From Tragedy to Triumph: Rebuilding Greensburg, Kansas, To Be a 100% Renewable Energy City[1]

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ABSTRACT

On the morning of May 4, 2007, Greensburg, Kansas, was a declining farm community in south-central Kansas with a population of about 1,400. That evening, an EF-5, 1.7-mile wide tornado with 200 mph-plus wind speeds, hit Greensburg and destroyed or severely damaged 90% of its structures. We discuss the progress made in rebuilding Greensburg, with a focus on the built environment and on meeting Greensburg's goal of 100% renewable energy, 100% of the time. We also discuss key disaster recovery efforts that enabled Greensburg to reach this goal. Key strategies included a *Sustainable Comprehensive Master Plan*, an ordinance resolving that city-owned buildings achieve LEED Platinum and 42% energy savings, a strong focus on rebuilding "right" with an integrated design process, attracting significant and sustained technical experts and national media attention, and linking renewable and energy efficiency technologies to business development. After three years, more than half the homes that have been rebuilt are rated at an average of 40% energy savings. All significant commercial buildings, including the school, hospital, banks, courthouse, and retail buildings, have been rebuilt to LEED Gold and Platinum standards and exceed 40% savings, with many exceeding 50% savings. Greensburg recently constructed a 12.5-MW community wind farm to provide all the remaining energy needed for its energy-efficient buildings and homes. A small rural community with strong leadership and committed citizens can indeed rebuild differently, with major improvements to energy efficiency and uses of renewable energy, to become a 100% renewable powered city.

Out of Crisis, Opportunity

On the morning of May 4, 2007, Greensburg was a declining but close-knit farming community in Kiowa County in south-central Kansas. Established in 1886, Greensburg grew rapidly between 1900 and 1910, and its population peaked at 1,988 in 1960. It was home to about 1,400 people in 515 single-family residences and 215 rental properties (*Greensburg Sustainable Comprehensive Plan* 2008). Greensburg also had a school, many businesses along a few downtown blocks, and City offices. And as the seat of Kiowa County, it housed the county courthouse, Kiowa County Memorial Hospital, the county library, and other county functions. It acted as a municipal utility, selling electricity, water, sewer, and trash services to Greensburg customers.

At 9:45 p.m. on May 4, 2007, an EF-5 tornado—the highest level on the standard meteorological scale—plowed through the city. It killed 11 people and destroyed or damaged more than 90% of the city's structures (including some historic buildings), most vehicles, and the electricity infrastructure. Most residents were displaced from their homes and businesses. All

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City and County services, including the school, city hall, hospital, and courthouse, were destroyed. Figure 1 shows the extensive devastation.

Figure 1. The Devastation Left Behind After the Tornado

NREL PIX #16290

DOE/NREL Involvement

When the initial shock subsided and the time to rebuild arrived, the residents realized that they had an opportunity to turn a tragedy into a triumph—an opportunity to make Greensburg something even better than it had been before. Living close to the land, they knew the value of solar and wind power and of using water efficiently. Conversations began about translating these concepts to rebuilding as a model "green" community, and the idea quickly picked up steam. Soon after the tornado, the U.S. Department of Energy (DOE) dispatched a team, including its own energy experts and some from its National Renewable Energy Laboratory (NREL), to Greensburg to assist the residents with the technical aspects of rebuilding. DOE's ultimate goal was to demonstrate energy efficiency and renewable energy solutions that would help Greensburg and could be replicated in other disaster recovery and general rebuilding efforts across the country. Researchers on the DOE/NREL team were interested in understanding how far a city, with the opportunity to completely rebuild, could go toward becoming a net-zero energy community. Project goals included helping rebuild the city as a model community of clean, affordable, and energy-efficient technologies and buildings; facilitating renewable electricity generation for long-term, clean, and economical power; and supporting the reconstruction of Greensburg with access to information and materials to achieve national goals related to energy diversity and reliability.

The technical scope of NREL's work from June 2007 through the end of May 2009 encompassed various studies, recommendations, and plans. The NREL team furnished specific guidance and technical analysis on individual projects, including several high-visibility buildings

and design of a community wind system. Several factors, including the needs of the city and its major constituents, competing nonrenewable energy options that others brought forth, and the pressure to move forward quickly, determined priorities. A full summary of NREL's work, which is expected to be complete in fiscal year 2010, is available at from DOE (2010).

