National Renewable Energy Laboratory
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Rebuilding Greensburg, Kansas, as a Model Green Community: A Case Study

NREL's Technical Assistance to Greensburg June 2007 – May 2009

Lynn Billman

Technical Report
NREL/TP-6A2-45135
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Link to Appendices

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

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National Renewable Energy Laboratory
1617 Cole Boulevard, Golden, Colorado 80401
303-275-3000 • www.nrel.gov

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NREL subcontractors:
Deb Bowditch, consultant, Denver, Colorado
René Howard, WordProse, Inc., Golden, Colorado
Alex Lukachko, Joe Lstiburek, and Betsy Pettit, Building Science Corporation, Boston, Massachusetts
Dale Osborn, Distributed Generation Systems (DISGEN), Lakewood, Colorado
Duncan Prahl, John Holton, Ari Rapport, and Steve Bolibruck, IBACOS, Pittsburgh, Pennsylvania
Lauren Poole, consultant, Denver, Colorado
Christina Thomas, Sage TechEdit Inc., Boulder, Colorado
John Thornton, consultant
Daniel Wallach, Mason Earles, Emily Schlickman, John Wickland, and other staff of Greensburg GreenTown, Greensburg, Kansas
Michael Wentz, BuildingGreen, Brattleboro, Vermont
Thomas A. Wind, Wind Utility Consulting, Jefferson, Iowa

Other crucial contributors:
City of Greensburg staff and elected officials
Berkebile Nelson Immenschuh McDowell Architects, Kansas City, Missouri
BTI Equipment, Greensburg, Kansas
John Deere Place, Moline, Illinois
Dwayne Shank Motors, Greensburg, Kansas
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Wardcraft Home, Kansas
Brian Wendland, HERS rater, Greensburg, Kansas
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Executive Summary

On May 4, 2007, Greensburg was a declining farm community in south-central Kansas with a population of about 1,400. That evening, an EF-5 tornado touched down more than 75 times, killed 11 people, and destroyed or severely damaged 90% of the city. The storm left a trail of debris longer than 22 miles and wider than 1.5 miles. As Figure ES-1 shows, the devastation was incredible.

Credit: Photographer Galen Buller, Ingalls, Kansas
Source: http://www.pbase.com/gbphotos/image/78573248

Figure ES-1. The EF-5 tornado destroyed most of Greensburg on May 4, 2007.

When it was time to rebuild, key leaders in Greensburg and Kansas expressed an interest in rebuilding as a model green community. The U.S. Department of Energy (DOE) was interested in what could be accomplished with technical assistance from DOE and its National Renewable Energy Laboratory (NREL). DOE's ultimate goal was not only to help Greensburg but also to demonstrate energy solutions that could be replicated elsewhere.

Many federal and state agencies, along with nonprofit, professional, and other organizations and individuals, also reached out to help Greensburg with professional expertise or material or cash donations. The work summarized in this report, for June 2007 through May 2009, involves the projects in which the DOE/NREL team made significant contributions. Every project, however, including those summarized in this report, was substantially helped by other people and organizations. Key partners on these projects are mentioned where appropriate in the text.

Summary of Successes

The work of the DOE/NREL team contributed to numerous successful outcomes, running the gamut from broad effects on Greensburg—and beyond—to specific effects within the Greensburg city limits.

Community support for the green rebuilding work continues to be strong. The leaders in the City of Greensburg include the mayor, city council members, city administrator, school

superintendent, county commissioner, hospital administrator, Ministerial Alliance members (a faith community), major business owners, Greensburg GreenTown executive directors, and others. During the time that the DOE/NREL team worked with these leaders, advocacy for green technologies within the community grew from a handful of people to include essentially all the city leaders, the business community, and a majority of the residents.

A local nonprofit organization, Greensburg GreenTown, became a strong leader and advocate for energy efficiency in the community, working with both the city leadership and the residents. GreenTown—created by Executive Director Daniel Wallach, a local green enthusiast, shortly after the tornado—worked under a memorandum of understanding with the city to coordinate the Green Initiative in support of the community's sustainability goals. GreenTown also worked with NREL as a subcontractor. GreenTown's board of directors, made up of local citizens, was very effective in involving and inspiring the residents to take actions and make decisions reflecting sustainability goals; increasing media exposure for the community, which contributes to donations for projects; and educating the residents about sustainability. GreenTown is likely to remain active in the community and continue to offer support and leadership to the city on the Green Initiative long after the many initial outside entities have left the community. GreenTown is also expanding its mission to work with other small communities interested in sustainability.

The Greensburg work expanded professional knowledge and is serving to promote energy efficiency locally, regionally, and nationally. For example, several regional builders and architectural and engineering firms working in Greensburg benefited from technical assistance and training to increase their knowledge and competency in green building projects. These firms are now designing or constructing green, high-efficiency buildings throughout their customer base in Kansas, Missouri, and beyond.

A valuable new partnership between DOE/NREL and the John Deere Corporation developed out of a Greensburg project. John Deere is now a member of the Commercial Building National Accounts alliance,[1] a partnership between DOE/NREL and key leaders in retail businesses and other areas aimed at identifying and promoting energy efficiency in large commercial buildings. A second John Deere dealership in Kansas is being built based on the lessons learned in Greensburg. Finally, John Deere Place, the corporate focal point for dealership design and marketing, has redirected its business plan to promote energy efficient, green dealerships throughout North America.

Another valuable partnership has developed between DOE/NREL and DOE's EnergySmart Hospitals project. Advising on the design of the Kiowa County Memorial Hospital, one of the first sustainably designed hospitals in the country, will benefit the guidelines DOE/NREL prepares on hospital design.

The work of the DOE/NREL team stimulated economic development in the community. For example, a significant new green business started up in Greensburg. BTI Equipment in Greensburg, the local John Deere dealer, became the North American distributor for a Canadian wind turbine company, after having had a positive experience with this wind turbine in the building of their new dealership. In their first nine months of business, they built a North

[1] See http://www.nrel.gov/buildings/national_accounts.html.

American dealer network across 32 states and 4 Canadian provinces, resulting in 120 new wind-related North American jobs (mostly U.S. jobs, including wind specialists, service technicians, and installers); nearly 300 existing sales representatives are learning the new business of wind energy.

Working with local business and economic development committees, a feasibility study was completed analyzing the biomass resource quantity and quality, conversion technologies, potential market opportunities, and potential business viability for converting local crop residues to pellets for solid fuel heating. The study indicated that certain feedstocks and certain market conditions could lead to a successful business. This study might be pursued further by interested local individuals.

The work has resulted in extensive education and outreach efforts at several levels. The K-12 school in Greensburg has embraced sustainability (Figure ES-2). The school is expanding its curricula on energy and green technologies, with hands-on educational experiences for the students to understand the real world of energy and sustainability. The new school campus and building have been designed to Leadership in Energy and Environmental Design (LEED) Platinum standards.

Credit: City of Greensburg
Source: http://greensburgks.org/resident/photo-gallery/greensburg-schools-groundbreaking-ceremony

Figure ES-2. Students and community leaders break ground for the community's new school facilities on Wednesday, October 29, 2008.

The high school students in Greensburg have enthusiastically supported the community's goals, and formed a Green Club under the leadership of Greensburg GreenTown. As an example of their enthusiasm, Green Club students used tornado debris and other found items to create a bench for the community (see Figure ES-3) and presented it to city leaders in April 2009 as thanks for bringing Greensburg back as a model green town. And students have frequently publicly expressed their intention to stay in the community or return to it after college, because the green commitment has made Greensburg more attractive to these young people.

Credit: Lynn Billman, NREL

Figure ES-3. Members of the high school's Green Club designed and built this bench while honing their welding and building skills. They were assisted by Master Sculptor Dustin Sypher, Greensburg High School Shop Teacher Peter Kern, and Green Club Advisor John Wickland, but the idea of using tornado debris was their own.

To share information on disaster recovery, Greensburg has entered into a formal agreement with a city in China (Mianchu, Sichuan Province) that was devastated by earthquakes in 2008.

And a DOE/NREL team is developing a wide range of educational materials for homeowners; business owners; builders, architects, and engineers; and community leaders facing a disaster recovery situation:

- *Rebuilding after Disaster—Going Green from the Ground Up*: A 24-page brochure that covers the why and how of energy planning in disaster recovery.
- *Greensburg, Kansas—A Better, Greener Place to Live*: An 8-page brochure that presents the overall story of Greensburg's recovery to illustrate successful disaster rebuilding and inspire others.
- *From Tragedy to Triumph—Rebuilding Green Homes after Disaster*: A 4-page fact sheet for homeowners.
- *From Tragedy to Triumph—Rebuilding Green Buildings after Disaster*: A 4-page fact sheet for commercial and public building owners.
- *From Tragedy to Triumph—Information Resources for Rebuilding after Disaster*: A 4-page fact sheet for builders, architects, and engineers.
- *From Tragedy to Triumph—Using Renewable Energy after Disaster*: A 4-page fact sheet for community leaders and individuals.

- *Rebuilding It Better—BTI-Greensburg John Deere Dealership*: A 4-page fact sheet highlighting energy saving and generating features and NREL contributions to this premier example of rebuilding green.
- *How Would You Rebuild a Town Green?*: A trifold brochure on the Greensburg Sustainable Building Database, showing examples of the variety of buildings and projects that can save a community energy and increase renewable energy use.

In terms of specific effects within Greensburg, the community has gained an understanding of integrated energy planning. The townspeople and leaders collaborated with a number of partners to successfully develop a new *Greensburg Sustainable Comprehensive Plan.* With energy guidelines based largely on NREL's studies and recommendations, the plan contains strong energy goals for the community and documents a possible reduction of 36% of pre-tornado carbon dioxide emissions if the plan's energy goals are met.

The community has also learned a great deal about residential energy efficiency. In all, 180 new homes were permitted after the tornado and before March 6, 2009. A number of homeowners volunteered to have their homes rated for energy efficiency, representing approximately 52% of the new homes permitted. Of these, nine townhome rental units in one facility (Prairie Point Townhomes; see Figure ES-4) were rated. These 106 single-family homes and townhome units are projected to use, on average, 41% less energy than a standard home built to the International Energy Conservation Code (IECC) 2003 (with 2004 Supplement).

Of 33 homes renovated and measured, ratings indicate these homes should use, on average, 25% less energy than a similar home built to the IECC code. As a reference, ENERGY STAR® homes typically use about 15% less energy than a standard building.

Credit: Photo by Anita Hohl
Source: http://greensburg.buildinggreen.com/images.cfm?ProjectID=1437

Figure ES-4. The Prairie Point Townhomes achieved LEED for Homes Platinum certification in 2009.

For its public and commercial buildings, the City of Greensburg passed a resolution that all city-owned buildings would be LEED Platinum. This also inspired other public and commercial buildings, such as the Greensburg School and the Kiowa County Memorial Hospital (Figure ES-5), to strive for building designs that will reach LEED Platinum or Gold. Greensburg should

soon have the greatest concentration (buildings per square mile) of LEED Platinum and Gold buildings in the country.

Credit: Emily Schlickman, Greensburg GreenTown
Source: http://greensburg.buildinggreen.com/images.cfm?ProjectID=1310

Figure ES-5. Kiowa County Memorial Hospital, shown under construction here and scheduled for completion in 2010, is planned to become the first LEED Platinum critical access hospital in the nation.

Greensburg's business community is rebuilding with a major focus on energy efficiency and green building principles. The John Deere dealership is being constructed to achieve LEED Platinum status, and has become the model for all future John Deere dealerships across the nation. The General Motors dealership, local banks, and other businesses are also designing for energy efficiency.

Other examples include the following:

- The new streetlight system with light-emitting diodes will be 40% more energy efficient and cost the city 70% less in operating costs per year.
- The Greensburg Green Building Program, formally launched at the event marking the second anniversary of the tornado on May 1, 2009, reflects the city's commitment to ultimately adopt the IECC 2006 for both residential and commercial construction and to launch two voluntary programs.
- For the Greensburg GreenHome Program, the city entered into a formal partnership with the Kansas Building Industry Association (KBIA), a branch of the National Association of Home Builders (NAHB). Greensburg will pilot the International Code Council (ICC) National Green Building Standard (NAHB-sponsored), with the assistance of KBIA.
- For the Greensburg GreenBusiness Program, the city is encouraging commercial buildings to use American Society of Heating, Refrigerating and Air-Conditioning

Engineers (ASHRAE)/DOE building guides that give design recommendations for 30% energy savings.

Greensburg has committed to relying on locally generated wind power. The city decided to end its commitment to a long-term power purchase agreement with a coal-based rural electric cooperative, and entered into a contract with a power provider, Kansas Power Pool, that focuses on developing renewable energy generation sources. In addition, John Deere Renewable Energy, Kansas Power Pool, and the city have entered into an agreement to build a new 12.5-MW wind farm about 5 miles from Greensburg. Kansas Power Pool has made a commitment to offer "100% renewable electricity, 100% of the time."

The city has also adopted new regulations for distributed renewable generation**.** Under the new regulations, residents will be able to put solar panels and, where feasible, individual wind turbines on their businesses or homes. These rulings include a net billing policy, an interconnection agreement, and solar and wind ordinances.

Opportunities exist to use locally produced biomass pellets or briquettes as a source of heat in the commercial, industrial, and residential sectors. Regional entrepreneurs are using the results of a biomass pellet analysis to determine next steps in building a plant in the area.

Finally, the DOE/NREL team has recommended the best ways to use solar energy; alternative vehicles and fuels (compressed natural gas, 85% blends of ethanol in gasoline [E-85], and biodiesel); and district heating and cooling in this community.

Conclusion

Greensburg's accomplishments in rebuilding green in the first two years after its destruction by a disastrous tornado are extraordinary. A small, rural community with strong leadership and committed citizens can indeed rebuild differently, with major improvements to energy efficiency, uses of renewable energy, and overall sustainability.

Greensburg has been fortunate in the amount of media attention and government support it has received. The DOE/NREL team concluded that the many and rapid accomplishments of the community in rebuilding green were helped by Greensburg's broad and sustained media exposure and by the extraordinary support of the Kansas state government, the U.S. Department of Agriculture, and DOE. Other communities will be inspired by all that Greensburg has accomplished, but should not be discouraged if their path forward is more incremental. All steps taken toward more sustainable development will benefit a community, the nation, and the world.

Acronyms and Abbreviations

AFUE	Annual Fuel Utilization Efficiency
ANSI	American National Standards Institute
AIA	American Institute of Architects
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BNIM	Berkebile Nelson Immenschuh McDowell Architects
BSC	Building Science Corporation
DOE	U.S. Department of Energy
DSIRE	Database of State Incentives for Renewables & Efficiency
EERE	Energy Efficiency and Renewable Energy (a DOE office)
EPA	U.S. Environmental Protection Agency
FEMA	Federal Emergency Management Agency
GEM	Global Electric Motorcar
Gsf	gross square feet
HERS	Home Energy Rating System
ICC	International Code Council
ICF	insulated concrete form (wall system)
IECC	International Energy Conservation Code
KBIA	Kansas Building Industry Association
KMEA	Kansas Municipal Energy Agency
LED	light-emitting diode
LEED	Leadership in Energy and Environmental Design
Mcf	million cubic feet
MKEC	Mid-Kansas Electric Company
MOU	memorandum of understanding
MRI	Midwest Research Institute
MVP	McCluggage Van Sickle & Perry Architects
NAHB	National Association of Home Builders
NREL	National Renewable Energy Laboratory
PV	photovoltaics
SEER	Seasonal Energy Efficiency Ratio
Sunflower RC&D	Sunflower Resource Conservation and Development
USGBC	U.S. Green Building Council
VOCs	volatile organic compounds

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Introduction

On the night of May 4, 2007, an EF-5 tornado—the highest level on the standard meteorological scale used to estimate wind strength—demolished Greensburg, an agricultural community of about 1,400 in south-central Kansas. With 205-mph winds, the tornado cut a swath 1.5 miles wide and 22 miles long through the community. Eleven people were killed, and more than 90% of the city's structures (including some historic buildings), most vehicles, and the electrical infrastructure were destroyed or damaged. Most of the residents were displaced from their homes and businesses, which were leveled. Figure 1 shows the grim scene in Greensburg right after the tornado.

