ReGen Villages: Development of Design Features & Software Applications for Integrating Regenerative Lifeline Resource Systems in Residential Communities

Impacts of Lifeline Resource System Failures

On Oct 29 2012, the approximately 1000 mile wide "eye" of a Category 3 hurricane made landfall on the New Jersey coastline, inducing high winds and pushing record-breaking storm surge through the New York harbor into the five boroughs of New York City. Flooding from this storm wreaked havoc on multiple infrastructure systems, including the explosion of a borough-critical electrical transformer along the East River, robbing hundreds of thousands of Manhattan residents of their electrical supply. At its peak impact, *Superstorm Sandy* caused 8.5 million people across 21 states to lose their electrical power and nearly 1 million alone in NYC.[1] When Sandy subsided, the effects of this natural catastrophe remained. In southern Manhattan, "R" train service connecting Manhattan and Brooklyn was non-operational for fourteen months,[2] and its electrical service network was notoriously out for six days. Residents of other parts of New York City were less fortunate, as electrical service in the Rockaways (Brooklyn) remained out for 8,200 residents through late January 2013.[3]

Context for Research

To sustain life in the built environment, infrastructural resource systems have been designed and constructed to provide a regional population with "lifeline" resource units such as food (KCals), communications (MHz), energy (MWhs), water (MGDs) and to also extract waste (tons). These systems are essential for dwelling in the built environment, yet are structurally and operationally independent of one another, with some nodal exceptions. The resource units generated by these lifeline systems are typically produced at industrial scales, transmitted through legacy centralized systems, and travel considerable distances between the rural or peri-urban settings from which they originate to where they are ultimately consumed. However, the operational fidelity of these lifeline systems is increasingly challenged by both an increasing number of threats and an increase in threat severity. For instance, acute shocks such as meteorological storms, and long-term stresses such as droughts, oftentimes introduce unwelcome interruptions or failures to our vital critical resource systems. A historical survey of these infrastructure failure events reveals shock events and hazards do not discriminate against any particular infrastructure type—spillways fracture, transformers fault, and subways flood. These failures introduce measurable consequences for end-users that range from temporary inconvenience to loss of human life.

For populations who dwell in urban contexts, the modus operandi of "living off the land" is not a viable option, as the density achieved by systems and people per unit of land precludes an

[1] "NYC utility cuts power to more households in Sandy's aftermath," *CBS News*, November 1, 2012, http://www.cbsnews.com/news/nyc-utility-cuts-power-to-more-households-in-sandys-aftermath/
[2] Alex Davies, "One Year Later: Here's How New York City's Subways Have Improved Since Hurricane Sandy," *Business Insider*, October 29, 2012, http://www.businessinsider.com/heres-how-nycs-subway-system-has-come-back-from-hurricane-sandy-2013-10
[3] Stephen Nessen, "As Cold Snap Hits, Some Sandy Victims Still Lack Heat," *WNYC News*, January 23, 2013, https://web.archive.org/web/20130128062812/http://www.wnyc.org/articles/wnyc-news/2013/jan/23/cold-snap-hits-some-sandy-victims-still-lack-heat/

individual urban dweller's securing of personal resources within their urban limits. While one branch of our human-centered design research at the Stanford Center for Design Research is committed to investigating the demonstrated needs of urban dwellers, another branch considers next-generation generative systems at the scale of a residential community in a peri-urban context. This research work is informed by in-field prototyping currently conducted by *ReGen Villages Holding BV.*

By eradicating the necessity for transmission between where resource units are generated and where they are consumed, de-centralized regenerative systems with closed loop capabilities can deliver lifeline resource units with improved reliability during periods of normal system operation, and with increased resilience for end-users during periods of stressed system operation. We are currently examining design requirements for regenerative stacked resource systems and are using the viability, feasibility and desirability of these regenerative system designs as metrics for evaluation.

