U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

REBUILDING IT BETTER: GREENSBURG, KANSAS

High Performance Buildings Meeting Energy Savings Goals

Introduction

On May 4, 2007, a massive tornado destroyed or severely damaged 95% of Greensburg, Kansas. Since then, city and community leaders have been committed to rebuilding the town as a model sustainable community.

Experts from the U.S. Department of Energy (DOE) and the National Renewable Energy Laboratory (NREL) worked with city leaders, business owners, and residents to identify ways to incorporate energy efficiency and renewable energy technologies into the new buildings. The town showcases energy-saving best practices that can be replicated not only in other communities recovering from disaster, but any location focused on sustainability.

The Town of Greensburg

Founded in 1886, Greensburg had a population of approximately 1,400 people prior to the tornado, and relied on the agricultural, oil, and gas industries to sustain its economy. According to the Greensburg Sustainable Comprehensive Plan 2008, Greensburg had 515 single-family residences, 215 rental properties, a school, many businesses along a few downtown blocks, and city offices.

As the seat of Kiowa County, Greensburg was also the location for the county courthouse, Kiowa County Memorial Hospital, county library, and other county functions. The city of Greensburg acted as a municipal utility, selling electricity, water, sewer, and trash services to Greensburg customers.

Like so many other rural towns across America, Greensburg had been experiencing a steady decline in population over the past several decades. In contrast to a disaster that affects isolated parts of a community, the near-complete devastation in Greensburg made long-range and comprehensive community planning imperative before substantial rebuilding could begin. Rather than moving away after the tornado, Greensburg residents turned disaster into opportunity and created a vision to rebuild as a sustainable community.

Greensburg's efforts to rebuild green are paying off. Thirteen Greensburg buildings are saving a combined total of $200,000 in energy costs per year.

The town's energy goals are driven by key values that are emphasized in the community vision:

"Blessed with a unique opportunity to create a strong community devoted to family, fostering business, working together for future generations."

Rebuilding Green: From Vision to Reality

Greensburg gathered a diverse group of experts, including DOE and NREL, to help make their vision of rebuilding green a reality. The town developed a master plan for community redevelopment, and the residents formed a nonprofit organization, Greensburg GreenTown™, to provide resources and support as Greensburg rebuilds.

