through providing a capability, managing the property, or as the end user. The WBCSD has a model of these external actors derived from extensive study of similar retrofits and new building practices around the globe (see Figure 7 below).⁶³

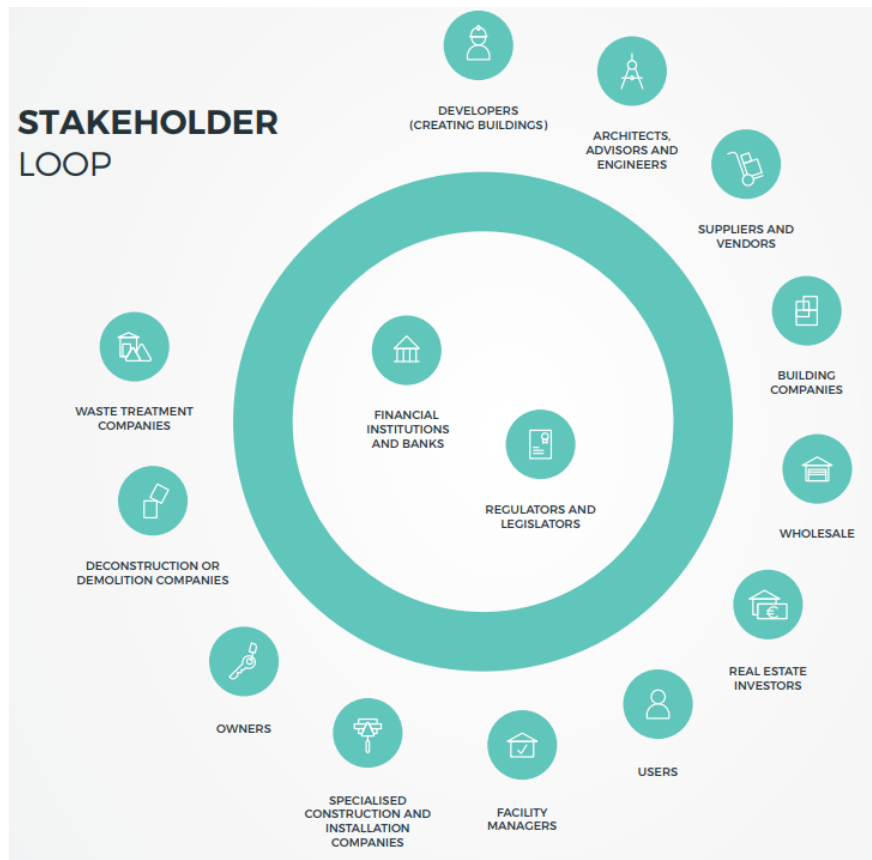


Figure 7. WBSCD Stakeholders for Building Deep Energy Retrofits

Source: Thelen, David, Mike van Acoleyen, Wouter Huurman, Tom Thomaes (Arcadis), Carolien van Brunschot, Brendan Edgerton, and Ben Kubbinga. “Scaling the Circular Built Environment.” Geneva, Switzerland, 2018. https://docs.wbcsd.org/2018/12/Scaling_the_Circular_Built_Environment-pathways_for_business_and_government.pdf.

The conclusion drawn here that MCICOM can and should expand its use of existing relationships with experts and institutions that bring a significant amount of expertise to infrastructure development or retrofitting existing structures. The lesson from the ESB ‘stakeholders’ above directly applies to the MCICOM’s current ecosystem in Figure 8 below. The MCICOM ecosystem contains members from municipalities located near installations, partners in academia, DoD partners and commands, and corporations and service industry partners. Missing from this ecosystem are key organizations like GSA NDER, RMI, and NREL

that have a plethora of experience that can be brought into development of options for recovery, retrofits, or planning resiliency improvements.⁶⁴

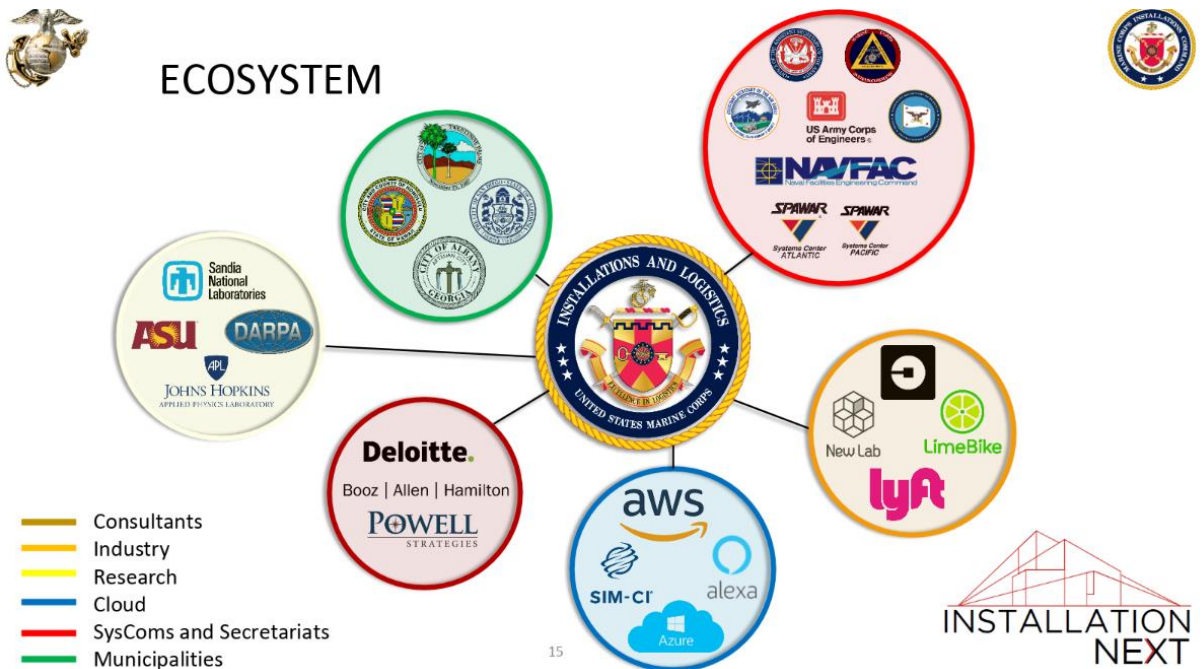


Figure 8. MCICOM - Installations neXt Depiction of Ecosystem

Source: Marine Corps Installations Command. “MCICOM IX Level Brief.” Washington, D.C., December 21, 2018.

A key recommendation would be for MCICOM and its subordinates to expand the current ecosystem to include the RMI, NREL, DOE Energy Efficiency & Renewable Energy (EERE), and GSA NDER programs into MCICOM’s ecosystem. MCICOM operates in a complex government environment that includes Congress for financing and oversight, fellow armed services competing for resources, and tenant units or other users. The point would be to use the knowledge and established relationships with ESCOs that GSA NDER, RMI, and NREL possess for additional benefits explained in the next case study. Adding RMI and the National Renewable Energy Laboratory (NREL) to the MCICOM ecosystem (see Figure 8) with the others from academia and think-tanks would make the most sense from a collaboration and research standpoint. Adding GSA NDER with the others in government would enhance its ability

to draw in a wide range of associated energy, architect, and engineering experts from other government projects to the Florence Recovery Working Group or future WGs of similar nature for any disasters that may hit Marine Corps bases close to the coast like MCAS Beaufort or Marine Corps Recruit Depot Parris Island *before* a storm hits, to be prepared in the event of such an event to move quickly in response. This would increase current recovery capacity and draw on existing relationships developed inside the U.S. Government and across the private sector to the Marine Corps' benefit. This should allow a more deliberate recovery response for the North Carolina area bases operating capacity and designing the working group system to operate better in the future – both for the NC area bases but also for others destroyed by future storms.

Case Study: Naval Air Station Oceana and Dam Neck Annex, Virginia

The Oceana Case shows where the ESCO turned a profit by performing the most of the ‘low hanging fruit’⁶⁵ and focused mostly on the active measures (mechanical systems) vice any passive measures. Technically this is a Deep Energy Retrofit due to its projected savings \$6 million annually for approximately a 40% reduction from prior to the project being undertaken. ECMs improvements employed across more than 100 buildings at NAS Oceana and Dam Neck Annex included lighting retrofits to ballast and updated 40,000 efficient fixtures, digital controls on more than 18,000 measurement points, and 10,000 fixtures replaced for water conservation. Beyond these basic measures, Trane U.S., Inc. as the ESCO, was centering its efforts on the decommissioning and decentralization of the out-of-date and inefficient steam plant. Incorporating the ECMs before this 70% downsizing was to occur helped them ‘right size’ the follow-on installation of cooling towers. As a multi-phase project, and having a heightened level of communication between the Navy and Trane allowed for the successful Phase 2

decommissioning of Dam Neck Annex's steam plant to provide the impetus for updating the main base steam plant and expansion of the lighting and water ECMs into Phase 3.⁶⁶

The combined retrofit and operations-maintenance team worked together in a complimentary effort for the steam plant decommissioning project in 2010 and installed more efficient ground-sourced heat pumps (GSHPs) in selected buildings and updated monitoring technology. Because Trane was written in to the ESPC to provide Operations and Maintenance (O&M) they were able to advise on placement for protection of key components away from corrosive coastal salt exposure avoiding future component replacement costs and maintain higher efficiency throughout the life of components. While still in phase 2, a Trane engineer recognized a Hampton Roads Sanitation District (HRSD) effluent pipeline running through the project area disposing 500 million gallons of graywater per day that could operate as a heat rejection loop trimming the GSHP cooling requirement.⁶⁷ More than 89 new GSHPs were added to the existing 211 GSHPs and 4,000 tons of water-cooled chillers were serviced from the water pipeline.⁶⁸

The Navy and Trane were able to move quickly and capitalized on this existing structure, establish a partnership with HRSD, where the US Navy granted a land easement in exchange for use of the affluent pipeline. Using the affluent pipeline allowed the engineers to redesign the 4,400-ton condenser for the 450-ton GSHP to eliminate several cooling towers. Using the affluent pipe was more efficient than traditional GSHP cooling methods and reduced steam-plant emissions and potable water use.⁶⁹ This case is a valuable example for the Naval services and is rightly used as a stellar example of teamwork and integrated design that uses the particular benefits at the site to the advantage of the design; for efficiency, resiliency of the components, and adapting benefits in as phases unfolded.

MCICOM will see a higher return on the initial investment as long as the UESCs and ESPCs have the appropriate level of specificity and incentives written in to the contracting vehicle that require the ESCO to incorporate the required efficiency measures and improve the building structure or envelope. A key difference between the two cases here is the difference in scope of the deep retrofit; the Empire State Building included changes to the envelope (windows, heat shields etc) that will work passively well beyond the life of the contracting vehicle. In the case of NAS Oceana, the DER was mostly ‘low hanging fruit’ spread over more than 100 buildings with the one large active mechanical system revision (steam plant). Both are impressive for different reasons. By requiring the ESCO to treat the whole system by including envelope improvements instead of just fixing the ‘low hanging fruit’ the Navy would get a better return on investment.⁷⁰ The case study on Naval Air Station (NAS) Oceana in Norfolk, VA shows some of those same proclivities, aiming for the ‘low hanging fruit’ instead of a Deep Retrofit of the infrastructure and associated ECMs.

The critique presented here notes the difference between the Empire State Building and NAS Oceana DER, being that the NAS Oceana DER lacked any positive changes to the efficiency of the structure envelopes from insulation, triple paned windows, or moisture controls from mechanical ventilation or moisture barriers. The NAS Oceana DER is an example of mechanical active measures (i.e. HVAC system) being enacted without addressing system wide issues like porous envelopes that force the HVAC system to run more just to mitigate lost ‘paid-for-air’ and humidity due to infiltration. Writing structural improvements into the ESPC, specifically envelope improvements that maximize passive features at incremental cost parity (like window shading, window glazing, insulation, or that works as both a moisture barrier and to prevent heat loss-gain) are all viable options that have not been worked in to any of the USMC

ESPC contracts to date.⁷¹ The ESCO is not going to want the ESPC to be structured with more ECMs as each measure adds to cost and length of time before payments from savings can be accrued. This trims the ESCO's profit margin but is more advantageous to the Marine Corps.

ESPCs are limited by both statute and definition of what ECMs are, and what they can be used for "retrofit" of buildings.⁷² According to the MCICOM Energy Program manager there are US Code and other legal limits on the changes to be performed on an existing structure; and an ESPC (with an ESCO) or UESC cannot be used to demolish the inefficient structure and rebuild a more efficient building.⁷³ The ECMs have to be linked to increasing energy or water-use efficiency⁷⁴ for which the envelope or building's closed system building structure is a key part to how it maintains, loses, or gains energy from-to the climate zone. However, improvements to the structure and envelope in the course of a deep retrofit are allowable; but have yet to be used by either the U.S. Navy or Marine Corps.

Both of these case studies are important to MCICOM because if the total cost of baseline operations of the infrastructure can be decreased by 30-40 percent, significant monetary resources can be allocated to other main vectors important to sustaining Marine Corps Operations and Warfighting Functions. The longer structures deteriorate and continue to draw funding away from other functions the worse it will get. Oceana also further emphasizes two main tenets of the Deep Energy Retrofit program; timing a DER with a planned upgrade and taking advantage of opportunities specific to the locale, site, or existing infrastructure. If the Marine Corps can incorporate a Camp Lejeune based DER of specific buildings slated for storm refurbishment in concert with recommendations forthcoming, this natural catastrophe can be turned into a benefit by using the "reset" to gain a better future position.

