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Session: Poster session

Title: ‘Resiliency from the rooftops down’

“Solar Roofpod”, a design-build research project to exploit the resource of urban flat roofs

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Abstract:

In cities, flat rooftops are a key to greater resiliency in the occurrence of power outages. The “Solar Roofpod”, developed as an interdisciplinary design-build project at the City College of New York (CUNY), offers an innovative, marketable method to create user-friendly, decentralized rooftop energy resources.

The Solar Roofpod offers a reproducible penthouse structure, which can be quickly and efficiently implemented to improve urban resiliency by using synergies among architecture, engineering, real-estate, policymaking, bioremediation and education. It leverages private and public potentials to localize energy production, mitigate run-off, raise stakeholder consciousness through climate-related activities, re-introduce biodiversity and improve the urban energy infrastructure via a decentralized approach.

One of the main challenges in fostering greater resiliency is to create a tangible paradigm that capitalizes on quality of life, complementing and integrating the challenge of improving our infrastructure with more ephemeral requirements stemming from consumer behaviors. By appealing to quality of life concerns, the Roofpd can build new resiliency-minded cohorts. It argues for the necessity of comprehensive thinking within the practice of resilient Architecture and Design.

Keywords:

Decentralized energy; Market-friendly solutions, Consumer education

1 Introduction and Concept

In cities, flat rooftops are currently seen as the source of problems: reflected solar radiation and re-radiation create heat island effect; solar absorption increases cooling loads and negatively impacts roof membrane longevity; impermeable roof surfaces transfer rainwater directly to combined sewers, creating overflow emergencies. We argue to the contrary that rooftops are a key to greater urban resiliency. The "Solar Roofpod", developed as an interdisciplinary design-build project at the City College of New York (CUNY), is a pioneering Net-Zero-Energy penthouse that leverages private and public potentials to localize energy production, mitigate run-off, raise stakeholder consciousness by means of climate-related activities such as urban farming and weather monitoring, and re-introduce biodiversity. Finally, it greatly increases resiliency in the urban energy infrastructure through a decentralized approach to renewable energy access.

The vulnerability of New York's infrastructure was experienced first-hand, when Superstorm Sandy struck in October 2012: flooding-related power losses exposed the city's infrastructural exposure, resulting in billions of dollars of economic loss. New Yorkers' comfort and quality of life, currently dependent upon centralized fossil-fuel combustion, was undermined by the consequences of centralized energy supply. In particular, the loss of power due to flooding, lasting for days in major parts of the city, generated widespread awareness of the need for resiliency. A wide-spread implementation of the Solar Roofpod could provide the necessary decentralized back-up power supply, operating from the top down. It is a unique and market-friendly approach to introducing renewable energy into the city at a large scale of deployment, and providing an up-to-date zero-carbon urban renewable energy strategy.

2 Decentralized, emission-free power, building by building

New York City's electrical power is supplied largely by gas-driven dual-fuel power plants, with a back-up oil supply. The other significant power source is a nuclear plant some 40 miles away. New York City's energy mix is about 70% natural gas + oil, and 30% nuclear power, with only a fraction of a percent coming from renewables ("Powering NYC through 2030, Electricity Outlook", NYBC, 10/2011). PlaNYC's emission inventory states that roughly 34% of our citywide carbon emissions, 18.2 million tons of CO2, are the result of electricity production (www.nyc.gov/html/planyc2030/ html/emissions.shtml).

Precedents for microscale photovoltaic power production are well-documented (www.nycsolarmap.com), especially in big box commercial and single-family contexts; and the innovation currently underway in the Northern European electrical grid offers ample precedent for cities such as New York to balance legacy centralized and new decentralized production models.