Credit: Photographer Galen Buller, Ingalls, Kansas
Source: http://www.pbase.com/gbphotos/image/78572891

Figure 1. Tornado devastation in Greensburg, Kansas.

But when the initial shock subsided and it was time to start rebuilding, the townspeople realized that they had been afforded an opportunity—a chance to turn a tragedy into a triumph. Conversations began about rebuilding as a model "green" community, and the idea quickly picked up steam. Soon after the storm, the U.S. Department of Energy (DOE) dispatched a team, including energy experts from the agency and its National Renewable Energy Laboratory (NREL), to Greensburg to assist the townspeople with the technical aspects of rebuilding along green lines. The hard work began immediately, and many national and local institutions, agencies, industries, and individuals pitched in.

The DOE/NREL team played an instrumental role in making the opportunity a reality, and this report summarizes the technical areas in which the team made significant contributions. First, the report examines the evolution of energy use in Greensburg, starting before the tornado and moving up to today. Next, the report summarizes available renewable energy sources and the integrated energy planning conducted in the area. This is followed by discussions of the work performed within each energy-related technical area—renewable resource availability; integrated energy planning; energy efficiency; renewable energy generation at both community and distributed (individual homeowner or business) scales; greener transportation options; green economic development; and leadership, outreach, and education.

The final project products are aggregated into the following appendices that are available electronically at www.eere.energy.gov/buildings/greensburg/publications.html:

- Appendix A: Cross-Cutting Information
- Appendix B: Residential Construction
- Appendix C: Commercial, Nonprofit, and Public Buildings
- Appendix D: Power Generation
- Appendix E: Alternative Transportation
- Appendix F: Green Building Codes and Standards
- Appendix G: Electricity Generation Policies and Ordinances
- Appendix H: Educational and Outreach Materials

Project Goals

In June 2007, representatives from DOE and NREL visited Greensburg, bringing a plan of action for rendering technical assistance to the city in key energy-related areas. The goals of the DOE/NREL project 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 June 2007 list of specific tasks was adjusted as work progressed, according to the evolving priorities and needs of the community in this unique situation.

DOE supported the project by supplying the funding for NREL's technical work in Greensburg.

Project Scope

The technical scope of NREL's work from June 2007 through the end of May 2009 encompassed various studies, recommendations, and plans. In addition, the team furnished specific guidance on individual projects, including several high-visibility buildings and design of a community wind system. Several factors determined which projects were given what level of priority at what time, such as the needs of the city and its major constituents; competing nonrenewable energy options that others brought forth; and the pressure to move forward quickly in rebuilding homes and businesses.

Although integrated energy planning should ideally be completed before implementing any energy-related projects, this was not possible in this disaster recovery situation. Some individual projects had to proceed while studies and discussions were shaping the overall energy plan. Under the real pressures of rebuilding a community and restarting a local economy, the team made compromises and adjusted the process to seize opportune moments as they arose to influence city decision making toward the ultimate goal of a model green community. Overall, during the project, the team studied and supported all energy areas originally planned within the

given budgets, and an integrated energy plan was ultimately created as part of the city's final *Greensburg Sustainable Comprehensive Plan* .[2]

NREL presented most of its studies to city leaders and residents in written and presentation formats and through meetings, mailings, and Web sites. The team also prepared short, formal recommendations on energy opportunities as necessary. NREL received and incorporated feedback from city leaders, various city groups, and advisers on these studies, recommendations, guidelines, and information. NREL's work in Greensburg is expected to be completed in fiscal year 2010.

Project Team

NREL established an office in Greensburg in space borrowed from either the Federal Emergency Management Agency (FEMA) or the Kansas Workforce Development organization. The NREL office was staffed full time from August 2007 through February 2008 with a rotating pair of architects who offered technical assistance on energy efficiency to residents and builders. At other times, the office was a base for NREL team members who visited for short periods of time.

NREL's team consisted of the individuals and subcontractors listed in Table 1.

Table 1. NREL Greensburg, Kansas, Team: Staff and Subcontractors

Name	Organization	Role or Specialty Area
Ren Anderson	NREL	Residential building
Lynn Billman	NREL	Project lead
Steve Bolibruck	IBACOS	Residential building energy efficiency
Eric Bonnema	NREL	Commercial building support
Deb Bowditch	NREL consultant	Communications
Alex Dane	NREL	Building codes
Mason Earles	Greensburg GreenTown	On-site coordination and support
Trudy Forsyth	NREL	Wind energy
Chris Gaul	NREL	District energy systems, biomass
Rachel Gelman	NREL	Biomass resource analysis
Alana Goodman	Greensburg GreenTown	On-site coordination & support
Scott Haase	NREL	Biomass utilization
Gerry Harrow	NREL	Alternative transportation
Catherine Hart	Greensburg GreenTown	On-site coordination
Al Hicks	NREL	Graphic design
John Holton	IBACOS	Residential building, building codes
René Howard	WordProse, Inc.	Writing and editing
Joe Lstiburek	Building Science Corporation	Residential building
Alex Lukachko	Building Science Corporation	Residential building
Anelia Milbrandt	NREL	Resource assessment
Ruby Nahan	NREL	Communications
Dale Osborn	Distributed Generation Systems	Wind energy
Dave Peterson	NREL	Biomass resource analysis
Betsy Pettit	Building Science Corporation	Residential building
Shanti Pless	NREL	Commercial & public buildings

[2] Visit http://www.greensburgks.org/recovery-planning/Greensburg%20Comprehensive%20Master%20Plan%2001-16-08%20DRAFT.pdf to download the plan.

Lauren Poole	NREL consultant	Communications
Adrienne Powell	NREL	Communications
Duncan Prahl	IBACOS	Residential building
Ari Rapport	IBACOS	Residential building
Emily Schlickman	Greensburg GreenTown	On-site coordination and support
Philip Shepherd	NREL	Biomass (landfill) resource assessment
Roger Taylor	NREL	Building efficiency
Paul Torcellini	NREL	Commercial building energy efficiency
Christina Thomas	Sage TechEdit Inc.	Editing
John Thornton	Consultant	Renewable generation: solar
Andy Walker	NREL	Renewable energy analysis
Daniel Wallach	Greensburg GreenTown	On-site coordination and support
Michael Wentz	BuildingGreen	Buildings database
Mary Werner (Colvin)	NREL	Technology manager
John Wickland	Greensburg GreenTown	On-site coordination and support
Tom Wind	Wind Utility Consulting	Wind energy

Many other federal and state agencies, professional organizations, universities, and nonprofit agencies sent representatives to help in Greensburg, and many of them had strong interests in energy and sustainability. NREL led weekly conference calls for those with interests in energy during the first year of the project. These organizations and individuals were instrumental in sharing ideas, disseminating information, developing related plans, and, in some cases, helping to fund Greensburg projects. The downside to this enthusiasm, however, was that the multiplicity of these many entities and of various citizen groups at times made coordination challenging as the team worked on making progress on energy plans and projects. This was particularly acute during the initial months of the project, but eased as the months passed.

The Evolution of Energy in Greensburg

Before the Tornado

Buildings were (and are) the largest users of energy in Greensburg. Established in 1886, Greensburg grew rapidly from 1900 to 1910, and its population peaked at 1,988 in 1960. When the tornado struck, the city was home to about 1,400 people in 515 single-family residences and 215 rental properties.[3] Greensburg also had a school, many businesses, and city offices. And as the seat of Kiowa County, the city housed the county courthouse, Kiowa County Memorial Hospital, the county library, and other county functions. Total gross square feet (gsf) of built space at the time of the tornado was estimated at 450,000 gsf for public buildings, 850,000 gsf for residential buildings, and 200,000 gsf for commercial buildings. Although exact data on the age of the structures standing before the tornado were not available, most were probably built during the boom period around 1960. They have been described anecdotally as having very poor energy efficiency measures, which was common at the time of their construction.

Before the tornado, the city acted as a municipal utility, selling electricity, water, sewer, and trash services to customers in Greensburg. A small portion of the revenue from the sale of electricity served as additional funding for other city departments, as is common in many rural communities. The city supplied electricity to residents and businesses through a power purchase agreement with Kansas Municipal Energy Agency (KMEA), which purchased power for its members through Mid-Kansas Electric Company (MKEC)/Southern Pioneer Electric/Sunflower Electric Power, and five city-owned dual-fuel (natural gas and diesel) generators with a total capacity of 6.5 MW. The generators were run on demand during peak periods or when there was a power outage. Base-load consumption was about 2.7 MW, with a peak load of about 4.3 MW. Electricity usage for about 1,000 customer accounts totaled 15.6 million kWh in 2005 and 14.0 million kWh in 2006, at an average retail price of 12–13¢/kWh. A 115-kV transmission line runs a few miles south of Greensburg.

Although no exact figures are available, annual natural gas use before the tornado was estimated at about 92,000 million cubic feet (mcf) at an average retail price of $7–$8/mcf.

Mid-Kansas Electric had about 1,000 MW of generating capacity in 2008. Although this capacity was predominantly coal based, about 100 MW was generated by wind (with additional wind capacity on the drawing board). BTI Equipment (a John Deere dealer) in Greensburg routinely burned corn and waste oil for some of the heat required in the dealership. There were no documented uses of solar photovoltaics (PV), solar hot water, biomass, or wind turbines for energy supply in Greensburg before the tornado.

Cars, trucks, and off-road vehicles were (and are) the second largest users of energy. Before the tornado, about 4,000 vehicles were used within a 30-mile radius of Greensburg, including about 100 flexible-fuel vehicles that could use gasoline or E-85 (85% ethanol, 15% gasoline blend), 300 diesel on-road vehicles, and 3,600 gasoline-fueled vehicles. Some of the larger fleet owners were Kiowa County, the Iroquois Center for Human Development, and Southern Plains Co-op.

[3] Berkebile Nelson Immenschuh McDowell (BNIM) Architects. *Long-Term Community Recovery Plan,* January 16, 2008, p. 26. http://www.greensburgks.org/recovery-planning/long-term-community-recovery-plan.

Many of these vehicles were destroyed in the tornado. Fuel sales volume was estimated at 1.6 million gallons of gasoline and 415,000 gallons of diesel. Alternative fuels (>10% ethanol blends, biodiesel blends, compressed natural gas, and propane) were not available in Greensburg.

Immediately after the Tornado

In the first few months after the tornado, everyone focused on regaining the stability of the community. Greensburg's first priority was to care for the needs of its citizens and restore services as quickly as possible. FEMA and Southern Pioneer Electric worked rapidly to make emergency electricity generators and phone service available. FEMA brought temporary trailers for those who indicated an intention to stay or move back into Greensburg, and to support city, county, and school functions. Figure 2 shows a mobile medical unit sent by Heart to Heart International, a humanitarian relief and development organization. And some businesses set up temporary operations in trailers or quickly constructed temporary metal structures.

Credit: Photographer Galen Buller, Ingalls, Kansas
Source: http://www.pbase.com/gbphotos/image/78690392

Figure 2. A mobile medical unit set up to offer assistance shortly after the storm.

Emergency generators supplied power until KMEA could—through its Mutual Aid Program—build overhead distribution lines to undamaged portions of the city and to the governmental trailers near the county courthouse at the center of town. Southern Pioneer Electric gave technical and physical assistance to the city in rebuilding the destroyed electricity distribution lines. Professional Engineering Consultants designed, and BBC Electrical Contractors and Parr Electric built, the new overhead electrical distribution system in less than 5 months. The $10-million distribution reconstruction project was funded 75% from FEMA, 10% by the state of Kansas, and 15% by the city, as is typical in disaster recovery. The entire community had electricity by December 2007. In June 2007, the city prepared a memorandum of understanding (MOU) with MKEC and Southern Pioneer that would require the city to sell them the distribution system and enter into a long-term power purchase agreement for electricity from Southern Pioneer at market rates. Ultimately, this MOU was not executed.

For immediate transportation needs, several agencies and entities donated older conventional vehicles to keep the city, county, school, and hospital fleets operating. Several new alternative-fueled or hybrid vehicles were also donated.

Energy in Greensburg Today

As of March 2009, about half the original population of 1,400 had returned to Greensburg and some new residents had moved in, for a total population of about 800. From the date of the tornado up to publication time for this report, the city issued approximately180 new home building permits. These included at least two rental properties, such that the number of individual homes available, including rentals, was about 225. A few remaining former residents are waiting for additional rental opportunities. The rest of the former residents have apparently resettled elsewhere. The city hopes to regain its former population of 1,400 by 2012, five years after the tornado.

Since the tornado, 71 building permits were issued for permanent commercial structures. About 50 individual businesses survived the tornado, have rebuilt, will soon be moving into business incubators, or have plans to rebuild or return.

By December 2007, electricity infrastructure was rebuilt, serving the entire community through 13.8-kV lines within the community and a 34.5-kV line around the outskirts of the community. Electricity is currently being supplied through a short-term agreement with Mid-Kansas. Current retail electricity rates are 12¢/kWh plus demand charges. Table 2 shows monthly electricity usage between December 2007 and October 2008.

Table 2. Example Amounts of Electricity Purchased by City from MKEC/KMEA

Month	Peak Kilowatt-hours	Total Kilowatt-hours
December 2007	1,100	780,133
January 2008	1,182	781,315
February 2008	1,838	810,629
March 2008	1,425	716,251
April 2008	1,320	606,791
May 2008	2,541	514,291
June 2008	1,620	610,935
July 2008	1,793	731,962
August 2008	1,916	649,098
September 2008	1,916	541,732
October 2008	1,411	593,722

11-month total	7,333,859
11-month average	666,987
Annualized total	8,003,846

Renewable Resource Availability and Integrated Energy Planning

Renewable energy resources are abundant in Greensburg and within a 50-mile radius.[4] Individual renewable energy resources are summarized here, but are discussed in more detail under various project accomplishments within the technical areas.

Wind resources are excellent, with wind power class 4, wind power density of 500–600 W/m^2 at 50-m height, and an average wind speed of 16 mph at 50-m height (Figure 3). Overall, Kansas is rated as the third-highest state for wind potential, although current state policies in Kansas are not as favorable for wind (or other renewable) energy as those of other states.