Second, using a ESPC contracting vehicle to perform a Deep Energy Retrofit revitalization of any structures after an environmental disaster like Hurricane Florence or during a reapportionment of units from Japan to Guam or Hawaii, allows a wider array of options to be considered for unit operations, and occupancy.⁷⁵ This also allows structures to be identified in the existing building stock instead of creating new buildings under MILCON contracts, saving the cost of construction and time required. Going beyond the low hanging fruit is a matter specific to the structure and situation, present in the context of the entire system as discussed during the background section. Best practices will be discussed after the next case study on Camp Lejeune, NC.

Case Study: Camps Lejeune, Johnson, and MCAS New River -- Deep Energy Retrofit?

Important to both the discussion on Deep Energy Retrofits and CLNC's energy resiliency is an effort that was undertaken without fanfare or previous academic attention. MCI-East and Camp Lejeune Installations Operations planned the decentralization of five 75-year-old steam plants, steam pit demolition, and dismantling of approximately 50 miles of steam and condensate piping that affected 548 buildings across CLNC, Camp Johnson and MCAS New River.⁷⁶ Planning started in 2010 with the first plant decommissioned in October 2015 and the project completed with the last steam plant shut down in April 2017. Ingenious planning spread the construction across stages in the final two years of the seven-year project and the blended use of both normal and incentive MILCON funding, and multiple third-party financing options. All told the project used one 3.6% 15-year term UESC, seven Energy Incentive Program (EIP) MILCON

contracts totaling \$73.8 million, two Energy Conservation Incentive Program (ECIP)¹ for \$11.7 million, one MILCON of \$27 million, and \$6 million for the 21 forgotten buildings. Most notably this project reaches simple payback within 4-7 years.⁷⁷

The biggest challenge this project overcame was minimizing the impact to base and unit operations. This was extremely important to the service and occupying units; that they saw minimum interruption in service with no critical failures. CLNC and MCI-East accomplished this feat by length of time, phasing, with temporary utilities, cutovers to test capacity, and in-depth testing and maintenance to ensure minimal operational disruption.⁷⁸ They overcame a variety of construction challenges including historical buildings without the most recent storm measures, asbestos, mold build-up, decades of grease, and as already mentioned the weather⁷⁹ and particular climate zone (3A hot-humid) found in coastal NC.

This project could qualify as a Deep Energy Retrofit based on the energy savings and water savings, a 50% reduction in heating energy used for the regional bases, and 87 million gallons of water per year. If this project were part of a bigger plan to phase a deep retrofit of structures on the bases but that is yet to be determined, and likely not until after Florence recovery construction is well underway. This savings does not include any accounting from O&M since it has yet to be calculated. The primary reason this project saved so much at once was the advanced age of the steam plants with the associated costs to such old equipment. Replacing the 75-year-old equipment and installing new control

¹ Note: ECIP was established by 10 USC § 2914 and is defined as a subset of the Defense-Wide MILCON Program specifically intended to fund projects that reduce DoD's energy costs or save energy; specifically new, high-efficiency energy systems and improvement and modernization of existing energy systems. EIP is a distinct funding program designed for energy related projects, requirements, and mandates within repair and/or minor construction limitations. Citation referenced is in the footnote at the end of the sentence.

systems reduced regularly occurring emergency repair costs and failures of the World War II era heating and cooling system. This immediately saved \$5.7 million in fuel costs and \$7 million in emergency repair expenses inside the plants and steam lines. Other O&M costs within terminal buildings are difficult to tabulate at this stage but are a hidden benefit. Finally, as a bonus it also eliminated the need for coal usage and reduced nearly 69,000 tons per year of greenhouse gases emitted on site.⁸⁰

Study of this case for CLNC, Camp Johnson, and MCAS New River also emphasized similar points to the previous two case studies other than important lessons specific to the military context required by the units residing on the bases. This CLNC retrofit again omits any improvements to the envelope, reinforcing a key point from the previous case study. The phasing and length of time of planning to execution may seem long (five years). Other measures like temporary utilities were key to the minimal disruption of infrastructure critical to the mission of the base and resident units. This case also emphasizes the cost-impact of 75-year-old equipment, well past its life-cycle identified for replacement, and the creative solutions that were found to work around the limitations, can create the greatest impact. In this case the deep energy retrofit achieves simple payback from energy savings inside 7 years.⁸¹

Steam Plant	Completion Date	Cost	Annual Savings	Buildings Affected
Camp Geiger	Jan 2016	\$7.5 million	\$300,000	48
MCAS New River	Dec 2016	\$20 million	\$650,000	52
Courthouse Bay	Dec 2016	\$9 million	\$2,500,000	29
Mainside CLNC	Jun 2017	\$99 million	\$1,700,000	289
Camp Johnson	Jun 2017	\$14.5 million	\$550,000	62

Table 3. MCI-East CLNC Retrofit: Decommissioning Five Regional Steam Plants

Source: Smith, E. “Steam Decentralization at Marine Corps Base Camp Lejeune” (2017)

What is currently being planned for any other retrofits or updates for CLNC and NC area bases is limited to an ESPC that has been in development since before the storm. This ESPC is

focused on completing the monitoring and automation of the control to systems covering about half of the mechanical systems currently in place and compliment those planned for the future. Details are in flux and not necessarily critical to continue discussing here other than to say that the work continues and work at CLNC is an evolution of progress and not revolutionary.⁸²

Housing - Advantage in Recovery from Hurricane Florence?

In addition to incorporating NDER based ESPCs for retrofits of existing structures to be saved in the MCICOM portfolio, MCI-East and Atlantic Marine Corps Communities (AMCC) have the challenge of replacing the approximately 144 homes that were destroyed by Hurricane Florence as mentioned above. Smart investment now not only replaces the destroyed homes; but can achieve both storm resilient and energy efficient structures. MCI-East and AMCC should consider the primary method has adapted the most useful characteristics from the spectrum of options and that has been determined the best model for North America climate ranges, energy prices, and includes examples for the hot-humid Coastal North Carolina climate that can be applied to the Hurricane Florence recovery. The Zero-Energy Ready Homes (ZERH) method has incorporated the best from Passive House/Passivhaus⁸³ and previous DOE design methods without ranging to extremes needed in more extreme climate zones or practiced on other continents with different climate zones. Again, as mentioned above, the primary concern here is the function that is achieved (storm resiliency and energy cost effectiveness) via the method vice the certification itself, and the climate zone specific challenges introduced are incorporated in recovery plans.

A review of the DOE Office of EERE *Building America* program from 2007-2010, which worked with eight builders to construct 267 homes in the hot-humid climate zone, shows that the

program achieved energy savings exceeding 40% – verified by each homeowner’s utility bill – to yield a net profit for each ranging from \$277 to \$1,392 per year as seen in Table 4 below. The extra investment in the build phase led to a slightly increased mortgage payment that was more than offset by the annual energy savings and the increased cashflow to the homeowner that would pay dividends after loan repayment.⁸⁴ Although AMCC finished replacing the WWII legacy housing at all NC bases in 2013 with Energy Star method constructed houses,⁸⁵ as mentioned in Best Practices, storms wiping out structures is a good opportunity for replacing destroyed homes with a more effective model well worth the cost as illustrated here. This is not the case for the less damaged homes.

Every Building America project yielded net annual gains for homeowners, after deducting increased mortgage costs from annual utility bill savings.

Builder	Added Builder Cost for Energy Improvements	Annual Mortgage Payment Increase for Energy Efficiency	Annual Utility Bill Savings vs. Benchmark	Net Annual Cash Flow to Homeowner	Total Energy Savings
David Weekley Homes	\$3,314	\$400	\$2,756	\$2,356	48%
Green Coast Enterprises	\$7,925	\$632	\$719	\$86	55%
Imagine Homes	\$4,800	\$746	\$2,067	\$1,321	54%
Tommy Williams Homes	\$3,314	\$265	\$930	\$665	42%
William Ryan Homes	\$7,889	\$699	\$1,615	\$916	46%
Castle and Cooke	\$5,723	\$457	\$886	\$430	44%
Brownsville Affordable Homeownership Corp.	\$2,970	\$237	\$977	\$740	41%
Forest City Military Communities	\$9,775	\$757	\$2,253	\$1,496	48%

In every case study, the energy-efficiency improvements are actually money makers for the homeowners.

Utility bill savings relative to the Building America benchmark were calculated using EnergyGauge and BEopt 0.8.6 software. Cost increases are based on builder estimates and additional data sources such as RS Means, DEER, supplier cost bids, etc. A 10% markup is assumed and the cost is converted into an annuity assuming a 7% loan over 30 years. Inflation, incentives, and rebates are not considered. The Building America benchmark is a home built to the 1993 Model Energy Code.

Table 4. Hot-Humid Climate Case Studies - Cost Savings

Source: Baechler, Michael C., T.L. Gilbride, M.G. Hefty, P.C. Cole, K. Adams, C.F. Noonan, and Pam M. Love. “40% Whole-House Energy Savings in the Hot-Humid Climate.” *Building America Best Practices Series*. Vol. 15. Washington, D.C., 2011. https://www.energy.gov/sites/prod/files/2013/11/f5/40percent_hot_humid.pdf.

Zero-Energy Ready Homes (ZERH).

ZERH was a re-naming of the previous DOE initiative called Challenge Home that came from the 2012 official recognition of Passive House Institute US (PHIUS) joining forces with the DOE on the Building America 2030 challenge. ZERH combines an optimized performance-based envelope design, and lower additional energy loads are combined to achieve zero energy goals. The structure performance characteristics of the ZERH program focus on the passive characteristics of the structure as defined above (insulation, limited thermal bridging, airtightness etc). These design factors were evaluated by the DOE EERE office based on three primary principles: airtightness with highly insulated envelopes limiting moisture problems, space conditioning, and energy transfer limiting energy loads levied on the system and increased heat gain-loss. There are quite a few similarities with Passivhaus/Passive House® parameters but a key difference in ZERH, is that the methodology uses the NREL Building Energy Optimization (BEopt™) simulations tool to evaluate cost-effectiveness of all measures employed in an active simulation-model that cross-cut the wide variance of sub-climate regions across North America. The ZERH approach is less narrow than Passive House/Passivhaus but is still based on performance focused metrics, and a field approach measuring and verifying output of ECMs.⁸⁶

A deliberate difference between current ZERH program and the German-developed Passivhaus standards were created in the 1990's (which improved upon 1970's American-Canadian passive measures and architectural research) is that the German standards are too severe and exacting for the specific climate zones that are found in the North American continent. As an example, these too tight parameters force overinvestment in insulation, which is unnecessary with a diminishing return in amount of energy saved beyond a certain R-value; which again varies depending on climate zone as discussed above.⁸⁷ The cost effectiveness of the

ZERH program is one of the most beneficial aspects, with multiple site-specific case studies available via the DOE Federal Energy Management Program (FEMP), Housing Innovation Award (HIA) and DOE Tour of Zero databases.⁸⁸

Economic Viability of Zero Energy Ready Homes (ZERH).

The business case or economics for implementing these efficiency measures has not been performed for the coastal NC area, Camp Lejeune specifically, and the particular measures used change drastically from one type of building to another and vary across different sub-climatic zones (CZ). This means the design and build teams that the Florence Recovery WG employs should incorporate a broader scope of experience and examples. Capitalizing on the existing relationships and expertise the RMI and other ecosystem members bring to the project design is crucial to a plan tailoring the architectural design that accommodates climatic factors specific to zone in addition to the operational requirements (see Figure 9). The designs used for the envelope (or enclosed and occupied space) incorporates insulation, airtightness, and moisture barriers; passive measures to mitigate cooling / heating loads, relative humidity and other design factors change how much energy is required for the climate; in this case hot-humid coastal NC.

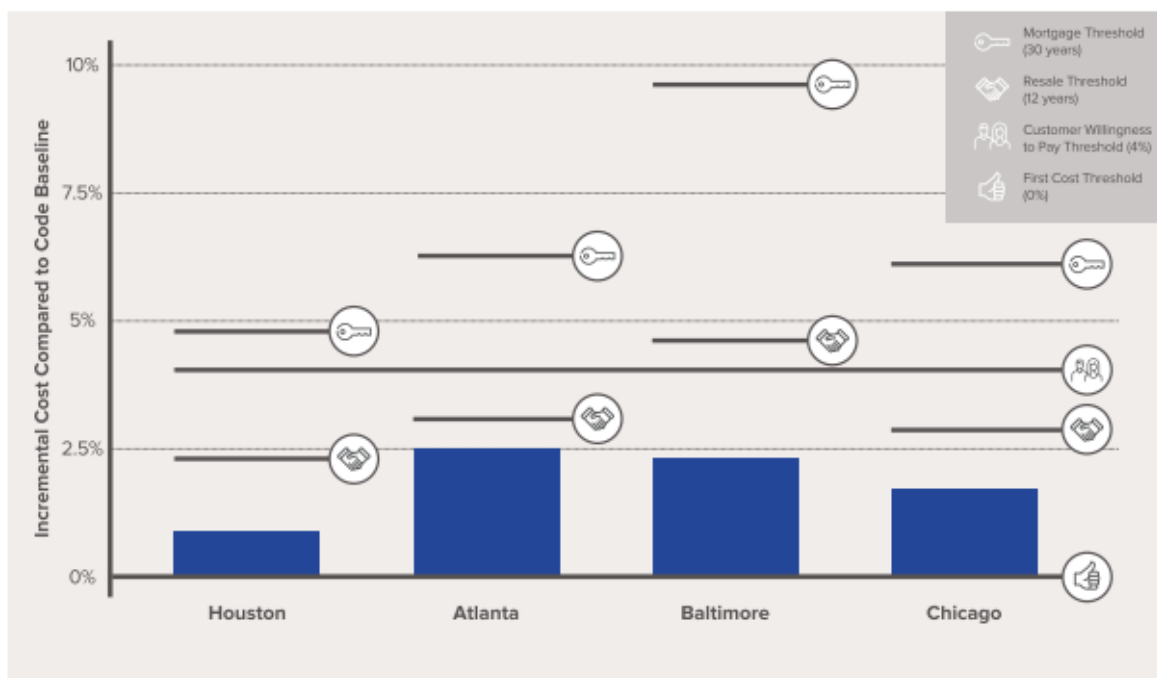


Figure 9. Incremental Costs for ZERH Compared Against Cost Thresholds

Source: Petersen, Alisa, Michael Gartman, and Jacob Corvidae. “The Economics of Zero-Energy Homes: Single Family Insights.” Boulder, CO, 2018. https://www.rmi.org/wp-content/uploads/2018/10/RMI_Economics_of_Zero_Energy_Homes_2018.pdf.