Thermal energy has a much higher efficiency rate (about 4-fold) than photovoltaic power. But especially in summer, most cooling is currently provided by means of electric systems, even though thermal energy, plentiful at this season, could potentially power cooling systems (adsorptive and absorptive cooling). Thermal energy for heating purposes is presently in some cases provided by Consolidated Edison (ConEd), which operates the largest district cogeneration steam system in the world. (Coned.com steam heating, accessed September 13, 2013). Buildings outside ConEd's district heat zone are mostly reliant upon oil (and more rarely, natural gas) furnaces. District heating's capacity to include cogeneration means greatly enhanced efficiency but centralized steam plants increase susceptibility to disruption; the negative public health effects of oil furnaces has effectively been benchmarked in New York City by tying increased asthma rates to oil combustion (nyccleanheat.org, accessed September 13, 2013).

As prototyped, the Solar Roofpod's overhanging "solar trellis" provides 900 ft^2 of surface for combined electrical (PV) and thermal (evacuated tube collector) energy generation. The surface utilized for thermal energy supersedes the proportional demand of the Roofpod. However, the idea is to maximize thermal energy, due to the much higher efficiency. Since the peak power demand in New York City is reached in the hottest days of summer (record peak: 11,424 MW on July 22, 2011; NYISO report), it makes most sense to reduce cooling loads with technologies that exploit that environmentally available thermal energy. In addition, it is estimated that New York City could meet half of its peak demand with rooftop photovoltaics (www. nycsolarmap.com). Peak demand could be fully met by combining wide-spread thermal cooling with PV electric generation, reducing black and brown-out disruption.

Harvested thermal energy is stored in a phase change tank integrated into the building's core. A highly effective means for storing thermal energy at the molecular level, this technique insures that the roof pod will cover its own thermal needs even for periods of time without sunny weather. The prototyped evacuated tube array produces about 12 kWp. The solar array, prototyped using PVs with a 20% yield, generates an estimated 10 kWp. The Roofpod could become a real-time "battery" for absorbing solar loads, transferring excess production in the host building underneath and reducing or eliminating its grid drawn-down immediately on site. As an alternated to grid buy-back models for distributing microproduced energy, this alternative has the advantage of eliminating network transmission loss while accomplishing significant reductions in demand. Because rooftop orientation is independent of zoning, street grid or other urban factors that impinge upon solar array efficacy, optimal results can be more easily secured.

In our preliminary studies, we estimated that approximately 150,000 buildings in New York City (all five boroughs) are feasible for Roofpod installations. By multiplying the 22 kWp that our Rooftop prototype is able to produce, the potential of applying this strategy to 150,000 sites would accumulate to a power

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contribution of about 3,300 MWp, which would account for about a quarter of the assumed record peak power in future projections on a sunny summer day.

This estimate, though optimistic since exclusive of efficiency loss, is supported by estimates that 14% of the annual electricity consumption of New York City could be met by solar power (Institute for Local Self-Reliance: www.ilsr.org/new-york-city-should-meet-half-its-peak-demand-rooftop-solar-pv/). In cases of black-outs, this decentralized power supply “cloud” would provide the necessary resiliency to run emergency back-up and other systems.

3 Mitigating heat island effect and storm water run-off through intensive green roofs

Storm water run-off from myriad impermeable surfaces is a significant cause of waterway and ground water pollution in the urban environment, where run-off rates are more than 500% of those in rural conditions (EPA 2003). Legacy sewage infrastructure, combining storm and grey/black water, hinders attempts to separate and treat different water types. From a resiliency standpoint, the capacity to allay the entry of storm water into the water treatment system during extreme weather events translates into reduced flooding and lower risk of contamination. In New York City in aggregate, 78% of the total land within city limits is used for building and therefore impermeable. (NYC.gov/planning, accessed September 13, 2013). In a city dominated by the presence of natural waterways, the impact of storm water run-off is of particular concern.

The Roofpod rests upon a structural dunnage system, adapted from typical water tower installation. This bearing system of beams spanning wall-to-wall on the host building creates the opportunity for a raised ground level for planting with much greater root depth than traditional greenroof systems, creating the opportunity for urban farming or for deep-root plants better able to withstand high roof-top winds. Deeper soil also translates into greater water absorption capacity. Based on the estimate that approximately 25% of the legacy building stock in New York City is appropriate to Roofpod installation, there is potential to transform at least one-quarter of the city’s surface area from hardscapes to absorptive cover.