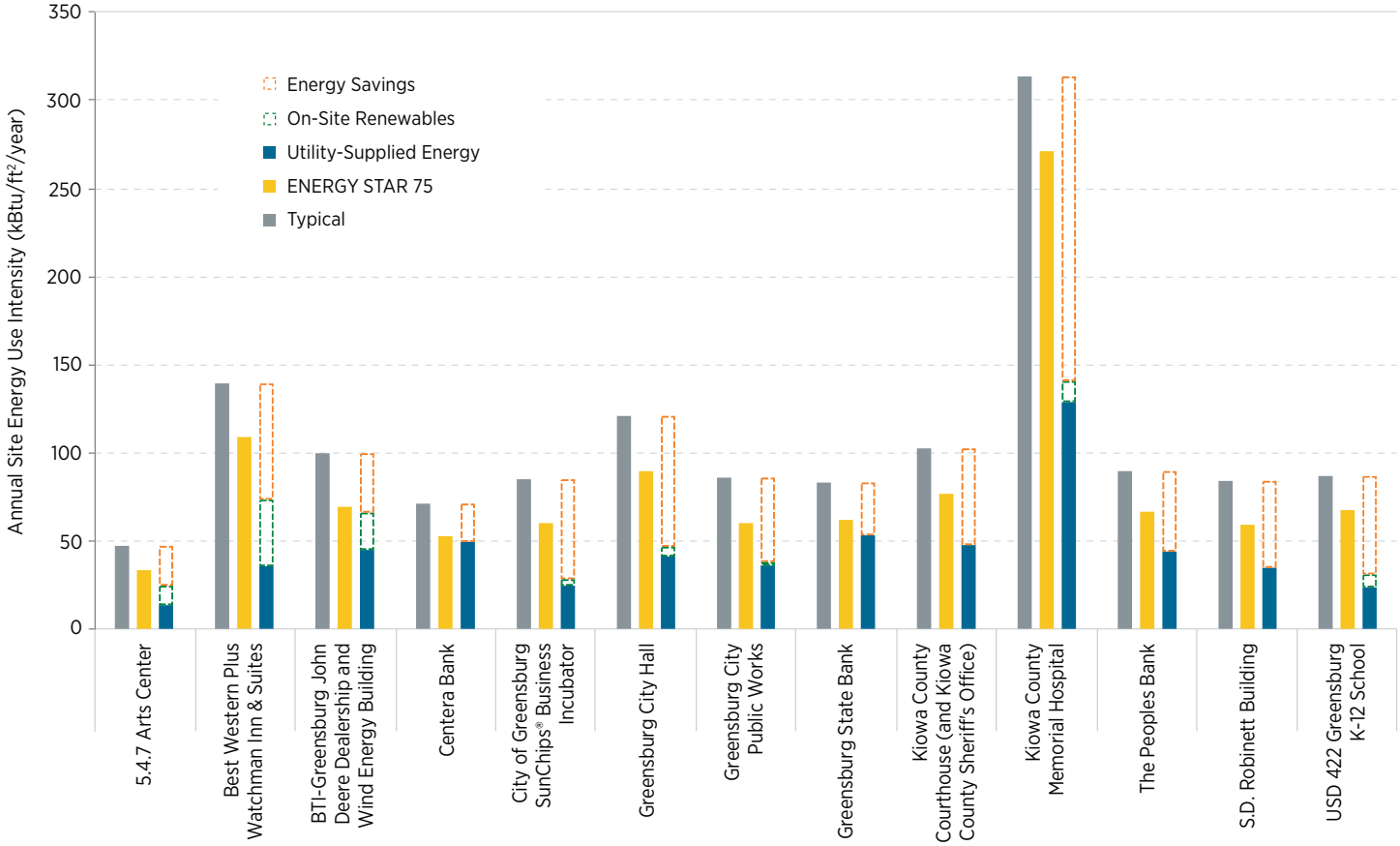
Incorporating energy efficiency targets and clear implementation recommendations into the master planning process was a key early step for Greensburg to reach its energy efficiency and renewable energy goals. Based on recommendations from NREL and architectural firm BNIM, the city passed an ordinance in December 2007 that all city-owned buildings (more than 4,000 square feet [ft^2]) be designed to the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED®) Platinum rating—with a minimum of 42% energy savings.

This unique requirement demonstrated the commitment of Greensburg's city leaders to sustainable rebuilding, which encouraged other Greensburg commercial and public projects to consider similar goals and to foster a sustainable business environment.

The buildings in Greensburg are each unique in their energy efficiency and renewable energy measures. This brochure highlights key features of select buildings based on available data provided by building owners that participated in the community-wide effort to establish energy-saving goals for building performance.

Greensburg Commercial and Civic Building Energy Savings

The chart below shows that when compared to typical existing buildings, Greensburg buildings realized annual energy savings through sustainable building practices. Each building's performance is measured by an energy use intensity (EUI) metric of 1,000 British thermal units per square foot of building area per year (kBtu/ft^2/year). Measured building performance over the 2010–2011 year is compared with average energy use of a similar building, as well as an ENERGY STAR® 75 rated building that performs at the top 25% of the nation's buildings of the same type. When appropriate, there is a comparison made to the baseline and proposed design energy model required for LEED submittals.



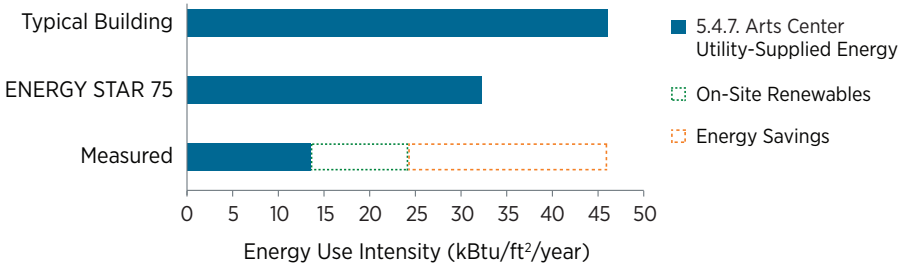
The typical building and ENERGY STAR 75 building comparisons are based on the Commercial Buildings Energy Consumption Survey (CBECS) and ENERGY STAR's Target Finder at www.energystar.gov/index.cfm?c=new_bldg_design.bus_target_finder.