The hard work began immediately, and many national and local institutions, agencies, industries, and individuals reached out to help Greensburg with professional expertise, donated materials, and cash donations. We discuss the progress made in rebuilding Greensburg, with a focus on the built environment and meeting the goal of a 100% renewable energy city.

Developing a Plan—A Vision for the Future

When disaster strikes a community, the initial response focuses on immediate needs. After those are met, and some of the shock wears off, the community can begin to recover. Inevitably, questions borne of despair follow devastation. Should we even rebuild here? Will enough people come back? Will we ever have a city again? And once a decision to rebuild is made, the residents are likely to want to return quickly to the way things were. In Greensburg, just days after the tornado, community leaders and residents came together and decided that their city was worth rebuilding. However, they did not want to return to the status quo—they wanted to create a new vision for the future. They wanted to turn disaster into opportunity—not just for themselves but for communities like theirs all over the world.

As part of the Federal Emergency Management Agency's (FEMA) *Long-Term Community Recovery Plan* (FEMA 2007), Greensburg residents developed a *Sustainable Comprehensive Plan* (2008) for the city's next 20 years. As the plan states, "A truly sustainable community is one that balances the economic, ecological, and social impacts of development." This balance is visible in the community's goals as stated in the master plan—goals that clearly represent solid Midwestern values:

- Be progressive while remaining unassuming.
- Open doors to newcomers while maintaining a traditional cultural heritage.
- Provide opportunities for young people— education, jobs, a future back home.
- Value the natural environment, balanced with growth and economic development.
- Build a variety of durable, healthy, energy-efficient houses and buildings.
- Look to renewable sources of energy, such as Greensburg's plentiful wind.
- Treat each drop of water as a precious resource.
- Remain affordable.

Integrating Renewable Energy and Energy Efficiency into Planning

In contrast to a disaster that affects isolated parts of a community, the nearly complete devastation in Greensburg made long-range and comprehensive community planning imperative before substantial rebuilding could begin. This planning took place in stages, first with a *Long-Term Community Recovery Plan* led by FEMA (2007), and then with the *Greensburg Sustainable Comprehensive Plan* (2008) led by BNIM Architects, a community planning and architectural firm in Kansas City, Missouri. Energy considerations were key to the FEMA- and BNIM-led planning efforts, in which early NREL analysis was a primary component. Greensburg's community vision—"Blessed with a unique opportunity to create a strong

community devoted to family, fostering business, working together for future generations"—emphasized key values that affect the community's energy goals:

- Treat each drop of water as a precious resource.
- Improve quality of life by promoting a healthy and active lifestyle.
- Promote a high level of efficiency in new construction and look to renewable options for generation.
- Greensburg's vast wind resources are part of an emerging economy and should be harvested.
- Build a city that encourages interaction between residents, welcomes guests, and serves as a model community. New development should be durable, healthy, and efficient. City projects will lead the way by becoming examples of green practices that are built to last.

Additional key energy efficiency and renewable energy concepts that were integrated into the *Greensburg Sustainable Comprehensive Plan* included residential efficiency targets of at least 40% energy savings and commercial efficiency targets of at least 30% energy savings. These were incorporated because they were achievable, cost effective, and did not require on-site renewable energy production. They were developed based on a series of life cycle optimization analyses that identified cost-effective solution sets for residential and commercial buildings (Billman 2009). These levels of energy efficiency can be achieved with a simple, prescriptive set of recommendations, such as the 30% Advanced Energy Design Guides (AEDGs) (www.ashrae.org/aedg). Incorporating energy efficiency targets and clear implementation recommendations into the master planning process was a key early step for Greensburg to reach its energy efficiency and renewable energy goals.

City Commitment and Leadership

Another key step was Greensburg's early and significant commitment to rebuild to the most stringent of green building standards. NREL joined BNIM in recommending that Greensburg adopt a resolution that all City-owned buildings (more than 4,000 sq ft) be designed to a LEED Platinum level with a minimum of 42% energy cost savings. The City passed this ordinance in December 2007 (Greensburg 2007). This unique requirement demonstrated the City's leadership to sustainable rebuilding. This leadership and commitment encouraged other Greensburg commercial and public projects to consider similar goals and to foster a sustainable business environment.

Greensburg has also been publically striving to become "100% renewable energy, 100% of the time." Early in the recovery and rebuilding efforts, City and business leaders recognized the potential of a local community wind system to offset all of Greensburg's electricity use. Local people understand the perfection of a scenario in which the same force of nature that brought down their city now powers its future. Central to Greensburg's identity as a model green community is ensuring that all local homes and business receive their energy from clean, renewable sources.