ReGen Villages Project Development

The ReGen Villages project was first introduced to the United Nations community in the form of a Global Sustainability Development Report authored in 2015. Titled *"RegenVillages – Integrated village designs for thriving regenerative communities,"*[4] this document outlines plans for developing symbiotic resource systems at neighborhood scales and with closed loops. The specific concept outlined in this report was aspirational and has since proven to be highly desirable by the general public through its global mass media exposure at the 2016 Venice Biennale for Architecture. Today, the operational goal of ReGen Villages is focused on establishing a perpetual state of regenerative resource units for community consumption, that under ideal conditions, require no external inputs for water or electricity. In this respect, system capacities would support approximately 150+ residential units and their respective occupants. While some dependency will exist on off-site sources for certain forms of nutrition (40% estimated), the system yields being planned and experimentally prototyped suggest an overall technological capability of generating greater than 100% of any single community's demonstrated demand for food, water, electricity, and for compostable waste.

While the stacking of regenerative systems introduces new challenges deserving of prototyping and performance testing, one of the first challenges addressed has been the creation of application program interfaces (APIs) for use with project partners and the development of a software operating system to provide baseline integrative system functionality and monitoring (Village OS).

One future for the planning, design and implementation of residential developments emphasizes, with some urgency, the integration of regenerative services that support resiliency at the

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[4] James Ehrlich, Larry Leifer and Chris Ford, "RegenVillages – Integrated village designs for thriving regenerative communities," *Sustainable Development Knowledge Platform, Department of Economic and Social Affairs, United Nations, 2015,* https://sustainabledevelopment.un.org/content/documents/622766_Ehrlich_Integrated%20village%20designs%20for%20thriving%20regenerative%20communities.pdf

neighborhood scale.[5] Features of ReGen regenerative systems include having immediate proximity and independent agency with natural resource generation of organic food, clean water, renewable energy, and circular waste-to-resource management; net-positive resource yields; access to autonomous transit powered by renewable energy; participation in blockchain - based economic models that consider the regeneration and conservation of resources as asset classes for larger ecosystem benefit.

Application Program Interfaces (APIs)

These decentralized neighborhood-scale systems, now characterized by a shift away from legacy district-scale infrastructures, affords natural and desirable opportunities to analyze data and discover relationships between resource inputs and outputs for training algorithmic machine learning (AI) across diverse technologies. Next generation responsive devices shall use open application program interfaces (APIs) upon which software systems are then developed for command/control and real-time data mapping of metabolic resource system performance. Over time, critical metabolic relationships between systems would develop higher levels of desirable automation, without any expectation for full autonomy.

This AI will be tasked to collect real-time and mission-critical data from participating regenerative neighborhood resource systems, and is in turn used to support both human and cyber-physical interventions for establishing and developing thriving residential communities. These data sets and their respective information and communication technologies (ICT systems) contribute to the development of a resource management knowledge base to be shared between connected residential communities in similar climate zones. The informational merit of sharing such data between similarly-tooled residential communities has yet to be understood and may lead to, under optimum conditions, exponential improvements to resource systems operating in these residential communities. Access to such data can reasonably inform questions of "what," "when," "why," and "how" when either human caretakers or cyber-physical interventions positively optimize system performance.

Village Operating System (OS)

The Village OS is a software platform that connects neighborhood resources of energy, water, food, waste management and mobility as a service that is dynamically responsive to other systems, designed specifically for the benefit of its inhabitants and to reducing the environmental impacts of these operating systems on the regional natural environment.

Facilitating a catalyst between technology partners with proven systems in the field, the Village OS establishes a viable communication protocol to interact with various infrastructure devices to maximize the regenerative output and circular flows of each resource. Real-time data is categorized into repositories crawled to both recognize mission critical information for immediate human intervention, and analyze patterns and trends for AI to trigger robotic-actuated responses. One of the key features of this methodology is the support of predictive learning in ways that increase operational knowledge, especially at nodes of integration between systems.