Name	Building Type	Floor Area (ft^2)	Total Energy Consumption ($kBtu/ft^2/year$)	Utility Energy Consumption ($kBtu/ft^2/year$)	Percent On-site Renewable Energy	Percent Energy Savings[1]
5.4.7. Arts Center	Interpretive center	1,670	24.2	13.6	44%	70%
Best Western Plus Watchman Inn & Suites	Lodging	27,000	72.9	35.4	51%	75%
BTI - Greensburg John Deere Dealership (Includes BTI-Greensburg Wind Energy Building)	Retail	41,000	65.5	44.6	32%	55%
Centera Bank	Financial and communications	4,100	49.5	49.5	0	29%
City of Greensburg SunChips Business Incubator	Commercial office; retail	9,580	28.1	24.7	12%	71%
Greensburg City Hall	Public order and safety	4,700	46.6	41.4	11%	65%
Greensburg City Public Works	Service facility	11,200	36.6	35.9	2%	58%
Greensburg State Bank	Financial and communications	4,000	52.7	52.7	0%	36%
Kiowa County Courthouse (Includes Kiowa County Sherriff's Office)	Public order and safety	26,820	47.2	47.2	0%	54%
Kiowa County Memorial Hospital	Healthcare	48,500	141.0	128.8	9%	59%
The Peoples Bank	Financial and communications	2,100	43.9	43.9	0%	51%
S.D. Robinett Building	Retail	4,500	34.9	34.9	0%	58%
USD 422 Greensburg K-12 School	K-12 education	132,000	30.6	23.6	23%	72%

1. Utility energy consumption compared to a typical building.

5.4.7. Arts Center

The LEED Platinum 5.4.7. Arts Center takes its name from the date of the tornado that devastated Greensburg on May 4, 2007. The 1,670 ft² building is a center for community arts and provides classes, exhibits, and performances.



Including renewable energy generation, the 5.4.7 Arts Center achieved a utility-supplied annual EUI of 13.6 kBtu/ft²/year, which is **a 70% annual energy savings** *compared to a typical existing arts center. The on-site renewable energy sources provide 44% of the building's total energy consumption.*

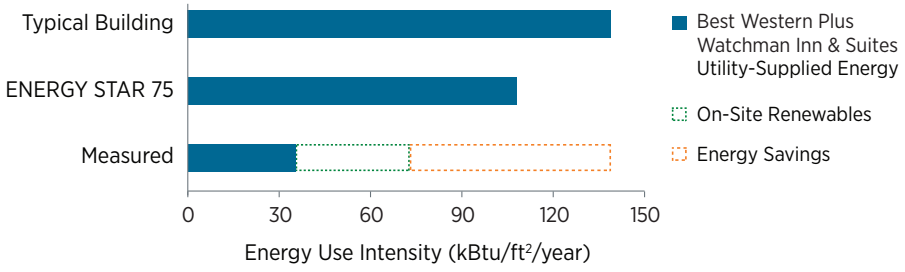
NOTE: ENERGY STAR Target Finder and CBECS do not have an art center building type. The comparison is made to the CBECS Entertainment/Culture building type.

Key Features:

- Daylighting with large south-facing glass area
- Well-insulated and air-sealed
- Three wind turbines produce 600 watts each
- Eight solar panels on the roof
- Ground-source heat pumps for heating and cooling.

Best Western Plus Watchman Inn & Suites

The Best Western Plus Watchman Inn & Suites had just been remodeled when the tornado hit. The motel owner decided to go the extra mile in getting on board with the town's green initiative when rebuilding the new 27,000 ft² building.