Key Technical Analysis

NREL's recommendations for the technologies considered for energy solutions in a community such as Greensburg follow these guidelines:

- Use technologies that have the most favorable environmental characteristics.
- Use commercially available, proven technologies.
- Use technologies with the lowest life cycle cost.
- Use technologies that are simpler and highly reliable rather than those with exceptional characteristics that more complex to operate.
- Strive for synergistic, integrated energy solutions.

In general, applying these guidelines to individual building projects resulted in an approach that focused first on energy efficiency, then on on-site renewable generation, and then on community-based renewable generation. This section summarizes our work in the built environment and discusses the community wind power system. NREL also evaluated alternative transportation and the feasibility of community-scale biomass. Billman (2009) provides a full review of this work.

Residential Buildings

The goal for residential energy efficiency was to encourage and offer technical assistance to the residents and builders to rebuild new homes with 40% or higher improved energy efficiency. (All energy efficiency is noted as energy savings compared to a home in this climate built to the 2003 International Energy Conservation Code [IECC] [RECA 2003] with 2004 Supplement [NFRC 2004].) To support this goal, NREL developed the specification packages with its BEopt computer model for 30%, 40%, and 50% energy savings for a 2,000-gsf residence, and calculated the cost savings at each level (see Table 1) (Billman 2009).

Calculations show that for a 2,000-gsf house built to achieve 30% energy savings relative to standard practice, a homeowner can save $512 per year more on his or her energy bills than the extra cost of the slightly larger mortgage. Homeowners can use savings in utility bills to pay for higher energy efficiency, which would result in a net positive monthly cash flow and improve energy efficiency by 30% to 50%. These calculations were summarized in a flyer that was distributed widely to help homeowners understand their potential long-term savings.

On-site NREL experts also assisted with the builder training sessions, advised potential builders and business owners at two housing fairs, advised major housing projects, and offered broad on-site technical assistance. One full-time person in a Greensburg NREL office offered on-site technical assistance, Monday through Friday, from August 2007 through February 2008. On-site support was then reduced to a few days per month, but telephone assistance was available five days per week through November 2008. This included answering questions from homeowners and builders who sought help at the NREL office, observing and assisting builders at building sites, meeting residents in their temporary living quarters to discuss the costs and benefits of energy-efficient homes, and reviewing and advising on individual house plans.

NREL also encouraged all homeowners to obtain Home Energy Rating System (HERS) ratings. HERS ratings tell homeowners their energy efficiency, and are most effectively done when plans are developed and after construction. A HERS rating is necessary to receive tax

incentives or an energy efficiency mortgage, help identify the most cost-effective energy measures, and help isolate performance problems after construction. NREL provided significant oversight to train a HERS rating specialist, who was funded by a grant from DOE to the State of Kansas, trained at the Energy & Environmental Ratings Alliance, and aligned with the Kansas Building Science Institute.

Table 1. Specifications for Residential Energy Savings in Greensburg, Kansas

Feature or Factor	Basic Efficiency Package (30% Energy Savings)	High-Efficiency Package (40% Energy Savings)	Premium Efficiency Package (50% Energy Savings)
Insulation			
Walls	R-19	R-21	R-19 + R-5 foam
Roof	R-40	R-50	R-50
Basement	R-10	R-10	R-10
Windows	Double-glazed, low-e	Double-glazed, low-e, argon-filled	Double-glazed, low-e, argon-filled
U-value	0.30	0.28	0.28
Solar rating	0.37	0.37	0.37
Lighting			
Compact fluorescents	50%	80%	80%
Heating efficiency rating (AFUE, %)	90+	90+	90+
Air-conditioning efficiency rating (SEER, Btu/Wh)	14	18	18
Appliances			
Water heater	Standard tank (gas)	Standard tank (gas)	ENERGY STAR tankless (gas)
Energy factor	0.61	0.61	0.80
Ventilation	Exhaust	Supply	Balanced
Air Sealing	Extensive caulking and sealing to reduce air leaking were specified for all packages.		