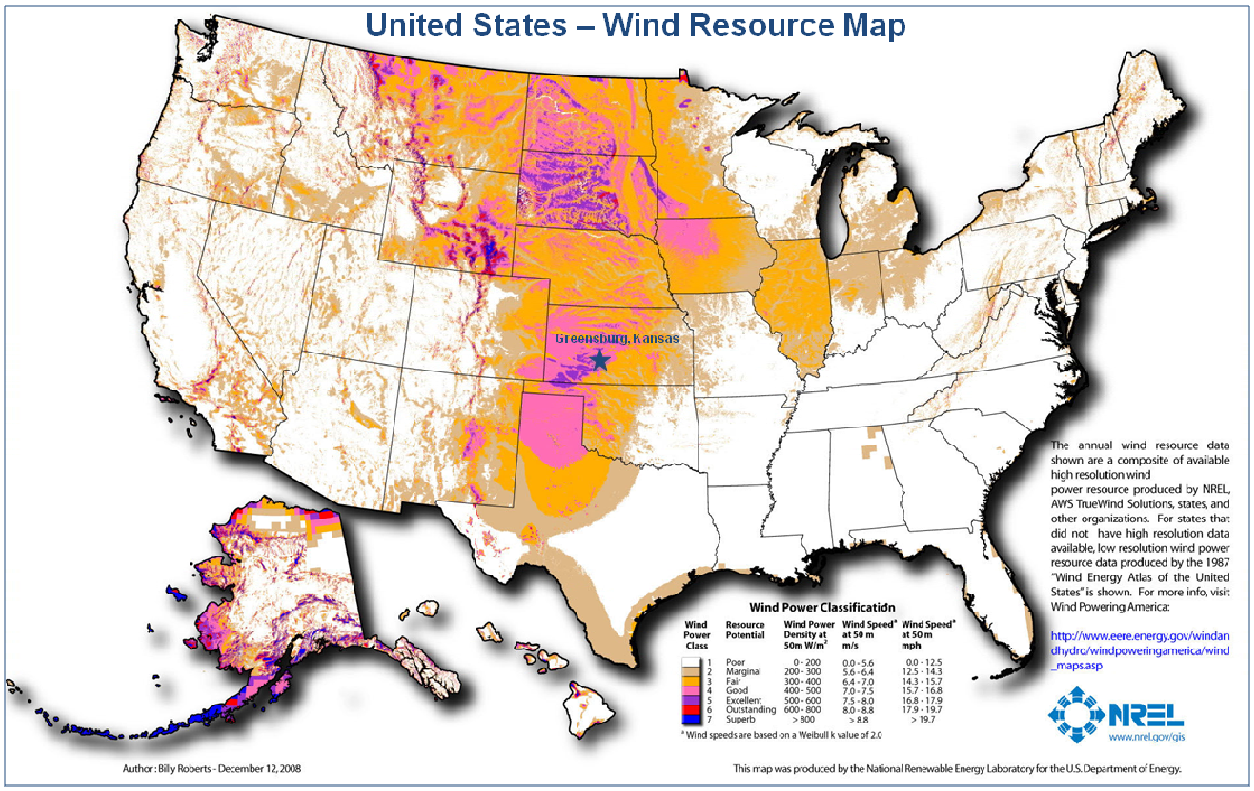

Figure 3. Wind resource map of the United States

Solar resources in the area are also very good, rated at 5.0–5.5 kWh/m^2/day (Figure 4). For comparison, the highest solar resources for flat-plate collectors in the United States are rated at 6.0–6.5 kWh/m^2/day in Arizona, and the lowest is Seattle at 3.5–4.0 kWh/m^2/day. In Greensburg, each kilowatt of a south-facing array mounted at 37.7° from the horizontal (Greensburg's latitude) would generate 1,200–1,400 kWh/year.

[4] See Appendix D, particularly D.2–D.9.

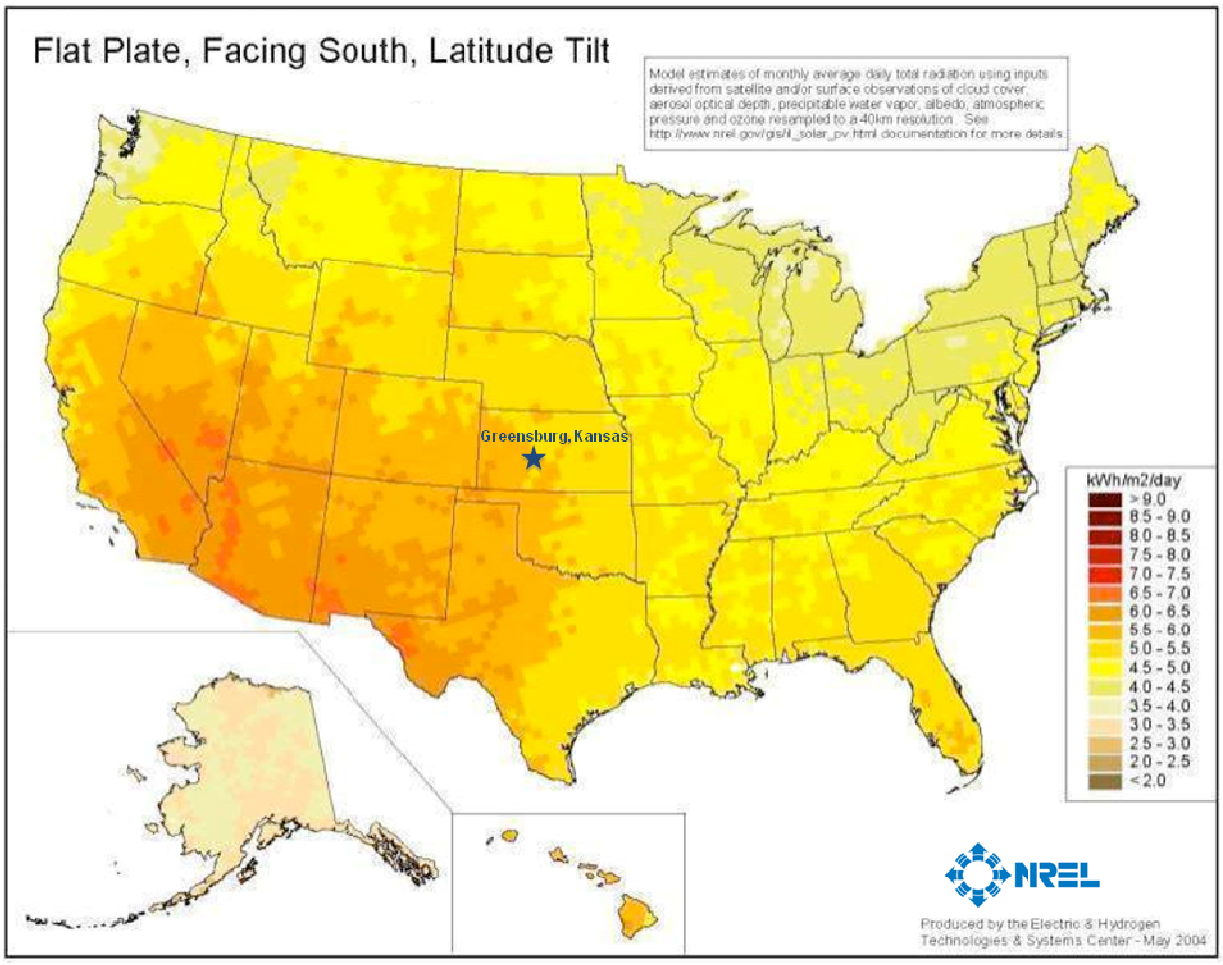

Figure 4. Annual PV solar radiation in the United States

Geothermal resources in the area are of low to moderate temperature, not suitable for electricity generation.

Integrated Energy 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*[5] led by FEMA, and then with the *Greensburg Sustainable Comprehensive Plan* led by BNIM Architects, a community planning and architectural firm in Kansas City, Missouri. Phase I of the comprehensive plan, which focused on land use and downtown design, began in September 2007 and was delivered in January 2008, an extremely short period of time for this type of plan. Phase II of the plan, adding implementation options and more details, was delivered and approved by the Greensburg City Council in May 2008. Energy

[5] FEMA. *Long-Term Community Recovery Plan: Greensburg + Kiowa County, Kansas.* August 2007. http://www.greensburgks.org/recovery-planning/long-term-community-recovery-plan/GB_LTCR_PLAN_Final_HiRes.070815.pdf.

considerations were a key component of both of the FEMA-led and the BNIM-led planning efforts, in which NREL was a major contributor. Figure 5 shows BNIM's architectural rendering of the Greensburg of the future.

Credit: Courtesy of BNIM

Figure 5. In rebuilding Greensburg, the importance of integrated master planning became clear. This architectural vision for the town from Greensburg's *Greensburg Sustainable Comprehensive Plan* emphasized walkability, which helps save energy. The master plan included NREL's recommendations on energy.

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:

- "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."[6]

NREL's integrated approach to energy planning considers the following areas:

- Reducing energy use in buildings, industry, and infrastructure
- Using renewable sources for electricity and heat at the community and distributed scales
- Using alternative transportation vehicles, fuels, and infrastructure
- Supporting new approaches with institutional and administrative actions.

[6] BNIM Architects. *Long-Term Community Recovery Plan,* January 16, 2008. http://www.greensburgks.org/recovery-planning/long-term-community-recovery-plan.

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 compared to those with exceptional characteristics, but more complex to operate.
- Strive for synergistic, integrated energy solutions.

The choice of the best renewable resources for any particular application depends on the resources available, energy requirements, operational requirements, economics, and goals of the decision makers. At the beginning of the work in Greensburg, NREL conducted an integrated energy modeling study to see if a modeling approach might give some immediate answers for Greensburg's energy plan.

Analysts now use a variety of computer modeling tools to determine the optimal choice of renewable energy technologies for any given community, military base, school system, or factory. NREL used a computer-based multivariate analysis approach to compare several electricity and heat sources against conventional fossil fuels for Greensburg to determine the optimal renewable energy mix for the community as a whole. This approach used estimates of the future energy requirements, knowledge of the local renewable resources, and estimates of the costs of all alternatives, then determined the most cost-effective solutions.[7]

This study verified that wind energy is the most cost-effective renewable source for electricity in Greensburg; agricultural residues were also favored for electricity and heat. Daylighting was considered not as an efficiency technology, but as an energy source in this study. Because NREL's recommendations were aimed at maximum cost-effectiveness and dependability, some technologies—among them geothermal direct usage, fuel cells, and microturbines—were not included in the study. And these findings offered only general guidance, because their practical application depends on factors beyond the scope of this case study.

Biomass resources in Kiowa County are abundant, but already under market and price pressures for production of not only food and feed but also corn and soybeans for nearby corn ethanol and biodiesel plants.[8] In 2007, corn and milo (grain sorghum) production rose to 711 million bushels, driven by high prices for ethanol feedstock grains. In 2008, the ethanol market began to decline. Corn ethanol plants near Greensburg include Garden City, which produces 55 million gallons/year, and Russell, which produces 48 million gallons/year. An existing corn ethanol plant in nearby Pratt went into receivership in 2008. Another ethanol plant proposed for mixed feedstocks, including cellulosic residues, has been partially funded through a DOE grant, and was still expected to be constructed in Hugoton. Figure 6 and Table 3 indicate the biomass residues available within a 50-mile radius of Greensburg.

[7] See Appendix A.3.
[8] See Appendix D, particularly D.9, D.10, and D.11.

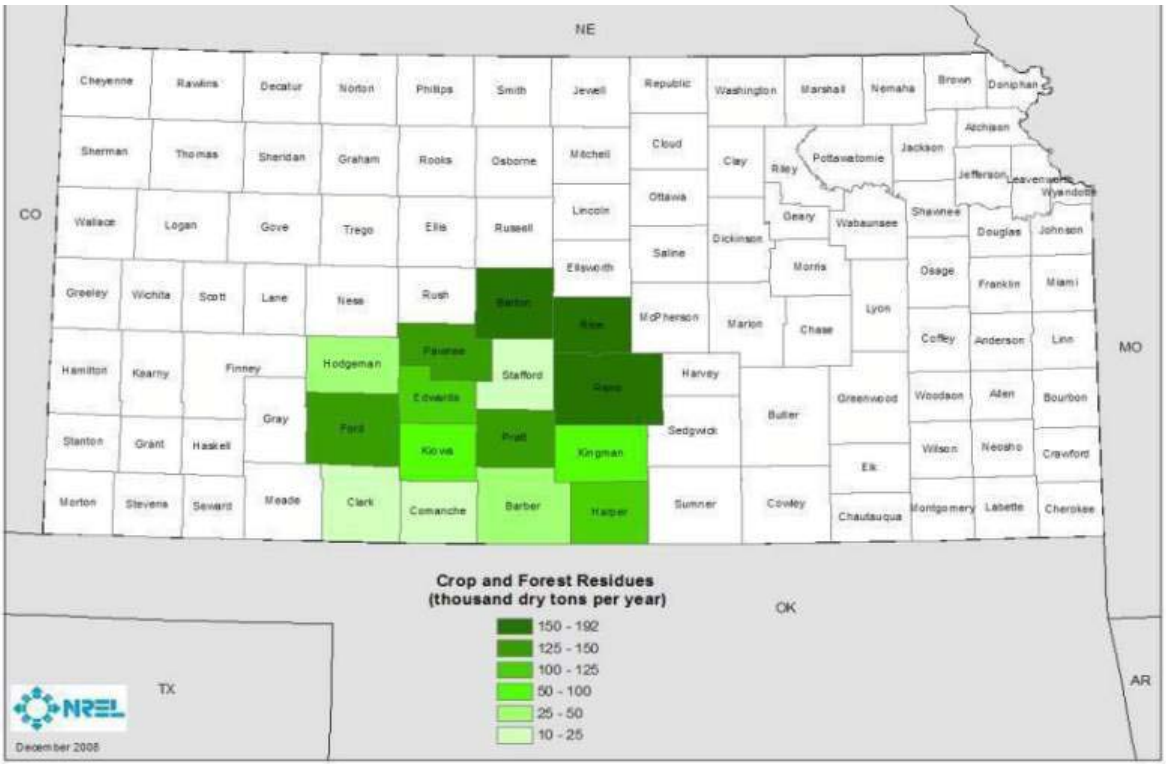

Figure 6. Crop and forest residues near Greensburg.

Table 3. Summary of Major Biomass Residues Available (billion dry ton per year [bdt/yr]) near Greensburg (10-year averages)

County	Wheat	Corn	Sorghum	Soybean	Sunflower	Cotton	Logging Residues	Other Forestry Removals	Corn Cobs	Total
Barber	25,283	407	4,004	1,337	46	210	161	2,818	623	34,888
Barton	74,604	17,556	47,399	14,320	222		22		14,760	168,882
Clark	469		9,681	345					218	10,713
Comanche	3,835	285	5,357	627					450	10,554
Edwards	31,955	39,921	18,599	21,961	60				31,913	144,409
Ford	55,368	22,632	53,883	10,214	136				21,533	163,765
Harper	96,815	146	9,270	1,821	65	436	0		135	108,687
Hodgeman	21,536	2,228	18,130	1,287					4,200	47,380
Kingman	78,586	5,270	8,869	6,458	185				3,810	103,177
Kiowa	17,281	15,562	12,205	12,255	24				15,113	72,438
Pawnee	59,127	21,710	35,327	16,494	52				18,915	151,626
Pratt	58,679	38,472	19,270	17,711	377	1,122		12,500	33,533	181,663
Reno	89,693	13,495	51,240	22,829	1,253		15		13,118	191,642
Rice	111,254	14,194	50,816	15,130	931		24		8,190	200,539
Stafford	35,258	18,182	20,366	14,845	85				31,935	120,670
Total	759,742	210,058	364,416	157,632	3,435	1,768	222	15,318	198,443	1,711,034

Source: Appendix D.10.