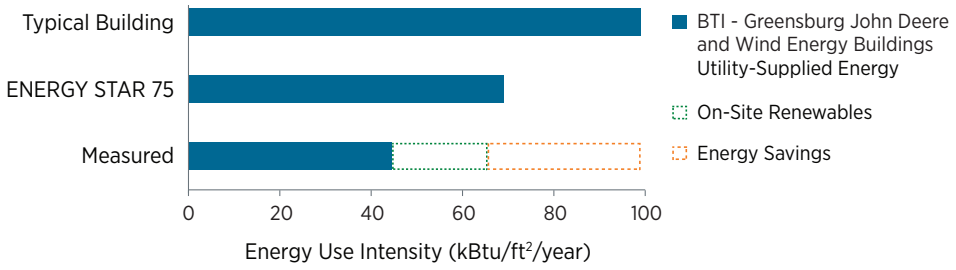
Including renewable energy generation, the Best Western Plus Watchman Inn & Suites achieved a utility-supplied annual EUI of 35.4 kBtu/ft²/year, which is **a 75% annual energy savings** *compared to a typical existing hotel. The on-site renewable energy sources provide 51% of the building's total energy consumption.*

Key Features:

- Wind turbine projected to provide 40%–60% of the facility's power
- Each of the 42 rooms features an energy-efficient heat pump, water-saving showerhead, and a can for recyclable materials
- The motel's walls, inside and out, are structural insulated panels (SIPs) and have an R-value of 16–18
- Sixteen inches of insulation in the ceiling has a rating of R-32
- Double-pane windows are used throughout the building.

BTI - Greensburg John Deere Dealership and Wind Energy Building

Brothers Kelly and Mike Estes rebuilt their new John Deere Dealership as a LEED Platinum certified 33,000 ft^2 metal prefabricated building. They also added an 8,000 ft^2 pre-engineered steel warehouse building for their new business, BTI - Greensburg Wind Energy. Constructed with high-performance walls and roof, the wind energy building contains an office, sales floor, and warehouse for wind turbines.



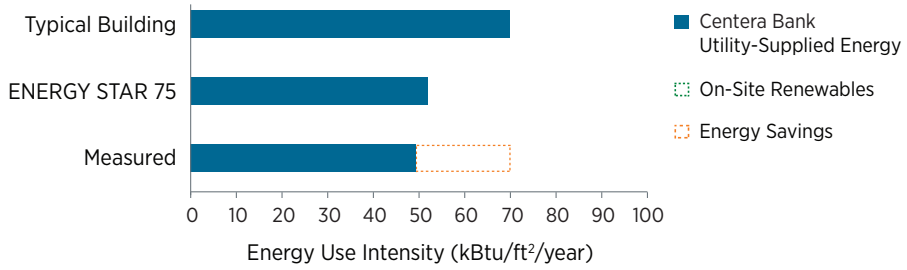
Including renewable energy generation, the BTI - Greensburg John Deere Dealership and Wind Energy Building achieved a utility-supplied annual EUI of 44.6 kBtu/ft^2/year, which is **a 55% annual energy savings** *compared to a typical existing retail facility. The on-site renewable energy sources provide 32% of the building's total energy consumption.*

Key Features (of the John Deere Dealership):

- Fully daylit with skylights and solar tubes
- High performance walls
- High-efficiency 16 seasonal energy efficiency ratio variable air volume provides heating, cooling, and outdoor air to the retail space
- Demand-controlled ventilation
- Radiant slab heating
- Hot water provided with a waste oil boiler and natural gas boiler combination
- Three on-site wind turbines (50 kilowatt [kW], 4.2 kW, and 1.9 kW) offset electricity consumption.

Centera Bank

Situated on a downtown corner lot across the street from the bank's former location, the 4,100 ft^2 Centera Bank building incorporates energy-efficient building principles and is LEED Certified.



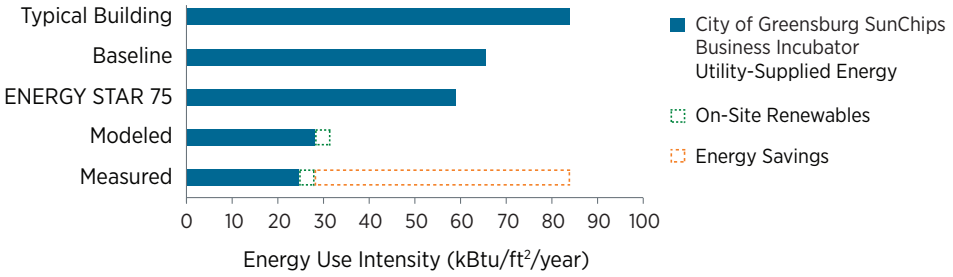
Centera Bank achieved a utility-supplied annual EUI of 49.5 kBtu/ft^2/year, which is **a 29% annual energy savings** *compared to a typical existing bank.*

Key Features:

- High performance walls
- Daylit through skylights
- Lighting controls include modulating photoelectric daylight sensors
- Light shelves on the south facade
- High-efficiency rated air conditioning system
- High-efficiency air-cooled heat pump.