Green roofs have documented capacity to reduce unwanted heat gain in summer, reduce thermal transmission against heat loss in the winter and absorb solar energy into a photosynthetic process, rather than re-radiating the heat as “heat island effect.” Studies have shown 6% savings in cooling costs, 10% in heating costs and reductions in overall ambient air temperature, presuming 100% conversion to green roofs, of nearly 2°F (EPA Green Roofs, 2-7).

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4 Marketability and kit-of-parts construction; code-related incentive policies

Part of the Roofpod's architectural intrigue is its modular kit-of-parts system, where diverse landscape, façade and trellis elements can be freely combined and thus customized in its assembly. Each component of the Roofpod was also conceived to facilitate installation without requiring a crane, and is dimensioned to a standard residential elevator cab. Potential for the prefabrication of elements translates into an economy of scales both for production and construction, as well as for larger-scale planning.
The rooftop pavilion and adjacent gardens are highly attractive spaces; each building owner or cooperative would have the chance to define the program of the available area, thereby creating local markets appropriate to real-estate and construction economies.

Communal use and reduced energy and waste costs benefit the building, its surrounding community and the city as a whole, repaying incentives in zoning regulations to increase the bulk of the host building, and alleviate the restrictions to develop the underutilized roofscapes.

5 Consumer education

The positive effects of user education on resource consumption rates and return to normal conditions after emergency events (resiliency) is well-documented (IEA Annex 46). The Roofpod integrates several features that support user awareness of resource usage and efficiencies, and several opportunities for direct user interaction with the Roofpod's unique combination of architectural, engineering and bio-based innovations that make sustainable living synonymous with high quality of life. The building integrates color-morph elements in the interior design that indicate by changing color the real-time power production-consumption ratio and the irrigation cistern water level, providing simple "dashboard" information within the design context. The complex monitoring and control dubbed "smart house system" supports data collection, to optimize the operation of electric lights, shades and daylight control, natural ventilation, cooling and heating, appliance use and irrigation of the roof garden. The Roofpod could also monitor and control the host building's performance, measuring all building emissions. These potentials are the subject of future research: the prototyped Roofpod is awaiting return to our campus for installation on the roof of the architecture building, where its use as a measuring and monitoring device could be implemented and studied.

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6 Conclusions

The Solar Roofpod design indicates that developing a successful strategy for urban rooftop utilization and implementing it as a resiliency strategy, is dependent on comprehensive thinking and interdisciplinary processes.

In the framework of this educational design-build project, the collaboration between our collegial engineering and architecture departments was primary, but intellectual input from other fields was essential: policy-making, construction management, real-estate development and marketing, to name a few. Architecture, by nature a mediating profession, is well suited for the challenges of interdisciplinary coordination in order to improve our built environment.

The Solar Roofpod can be seen as an industrial design challenge: Prototyping an artifact must be negotiated in terms of economic viability, technical feasibility and user desirability, in order to develop consumer satisfaction and feedback. Any artifact, as an agent for cultural change, needs a ‘human scale’, which addresses phenomenological and cultural acceptance on the consumer side. Tangible projects, with a powerful experiential potential, have a much stronger impact on consumer behavior than abstract policies or larger infrastructural approaches, which remain hidden from the users’ eyes and minds. The strategy of developing components, which engage the user scale, in this case the realm of the single Solar Roofpod, and then bundling them to provide and complement a decentralized infrastructure to serve the urban scale, is advantageous.

The development of decentralized infrastructure can thus provide both greater consumer participation and enhanced resiliency. If 150,000 Solar Roofpods were installed in New York City, not only would up to 25% of energy peak demand be supplied by this system, simultaneously providing back-up power for black-outs, but the people using them, presumably millions of consumers, would understand and embrace the benefits of a more sustainable, net-zero-energy lifestyle, mitigating the demands on resiliency overall. The Solar Roofpod provides for both shorter-term improvement in carbon-free energy infrastructure and long-term improvement in people’s cultural mindsets.