In this study the closest area identified to CLNC was for Zero Energy Ready Homes in the Atlanta, GA area, also in Climate Zone 3 (CZ3). The average house had an incremental cost increase on the price of building a new single-family home of 2.5% incremental cost (or \$6,094) beyond the baseline cost required by IECC 2009 energy code regulations. This cost was above a \$0 cost baseline (first threshold i.e. costs the ‘same’ as an IECC 2009 Code built home), but was well under the expected cost thresholds for a return on investment for both the life of the loan (Mortgage Threshold), average Resale Threshold (averaging 12 years). The main reason it did not meet the First Cost Threshold, all Zero, was that level was set at parity with 2009 IECC Code levels at construction or purchase date without any further investment (see Figure 9). Education is an important aspect, as construction firms expected ZER methods to still be outside the realm of possibility based on most cost estimates. Factors effecting the total cost of the ZERH build directly related to the experience of

the builder, on the specifics of the higher standards of ZERH building and Energy Star improvements vice the minimum 'to 2009 code' builders. Minimum code builders also had a longer total time to build and a steeper learning curve when using the efficiency measures.⁸⁹ This difference leveled out to parity with existing methods within a few iterations.⁹⁰

With the lower total energy requirements from the efficiencies in the envelope design and construction, Zero Energy or Energy Star® based homes then require a significantly smaller HVAC system to maintain the living space comfortable. The construction team then uses technological improvements like Heat Pumps for the building HVAC system (ductless, partial ductless mini-split, or Air Sourced Heat Pumps) that have updated efficacy and are more than adequate to keep the inside environment within parameters. Other easy energy load decreasing improvements come from using LED Lighting, Energy Star® Appliances and water fixtures reducing overall electric load by about \$3,100-\$4,000 per year. The most recent and now widely available updates to Heat Pump Water Heaters are now three times more efficient compared to traditional domestic hot water heaters. These technologies, with their lower energy draws were able to perform for the single-family home due to the radical efficiencies used in the building envelope, or occupied living space. Some additional techniques used by the ZE builders were structurally insulated panels, insulated concrete forms, and double studded construction for the walls but also included high-performance windows; and all three: walls (continuous R5 sheathed layer), roof (2012 or 2015 IECC code levels), and ground slab insulation at the 2013 code compliant level.⁹¹

Along with achieving return on investment within the thresholds above for a 2.5% incremental cost for Atlanta, the ZER homes (without solar panels installed) reduced their overall energy consumption from 23.6 kBtu/sf/yr down to 13.3kBtu/sf/yr;⁹² or a 45% reduction in energy

consumption. Added benefits of the higher Energy Star level program being used mirrored benefits already discussed above for Deep Retrofits but entailed better indoor air quality reducing mold risk, asthma symptoms, moisture control, radon gas, carbon monoxide dangers, and removing other toxic chemical contaminants.⁹³ The air quality improvements, moisture reductions, and associated reductions to mold/mildew are essential to buildings in the sub-tropical CZ-3A where CLNC lies (see Figure 2).

Frugal Zero Energy Ready Homes: AmeriSIPS Homes and Habitat-For-Humanity.

The Amerisips home on Johns Island, SC was custom designed to be within the ZERH program and is made of structural insulated panels (SIPs), an innovation the builders discovered during the economic downturn in 2008-2009. SIPs are preconstructed panels manufactured and precision cut in the factory and come for quick assembly that can also withstand hurricane force winds up to 200 miles per hour. Without solar panels this home is rated at 30 on the 150 scaled Home Energy Rating System (HERS); and with solar panels rates a 1 on the HERS scale; with projected annual energy costs at \$313 for the 2,085 sqft single level 3-bedroom, 2.5-bathroom house. Projected annual savings compared to a 2009 IECC standard house is approximately \$3,200 per year. In addition to the 6 kWh solar panels, the structure has an air-to-water heat pump, optional heat recovery ventilation, LED lighting, ENERGY STAR appliances, and a high-performance envelope with a minimum R-24 insulation.⁹⁴

The South Sarasota Habitat affiliate commissioned fifteen DOE ZERH as of 2015; of which the Laurel Gardens #794 as the exemplar that received the Housing Innovation Award (HIA) in 2015 and a HERS rating of 51. The simple, one-level, 1200 sqft homes have 3 bedrooms, two baths and is expected to cost the owners about \$860 per year (or \$72 per month) in energy bills. Using sprayed foam inside the cinderblock walled construction and layers of

moisture and insulation to condition the attic and add a gluing affect to the hurricane strapping required by code. EPS foam board with high-efficiency rated windows and GSHP sourced for domestic hot water and cooling-heating needs and mechanical ventilation have allowed this house's envelope to be extremely efficient. Energy Star appliances, ultra-efficient LED or compact fluorescents lights, and filtered ventilation complete the package.⁹⁵ These homes are just two examples of the wide variety of frugal but high-performance domiciles specifically designed for the hot-humid climate zone 3A that can be used to replace the 144 destroyed homes at Camp Lejeune, NC.

Beyond Cost Parity – Added Benefit Specific to North Carolina Hot-Humid Climate.

As passive measures are designed into the structure and require little maintenance to consistently implement, they are an optimum avenue to pursue for gaining relative efficiency across the life of a structure. They were designed around the human component of the system, to work symbiotically to achieve extremely energy efficient modules that then require less energy to achieve stasis. The point overall is that maximizing use of Passive measures is just practical and smart design, getting the structure itself to work towards the functional goal. Using excellent thermal insulation and airtight envelope avoiding thermal bridges (structural transfer points via conductive material, and/or wind gaps in the building envelope losing/gaining heat); coordinated passive solar design measures 'soaking' to maximize in the winter months or 'shading' to minimize in warmer periods can be based on climate with the orientation relative to the sun & geographic latitude (to minimize gain in hot climates for the summertime). Then and only then adapting the mechanical systems specific to the adjusted requirements is the preferred method. Then using of high-performance ventilation units reducing heat and relative humidity

lost (or gained) with the outside environment minimizes the HVAC time used to control relative humidity and moisture.⁹⁶

The high-performance ventilation units now available limit the amount of total moisture and energy transferred-lost to the outside environment and filter contaminants at the same time. Beyond limiting the energy required to keep the inside constant this also positively affects the air quality; which is one of the biggest issues facing livability in the coastal hot-humid region of the Carolinas. For structures outfitted with conventional air conditioning systems, especially in North Carolina, a significant portion of the energy used is directed at the latent load removing humidity vice the useful load required to cool the building.⁹⁷

Best practices: Florence Recovery and Long-Term Efficiency and Resiliency

From the above case studies and the many more that governmental, commercial, and private institutions have practiced and researched, a core of best practices emerges as follows, which can be applied not only to CLNC but to the entirety of MCICOM building stock. The most important are in the beginning but as the DER and ZERH methods look at the whole system, should all be leveraged for a maximum impact.

1. **Set aggressive goals.** Establish long term goals that align with a facility master plan. Clearly state desired outcomes and constraints that the leadership understands and works to improve. Push for longer contract terms to achieve deeper bundled savings.⁹⁸ The collective impact seen in the Empire State Building Case shows how effective this and substantial leadership support can do for a project team and the energy they are willing to commit.
2. **Focused on Operational Support.** Most important, the *mission* of the CLNC area bases and all Marine Corps Installations is to train and enable projection of the Warfighting functions that each

unit brings to bear. All efficiency upgrades or design improvements are designed around that goal and were reflected in the phased implementation of the steam plant decommissioning over a seven-year period; five years to plan and coordinate, and two years to execute. From a practical standpoint and simply put, if technology or technique does not work, it will not be used. If it does not work to increase operational capacity or resiliency, it does not meet the intent of this thesis. By ‘Working’ appropriately this also means within the particular ranges and limitations of the sub-climatic zone of the coastal Carolinas; which has specific relative humidity and cooling requirements and must account; while accounting for storms and flooding mitigation.⁹⁹

3. **Go Deep at the Right Time and in the Right Order.** Disaster Recovery is one of the highlighted key events that may trigger an optimum time for DER or using radically efficient measures. Others include planned renovations or major systems replacements, envelope replacements or required code upgrades, and new occupancy or mission profiles for the structure.¹⁰⁰ Again this was seen in the ESB case when the more than twenty ECMs combined allowed for a smaller chiller replacement to be implemented, saving \$17.4 million with that change alone.¹⁰¹

4. **Engage Diverse Stakeholders and Engage Collaborative Expertise** for both the Leadership teams providing resources and Design Teams executing the DER. Part of this is taking advantage of all of the resources and expertise available for the internal work of getting the DER complete; where the other is externally to make sure the entire stakeholders are engaged when and where needed. The current Florence Recovery Working Group (FRWG) is composed of architects, engineers, program managers, installation energy managers, program managers, and contract specialists from MCICOM, NAVFAC, and MCI-East. Increasing participation, to include expertise from GSA NDER, RMI, and NREL, would allow the FRWG to address

underlying issues and not just return to status quo. So far, MCICOM has used some ESPCs or the GSA umbrella ESPC program on a few documented cases but as highlighted by the CLNC steam plant decentralization case study, has not maximized its usage of GSA NDER, RMI, or NREL with their experience and government-commercial sector connections. Note that in this diagram illustrates more of the context and stakeholders vying for their interests in which the DER team must perform their design. MCICOM integrated entities are on the right of the diagram and external actors or ‘ecosystem’ dwellers are on the left (see Figure 10).

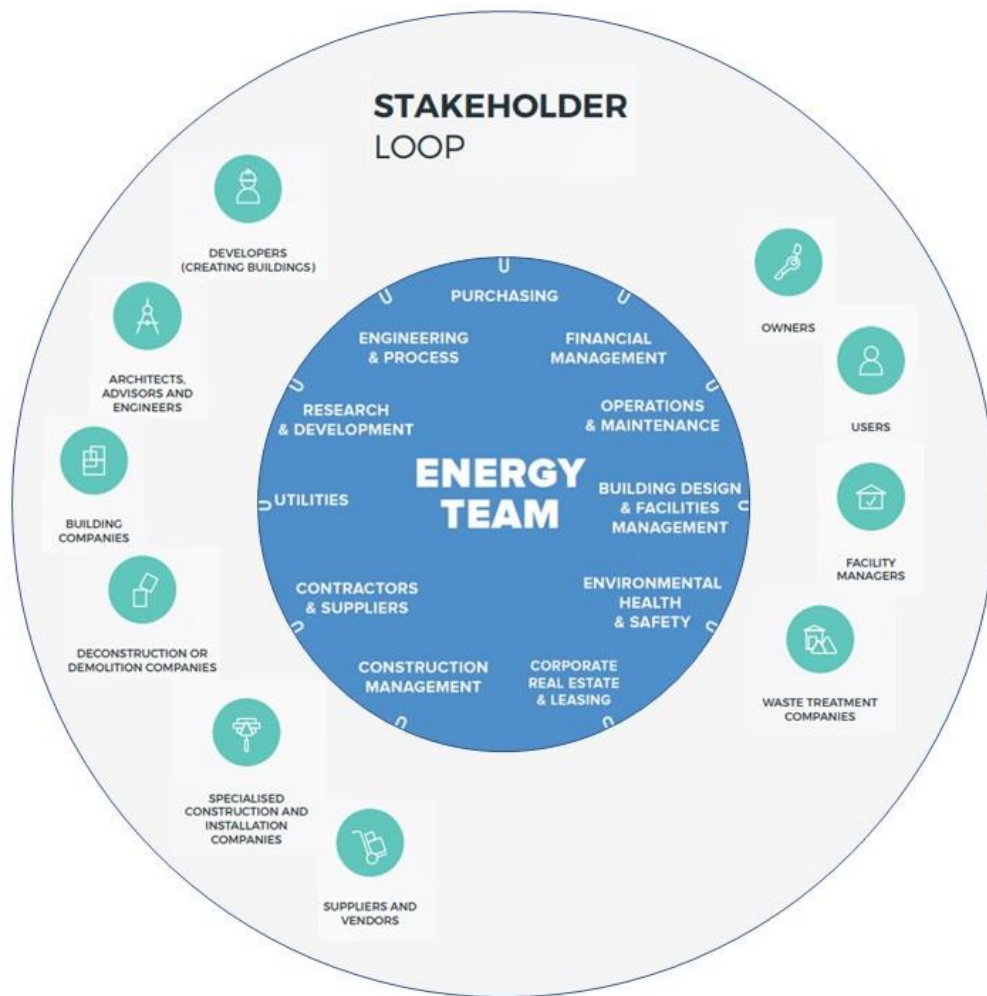


Figure 10. Possible Working Group Augments and Long Term– DER Team Composition

Source: Combination. Peter Bronski et al., “Deep Energy Retrofits Using Energy Savings Performance Contracts: Success Stories” (Boulder, Colorado, 2015), 6, https://rmi.org/wpcontent/uploads/2017/03/Deep_Energy_Retrofits_Using_ESPC.pdf. and Thelen, D. et al.

