

REIs: Renewable Energy Infrastructures

Chris Ford

Associate Professor in Architecture

University of Nebraska

ABSTRACT

If we recognize that architects have historically played a role as technological innovators, then we must also recognize that architects are engaged in a form of applied research. Infrastructure design, although traditionally led by the engineering discipline, is one particular area in which an increasing number of architects are seeking to engage, and rightfully so. While the question concerning infrastructure is typically thrust into the national consciousness at times of system failure (New Orleans' levees, Minneapolis' I-35 West bridge, Japan's Fukushima Daiichi nuclear plant, and the recent calamities in the American northeast triggered by Hurricane Sandy), the subject of infrastructure has sustained a level of buzzworthiness in the larger architectural discipline.

This essay argues the basis for architect-led Infrastructure design. Furthermore, this essay identifies the problem of Infrastructure design in which an architect's demonstrated skill set in comprehensive thinking becomes a competitive edge over the specialized thinking demonstrated by engineers. Precedents, some built and some unbuilt, are used to support this claim. Research is conducted into contemporary issues concerning the electrical power grid in the United States and the ramifications of continued generation, transmission and distribution of electrical energy across this grid are identified. As a research-first design problem, our university-based design / research team has applied design thinking skills to a problem that involves energy production, energy transmission, and urban living.

An REI generates renewable energy megawatts (MW) at an industrial scale through the simultaneous harnessing of wind, solar, and geothermal resources, but within an integrated, holistic, and free-standing facility positioned in an urban environment. An REI is not a retrofit of a pre-existing architectural condition, but rather is conceived as a new typology to be owned and operated by an electrical utility. The essay documents the respective design process behind the design of an REI for a specific urban site in Lincoln Nebraska and shares a quantified assessment of (estimated) overall electrical yields.

If architects are truly interested in the prognostication of a fundamentally new infrastructure type, then we must proceed with a heightened seriousness in our design intelligence, a dire sense of urgency in the timeliness that we work, and focused clarity upon the effect that we want to induce, just as other technological innovators have done before us.

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Figure 1: A composite ideogram that identifies issues related to an REI: Renewable Energy Infrastructure.



INTRODUCTION

Despite recent scholarship and interest in interdisciplinary operations, our intellectual world still champions those knowledge bases that reside within the centers of distinct disciplinary realms. While this tendency necessarily protects a professional discipline's operational boundaries (for instance, in the governance of engineers engaged in issues of life-safety), it also fosters an insulated intellectual environment in which the development of its collective knowledge base is characterized by reproductive thinking. In turn, these boundaries discriminate against new creative discoveries by outside individuals who demonstrate productive thinking in the conception of unprecedented solutions in another discipline. For instance, consider the wide ranging differences between art, design, and science while also recalling the types of individuals who have contributed to two or more of these realms in a significant way. If artists and scientists anchor two ends of a figurative spectrum, then designers would occupy the conceptual midpoint between the two, in terms of both disciplinary interest and operation -- Designers are equally dependent upon both creative and analytical thinking, and their thinking process oscillates between both as they yield creative solutions for problems framed outside of themselves. Like artists, designers use creative thinking to narrow their search for acceptable solutions. Like scientists, designers use analytical thinking to address problems outside of themselves and are therefore engaged in a form of applied research.

THE ARCHITECT AS TECHNOLOGICAL INNOVATOR

While most artists are unlikely to make key contributions to the knowledge base of science, architects have historically played a role as technological innovators. Among them are:

- Filippo Brunelleschi and his inventive structural solution for the Florence Cathedral dome.
- Frank Lloyd Wright and the structural performance of custom concrete columns in the Johnson Wax building in Racine Wisconsin.
- Norman Foster and the various inventive architectural systems in the HongKong Bank headquarters.
- Jean Nouvel and the operable south façade design for the Arab World Institute (IMA) in Paris France.

Of all architects who have also established themselves as technological innovators, then Eero Saarinen is arguably the greatest of these. Throughout Saarinen's distinctive portfolio of modern architecture, we find unprecedented architectural types that not only require new technological solutions, but are conceptually dependent upon the success of these innovations. For instance, the Jefferson Memorial (Gateway Arch) in St Louis, neverminding its structural design, required an inventive design for a new vertical conveyance system that would respond to a varying arc of incline as well as accommodate a high volume of visiting patrons. The General Motors Technical Center in Warren Michigan was a design vehicle for inventing several new architectural products that would eventually become industry-standard. These include the use of neoprene gaskets for sealing glass units in metal frames, the creation of insulated metal panels with porcelain enamel finish, and the glazed brick (Serraino, 2005). Similarly, Dulles Airport outside of Washington DC required an inventive solution to transport airline passengers to larger jetliners that were necessarily parked away from the terminal proper due to the feared effects of jetwash on architectural surfaces. (This was later circumvented with tug taxis which are now industry-standard in airports worldwide. Nonetheless, some of Dulles' mobile lounges remain in operation.)