Commercial Buildings

The goal for commercial building reconstruction was to encourage and help owners rebuild to the highest cost-effective energy efficiency level. When energy efficiency is considered early in a design process, 30% savings over ASHRAE 90.1-2004 can be achieved cost effectively. Thirty percent savings was the starting point for energy goals for all commercial projects; additional savings were considered when possible. With additional modeling, applying an integrated design process, and considering life cycle cost savings, 50% savings can be achieved cost effectively. As all the significant commercial buildings needed to be rebuilt or significantly renovated, our work covered many public buildings such as the K-12 school, hospital, city hall, courthouse, and business incubator, and many businesses such as the local John Deere dealership, the General Motors dealership, Dillon's Kwik Shop, a Best Western, the banks, and a few nonprofits. Before rebuilding began, NREL staff members gave presentations to City leaders, business leaders, and owners about the benefits of energy efficiency in these buildings, suggested specific guidelines and goals, and distributed copies of 30% Savings AEDGs (ASHRAE 2010). These guides provide easy-to-use design recommendations to achieve 30% energy efficiency compared to code, in specific climate zones, for small retail, small office, warehouses and self-storage facilities, small hospitals, highway lodging, and schools.

NREL staff supported an integrated building design process for high-profile projects. We met with each project owner to set clear energy efficiency goals and ensure these goals were communicated to the design team and builder. We tried to do this as early as possible, when the program for each building was being developed. As part of this initial goal-setting exercise and in subsequent meetings with the design team, builder, and owner, we focused on helping the owner and design team understand the following core integrated design concepts:

- Set clear and measurable energy efficiency goals.
- Use the climate, optimal massing and orientation, architecture, and envelope to reduce as many loads as possible. Focus on passive strategies such as an enhanced envelope, daylighting, shading, and passive solar heating early in the design process. If done early enough, these strategies can be well-integrated, cost-effective solutions.
- Evaluate design decisions based on life cycle analysis. Identify strategies that have capital cost tradeoffs, such as reducing the cost of mechanical equipment to account for reduced heating and cooling loads. Use energy modeling and other tools to identify these strategies.
- Identify value-added opportunities to further justify investments in energy efficiency. Understand the synergies and integration opportunities between enhanced disaster resistance and energy efficiency opportunities, as well as the economic development and marketing differentiation opportunities.
- Focus on rebuilding "right" and keeping it as simple as possible.
- Expect to measure and verify the solution to ensure the investment payback is realized.

The level of effort varied for each project, depending on the needs and experience of the design team. For the larger commercial projects such as the business incubator, school, hospital, and John Deere dealership, NREL staff ran advanced life cycle cost optimization models using the latest version of EnergyPlus to develop optimized conceptual design strategies. They also provided energy modeling training for the design teams of the business incubator and for the renovation of the badly damaged Kiowa County Courthouse. NREL staff offered varying amounts of technical analysis and integrated design concept facilitation on the construction of many smaller projects. The work primarily focused on communicating cost-effective pathways to meet energy goals. For many projects, the AEDGs provided the core set of recommendations. Based on previous NREL energy modeling and life cycle optimizations in developing the AEDGs in partnership with ASHRAE and DOE, the authors gleaned a key insight into the recommendations in these guides (ASHRAE 2010). To supplement the AEDG recommendations for many metal buildings projects, the NREL team developed additional detailed recommendations to address some unique challenges of the metal building industry. These focused on cost-effective daylighting and insulation details (Billman 2009).

Wind Turbine Analysis

As noted earlier, the city's electricity distribution system was destroyed. City and local contractors used insurance, state, and FEMA funding to rebuild the system and delivered electricity to every resident within about six months. The City also quickly developed a draft Memorandum of Understanding with the largely coal-based rural electric cooperative, with which it had done business for many years, to disband the Greensburg municipal utility and enter