“Scaling the Circular Built Environment.” Geneva, Switzerland, 2018. https://docs.wbcsd.org/2018/12/Scaling_the_Circular_Built_Environmentpathways_for_business_and_government.pdf.

*Note: changed to reflect the MCICOM, MCI-East, and NAVFAC structure as core of current Florence Recovery Working Group.

5. Combine Best Aspects of Appropriated Funds with Third Party Financing Options.

As was shown in the CLNC case study, MCICOM and MCI-East are aware of some of the more obscure financing options. Appropriated funding used for the longest payback ECMs and new structures complements use of ESPCs, which do not require further study to improve energy efficiency of large projects. Using UESC financing offsets specific phased monitoring or technology upgrades like in the MCAS Beaufort example would be ideal to combine with a DER in a later phase (see Figure 14).¹⁰²

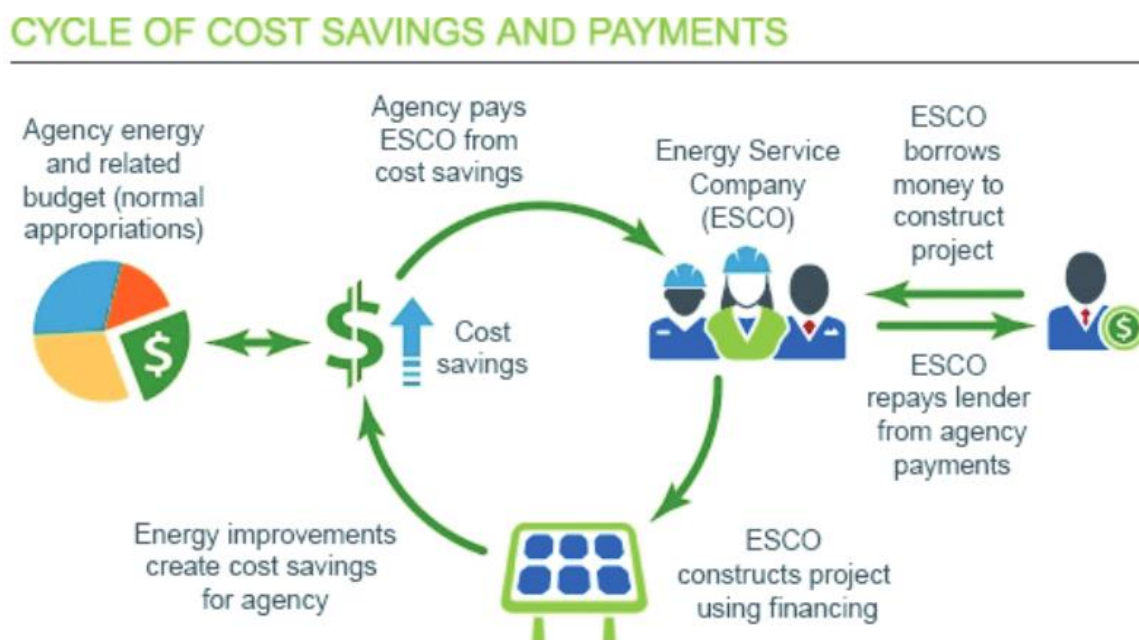
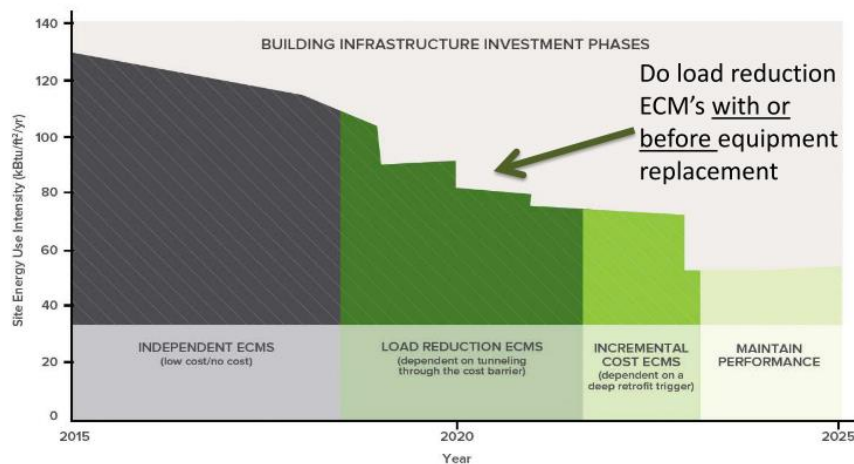


Figure 11. Recommended Federal ESPC project structure

Source: Jungclaus, Matt, Cara Carmichael, Chris McClurg, Margaret Simmons, Randall Smidt, Kinga P. Hydras, Sharon Conger, et al. “Deep Energy Retrofits in Federal Buildings: The Value, Funding Models, and Best Practices.” *ASHRAE Transactions* 123, no. 1 (2017): 55–70. <https://rmi.org/wp-content/uploads/2017/06/ASHRAE-D-LV-17-006.pdf>.

6. **Ask for the Deep Energy Retrofit and maximize Bundling Energy Conservation Measures.** Consider the total system vice each individually, and where able, identify the best way to complement measures into a working whole. This was most successful in the Empire State Building case for the aggregated effect all the chosen ECMs minimized the size of the chiller upgrade, but showed up in smaller ways for the NAS Oceana retrofit where the engineers recognized the utility of using the affluent pipeline. The CLNC area bases have not specifically asked for the DER but they are working their way into it based on the change in ‘energy mindset’ that they have incorporated into the people working at MCI-East and CLNC. They achieved the amount of savings expected simply based on how non-functional the 75-year-old steam plant was, but could do more to benefit the Marine Corps by wrapping this into a larger project like NAS Oceana. Each time one of the Load Reduction ECM’s are implemented (like in Figure 14) they reduce the required measures and incremental costs like the chiller replacement in the Empire State Building case study.



- Load Reduction ECM's:**
- Lighting
 - Sealing and weatherization
 - Window replacement or films
 - Roof or wall insulation
 - Shading
 - Daylighting
 - Plug load reduction
 - Controls (i.e. DCV, programmable Tstats)
 - Passive strategies (i.e. night flush w/ thermal mass)

Figure 12. Example - Deep Energy Retrofit ECM Applications Over Time

Source: Carmichael, Cara, Porst-Hydras Kinga, Randy Smidt, Yolanda Robinson, and Freeman Nnsa. “Deep Energy Retrofits.” In *Energy Exchange*, 65. Denver, Colorado: Energy Exchange

2017, https://www.energy-exchange.com/wp-content/uploads/T6S3_Carmichael_Hydras_Robinson_Smidt.pdf.

7. **Widely Varied – No One-Size-Fits-All.** Second, the portfolio of building types present on the three NC bases vary widely from relatively new construction to historical landmarks or heritage sites. They include warehouses, armories, automotive bays, aircraft hangars, single-family homes, office buildings, communications infrastructure, and commercial spaces. Military-use buildings are extremely task and unit specific in type that may not have easy parallels in existing case studies or research avenues. This wide-ranging building portfolio rotates through approximately a 20-year renovation cycle, that the destruction from Hurricane Florence bypassed and made a higher priority. Where less damage was imposed on the newer structures, it exacerbated those in worse repair, and outright obliterated the oldest or worst repaired structures. This is challenging the budgetary constraints of MCICOM and MCI-East FRSM, driving a request of \$3.6 billion dollars above the baseline FY2019 budget.¹⁰³

8. **Consider the Value beyond Energy Costs** recouped regarding increased resiliency and benefits to the working population (see Table 5). Some added benefits to DER specific to the private and business sectors are depicted that go beyond the bare minimum “low hanging fruit” discussed before. The Marine Corps can capitalize on some of the same benefits, namely the reduction in maintenance costs, occupant (tenant unit) satisfaction, employee productivity, and reduction to employee sick days. This was seen in the case of the Empire State Building but would likely have a greater impact in the hot-humid climate of coastal NC due to the prevalence of mold and mildew that complicate respiratory issues and stress post-storm.

Maintenance Costs Pacific Northwest National Laboratory (2008); Leonardo Academy (2008); Aberdeen Group (2010)	↓	9.0-14%
Occupant Satisfaction GSA (2011)	↑	27-76%
Rental Premium Eicholtz, Kok & Quigley (2010); Wiley et al. (2010); Fuerst & McAllister (2011); Eicholtz, Kok, et al. (2011); Newell, Kok, et al. (2011); Miller, Morris & Kok (2011); Pogue et al. (2011); McGraw Hill/Siemens (2012)	↑	2.1-17%
Occupancy Premium Wiley et al. (2010); Pogue et al. (2011); McGraw Hill/Siemens (2012)	↑	3.14-18%
Property Sale Price Premium Eicholtz, Kok & Quigley (2010); Fuerst & McAllister (2011); Eicholtz, Kok, et al. (2011); Newell, Kok, et al. (2011)	↑	11.1-26%
Employee Productivity Lawrence Berkeley National Laboratory	↑	1.0-10%
Employee Sick Days Miller, Pogue, Gough & Davis (2009); Cushman & Wakefield et al. (2009); Dunckley (2007); City of Seattle (2005); Romm & Browning (1995)	↓	0-40%

Table 5. Potential Value Beyond Energy Cost Savings

Source: Jungclaus, Matt, Cara Carmichael, Chris McClurg, Margaret Simmons, Randall Smidt, Kinga P. Hydras, Sharon Conger, et al. “Deep Energy Retrofits in Federal Buildings: The Value, Funding Models, and Best Practices.” *ASHRAE Transactions* 123, no. 1 (2017): 55–70. <https://rmi.org/wp-content/uploads/2017/06/ASHRAE-D-LV-17-006.pdf>.

9. **Measure and Verify for Success.** This holds the ESCO accountable for the ESPC guaranteed savings in the contract but also provides the data needed to forecast maintenance and replacement timing in the future. Measuring consumption before a DER and after will further validate the unforeseen benefits and may prove more benefit than modeled before the project is implemented like in the GSA NDER sponsored projects and when using ESPCs, receiving nearly twice the return guaranteed by the ESCO.¹⁰⁴ In all of the cases presented it allowed the full fiscal

impact of the DER to be apparent and would facilitate the impact to be known for the NC Marine bases regarding the O&M savings not yet calculated.

10. **The Best Ideas Just Work.** Maintenance and upkeep at the user level is contracted outside the military and civilian workforce at Marine Corps installations level where training for complicated and/or sophisticated technology is limited by the capacity of the workforce.¹⁰⁵ When the DER and associated ECMs work as or better than advertised they will continue to be used. Otherwise, if they prove faulty or non-functional then they will likely be relegated to the trash heap. The specific technical measures are beyond the scope of this writing, but there is potential in passive measures that are designed into the structure for deep retrofits or new builds that would require minimal maintenance, additional training, or skills required by the personnel doing upkeep.¹⁰⁶ Examples include oversized window shading devices limiting solar heat gains at all sunlight angles, solar chimney driven circulation for warehouses or garages, and geothermal intakes.¹⁰⁷

Conclusion

RECOMMENDATION 1:

Incorporate improvements to the envelope in addition to the upgrading the HVAC systems and light bulbs and water ECMs as ‘low hanging fruit’ that are easy to accomplish and have a high payoff for the ESCO as seen with the NAS Oceana case. MCICOM, and MCI-East are on a slow start with some use of GSA NDER their blanket ESPC, and other funding vehicles using their growing core group of ESCOs with which GSA NDER continue to collaborate. However good the start with NAS Oceana, MCAS Beaufort, and the NC Bases has been, there have been no actions to improve the envelope through windows, doors, or insulation to walls/roofs/floors included in the ESPCs that MCICOM or subsidiaries have used thus far. The

ESCOs continue to turn a profit by doing the bare minimum ‘low hanging fruit’ updates to lights, water efficient fixtures, and updating the HVAC systems as the default. Improving the envelope will further limit the heat gain-loss and enable better right sizing of the mechanical or active measures needed to get buildings within their best operating parameters. Using appropriate storm designed materials like concrete forms and preconstructed panels instead of legacy building materials will help mitigate impacts of future storms. This will also pay dividends in the resiliency to storms, moisture, humidity, and provide increased air quality beneficial to human occupant and sensitive computer hardware. MCICOM and subsidiaries should aggressively pursue this option further in the future, not just in concert with the Hurricane Florence recovery effort, but across the MCICOM installations and infrastructure portfolio. This recommendation brings together most of the best practices in the previous section but specially emphasizes collaborative expertise, setting aggressive goals, and making the most of the resources available to the Marine Corps – which cross cut best practices.