The inventive spirit with which these architects acted is enviable. When these architects are considered together, it is clear they have embraced a very high-risk, high-reward design strategy that we seldom find in the United States today. This is due likely to a combination of greater exposure to legal liability, the prevalence of re-productive thinking at our discipline's center, and a relative lack of professional bravery.

THE OPPORTUNITY FOR INFRASTRUCTURE

If the architectural discipline is to re-affirm its stewardship of the built environment, then it must conceive of research-led and performance-based solutions that address issues beyond the market-serving provision of habitable space and material finish. Furthermore, as issues and problems relating to the built environment become ever more layered and complex, architect-led interdisciplinary teams will become necessary to address them.

One such opportunity for leadership is infrastructure design, although it is historically shaped by the engineering discipline. However, if we share Buckminster Fuller's observation that "society operates on the theory that specialization is the key to success, not realizing that specialization precludes comprehensive thinking," (Fuller, 1970) then as the discipline of Engineering requires higher modes of specialized thinking, architects remain in an advantageous position to continue to act comprehensively, and engage both technological and infrastructural innovation in a critical way. The challenge for architects first lies in the recognition of their own comprehensive propensities, and then the deliberate engagement with true issues of infrastructural performance and associative yields.

While the question concerning infrastructure is typically thrust into the national consciousness at times of system failure (New Orleans' levees, Minneapolis' I-35 West bridge, Japan's Fukushima Daiichi nuclear plant, and the recent calamities in the American northeast triggered by Hurricane Sandy), the subject of infrastructure has sustained a level of buzzworthiness in the larger architectural discipline. Not only is infrastructure becoming an increasingly popular form of government investment, but we are witnessing a surge of interest in the subject of Infrastructure from architectural educators and practitioners alike. This discussion has been buoyed by recent design competitions, periodicals dedicating entire issues to the subject, new book titles, and the annual comparative analysis on the state of infrastructure between the US and other nations, published by the Urban Land Institute. Perhaps the greatest device in capturing our attention is the American Recovery and Reinvestment Act of 2009. Of the \$787 billion dollars appropriated by this Act, \$132 billion (17%) was earmarked for either new infrastructure projects or the repair of existing ones (Miller, 2010).

While the discipline of engineering continues to generate re-productive and mono-functional infrastructural solutions, then architects, qualified by their comprehensive propensities, are positioned as "impact players" for conceiving of multi-functional infrastructural solutions to address the demonstrated needs of society. The design of new infrastructure typologies, especially those with hybridized qualities, drastically changes the position, contribution, and responsibility of the professional disciplines involved in their creation (Shannon, 2010). To this end, architects should no longer wait for an invitation to produce viable infrastructure solutions.

The opportunity must be claimed.

PREMISE

Our university-based design / research team has focused on a problem that is defined by renewable energy production, electrical transmission, and urban land use policy. We believe a Renewable Energy Infrastructure (REI) addresses this problem in an effective way and challenges each of these attributes on their own singular terms. Although today the economic impetus is weaker compared to anytime before our current recession, we recognize the increasing need for developing alternate modes of electrical production, and see an opportunity for an infrastructure typology located in geographic areas with access to multiple renewable resources.

While the issues framed within this REI investigation are easily identified, single infrastructural solutions that address the production of electrical energy on urban sites at industrial scales are largely unprecedented. However, we were able to find seven relevant projects, both built and unbuilt, that possess either desirable mechanical qualities or address a plausible constraint that an REI would also likely face.

01. Energy Tree, Richard Horden (1999), Munich Germany

This unbuilt project was conceived in 1999, prior to our currently prevailing renewable energy market and sociological level of acceptance. This approximately 984' tall structure is divided into equal sections which when affected by wind, revolves around a central core, thereby converting incidental wind energy (gathered from five upright airfoils) into electrical energy. This tower was also intended to have the architecturally programmed spaces of restaurant, hotel, conference center and observation deck.

02. Solar Net, Solomon Cordwell Buenz/Arup (2001), 2001 US Department of Energy Sunwall Design Competition, Washington DC.

The intelligent form of the sloped concave photovoltaic wall is climatologically-determined by the winter and summer solstice positions. Furthermore, as with all of the Sunwall competition entries, we appreciated its willingness to engage non-rural, densely populated sites for generating renewable energy.

03. Forum Esplanade, Jose Antonio Martinez Lapena & Elias Torres Architects (2004), Barcelona Spain.

This 48,437sf photovoltaic canopy is dual purposed as both an industrial-scale generator of renewable energy, but also as a canopy to provide shade in a shadeless park on Barcelona's waterfront. This canopy is just one feature of a much larger hybridized infrastructure project which includes a water treatment plant, garbage incinerating plant, the photovoltaic array itself, and a recreational park / marina.

