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Innovations in Sustainable Energy

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In this issue...

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Guest Editor Column

By Mike Schiller

Green Building Alliance celebrated its 20th (Emerald) Anniversary in September, reaffirming our commitment to Healthy and High Performing spaces for everyone. As we plan and anticipate the next 20 years, we are thrilled at the chance to corral some content for this edition of Pittsburgh Engineer regarding an important and timely aspect of our mission: Energy.

Healthy and High Performing Spaces involve much more than energy, of course. The Big Five categories of topics that comprise a “green” building would include Energy, Water, Indoor Environmental Quality, Site Management and Material Use. All affect the health of a) building occupants, b) the building itself and c) the environment as a whole; and ultimately all five topics keep a building high-performing, from both a resource conservation as well as a financial perspective. Moving forward, GBA expects to increase its focus on health, environmental quality, productivity and people, but for the things we can do NOW, energy remains the most accessible.

Energy is at the forefront of many conversations in the USA. From overall energy policy (there is none) to global foreign affairs to socio-economic equity to local economic development to ongoing health and wellness of our families, energy impacts our lives in large and small ways. Because we can easily measure energy, we also have many very direct ways to manage it.

According to the Energy Information Administration, building operations consume 40% of the energy and 71% of the electricity in the United States. When you add in the energy use in the original construction, then buildings are responsible for almost 50% of the energy consumed in this country.

We consider the generation, transmission and distribution, and eventual use of energy all part of the same energy equation. It’s a large topic! In this magazine, GBA presents some of the leading edge work being done here in western PA to address both the use of and the generation of energy in a healthy and high-performing way.

On the energy conservation side, my friend Paul Wiegman, retired Chief Scientist at the Western Pennsylvania Conservancy, would always say “The cheapest kilowatt-hour of electricity is the kilowatt-hour that you don’t use.” So true, and in this magazine you’ll read two articles addressing energy conservation; one from a traditional perspective that still provides HUGE opportunity; and one from the BIG DATA perspective and how new technologies enable energy conservation in ways not possible just a few years ago.

On the energy generation side, we have articles from some of the leading practitioners in western PA regarding the state of the art in solar, wind and geothermal energy production. As renewable energy technology evolves and market demand continues growing, expect that renewable energy technologies will serve not just as the long term solution to energy but will also drive innovation, support overall resiliency, and provide a revolutionary brand of equity across the region and the globe by eventually providing clean water, information, mobility and health to the entire community.

Mike Schiller
CEO Green Building Alliance

Finally, to leave you wanting more and anticipating the future, Jeff McDaniel of Innovation Works highlights just three of many cool and interesting new energy technologies being developed right here in our region. It is our hope that this issue of Pittsburgh Engineer inspires you to learn more, consider energy impacts in all of your own projects, and help to spread the word with your peers and clients.

The Spanish poet Antonio Machado wrote “We make the road by walking.” Sometimes there is not a clear path or direction, but by walking ahead and making a path one step at a time, the road becomes clearer. We hope that you enjoy this issue of Pittsburgh Engineer, as Green Building Alliance showcases some of the very interesting energy conservation and generation work happening in western PA to “make the road by walking.”

Mike Schiller is the CEO of Green Building Alliance (GBA) , a chapter of the U.S. Green Building Council and the oldest regional green building organization celebrating 20 years in 2013. GBA inspires the creation of healthy, high-performance places for everyone by providing leadership that connects knowledge, transformative ideas, and collaborative action. More information about GBA, their education and network events, and local green buildings is available online at www.go-gba.org.

The Evolution of Solar Energy

By Mike Carnahan

Five years ago, I may have started this article by trying to convince people that solar energy is a realistic option in Western Pennsylvania. I would've written paragraphs dispelling myths about our lack of sunlight, the need for batteries, or unproven photovoltaic technologies (that have been around since the 1950's). Since then, education about renewable energy has made significant progress in overcoming local objections, and deployment by local institutions and corporations have validated the industry as a whole. Researchers from Carnegie-Mellon University (CMU) have determined that solar energy is better suited for Pittsburgh than locations on the West Coast. Organizations like Conservation Consultants, Inc., Green Building Alliance, the Joint Apprenticeship Training Program of the IBEW, and the Community College of Allegheny County (CCAC) are educating people in solar adoption and installation, as will the new Energy Innovation Center at the old Connelly School. Citizens for Pennsylvania's Future (PennFuture) has also worked with local municipalities and industry experts to develop a zoning and permitting guidebook with sample ordinances, making it easier and less risky for local communities that are new to renewable energy to facilitate these projects. It has taken hundreds of Pittsburgh homeowners, businesses, and nonprofits to lead the way--showing that solar is not just a West Coast solution to energy shortages and reliance on fossil fuels, it's part of our local fabric. It's these leaders that have forged the path to greater acceptance of solar in our region.

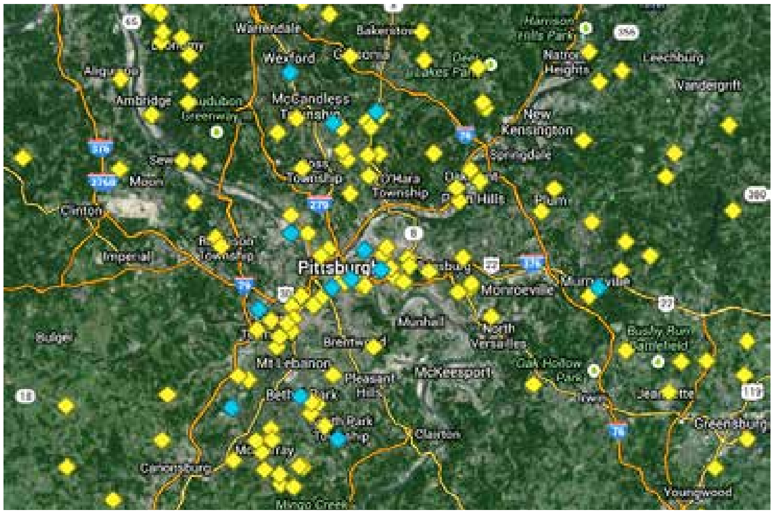
WPA Solar Projects

Phipps Conservatory leads this effort with their Center for Sustainable Landscapes that is pursuing the Living Building Challenge and generating all of their own energy (over 130 MWh) through solar photovoltaics and a small amount of wind. Another leader is Chatham University, whose School of Sustainability and the Environment's Eden Hall campus is under construction as an entire net zero campus in Richland Township. This self-sustaining campus aims to produce zero emissions and more energy that it uses with solar on every building on campus.

One solar panel generates as much energy over its lifespan as burning 3-3/4 tons of coal.

It's not a surprise that these institutions want to lessen or eliminate their dependency on fossil fuels. Just one 3'x5' solar panel can produce as much as 300 kilowatt-hours (kWh) each year. Multiply that times its 25-year production warranty, and that's 7,500 kWh. The U.S. Bureau of Land Management says it takes a little over a pound of coal to generate just 1 kWh. So, the output of ONE solar panel over its lifespan is equivalent to burning 3-3/4 tons of coal.

Figure 1: Map of Pittsburgh Region Solar Installations



Blue = Commercial, Yellow = Residential. Source: Citizens for Pennsylvania's Future

It's not just institutions that are leading the way locally either. The IKEA store in Robinson has the largest rooftop solar array in Western Pennsylvania with 2,884 solar panels, producing 852mWh annually. Locally-owned Giant Eagle utilizes wasted space above their fueling canopies for solar on two new GetGos, with 27kW at the Southside GetGo and 36 kW on the McKnight Road GetGo. That adds to a 150 kW array they have on a Cleveland grocery store and two new similarly sized Market Districts scheduled to open in Spring 2014. When local institutions, local companies, and national retailers alike make the economic and environmental commitment to invest in solar, people can physically see that solar does make sense in this region.

Technologies

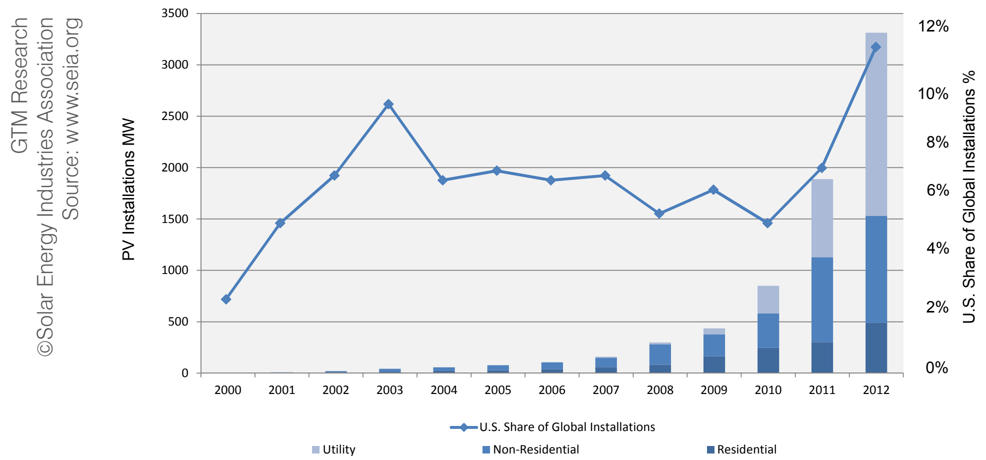
Which technology is best suited for Western Pennsylvania? There are two basic types of active solar energy: solar photovoltaics (solar electricity or PV) and solar thermal (heat). Solar thermal captures the sun's heat in air, water, or another medium and uses that heat directly. For example, solar thermal can be used in transpired solar collectors mounted vertically on a wall, known as a "solar wall." The heated air that is created in this wall is then ducted into the building through a connection to the HVAC system. The new visitor center at the Flight 93 Memorial in Shanksville will incorporate approximately 700 square feet of this type of thermal wall on its south face.