Energy Efficiency

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 30% 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] with 2004 Supplement.) 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 Figure 7 and Table 4). The costs were calculated based on national averages, because no Greensburg-specific cost data were available. Calculations show (Table 5) that for a 2,000-gsf house built to achieve 30% energy savings relative to standard practice, a homeowner can save $512 a year more on his or her energy bills than the extra cost of the slightly larger mortgage. In fact, Greensburg residents could use savings in utility bills to pay for higher energy efficiency in their new homes for a net positive cash flow every month up to a level from 30% to 50% improved energy efficiency. These calculations were summarized in a flyer that was distributed widely in Greensburg to help residents understand the long-term savings they would enjoy from an energy efficient home.[9]

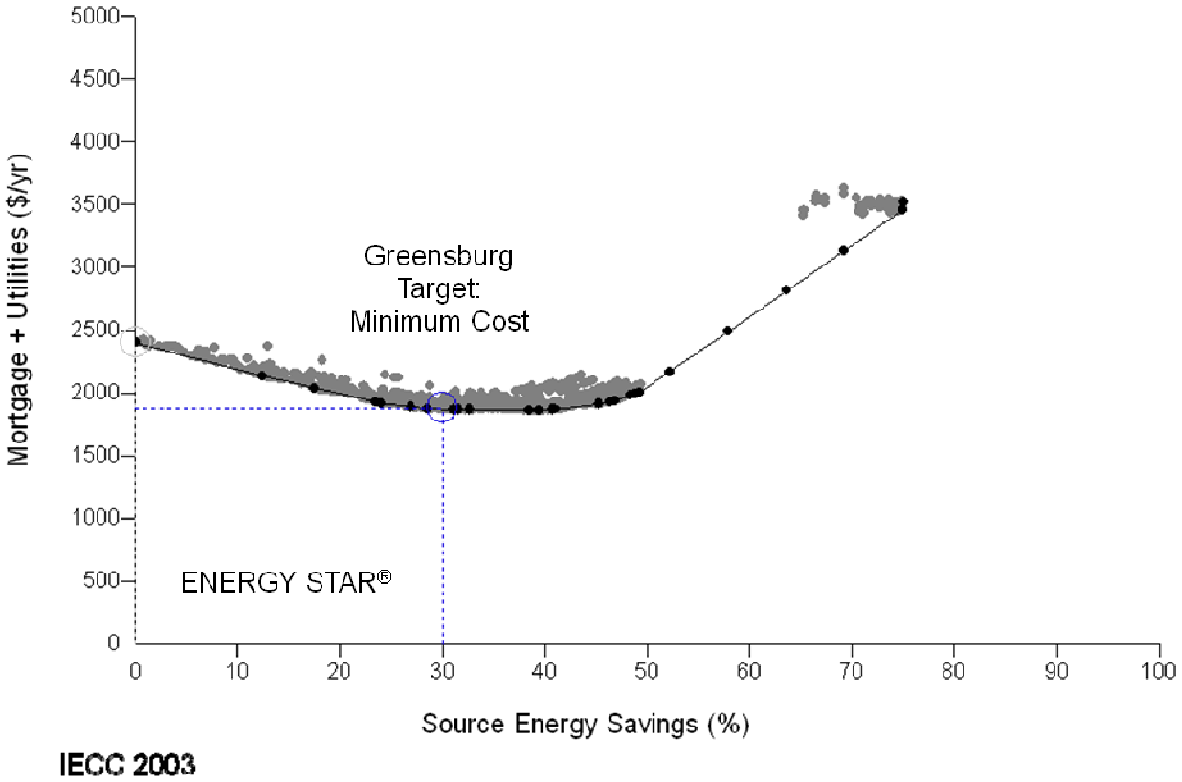

Figure 7. NREL analyses of cost versus energy savings.

[9] See Appendix B.

Table 4. 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,%)[a]	90+	90+	90+
Air-conditioning efficiency rating (SEER, Btu/watt-hour)[b]	14	18	18
Appliances	Standard	Standard	ENERGY STAR
Water heater	Tank—gas	Tank—gas	Tankless—gas
Energy factor[c]	0.61	0.61	0.80
Ventilation	Exhaust	Supply	Balanced

[a]AFUE (Annual Fuel Utilization Efficiency) is a rating system for the seasonal or annual efficiency of heating systems, expressed in percentages. The rating system takes into account the cyclic on/off operation and associated energy losses of the heating unit as it responds to changes in the load, which in turn is affected by changes in weather and occupant controls. Higher percentages indicate higher efficiencies.
[b]SEER (Seasonal Energy Efficiency Ratio) is a rating system for the efficiency of heat pumps and air conditioners. The SEER rating of an air-conditioning unit is the Btu of cooling output during a typical cooling season divided by the total electric energy input in watt-hours during the same period.
[c]The energy factor is a number indicating the overall efficiency of a water heater, the maximum being 1.0.

Table 5. Projected Monthly Energy Cost Savings for Energy Efficient Homes in Greensburg

For a Typical 2,000-gsf Home	**Upgraded Energy Savings Levels**		
	Base Efficiency ($)	High Efficiency ($)	Premium Efficiency ($)
Estimated incremental first cost	4,000	7,000	13,000
Savings on monthly utility bill[a]	60.25	76.58	96.83
Increase in monthly mortgage payment[b]	17.58	34.25	58.83
Net monthly savings	42.67	42.33	38.00

[a]Evaluated compared to IECC 2003 with 2004 Supplement.
[b]Based on a 30-year mortgage at 7% APR with an increase in loan value of $4,000 for the 30% option (base), $7,000 for the 40% option (high), and $13,000 for the 50% option (premium).

The key recommendations for residential construction that NREL offered the city in April 2008 are broken down by category and outlined in the sections that follow.

NREL Recommendations for the City

- Encourage all new residential construction to be designed, contracted, and built to achieve whole-house energy savings of at least 40% relative to minimum code using a green building approach.
- Encourage renovators of all existing residences and housing projects to target maximum cost-effective energy savings.
- Encourage residents and builders to design homes for potential solar use. As examples, one major roof slope should face south and buildings should be spaced to enhance solar access.

NREL Recommendations for the Homeowner

- Learn what actually makes a home energy efficient and gain an understanding of the benefits of an energy efficient home. Whether involved with new construction or renovation, better informed homeowners can make better choices among builders. Use local experts with reputable experience in energy efficient construction. The Internet has an astounding amount of good information from many reputable sources.
- Verify credentials and levels of experience with energy efficient construction of several builders before choosing one.
- Think ahead about solar panels. A homeowner may not be interested in solar panels right now, but orienting the home for solar (one major roof slope facing south) will make this choice more attractive in the future. A further enhancement would be to add wiring and plumbing (very low marginal cost during construction) to facilitate adding solar electric and hot water panels in the future.

NREL Recommendations for the Builder

- Seek continued education to improve skills and marketability in this fast-growing housing market. NREL and its subcontractors developed and gave training sessions for builders in Greensburg in July and December 2007; similar sessions will be offered periodically in the future.[10] Take advantage of the abundant information available on energy efficient home design and construction to improve knowledge. Besides information already available for the Greensburg climate,[11] NREL and its subcontractors developed a series of fact sheets on improving the energy efficiency of specific components of the house system specifically for Greensburg.[12]
- Learn about and stay current on the federal and state tax incentives available to builders for energy efficiency and renewable energy.[13]

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[10] See Appendix B.5.
[11] U.S. DOE Building America. *Designs that Work—Mixed-Humid Climate (Haymount, VA).* 2006. http://www.buildingamerica-greensburg.com/downloads/BSP-033_MH_Haymount.pdf.
[12] See Appendix H.
[13] Visit the Database of State Incentives for Renewables & Efficiency (DSIRE) at http://www.dsireusa.org/ for up-to-date information on incentives.

NREL Recommendations for Community Leaders and Businesses

- Encourage the further education of the homeowners and youth on energy efficiency. Bill Hanlon, an instructor in the Construction Technology program and director of the Sustainable Living Center at Flint Hills Technical College in Emporia, Kansas, and Russ Rudy, who was with the Kansas State Energy Office at the time, offered a homeowner session in February 2008. Similar sessions should be encouraged periodically. Various organizations have K-12 educational curricula on energy efficiency, and there are countless creative ways to involve students in energy efficiency projects to help teach math and science skills.
- Encourage all homeowners to get a Home Energy Rating System (HERS) rating on their homes, perhaps through the building permit process.[14] HERS ratings will tell the homeowner their energy efficiency, and are most effectively done both when plans are developed and after construction. A HERS rating is necessary to receive tax incentives or an energy efficiency mortgage, will help identify the most cost-effective energy measures, and will help isolate performance problems after construction.
- Work with the State of Kansas to continue to support a trained person to do HERS ratings in Greensburg at no or reduced cost after the DOE grant for the current rater is depleted.
- Establish a program to acknowledge and reward owners of highly energy efficient or green homes. This is more difficult to accomplish than it may seem at first glance. In any community, several stakeholder groups are naturally affected—homeowners, builders, and city staff issuing permits, among others. There are several existing home rating programs besides the HERS approach mentioned (ENERGY STAR, Leadership in Energy and Environmental Design [LEED], National Association of Home Builders [NAHB], and some specially developed by individual cities).[15] In most cases, stakeholders should be involved in developing the program, and administering the program will most likely require professional expertise.[16]
- Be cautious about donated materials for buildings. They can help reduce cost, but they should also have the characteristics that will best serve in the building in the long run for energy efficiency and durability, and should function effectively with other materials and building systems.

[14] See the Residential Energy Services Network Web site at http://www.natresnet.org/ for more information on HERS.

[15] NAHB. National Green Building Program™, http://www.nahbgreen.org/; U.S. Green Building Council (USGBC), http://www.usgbc.org/; and austinenergy.com Energy Efficiency, http://www.austinenergy.com/Energy%20Efficiency/Programs/Green%20Building/Participation/index.htm.

[16] Global Green USA. *Developing Green Building Programs—A Step-by-Step Guide for Local Governments.* Undated. http://www.globalgreen.org/docs/publication-71-1.pdf; P. Bruck. "Developing Green Building Programs or Ordinances," *Building Safety Journal.* August 2007. http://www.iccsafe.org/news/green/0807BSJ22.pdf.

Residential Energy Efficiency Solutions

Building Science Corporation (BSC) developed a 50% efficient house design appropriate for Greensburg, with full construction drawings, and offered house plans at no cost to any resident who wished to use them.[17] Greensburg Homes LLC (Greensburg, Kansas) used these plans for six high-performance spec homes it built and offered for sale in Greensburg (see Figure 8). BSC also took the initiative to find some companies who were willing to donate building materials appropriate for a high-efficiency home, and offered a package of materials worth $3,800 to the first 10 builders who were willing to build to 50% efficiency in Greensburg. The package of materials was also used in some homes by Mennonite Housing and others.

Credit (left): Greensburg GreenTown, NREL/PIX 16293
Source: http://greensburg.buildinggreen.com/index.cfm#search
Credit (right): Lynn Billman, NREL/PIX 16677

Figure 8. Left: High-efficiency homes under construction in Greensburg. The bright pink material is insulating vapor wrap.

Right: The finished homes.

BSC also conducted three training sessions (in July and September 2007, and in November 2008) for local builders. About 25 individuals from 12 different builders or organizations attended these training sessions, and several builders subsequently used these ideas in their plans. In addition, BSC prepared an educational display (see Figure 9), which was erected on a prominent street in Greensburg for several months. Finally, BSC produced a series of fact sheets (see Appendix B.4) for local builders on key aspects of construction details—ranging from insulation through ventilation to appropriate ductwork—that make a difference in energy performance.

[17] See Appendix B.7.

Credit: Lynn Billman, NREL

Figure 9. This educational display consists of a full-size corner section of a home, showing how advanced framing, advanced windows, and caulking can be used to save energy.

The Mennonite Housing organization, which helps low-income individuals build affordable, single-family homes with so-called sweat equity, adopted NREL's recommendations for the construction of high performance homes in the Greensburg climate region. Key features of NREL's package of recommendations follow:

- Water management for durability through the installation of a wall drainage plane with effective flashing at windows and doors
- Excellent insulation, including fiberglass in the attic, rigid foam on basement walls, and a layer of exterior foam board on the walls—as well as cellulose inside the walls—for condensation control
- Good-quality windows with low-e surfaces and argon gas fill for good insulation and solar control
- Extensive caulking and sealing to reduce air leakage
- A high-efficiency gas furnace (94 AFUE) and air conditioner (SEER 14)
- All ductwork installed inside the insulated envelope of the house
- Controlled fresh air ventilation with exhaust fans in kitchen and baths ducted to the outside
- Compact fluorescent lighting.

So far, 20 such houses have been built and as many as 50 are planned. Figure 10 shows a Mennonite house during construction.

Credit: Lynn Billman, NREL

Figure 10. Mennonite house under construction in Greensburg.

IBACOS (Integrated Building and Construction Solutions) contributed to the planning process as well, developing sections on residential energy efficiency for both the *Long-Term Community Recovery Plan* and the *Greensburg Sustainable Comprehensive Plan*. IBACOS 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 an NREL office in Greensburg 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 a week through November 2008. This technical assistance 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.

Major housing projects that benefited from extensive technical assistance included modular homes by Wardcraft (modular homes built off site) as well as the Prairie Point townhomes (32 units; see Figure 11), which were subsequently managed by Kiowa County. The Prairie Point project was an in-fill development on land where the high school once stood. Each structure has 2 × 6 framed walls with blown-in cellulose insulation, and the concrete slabs were constructed using a "floating floor" design. Every townhome has compact fluorescent lights and low-flow toilets, showerheads, and aerators. To the extent possible, ENERGY STAR appliances were used in the kitchen and laundry room. High-efficiency air-source heat pumps were used, and the homes achieved an overall HERS score of 64. All interior walls of the apartments were painted with low-VOC (volatile organic compound) paint. Biobased tile forms much of the flooring. Drought-resistant landscaping and turf and an efficient irrigation system complete the complex.

All of the homes mentioned and pictured here were designed to save 45%–50% of the energy compared to a home built to the standards of IECC 2003 with 2004 Supplement.

Credit: Mason Earles, NREL/PIX 16644
Source: http://greensburg.buildinggreen.com/images.cfm?ProjectID=1437

Figure 11. The Prairie Pointe Townhomes have achieved LEED for Homes Platinum status.

IBACOS also gave significant oversight to the 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.

IBACOS and NREL also installed energy monitoring equipment in two of the Mennonite homes. The monitoring period is December 2008 through December 2009.