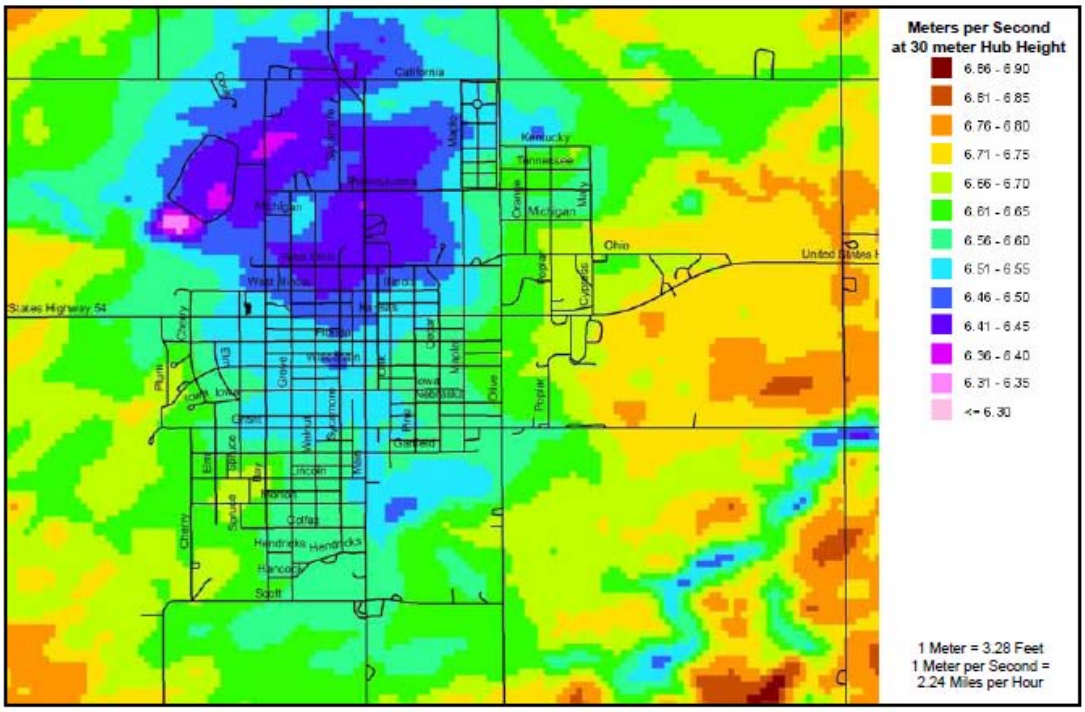
into a long-term power supply contract. Before the Memorandum was finalized, however, the City leadership and the community became increasingly interested in moving forward with a green vision. In August 2007, NREL wind experts gave a public presentation in Greensburg on community-scale wind systems (Billman 2009). They introduced the possibilities for Greensburg, using examples of other communities that had successfully completed wind projects.

Greensburg's future energy requirements were assumed to be at least equal to those before the tornado, plus an uncertain amount for growth. The NREL team prepared an analysis indicating that the excellent wind resource was likely to make a 4-MW, grid-connected wind energy system a feasible option for supplying 100% of the annual electricity needs. Wind resource data were estimated from public land use and state-based wind resource databases, refined through a more detailed computer algorithm, and finally measured with meteorological equipment beginning in June 2008. The intended site for the community wind turbines was at the edge of Greensburg City limits, a few miles from a major highway passing. This would become an excellent wind resource and an excellent visual message. Figure 2 shows a high-resolution mean annual Greensburg wind speed map generated to help residents estimate the energy production wind turbines would generate over one year. In general, all areas in southwestern Kansas have an exceptionally high class 4 wind resource.

The NREL team helped the City form a new relationship with the Kansas Power Pool (KPP), a rural electric cooperative with a strong renewable energy generation portfolio. KPP expressed a desire for additional wind generation capacity for its City members and indicated an interest in as much as 10–12 MW of wind-generating capacity. KPP also agreed to formalize an understanding with the City that KPP would support Greensburg by managing its generation resources such that renewable energy, whether wind or other resources such as hydropower, would be available to Greensburg 100% of the time.

The NREL team recommended as a business strategy the model known in the wind industry as the Minnesota Flip. The City would begin the project with a small percentage of ownership compared to the private equity owner, who would benefit from the federal production tax credit for 10 years. At the end of that time, the City would have the option of owning most or all of the system. Greensburg's ability to sell renewable energy credits helped the economics of that proposed model. The team continued to work through July 2008 to develop this business strategy and pro forma, and to identify investors who could provide capital and debt equity, estimated at $22 million for a turnkey 12-MW system. The City decided, however, to pursue a partnership with John Deere Renewable Energy. In September 2008, based on the speed with which a system could be installed and expected lower electricity costs during the initial years, the NREL team, KPP, and the City decided to use the 12.5-MW system developed by John Deere Renewable Energy.

Figure 2. Greensburg Estimated Mean Annual Wind Speed



This detailed high-resolution mean annual wind speed map was developed by Wind Utility Consulting, PC. It is based in part on the Kansas Corporation wind speed map and local land use profiles from the U.S. Geological Survey.