City of Greensburg SunChips Business Incubator

The 9,580 ft^2 LEED Platinum City of Greensburg SunChips Business Incubator is a two-story building that provides affordable office space for small, start-up businesses in the town. Five street-level retail shops and nine second-level professional service offices make up the building; a storm shelter is also included.



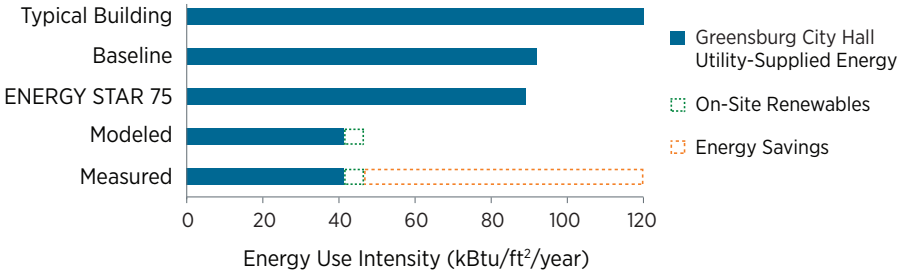
Including renewable energy generation, the City of Greensburg SunChips Business Incubator achieved a utility-supplied annual EUI of 24.7 kBtu/ft^2/year, which is **a 71% annual energy savings** *compared to a typical existing retail building. The total energy use was 11% lower than the energy model predictions. The on-site renewable energy sources provide 12% of the building's total energy consumption.*

Key Features:

- Ground-source heat pumps provide heating and cooling
- Daylit through north/south roof monitors and/or clerestories
- Air-side economizer for cooling
- A 6.8-kW photovoltaic system generates electricity on site
- Slab perimeter insulation with an insulating value of R-7 or greater
- On/off elevator controls.

Greensburg City Hall

Built to LEED Platinum standards, the 4,700 ft^2 City Hall building is the symbol of Greensburg's vitality and leadership in becoming a model sustainable community where social, environmental, and economic concerns are held in balance. It houses the city's administrative offices and council chambers, and serves as a gathering space for town meetings and municipal court sessions.



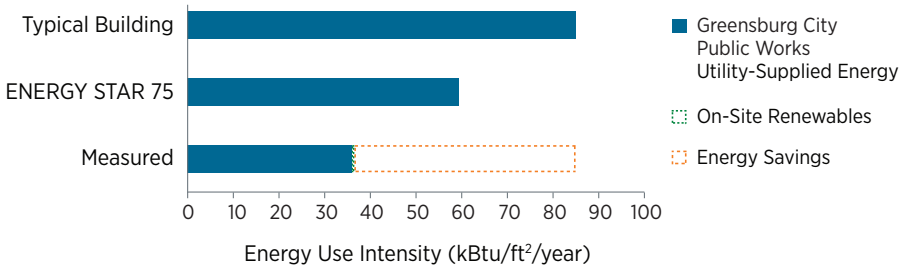
Including renewable energy generation, the Greensburg City Hall achieved a utility-supplied annual EUI of 41.4 kBtu/ft^2/year, which is **a 65% annual energy savings** *compared to a typical existing city hall. The total energy use was within 1% of the energy model predictions. The on-site renewable energy sources provide 11% of the building's total energy consumption.*

Key Features:

- Well-insulated and air-sealed walls and roof
- High performance windows
- 4.8-kW photovoltaic system on the roof
- High-efficiency ground-source heat pumps
- Humidity sensors allow heat pumps to slow fan speeds and provide dehumidification
- Incorporates daylighting and lighting controls.

Greensburg City Public Works Facility

The Greensburg City Public Works Facility was designed to achieve LEED Gold certification. The main building, at 5,200 ft^2, includes maintenance, crane, mechanics, and wash bays, as well as an administrative area. A separate 6,000 ft^2 storage structure was designed to house vehicles and equipment.