Other versions of solar thermal use evacuated tubes or flat plate collectors along with components like storage tanks, pumps, heat exchangers, and controllers to create solar domestic hot water (SDHW). The City of Pittsburgh has installed these systems on five local fire station's roofs.

According to the National Renewable Energy Laboratory (NREL), the largest portion of solar energy being installed in the U.S is photovoltaics (PV), with crystalline silicon (C-Si) PV accounting for 86% of all PV production in 2010. These modern day solar cells are what people are most familiar when you talk about solar – and they were actually invented by Bell Labs in 1954. According to the Solar Energy Industries Association (SEIA), PV installations exceeded 3,300 megawatts (MW) in 2012, up from 160 MW five years earlier.

Both solar PV and solar thermal have large-scale versions that use concentrators and large parabolic mirrors, but these are not employed in the Northeastern U.S.

Probably the biggest misconception I hear with PV is how "increases in efficiency" have led to this "boom" in solar adoption. The current efficiency record for monocrystalline cell efficiency belongsto the University of New South Wales in Australia. They developed this PV cell in 1999 and, according to NREL, there has been only a 5% increase in cell efficiency since 1985. Those who are waiting for efficiency to double before they install solar may wait a long time, as the average improvement per year is only 0.17%.



Installations MWdc	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Residential	1	5	11	15	24	27	38	58	82	164	246	302	488
Non-Residential	2	3	9	27	32	51	67	93	200	213	336	826	1043
Utility	0	3	2	3	2	1	0	9	16	58	267	760	1781
Total Installations	4	11	23	24	58	79	105	160	298	435	848	1887	3313

But, something has changed to lead to an increase in solar installations. GTM Research just reported in August 2013 that two-thirds of the world's solar capacity has been installed in the last 2.5 years–and that cumulative solar total is expected to double again by the end of 2015[1]. As reported by Bloomberg New Energy Finance, the cost of C-Si PV went from $76 per watt in 1977 to $0.74 per watt in 2013. This dramatic change in pricing along with the worldwide focus on sustainability and the environment has led to the proliferation of solar throughout the U.S. and abroad.

Though slightly less efficient and more expensive, other PV technologies like amorphous (a-Si), cadmium telluride (Cd-Te), and copper indium gallium selenide (CIGS, known as thin films) can provide lighter weight and architecturally designed solutions. Some of these technologies can be placed on flexible substrates and used on a curved or arched surface of a building. Atas International, a large metal roofing manufacturer based in Allentown, Pennsylvania, provides thin film solar pre-applied to their standing seam roofing panels. These technologies can allow solar to be virtually inconspicuous to the building envelope.

Newer innovations in the chemical treatment of the c-Si PV cell have led to bi-facial technologies that collect power on the front and back of the cell. They allow light to pass through the spaces between cells, making them semi-transparent, and giving them a gain in energy from the diffused light and albedo of the surfaces around it. These "glass-on-glass" PV options (like those from Prism Solar in Highland, New York) claim increases of up to 30% over similarly sized modules. These solutions make up a small portion of the solar market, but have their place in PV's architectural solutions portfolio.

Efficiency First

So when is the best time to incorporate solar into your building? Simply put: once your building is already energy efficient. Solar is a clean, zero emission form of energy. Putting such a source of power on your building and letting it escape through inefficient HVAC equipment and lighting systems without daylight harvesting and occupancy sensors is akin to heating a home without insulation. According to the U.S. Department of Energy's "Bui ldings Energy Data Book", our buildings use 41% of our primary energy consumption, more energy than any other sector of our economy. Making every effort to conserve energy and use it efficiently is just as important as generating it.

A soaring downtown building with a small rooftop does not have the on-site area available to generate a great deal of solar energy. Treating it as a part of the energy pyramid however, the wasted space of the roof could still install solar to slightly reduce the building's electricity demand on fossil fuels and save money. In this instance, solar is comparable to any other efficiency measure. For warehouse and office buildings with wider footprints, the opportunity to employ renewables and produce the bulk of the energy they consume is certainly attainable.

Incentives

That brings us to the crux of the issue that keeps people from adopting solar. If we accept that modern day solar is a 60-year old technology that works in Pennsylvania, and we recognize that it makes sense as the top tier of energy conservation and efficiency measures, then the only trepidation must be the overall cost of deploying it. Understanding how incentives reduce the cost of solar is the key to making it not only a viable option for your clients, but an affordable one.

A 2011 report from Citizens for Pennsylvania's Future shows that Pennsylvania's fossil fuel subsidies are almost $2.9 billion per year[2]. In fact, every utility available to consumers is subsidized with a combination of federal and state incentives to the tune of billions of dollars annually. The "generator" of the utility gets these subsidies and (hopefully) passes these savings along to the public. But, when employing solar, it is the end-user or building owner that is the "generating facility." The federal government recognizes this distinction and provides incentives to building owners in the form of tax credits and favorable depreciation schedules for "energy property."

The federal Investment Tax Credit (ITC) is a 30% tax credit against the installed price of energy property, including solar modules, supporting systems, electrical equipment, and the labor to install it all. An accounting method of depreciating business assets allows for accelerated (and occasional bonus) depreciation on energy property placed in service that calendar year. Where "real property" (i.e., a building) is depreciated over 40 years, "energy property"

1. Lacey, Stephen. (2013). "Chart: 2/3rds of Global Solar PV Has Been Installed in the Last 2.5 Years." GreenTech Media Solar. August 13, 2013. www.greentechmedia.com/articles/read/chart-2-3rds-of-global-solar-pv-has-been-connected-in-the-last-2.5-years

2. Simeone, Christina. (2011). Pennsylvania Fossil Fuel Subsidies: An Overview. Citizens for Pennsylvania's Future. www.pennfuture.org/UserFiles/File/FactSheets/Report_FossilFuelSubsidy_201112.pdf

can be depreciated over 5 years. The combination of these two items alone can account for more than a 50% reduction in the cost of solar for commercial clients. State incentives can reduce costs even further; these include the PA Sunshine Program started under Governor Rendell, as well as selling the environmental attribute of your solar array (known as a renewable energy credit) to the utility companies so they can meet their mandated renewable portfolio standards.

For larger and more complex projects, there may be opportunities to include solar in the Low Income Housing Tax Credits (LIHTC), New Market Tax Credits (NMTC), and Historic Tax Credits. Several other competitive grants and funding sources can also be pursued. As a result, the financial options that support solar installations can be numerous and even somewhat complicated. Finding a consultant or a professional tax advisor who is knowledgeable in the area of renewables is paramount for making the most of your solar investment.