RECOMMENDATION 2:

Second, seek added expertise to the Florence Recovery Working Group and all future MCICOM efforts with Installations neXt efforts in order to capitalize on existing beneficial relationships within the federal government and include additions to their ecosystem of experts from Rocky Mountain Institute (RMI), National Renewable Energy Lab (NREL), and the General Services Administration (GSA) National Deep Energy Retrofit (NDER) programs. Their cadre of experts have worked across the challenging climates present in North America and bring in corporate expertise that would be a boon to the Hurricane Florence recovery effort and MCICOM and future Facilities, Restoration, Sustainment, and Maintenance (FRSM) efforts. Not only would this benefit the Florence Recovery but it could round out the plan for recovery in the

case that other coastal Marine Corps bases are struck by future storms. Baking this level of collaboration in now turns a catastrophe into a long-term advantage, incorporates broad ranging expertise, and builds relationships of long-term benefit to the Marine Corps. This recommendation embodies the fourth “engage diverse stakeholders and collaborative expertise” best practice the most, and may be one of the most crucial. The best working group team internal to the project structure, combined with invested leadership and stakeholders to directly enable successful implementation. The possibilities presented here for both DERs and ZERHs are not only prudent but impactful to resiliency and stewardship of resources.

RECOMMENDATION 3:

Finally, use AMCC to implement the Zero-Energy Ready Homes (ZERH) construction model to replace the 144 homes needed at CLNC and fully capitalize on an opportunity for evolving improvements to energy consumption. This also provides improved domiciles like the AmeriSIPS home in SC and for Habitat-for-Humanity in FL that have also increased level of comfort and air quality. This means moisture control and particulate contaminants will be minimized at the same time as energy resources are protected for the future. As covered above, repositories of examples and case studies that can provide the professional with use cases that back up the cost parity research conducted. This recommendation especially portrays the aggressive goal setting, considering effects beyond energy savings to the communities and the Marine Corps, and leveraging the holistic design principles.

Closing Summary. The hurricane that hit the three Marine Corps bases in NC during September 2018 was tragic in the amount of devastation it caused but it can be leveraged as an opportunity to deep retrofit existing structures and build radically efficient domiciles for the future benefit of the Marine Corps. In light of the severe impact of similar events and the

increasing frequency of extreme weather, when the Marine Corps decides to rebuild CLNC, they should avoid just rebuilding in the legacy format but look to update infrastructure and rebuild CLNC as a model base and community resilient to future storms. This approach will help correct underlying problems associated with increasing rates of consumption and limited Marine Corps resources.

The reasons for recommending that CLNC adopt deep energy retrofits, Zero-Energy Ready Homes for new housing, and radical efficiency measures thus are threefold. First, infrastructure, as a long-neglected area of investment, has become even more of a problem for the Marine Corps as highlighted by Hurricane Florence's damage in North Carolina.¹⁰⁸ Second, the damage to the budget will increase as structures that now constitute a drain on reconstruction funding will continue to atrophy, where instead deep retrofits can revitalize our building stock. Third, the solution concepts presented above are available now, through existing methodologies, programs, and technologies. Now is the time where the particular brand of Marine Corps leadership – doing the hard right instead of the easy status quo – becomes increasingly important to national solvency. Stewardship of finite resources is the 'right' mission to accomplish.

Using currently available technologies and programs like Deep Energy Retrofit and Zero Energy Home, MCICOM and subsidiaries can work with NAVFAC to better tailor their contracting vehicles to improve stewardship of Marine Corps funding and global resources. This will limit continued losses from poorly maintained facilities and underfunded maintenance efforts to increase the resilience, storm durability, quality of life, and community essential to high performing Marine Corps units.

In the long run, the costs of maintaining installations and providing for the military and civilians that work on these installations will increase and become harder to sustain in a turbulent

and increasingly resource constrained global environment. The practicalities of addressing the present symptoms of resource shortfalls, increasing frequency of storms, and the cutthroat global competition for finite resources require our full attention; as they have implications for combat readiness in addition to the health, welfare, livelihoods and effectiveness of the key strength of the Marine Corps: the Marine.

EndNotes

¹ Marine Corps Installations Command, “Office of Management and Budget Requests: Department of the Navy Hurricane Florence & Hurricane Michael” (Washington D.C., 2018), 4–5.

² Ibid.

³ Atlantic Marine Corps Community, “Atlantic Marine Corps Community - Hurricane Restoration Progress,” *AMCC Webpage*, 2019, <https://cl.atlanticmcc.com/hurricane-help>.

⁴ Shawn Snow, “\$3.6 Billion Price Tag to Rebuild Lejeune Buildings Damaged by Hurricane Florence,” *Marine Corps Times*, 2018, 2, <https://www.marinecorpstimes.com/news/your-marine-corps/2018/12/12/36-billion-price-tag-to-rebuild-lejeune-buildings-damaged-by-hurricane-florence/>.

⁵ Southeast region Federal Construction, “North Carolina Programs & Requirements Session,” in *2017 Summit: Infrastructure & Environmental Summit* (North Carolina Military Business Center, 2017), 27–29, <http://www.ncmbc.us/docs/17Summit/NorthCarolina.pdf>.

⁶ Turner Construction Company, “Camp Lejeune 2nd Anglico and 2nd Intel Battalion Operations Complexes,” *Turner Construction Company Website*, 2019, 2, <http://www.turnerconstruction.com/experience/project/67A9/camp-lejeune-2nd-anglico-and-2nd-intel-battalion-operations-complexes>.

⁷ Amory B. Lovins and Rocky Mountain Institute, *Reinventing Fire: Bold Business Solutions for the New Energy Era*, ed. Nancy Ringer, kindle (White River Junction, Vermont: Chelsea Green Publishing Company, 2011), location 2525. and “Improving Federal Energy Savings Through Performance Contracting,” *National Association of Manufacturers Webpage Nam.Org* (Washington, D.C., 2013), 1, <https://www.nam.org/Issues/Energy-and-Environment/Affordable-Energy/Domestic-Energy/Improving-Federal-Energy-Savings-Through-Performance-Contracting--Full-Report/>.

⁸ Lewis R. Wallace, “Lingering Long After a Storm, Mold and Mental Health Issues,” *Environmental Health News*, January 22, 2015, 2–4, <https://www.ehn.org/lingering-long-after-a-storm-mold-and-mental-health-issues-2625546179.html>. and John Manuel, “In Katrina’s Wake,” *Environmental Health Perspectives* 114, no. January (2006): A32–34, <https://www.ehn.org/lingering-long-after-a-storm-mold-and-mental-health-issues-2625546179.html>.

⁹ Shawn Snow, “Norway Deployments Frozen as Camp Lejeune Cleans up from Hurricane Florence,” *Marine Corps Times*, 2018, 2–3, <https://www.marinecorpstimes.com/news/your-marine-corps/2018/09/18/norway-deployments-frozen-after-camp-lejeune-cleans-up-from-hurricane-florence/>.

¹⁰ Marine Corps Installations Command, “Office of Management and Budget Requests: Department of the Navy Hurricane Florence & Hurricane Michael.”

¹¹ James S. McLean, “Meeting with MCICOM Commander and Staff Visit-Discussions” (Washington, D.C., December 21, 2018).

¹² Marine Corps Warfighting Laboratory: Futures Directorate, “2015 Marine Corps Security Environment Forecast: Futures 2030-2045” (Quantico, VA, 2015), 27, [https://www.mcwl.marines.mil/Portals/34/Documents/2015 MCSEF - Futures 2030-2045.pdf](https://www.mcwl.marines.mil/Portals/34/Documents/2015%20MCSEF%20-%20Futures%202030-2045.pdf).

¹³ Headquarters Marine Corps (HQMC), “Marine Corps Operating Concept: How an Expeditionary Force Operates in the 21st Century” (Washington, D.C., September 2016), 23.

¹⁴ Matthew J. Burrows, “Global Trends: Alternative Worlds” (Washington, D.C., 2012), 31, www.dni.gov/nic/globaltrends/; Headquarters Marine Corps (HQMC), “Marine Corps Operating Concept: How an Expeditionary Force Operates in the 21st Century,” 5. and Marine Corps Warfighting Laboratory: Futures Directorate, “2015 Marine Corps Security Environment Forecast: Futures 2030-2045,” 53–55.

¹⁵ Headquarters Marine Corps (HQMC), “Marine Corps Operating Concept: How an Expeditionary Force Operates in the 21st Century,” 5–7. and Marine Corps Warfighting Laboratory: Futures Directorate, “2015 Marine Corps Security Environment Forecast: Futures 2030-2045,” 7-8 and 53-57.

¹⁶ USGCRP was set by Presidential mandate in 1989 and by Congress in the Global Change Research Act (GCRA) of 1990 to “assist the Nation and the world to understand, assess, predict, and respond to human-induced and natural processes of global change.” U.S. Global Change Research Program, “Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II: Summary-Findings,” in *Fourth National Climate Assessment*, ed. D.R. Reidmiller et al., vol. II (Washington, D.C.: U.S. Government Publishing Office, 2018), 1, <https://nca2018.globalchange.gov/chapter/24/>.

¹⁷ *Ibid.*, 1–8.

¹⁸ Office of the Under Secretary of Defense for Acquisition and Sustainment, “Report on Effects of a Changing Climate to the Department of Defense,” vol. January (Washington, D.C., 2019), <https://media.defense.gov/2019/Jan/29/2002084200/-1/-1/1/CLIMATE-CHANGE-REPORT-2019.PDF>.

¹⁹ Les Martin, “Third Party Financing ESPC / UESC / ENABLE,” in *Energy Exchange 2017 Conference Proceedings* (Denver, Colorado: Energy Exchange 2017, 2017), 10. and Rocky Mountain Institute and General Services Administration, “The Path to A Deep Energy Retrofit: Using an Energy Savings Performance Contract” (Boulder, CO, 2015), 8–10, https://rmi.org/wp-content/uploads/2017/05/RMI_Document_Repository_Public-Reprrts_2015-02_Path_to_DR_using_ESPC.pdf.

²⁰ Marine Corps Installations East, “MCIEAST ENERGY & WATER STRATEGY Marine Corps Installations Command, Regional Energy Program” (Camp Lejeune, NC, 2013), 3, <https://www.mcieast.marines.mil/Portals/33/Documents/COMREL/Energy-Awareness/2015-MCIEAST-Energy-and-Water-Strategy.pdf>.

²¹ Construction, “North Carolina Programs & Requirements Session,” 27–29.

²² “Renovation vs Refurbishment vs Retrofit,” *Institute of Historical Building Conservation Wiki Webpage*, 2016, 2, https://www.designingbuildings.co.uk/wiki/Renovation_v_refurbishment_v_retrofit. and Sophie Schnapp, Rosa Sitja, and Jens Laustsen, “What Is a Deep Renovation Definition?,” 2013, 6, 10 and 19, http://www.gbpn.org/sites/default/files/08.DR_TechRep.low_.pdf.

²³ Caroline Fluhrer, Eric Maurer, and Aalok Deshmukh, “Achieving Radically Energy Efficient Retrofits : The Empire State Building Example,” *ASHRAE Transactions* 116, no. 2 (2010): 1–2. and Schnapp, Sitja, and Laustsen, “What Is a Deep Renovation Definition?,” 10.

²⁴ Cathy Higgins et al., “A Case for Deep Savings” (Portland, OR, 2011), 1, <http://newbuildings.org/advanced-design/getting-50-beyond>. and Rocky Mountain Institute, “Managing Deep Energy Retrofits Retrofit Depot” (Boulder, Colorado, 2012), 20, www.RetroFitDepot.org.

²⁵ Schnapp, Sitja, and Laustsen, “What Is a Deep Renovation Definition?,” 10 and 19.

²⁶ J Mcilvaine, K Sutherland, and E Martin, “Energy Retrofit Field Study and Best Practices in a Hot-Humid Climate,” no. March (2013): 65–69. and Alisa Petersen, Michael Gartman, and Jacob Corvidae, “The Economics of Zero-Energy Homes: Single Family Insights” (Boulder, CO, 2018), 21–25, https://www.rmi.org/wp-content/uploads/2018/10/RMI_Economics_of_Zero_Energy_Homes_2018.pdf.

²⁷ Gonzalo Roberto and Rainer Vallentin, eds., *Passive House Design: Planning and Design of Energy-Efficient Buildings*, Second ed (Munich, Germany: The Detail Business Information GrmbH, 2014), 7–8, <https://libraryofthemarinecorps.on.worldcat.org/oclc/1031633574>.

²⁸ G Wright, K Klingenberg, and Betsy Pettit, “Climate-Specific Passive Building Standards” (Springfield, VA, 2015), x, <http://www.osti.gov/bridge>.

²⁹ *Ibid.*, 1–6.

³⁰ Snow, “\$3.6 Billion Price Tag to Rebuild Lejeune Buildings Damaged by Hurricane Florence.” and Lolita C. Baldor, “Marine Corps Says \$3.6B for Storm Repairs at East Coast Base - Houston Chronicle,” *Chron.Com*, 2018, 2, <https://www.chron.com/news/article/Marine-Corps-says-3-6B-for-storm-repairs-at-East-13464673.php>. and

³¹ Martin, “Third Party Financing ESPC / UESC / ENABLE,” 6. and “Improving Federal Energy Savings Through Performance Contracting,” 5.

³² Martin, “Third Party Financing ESPC / UESC / ENABLE,” 4. and “Improving Federal Energy Savings Through Performance Contracting,” 5.

³³ Matt Jungclaus et al., “Deep Energy Retrofits in Federal Buildings: The Value, Funding Models, and Best Practices,” *ASHRAE Transactions* 123, no. 1 (2017): 60–63, <https://rmi.org/wp-content/uploads/2017/06/ASHRAE-D-LV-17-006.pdf>. and Rocky Mountain Institute and General Services Administration, “The Path to A Deep Energy Retrofit: Using an Energy Savings Performance Contract,” 1–7.