Including renewable energy generation, the Greensburg City Public Works achieved a utility-supplied annual EUI of 35.9 kBtu/ft^2/year, which is **a 58% annual energy savings** *compared to a typical existing service facility. The on-site renewable energy sources provide 2% of the building's total energy consumption.*

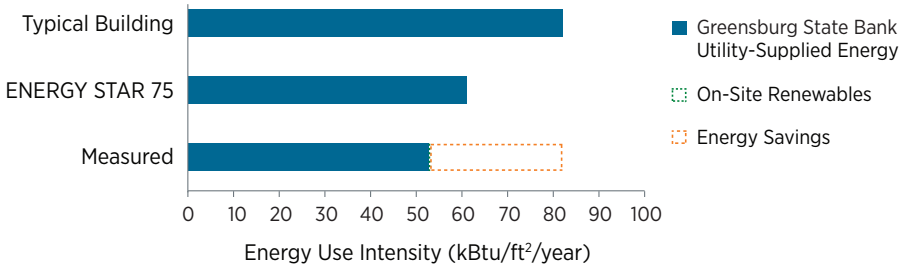
NOTE: ENERGY STAR Target Finder and CBECS do not have a public works building type. The comparison is made to the CBECS Service (Vehicle Repair/Service, Postal Service) building type.

Key Features:

- Constructed of insulated precast concrete panels
- Utilizes ground-coupled heat pumps for heating and cooling.

Greensburg State Bank

The 4,000 ft^2 Greensburg State Bank was the second building to open after the tornado. Employees uncovered the bank's original vault, unscathed, under piles of debris. The bank decided to rebuild at the same location, but this time with a variety of green features.



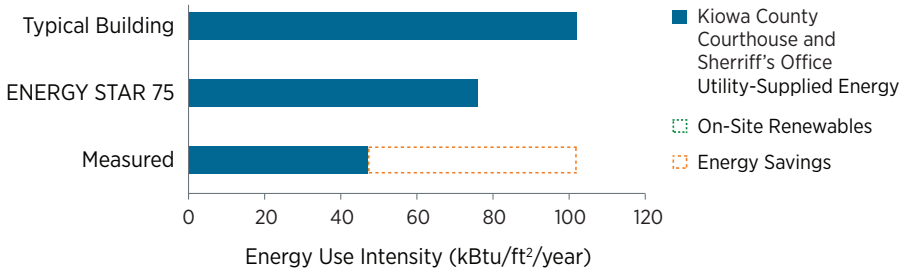
The Greensburg State Bank achieved a utility-supplied annual EUI of 52.7 kBtu/ft^2/year, which is **a 36% annual energy savings** *compared to a typical existing bank.*

Key Features:

- High-efficiency heating and cooling systems
- A highly insulated roof
- Reflective shades or blinds
- Large windows increase daylighting penetration
- High performance windows and doors
- Timing controlled lighting
- ENERGY STAR computer equipment.

Kiowa County Courthouse and Sheriff's Office

The Kiowa County Courthouse, at 18,600 ft^2, is one of the few buildings that survived the force of the Greensburg tornado. However, the building did not go unscathed. Rather than tear down the building, the county chose to restore and renovate a piece of local history with a LEED Gold rating. Within the three levels of the courthouse, there are offices for Kiowa County, a courtroom, judge offices, and the treasurer's office, among others. Additionally, the 8,200 ft^2 sheriff's office was renovated and designed to LEED Silver standards.



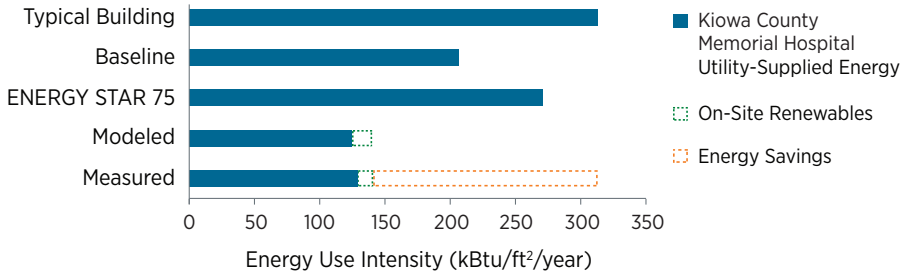
The Kiowa County Courthouse and Sheriff's Office achieved a utility-supplied annual EUI of 47.2 kBtu/ft^2/year, which is **a 54% annual energy savings** *compared to a typical existing courthouse.*

Key Features:

- Utilizes original daylighting design
- High performance windows
- Existing brick veneer and concrete structure were salvaged
- Spray-foam insulation added to the interior of the existing walls and roof deck for extra insulation and air-sealing
- All-electric, multistage, ground-source heat pump
- Exhaust recovery ventilators provide fresh air
- High performance lighting and controls.