Incentives for Nonprofits

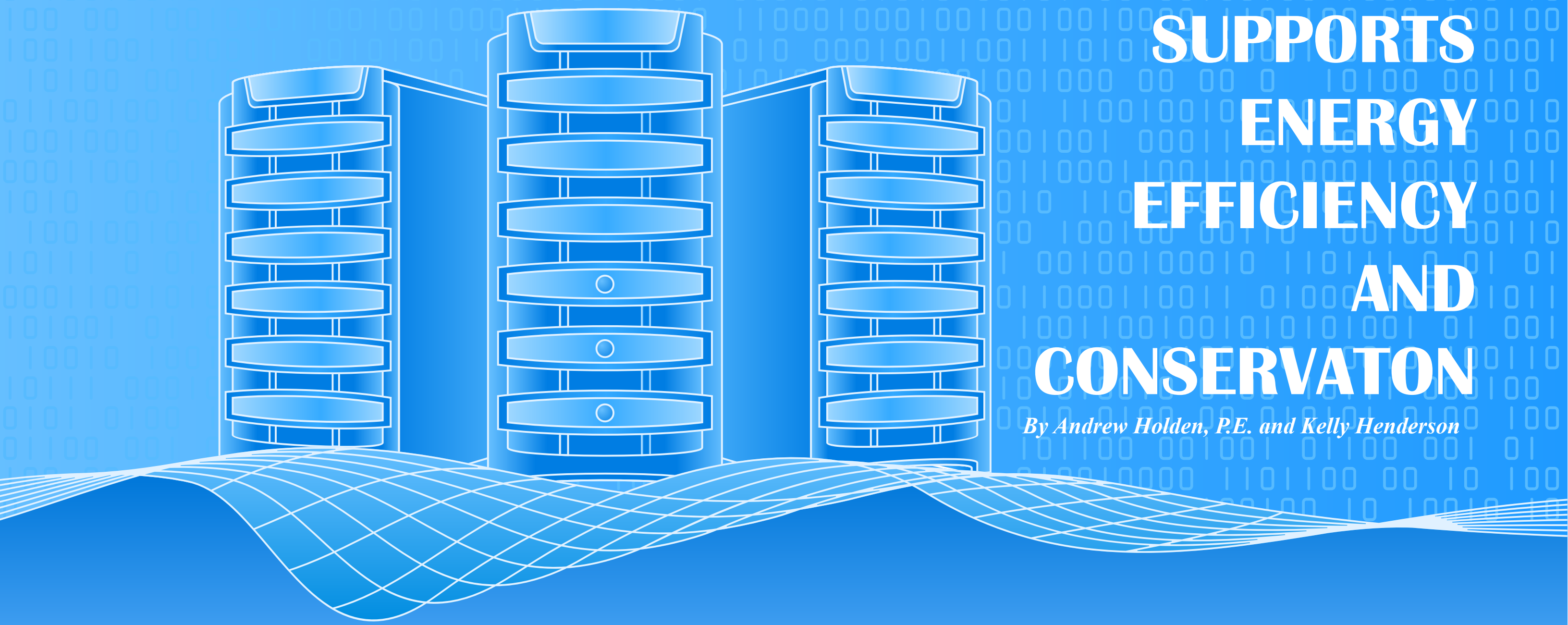
With all these tax credits, how can nonprofits in our region install solar if they're not eligible for such incentives? Tax-exempt entities such as universities, charitable organizations, and municipalities have consistently been in the forefront of the environmental movement, leading the educational charge to understanding sustainability. "These organizations understand 'limited resources' better than most of us," says Sharon Pillar, Solar Energy Consultant and Grant Management Advisor for Penn Future. "Their need to reduce operating costs, conserve energy, and run as efficiently and sustainably as possible is essential to them providing the services that are so vital to our communities."

If nonprofits consume energy from fossil fuels, they are benefiting from the subsidies that the utilities are given. But if they generate their own clean, renewable energy (which often aligns more with their missions), they are unfairly disenfranchised from receiving traditional subsidies. Through innovative deal structures, there exist opportunities for nonprofits to lease their roof to a taxable entity (investor), who then installs a solar array. The investor owns the solar property, takes all the tax subsidies to which they may be entitled, and sells the solar power back to the nonprofit. These relationships are known as Power Purchase Agreements (PPAs) and are commonly used across the country. The adoption of solar by nonprofit, higher education, and governmental organizations is thus attainable and should not be discounted strictly based on their taxable status.

Local Solar Industry

Since Pittsburgh's designation as a Solar America City in 2007, our local solar industry has matured greatly. There are lots of trained and certified installers in our region, including locally-based solar consultants, manufacturer's representative agencies, and developers based here in Pittsburgh. Gexpro, a national distributor of electrical products, is stocking solar panels and associated equipment right on Carson Street in the South Side. There's even a budding trade organization of solar professionals and advocates called the Solar Unified Network of Western Pennsylvania (SUNWPA). With the costs of solar panels plummeting nearly 300% from just a few years ago and an ever-growing acceptance and understanding of solar amongst building owners and design professionals, the ability to join the "rooftop revolution" is more attainable than you may have previously thought. Tapping the endless resources of the sun, lowering our carbon footprint, and improving public health and environmental quality are all goals that we can achieve today…one roof at a time.

About the author...
Mike Carnahan is the General Manager of Scalo Solar Solutions, a solar design and development company based in Pittsburgh. He is certified by the North American Board of Certified Energy Practitioners.



BIG DATA SUPPORTS ENERGY EFFICIENCY AND CONSERVATON

By Andrew Holden, P.E. and Kelly Henderson

The rate of change in the world is accelerating dramatically. Whereas it had taken 150 years for all human knowledge to double by the year 1900, today it only takes 1-2 years – and this number will be more like 72 days by 2020.[1] One byproduct of all this change is vast amounts of data. According to an International Data Corporation Study, there were 1.8 zettabytes of data created in the year 2011. That's enough data to fill 57.5 billion iPads, or enough tablets to create a 20-foot high wall around South America.[2] In the field of energy and resource conservation engineering, a number of new technologies and methodologies are emerging that take advantage of all this data. Revolutionizing how both customers and engineers approach energy conservation projects, these innovations will lead to higher ongoing building efficiency, greater accountability, and new opportunities for savings that could not have been imagined in the past.

Together, networks of data and people are changing the energy efficiency landscape. As we all know, the proliferation of data from highly connected sensors in non-traditional settings is advancing at an ever increasing rate. For years, engineers have been specifying additional sensors on equipment both at the original equipment manufacturer (OEM) and building level. On the OEM side, for example, water chillers now come standard with sensors with computer access through sophisticated on-board graphics packages that were unheard of just 20 years ago. At the building level, engineers are routinely specifying demand control ventilation (DCV) with self-calibrating carbon dioxide (CO2) sensors interfacing with accurate air flow stations, variable frequency drives, and damper controls to ensure that buildings are ventilated according to code without ventilating excessively. As buildings under 50,000 square feet start to gain more controls and sensors, a 2012 Lux Research Report expects the market to grow by 18% per year between now and 2020.[3]

These technological advances have made it economical to outfit all kinds of equipment with sophisticated sensors—and their uptake is continuing, unabated, into the consumer sector.

In our private lives, most smartphone devices on the market now come standard with an accelerometer, a light sensor, a barometer, a proximity sensor, a digital compass, a global positioning system (GPS), and a gyroscope. Samsung's Galaxy S4 debuted early this summer as the first smartphone to have both temperature and humidity sensors. As Samsung sold 10 million units in the first month of release[4], this means there are now millions of new, micro-weather stations worldwide--many of which will eventually find their way into buildings that we, as engineers, have designed or retrofitted.

Imagine the power of having an arsenal of sensors on every occupant in just a single building. Instantaneous readings can be recorded in any smartphone's microprocessor and uploaded to a centralized "cloud" database--or even instantly processed in an app to give real-time alerts, without the need to install new infrastructure or buy new technology.

In addition, vast amounts of user data also comes from the widespread popularity of social networking (e.g., tagging, location awareness). Each of these "big data" sets can inform our interactions with other data sets--as long as we appropriately catalogue and analyze it all.

As the amount of data available on both building systems and their users reaches an all-time high, engineering will benefit from understanding how each data set can be used to its greatest potential. In the past, data relevant to energy efficiency has been vast, disjointed, and difficult (or even impossible) to gather completely and cohesively into a comprehensive database. Think of all the data relevant in building system engineering: building features; equipment specs, install options, and maintenance records; occupancy patterns; weather records; utility consumption and rate structures; government incentive and rebate programs; and many other factors that may impact resource conservation in a built environment.

Powerful new databases have begun to use

1. http://darrenhardy.success.com/2011/03/changing-world/
2. http://siliconrepublic.com/strategy/item/22420-amount-of-data-in-2011-equa
3. http://www.luxresearchinc.com/blog/2012/04/big-growth-in-the-small-building-market-advanced-sensors-and-controls-for-building-energy-management-systems/
4. http://news.cnet.com/8301-1035_3-57585826-94/samsung-touts-10m-sales-figure-for-galaxy-s4/

the unifying framework and language of an innovation called the Semantic Web to bring together this distributed and massive amount of data.

Information available on the internet is largely unstructured – usually only understandable to human brains through contextualization of the information presented on a webpage. The Semantic Web movement is a push towards making this unstructured information more unified by embedding metadata so that online data becomes comprehensible by machine intelligence. If machines can understand and blend together the large amounts of data from various sources (including building systems, smart phones, and external sources like websites), then this all-encompassing and updated information can be made available in one place with minimal effort. The comparable effort required for humans to complete such a task has made this type of information integration inaccessible until now.

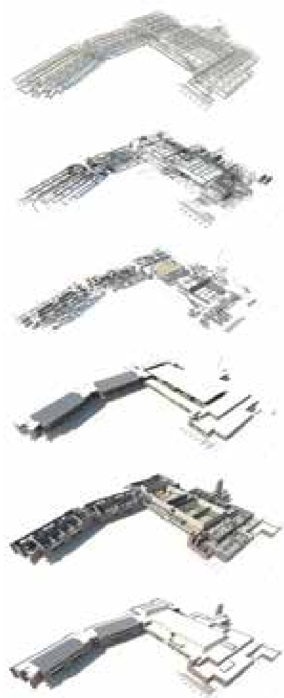
Semantic web technology is on the cutting-edge, and has been demonstrated in Apple's Siri and IBM's Watson computer (the latter known for holding its own against Jeopardy legend Ken Jennings). These technologies reveal an ability for computers to "understand" complex human requests and return valuable information based on this "understanding." Semantic tagging of data and equipment allows computers to reason through the data and find relationships in a way and at a pace no human can duplicate. With machine intelligence's capability to reason over vast amounts of data and return valuable summaries and analytics, we can use the available data more comprehensively and accurately than ever before, increasing the engineering significance of the results accordingly.