04. Urban Oasis, Chetwoods Architects (2007), Chelsea London UK.

Although conceived as an urban-sited sculpture, this high-tech art captures sunlight (via PV cells) and wind (via single vertical axis turbine located within the structural spine) to power a fuelcell that in turn, illuminates the entire sculpture at night in colored light. The operable "petal" components also act as rainwater harvesting devices.

05. Wind-It, Delon Choppin & Menard, (2009), 2009 NEXT Generation Prize, Metropolis Magazine

Although this unbuilt proposal is positioned in a rural setting, it allows today's prevailing solutions for transmission and distribution to identify an opportunity for generation. More specifically, the "Wind-Its" position themselves inside of existing electrical pylon designs thereby furthering the efficiency of existing infrastructure.

06. Canop'City, GAPTA (2009), Los Angeles CA

This proposal for infrastructure improvements to impoverished areas is the most hybridized of infrastructure proposals found to date – It concerns itself with electrical production, but also water, agriculture, and recreation. However altruistic and compelling as an urban prognostication, there are however losses to the quantity of electrical power that can be yielded due to interference caused by the juxtaposition of spatial programs in the same physical space.

07. Greenway Self Park, HOK (2010), Chicago IL

Although not generating energy at industrial scales, the Greenway Self Park is a bold example of a developer taking on risk of placing renewable energy technology into an urban environment with a high amount of turbulence. These turbines are manufactured by Helix Wind, although the Project was originally specified to use Aerotecture products and consulting services. Aerotecture withdrew from the project on the belief that performative yields would be too low to justify the cost of the renewable energy technology, and in turn, speculated it was being designed for popular greenwashing effect.

Figure 2: Urban grain elevator, suburban electrical transformer station, and wastewater digesters. Examples of existing infrastructure types in the Lincoln NE viewshed.



THE EMERGENCE OF A NEW TYPOLOGY

As a pre-emptive strategy for placing new infrastructure typologies in our viewsheds, it is important to first understand the historic trend of the act of emergence and the level of acceptance attained with the population that it serves. To this end, larger society has demonstrated, on multiple occasions, to psychologically accept the presence of large-scale infrastructure types if it directly benefits from its performance – It

is implicitly understood that the level of performative yield and benefit of infrastructure shall exceed any adverse impact that said infrastructure has in the collective viewshed. While both urban and suburban dwellers alike have multiple exposures to various infrastructures in a given day, these populations have developed a psychological comfort with infrastructure through unchanging familiarity, and their physical presence (if non-kinetic) does not adversely affect us.

Specifically, we investigated the emergence of water towers, cell phone towers, and grain elevators. Surprisingly, we found very little opposition during the proliferation of water towers, but only praise – The public at large understood the performative benefits of this emerging type and were immediate beneficiaries of widespread proliferation and successful operation. However, with the emergence of cell phone towers in the late 1980s, there was widespread vocal opposition to this new infrastructure type and its impact on viewsheds. Unlike water towers which were immediately understood as a public amenity, cell phone service was an endeavor of private commerce and did not serve the needs of the public at-large. Furthermore, the price point for early cell phone service and equipment was cost prohibitive for most and was considered a luxury service, hereby working against any rapid psychological assimilation of cell phone towers in our cultural consciousness. However, as cellular service costs decreased, an increasingly large portion of society became users, and we have since conditionally accepted the visual presence of these towers in our viewsheds as long as they continue to provide cellular service and enhanced signal strength.

FIVE AXIOMATIC TRUTHS

Our research-led design effort seeks to gain credibility in the ultimate postulation of technically-plausible design solutions using existing and emerging renewable energy technologies that can be found on the market in the year 2012. Our forthcoming solutions seek to address and fulfill the demonstrated needs of society with viable solutions that are both “design-ready” and “shovel-ready.” To this end, the REI research / design investigation is premised upon five axiomatic truths.

Number One: Due to the Greenhouse Effect caused by carbon dioxide emissions from fossil fuels, there is a need to invent and deploy more environmentally-responsible modes of electrical production to meet an increased demand by modern society.

Number Two: On a per square mile basis, urban areas have significantly more demand for electrical energy than rural areas.

Number Three: Modes of renewable energy production are typically located in rural areas due largely to social and political forces. Furthermore, these modes are technologically proprietary and so far only capitalize on one exclusive resource.

Number Four: Due to the physical properties of our current electrical

grid system, there are measurable falloff rates of megawatts from their originating power source (in rural areas) along the transfer length to the end user (in urban areas). Current renewable energy technologies of industrial scale, such as wind farms and solar arrays, are typically located in rural areas and therefore the efficiency with which they serve energy-thirsty urban areas is compromised. For every single megawatt lost during transmission, .4 is due to “evaporation” along transmission lines and .6 occurs during step-downs at sub-stations and transformers.