³⁴ Michael C. Baechler et al., “40% Whole-House Energy Savings in the Hot-Humid Climate,” *Building America Best Practices Series*, vol. 15 (Washington, D.C., 2011), 6.2-6.5, https://www.energy.gov/sites/prod/files/2013/11/f5/40percent_hot_humid.pdf.

³⁵ Marine Corps Installations Command, “Office of Management and Budget Requests: Department of the Navy Hurricane Florence & Hurricane Michael,” 4-5 and 10-13.

³⁶ Snow, “\$3.6 Billion Price Tag to Rebuild Lejeune Buildings Damaged by Hurricane Florence.” and Baldor, “Marine Corps Says \$3.6B for Storm Repairs at East Coast Base - Houston Chronicle,” 2. And Megan Eckstein, “Neller: Marine Need \$3.5 Billion for Camp Lejeune Repairs, Despite MILCON Cuts for Border Spending,” *USNI News*, February 17, 2019, <https://news.usni.org/2019/02/17/neller-marines-need-3-5-billion-camp-lejeune-repairs-despite-milcon-cuts-border-spending>.

³⁷ DOE Office of Energy Efficiency and Renewable Energy, “Preliminary Energy Savings Analysis ANSI/ASHRAE/IES Standard 90.1-2016” (Washington, D.C., 2017), 5–7, https://www.energy.gov/sites/prod/files/2017/07/f35/Preliminary_90.1-2016_Energy_Savings_Analysis.pdf.

³⁸ Michael C. Baechler et al., “Guide to Determining Climate Regions by County,” vol. 7.1 (Washington, D.C., 2010), 1-4 and 19-20.

³⁹ McLean, “Phone Conference Call with Camp Lejeune and MCAS New River Energy Managers” (Quantico, VA, February 4, 2019). February 4, 2019.

⁴⁰ Higgins et al., “A Case for Deep Savings.” and Mcilvaine, Sutherland, and Martin, “Energy Retrofit Field Study and Best Practices in a Hot-Humid Climate.” and Cara Carmichael et al., “Deep Energy Retrofits,” in *Energy Exchange* (Denver, Colorado: Energy Exchange 2017, 2017), 12–13, https://www.energy-exchange.com/wp-content/uploads/T6S3_Carmichael_Hydras_Robinson_Smidt.pdf.

⁴¹ These mandates were the Energy Independence and Security Act of 2007 (requiring 30% reduced energy consumption by 2015); Executive Order 13423 requiring reduced water usage by 16% by 2015; Energy Policy Act of 2005 requiring 7.5% of federal energy to come from renewable sources; and then President Obama’s challenge for federal Agencies to commission more than \$2 billion in performance-based contracts by the end of 2014.

⁴² John Shonder, *Energy Savings from GSA’s National Deep Energy Retrofit Program*, 2014, 1–2.

⁴³ DOE Federal Energy Management Program, “Department of Energy’s Qualified List of Energy Service Companies” (Washington, D.C., 2019), https://www.energy.gov/sites/prod/files/2019/04/f62/doe_ql.pdf.

⁴⁴ Shonder, *Energy Savings from GSA’s National Deep Energy Retrofit Program*, 1–2.

⁴⁵ *Ibid.*, 14–15.

⁴⁶ Cara Carmichael and Kinga Porst, “Energy Efficiency and Net-Zero Buildings: GSA and RMI Answer the Call,” in *GSA National Deep Energy Retrofit Charrette* (Washington, D.C.: 10xe.org, 2015), 2–3, http://www.10xe.org/www.10xe.org/Content/Files/GSA_P_to_P_WS_2015-Exec_Summ.pdf.

⁴⁷ Shonder, *Energy Savings from GSA’s National Deep Energy Retrofit Program*, 14–15.

⁴⁸ “Improving Federal Energy Savings Through Performance Contracting,” 9–10.

⁴⁹ Carmichael et al., “Deep Energy Retrofits,” 12–13.

⁵⁰ Federal Energy Management Program, “U.S. Marine Corps Stands at Forefront of Energy and Water Savings” (Washington, D.C., 2015), https://www.energy.gov/sites/prod/files/2013/10/f3/usmc_energysavings.pdf.

⁵¹ Elizabeth Smith, “Steam Decentralization at Marine Corps Base Camp Lejeune” (Camp Lejeune, North Carolina, 2017).

⁵² Federal Energy Management Program, “U.S. Marine Corps Stands at Forefront of Energy and Water Savings,” 1–2.

⁵³ Lovins and Rocky Mountain Institute, *Reinventing Fire: Bold Business Solutions for the New Energy Era*, location 235-456.

⁵⁴ Ibid., location 441-553.

⁵⁵ Ibid., location 5051-5078.

⁵⁶ Ibid., location 2454-2492.

⁵⁷ Ibid., location 170-188.

⁵⁸ Ibid., location 250-372.

⁵⁹ Eric Harrington and Cara Carmichael, “RetroFit Project Case Study: Empire State Building,” *Rocky Mountain Institute Case Study Database*, 2009, 2, <http://www.rmi.org/Content/Files/ESBCaseStudy.pdf>.

NOTE: The Clinton Climate Initiative (non-profit working to dramatically reduce global greenhouse emissions), the property manager Jones Lang Lasalle, Johnson Controls Inc. (a large energy service company) and the Rocky Mountain Institute serving as design partner, peer reviewer and lead on the collaborative-integrative design process.

⁶⁰ Ibid., 1–2.

⁶¹ Ibid., 2–3.

⁶² Ibid., 1 and 6.

⁶³ David Thelen et al., “Scaling the Circular Built Environment” (Geneva, Switzerland, 2018), 14–16, https://docs.wbcsd.org/2018/12/Scaling_the_Circular_Built_Environment-pathways_for_business_and_government.pdf.

⁶⁴ Marine Corps Installations Command, “MCICOM IX Level Brief” (Washington, D.C., 2018), 15.

⁶⁵ Shonder, *Energy Savings from GSA’s National Deep Energy Retrofit Program*, 11.

⁶⁶ Peter Bronski et al., “Deep Energy Retrofits Using Energy Savings Performance Contracts: Success Stories” (Boulder, Colorado, 2015), 14–15, https://rmi.org/wp-content/uploads/2017/03/Deep_Energy_Retrofits_Using_ESPC.pdf.

⁶⁷ Ibid., 15.

⁶⁸ Steam Distribution and N A S Oceana, “Boiler Upgrades and Decentralizing Steam Systems Save Water and Energy at Naval Air Station Oceana” (Dam Neck, VA, 2011), 2, https://www.energy.gov/sites/prod/files/2013/10/f3/oceana_water_cs.pdf.

⁶⁹ Bronski et al., “Deep Energy Retrofits Using Energy Savings Performance Contracts: Success Stories,” 15–16.

⁷⁰ Shonder, *Energy Savings from GSA’s National Deep Energy Retrofit Program*, 11 and 15.

⁷¹ McLean, “Phone Conversation and Email Correspondence with MCICOM Energy Manager,” 2.

⁷² DOE Federal Energy Management Program, “Federal Energy Savings Performance Contracts” (Washington, D.C., 2016), 6, https://www.energy.gov/sites/prod/files/2016/12/f34/espc_faq_42_usc.pdf.

⁷³ McLean, “Phone Conversation and Email Correspondence with MCICOM Energy Manager,” 2.

⁷⁴ DOE Federal Energy Management Program, “Federal Energy Savings Performance Contracts,” 6.

⁷⁵ Kari Burman, Alicen Kandt, and Lars Lisell, “Targeting Net Zero Energy at Marine Corps Base Hawaii - Kaneohe Bay” (Golden, CO, 2012), 2–5, <https://www.nrel.gov/docs/fy12osti/52897.pdf>.

⁷⁶ Smith, “Steam Decentralization at Marine Corps Base Camp Lejeune,” 4–5.

⁷⁷ Ibid., 5 and 14-16. and Installation Energy and Lisa A. Jung, “FY 2018 Energy Conservation Investment Program (ECIP) and Plans for the Remainder of the Future Years Defense Program Guidance” (Washington, D.C., 2016), 1–2, [https://www.acq.osd.mil/eie/Downloads/IE/FY2018 ECIP Guidance Memo and Attachment A.PDF](https://www.acq.osd.mil/eie/Downloads/IE/FY2018%20ECIP%20Guidance%20Memo%20and%20Attachment%20A.PDF). and Marine Corps Installations Command, “United States Marine Corps Energy Investment Program (EIP) Project Documentation Instruction,” vol. 1.1 (Washington D.C., 2013), 5–6, [https://www.mcicom.marines.mil/Portals/57/Docs/GF_Energy_USMC_EIP_Project_Documentation_Instruction_v1.1_FINAL Jun 26 2013.docx](https://www.mcicom.marines.mil/Portals/57/Docs/GF_Energy_USMC_EIP_Project_Documentation_Instruction_v1.1_FINAL_Jun_26_2013.docx).

⁷⁸ McLean, “Phone Conversation and Email Correspondence with MCICOM Energy Manager,” 2.

⁷⁹ Smith, “Steam Decentralization at Marine Corps Base Camp Lejeune,” 11–12.

⁸⁰ Ibid., 13.

⁸¹ Ibid., 5 and 14-16. and Energy and Jung, “FY 2018 Energy Conservation Investment Program (ECIP) and Plans for the Remainder of the Future Years Defense Program Guidance,” 1–2. and Marine Corps

Installations Command, “United States Marine Corps Energy Investment Program (EIP) Project Documentation Instruction,” 1.1:5–6.

⁸² McLean, “Phone Conversation and Email Correspondence with MCICOM Energy Manager,” 1. ⁸²
Ibid.

⁸³ Note: Passive House® - Solar Orientation; Extremely efficient Building Envelope to minimize variance in heat gains or losses (incorporates building materials, construction techniques to minimize thermal bridging, insulation, water barrier by CZ, extreme airtightness, triple paned insulated windows and glazing); Ventilation w/ heat recovery and moisture regulation; minimizing passive solar heating in the summer and maximizing in the winter.

⁸⁴ Baechler et al., “40% Whole-House Energy Savings in the Hot-Humid Climate,” 15:2.2-2.6.

⁸⁵ Paul Peterson, “Midway Park, AMCC Move into New Era for Housing & Marine Corps Base Camp Lejeune & Camp Lejeune News,” *Camp Lejeune News Website*, 2012, 1–4, <https://www.lejeune.marines.mil/News/Article/513013/midway-park-amcc-move-into-new-era-for-housing/>.

⁸⁶ Wright, Klingenberg, and Pettit, “Climate-Specific Passive Building Standards,” x–xi and 4-7.

⁸⁷ Ibid., 4–7 and 18.

⁸⁸ Office of Energy Efficiency & Renewable Energy, “DOE Tour of Zero Database,” *Department of Energy Webpage*, 2019, <https://www.energy.gov/eere/buildings/doe-tour-zero>. Note: Sorted for “Mixed-Humid” or “Hot-Humid” to get examples in the CZ 3A.

⁸⁹ Petersen, Gartman, and Corvidae, “The Economics of Zero-Energy Homes: Single Family Insights,” 13–15.

⁹⁰ Ibid., 18.

⁹¹ Ibid., 22–25.

⁹² Ibid., 16.

⁹³ Ibid., 19.

⁹⁴ Robert Bolus, “Amerisips Homes: Custom Designed Residence Johns Island, SC,” *DOE Home Innovation Award* (Charleston, SC, 2014), 1–4, https://www.energy.gov/sites/prod/files/2015/06/f22/DOE_ZEH_Amerisips_09-20-14.pdf. and Hal Knowles, “Performance Under Pressure: Structural Insulated Panel (SIP) Walls” (Tallahassee, FL, 2004), <http://flash.org/resources/files/SIP2005-05-04.pdf>.

⁹⁵ Laurel Gardens and Jeremy Gary, “Habitat for Humanity South Sarasota County,” 2015, 1–4.

⁹⁶ Roberto and Vallentin, *Passive House Design: Planning and Design of Energy-Efficient Buildings*, 7–8.

⁹⁷ Baechler et al., “40% Whole-House Energy Savings in the Hot-Humid Climate,” 15: A3.1.

⁹⁸ Carmichael et al., “Deep Energy Retrofits,” 22–24.

⁹⁹ MCICOM meetings 21 Dec 2018 and confirmed with Convo w/ CLNC energy managers

¹⁰⁰ Carmichael and Porst, “Energy Efficiency and Net-Zero Buildings: GSA and RMI Answer the Call,” 21–25.

¹⁰¹ Kelly Vaughn, “Empire State Building Retrofit Surpasses Energy Savings Expectations,” *Rocky Mountain Institute: Outlet Blog* (Boulder, CO: Rocky Mountain Institute online content, 2012), 5, https://www.rmi.org/blog_empire_state_retrofit_surpasses_energy_savings_expectations/.

¹⁰² Jungclaus et al., “Deep Energy Retrofits in Federal Buildings: The Value, Funding Models, and Best Practices,” 7.

¹⁰³ Marine Corps Installations Command, “Office of Management and Budget Requests: Department of the Navy Hurricane Florence & Hurricane Michael,” 1–4.

¹⁰⁴ Bronski et al., “Deep Energy Retrofits Using Energy Savings Performance Contracts: Success Stories,” 4. and “Improving Federal Energy Savings Through Performance Contracting,” 8–9.