The growing importance of our ability to analyze complex and comprehensive data sets has become increasingly evident, as diverse industries have launched new technologies, research opportunities, and business models that embrace "big data". As this potential is realized, engineers in the building industry will see their customers gain a more powerful voice and have an increased role in decision-making.

For energy engineers, this greater degree of control can manifest itself in the ability to design systems that reflect real-time information and then make decisions based on that information. For example, demand-response strategies used to be a tool for managing energy consumption during emergency periods when demand exceeded supply, but technology now allows its use as a continuous planning tool. Real-time weather data merges with historical records, real-time occupancy and utility usage patterns, and hourly utility rate structures to create a greater degree of granularity and system knowledge that empowers engineers and building owners to use demand response as a day-to-day, hour-to-hour tool to reduce building operating costs.

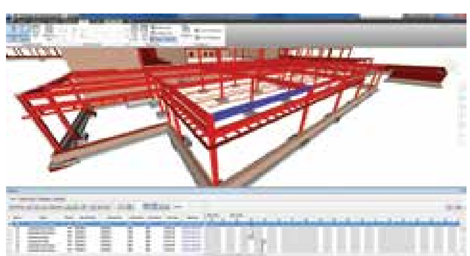
Building Information Modeling (BIM) is also changing the relationship that energy conservation engineers have with their customers. As we begin to obtain customer data in BIM data exchange formats, we can see semantics describing building system design and construction. Naturally, once a follow-up energy efficiency retrofit is completed, that same customer will expect to receive a revised BIM data set reflecting system and equipment changes. Overall, there has been a 75% increase in the use of BIM in the US building industry since 2007, so we can expect to see more customers anticipating access to these data sets as it becomes the norm.[5]

Some of the most interesting changes might begin to occur as end-users take advantage of recent data democratization to explore these data relationships themselves.



Sample BIM screen image

The smartphone revolution challenged IT professionals everywhere to manage the security implications of people using consumer-grade devices for work-related business. Could some of the same issues affect building owners (and by extension their engineering and design professionals)? From our perspective, the increased user-influence in data collection will challenge engineers to completely sidestep the internal building control system to allow for direct, real-time recording and uploading of environmental data to an externally-hosted cloud database. When data is aggregated and reported back to users, conditions throughout the facility and the facility's performance could be put under a constant and unrelenting microscope (including the performance of everyone from the building manager and maintenance staff to the engineers who design and maintain the building systems).



Sample BIM screen image

Another way to manage user-influence might be to integrate end-user data directly into the building management and control systems. This could potentially add hundreds of highly connected (but, admittedly uncalibrated and highly mobile) sensor points to the system. In this way, temperature complaints could be anticipated and big data reasoning could give building professionals insight into patterns that might otherwise go undetected. This could, in turn, lead to more proactive responses through improvements in equipment or their control algorithms.

From past experience, we have seen that users who are involved in and educated about their built environment are more willing to embrace operational changes and to accept temporary, sub-optimal conditions if they know the reason why these conditions exist (e.g., during demand response events). There is every reason to believe that end-users can embrace long-term changes given user-involvement in data collection and data democratization.

As engineers, we continuously need to prepare ourselves and our customers for change. The era of highly educated users armed with abundant, highly connected sensors connected to the semantic web and big data analysis is upon us. This era is poised to change energy efficiency and will raise the bar in how we approach buildings, system design and operation, and building occupant involvement.

About the authors…

Andrew Holden, PE, CEM, LEED AP, is the VP of Engineering at The Efficiency Network (TEN), a next-generation company that provides specialized, turnkey energy efficiency programs for a range of building types. Andrew is an industry-recognized energy efficiency engineering expert who was previously the Director of Engineering at NORESCO/ERI Services.

Kelly Henderson, LEED AP O+M, is TEN's Sustainability and Communications Coordinator. She holds particular expertise in high-performance buildings, renewable technologies and data management and has worked for the Department of Energy's National Renewable Energy Laboratory (NREL) and the Green Building Alliance.

5. http://images.autodesk.com/adsk/files/final_2009_bim_smartmarket_report.pdf

ESWP Member News

More than 80 firms are represented in the Corporate Member program of the Engineers' Society of Western Pennsylvania (ESWP). Memberships are available at 3 levels: Gold, Silver and Bronze. Gold members are entitled to 14 memberships that can be exchanged by employees; Silver, 9; and Bronze, 5 — annual dues are $2400, $1700, and $1000 respectively. In addition, ESWP Corporate Member Firms may add 2 additional individuals in our Under-35 age category at no additional cost. More information can be found at eswp.com. Please contact the ESWP Office (412-261-0710) for additional details.

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Membership in ESWP comes with a long list of benefits! From our continuing education opportunities earning you Professional Development Hours (PDHs), to the business networking events in our fine dining city club, there is something for everyone in your organization. Also, ESWP is helping the next generation of engineers with student outreach programs, giving you the opportunity to participate in many rewarding programs.

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Hill International
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mascaro construction ... build with the best
MKA McTish, Kunkel & Associates
menard Ground Improvement Specialists
MOC, Inc.
ms consultants, inc. engineers, architects, planners
NGE Environmental & Geotechnical Engineering Solutions
Nicholson
PB Parsons Brinckerhoff
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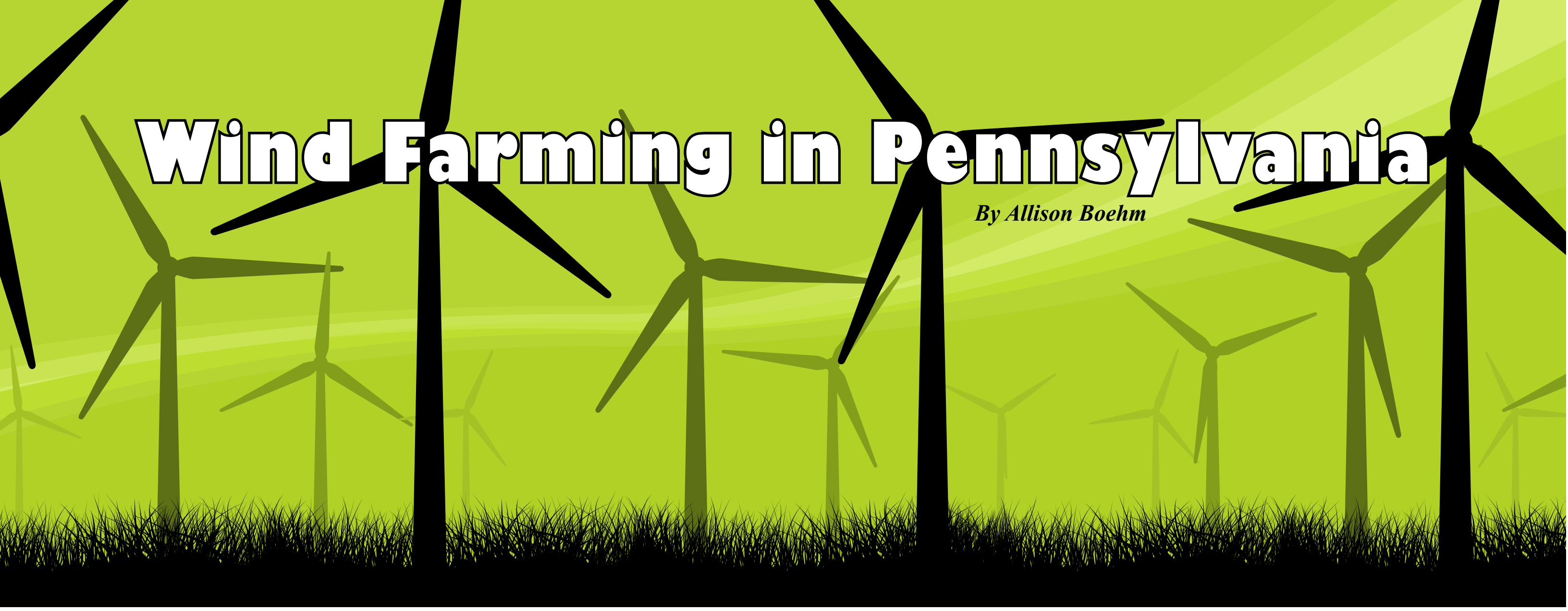
Wyatt Incorporated Interior Construction
Zell Engineers