Number Five: Transfer efficiency can be increased by collapsing the physical distance between the original renewable energy powersource (in an urban area) to the end user (in an urban area).

Considering these axiomatic truths, is it then possible to design a free-standing infrastructure for an urban environment that holistically considers renewable energy-producing resources such as wind, solar, geotechnical, and if applicable, hydrological resources into one holistically-designed entity?

DESIGN CONSTRAINTS

An REI seeks to generate renewable energy megawatts (MW) at an industrial scale through the simultaneous harnessing of wind, solar, and geothermal resources, but within an integrated, holistic, and free-standing facility positioned in an urban environment. An REI is not a retrofit of a pre-existing architectural condition, but rather is conceived as a new infrastructure typology to be owned and operated by an electrical utility for purposes of servicing users in high-population areas.

According to the 2010 US Census, the State of Nebraska ranks 38th in population with 1,826,341 residents. This ranking places Nebraska in the lowest quarter percentile of the United States. In contrast to its lower population however, the State of Nebraska ranks relatively high in access to wind (4/50), solar (19/50) and geothermal (core temps of 200 degrees Celsius) resources capable of producing renewable energy. In terms of wind, the US Department of Energy ranks the State of Nebraska as 4th in wind energy potential. Despite this strength in climatological circumstances, Nebraska in 2009 surprisingly ranks only 24th in actual wind energy production with a current rate of 153.2 MW. In terms of solar, the US Department of Energy ranks the State of Nebraska as 19th in solar energy potential with a Sun Index of .89, but there are no industrial-scale photovoltaic arrays currently operating.

Of the 153.2 MW of renewable energy currently produced in the State, 10%-15% of this amount is believed to be lost during transfer due to degradation along transmission lines and processing through transformers. This amount totals 15.3 - 23.0 MW lost over 906 miles of long span transmission lines from five different wind farm locations, all of which are located in rural areas. Whereas super-conducting materials and higher voltage lines will reduce some loss throughout the emerging

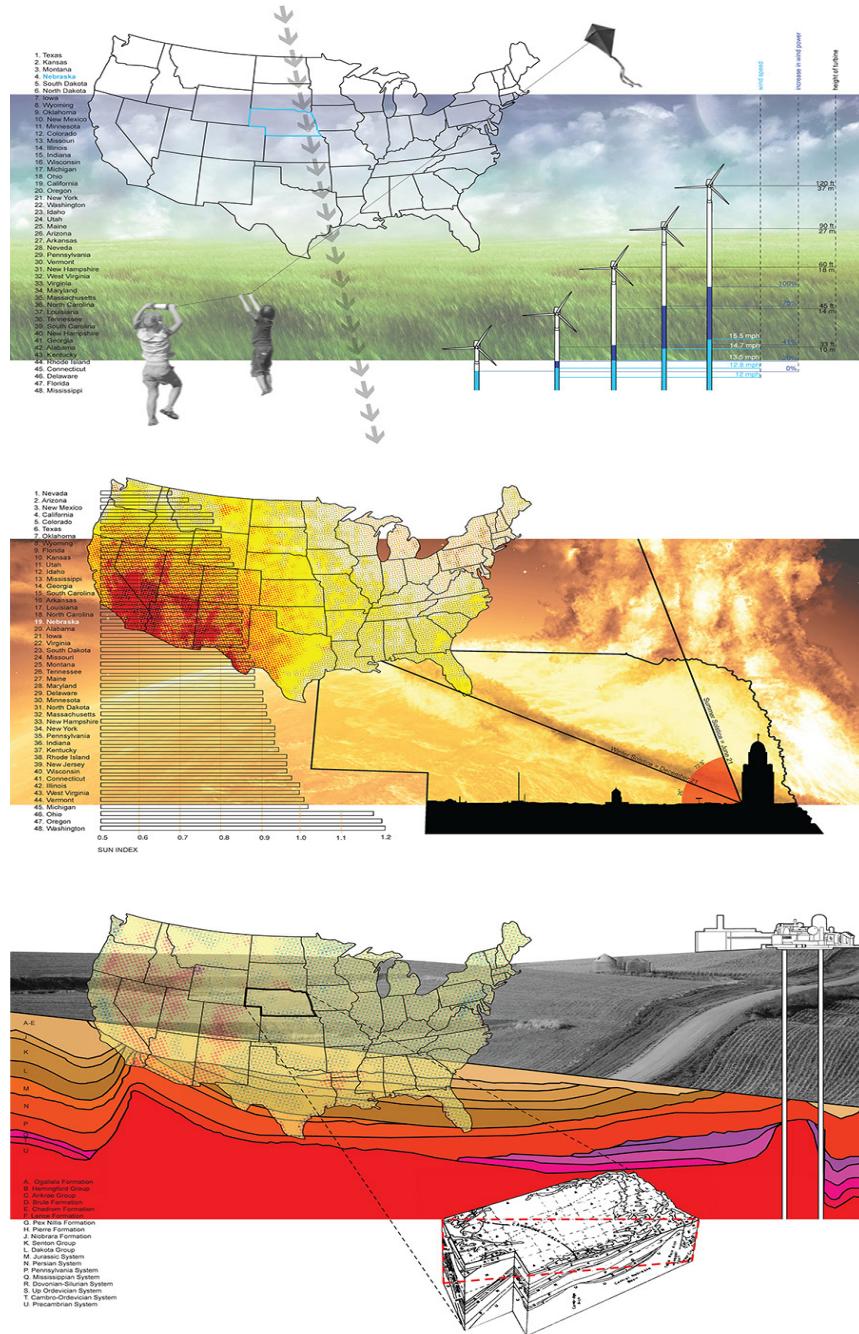
US "SmartGrid," we can also eradicate this loss by collapsing the physical distance between where renewable energy is produced and where it is consumed. This action would require however an intolerance of the Culture of Acceptable Losses that has emerged from federal deregulation of the electric industry, first set in motion in 1978. There are several constraints in play when determining an appropriate site for an REI. Due to the highest interest in performance, a chosen REI site should not be compromised by positioning itself amongst urban obstacles, such as other buildings. Depending upon their respective size, proportion and solar position, these urban obstacles could foil the operation of the REI by either creating wind turbulence or shade the REI from valuable solar exposure. Another constraint in play is the economic feasibility of an REI given real estate property values.