Kiowa County Memorial Hospital

Replacing the original hospital that was destroyed in the tornado, the new 48,500 ft^2 Kiowa County Memorial Hospital is the first critical access hospital in the nation to achieve LEED Platinum certification. It includes 15 acute-care beds, a five-provider clinic, a specialty clinic, an emergency department with two trauma rooms, a physical/occupational therapy department, a radiology department, a laboratory, and other support areas such as an on-site daycare facility.



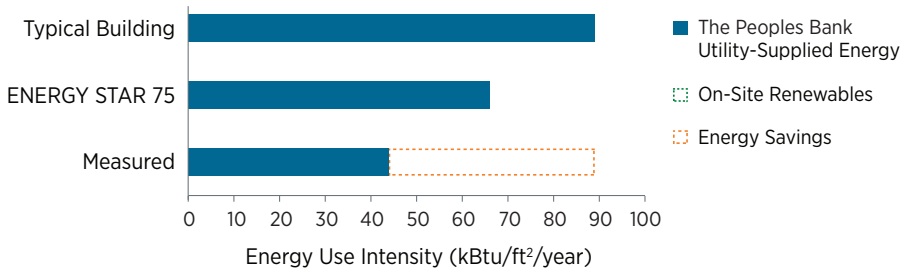
Including renewable energy generation, the Kiowa County Memorial Hospital achieved a utility-supplied annual EUI of 128.8 kBtu/ft^2/year, which is **a 59% annual energy savings** *compared to a typical existing hospital. The total energy use was within 1% of the energy model predictions. The on-site renewable energy sources provide 9% of the building's total energy consumption.*

Key Features:

- Daylit with skylights, light-sensing dimmers, highly efficient luminaries, and occupancy sensors
- LED exterior lighting
- High performance windows
- R-25 sprayed polyurethane foam on precast panels and interlocking metal studs
- On-site, grid-tied, 50-kW wind turbine
- Ultra high-efficiency magnetic bearing chiller with secondary unit for waste heat recovery
- Energy recovery wheels for preconditioning ventilation air.

The Peoples Bank

The 2,100 ft² Peoples Bank is 300 ft² larger than the pre-tornado building and opened its doors to the public in December 2009. It has many sustainable features that are designed to save money and energy and better serve customers.



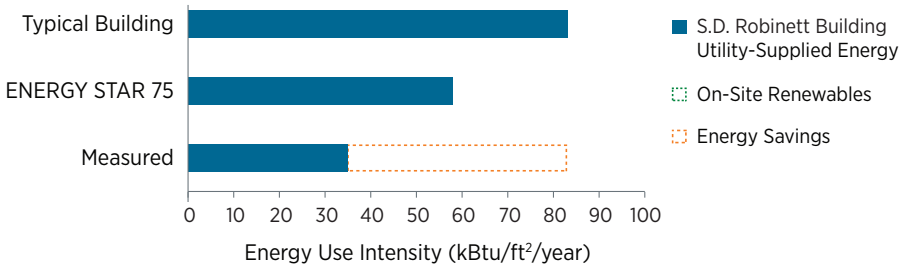
The Peoples Bank achieved a utility-supplied annual EUI of 43.9 kBtu/ft²/year, which is **a 51% annual energy savings** *compared to a typical existing bank.*

Key Features:

- Whole-wall insulation R-value greater than 25
- Ground-source heat pumps provide heating and cooling
- Southern orientation takes advantage of passive solar heating
- Open floor plan allows sunlight to penetrate the interior
- Minimized plumbing, electrical, and other penetrations throughout the building envelope to reduce air infiltration
- Outdoor lighting controlled by motion-detectors or timers.

S.D. Robinett Building

The two-story, 4,500 ft² S.D. Robinett Building was one of two Greensburg historic buildings to survive the tornado. It was purchased from Centera Bank by Erica and Gary Goodman, who lost their antique store and home in the tornado. The Goodmans renovated the 1914 building to historical accuracy to house their new business and residence. The building was included in the National Register of Historic Places on May 1, 2010.