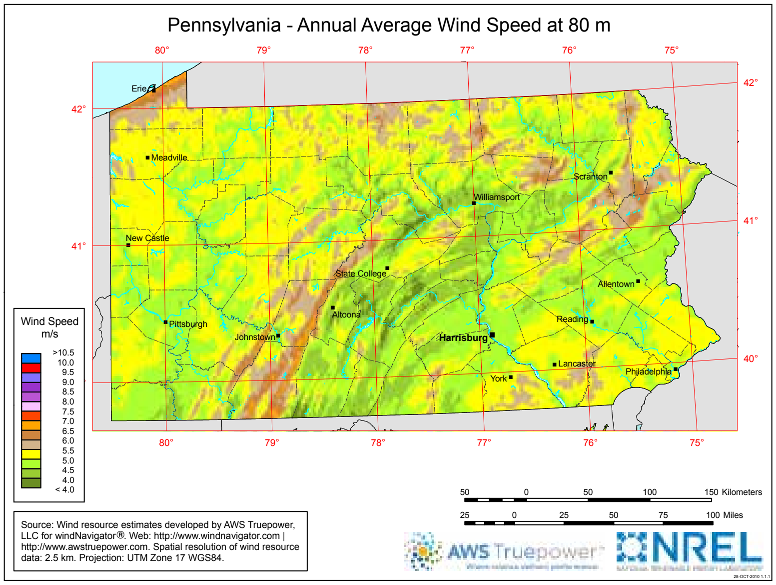
Wind Farming in Pennsylvania

By Allison Boehm

Pennsylvania is rich in farming history. Long before the founding of the commonwealth in 1682, Native Americans harvested the land for corn, beans, and a variety of squashes. As settlers arrived from Europe, they introduced other farming techniques and crops. Today, the top five agricultural commodities in Pennsylvania are dairy products, cattle, greenhouse products, mushrooms, and chicken eggs. In the last ten years, however, Pennsylvanians have begun harvesting a unique crop from the land - wind energy.

Utility scale wind farming in Pennsylvania began at the Somerset Wind Farm, with that first wind energy site connecting to the grid and coming online in the year 2001. Since then, Somerset County has been a leader in wind energy development and production. The county has eight operational wind farms that host 192 wind turbines with at total generation capacity of 343 MW. The utility wind farms vary in size, ranging from a small six turbine site up to a large 68 turbine site.

The wind resource map below, produced by the National Renewable Energy Laboratory, indicates the wind resource located across the state. As you can see, the ridge top topography features in Somerset County offer some of the best wind resources in the state.



While ridge top topography has long been a standard in Pennsylvania wind farm development, technology advancements are opening up previously overlooked land parcels for advancement.

Technology

Wind turbine technology has advanced tremendously over the past 10 years. The biggest and most noticeable change has been in turbine size. Taller towers and larger rotors make producing power at less favorable sites more possible than ever. To better understand these changes, it's important to recognize the key factors that determine the power generated by a wind turbine. The available power from the wind can be described by this simple equation:

$$Pw = \frac{1}{2} \rho A V3$$

The variables, air density (ρ), rotor area (A), and wind speed (V), ultimately determine the power available from the wind. Because of this, researchers and developers have focused their efforts on ways to reach and harness maximum wind speeds and increase the total surface area swept by the blades (also known as the rotor swept area).

Per the above equation, an increase in wind speed results in a cubic increase in total power available; therefore, focusing research efforts on ways to capture higher wind speeds is essential. Typical wind shear profiles show an increase in wind speeds at higher heights in the atmospheric boundary layer (up to 1,000 meters above the surface). This means that higher towers are capable of capturing higher wind speeds. Fifty to 80 meter hub heights that were the norm in the year 2000 are approaching 100 meters and higher in projects constructed today. For example, Green Mountain Wind Energy Center (the first wind site constructed in Pennsylvania) has Nordex N60 wind turbines with hub heights of 65 meters. The Patton Wind Project, commissioned in 2012 and discussed later in this article, has Gamesa turbines with 90 meter hub heights. This change in size dramatically increases the total power available to the wind turbine.

As previously mentioned, the shear profile of the wind can be modeled as a mathematical function that relates wind speeds at a reference height to predict wind speeds at another height. The wind profile power law is:

$$u/ur = (z/zr)\alpha$$

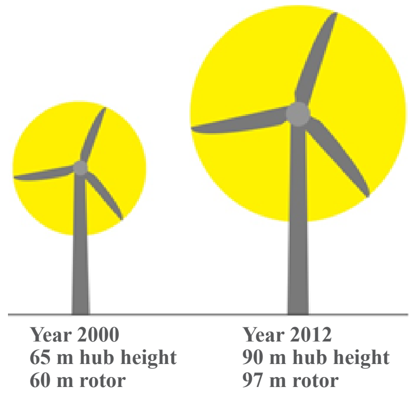
where u is the wind speed at height z, and ur and zr are the reference wind speed and reference height respectively. The exponent, , represents an empirically derived coefficient that describes the stability of the atmosphere. For stable conditions, an value of 1/7 is typically used.

If the original Green Mountain site had average wind speeds of 7 m/s at a 65 meter hub height (a typical wind speed for development at that time), we can estimate what the wind speeds would be at a 90 meter hub height by using the above wind shear power law. At 90 meters, the average wind speed would be roughly 7.3 m/s. Keeping the rotor area and air density constant, we can compare the power available from 7.0 m/s and 7.3 m/s using the previous power equation and see that this increase in hub height offers approximately a 14% (7.33 versus 7.03) increase in total power available from the wind.

Another opportunity to extract more power from the wind is to increase the area swept by the blades. Unlike the velocity variable, the relationship between the increasing rotor area and the resultant increase in power available is linear. If you double the swept area, you double the power output. But the swept area is related to the square of the radius of the turbine blades (ϖr2), so increasing the size of the blades can have significant impact on power. Again, let's compare the first Somerset County site to the most recently commissioned Patton site. The Nordex N60 has a 60 meter rotor diameter, while the Gamesa G97 has a 97 meter rotor diameter. The swept area of the older rotor is 2,826 m2 and the swept area of the newer technology is 7,386 m2. Keeping wind speed and air density constant, the 62% increase in blade length increases the total power available from the wind by 161%!

Along with offering tremendous potential power output increases, turbines with larger rotors can be placed in areas with below average wind speeds and still produce as much power as the older models would produce in excellent wind resource locations. Bigger turbines are not necessarily more efficient, they simply have the ability to capture more wind and therefore generate more power. It should be noted that the power calculated in the equation discussed above is the power available from the wind, and not the total power produced by the turbine. The power produced by the turbine will never be 100% of the total power available. The ideal scenario, also known as the Betz' Limit, is derived from the principles of conservation of mass and momentum and limits the total kinetic energy available to a wind turbine to roughly 59% of the total kinetic energy available in the wind.

Figure 1: Scaled graphic of the sized difference between the Somerset and Patton turbines



The last 20 years have seen turbine sizes grow dramatically, to the point where transportation and crane logistics stymie the development of larger turbines. Future projects will involve assembling taller tower sections and blades on-site in order to continue growth of turbine size. These "segmented" technologies are still in research and development phase and have not yet been implemented in Pennsylvania.

Turbine Siting

Turbine components are manufactured in the plants and transported to project sites. Construction crews on-site dig the foundation for the turbine, install above and/or below ground transmission lines, and generally prepare the site for installation. When the turbines arrive on site, high capacity cranes are used to erect the towers sections and nacelle. Two cranes are used to install the hub and rotor. Once assembled, crews install high voltage wiring and connect the turbine to the grid. After commissioners ensure the tower is properly assembled, the turbine can couple to the grid and begin to produce power.

Wind turbine generators require a certain wind speed to begin to deliver power. This speed, also known as 'cut in speed,' is generally between four and five meters/second for large scale turbines. Once the turbine reaches it's cut in speed, it couples to the grid and begins to produce power. As the wind speeds increase, the turbine produces more power until it reaches its rated capacity. Typically, winds above 25 m/s will shut the turbine down (feathering the blades into the wind) to protect the blades and the drive train components. In the event of hurricane or extreme weather, the turbine will stay yawed into the wind but will not produce power.

Pennsylvania Wind Energy

The technology of taller towers and larger rotors is making wind energy development in Pennsylvania more feasible than ever. The best wind resource available in Pennsylvania was previously regarded as above 2,000 feet in elevation; this is no longer a limiting factor in project development. Rural features like wide open farmlands throughout Pennsylvania may provide ideal conditions for new wind farm development.

Pennsylvania farmers all over the state are adding "wind farming" to their portfolio of harvested crops and reaping financial benefits. The American Wind Energy Association (AWEA) estimated that annual land lease payments to farmers and landowners in Pennsylvania in 2012 were $2.3 million. Landowners are typically paid by the number of turbines on their property and collect a percentage of the revenue generated by each turbine. Turbines have minimal effect on farming capabilities and, in some instances, can make farming easier through the addition of more access roads.

As well as hosting multiple wind farms (a total of 1,029 MW as of 2012), Pennsylvania also hosts a myriad of wind turbine manufacturing companies. AWEA statistics from 2012 show that Pennsylvania is home to 22 facilities that manufacturer wind energy components. Gamesa, one of the industry's leading manufacturers, has blade plants in both Ebensburg and Fairless Hills.