The best urban sites for an REI are likely to be on the periphery of our downtown areas. In an optimum scenario, if all other site requirements allow, REIs would be ideally positioned on sites already operated by electrical utilities and with existing transformer equipment. If the presence of this new REI construction would not itself precipitate a significant upgrade or overhaul of pre-existing transformer equipment, then the REI could feasibly occupy the airspace of this site, thereby tapping into an existing network without increasing project costs and yet improving urban land use policy. Although an REI would have a physical presence similar to that of a building, the REI would not have appropriated square footage per se, and would only be occupied as required by inspection, service and repair.

Due to the danger presented by large-scale mechanical components in motion, we recognize the very real life-safety concerns that are associated with generating renewable energy in an urban environment. Whereas photovoltaic panels present a very low hazard level of operation, the failure of large horizontal-axis wind turbines are oftentimes both spectacular and irreparable. In the event that a bearing generates too much wear by wind shear across the face of the turbine blades, the turbine house sometimes ignites due to an internal fire caused by friction between metals. However, these turbine types are typically located in rural areas. Firefighting teams will set up a secure perimeter around the problem turbine, allow them to burn in place, and protect against falling debris including the turbine housing itself. In urban areas, a burning turbine presents real threats to both people and property. While proper maintenance can prevent fantastic failures for wind turbines, we are seeing that horizontal axis turbines installed ten years ago are now being brought off-line and systematically deconstructed due to the end of bearing life.

In the 2010 renewable energy market, it is now more cost effective to replace the turbine entirely with current-generation technological upgrades than it is to repair or replace the original bearing. While bearing wear is the primary cause of wind turbine failure, high wind speeds present another set of life-safety issues.

Figure 3: Layered infographics representing the renewable wind, solar and geothermal resources of the State of Nebraska.



REI v1.0: LINCOLN NE

The city of Lincoln Nebraska has a population of approximately 250,000 people, possesses an atypically dense urban downtown that is rare in Midwestern cities of its relative size, and has access to above-average wind resources.

The site selected for our REI v1.0 study is located in downtown Lincoln NE, immediately south of the historic Haymarket District. The site is owned by the City of Lincoln, but is leased to the Lincoln Electric System utility as an electrical transformer site. The REI site is the airspace above this existing electrical infrastructure and as such, affords the ability to tap into a pre-existing electrical distribution network without increasing project costs. Furthermore, it allows an REI to occupy an

urban context without acquiring privately-held land and / or demolishing existing real property.

With the design problem reasonably formed, schematic design operations recalled the larger-scale Solar Net winning entry for the 2001 US Department of Energy Sunwall Design Competition (National Renewable Energy Laboratory, 2001). Upon familiarizing ourselves with the design intent behind this Solomon Cordwell Buenz / Arup proposal, we appreciated the intelligent form of the sloped concave photovoltaic wall informed by the winter and summer solstice positions.

An inventory was created and periodically updated of the top five performing photovoltaic panels and vertical axis turbines. These were the only two types of renewable energy technologies that were of interest due to issues of life-safety and the fail-proofing of kinetic technologies when placed in an urban environment.