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Christian Volkmann is an Associate Professor at the City College of New York, Spitzer School of Architecture. He graduated with a Master’s degree in Architecture from the Swiss Federal Institute of Technology Zurich (ETH). He established his own firm aardvarchitecture LLP. in New York in 1998. He has taught and developed several pedagogic concepts focusing on the integration of technical and environmental topics into the design process and into design-build implementation.
He was the Program Manager of City College’s ‘Solar Roofpod’ for the Department of Energy’s Solar Decathlon. The house was exhibited on the National Mall in Washington DC in the fall of 2011.

Lynnette Widder holds a Master of Architecture degree from Columbia University, where she is currently a faculty member in Sustainability Management. Her research includes thermal energy assessment for building envelope retrofit, building construction history and participatory design strategies for sustainability applications. She is a partner in the firm aardvarchitecture llp.

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The City College of New York

Resilient Cities 2013

SOLAR ROOFPOD – RESILIENCY FROM THE ROOFTOPS DOWN

NYC black-out, Superstorm Sandy,. 2012 MoMA/I.Baan

INTRODUCTION:

In cities, flat rooftops are a key to greater resiliency. The “Solar Roofpod”, developed as an interdisciplinary design-build project at the City College of New York (CUNY), is a pioneering Net-Zero-Energy project that leverages private and public potentials to localize energy production, mitigate run-off, raise stakeholder consciousness with climate-related activities such as urban farming and weather monitoring, re-introduce biodiversity and improve the urban energy infrastructure in a decentralized approach .

The vulnerability of New York’s infrastructure was experienced first-hand, when Superstorm Sandy struck in October 2012: flooding-related power losses exposed the city’s infrastructural shortcomings to such occurrences, with billions of dollars of economic loss.

The level of comfort and quality of life, often based on centralized fossil-fuel combustion, was actually cancelled out by the consequences of generating energy in this exact fashion. Especially the loss of power due to flooding, lasting for days for major parts of the city, generated widespread awareness of the need for resiliency. The “Solar Roofpod” could provide the necessary back-up power in a decentralized fashion, operating from the top down, and provide an up-to-date urban renewable energy approach.

OBJECTIVES:

- DELIVER DECENTRALIZED, EMISSION-FREE POWER TO NEW YORK CITY.
- PROVIDE BACK-UP POWER TO *HOST-BUILDINGS* IN CASE OF BLACK-OUTS.
- MITIGATE STORMWATER RUN-OFF BY USING INTENSIVE GREENROOFS.
- DEVELOP AN AFFORDABLE, MODULAR, MASS-PRODUCABLE KIT-OF-PARTS.
- PROVIDE A TANGIBLE PARADIGM TO CHANGE PEOPLE’S PERCEPTION OF RENEWABLE ENERGY DESIGN IMPLEMENTATION IN URBAN ENVIRONMENTS.

PROJECT DATA:

- PHOTOVOLTAIC ARRAY: 40 PANELS (a 240 W), 49.7 m^2/535 ft^2 (EFFECTIVE AREA)
  PEAK POWER: ~10 kWp
- SOLAR THERMAL: 180 EVACUATED TUBES, 14.6 m^2/157.3 ft^2 (ABSORBER AREA)
  PEAK POWER: ~12 kWp
  (HOT WATER FOR HEATING, ADSORPTIVE COOLING, DOMESTIC HOT WATER)
- MONITORING + CONTROL (“SMART HOUSE”) SYSTEM, CONTROLLING:
  a) ELECTRICAL LIGHTS, b) SHADES (DAYLIGHT), c) HVAC SYSTEM,
  d) APPLIANCES, e) IRRIGATION, f) NATURAL VENTILATION.
  (THE SYSTEM COULD ALSO CONTROL/IMPROVE THE HOST BUILDING’S OPERATION.)
- COLOR-MORPH INDICATORS FOR POWER + WATER CONSUMPTION DISPLAY.
- CONSTR.TYPE: 2 (IBC); SUITABLE FOR MOST URBAN BUILDING STRUCTURES.
- CUSTOMIZABLE HIGH-PERFORMANCE MODULAR ENVELOPE SYSTEM.
- COSTS: CONSTRUCTION PROTOTYPE: $450,000; MASS-PRODUCED: ~$300,000.