The Patton Wind Farm located in Cambria County, is one of the most recent projects to come online and implement new technology in Pennsylvania. The wind farm is located on operational farmlands and is owned and operated by Everpower, a renewable energy company with headquarters in Pittsburgh. Wind speed data collection and analysis in the initial stages of development was performed by the Saint Francis Renewable Energy Center's Anemometer Loan Program, located in Cambria County. Gamesa, whose U.S. headquarters are located in Trevose, Pennsylvania as well as a blade plant in Ebensburg, is the manufacturer of the 15 G97 2.0 MW turbines onsite (with 97 meter rotor diameters and hub height of 90 meters). As you can see, there is a Pennsylvania theme to this wind farm. The site is an excellent example of community wind farm development, a practice in which local community members, farmers, developers, investors, and manufacturers participate in a wind energy project.

Future Directions

Wind energy is showing its market strength at both a state and national level. Nationally, wind energy power generation installed in 2012 accounted for 42% of the total installed NEW generation capacity for the year. According to AWEA, Pennsylvania added 240 MW of installed capacity in 2012, making it the 15th state to join the "1 GW Club." A National Renewable Energy Lab (NREL) study showed that Pennsylvania has the potential to install up to 3.3 GW of wind power at the 80 meter level.[1] If this is accurate, much of the state's wind potential has yet to be developed.

Wind energy is not a perfect source of energy. It is a non-dispatchable form of energy, which means that when the wind doesn't blow, electricity can not be produced. Siting wind projects can be problematic. Transmission line access, environmental impacts, proximity to state game lands and airports, and community opposition are all factors that affect the development of a wind energy site in Pennsylvania. Just because a site has ideal wind resources does not necessarily mean that someone can develop the project location.

The combination of ever improving technology and the possession of excellent wind resources provides an ideal climate for making the Keystone State a leader in wind energy power production. Whether we expand projects on existing ridgelines or utilize new technology to develop wind farms at lower elevations, the future of wind energy in Pennsylvania has potential to be a cash crop harvested for many decades to come.

Allison Boehm is the Director of the Saint Francis University Renewable Energy Center. If you're interested in wind farming on a project or your property, contact the Saint Francis Renewable Energy Center at renewable@francis.edu to learn more about the Center's affordable Anemometer Loan Program and Sodar Rental.

[1] http://www.windpoweringamerica.gov/wind_resource_maps.asp?stateab=pa

Local Startups Engineer Leading Edge Sustainable Energy Solutions

By Jeffrey McDaniel

Energy in its various forms drives virtually all that we do and impacts our lives non-stop. From the rise and fall of economies, to the rise and fall of nations, energy – or perhaps the unbalanced distribution of energy – has remained a constant. A root cause of so many conflicts in history arise from disputes over ownership and access land, the source of the vast majority of the fuel that can be transformed into energy. The first Messenian War between Sparta and Messenia in 743 BC resulted in a territorial redistribution that included the most fertile environment for olive trade. Perhaps the first true bio-fuel, the oil extracted from olives was used to power lamps as well as other aspects of the economy of that time. From the Roman Empire to the modern day, bodies of water like the Rhine in Europe bind and define regions, transport economies and possess strategic importance. Closer to home, Pittsburgh and the region that surrounds it has often found itself an active participant in the dialogue of the day. The region's resources have not only fueled local and national economies, but stimulated innovation, research and development. Today is no different.

The Pittsburgh region, rich in natural resources is also rich in innovators and inventors. It is the combination of these resources (that include fossil, nuclear, and renewable) with a talented workforce that enable (and sustain) success, and makes a lasting global impact.

In addition to being a very active energy contributor globally, the region is home to a very active venture investing community as well. Last year, there were 190 early-stage technology deals done in Southwestern PA companies which attracted nearly $330 million in funding – a 54% increase in the number of fundraising rounds versus the previous year. The Pittsburgh region's increasing appeal to private investors, venture capitalists, strategic partners and others is bucking a national decline in funding for early-stage companies – a testament to the region's capable entrepreneurs and strong technologies that spin out from our research universities, established companies, National Energy Technology Laboratory and other sources of innovation.

Innovation Works (IW) is a non-profit organization providing funding and business assistance to many of these companies; three out of four companies that raise venture capital in our region received seed funding early in their development from Innovation Works. This level of activity reaches across all technology sectors, including energy. Since launching a fund in 2009 specifically for energy-related innovations, IW has made 64 separate investments in 49 companies for a total of $5.4 million invested. This makes IW the most active energy-sector investor in Southwestern PA.

One of the most common questions investors of all sizes and sophistication ask is: What are the best energy bets for the future? The answer to that question is obviously not a simple one, but it is highly likely that the best energy bets in the future will apply the principles that are often referred to as being "sustainable."

> *"Last year, there were 190 early-stage technology deals done in Southwestern PA companies which attracted nearly $330 million in funding"*

Sustainability may mean different things to different audiences, but it is consistently – at its core – an approach for problem solving. As one of the most common question an investor asks of an entrepreneur is: "What problem does your "solution" (e.g., idea, innovation, product, service, etc.) solve?" It would make sense for every problem solver to apply these principles to his or her tool belt.

The energy technologies that fuel our power plants, light and power our industries and communities, transport us, and otherwise connect and entertain us will not change overnight. Today's challenges include how to meet a global energy demand and how to deliver it to more places. Today's energy technologies, therefore, must evolve…and new technologies will need to be innovated.

Whether the basis of an energy source is fossil or alternative, the future form must be more sustainable than the present. Its impact to the environment, communities, and future generations will/must be considered and minimized. The disruptive energy technologies of our future will likely include high energy storage devices, new energy transportation methods, and breakthroughs in materials.

The IW energy portfolio continues to grow, as has the number of energy investments over the past few years nationally. IW works with entrepreneurs and companies that represent all areas of energy innovation:

What is it? Read on to find out where this piece fits into the energy puzzle

Energy Efficiency & Storage, Transmission & Distribution, Sensors and Material Technologies, Advanced Fossil technologies, and Renewables (including Wind, Solar, Geothermal and Hydro).

There are a number of innovative, exciting companies working on solutions to energy challenges, and a growing number of these entrepreneurs and startups apply sustainable design principles to their solutions. The approach is basically to design products and services that minimize or reduce the negative impact on an environment, including the health and safety of communities. They answer the investor question of "What problem do you solve?" through this sustainable design methodology.

Even with a solid methodology, trying to tackle the big questions ("problems") can be daunting as well as complex. For instance, how would one answer the question;

"How can the global demand for more electricity be met when there no grid exists to deliver it?" or "How do we build energy efficient materials and structures without expending more energy in the process?

The answers will be broad, complex, and likely implicate a myriad of technologies, processes, and layers. Surprisingly, the seemingly simple approach of framing the problem in a smaller, more localized way can produce much larger, impactful results. Perhaps rephrasing the question(s) is the start:

- Is it possible to generate energy from smaller bodies of water?
- Is there a simple, sustainable way to keep a mobile phone charged?
- Can energy efficient structure be built at the same (or lower cost) than an inefficient one?

Here is a snapshot of three of these companies, applying innovation and engineering knowhow in the Sustainable Energy segment to address those questions:

Renerge, Inc

Renerge (rhymes with energy) is currently developing a hydropower technology named

REEDs (River Electrical Energy Devices). Its CEO and founder, Lisa Wieland is a Ph.D., Mechanical Engineer and her startup is answering the challenge of *how to build a device that can effectively harvest electricity from nontraditional hydropower sources?*

Water remains the most utilized renewable resource in the US at nearly 2.6 quadrillion BTUs and the net hydroelectric power is roughly 80,000 MW or roughly 10% of the nation's electrical generating capacity. Conservative estimates suggest existence of another 170,000 MW of hydrodrokinetic energy in the US. that could be developed. There are 2.9 million riverine segments in the continental US large enough to be evaluated for electrical power potential, but fewer than 100 have exactly the right qualities (water velocity, water depth at high/low flows, and environmental) for conventional hydropower generators.

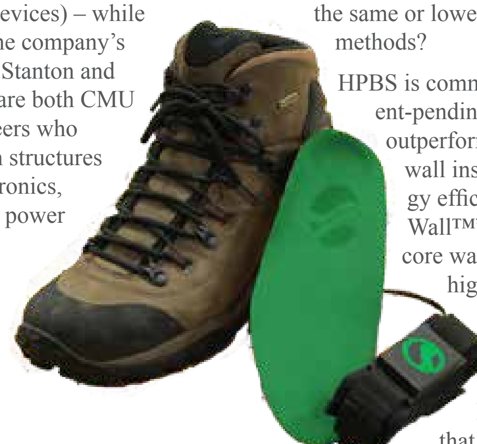
Smaller resources as well as large ones have untapped potential. According to the National Renewable Energy Laboratory, the local Ohiopyle segment of the Youghiogheny River embodies about 10 times the energy potential of that at the confluence of three, more prominent nearby rivers: the Monongahela, Allegheny and Ohio. The Recovery Factor at Ohiopyle – or the proportion of the flow energy which could be harvested with known – existing technologies, however, is zero. Renerge sees the Yough as an opportunity; a high energy, untapped renewable resource that is currently excluded from most (if not all) theoretical energy assessments.