Multiple schematic options were generated for consideration, and only then were schemes identified to analyze those traits and qualities ultimately carried forward into a more developed REI design.

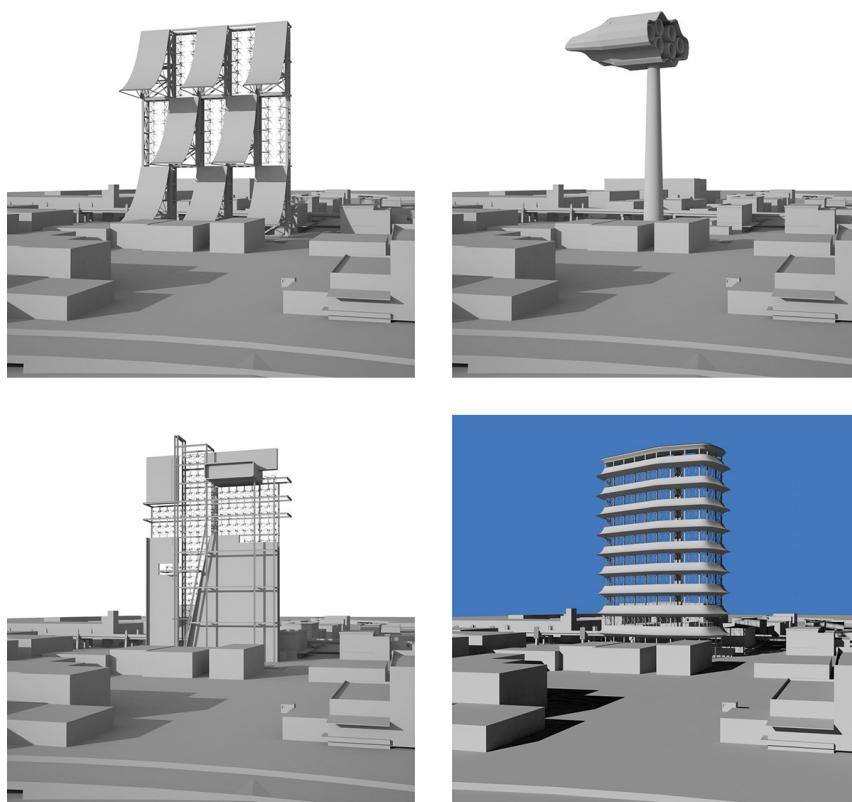


Figure 4: Four preliminary REI designs for Lincoln NE. The design chosen for further development is shown at the bottom right.

The first scheme sought to feature sloped concave profiles to optimize yearly solar angles for the 41st latitude. However, these profiles were also arranged to deflect prevailing southern winds upwards to effectively multiply the air velocity moving through the vertical axis turbines located immediately above. However, due to the staggered patterning of the solution, self-casting shadows upon the photovoltaics were self-defeating.

The second scheme explores the possibility of (6) small diameter horizontal axis turbines covered with a photovoltaic fuselage skin. Supported by a single mast, the face of the turbine blades would always rotate to front applicable winds, and the photovoltaic fuselage would further assist the proper wind orientation with fin profiles. In order to best capture wind resources, REI schemes incorporating wind technology would need to occupy the highest elevations that municipal zoning regulation will allow.

Whereas the first and second schemes possessed a resultant aesthetic informed by scientific determinism, the third scheme explored a composition of vertical axis turbines and photovoltaic surfaces for its own compositional sake. Furthermore, possible architectural programs were considered that may also benefit from being incorporated into this scheme. However, any interest that was gained in composition came at the consequence of losing credibility in energy performance and final electrical yields. This scheme was immediately rejected since it was not consistent with the criteria for beneficial infrastructure design – Infrastructure design should not sacrifice performative yields for the sake of compositional aesthetics. Infrastructure is compositionally pragmatic, and is ultimately justified through its own performance. Since infrastructure operates instrumentally, then infrastructural design “is indifferent to formal debates” (Allen, 1999).

The fourth scheme is informed by attributes of each of the first three schemes. It is not self-conscious about its own aesthetic, but rather seeks maximum electrical production through wind, solar and geothermal resources. This fourth scheme was identified for further development.

The REI v1.0 design assumes its construction would be a scalable, modular system where smaller portions of an REI can become operational prior to a complete build-out of the overall design. This economic model for implementation would benefit from streams of funding over time and would only then yield the highest amounts of MW once completed. For instance, this scheme provides (7) stacked tiers of integrated wind / solar modules each set every 40'-0" in infrastructure height. However, we assume a maximum allowable REI zoning height of 375'-0" as determined by the City of Lincoln with respect to the 400'-0" height of the Nebraska State Capitol building by Bertram Goodhue (1932). The REI uses a piling foundation with a tube steel structural frame with galvanized finish. Whereas the vertical-axis turbines are secured to the permanent site-specific tube steel frame, the photovoltaic modules are separate entities with their own structurally-rigid modules.