INCENTIVES/PROMOTION:

- ADDITIONAL FAR (GFZ) PERMISSIBLE DUE TO RENEWABLE POWER BACK-UP INFRASTRUCTURE; PUBLIC INTEREST IN AVOIDING POWER FAILURES.
- NECESSARY START-UP SUBSIDIES FOR PREFAB MANUFACTURING SET-UP.
- JOB GENERATION PROGRAMS / REDUCING HEALTH + CLIMATE DAMAGE.

CURRENT RESULTS:

- A FUNCTIONING PROTOTYPE TO EVALUATE REAL-TIME PERFORMANCE.
- 60 STUDENTS TRAINED IN INTEGRATIVE INTERDISCIPLINARY DESIGN.
- FIRST NET-ZERO-ENERGY ON CCNY CAMPUS (INSTALLATION: SUMMER 2013)

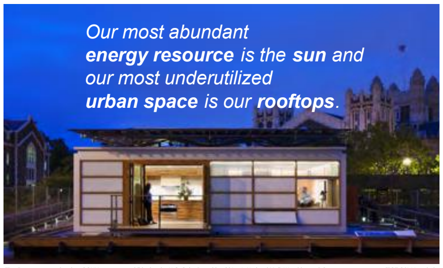
POTENTIAL:

150,000 UNITS (FOR NEW YORK CITY AREA):
x 10 kWp (ELECTRICAL ENERGY) = **1,500 MW**
x 12 kWp (THERMAL ENERGY) = **1,800 MW**
ENERGY (TOTAL) = 3,300 MW

NYC, (POWER DEMAND, SUMMER 2011) **11,424 MW** [1)]

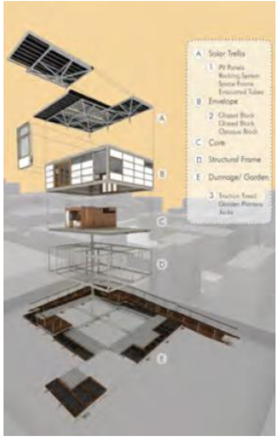
- SOLAR ROOFPODs COULD COVER UP TO **25%** OF NYC’s POWER DEMAND!

[1)] “Powering NYC through 2030, Electricity Outlook”, New York Building Congress, Energy Committee, 10/2011



Our most abundant ***energy resource*** *is the* ***sun*** *and our most underutilized* ***urban space*** *is our* ***rooftops****.*

First Prototype, completed on CCNY campus; exhibited at the U.S. Solar Decathlon 2011, National Mall, Washington DC (ESTO/A.Vecerka)



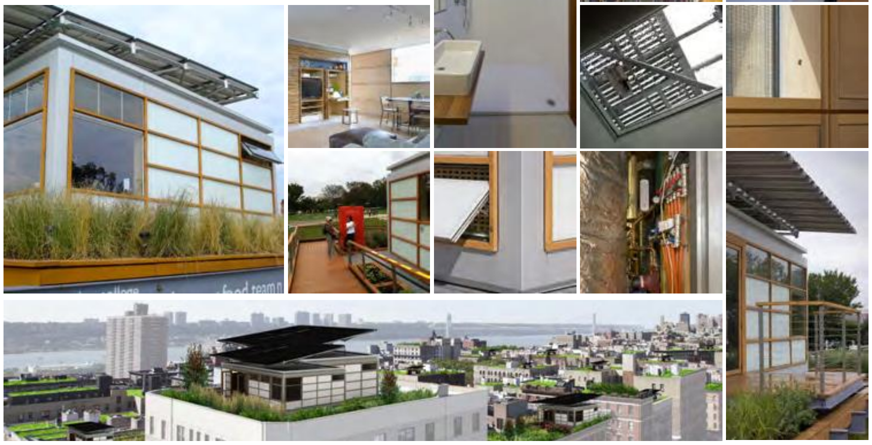


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Fig.1: *Poster exhibited at the 2013 ICLEI – Resilient Cities Conference in Bonn, Germany*

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