Greensburg Three Years Later

Three years after the tornado, Greensburg is rebuilding to become a model green city powered by 100% renewable energy. Figure 3 shows the downtown rebuilding progress.

Figure 3. Greensburg Three Years Later

Courtesy Joah Bussert, Greensburg GreenTown. Used by permission.

Residential Results

The measured results of these efforts as technical assistance, education, and encouragement in the residential area are impressive, as verified with the HERS ratings. Of the 180 new homes permitted between May 5, 2007 and March 6, 2009, approximately 52% were voluntarily rated for energy efficiency. Of these, 9 townhome rental units in a multifamily complex were measured. These 106 homes are projected to use, on average, 41% less energy than a standard home built to the IECC 2003 code with 2004 Supplement. Ratings indicate that the 33 homes renovated and measured should use, on average, 25% less energy than similar homes built to IECC 2003. (ENERGY STAR homes typically use about 15% less energy.) Obtaining a HERS rating was voluntary, so these numbers should not be extrapolated to be an average for all the rebuilding and renovation.

Commercial Buildings Results

The results of the integrated design efforts with many commercial building projects through technical assistance, training, and encouragement include a substantial list of high-performance buildings (Table 2). Many projects are attempting LEED Platinum certification, and many are designed with 50% savings goals. All projects are described in some detail in Greensburg Sustainable Building Database (Greensburg GreenTown 2010). The database includes buildings on which NREL had significant influence on design, and others on which NREL had no direct consultation, but which are nonetheless important examples of energy efficiency that were influenced by the overall efforts in Greensburg.

Table 2. Selected High-Performance Commercial and Public Buildings in Greensburg

Name	Building Type	Floor Area (ft^2)	Energy Goals
Greensburg State Bank	Financial & communications	2,000	30%
5.4.7 Arts	Interpretive Center	1,670	LEED Platinum*
The Peoples Bank	Financial & communications	2,100	30%
Centera Bank	Financial & communications	4,000	30%
Greensburg City Hall	Public order & safety	4,700	LEED Platinum, 42%
Dillon's Kwik Shop	Retail	8,000	30%
Dwane Shank-Greensburg General Motors Dealership	Retail	8,300	30%
Business Incubator	Commercial office; retail	9,580	LEED Platinum, 50%*
Kiowa County Courthouse	Public order & safety	18,600	LEED Gold, 35%
Prairie Pointe Townhomes	Multi-unit residential; assembly	23,996	LEED Platinum*
BTI-Greensburg John Deere	Retail	30,000	LEED Platinum, 48%*
Kiowa County Memorial Hospital	Healthcare	48,500	LEED Platinum, 42%
USD 422 Greensburg K-12 School	K-12 education	120,000	LEED Platinum, 50%
* Indicates LEED Certification achieved as of May 2010			

The public buildings have all been built with aggressive energy efficiency goals. The K-12 school is attempting LEED Platinum and 50% savings, the hospital is attempting LEED

Platinum and 40% savings, the business incubator reached LEED Platinum and exceeded 50% savings, the City Hall LEED Platinum and 42% savings, and the courthouse is attempting LEED Gold and 35% savings. Greensburg's business community is also rebuilding with a major focus on energy efficiency and green building techniques. The John Deere dealership, completed in January 2009, is the first metal building to achieve LEED Platinum status and 50% energy savings. This facility has become the recommended model for all future John Deere dealerships in North America. The General Motors dealership, Greensburg State Bank, Centera Bank, People's Bank, the Kiowa County United Building (a second business incubator), Dillon's Kwik Shop, and other businesses are also designed for 30% savings (or greater). The Big Well Museum and a County Commons project are in early design and fundraising efforts and have also committed to LEED Platinum goals. Additional design process and energy strategy details are available from Greensburg GreenTown (2010). All these buildings feature extensive natural daylighting, a well-insulated envelope, and high-performance lighting and controls. Many include ground-source heat pumps; two have photovoltaic panels; four have on-site wind turbines. As shown in Table 2, Greensburg—with 1 square mile and 800 residents—will soon have the greatest concentration in the country (buildings per square mile) of LEED Platinum and Gold buildings with greater than 30% energy savings.