The measured results of these efforts at technical assistance, education, and encouragement in the residential area are impressive, as seen in the HERS rating in Table 6. Of the 180 new homes permitted after the tornado and before March 6, 2009, approximately 52% were voluntarily rated for energy efficiency. Of these, nine townhome rental units in the Prairie Point complex were measured. These 106 single-family homes and townhome units are projected to use, on average, 41% less energy than a standard home built to the IECC 2003 code with 2004 Supplement. Of 33 homes renovated and measured, ratings indicate these homes should use, on average, 25% less energy than a similar home built to IECC 2003. As a reference, ENERGY STAR homes typically use about 15% less energy. Obtaining a HERS rating was voluntary. As a result, these numbers should not be extrapolated to be an average for all of the rebuilding and renovation after the tornado.

Table 6. Residential Energy Savings in Greensburg, Kansas

Type of Construction	Average HERS Rating	Average Energy Savings (%)[a]	Number of Houses/Units
New construction	59	41	106
Renovations	75	25	33

[a]Energy savings compared to a home built to the IECC 2003 code with 2004 Supplement.

Local builders also benefited from this residential building effort. At least eight individual companies or builders used the formal training, on-site discussions, building plans, and fact sheets to affirm and often go beyond their level of understanding of the best practices for high performance homes. Three of these companies have affirmed in anecdotes that they are already building higher-efficiency homes in all their markets, including beyond Greensburg; other builders can be assumed to be benefiting as well.

NREL subcontracted with BuildingGreen, a green publishing company, and Greensburg GreenTown, to develop and populate the Greensburg Sustainable Building Web site. This online database makes descriptions of green residential homes available to the wider home-building community as part of the effort to maximize the benefit from the DOE work in Greensburg in its application to other similar communities.[18]

Energy Efficiency Solutions for Commercial and Public Buildings

The goal for commercial and public building reconstruction in Greensburg was to encourage and help owners in rebuilding to as high an energy efficiency level as possible. Although the original action plan included only the school complex (K-12), it soon became apparent that other excellent opportunities existed as well.

NREL staff members gave presentations to city leaders about the benefits of energy efficiency in these buildings, suggested specific guidelines and goals, and distributed copies of Advanced Energy Design Guides.[19] These guides give design specifications to achieve 30% energy efficiency compared to code, in specific climate zones, for small retail, small office, warehouses and self-storage facilities, and schools.

In addition to these educational efforts, NREL staff ran highly advanced energy models using the latest version of EnergyPlus to optimize the designs of several high-profile buildings that were intended to achieve a Platinum LEED level. These buildings included the Sun Chips Business Incubator (owned by the city; Figure 12), the Greensburg School Complex, the Kiowa County Memorial Hospital, and the BTI Equipment/John Deere dealership. NREL staff also did extensive energy modeling for the renovation of the Kiowa County Courthouse, badly damaged but not destroyed in the tornado (Figure 13). Finally, NREL and IBACOS staff offered varying amounts of technical consultation on the construction of Shank Motors (General Motors dealership); Greensburg State Bank; Dillon's Kwik Shop (Figure 14); Centerra Bank; People's Bank; Fleener Life Celebration Center; the Senior Center; and several churches.

[18] Visit http://greensburg.buildinggreen.com/ and click on "Our Projects" to explore the Greensburg Sustainable Building Database.
[19] ASHRAE, et al. *Advanced Energy Design Guides.* Available for free download at http://www.ashrae.org/publications/page/1604.

Credit Lynn Billman, NREL/PIX 16660
Source: http://greensburg.buildinggreen.com/images.cfm?ProjectID=1151

Figure 12. The Sun Chips Business Incubator in Greensburg is designed to offer affordable spaces for businesses getting back on their feet, as well as for new retail ventures. This building received a major funding boost from Frito-Lay Sun Chips division, a company known for its environmental advocacy, and additional help from actor Leonardo DiCaprio, a well-known sustainability advocate.

Credit: Catherine Hart, Greensburg GreenTown, (left) NREL/PIX 16671, (right) NREL/PIX 16670

Figure 13. In rebuilding the Kiowa County Courthouse in Greensburg—originally constructed in 1914—the community decided to salvage the original white trim (left) along with several ornate doors (right) from the stately and historic building. The rebuilt structure is a highly energy efficient green building and serves as an excellent example of building design that combines the best of the old and the new.

Credit: Photographer Galen Buller, Ingalls, Kansas
Source: http://www.pbase.com/gbphotos/image/112145081

Figure 14. This hybrid convenience store/gas station, completed in February 2009, features an insulated concrete form (ICF) wall system, skylighting, light-emitting diodes (LED) for lighting, and high-efficiency refrigeration.

NREL joined BNIM in recommending that Greensburg adopt a resolution that all city-owned buildings (more than 4,000 square feet) be designed to a LEED Platinum level with a minimum of 42% energy cost savings. The city passed this ordinance in December 2007. In addition, NREL also made the following more general recommendations to the city in April 2008:

- Encourage all new commercial, nonprofit, and non-city-owned public buildings to be designed, contracted, and built via a green building approach to achieve at least 30% energy efficiency compared to current building code.
- Strive for at least 30% energy efficiency, because the specific, integrated design recommendations needed by architects and builders for office buildings, small retail, and some other types of buildings are already determined at this level for this climate and available to all owners, architects, and builders free of charge.[20] Better yet, strive for 40%–50% energy efficiency.
- Incorporate additional green features as outlined to achieve at least the LEED Silver certification level.
- Use an integrated, whole-building design to minimize cost.[21] The only way that highly efficient buildings can be built at the same cost as or only slightly more cost than conventional code buildings is if energy efficiency, reduced water use, and other green features are designed in from the beginning.[22,23] Siting, building orientation, building envelope, daylighting, windows, overhangs, and many other features all work together to lower energy use. Using building energy modeling programs during the design phase will

[20] ASHRAE, et al. *Advanced Energy Design Guides.* Available for free download at http://www.ashrae.org/publications/page/1604.
[21] See Appendix C.3.
[22] D. Langdon. *Cost of Green Revisited: Reexamining the Feasibility and Cost Impact of Sustainable Design in the Light of Increased Market Adoption.* July 2007, http://www.davislangdon.com/upload/images/publications/USA/The%20Cost%20of%20Green%20Revisited.pdf.
[23] USGBC Web site. Green 101 and 102 presentations from the Green Affordable Housing Training in Chicago, Illinois, November 5, 2007. http://www.usgbc.org/DisplayPage.aspx?CMSPageID=1810.

help with this integrated design, identifying the options that minimize energy use at the lowest cost.[24]

- Use a competitive bidding process, which will help building owners identify the architects and builders who have the most experience, knowledge, and training to design and build energy efficient buildings.
- Use specific recommendations for metal building efficiency developed for Greensburg. Metal buildings are inexpensive for commercial construction (low capital costs), but often are not designed to be energy efficient (high life-cycle costs) to the levels required to achieve Greensburg's goals.[25]
- Establish a program to acknowledge and reward owners of highly energy efficient or green government, nonprofit, and agency buildings.

The results of these efforts in technical assistance, training, and encouragement include a substantial list of high-performance buildings (Table 7). Several of these buildings have been described in some detail in the Greensburg Sustainable Building Database. The database includes buildings on which NREL had significant influence on design, and other buildings in which NREL did not have direct consultation, but which are nonetheless important examples of energy efficiency that were influenced by the overall efforts of NREL, BNIM, McCluggage Van Sickle & Perry (MVP) Architects, and others.

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 (see Figures 15 and 16), is under consideration for LEED Platinum status, and has become the recommended model for all future John Deere dealerships in North America. The General Motors dealership, Greensburg State Bank, Centerra Bank, People's Bank, the Kiowa County United Building (a second business incubator), and other businesses are also designed for exceptional energy efficiency.

Credit Lynn Billman, NREL.

Figure 15. The John Deere dealership in Greensburg, Kansas, owned by BTI Equipment, uses two wind turbines to produce electricity for the building.

[24] See Appendix C.3.
[25] See Appendix C.6.

Credit: Lynn Billman, NREL
Source: http://greensburg.buildinggreen.com/images.cfm?ProjectID=1150

Figure 16. The John Deere dealership burns waste oil in this boiler to heat its service shop.

All of these buildings feature extensive natural daylighting (see Figure 17), a well-insulated envelope, and high-performance lighting and controls. Some include ground-source heat pumps; two have PV panels; two have wind turbines; and two more are trying to procure wind turbines. As shown in Table 8, Greensburg—with 1 square mile and 800 residents—may soon have the greatest concentration (buildings per square mile) of LEED Platinum and Gold buildings in the country.

Table 7. Selected High-Performance Commercial and Public Buildings in Greensburg

Building	Owner	Size (gsf)	Design Intent	Certified Award (as of March 2009)
Sun Chips Business Incubator	City of Greensburg	9,580	LEED Platinum, 50% energy savings	Not available
City Hall	City of Greensburg	4,700	LEED Platinum	
Kiowa County Courthouse (renovation)	Kiowa County	18,600	LEED Gold	
Kiowa County Commons	Kiowa County	14,800	LEED Platinum	
Kiowa County Memorial Hospital	Kiowa County	48,500	LEED Platinum	
Greensburg K-12 School	USD422 School District	120,000	LEED Platinum	
5.4.7 Art Center	5.4.7 Art Center	1,670	LEED Platinum	LEED Platinum

Prairie Point Townhomes (32 units)	Kiowa County	24,000	LEED Gold	LEED Platinum
BTI Equipment John Deere Dealership	BTI Equipment	30,000	LEED Platinum, 42% energy savings	
Dillon's Market	Dillons	8,000	Not available	
Dwane Shank General Motors Dealership	Dwane and Ester Shank	8,300	Not available	

Credit: Lynn Billman, NREL

Figure 17. This photo of the parts area in the John Deere dealership building clearly shows the power—and beauty—of daylighting.

Table 8. LEED-Certified Buildings in Greensburg Compared to Kansas and United States as of March 2009

LEED Certification Level	**United States** (certified)	**Kansas, not including Greensburg** (certified)	**Greensburg** (certified)	**Greensburg** (not yet certified/design intent)
Platinum	117	0	2	6
Gold	679	2	0	1

A Green Building Program for Greensburg

Greensburg was interested in a formal green building program from the earliest days after the tornado. The primary desire expressed was to develop a checklist representing the key features of a green building that could be used as the basis for an award or recognition.

The NREL project did not originally budget for helping the city develop a green building program. Also, because of the abundance of existing programs already available and nationally recognized, the NREL residential energy team did not agree with the idea of developing a program unique to Greensburg. During 2007 and early 2008, staff from the U.S. Environmental Protection Agency (EPA) took the lead on developing a unique green building program for the city. NREL offered written comments on this proposal. The city did not adopt the EPA guide, opting instead for a green building program that would garner more support from local builders and could be recognized at a national level.

Beginning in September 2008, the city expressed an interest in having NREL's assistance on formalizing green building codes. As of that date, Greensburg used the 2003 International Residential Code for residential buildings and the 2003 International Building Code for commercial buildings. Both codes contain health and safety specifications along with very limited energy provisions. Kansas has no required code for residential structures, and adopted IECC 2006 for commercial buildings without any enforcement mechanism in the state statute.[26]

From October 2008 through February 2009, NREL and IBACOS summarized the rapidly changing field of green building codes and green building programs at three briefings for a city leadership team. At each discussion, recommendations were updated based on the feedback from the city and the best available options. The city expressed concerns about how the residents, business owners, and builders would respond to perceived higher building costs for green buildings, and about how the city staff would learn the new energy code or program requirements.

In the period of these discussions, the National Association of Home Builders (NAHB) through the American National Standards Institute (ANSI) completed the transformation of their Model Green Home Building Guidelines into the National Green Building Standard. This has been adopted by the International Code Council (ICC) as the ICC 700-2008. The NREL team approached NAHB about a partnership with the City of Greensburg to help them conduct a pilot program for this new standard. At NAHB's suggestion, this partnership was pursued at the state affiliate level with the Kansas Building Industry Association (KBIA). NREL prepared a draft MOU for this partnership, in which the city would adopt the National Green Building Standard as a voluntary program and KBIA would give training, offer some discounted services, and support public awareness of the partnership. Greensburg welcomed this partnership approach as a response to the city's concerns about learning the new energy-related building requirements and options. Also, the city felt that KBIA's solid reputation with local builders would help allay some of the fears about perceived higher costs of green building.

[26] See Building Codes Assistance Project. http://www.bcap-energy.org/node/69.

In March 2009, based on these discussions with the city and NAHB, and new information about incentives for building code development related to the February 2009 *American Recovery and Reinvestment Act,* NREL made its final recommendation to the city. The NREL team recommended that the city establish a Greensburg Green Building Program, consisting of two main elements, the Greensburg GreenHome Program and the Greensburg GreenBusiness Program.[27] NREL recommended the overall adoption of IECC 2006 as the basic energy code because it applies to both residential and commercial sectors and has reasonably achievable energy requirements. Given the city's concerns about perceived costs and new code complexity, the NREL team decided that, as a separate commercial energy code, American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) 90.1 might be too difficult for the city to implement at this time.

In addition to adopting IECC 2006 as code, NREL recommended that the city encourage higher energy efficiency and green performance on a voluntary basis. The program to guide voluntary residential efforts would be the partnership with KBIA, using the ICC 700-2008, National Green Building Standard. The program to guide voluntary commercial efforts would be to encourage or incentivize architects and builders to use the ASHRAE Advanced Energy Design Guides, which spell out climate-specific design recommendations for four common commercial structures that will achieve 30% energy use improvement compared to ASHRAE Standard 90.1.

The city approved a portion of the overall Greensburg Green Building Program in April 2009. The portion approved at that time was the voluntary GreenHome Program and the related memorandum of understanding between Greensburg and KBIA. As of May 2009, the city was still working with NREL to move toward adopting either the IECC 2006 or IECC 2009 building codes. This adoption may be phased, first with commercial buildings and later with residential. A voluntary GreenBusiness Program is also being discussed.

Efficiency in City and County Infrastructure Equipment

City and county infrastructure includes street lighting, lighting at fairgrounds and parks, water and sewage pumps, and other miscellaneous motors and generators. The NREL team recommended that the city and county choose equipment for their infrastructure with the highest practical energy efficiency. These include high-efficiency lights using LEDs for streets, parks, and parking lots; high-efficiency pumps for water and sewage; and high-efficiency motors and generators in shops and other miscellaneous uses.

Although not all these areas have reported results, the city did install LED streetlights, with project design by Professional Engineering Consultants (Wichita, Kansas). Greensburg appears to be the first city in the United States to use all-LED streetlights. The new streetlight system should use 40% less energy compared to standard metal halide streetlights, and cost the city 70% less in operating costs per year. The streetlights are pictured in Figure 18.

[27] See Appendix F.

Credits: City of Greensburg (top left); Lynn Billman, (top right) NREL/PIX 16665, (bottom) NREL/PIX 16664
Source: http://greensburg.buildinggreen.com/images.cfm?ProjectID=1395

Figure 18. Daytime and nighttime views of the LED streetlights along Highway 54, the primary east-west highway through town, along with a close-up of a single streetlight.

Community-Scale and Distributed Power

Community-Scale Power

As noted earlier, the city's electrical distribution system was destroyed by the tornado. Using insurance, state, and FEMA funding, the city and local contractors rebuilt the distribution system and delivered electricity to every resident within about six months. The city also quickly developed a draft MOU with the rural electric cooperative, largely coal based, with whom they had done business for many years, to disband the Greensburg municipal utility and enter into a long-term power supply contract. Before the MOU was finalized, however, the city leadership and the community became increasingly interested in moving forward with a green vision.