¹⁰⁵ McLean, “Meeting with MCICOM Commander and Staff Visit-Discussions.”

¹⁰⁶ McLean, “Phone Conference Call with Camp Lejeune and MCAS New River Energy Managers.”

¹⁰⁷ Baechler et al., “40% Whole-House Energy Savings in the Hot-Humid Climate,” 15: 6.2.

¹⁰⁸ Southeast region Federal Construction, “North Carolina Programs & Requirements Session,” in *2017 Summit: Infrastructure & Environmental Summit* (North Carolina Military Business Center, 2017), 29-32, <http://www.ncmbc.us/docs/17Summit/NorthCarolina.pdf>. and Marine Corps Installations Command, “Office of Management and Budget Requests: Department of the Navy Hurricane Florence & Hurricane Michael.”

Bibliography

“Identifying Design Opportunities for Deep Energy Retrofits Introducing the Retrofit Depot : Deep Energy Retrofit Guides,” n.d.

“GreenBiz_How the USN Will Save 6mil per Year 2015 OCEANA.Pdf,” n.d.

“Improving Federal Energy Savings Through Performance Contracting.” *National Association of Manufacturers Webpage Nam.Org*. Washington, D.C., 2013. <https://www.nam.org/Issues/>

Energy-and-Environment/Affordable-Energy/Domestic-Energy/Improving-Federal-Energy-Savings-Through-Performance-Contracting--Full-Report/.

“Rocky Mountain Institute and Carbon War Room Merge in Strategic Alliance.” *Rocky Mountain Institute: About Website*, 2014. http://www.rmi.org/rmi_carbonwarroom_merger.

“Renovation vs Refurbishment vs Retrofit.” *Institute of Historical Building Conservation Wiki Webpage*, 2016. https://www.designingbuildings.co.uk/wiki/Renovation_v_refurbishment_v_retrofit.

“Real Numbers.” *Issues in Science & Technology* Winter (2010): 81–84.

Alsup, Frank. “A Challenge to Building Portfolio Owners.” *RMIOutlet Website Blog*, 2012. http://blog.rmi.org/blog_a_challenge_to_building_portfolio_owners.

Atlantic Marine Corps Community. “Atlantic Marine Corps Community - Hurricane Restoration Progress.” *AMCC Webpage*, 2019. <https://cl.atlanticmcc.com/hurricane-help>.

Baechler, Michael C., T.L. Gilbride, M.G. Hefty, P.C. Cole, K. Adams, C.F. Noonan, and Pam M. Love. “40% Whole-House Energy Savings in the Hot-Humid Climate.” *Building America Best Practices Series*. Vol. 15. Washington, D.C., 2011. https://www.energy.gov/sites/prod/files/2013/11/f5/40percent_hot_humid.pdf.

Baechler, Michael C., Jennifer Williamson, Theresa Gilbride, Pam Cole, Marye Hefty, and Pam M. Love. “Guide to Determining Climate Regions by County.” Vol. 7.1. Washington, D.C., 2010.

Baldor, Lolita C. “Marine Corps Says \$3.6B for Storm Repairs at East Coast Base - Houston Chronicle.” *Chron.Com*, 2018. <https://www.chron.com/news/article/Marine-Corps-says-3-6B-for-storm-repairs-at-East-13464673.php>.

Bolden, A. Che. “Installation-NeXt.” *Marine Corps Gazette* 103, no. 3 (2019): 60–62. www.mca-gazette.org/gazette.

Bolus, Robert. “Amerisips Homes: Custom Designed Residence Johns Island, SC.” *DOE Home Innovation Award*. Charleston, SC, 2014. https://www.energy.gov/sites/prod/files/2015/06/f22/DOE_ZEH_Amerisips_09-20-14.pdf.

Bronski, Peter, Romy Purshouse, Kelly Vaughn, David Labrador, and Marijke Jongbloed. “Deep Energy Retrofits Using Energy Savings Performance Contracts: Success Stories.” Boulder, Colorado, 2015. https://rmi.org/wp-content/uploads/2017/03/Deep_Energy_Retrofits_Using_ESPC.pdf.

Broome, Frederick R, Hubert Smigelski, Russell McNair, and Johan Ulloa. “Renewable Energy Case Study for Marine Corps Logistics Base Albany.” In *Energy Exchange 2017*, 23. Tampa, FL: US Department of Energy Federal Energy Management Program, 2017.

https://www.energy-exchange.com/wp-content/uploads/T15S3_Broome_Smigelski_McNair_Ulloa.pdf.

Brown Ceng, Peter A. “Passive & Active Design CIBSE Building Simulations Group CIBSE Building Simulations Group,” 2010. [https://www.cibse.org/getmedia/22be4d3b-2b5f-410d-bda4-79ce098baf66/Peter-Brown-\(Atkins\)-Passive-and-Active-Design\(1\).pdf.aspx](https://www.cibse.org/getmedia/22be4d3b-2b5f-410d-bda4-79ce098baf66/Peter-Brown-(Atkins)-Passive-and-Active-Design(1).pdf.aspx).

Burman, Kari, Alicen Kandt, and Lars Lisell. “Targeting Net Zero Energy at Marine Corps Base Hawaii - Kaneohe Bay.” Golden, CO, 2012. <https://www.nrel.gov/docs/fy12osti/52897.pdf>.

Burrows, Matthew J. “Global Trends: Alternative Worlds.” Washington, D.C., 2012. www.dni.gov/nic/globaltrends.

Carmichael, Cara, Porst-Hydras Kinga, Randy Smidt, Yolanda Robinson, and Freeman Nnsa. “Deep Energy Retrofits.” In *Energy Exchange*, 65. Denver, Colorado: Energy Exchange 2017, 2017. https://www.energy-exchange.com/wpcontent/uploads/T6S3_Carmichael_Hydras_Robinson_Smidt.pdf.

Carmichael, Cara, and Kinga Porst. “Workshop Report: 360° Perspective on Deep Energy Retrofits.” *RMI.Org*. Washington, D.C., 2014. https://rmi.org/wp-content/uploads/2017/05/RMI_Document_Repository_Public-Reprrts_2014-27_360PerspectiveonFederalDeepEnergyRetrofits-ExecSummary.pdf.

Carmichael, Cara, and Kinga Porst. “Energy Efficiency and Net-Zero Buildings: GSA and RMI Answer the Call.” In *GSA National Deep Energy Retrofit Charrette*, 26. Washington, D.C.: 10xe.org, 2015. http://www.10xe.org/Content/Files/GSA_P_to_P_WS_2015-Exec_Summ.pdf.

Carmichael, Cara, Kinga Porst, and Folsom Street. “Deep Energy Retrofits in GSA Buildings.” Boulder, CO, 2013.

Charoenkit, Sasima, and S Kumar. “Building Low-Carbon and Disaster-Resilient Communities: Integrating Climate Mitigation and Adaptation into the Assessment of Self-Help Housing Design,” 2017, 695–728. doi:10.1007/s11027-015-9694-4.

Construction, Southeast region Federal. “North Carolina Programs & Requirements Session.” In *2017 Summit: Infrastructure & Environmental Summit*, 131. North Carolina Military Business Center, 2017. <http://www.ncmbc.us/docs/17Summit/NorthCarolina.pdf>.

Distribution, Steam, and N A S Oceana. “Boiler Upgrades and Decentralizing Steam Systems Save Water and Energy at Naval Air Station Oceana.” Dam Neck, VA, 2011. https://www.energy.gov/sites/prod/files/2013/10/f3/oceana_water_cs.pdf.

DOE Federal Energy Management Program. "Department of Energy's Qualified List of Energy Service Companies." Washington, D.C., 2019.
https://www.energy.gov/sites/prod/files/2019/04/f62/doe_ql.pdf.

DOE Federal Energy Management Program. "Federal Energy Savings Performance Contracts." Washington, D.C., 2016. https://www.energy.gov/sites/prod/files/2016/12/f34/espc_faq_42_usc.pdf.

DOE Office of Energy Efficiency and Renewable Energy. "Preliminary Energy Savings Analysis ANSI/ASHRAE/IES Standard 90.1-2016." Washington, D.C., 2017.
https://www.energy.gov/sites/prod/files/2017/07/f35/Preliminary_90.1-2016_Energy_Savings_Analysis.pdf.

Eckstein, Megan. "Neller: Marine Need \$3.5 Billion for Camp Lejeune Repairs, Despite MILCON Cuts for Border Spending." *USNI News*, February 17, 2019.
<https://news.usni.org/2019/02/17/neller-marines-need-3-5-billion-camp-lejeune-repairs-despite-milcon-cuts-border-spending>.

Energy, Installation, and Lisa A. Jung. "FY 2018 Energy Conservation Investment Program (ECIP) and Plans for the Remainder of the Future Years Defense Program Guidance." Washington, D.C., 2016. [https://www.acq.osd.mil/eie/Downloads/IE/FY2018 ECIP Guidance Memo and Attachment A.PDF](https://www.acq.osd.mil/eie/Downloads/IE/FY2018%20ECIP%20Guidance%20Memo%20and%20Attachment%20A.PDF).

European Ocean Energy. "Industry Vision Paper 2013: Ocean Energy for Europe," 2013, 27.
https://www.oceanenergy-europe.eu/images/Publications/European_Ocean_Energy-Industry_Vision_Paper_2013.pdf.

European Small Hydropower Association. "European Renewable Energy Council: Hydropower," 2015. <http://www.erec.org/renewable-energy/hydropower.html>.

Expeditionary Energy Office. "USMC Expeditionary Energy Strategy and Implementation Plan: Bases-To-Battlefield." Quantico, VA, 2011.
[https://www.hqmc.marines.mil/Portals/160/Docs/USMC Expeditionary Energy Strategy Implementation Planning Guidance.pdf](https://www.hqmc.marines.mil/Portals/160/Docs/USMC%20Expeditionary%20Energy%20Strategy%20Implementation%20Planning%20Guidance.pdf).

Federal Energy Management Program. "U.S. Marine Corps Stands at Forefront of Energy and Water Savings." Washington, D.C., 2015. https://www.energy.gov/sites/prod/files/2013/10/f3/usmc_energysavings.pdf.

Fluhrer, Caroline, Eric Maurer, and Aalok Deshmukh. "Achieving Radically Energy Efficient Retrofits : The Empire State Building Example." *ASHRAE Transactions* 116, no. 2 (2010): 1–8.

Freeland, Chrystia. *Plutocrats: Rise of the New Global Super Rich and the Fall of Everyone Else*. Kindle. New York, NY: Penguin Press, 2012.

-
- Friedman, Thomas L. *Hot, Flat, and Crowded 2.0: Why We Need a Green Revolution--and How It Can Renew America*. Kindle ebook. New York, NY: Picador, 2009.
- Gardens, Laurel, and Jeremy Gary. "Habitat for Humanity South Sarasota County," 2015.
- Green, Gulf Coast. "Passive House Strategies for Hot and Humid Climates," 2013.
- Harrington, Eric, and Cara Carmichael. "RetroFit Project Case Study: Empire State Building." *Rocky Mountain Institute Case Study Database*, 2009, 1–9. <http://www.rmi.org/Content/Files/ESBCaseStudy.pdf>.
- Headquarters Marine Corps (HQMC). "Marine Corps Operating Concept: How an Expeditionary Force Operates in the 21st Century." Washington, D.C., September 2016.
- Heinrich, Mariana, and Lindee Wong. "New Energy Solutions for 1.5°C Pathways and Technologies to Achieve the Paris Agreement." Geneva, Switzerland, 2018. https://docs.wbcsd.org/2018/12/WBCSD_New_Energy_Solutions_for_1.5C.pdf.
- Higgins, Cathy, Liz Whitmore, Mark Lyles, Ric Cochrane, Mark Rehley, John Jennings, and Peter Wilcox. "A Case for Deep Savings." Portland, OR, 2011. <http://newbuildings.org/advanced-design/getting-50-beyond>.
- James R. Clapper. "Statement for the Record Worldwide Threat Assessment of the US Intelligence Community." *Worldwide Threat Assessment*. 2013. [http://www.dni.gov/files/documents/Intelligence Reports/UNCLASS_2013 ATA SFR FINAL for SASC 18 Apr 2013.pdf](http://www.dni.gov/files/documents/Intelligence%20Reports/UNCLASS_2013_ATA_SFR_FINAL_for_SASC_18_Apr_2013.pdf).
- Jungclaus, Matt, Cara Carmichael, Chris McClurg, Margaret Simmons, Randall Smidt, Kinga P. Hydras, Sharon Conger, et al. "Deep Energy Retrofits in Federal Buildings: The Value, Funding Models, and Best Practices." *ASHRAE Transactions* 123, no. 1 (2017): 55–70. <https://rmi.org/wp-content/uploads/2017/06/ASHRAE-D-LV-17-006.pdf>.
- Jungclaus, Matt, and Michael Gartman. "How the USN Will Save \$6 Million per Year on Energy at One Air Station." *Green Biz Website*, 2015. <https://www.greenbiz.com/article/how-navy-will-save-6-million-year-energy-one-air-station>.
- Kidder, Rushworth. *How Good People Make Tough Choices: Resolving the Dilemmas of Ethical Living*. Revised. New York City, NY: Harper Perennial, 2009.
- Knowles, Hal. "Performance Under Pressure: Structural Insulated Panel (SIP) Walls." Tallahassee, FL, 2004. <http://flash.org/resources/files/SIP2005-05-04.pdf>.
- Lovins, Amory B., and Rocky Mountain Institute. *Reinventing Fire: Bold Business Solutions for the New Energy Era*. Edited by Nancy Ringer. Kindle. White River Junction, Vermont: Chelsea Green Publishing Company, 2011.