Renerge's fundamental design concept derives from the observation that the physics of stability is appropriate for stable flows (think Hoover Dam), while the physics of instability is appropriate for unstable flows (think a tumbling stream). Most assume that water must turn a turbine while Renerge believes otherwise. According to Wieland, "a kinetic device doesn't care about elevation drop, it cares only about the speed of the water at that location. So instead of energy terms that look like potential energy ('mgh') you need energy terms that look more like kinetic energy ('1/2mv^2')." To achieve control over river instabilities, the REED device integrates what Renerge's calls "aircraft ideology" for these unstable flows. The REED is designed to generate hydrodynamic energy similar to a fish. The design methodology is sustainable. REEDs can operate in free flowing conditions, and thus are inherently lower profile than traditional hydro generators that would likely require dams and significant infrastructure.

Renerge intends to offer its first commercial generator by 2015.

SolePower

SolePower LLC is an early-stage startup commercializing power-generating shoe insoles for charging portable electronics (such as cell phones and GPS devices) – while the user walks. The company's co-founders, Matt Stanton and Hahna Alexander are both CMU mechanical engineers who have experience in structures design, biomechatronics, wearable robotics, power management, and energy harvesting robotics. Through SolePower, they are working to answer the challenge:



Is there a simple, sustainable way to keep a mobile electronic devices charged?

SolePower is an alum of the Pittsburgh-based AlphaLab, and is designing an inherently sustainable energy technology literally from the ground up. The technology generates power using an efficient mechanical system that is reliable and robust – and fits within the profile of an orthotic insole. The device is actuated by the impact ("heel strike") phase of walking gait, and maintains efficiency by continuing power generation through the swing phase of the gait. The generated power is fed through a thin wire that can be integrated through the shoelaces into a power pack. The output port of the device is a USB, making it compatible with the most devices currently on the market.

While there are others looking to harvest human power through microfluidic and piezoelectric technologies, SolePower differentiates itself by being the only mechanical energy harvesting shoe product being built into a versatile, interchangeable insole.

High Performance Building Systems, LLC

Dave and Clark Martens are entrepreneuring brothers who recently decided to leverage their industry experience, engineering and process know-how to create a more energy and operationally efficient building technology. Their company, High Performance Building Systems (HPBS), is an early stage company that is addressing the challenge of:

How can we build energy efficient structures at the same or lower cost of current construction methods?

HPBS is commercializing a new, patent-pending technology that dramatically outperforms conventional fiberglass wall insulation in both cost and energy efficiency. The system "HighperWall™" utilizes an innovative foam core wall panel design that offers 30% higher insulating values at the same or lesser cost vs. current conventional fiberglass installations.

Dave and Clark recognized that the conventional process of step-by-step, on site construction of homes could be improved by integrating optical scanning technology into the 30-year old wall panel manufacturing industry. This customized, more modular approach not only reduces the energy costs of a structure, but is also capable of significantly reducing installation times as well as material waste.

The technology combines a number of formerly separate processing and manufacturing methods to improve the homebuilding process. The innovation recognizes many of the sustainable building design principles cited by the US GSA, including the ability to: minimize non-renewable energy consumption; use environmentally preferable products; enhance indoor environmental quality; and optimize operational practices. HPBS has teamed with Atlas EPS and are releasing their first product "Thermalstar LCCi-SS" October 2013.

Energy Management starts with Conservation

By Katie Flynn

The electricity grid is getting greener. The cost of renewable energy technology decreases every year and usage is increasing. So why should facilities worry about conserving if the environmental and financial impacts associated with our energy use is decreasing? Although improvements to the grid can make it easier for companies and facility managers to meet their sustainability goals, it does not mean that we can leave our energy consumption unmanaged.

Make a Plan

Energy deserves a formal management plan. Without a management plan, energy consumption could increase over time and energy and financial waste will follow. Therefore, the plan should include measureable goals, tracking of energy consumption, ways to prioritize and implement energy conservation measures, building maintenance routines, and a budget for energy costs.

The first step for facility managers is to analyze how energy is used in their buildings, identify where waste happens, and determine where improvements can be made through behavior changes, controls and/or upgrades. Focusing on equipment that uses a relatively small percentage of the overall energy consumption is not as effective as focusing on the equipment that is responsible for the bulk of a building's energy use, such as lighting, HVAC, and similar loads.

At a minimum, a facility manager should log and review energy consumption at a facility to ensure that the facility is performing as expected. If energy use spikes without explanation, the cause of the increase should be investigated and corrected.

Eliminate Waste

The opportunities to improve the energy efficiency of buildings are enormous. The U.S. Environmental Protection Agency estimates that 30% of the energy used in commercial buildings is wasted because of inefficiencies. By simply improving the efficiency of buildings, it is possible to reduce the energy consumption of a building without having to sacrifice performance – a building should not need to turn back the thermostat to 60°F in the winter to save on winter heating bills.

The U.S. Environmental Protection Agency estimates that 30% of the energy used in commercial buildings is wasted because of inefficiencies

When planning for energy efficiency and conservation in an existing building, facility managers should review their operation and maintenance routine. The frequency with which air filters are changed, air handling coils are cleaned, and lighting fixtures are cleaned can all affect the energy efficiency of building systems. Regular maintenance of these items alone can decrease energy consumption.

Capturing the energy savings and applying them to future energy conservation projects ensures that capital will be available for future energy reduction improvement projects

Turning off lights and electrical equipment when not in use are easy ways to eliminate energy waste in any building. Installing controls, which can be as simple as timers or occupancy sensors, require a little more of an investment, but they can reduce energy consumption with a payback of less than one year. Installing and utilizing a programmable thermostat can payback in less than a month.

Tackling equipment and system efficiencies through operational changes and making a few energy-efficient upgrades, such as installing daylighting systems and HVAC controls, present more of a challenge. These typically require some planning and capital investment. But with some creativity, facility managers can find other energy-efficient options for office and building equipment that align with their time and budget constraints.

When looking for opportunities to conserve energy used by the HVAC system, facility managers often focus on the efficiency of the central boiler or chiller. The distribution system and HVAC controls can have a much larger impact on the system's energy consumption. If an 80% efficient furnace is replaced with one that is 95% efficient, much of the potential energy and cost savings would be lost if the duct work for the furnace leaked 30% and the thermostat was set to a constant 78°F.

Capturing the energy savings and applying them to future energy conservation projects ensures that capital will be available for future energy reduction improvement projects. Often, after energy conservation measures are implemented and begin to show a decrease in energy consumption, operational budgets get reduced. The anticipated savings for such improvements should be included and specified in the formal management plan and at the onset of any energy-efficiency project.

Regardless of building type, size, location, and budget, the principles of energy efficiency can be applied to any building. There are a number of steps that can be taken immediately to start implementing energy-efficiency strategies. A large budget is not required.

Energy-efficient Equipment

Implementing a facility-wide energy consumption policy around equipment purchasing, such as making it a requirement that new office equipment carry the ENERGY STAR label, simplifies the energy management process. Having such a policy in place also gives facility and energy managers the ability to guide purchasing decisions for the company, specific departments and entire buildings. This is important because ENERGY STAR certified office equipment, appliances, and other plug load equipment can be as much as 65% more energy efficient than standard equipment. These types of purchasing decisions can translate to big savings in the short and long term.

The policy also can address the lifecycle costs of equipment. Too often, the price of the equipment determines what is purchased without consideration for the cost of operating the equipment, which often can greatly outweigh the initial purchase price. For example, the upfront cost typically represents only 10% of the overall cost associated with a motor. If 90% of the cost comes from operating the motor, the decision as to which motor to purchase should be based more on efficiency, and less on the initial purchase price.

Facility and energy managers are finding new ways to conserve energy and improve efficiency as new technologies emerge. For example, most organizations use Uninterruptible Power Systems (UPS) for immediate backup power for critical work equipment, such as computers, data centers, telecommunications and even medical devices. The problem is that not all UPS devices are the same and often facility managers don't realize the differences in the energy performance of these units. All UPS models continually draw power. However, energy-efficient units can reduce energy consumption by 30 to 55%, according to ENERGY STAR. Eaton, located in Moon Township, offers a UPS that operates at 99% efficiency to significantly reduce energy costs.