Wind Energy Systems Results

One of the most remarkable aspects of the Greensburg project is the commitment to renewable energy, especially wind. Far from distrusting the force that destroyed their city, the residents have embraced it as the foundational building block of their new community. The city is already home to small-scale turbines at the 5.4.7 Arts Center and the BTI-Greensburg John Deere dealership; larger scale (50-kW) turbines are located at the new school, John Deere dealership, and hospital. Construction is also complete for the Greensburg Wind Farm, which consists of 10, 1.25-MW wind turbines that supply 12.5 MW of renewable power—enough energy to power 4,000 homes (see Figure 4). The city expects to consume about a quarter of the electricity; the rest will be sold back to KPP. When the wind is not blowing and the turbines cannot generate electricity, KPP will energize the city with clean power from other sources, including hydropower, to meet the goal of being powered entirely by renewable sources

Another key player in the wind farm project is NativeEnergy, a Vermont-based company that offers carbon offsets and renewable energy credits. NativeEnergy helps finance sustainable power projects that benefit family farms, community-based operations, and Native American projects. The company is furnishing some of the gap funding that is enabling the project to be completed. More funding is coming from the U.S. Department of Agriculture through a $17.4-million loan from the Rural Development program. Total cost is projected at $23.3 million. The remainder of the funding will come through an equity investment by John Deere Renewable Energy, which will also maintain the wind farm. The City anticipates that the system will be paid for in less than 12 years.

Figure 4. Greensburg Community Wind Farm

Courtesy Joel Boucher, NativeEnergy Inc. Used by permission.

Key Lessons Learned in Rebuilding a 100% Renewable Powered City

Plan

One of Greensburg's key early successes was a community sustainability plan that focused on cost-effective energy efficiency and renewable energy. Based on the lessons learned from developing this plan, and to help other communities and cities rebuild with core energy efficiency and renewable energy goals, the DOE/NREL team developed a review of the whys and hows of energy planning during disaster recovery for City leaders (DOE 2009). It is intended to show how communities of any size can incorporate green principles and technologies such as energy efficiency and renewable energy into their rebuilding plans. Key steps are:

1. Identify and bring stakeholders together.
2. Choose your leaders.
3. Visualize and capture the vision.
4. Get the lay of the land.
5. Set your goals.
6. Find your funds.
7. Write your plan.

Lead

Numerous local leaders have been instrumental in Greensburg's rebuilding. From the local grassroots nonprofit organization, Greensburg GreenTown, which provides resources, support, education, and advocacy as Greensburg rebuilds, to the City LEED Platinum ordinance, to the largest business (the John Deere dealership) committing to the first LEED Platinum metal

building, and the first LEED Platinum critical access community hospital (awaiting certification), Greensburg is a city of green building firsts. This leadership has attracted significant and sustained outside technical expertise, financial contributions, and media attention. This leadership and these examples of high-performance buildings have served as the face of the community, setting standards and expectations through their usability and aesthetic appeal, and have been instrumental in encouraging other projects to follow their lead.

Tell the World

Greensburg has captured the attention of the media and the imagination of the world. Its comeback, and the idea of turning adversity into opportunity, tells a story that Greensburg has used to develop and maintain outside interest. The story is uplifting, inspiring, and hopeful. Greensburg residents are committed to keeping their city in the spotlight as an ever-evolving focal point of sustainable building, the new energy economy, and green living. In addition to the funding, technical assistance, and efforts of government agencies, nonprofit organizations, and private business, the media have flocked to the small-but-mighty city. The Discovery Network's Planet Green channel documented the city's comeback with 13, 1-hour episodes in 2008. The series, hosted by well-known sustainability advocate Leonardo DiCaprio, continued in 2009 with 6 episodes, and filming is currently underway for a third season. Recognition from the highest levels of government, as quoted below, has helped to keep the Greensburg story in the national spotlight.

> *"Greensburg … is being rebuilt by its residents as a global example of how clean energy can power an entire community—how it can bring jobs and businesses to a place where piles of bricks and rubble once lay."*
> *– President Obama, State of the Union joint session of Congress, February 22, 2009*

Greensburg's national leadership in rebuilding as a renewable powered city has allowed for sustained investment from outside sources. Funding for most commercial projects included payouts from insurance companies, grants and loans from federal or state agencies such as the U.S. Department of Agriculture and the State of Kansas, FEMA recovery funds, and from significant corporate and personal donations dedicated to helping Greensburg meet its sustainability goals.