-
- Manuel, John. "In Katrina's Wake." *Environmental Health Perspectives* 114, no. January (2006): A32–39. <https://www.ehn.org/lingering-long-after-a-storm-mold-and-mental-health-issues-2625546179.html>.
- Marine Corps Installations Command. "MCICOM IX Level Brief." Washington, D.C., 2018. Microsoft PowerPoint presentation received December 21, 2019.
- Marine Corps Installations Command. "United States Marine Corps Energy Investment Program (EIP) Project Documentation Instruction." Vol. 1.1. Washington D.C., 2013. [https://www.mcicom.marines.mil/Portals/57/Docs/GF Energy/USMC EIP Project Documentation Instruction_v1.1_FINAL Jun 26 2013.docx](https://www.mcicom.marines.mil/Portals/57/Docs/GF%20Energy/USMC%20EIP%20Project%20Documentation%20Instruction_v1.1_FINAL%20Jun%2026%202013.docx).
- Marine Corps Installations Command. "Office of Management and Budget Requests: Department of the Navy Hurricane Florence & Hurricane Michael." Washington D.C., 2018. Microsoft PowerPoint presentation received December 21, 2019.
- Marine Corps Installations East. "MCIEAST ENERGY & WATER STRATEGY Marine Corps Installations Command, Regional Energy Program." Camp Lejeune, NC, 2013. <https://www.mcieast.marines.mil/Portals/33/Documents/COMREL/Energy-Awareness/2015-MCIEAST-Energy-and-Water-Strategy.pdf>.
- Marine Corps Warfighting Laboratory: Futures Directorate. "2015 Marine Corps Security Environment Forecast: Futures 2030-2045." Quantico, VA, 2015. [https://www.mcwl.marines.mil/Portals/34/Documents/2015 MCSEF - Futures 2030-2045.pdf](https://www.mcwl.marines.mil/Portals/34/Documents/2015%20MCSEF%20-%20Futures%202030-2045.pdf).
- Martin, Les. "Third Party Financing ESPC / UESC / ENABLE." In *Energy Exchange 2017 Conference Proceedings*, 10. Denver, Colorado: Energy Exchange 2017, 2017.
- Mcilvaine, J, K Sutherland, and E Martin. "Energy Retrofit Field Study and Best Practices in a Hot-Humid Climate," no. March (2013).
- McLean. "Phone Conference Call with Camp Lejeune and MCAS New River Energy Managers." Quantico, VA, February 4, 2019.
- McLean. "Phone Conversation and Email Correspondence with MCICOM Energy Manager." Washington, D.C.: research notes, 2019.
- McLean, James S. "December 12, 2018 Energy and Innovation Scholars Pitch Session with LtGen Chiarotti DC-IL." Quantico, VA: session notes, 2018.
- McLean, James S. "Efficient Stewardship as America's Economic Future." *National Intelligence University BlackBoard* 1, no. May (2016): 11. doi:10.1017/CBO9781107415324.004.
- McLean, James S. "Meeting with MCICOM Commander and Staff Visit-Discussions." Washington, D.C., December 21, 2018.

-
- McLeod, Rob, Kym Mead, and Mark Standen. "Passivhaus Primer: Designer's Guide A Guide for the Design Team and Local Authorities." Hertfordshire, United Kingdom, 2017. www.passivhaus.org.uk.
- Mead, Kym, and Robin Brylewski. "Passivhaus Primer: Introduction An Aid to Understanding the Key Principles of the Passivhaus Standard." Hertfordshire, United Kingdom, 2017. www.passivhaus.org.uk.
- Mlecnik, Erwin. *Innovation Development for Highly Energy-Efficient Housing : Opportunities and Challenges Related to the Adoption of Passive Houses*. Online. Amsterdam, The Netherlands: IOS Press, 2013. <https://ebookcentral.proquest.com/lib/usmcu-ebooks/reader.action?docID=1183054&ppg=5>.
- Mountain, Rocky. "'Further, Faster, Together:' Rocky Mountain Institute and Carbon War Room Merger." *RMI Webpage and Youtube.Com*, 2016. <https://youtu.be/rOBsmMUEg7g>.
- National Intelligence Council. *Global Trends 2025: A Transformed World*. National Intelligence Council. Washington, D.C.: US Government Printing Office Internet: bookstore.gpo.gov, 2008. doi:10.1111/j.1728-4457.2009.00270.x.
- National Intelligence Council. *Global Trends: Paradox of Progress*. Online. Washington, D.C.: National Intelligence Council, 2017. <https://www.dni.gov/index.php/global-trends-home>.
- New Buildings Institute. "Project Profile: A Zero Energy Building - IDEAs Z2 Design Facility," 2012. https://newbuildings.org/wp-content/uploads/2015/11/CaseStudy_IDeAs1.pdf.
- Office of Energy Efficiency & Renewable Energy. "DOE Tour of Zero Database." *Department of Energy Webpage*, 2019. <https://www.energy.gov/eere/buildings/doe-tour-zero>.
- Office of Energy Efficiency & Renewable Energy. "DOE Tour of Zero." *DOE EERE Buildings Webpage*, 2019. <https://www.energy.gov/eere/buildings/doe-tour-zero>.
- Office of the Under Secretary of Defense for Acquisition and Sustainment. "Report on Effects of a Changing Climate to the Department of Defense." Vol. January. Washington, D.C., 2019. <https://media.defense.gov/2019/Jan/29/2002084200/-1/-1/1/CLIMATE-CHANGE-REPORT-2019.PDF>.
- Passivhaus Trust. "How to Build a Passivhaus: Rules of Thumb." *How to Build a Passivhaus: Rules of Thumb*, 2015, 28. www.passivhaustrust.org.uk.
- Petersen, Alisa, Michael Gartman, and Jacob Corvidae. "The Economics of Zero-Energy Homes: Single Family Insights." Boulder, CO, 2018. https://www.rmi.org/wp-content/uploads/2018/10/RMI_Economics_of_Zero_Energy_Homes_2018.pdf.
- Peterson, Paul. "Midway Park, AMCC Move into New Era for Housing Marine Corps Base Camp Lejeune Camp Lejeune News." *Camp Lejeune News Website*, 2012.

<https://www.lejeune.marines.mil/News/Article/513013/midway-park-amcc-move-into-new-era-for-housing/>.

Rhodes, Bill. "An Overview of Applied Ethics for the Military." In *An Introduction to Military Ethics: A Reference Handbook*, 165. Santa Barbara, CA: Praeger, 2009.

RMI New Building Initiative, and The Advanced Buildings. "New Construction Guide and the 2030 Challenge." Advanced Buildings Factsheet. Boulder, Colorado, 2015.
http://newbuildings.org/wp-content/uploads/2015/11/nbi_ab_2030_Factsheet2.pdf.

Roberto, Gonzalo, and Rainer Vallentin, eds. *Passive House Design: Planning and Design of Energy-Efficient Buildings*. Second ed. Munich, Germany: The Detail Business Information GrnbH, 2014. <https://libraryofthearmycorps.on.worldcat.org/oclc/1031633574>.

Rocky Mountain Institute. "Rocky Mountain Institute: Insights Webpage." *Insights*, 2018.
<https://rmi.org/rmi-insights/>.

Rocky Mountain Institute. "How to Calculate and Present Deep Retrofit Value: A Guide for Investors." Boulder, CO, 2015.

Rocky Mountain Institute. "Managing Deep Energy Retrofits Retrofit Depot." Boulder, Colorado, 2012. www.RetroFitDepot.org.

Rocky Mountain Institute, RMI. "Rocky Mountain Institute: Retrofit Depot: Case Studies." *Webpage*, 2016. http://www.rmi.org/retrofit_depot_get_connected_true_retrofit_stories#empire.

Rocky Mountain Institute, RMI. "Rocky Mountain Institute: Vision and Mission." *Webpage*, 2016. [http://www.rmi.org/Vision and Mission](http://www.rmi.org/Vision_and_Mission).

Rocky Mountain Institute, RMI. "RMI Retrofit Guide to Building The Case 1.1." Boulder, Colorado, 2012. http://www.rmi.org/Content/Files/RetroFit_Depot_Managing_Guide_1.1.pdf.

Rocky Mountain Institute, RMI. "Rocky Mountain Institute: Buildings." *Webpage*, 2016.
<http://www.rmi.org/Buildings>.

Rocky Mountain Institute, RMI. "Guide to Building the Case for Deep Energy Retrofits." *Rocky Mountain Institute Publications*, 2012, 21. http://www.rmi.org/Content/Files/RMI_Retrofit_Guide_BuildingTheCase_1.1.pdf.

Rocky Mountain Institute, and General Services Administration. "The Path to A Deep Energy Retrofit: Using an Energy Savings Performance Contract." Boulder, CO, 2015.
https://rmi.org/wp-content/uploads/2017/05/RMI_Document_Repository_Public-Reports_2015-02_Path_to_DR_using_ESPC.pdf.

-
- Rosenberg, Nathan. *Studies on Science and the Innovation Process: Selected Works*. World Scientific, 2010. <https://books.google.com/books?id=MFWNPgAACAAJ>.
- Sale, Michael J., M.J. Sale & Associates, and CDM Federal Programs Corporation. “2011-WRO-P-02: Water Resources Outlook.” Wartburg, Tennessee, 2011. <https://www.iwr.usace.army.mil/Portals/70/docs/iwrreports/2011-WRO-P-02.pdf>.
- Shnapp, Sophie, Rosa Sitja, and Jens Laustsen. “What Is a Deep Renovation Definition?,” 2013. http://www.gbpn.org/sites/default/files/08.DR_TechRep.low_.pdf.
- Shonder, John. *Energy Savings from GSA’s National Deep Energy Retrofit Program*, 2014. <https://www.gsa.gov/cdnstatic/NDEREnergySavingsReport5.pdf>
- Smith, Elizabeth. “Steam Decentralization at Marine Corps Base Camp Lejeune.” Camp Lejeune, North Carolina, 2017. Microsoft PowerPoint emailed April 17, 2019.
- Snow, Shawn. “\$3.6 Billion Price Tag to Rebuild Lejeune Buildings Damaged by Hurricane Florence.” *Marine Corps Times*, 2018. <https://www.marinecorpstimes.com/news/your-marine-corps/2018/12/12/36-billion-price-tag-to-rebuild-lejeune-buildings-damaged-by-hurricane-florence/>.
- Snow, Shawn. “Norway Deployments Frozen as Camp Lejeune Cleans up from Hurricane Florence.” *Marine Corps Times*, 2018. <https://www.marinecorpstimes.com/news/your-marine-corps/2018/09/18/norway-deployments-frozen-after-camp-lejeune-cleans-up-from-hurricane-florence/>.
- Texas Instruments. “Richardson Fabrication (RFAB): Green Design Green Design Overview The World’s First LEED Gold Certified Fab.” Dallas, TX, 2010. <http://www.ti.com/corp/docs/manufacturing/RFABfactsheet.pdf>.
- The White House. “National Security Strategy of the United States of America.” Washington, DC, 2017. <https://www.whitehouse.gov/wp-content/uploads/2017/12/NSS-Final-12-18-2017-0905.pdf>.
- Thelen, David, Mike van Acoleyen, Wouter Huurman, Tom Thomaes (Arcadis), Carolien van Brunschot, Brendan Edgerton, and Ben Kubbinga. “Scaling the Circular Built Environment.” Geneva, Switzerland, 2018. https://docs.wbcsd.org/2018/12/Scaling_the_Circular_Built_Environment-pathways_for_business_and_government.pdf.
- Turner Construction Company. “Camp Lejeune 2nd Anglico and 2nd Intel Batallion Operations Complexes.” *Turner Construction Company Website*, 2019. <http://www.turnerconstruction.com/experience/project/67A9/camp-lejeune-2nd-anglico-and-2nd-intel-batallion-operations-complexes>.
- U.S. Department of Defense. “Summary of the 2018 National Defense Strategy of the United States of America: Sharpening the American Military’s Competitive Edge.” Arlington, VA:

Office of the Secretary of Defense, 2018. <https://www.defense.gov/Portals/1/Documents/pubs/2018-National-Defense-Strategy-Summary.pdf>.

United States Marine Corps. "Marine Corps Order P11000.12C w/Ch 1. Real Property Facilities Manual, Vol II Facilities Planning and Programming." Washington, D.C., 1986. <https://www.marines.mil/Portals/59/Publications/MCO P11000.12C W CH 1.pdf>.

University of Texas. "Consequentialism - Ethics Unwrapped." *McCombs School of Business Webpage*, 2018. <https://ethicsunwrapped.utexas.edu/glossary/consequentialism>.

Vaughn, Kelly. "Empire State Building Retrofit Surpasses Energy Savings Expectations." *Rocky Mountain Institute: Outlet Blog*. Boulder, CO: Rocky Mountain Institute online content, 2012. https://www.rmi.org/blog_empire_state_retrofit_surpasses_energy_savings_expectations/.

Wallace, Lewis R. "Lingering Long After a Storm, Mold and Mental Health Issues." *Environmental Health News*. January 22, 2015. <https://www.ehn.org/lingering-long-after-a-storm-mold-and-mental-health-issues-2625546179.html>.

Wright, G, K Klingenberg, and Betsy Pettit. "Climate-Specific Passive Building Standards." Springfield, VA, 2015. <http://www.osti.gov/bridge>.