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[5] Aspects of the ReGen concept align with UN Sustainable Development Goals numbers 09, 11 and 12.

Considerations for autonomous transit and shared electric mobility at various scales requires maintaining awareness of vehicle positioning and their proximity relationships to passenger and freight destinations. From an opportunistic fuel management perspective, electric vehicle energy storage beyond charging shall be load-balanced by storing excess supply into neighborhood micro-grids. Planning for the emergence of autonomous automotive vehicles and unmanned aerial vehicles allows for the removal of conventional garages and driveways, thereby preserving the Village's inner core for pedestrian, bicycle and EV modalities.

An additional economic layer is being employed as part of a decentralized fork of the blockchain for both ledgering resident participation and aggregating large raw data feeds into bundles that can be further crawled for greater machine learning knowledge distribution. The concept of wrapping infrastructure resources with resident economics supports the emergence of a universal basic income (UBI) at the networked neighborhood scale.

Design requirements for user experience include contact-free voice recognition efficiency for search, and command/control functionality through conversational language. Evolving systems with anonymized information can be further customized to physiological and biometric digital devices integration.

The Village OS will be implemented through embedded AI chips for a networked neighborhood appliance (OS in a box) located at each village site. The system approach is based on regional climate zones and is otherwise agnostic to both specific architectural typologies and/or partner platforms. At the highest level of Village organization, the Village OS bundles new residential construction, new regenerative systems, and retrofit development sites around the world.

ReGen Villages Oosterwold

The first ReGen Villages pilot community will be developed in the Oosterwold organic farm district of Almere, Netherlands, which in turn is approximately a 30-minute commute from Amsterdam. The district designated by the Dutch government is intended to showcase off-grid capable housing and responsible neighborhood development planning that considers conservation and stewardship of natural areas and resources. The ReGen Villages master plan maximizes whole ecosystem thinking to establish a prescribed balance between built and open spaces. Planning for resiliency is key for developing neighborhood-scale services that establish internal capacities for resource unit self-reliance despite external connectivity to municipal lifeline systems. ReGen Villages has also engaged governments, landowners and industry partners to secure *Memoranda of Understanding* for future developments in Northern Europe, Asia, North and South America, Middle East and Africa.

In conclusion, self-reliant and resilient communities such as ReGen Villages introduce new benefits to community members while reducing burdens for governments at all levels, alleviates demand for healthcare systems, reduce stress on banks, and decreases risk for insurance companies and pension funds alike. Above all, the ReGen Village concept establishes just and equitable residential housing solutions for increasing personal well-being while reducing exposure to impacts of climate-induced threats to lifeline resource systems.

Bios

James Ehrlich is the founder of *ReGen Villages Holding BV* and is also an Entrepreneur in Residence at the Stanford University CCARE Institute. In 2017, James joined the faculty of Singularity University, and maintains appointments as a Senior Fellow at NASA Ames Research Park, Opus Novum Consortium, and member of White House Office of Science Technology & Policy (OSTP) Joint Task force under the Obama administration on the Nexus of Food, Water, Energy + Waste.

Chris Ford AIA is the Hamamoto Interdisciplinary Graduate Fellow and a PhD candidate in Mechanical Engineering at Stanford University. Chris is a design professional, educator, and researcher in the areas of both Architecture and Infrastructure design. He is interested in the research and design of next-generation solutions for the built environment from a human-centered perspective.

Professor Larry Leifer PhD is founding director of the Stanford Center for Design Research (1984) where he works with colleagues across different disciplines to understand and facilitate creative technical design-team activity. He is developing objective measures of design team performance under various structured methodology conditions. He presently coordinates and co-teaches *ME310: Project-Based Engineering Design, Innovation, and Development;* a high-tech, globally distributed graduate course that is both pedagogically and economically supported by international companies including Audi, IKEA, Microsoft, SAP, Siemens, Panasonic and Volvo CE, among others.