In August 2007, NREL staff member Trudy Forsyth and subcontractor Tom Wind of Wind Utility Consulting gave a public presentation in Greensburg on community-scale wind systems.[28] They introduced the possibilities for Greensburg, using examples of other communities that had been successful in completing wind projects. Several city and county officials attended, as did a handful of interested residents.

Further, NREL and its subcontractors Wind Utility Consulting and Distributed Generation Systems helped the city arrive at these goals for a community-scale electricity solution:

- Sell electricity at retail rates about the same as before the tornado, including covering the city's expenses for staff and other obligations at the same level as before.
- Design an electricity system that would be reliable and reasonable for city staff to operate and maintain.
- Produce enough electricity so that peak conditions would be met.
- Be as close to 100% green as possible, in support of community goals for sustainability.
- Demonstrate a solution that other communities in Kansas could possibly emulate.
- Clearly demonstrate a cutting-edge green electricity source.
- Offer flexibility to the community to determine its electricity source as technologies and opportunities change in the future.
- Minimize the uncertainties and financial risk inherent in fossil-fuel-based electricity costs and supply in the future.

In contemplating a project to generate wind energy for the city, some city leaders expressed the irony that the power of the wind destroyed the community in May 2007, and now the community wanted to harness the power of that wind for their benefit. To accentuate the positive, Greensburg GreenTown adopted this slogan: "Greensburg: A Wind-Wind Situation."

Greensburg's future energy requirements were assumed to be at least equal to the energy requirements before the tornado, plus some uncertain amount beyond for growth in new businesses and industries. The NREL team prepared an analysis indicating that the excellent

[28] See Appendix D.2.

wind resource in this area of Kansas was likely to make a 4-MW grid-connected wind energy system a feasible option for supplying 100% of the city's annual electricity needs. (Figure 19 graphs historical and projected electricity supply requirements.)

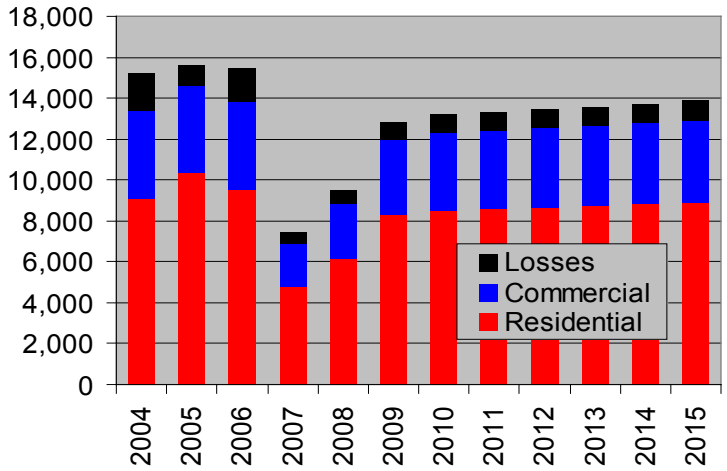

Figure 19. Greensburg historical and projected electricity needs in megawatt-hours.

NREL also recommended to the city that several other technologies should not be considered prime candidates for community-scale electricity supply for Greensburg, for the following reasons:

- Purchase of renewable energy credits (buying a certificate that pays for the extra generation cost of some other entity's wind turbines or solar systems): This would not visibly demonstrate the city's commitment to renewable energy.
- Conventional grid electricity: The current Mid-Kansas generation mix, at 10% renewable and the rest primarily coal, obviously met several of the goals. But it would not ensure clearly demonstrated 100% green electricity or flexibility, or avoid risks of future fossil fuel costs.
- Geothermal power plant: Ground temperatures at reasonable depth would be too low for electricity generation.
- Solar thermal electric: The solar resource would be insufficient and the project would be too small to be economical.
- Fuel cells: For electricity alone, the cost would be higher than other options. Fuel cells are best for large cogeneration (heat and electricity) loads, such as a possible future industrial park.
- Diesel generators: Operating cost would be uncertain, and sometimes could be extremely high; diesel generators require biodiesel to meet 100% green goal, and the biodiesel supply and cost would be uncertain.
- Natural gas generators: The future cost of natural gas would be uncertain and the technology is not 100% green.
- Wind turbines with vanadium battery storage: The cost would be high.

- Wind-electrolyzer system using hydrogen storage: The technology is immature and the cost would be high.
- Wind-compressed air energy storage: The relatively small size of the system and the unlikelihood that suitable underground resources would be available in the area would make this impractical.
- Wind turbines with ice storage: This would be more suitable for a single building rather than a community.
- Gasification of biomass as a substitute for natural gas: The fuel supply would be uncertain and the technology is immature.
- PV: The cost would be high.

Beginning in August 2007, Tom Wind prepared a set of extensive feasibility studies on this and other configurations for possible wind systems for Greensburg. In December 2007, Dale Osborn of Distributed Generation Systems joined Tom and NREL staff in a series of meetings involving the city leadership, representatives from the state energy office, representatives from two rural cooperatives, and several other stakeholders to debate the pros and cons of the city's electricity options. In January 2008, Marc O'Connor, Tom Rath, and Ben Speed from Maxon Holdings also joined the team to assist with financing opportunities. Tim Lenz of Professional Engineering Consultants, under contract to the city, assisted throughout the process with electrical engineering expertise. In April 2008, NREL arranged a site visit for Greensburg city representatives with counterparts in two small communities in Colorado—Lamar and Springfield—that had experience owning and operating one or more wind turbines (see Figure 20). This visit helped convince the Greensburg city staff that owning and operating a wind turbine would work for their community.

Credit: Leon Sparks
Source: Presentation, City of Lamar Light & Power and ARPA /Springfield Wind Project, Colorado Wind and Distributed Energy Conference, April 2004.

Figure 20. Talking with community leaders in Lamar, Colorado, who had experience operating these wind turbines, helped convince Greensburg leaders that wind-generated electricity would be feasible for their town as well.

By January 2008, the city had decided to retain ownership of its distribution lines and thereby remain a municipal utility, which preserved the city's flexibility in determining its future energy choices as its sustainable community vision unfolds. The city made a short-term rather than long-term arrangement to continue to purchase electricity from its conventional supplier while studies and decision making were in process. Greensburg also chose to remain connected to the grid because energy storage would have added markedly to the cost of electricity.

Wind resource data for Greensburg were estimated from public databases, refined through a more detailed computer algorithm, and finally measured with meteorological equipment beginning in June 2008. The intended site for the wind turbines was at the edge of Greensburg city limits, and about 1 mile from the major highway passing through the community, which would be not only an excellent wind resource but also an excellent visual message for the city.

The team helped the city form a new relationship with the Kansas Power Pool, a rural electric cooperative with a strong renewable energy generation portfolio who expressed a desire for additional wind generation capacity for its city members. Representatives of Kansas Power Pool indicated an interest in not just 4 MW of wind generating capacity, but as much as 10–12 MW. Kansas Power Pool also agreed to formalize an understanding with the city that Kansas Power Pool would manage their generation resources such that renewable energy, whether wind or other available resources such as hydropower, would be available to Greensburg 100% of the time. This was an expression of support from Kansas Power Pool to the city, given its difficult challenges in recovering from the tornado devastation.

The business strategy recommended by the team was the model known in the wind industry as the Minnesota Flip model. In this model, 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. The city's ability to sell renewable energy credits helped the economics of that proposed business model. The team continued to work through July 2008 on developing this business strategy and pro forma, and to identify investors who could give the capital and debt equity for the project, estimated at $22 million for a turn-key 12-MW system.

After initially declining interest in developing a 4-MW system, John Deere Renewable Energy finally did express an interest in being the developer for a 12.5-MW wind system to serve the city. In September 2008, based on the speed with which a system could be installed and expected lower electricity costs in the initial years of the project, Kansas Power Pool and the city decided to go with the John Deere Renewable Energy proposal. Based on the information that was shared at that time, the NREL/Maxon team endorsed this decision.

The Greensburg Wind Farm will include 10 turbines, each rated at 1.25 MW. John Deere Renewable Energy will build and maintain the wind farm, and it will sell power to the Kansas Power Pool. Greensburg expects to consume about a quarter of the electricity the wind farm generates. When the wind is not blowing and the turbines cannot generate electricity, the Kansas Power Pool will have enough other clean power sources online, including hydropower, to meet the community's goal of being powered entirely by renewable sources.

Before the tornado, the city owned five dual-fuel generators (diesel and natural gas) totaling 6.5 MW of capacity. Under the new electricity agreement with Kansas Power Pool, additional peak power was not expected to be required. The other purpose of those original generators, as back-up power in an emergency, was rendered unnecessary by the use of individual generators by key service providers. Therefore, the city decided not to replace the diesel generators.

Distributed Power

The goal for distributed power in Greensburg was to identify power solutions for individual homes, businesses, or district systems that could cost-effectively produce heat or electricity from solar, wind, biomass, or geothermal resources. Because of the potential for donations, fuel cells were also considered. The NREL team assisted the city in developing and adopting ordinances and policies to support distributed wind and solar systems. Team members prepared feasibility studies on options for small wind turbines, PV, and a downtown district heating and cooling system. Biomass options, regardless of scale, are discussed at the end of this section.

Distributed Power Policies and Ordinances

NREL developed four related policy documents for the City of Greensburg: Interconnection Agreement, Net Billing Tariff, Wind Ordinance, and Solar Ordinance.[29]

[29] See Appendix G.

The Interconnection Agreement describes the details of the requirements and commitments for the city municipal utility and the owner of a distributed wind or solar regarding how that system is interconnected to the municipal grid. The city adopted the Interconnection Agreement.

The Net Billing Tariff describes the financial agreements between the municipal utility and customer. Net billing encourages the installation of distributed wind and solar by allowing the electricity produced by these systems to run the owner's meter backward, effectively valuing electricity produced by the owner's system at the retail rate for municipal utility electricity. This gives more value to the system owner than the current Kansas parallel generation legislation, which only allows the system owner to receive a payment for his solar or wind electricity that is a little more than the grid operator's wholesale cost of electricity. Without net billing, small wind and solar systems are likely to be rare in Greensburg because of the high capital costs. Limiting net billing to distributed systems up to 100 kW, and using a "perpetual" approach such that system owners are never paid outright for extra electricity their systems generate, discourages entities from installing systems large enough to end up effectively competing with the municipal utility. The city adopted the Net Billing Tariff.

The Wind and Solar Ordinances describe details of installation and operation requirements to enhance safety and lessen potential issues with these distributed technologies, and were adopted by the city.

Greensburg may have to create additional guidance or ordinances at some time in the future on solar access (e.g., making sure that one owner's solar panels are not shaded by another owner's building additions or growth of trees or shrubs). Encouraging the use of solar panels should not, however, be delayed until solar access is clarified at the city level. For this type of community, solar access may be able to be effectively handled case by case.

Distributed Wind Systems

NREL recommended that individual, public, and business land and property owners consider generating their own electricity using wind turbines if they have sufficient space (e.g., turbines setbacks from property lines must be at least equal to the height of the turbine), meet other city requirements for the safe installation and interconnection of relatively quiet wind turbines, and can afford or finance the turbines.[30]

NREL recommended against attaching wind turbines directly to buildings or building components to generate electricity. Wind turbines produce significantly less electricity in an urban setting or close to a building because tower heights are generally restricted and wind patterns are disrupted by the building, adjacent trees, other buildings, and other obstructions. Also, many small wind turbines, especially older models, can be noisy and induce vibration if secured to a building component.[31]

One resident wanted to install a wind turbine on a city-sized, one-quarter-acre lot, which was not large enough to meet the setbacks NREL had recommended in the Wind Ordinance. NREL's wind team, and other experts from the DOE Wind Program's Community Wind project, developed a short white paper further analyzing the key issues that influenced the

[30] See Appendix D.4.
[31] See Appendix D.7.

recommendations for setbacks: safety, visual impacts, sound emission, and economics.[32] Although the NREL team appreciated the recognition in the community of the value of wind energy and distributed wind turbine usage in the Greensburg city limits, the team also had to control the expectation that every homeowner could lower their electrical bill by putting up a wind turbine outside their back door. The city followed NREL's original recommendations.

As of February 2009, two building owners had installed small wind turbines in Greensburg. The BTI Equipment John Deere dealership, located just outside of city limits, installed both a Southwest Windpower Skystream, rated at 1.4 kW, and an Endurance turbine, rated at 4.2 kW. The Endurance turbine has been operating constantly since it was installed in March 2008. It powered the John Deere dealership job site and produced between 1150 and 1250 kW per month in 2008. Together the two wind turbines offset approximately 8% of the building's electrical load.

The 5.4.7 Art Center, designed by students from the University of Kansas Studio 804 graduate design/build program, has 3 Kestrel wind turbines connected to a bank of 12 batteries. Each wind turbine is rated at 600 W. Actual power output data are not available.

As of March 2009, the Greensburg K-12 School and Kiowa County Memorial Hospital each intend to add a wind turbine, perhaps with 50 kW capacity, to their new facilities. Success will depend on finding additional funds or a financing mechanism to lower upfront capital costs.

Distributed Solar Systems

NREL's solar subcontractor, John Thornton, prepared a feasibility study analyzing appropriate uses for PV systems in Greensburg.[33] The study emphasized the importance of first optimizing energy efficiency in any building being considered for solar, and presented the current market prices for PV. It identified many appropriate uses for PV in Greensburg, as noted in the following recommendations.

NREL recommended in April 2008 that individual, public, and business land and property owners consider generating their own electricity from PV panels where desired. It was noted, however, that small PV systems were still not cost-effective at this time compared to grid electricity, especially in Kansas, which has no state incentives. But some entities may want to install PV for noneconomic reasons. To generate the greatest electricity, NREL recommended that PV panels be mounted on a south-facing slope, ideally at an angle of 37.7° from the horizontal (plus or minus 20° will still work). PV panels should also be installed in accordance with city guidelines. They can be connected to the grid (less expensive) or to batteries (more expensive) for off-grid applications. PV panels can easily be used for lighting signs at night for businesses and city and county buildings (batteries required); for overhead shade as well as electricity when used as window awnings, carports, and canopies for gas stations; for powering park pavilions; for powering streetlights with LEDs; and on farms and ranches to control irrigation, pump water, run a workshop, and maintain communications.

As of March 2009, a few buildings in Greensburg had PV panels or they were under construction. The city-owned Sun Chips Business Incubator has a 6.8-kW DC system on the roof

[32] See Appendix G.5.
[33] See Appendix D.8.

that should produce 10% of the building's total energy load. The 5.4.7 Art Center has eight panels. Solar panels are planned for the Greensburg City Hall, which is under construction (see Figure 21). And Bauer Power in Michigan donated a 2-kW PV system with inverter (Figure 22) to Greensburg GreenTown for its Silo Eco-Home.

Credit: Emily Schlickman, Greensburg GreenTown
Source:http://greensburg.buildinggreen.com/overview.cfm?projectid=1341

Figure 21. Greensburg City Hall, scheduled for completion in July 2009, will house the city's administrative offices and council chambers and serve as a gathering place for town meetings. The building incorporates solar panels and geothermal technology, and the city is striving to make it the first LEED Platinum-certified city hall building in America. Building materials include recycled wood and reclaimed brick left in the storm's wake. The east end of the roof will feature living vegetation (a so-called "green roof").