Focus on Economic Development

Greensburg residents envisioned that committing to world-class sustainability rebuilding goals would turn around Greensburg's declining industry and community. Before the tornado, most high school graduates moved elsewhere to look for higher paying jobs. Citizens saw the opportunity to make Greensburg something even better than it had before, and have used their rebuilding goals to keep people in the city and attract new visitors, businesses, and residents.

Wind energy has become an important economic development strategy. For example, the owners of the BTI-Greensburg John Deere dealership used a wind turbine to power its construction site. The dealership now includes three wind turbines (50 kW, 4.2 kW, and 1.9 kW) that provide electricity to the facility, offsetting an estimated 8% of the building load. The

owners had such a positive experience with the Canadian turbine building company that the BTI-Greensburg dealership became the company's North American distributor, BTI Wind Energy (http://windenergyisrenewable.com). In its first 9 months of business, BTI Wind Energy built a North American dealer network across 32 states and 4 Canadian provinces, resulting in 120 new wind-related North American jobs. Nearly 300 sales representatives, wind specialists, service technicians, and installers are learning the new business, and have already installed 3, 50-kW wind turbines in Greensburg alone.

Link Energy Efficiency to Disaster Resistance

The courthouse and a downtown bank were the only commercial buildings not completely destroyed. Both were built almost 100 years ago with significant concrete structural elements—the walls were constructed with more than 17 inches of solid concrete. In addition to proving their disaster resistance by withstanding the tornado, the NREL team used these buildings as examples of how buildings were designed before the time of electrical lighting, when daylighting provided interior illumination. The courthouse guided many rebuilding efforts that showed how a well-daylit, naturally ventilated commercial building could be designed and built to be energy efficient and survive the most destructive of tornados. In response, most Greensburg commercial projects (as well as many residential ones), have used R-22 insulated concrete forms that offer enhanced insulation with minimal thermal bridging and significant structural capabilities.

Greensburg Commercial Building Energy Efficiency Trends

Because of the focus on simple systems and rebuilding "right" during early design development, all the commercial building projects were able to successfully integrate cost-effective energy efficiency strategies such as an enhanced envelopes, good window orientation, shading to optimize daylighting and solar load avoidance, and effective building orientation. All commercial building projects have significantly enhanced insulation systems such as insulated concrete forms (business incubator, Kiowa County downtown retail, two banks, a mortuary, and Dillon's Kwik Shop), metal structural insulated panels (the metal buildings and churches), and oriented strand board structural insulated panels (in the school). Spray foam with structural concrete walls is also a common wall insulation system (in the hospital and courthouse). Another common trend is ground-source heat pumps. Various test wells showed favorable thermal properties of the local soil, and with fairly cost-effective drilling contractors, many teams focused on this HVAC system type. Ground-source heat pumps are used in the school, business incubator, City Hall, one bank, and the courthouse. Fully electric heat pump systems were also considered because of the abundant local renewable electricity. Finally, all projects maximized the use of daylighting systems with strategies such as tubular daylighting devices, south- and north-facing glazing, and skylights. Lighting commissioning is in an ongoing process to ensure daylighting controls are adjusted so the electric lights are dimmed or turned off when daylighting is sufficient.

Conclusions

Three years after a devastating disaster, Greensburg is rebuilding to becoming a true net-zero energy city—an energy-efficient community that generates as much electricity from renewable energy as it uses. It is the first city in the world to adopt these kinds of resolutions. It sets a new standard for its own citizens and for other rural and urban communities. Greensburg's unique situation of near-total destruction, for which there are few precedents, represented an opportunity to try alternative energy solutions on a community-wide scale. A small rural community with strong leadership and committed citizens can indeed rebuild differently, with major improvements to energy efficiency and uses of renewable energy to become a 100% renewable-powered city. Pursuing a wide range of new energy solutions has placed Greensburg in a leadership position in Kansas and throughout the world. Becoming known as a leader in sustainable development may add to Greensburg's economic competitiveness and allow the community to take advantage of the upsurge of interest in green initiatives from many businesses and surrounding communities. Because of Greensburg's aggressive and unique green rebuilding commitments, it has received significant and sustained media attention, financial assistance, and government support. Greensburg's efforts have begun to inspire and assist other communities facing similar challenges in rebuilding after natural and economic disasters. Local Greensburg leaders and NREL/DOE technical experts have worked with the earthquake-ravaged Chinese city in HanWang and have helped FEMA with its recovery planning processes. The rebuilding of Greensburg as a 100% renewable-powered city has been an inspiration to those looking to use a green model to recover from disaster.

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