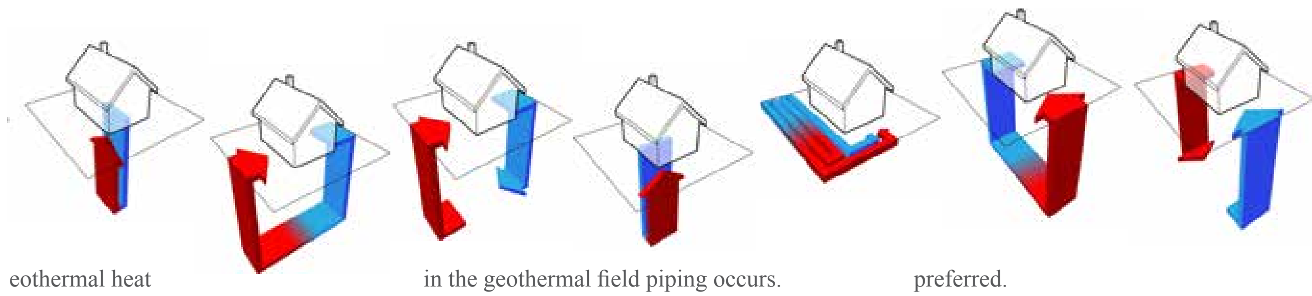
Companies like WESCO International offer expertise to help select the most appropriate products for a facility's needs. WESCO, for example, uses its Value Creation Solutions to engage with organizations to determine their needs and help them identify energy-efficient and cost-saving solutions. Energy audits, water conservation assessments, and sustainability planning are examples of services offered by WESCO that can streamline operations in a variety of areas, including project management, working capital, and procurement.

Don't Stop Conserving

Energy conservation and efficiency measures are not everlasting and should be addressed on an annual basis. New personnel, changes in protocols, and fluctuation in building use occur, which can result in energy waste. Innovative controls and more energy-efficient equipment constantly enter the market and opportunities to improve building controls and efficiency should be explored periodically. An energy auditor can analyze a facility's energy consumption and the facility can be upgraded, but vigilance is required to ensure that the building's energy use is consistently minimized and further reduced when innovative technologies become available.

Evolution of Geothermal

By Jonathan C. Iams, P.E.



Geothermal heat pump systems have been around for more than half a century. In fact, the very first geothermal heat pump system was installed in the Commonwealth Building in Portland, Oregon, in 1946 and is still in operation. During the oil crisis in 1973, many countries began looking for renewable energy sources and by 1980, geothermal gained popularity as a means for which to reduce heating and cooling costs.

Early geothermal systems were open-loop type systems where water was drawn from bodies of water or water wells and used to reject or extract heat directly or indirectly from a building's heating/cooling system, and/or plant process. Water used in the heat transfer process was then returned to its source or dumped in the ground.

For the past two to three decades, engineers have designed closed loop ground source heat exchangers with glycols such as methanol, ethylene, and propylene as the heat transfer medium. This eliminates the need for nearby bodies of water and the consequential impact of water being returned at temperatures other than the current temperature found in nature. The glycol in a closed loop system prevents the heat transfer medium from freezing, allowing the geothermal field to be designed for lower temperatures during the heating season and higher temperatures during the cooling season (typical closed loop field temperatures range from 30°F. – 90°F.).

Over the years, geothermal systems have evolved and the technology has grown better and more efficient, but there are still tradeoffs. Open loop systems prove to be more efficient than closed loop types of geothermal systems since they use less pumping energy as the result of moving 50% less water per ton (typically 1.5 gallons per ton versus 3.0 gallons per ton in closed loop systems). However, open loop systems can have higher maintenance costs related to system fouling due to water quality issues. Closed loop systems can cost less initially, as fewer wells are required but has increased operating costs due to the lower heat transfer capabilities and higher viscosity of the glycol solutions. Not to mention, there can be definite environmental impact from the glycol if a leak in the geothermal field piping occurs.

Until 1979, open loop geothermal systems dominated the market, but in 1979 the development of polybutylene piping made closed loop water-based geothermal systems economically viable. These systems indirectly trade energy with the earth through the wall of the piping, which is typically surrounded by a thermally conductive bentonite grout/sand mixture. Early closed loop geothermal systems proved to solve the maintenance problems associated with the open loop system design, but with higher operational energy costs (due to increased water flow, increased pumping head loss from the longer piping runs needed for heat rejection) and increased installation costs (due to the cost of piping installation.)

In the past ten years, enhanced modeling capabilities have allowed engineers to better predict the operating range of a geothermal well field and optimize the design of the field (i.e. the number, depth and spacing of the wells) to maintain the field temperatures above freezing (typically field temperature ranges between 40° and 80°F). This increases initial cost slightly due to the need for additional wells (to spread the load out over more land so that when we extract heat from the earth's its temperature does not fall below freezing), but has better operating costs and is more environmentally friendly.

Table 1: Relative Environmental Impact of Conventional Geothermal Systems

Geothermal System Type	Open Loop	Closed Loop with Glycol	Closed Loop with Water
Initial Cost	1	2	3
Operating Cost	1	3	2
Maintenance Cost	3	2	1
Environmental Impact	1	3	2
Total Score	6	10	8

Table 1 illustrates this author's relative rankings of the different geothermal system types with regard to environmental impact (1 being the best, 3 being the worst). Each system's total score is in the last column, with lower scores preferred.

Assuming that the inside of the building is designed similarly in each option, the open loop geothermal has the least impact on the environment related to initial cost, operating cost, and overall environmental impact.

From an initial cost perspective, open loop systems require substantially less material, as there are substantially fewer wells. A thirty-ton open well system may have two wells 200 feet deep, whereas a closed loop system may require 10 wells at 480 feet deep. Less material equates to less initial cost and less embodied energy.

Lower operating cost for the open loop water system is the result of moving substantially less fluid than in a closed loop installation. In a thirty-ton cooling system, an open loop system design might require moving approximately 45 gallons per minute (gpm), whereby the corresponding closed loop geothermal system may require 90 gpm of water. As a result, an open loop system typically uses 30% less electrical energy than a similar closed loop system. This results in less operating cost and a smaller carbon footprint.

Environmentally, water as a medium has no ozone depletion factor, no global warming potential, and if it is released into the earth (from a leak), it has no environmental impact. Assuming that the designer is prudent in the design of the open loop wells and takes into account environmental issues related to the discharge water (i.e. temperature and water quality), the open loop system will prove to have less of an impact on the environment than other geothermal options.

As Table 1 shows, the water based closed loop system takes second place and the glycol based closed loop system comes in third in our three-system comparison. Both closed loop systems typically have lower maintenance costs compared to an open loop water system. For the open loop system, higher maintenance costs associated with water quality issues can require filtering out particulates, dissolved solids, metals, etc. The glycol based closed loop system comes with a higher cost than the water based closed loop system based on the cost of glycol.

With all geothermal systems, it should be noted

Table 2: Relative Environmental Impact of CO_2 Geothermal Systems Related to Conventional Geothermal

System Type	CO2 Geo-thermal	Open Loop	Closed Loop with Glycol	Closed Loop with Water
Initial Cost	2	1	3	4
Operating Cost	1	2	3	2
Maintenance Cost	2	4	3	1
Environmen-tal Impact	1	2	4	3
Total Score	6	9	13	10

that the rankings above are only relative to each other; overall the environmental impact of geothermal systems (regardless of system choice) is substantially less than other fossil-fuel based options.

In the next decade, it is anticipated that the design of geothermal systems will continue to develop. One option will include the use of CO_2 (R-744) as the medium to transfer energy between buildings and the earth. The use of CO_2 has many benefits (it is a safe, non-toxic, non-corrosive, environmentally benign refrigerant) and will provide all of the benefits of an open loop system in a closed loop configuration. As a result, Table 2 provides an update on Table 1 by including CO_2 geothermal systems.

From an initial cost perspective, CO_2 geothermal costs more than open loop water-based geothermal as the result of it being a closed loop system, but due to a much smaller borehole size, CO_2 geothermal can be installed at a fraction of the cost of conventional closed loop geothermal systems. CO_2 geothermal utilizes 3/8” stainless steel or copper piping in a 3” bore hole. As the result of the reduced size of the piping and borehole, small scale directional drilling rigs and directional drilling techniques can be utilized, eliminating the need to excavate a large portion of land for horizontal main piping runs.

From an operating cost perspective, both the mass flow and viscosity of the CO_2 are lower than that of water, translating into less energy usage. As a result, CO_2 geothermal systems have coefficients of performance in the 4.0 to 6.0 range, whereas conventional closed loop geothermal water type systems have a coefficient of performance in the 3.5 to 4.5 range.

From a maintenance cost, the closed loop geothermal system with water has less maintenance than the CO_2 system, but this is only based on the fact that water can be automatically fed into the system whereas the CO_2 system requires some management via CO_2 cylinders.

From an environmental view point, CO_2 used as a refrigerant is similar to water in that it has no ozone depletion factor and no net global warming potential.

Locally, companies like Thar Geothermal have been conducting CO_2 research and developing products to meet the challenges of creating a commercially viable CO_2 geothermal system. In the past year, Thar has gained approval of their patent, and demonstrated a CO_2 geothermal system incorporating geothermal well fields at their production facility in RIDC Park, noting that their system is operating with an average COP of approximately 5.0. The CO_2 geothermal system interfaces with a broad range of heating and cooling systems such as air-handling units and radiant floor systems, and shows much promise as a locally developed geothermal technology for the future.

About the author...

Jonathan Iams, P.E. is Principal and Owner of Iams Consulting, LLC, a Pittsburgh based MEP firm, which specializes in the design of unique sustainable solutions.

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