Credit: Lynn Billman, NREL

Figure 22. This 2-kW PV array supplies power to the Greensburg GreenTown Silo Eco-Home. Pictured are David Moffitt the home's architect, and Executive Director Daniel Wallach and Mason Earles of Greensburg Greentown.

For solar hot water, NREL recommended that entities in Greensburg consider the use of solar hot water systems with care. To be effective, a solar hot water system has to be very carefully designed and skillfully installed for freezing conditions. Even then, system performance can be degraded by losses from long pipe runs from the panels and mismatch of solar resource with use patterns. Investments in solar hot water systems are typically not as cost-effective as investments in energy efficiency (insulating pipes, a building design with short pipe runs, and highly efficient water heaters, including tankless heaters).

Solar hot water systems are, however, generally more cost-effective than PV systems. NREL recommended that building owners consider solar hot water systems if initial cost is not a major issue or if a building owner wants to install solar hot water to achieve a zero-net-energy building or to demonstrate the use of solar energy.[34] In commercial applications, solar hot water systems are most easily justified where there is large hot water demand such as showers at the school, a motel, hospital, or industrial plants with high hot water usage.

Distributed Geothermal Systems

Geothermal energy for homes and buildings is captured through a ground-source heat pump, which is simply a two-way air conditioner with a low-energy circulating loop that transfers heat to and from the ground through pipes buried underground. The fluid carries heat from the earth to the building in the winter, and carries heat from the building to the earth in the summer. NREL recommended that individual, public, and business owners consider the use of ground-source heat pumps, depending on local costs.

The primary concern with ground-source heat pumps is the relatively high and hard-to-predict cost of installation because of the drilling or trenching necessary to bury the pipes in the ground. The ground loop inherent in a ground-source heat pump system typically doubles the first cost of a conventional heating/cooling system. Annual energy costs can, however, be reduced by as much as 70% compared to conventional electric heating and cooling. Costs vary depending on the local soil conditions and water table depth, the familiarity of the installer with the locale and technology, and the number of units being done. Although not yet widely adopted in Kansas, numerous residential and large commercial systems are being built nearby in Oklahoma. Homeowners, businesses, or public entities collaborating on a shared (district) system using ground-source heat pumps can reduce the cost and make this solution more economical.

As of March 2009, ground-source heat pumps had been installed or chosen for the designs of at least four public buildings:

- 5-4-7 Art Center (3 wells, 200 feet deep)
- Greensburg K-12 School
- Sun Chips Business Incubator (21 wells, 340 feet deep; see Figure 23)
- Kiowa County Courthouse (32 wells, 300 feet deep)

[34] DOE EERE. *Volume 6: Building America Best Practices Series – High Performance Home Technologies: Solar Thermal & Photovoltaic Systems.* June 4, 2007. NREL/TP-550-41085. http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/41085.pdf.

Five homeowners have also installed ground-source heat pumps. This is not an exhaustive list. Other facilities in Greensburg may have already installed or plan to install ground-source heat pumps.

Credit: City of Greensburg
Source: http://greensburg.buildinggreen.com/images.cfm?ProjectID=1151

Figure 23. This photo of the mechanical room in Greenburg's Sun Chips Business Incubator building shows the ground-source heat pump's loop piping.

District Heating and Cooling Systems

NREL recommended that Greensburg pursue district heating and cooling systems with caution. District heating and cooling systems use a centralized set of heating and cooling equipment with underground pipes to carry hot or cold water or air to a set of closely located buildings. They are used quite successfully in such applications as college campuses, office parks, and downtown districts. In Greensburg, no situation lent itself well to centralized ownership of a set of closely located buildings with large enough heating and cooling loads to make such a system economical, nor was there a business model in which a heating and cooling system owner could economically develop a district system for individual users.

The downtown district was studied as a possible application. Greensburg's "Big Well" is immediately adjacent to the downtown district. The Big Well, 23 feet in diameter and 109 feet deep, was hand dug in the 1880s and supplied city water from 1888 to 1932. Since 1937 it has been a significant tourist attraction. The district heating and cooling study noted that using the 55°F water in the Big Well, if circulated to a nearby set of buildings in a closed-loop system, might produce some of the summertime cooling required. This was identified as a potentially unique use of Greensburg's most important tourist attraction as an energy asset for the city.[35] The high cost of installing the underground pipes, the relatively small loads, the uncertainty of when individual business owners would build, and whether they would consent to be part of the district system, though, made the project very high risk. Homeowners or businesses or public agencies who can work together in a modest geographic area to develop more than one building into a heating and cooling district could make the idea worth reconsidering. The study was done

[35] See Appendix D.12.

only on the concept of the independently owned lots in the downtown area without such a collaboration.

Fuel Cells

As noted earlier, some major corporate donors showed interest in assisting Greensburg. One of these was UTC Power. NREL and UTC discussed UTC's latest fuel cell systems, and concluded that the most cost-effective application would be users with high energy needs for both heat and electricity. Next-generation fuel cell technology, to be introduced to the marketplace in 2009, may significantly lower the life cycle cost of energy compared to previous technology. This type of fuel cell technology uses natural gas to generate electricity and heat (cogeneration), and can be used for chilling as well (trigeneration). In the near future, UTC plans another commercial advance that will operate on anaerobic digester gas or biomass gasification instead of natural gas. Both methods produce a product similar to natural gas from biomass.

The fuel cell technology currently available is not as modular as renewable energy systems and requires large energy loads to be cost-effective, including large heating loads. No single load currently planned in Greensburg is large enough, but the future industrial park might be the type of load that is a good match for the capabilities of a next-generation fuel cell system.[36] Operating a fuel cell with digester gas would bring such a system closer to Greensburg's goals for 100% green power, but this technology requires maturation and demonstration before being considered by Greensburg.

In 2008, UTC Power donated three 5-kW polymer electrolyte membrane fuel cells to the Greensburg K-12 School. UTC also donated an electrolyzer to generate the hydrogen gas needed as the fuel for the fuel cells. The fuel cells will be used for back-up generation during an emergency or power outage, using wind-generated electricity for the electrolyzer.

Energy from Biomass

Biomass is generally considered to include such energy sources such as wood or forestry waste, agricultural products or residues, municipal solid waste, methane or manure form cattle feeding lots or other animal operations, or crops grown especially as an energy resource.

Biomass can be gasified in a high-temperature, oxygen-starved environment to make synthesis gas, a mixture of hydrogen and carbon monoxide. Gases generally burn cleaner and more efficiently than solids, avoiding the release of particulate matter into the atmosphere. After gasification, the synthesis gas can be used in place of natural gas. In Greensburg, the DOE/NREL team did consider using municipal solid waste for producing electricity. But because only a relatively small quantity of waste is available, the team determined that installing a gasification system—of any scale—would not be cost-effective.

Manure from cattle feed lots and dairy farms represents an energy source that could be fuel for the feed lot or dairy operations and produce valuable byproducts. Feed lots have long been a

[36] See Appendix D.13.

staple, and dairy farms are expanding, in western Kansas.[37] Such an operation could be designed as a closed-loop energy and material system, though such operations are in the experimental stages, through use of anaerobic digestion. This technology is fully commercial in Europe and is beginning to be widely adopted in the United States. Most animal feed lots or other operations were, however, too far from Greensburg to be useful to the city. No further feasibility studies were done for this idea.

In the course of learning about sustainable living and building design following the tornado, some of the leaders in the community also realized that urban debris in the form of scrap lumber or downed trees could also be a useful source of biomass for recycling in buildings and trim. Not realizing this at the time, however, the community burned most of the debris from the tornado as quickly as possible. The team discussed with the local residents ideas about collecting and composting yard clippings and other suitable urban waste for use on local gardens in support of the community's interest in locally grown foods.

Biomass can be cofired with coal to reduce greenhouse gas emissions, if allowed by local regulations. With 53,000 acres of Conservation Reserve Program land in Kiowa County that could be planted in switchgrass or similar energy crops, 27,610 acres of corn producing stover and cobs, and a railroad line through Greensburg, such biomass could be collected, compressed, and shipped to a coal plant. No further feasibility studies were done for cofiring, although biomass collection and densification has been evaluated.

NREL recommended in April 2008 that entities in Greensburg consider using biomass, especially agricultural wastes, for various solid fuel, commercially proven, heating applications. Boilers are available that will burn almost any type of dry biomass to generate hot water; and heaters are available that will burn corn or biomass pellets, briquettes, or other solid or loose forms of material. Boilers and heaters need to have emissions acceptable to Kansas and EPA regulations. Collecting and supplying waste biomass to use with boilers in the community, or pelletizing biomass into a solid fuel for customers using heaters in the community, could represent a business opportunity for an entrepreneur.[38]

Based on community interest in this idea, NREL subsequently developed an extensive feasibility study for the concept of developing a pelletizing mill in or near Greensburg using biomass residues. Because the larger amounts of potential biomass feedstocks reside mostly outside the city limits, the pelletizing feasibility study considered counties within a 50-mile radius of Greensburg.

NREL conducted its study in cooperation with Sunflower Resource Conservation and Development (RC&D), a local nonprofit. The study consisted of several steps:

- Understand the local biomass resource base.
- Assess potential biomass resource chemical and performance characteristics.
- Assess local competitors (both for biomass feedstocks and for pellets produced).

[37] Kansas Department of Agriculture Web site. "Kansas Dairy in Industry," 2006. http://www.ksda.gov/dairy/content/122.
[38] See Appendix D.9.

- Understand the economics of the process.
- Assess the local market and potential for biomass to produce thermal energy.

A detailed biomass feedstock assessment was conducted as part of the analysis; the appendices contain the technical report with assessment results.[39] The current pellet market is dominated by premium pellets, predominantly from clean-burning wood products, which have ash content less than 1% and low alkalis. The actual agricultural residue samples tested from the study area, however, indicated high ash content and high alkalis. High ash leads to excessive amounts of ash to dispose of, and high alkali content leads to excessive slagging, which contaminates the combustion equipment. In addition, some agricultural residues do not bind into pellets as readily as wood, creating greater fines.

The partnership with Sunflower RC&D identified a local person who had access to a substantial amount of eastern red cedar, which is cleared as an undesirable competitor with crops in local fields. In contrast to the agricultural residue samples, the clean-burning eastern red cedar was suitable for premium pellets. This individual suggested the possibility of using wood-agricultural residue blends as a potential feedstock.

The study considered wood-agricultural residue pellets compared to the primary competitors for providing process heat, which include natural gas, propane, electricity, cedar chips, and unprocessed straw bales or other unprocessed agricultural residues. The study also examined several potential competing pellet companies, including wood-pelletizing companies and the closest cellulosic/corn ethanol plant in development. One company was identified (Show-Me-Energy Cooperative of Centerview, Missouri) that had developed a plant to make pellets from biomass residues; this company contributed their experiences to the conclusions of the study.

One large industrial company was identified in the area that could be a substantial user of pellets for heating. This company, National Gypsum of Medicine Lodge, Kansas, expressed some tentative interest in considering biomass pellets to replace natural gas. A detailed economic analysis should be conducted for National Gypsum to evaluate this option.

A study of process and market economics included the investment costs of a startup pellet plant, total feedstock costs, costs of competing natural gas, and the difficulty of customers changing from natural gas combustion equipment to pellet combustion equipment.

The key conclusions of the study were as follows:

- There is potentially enough agricultural residue feedstock and eastern red cedar to support a 24,000 ton/year pellet, briquette, or bripell plant making wood-biomass blended pellets with potentially acceptable performance characteristics.
- Given market prices in early 2009, biomass pellets will have a hard time competing with industrial natural gas rates. Pellets are much more competitive when compared to propane, fuel oil, electric heat, and commercial and residential natural gas.

[39] See Appendix D.10 and D.11.

- Cedar chips and unprocessed straw bales are lower cost biomass resources than any pellet, although these feedstocks are bulkier to store and more difficult to feed into boilers.
- The need for end users to buy a new boiler or furnace is a barrier; third-party financing might be helpful.
- Considerable market development efforts are still needed:
    - There are not many incentives for users to switch to biomass at this time.
    - There are not incentives to be the first biomass pellet plant owner.
- A carbon tax or a national renewable portfolio standard may change the situation dramatically.

NREL does not intend to continue any further development of this study at this time.

Transportation Alternatives

A major consideration for any sustainable community is reducing the use of gasoline and diesel fuel, which are major contributors to carbon dioxide and other emissions. NREL analyzed the fleet composition before the tornado, availability of various fuels, cost of new infrastructure such as dispensing equipment for new fuels, and interest on the part of key stakeholders in using alternative fuels and alternative fueled vehicles.[40] Alternative fuels include electricity; biofuels such as ethanol/gasoline blends and biodiesel/diesel blends; compressed natural gas and propane; and hybrid vehicles (combining electricity and gasoline) and plug-in hybrids (an emerging technology that includes the ability to charge the vehicle in an electrical outlet, increasing the electricity use and range of a hybrid vehicle; Figure 24).

Credit: City of Greensburg, NREL/PIX 16667
Source: http://greensburgks.org/resident/photo-gallery/scholfield-honda-civic-donation/SANY0106.JPG/view

Figure 24. Scholfield Honda in Wichita donated this natural-gas-powered Honda Civic to the City of Greensburg.

Table 9 lists other vehicles donated to or purchased in Greensburg.

Table 9. Alternative Transportation Options Donated to or Purchased in Greensburg

Type	Technology	Number	Donor	Owner/Driver
Honda Civic	Compressed natural gas (CNG)	1	Scholfield Honda, Wichita, Kansas	Greensburg GreenTown
CNG filling station	CNG	1	Scholfield Honda, Wichita, Kansas	Greensburg GreenTown
Ford sedan	E-85/hybrid electric vehicle (HEV)	1	Ford dealer, Missouri	City administrator

[40] See Appendix E.

Chevrolet Tahoe	HEV	3	General Motors	City staffers
Honda Insight	HEV	1	Not applicable	GreenTown staffer (privately owned)
Toyota Prius	HEV	1	Not applicable	GreenTown staffer (privately owned)

NREL recommended that Greensburg lower the vehicle miles traveled as much as possible. Given that Greensburg is about a mile square, many residents are able to walk or bicycle. This was encouraged in the *Greensburg Sustainable Comprehensive Plan*, which included suggestions for attractive paths and sidewalks and bicycle racks. Also, the city could introduce the Segway people mover to the community through a city or county purchase or donation. Greensburg can also encourage the purchase of locally grown food and locally manufactured products, further reducing the need for regional transportation.

NREL also recommended that city and county leaders promote small electric vehicles such as the two-passenger Global Electric Motorcar (GEM; a division of Chrysler) or equivalent. These vehicles, which are a step beyond electric golf carts, currently cost about $12,000 each. If the goal of 100% green electricity can be met for the community, all electric vehicles would then be considered green as well. The city and county could purchase these for meter reading, building inspections, small repair tasks, and other short runs around town. These closed vehicles with heaters and storage space will operate in normal traffic but have a short range that limits their usefulness to in-town tasks. The community should also encourage using small electric vehicles in a community cooperative program that makes some of these available to businesses and residents, and could install electric recharging stations along Main Street. These vehicles would be especially useful to the older population who cannot easily walk to key locations within town. Encouraging small electric vehicles would also open up possibilities for a new dealership and service shop for electric vehicles in Greensburg.