These modules are composed of cast aluminum frames that allow for quick attachment and detachment to the fixed structural frame itself.

While the creation of the module was a design response to questions of component assembly and unit installation, there are advantageous benefits to thinking about the REI as a module-based system. First and foremost, it achieves a higher level of efficiency where modules can be pre-engineered, pre-fabricated and assembled in anticipation of future end-use on, or near, a specific latitude. This strategy creates an efficiency in the construction of site-specific foundations, structural framework, and vertical circulation system while the technological modules are then transported on site, lifted, and installed. Benefits in this design intent include reduced schedules for construction, the introduction of a scalable solution that can be brought on-line in a phased way prior to full project completion, and the possibility of upgradeable technological components to maximize life expectancy of the REI framework and to further stall the inevitable point of technological obsolescence.

PERFORMATIVE YIELDS (ESTIMATED)

Wind Turbines

(20) Vertical-axis turbines per floor, (8) floors = 160 Turbines Total

(1) Quiet Revolution QR5 vertical-axis turbine @ 11m/s = 4.6 kW

160 Turbines x 4.6 kW = 736 kW

Solar Photovoltaics

(7676.4) sf of solar photovoltaic panel per REI floor x (9) REI floors
69,087.6sf total PV surface area.

(1) Schott Solar ASE-300-DGF/50-320 (320w) Solar Panel = 26.1267sf

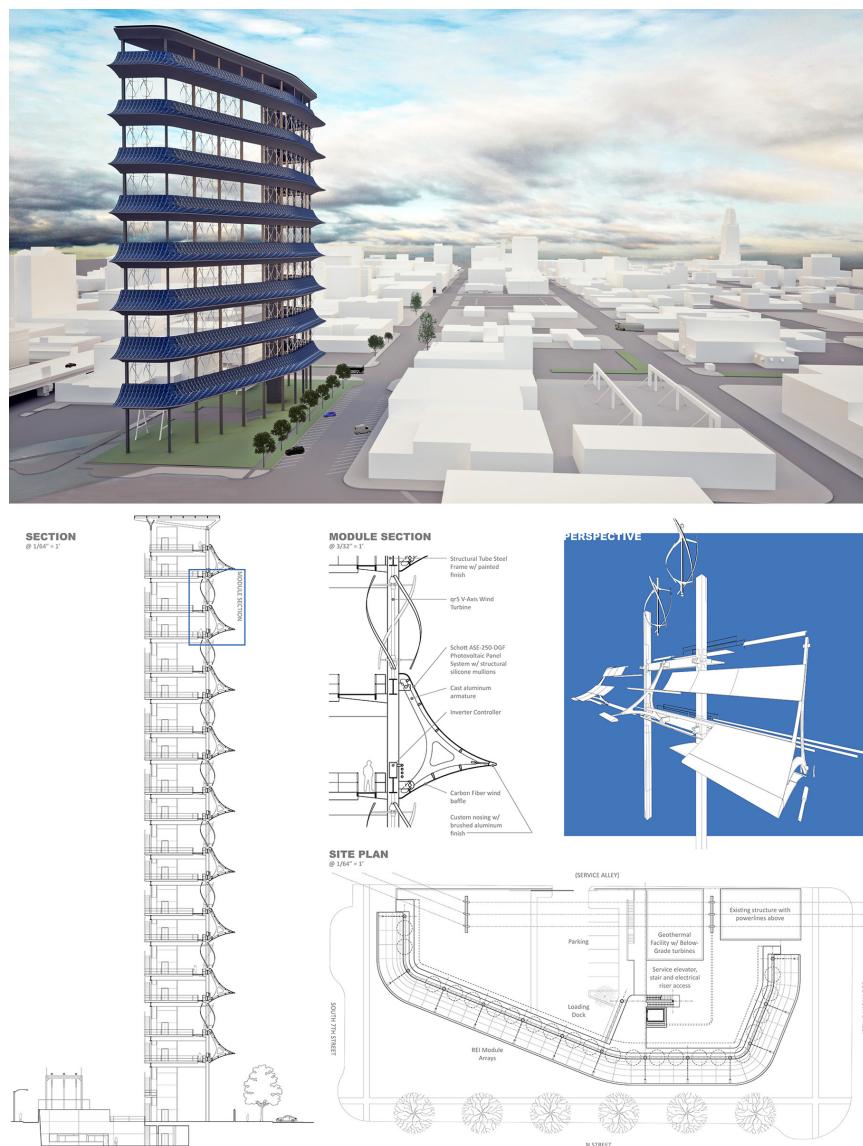
(1) sf of 320w PV panel (284.8w PTC) = 10.9 W

69,087.6sf PV surface x 10.9 W = 573,054.8 W generated (or 573.0548 kW generated)

Total

736 wind kW + 573.0548 solar kW = 1.309 MW

Figure 5: Final REI v1.0 design.