Green Economic Development

The NREL team supported green economic development through a feasibility study of community wind development; the addition of John Deere as a member of the DOE/NREL Commercial Building National Accounts partnership; assistance to a new wind division of a Greensburg company with national impact; a feasibility study of biomass pelletizing potential; training of a HERS rater; subcontract funding to a new sustainability nonprofit (Greensburg GreenTown); and education and training of two dozen architects, engineers, and builders on energy efficiency.

Because the wind farm will be owned and developed by an existing company, John Deere Renewable Energy, it is not likely that this relatively small installation and operation of 10 wind turbines will result in additional jobs or economic development in the area.

A valuable new partnership developed out of a Greensburg project between DOE/NREL and the John Deere Corporation. John Deere is now a member of the Commercial Building National Accounts activity,[41] which is a partnership between DOE/NREL and key leaders in business and government aimed at identifying and promoting energy efficiency in commercial and public buildings. A second John Deere dealership in Kansas is being built based on the lessons learned in Greensburg. And John Deere Place, the corporate focal point for dealership design and marketing, has redirected its business plan to promote energy efficient, green dealerships throughout North America.

A significant new green business started up in Greensburg. BTI Equipment in Greensburg, the local John Deere dealer, became the North American distributor for a Canadian wind turbine company, after having had a positive experience with this wind turbine in the building of their new dealership. In their first nine months of business, they built a North American Dealer network across 32 states and four Canadian provinces, resulting in 120 new wind-related North American jobs (mostly U.S., including wind specialists, service technicians, and installers), and nearly 300 existing sales representatives who are learning the new business of wind energy. NREL staffers worked extensively with BTI Equipment executives and other personnel to improve their understanding of small wind turbine technology and marketplaces during the planning stages of this new business venture.

Working with local business and economic development committees, the NREL team completed a feasibility study analyzing the biomass resource quantity and quality, conversion technologies, potential market opportunities, and potential business viability for converting local crop residues to pellets for solid fuel heating. The study indicated that certain feedstocks, and certain market conditions, could lead to a successful business. There is a possibility that this study will be pursued further by interested persons in the local area.

DOE provided funding to the Kansas State Energy Office to train a HERS rater for Greensburg and allow him to conduct 200 to 300 energy audits. The local person chosen for this, Brian Wendland, is an excellent example of how someone without a background in energy can learn

[41] See http://www.nrel.gov/buildings/national_accounts.html.

the necessary skills and enter the green collar job market. Wendland's success has inspired other residents to inquire about training in energy auditing.

As noted below in more detail, Greensburg GreenTown was established shortly after the tornado by a local resident, outside the city limits but nearby, who had the desire and appropriate background to organize this nonprofit and offer its assistance to the City of Greensburg. In terms of green economic development, NREL assisted by choosing this nonprofit as a subcontractor to provide extensive and detailed information and advice on the city and its residents, leaders, businesses, stakeholders, media opportunities, meeting opportunities, and other areas. As a subcontractor, NREL funding helped GreenTown hire two local residents, adding to the growing number of green jobs in the community. As its successes and reputation grew, GreenTown was also able to attract three AmeriCorps volunteers, who have worked on green projects for GreenTown and the city for a year, and will then move into other types of green careers with this valuable experience.

The efforts of the NREL team to educate and train architects, engineers, and builders appear to have ramifications well beyond Greensburg. Professional Engineering Consultants of Wichita, Hastco Builders of Emporia, MVP Architects, Mennonite Housing, and Wardcraft Homes are representative of the several dozen companies who had limited experience with high-performance green buildings and received extensive guidance and training from NREL. Each has shared anecdotally with the NREL team about the value of that training, and how it is enabling them to replicate the high-performance concepts in their work well beyond Greensburg.

Leadership, Education, and Outreach

City Leadership

The general actions and attitudes of city leadership and various community groups strongly affected the successes achieved in Greensburg.

In April 2008, NREL made the following recommendations to the city leadership to help the city continue to actively promote the adoption of sustainable technologies in support of the community vision:

- Designating one person or organization to guide or be the primary point of contact for promoting energy efficiency, renewable energy, and other green advances on behalf of the community should help focus efforts and improve communication. If city resources will not support dedicated staff, any available city resources should be spent with a local, committed organization to accomplish this. Greensburg GreenTown has already established a mission along these lines, using a board of citizens in various leadership roles in the community, and may be able to continue serving this role for the community.
- The city should encourage, hire, or contract with a centralized person or organization to become familiar with, and stay current with, up-to-date information on all financial incentives available for energy efficiency and renewable energy. This person would act as a source of information for entities within the community, and thus would help encourage the adoption of such technologies. Similarly, the economic development professionals assisting in Greensburg should stay abreast of incentive programs that encourage the development of green businesses and industries. These incentives, including tax credits, tax deductions, and rebates, are available from federal agencies, state agencies, utility companies, some large banks, and foundations. Because this is a complex and rapidly changing marketplace, such local expertise will help Greensburg adopt green technologies more effectively.
- Engaging the youth in the community in green technologies has already begun with the establishment of the Green Club at the high school, supervised by Greensburg GreenTown. Involvement of the youth at all ages should be encouraged. Many organizations offer training materials, curricula, activities, and ideas in these areas for youth.
- The faith community is very strong in Greensburg, and some churches have already shown a strong interest in pursuing energy efficient buildings and embracing the sustainable development vision of the community. Church leaders who support the sustainability vision should encourage others within the community and consider becoming spokespersons for energy efficiency and renewable energy among the wider faith communities of Kansas and the nation.
- Education and awareness among the residents of Greensburg should be constantly encouraged. Public recognition programs were mentioned previously, and should be developed to reward energy efficiency, use of renewable energy, recycling, green landscaping, and other green technologies. Various media approaches, community

events, and information workshops should be sustained to continue to educate and encourage the residents.

- Ecotourism has been effective around the world for improving the local economy, and with Greensburg's growing reputation for a unique community demonstrating sustainable development, ideas for ecotourism (such as GreenTown's Chain of Eco-Homes concept for ecolodging) should be encouraged.[42]
- Maintaining a high public profile within Kansas and across the nation will be important to bring in the outside investments the community needs to implement or help some of the energy efficiency and renewable energy recommendations made in this strategy. Although the work of the Discovery Channel and others was effective during the first year, other long-term relationships will be needed to sustain a high profile at a national level, such as the USGBC, the American Institute of Architects (AIA), NAHB; *Mother Earth News*, *Home Power*, and similar green publications; providers of green technologies; the major dealerships or businesses in Greensburg that are nationally based; environmentally sensitive companies; federal agencies; and others who have not yet been much involved in Greensburg but could be, such as the Rocky Mountain Institute, Urban Land Institute, and various foundations.

The city leaders continued to grow steadily in their confidence and commitment to energy efficiency and renewable energy, and the overall sustainability vision and goals, throughout the period of this project. This has been because of a multiplicity of factors, including influence from the NREL team. In fact, on May 2, 2009, Greensburg recognized NREL with the city's first annual Outstanding Support Award for playing an "instrumental" role in the town's recovery. NREL advisers will work in Greensburg for another year (through fiscal year 2010) to complete on-the-ground projects and additional outreach to share the lessons learned from Greensburg that will help other cities and towns.

As of June 2009, the city has maintained its active relationship and MOU with Greensburg GreenTown to coordinate and promote the sustainability initiative in Greensburg. GreenTown's executive director, staff, and board of directors (all local citizens) have continued to supply the most consistent leadership and focus on sustainability opportunities throughout the community, working wherever possible with other volunteer citizen groups. As was pointed out to the city leadership on more than one occasion, the Discovery Channel advocates would come and go, and the federal agencies providing support would also end their activities after a while. At that point, local advocates such as Greensburg GreenTown are vital to continue to carry and promote the green vision for Greensburg.

The city established a tourism committee, which is focusing on ecotourism ideas in conjunction with Greensburg GreenTown. GreenTown developed a vision for a dozen Eco-Homes, which are residences built to display different types of sustainable residential design. They will operate as bed and breakfast stops for tourists. The first of these, the GreenTown Silo Eco-Home, is nearing

[42] Visit http://www.greensburggreentown.org/the-chain-of-eco-homes/ and www.thechainofecohomes.org for more information about these homes.

completion (Figure 25). The University of Colorado Solar Decathlon house from 2005,[43] pictured in Figure 26, has been committed to Greensburg, and fundraising is under way to pay the cost of transport and local infrastructure. Other ideas have been developed and are in various stages of design and fundraising.

Credit: Lynn Billman, NREL

Figure 25. The Silo Eco-Home is built similarly to a grain silo, which was one of the few structures left standing in Greensburg after the tornado. On April 9, 2009, the builder (Armour Homes of Bushnell, Florida) tested the home's ability to withstand pressure by dropping a 1980 Honda Civic on the roof from a height of 60 ft. The home, unlike the car, was undamaged.

Credit: Chris Gunn
Source: PIX# 14622

Figure 26. The University of Colorado donated its winning home from the 2005 Solar Decathlon to Greensburg GreenTown. Greensburg leaders plan to add it to the Chain of Eco-Homes.

[43] The Solar Decathlon is a DOE-sponsored competition that challenges 20 universities from around the world to build the most state-of-the-art, sustainably designed residence. Visit http://www.solardecathlon.org/ for more information.

The city hired a housing coordinator as a central point for information on financial incentives available for housing. The city did not hire someone to be a source of information on financial incentives for energy efficiency and renewable energy. In the absence of this person, the NREL team drew from the Database of State Incentives for Renewables & Efficiency (DSIRE)[44] to prepare summary tables highlighting federal and state incentives applicable in Greensburg.

Education

NREL and its subcontractors offered several educational briefings for selected audiences in Greensburg, including a community presentation on community wind energy; training sessions for builders; fact sheets for builders; presentations to the City Council on several topics (energy efficiency for buildings, distributed solar, alternative transportation, biomass pelletizing, community wind systems, and distributed generation ordinances and policies); and a briefing for the business owners on energy efficiency.

In March 2008, NREL and GreenTown staff jointly organized and presented a Green Day Celebration for the community. The purpose of this set of events, culminating with a well-attended (about 175 people) community meeting, was to continue the momentum and interest in the community for the green initiative and to publically highlight NREL's work and information on energy efficiency and renewable energy. For this event, a staff person and subcontractor from NREL's Education Office drove NREL's RnE²EW truck and trailer to Greensburg (see Figure 27). Over two days, the NREL team helped each class in the Greensburg school with hands-on projects to build working wind turbine models, solar-powered cars, solar-powered circuitry, and paper wind mills for the youngest grades. The NREL team also attended a local football game, socializing with residents from three nearby towns who gathered for the game. The NREL team also hosted many visitors to the RnE²EW vehicle at the Green Day Celebration event itself.

Credit: Lynn Billman, NREL/PIX 16667

Figure 27. The RnE²EW vehicle is designed to take renewable energy technologies on the road.
The vehicle is equipped with solar panels and a wind turbine, which produce enough power to run everything that requires energy during an educational event like this one in Greensburg.

[44] See http://www.dsireusa.org.

At the Green Day Celebration, panels of local leaders and experts and NREL staff discussed specific projects and lessons learned relating to building energy efficiency design, construction, and financing, and other sustainability projects. The NREL team lead gave a presentation on the work NREL had been doing in the community. NREL also hosted tables of free information on energy and sustainability for the community. Midwest Research Institute (MRI) helped offset the cost of the event, and sent a representative to attend and explain MRI's support.

In August 2008, NREL hosted six students from the Green Club and two GreenTown staff on a tour of NREL's research facilities. This tour helped give the students a sense of the work to develop better energy sources and technologies for the future, and each prepared a short paper for their classes on specific research areas on the tour.

Outreach

NREL staff gave invited presentations on the work in Greensburg at the following national venues:

- National Energy and Utility Affordability Conference, June 17, 2008
- Heartland Energy Policy and Climate Protection Symposium, sponsored by the Greater Kansas City Chamber of Commerce, August 12, 2008
- National Association of State Energy Officials National Conference, September 8, 2008.

NREL also organized and proposed a 90-minute educational session, "Greensburg and Beyond," for the GreenBuild 2009 Conference to be held in Phoenix November 11–13, 2009. The session will present the impact that the work of DOE/NREL has had in Greensburg and beyond, in the region and nation. In addition, the City of Greensburg and GreenTown proposed and organized a session where they could share their experiences in rebuilding green. The annual GreenBuild conference typically draws 20,000–30,000 professionals in sustainability. More than 1,300 session proposals were submitted for GreenBuild 2009; these two were among the 112 selected.

Various city leaders have given dozens of high-level briefings all around the country about Greensburg and its green initiative. City leaders have briefed the Kansas state legislature, given congressional testimony, and given presentations around the country and the world on Greensburg. President George W. Bush visited the community immediately following the tornado, and again a year later to give the high school commencement address. Greensburg was also acknowledged in President Obama's nationwide address on the state of the nation in February 2009.

The story of Greensburg and its residents caught the attention of the national media as well. The Discovery Channel decided to film the rebuilding of Greensburg as part its efforts to launch Planet Green, a new channel, with a 13-part series called "Eco-Town."[45] Discovery Channel crews filmed and interviewed at essentially every significant event related to sustainability (including energy) for more than a year. The Discovery Channel also introduced an energy consulting company and others to the city. These individuals spent several intense months

[45] Visit http://planetgreen.discovery.com/tv/greensburg/ for more details.

working with city leaders to help with vision and planning, and to attract potential corporate donors. Their intent was to help meet the city's needs for additional project funding and their own need for marketing partners. Although the NREL educational team was highlighted briefly in one episode, in general the series focused more on human interest stories than energy projects. The series did, however, certainly raise the national level of visibility of Greensburg. A follow-on series of about six episodes was released in the spring of 2009.

Media interest and articles on Greensburg from broadcast news programs, major newspapers, major magazines, online news organizations, and other venues have been too numerous to mention. NREL staff members have been interviewed for many of these media efforts, though inclusion of DOE or NREL in the final product has not been as frequent as hoped.

For the second anniversary of the tornado, May 2–3, 2009, NREL developed a number of educational documents to take advantage of the anticipated presence of high numbers of visitors. The Executive Summary of this report contains a full list of these products.[46]

As mentioned, one Web site was developed to highlight sustainable buildings in Greensburg, using an NREL subcontractor who works with the High-Performance Buildings Program, and under the branding of Greensburg GreenTown. A new DOE Web site, Rebuilding Green in Greensburg, Kansas, recently came online at www.buildings.energy.gov/greensburg/.

[46] See Appendix H.

Conclusion

Energy affects all aspects of a community, and that is abundantly apparent when rebuilding after a disaster. Greensburg's unique situation of near-total destruction represented an opportunity to try alternative energy solutions on a community-wide scale, for which there are few precedents in the world.[47] Pursuing a wide range of new energy solutions throughout the city has placed Greensburg in a leadership position not only among Kansas communities but also among communities throughout the United States and the world. In addition, 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.

We hope these efforts in Greensburg, Kansas, will inspire and assist other communities facing similar challenges.

[47] Carlisle, N.; J. Elling, J.; Penney, T. *A Renewable Energy Community: Key Elements*. NREL/TP-540-42774. Golden, CO: National Renewable Energy Laboratory, January 2008.

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