CONCLUSION

With an estimated performative yield of only 1.309 MW, both the cost effectiveness and total generation capability of the REI v1.0 are disappointingly low. Within our current energy market, an REI v1.0 is unviable.

Despite marginal advantages gained in a collapsed space for both transmission and distribution, the generation capabilities of this REI design can be exceeded by two large scale horizontal-axis turbines. Considering the current pricepoints in today's electrical energy market, an REI v1.0 would be further challenged to compete with current generation solutions on a construction cost basis. In the meanwhile, a performance mock-up may be developed to better evaluate the performative yields of REI modules in different conditions, and also serve as a vehicle for forming partnerships with industry partners.

One benefit of the REI v1.0 however is that the 1.309 MWs generated would have (0) Carbon emissions. In consideration of any future carbon tax legislation, an REI would begin to find cost viability as the cost of coal-fired, natural gas, and nuclear electrical plants begin to demonstrate higher operational costs.

Without the resources to satisfy our own national demand, embracing renewable energy would help us transform our energy market from its current fossil-based forms to domestic wind, solar and geothermal resources that can already be found in abundance stateside. To this end, we may recognize 2012 as a turning point in electrical generation policy. For instance, a number of auto manufacturers such as Chevrolet and Nissan are debuting all-electric vehicles (such as the Volt and Leaf respectively), which in turn, will subvert the prevailing model of petroleum-fuel automobiles. If and when all-electric vehicles are embraced in the automotive market, then electrical companies will need to re-assess generation strategies to meet the increased demand of today's plug-in society.

Within a different economic context, the execution of an REI would be transformational in its ability to combine, in a deliberate and intentional way, multiple renewable energy technologies in the same physical location and without proprietary technological exclusion. This would effectively diverge from the current trend of proprietary system design by companies that exclude other renewable energy types due to the specificity of their business model / expertise. We believe the innovative value of our REI proposal lies in the bringing together of multiple renewable energy technologies on a single urban site in a deliberate, hybridized, and technologically unbiased way. While the REI sought to establish credibility through generating quantifiable electrical yields at industrial scales, it also addresses other multiple aspects of our nation's energy problem (the political, economic, carbon emissions, and technical) while having some collateral benefit to non-energy areas (in commerce, design, and engineering).

Infrastructure cannot be fully realized in ideological form alone. If architects are truly interested in the prognostication of a fundamentally new infrastructure type, then we must proceed with a heightened seriousness in our design intelligence, a dire sense of urgency in the timeliness that we work, and focused clarity upon the effect that we want to induce, just as the technological innovators Brunelleschi, Wright, and Saarinen have done before us.

ACKNOWLEDGEMENTS

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award and has since been awarded additional funding with a 2009 AIA Upjohn Research Initiative grant and a 2009 energy research grant from the Nebraska Center for Energy Sciences Research. These funds are used to develop the REI design with the research assistants above and with external partners who are disciplinary experts in their respective fields. These external partners include Mr. Thomas J. Davlin, Manager, Projects Engineering for Lincoln Electric System (LES), Lincoln NE; Mr. John R Larson, P.E., Manager of the Renewable Power Program, HDR Engineering, Minneapolis MN; and Mr. Frank L. Thompson, Manager for Renewable Energy Development, Nebraska Public Power District (NPPD), Columbus NE.

In Oct 2009, this REI design received a 2009 “Monster of Design” award from the AIA Kansas City Young Architects Forum.

To date, this REI funded research project has been presented previously in multiple forms. A significant portion of this paper is from a Final Report for a 2009 AIA Upjohn Research Initiative grant. This same REI investigation has been presented at academic conferences including “Eco-Architecture III” in La Coruna Spain, “ConnectED 2010” in Sydney Australia, and “Digital Aptitudes,” the 100th ACSA Annual Meeting in Boston Massachusetts. Invited lectures on this REI investigation have been given at the University of Nebraska – Lincoln, the City of Lincoln, and the University of Hawai’i at Manoa.

Whereas the specific consideration of an REI has now come to a close, the pursuit of architect-led infrastructure design continues in Master of Architecture design studios at the University of Nebraska-Lincoln. For each of the past three years, students have been asked to research, plan and develop hybridized urban infrastructure proposals for yielding the performative aspects of agriculture, energy, transportation, waste or water at industrial scales. In Spring 2011, students developed proposals for sites in either Lincoln NE or Knoxville TN. In Spring 2012, students developed proposals for the borough of Manhattan in New York City. For Spring 2013, students will be developing proposals for the city of London England, which shall include an immersive stay of eight weeks.

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