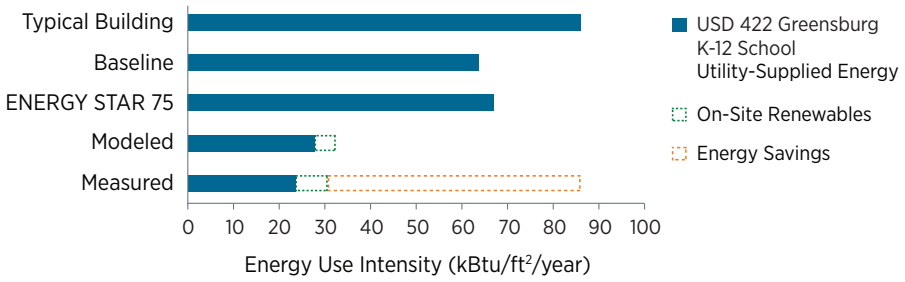
The S.D. Robinett Building achieved a utility-supplied annual EUI of 34.9 kBtu/ft²/year, which is **a 58% annual energy savings** *compared to a typical existing retail building.*

Key Features:

- Open floor plan
- Large exterior and interior windows increase daylighting penetration
- Operable windows and ceiling fans improve comfort at higher temperatures
- Heating loads reduced by unshaded south side of the building
- High performance windows and doors
- Energy-efficient appliances
- Spray-foam insulation added to the interior of the existing walls and roof deck.

USD 422 Greensburg K-12 School

The new LEED Platinum 132,000 ft² Greensburg K-12 School was built green from the ground up. School leaders and the design/construction team worked together to design an environmentally responsible, student-focused academic environment that reinforces the community's commitment to sustainability. The school has the capacity to hold more than 300 students ranging from preschoolers to high-school seniors.



Including renewable energy generation, the USD 422 Greensburg K-12 School achieved a utility-supplied annual EUI of 23.6 kBtu/ft2/year, which is **a 72% annual energy savings** *compared to a typical existing school. The total energy use was 5% lower than the energy model predictions. The on-site renewable energy sources provide 23% of the building's total energy consumption.*

Key Features:

- Daylighting with skylights and daylight controls
- SIPs rated from R-30 to R-40
- Overhangs on south-facing windows limit summer solar gains and allow for winter passive solar tempering
- On-site wind generator produces 50 kW of power
- Three 5-kW polymer electrolyte membrane fuel cells along with an electrolyzer
- A hybrid closed-loop ground-source heat pump system, combined with a fluid cooler
- Energy recovery ventilators with demand control.

Lessons Learned

The sections that follow highlight the most successful green technologies and energy efficiency measures that have been implemented in Greensburg since the tornado in 2007. Several suggestions are also provided on how to further improve the energy performance of buildings in Greensburg.

As new Greensburg projects are planned, it will be important to utilize these lessons learned.

Set Community-Scale Goals

After the disaster, Greensburg residents developed a Sustainable Comprehensive Master Plan for the town's next 20 years, which was adopted by the City Council. The plan states: "A truly sustainable community is one that balances the economic, ecological, and social impacts of development."

With community-scale goals in place, there was a general feeling in Greensburg that living sustainably was the right thing to do. Business owners, leaders, and others felt that the support from the majority of the community for its sustainability goals helped lower the risk of implementing green technologies and energy efficiency measures.

A city-wide initiative for sustainable design and operation was implemented by passing an ordinance that required city-owned buildings to be LEED Platinum certified and have 42% energy cost savings. Many owners of commercial and residential properties not covered by this ordinance followed suit in order to support the goals of the community. This city initiative served as a major driving force in the effort to rebuild Greensburg as a model of sustainability.

The 30% Advanced Energy Design Guide (AEDG) series (*www.ashrae.org/aedg*) was also used as a starting point for many of the projects in Greensburg. The AEDGs provide building type and climate-zone-specific recommendations to help achieve 30% energy savings relative to a code-compliant building. The USD 422 Greensburg K-12 School was so successful in implementing energy-efficient measures that it was selected as a case study for the *AEDG for K-12 School Buildings: Achieving 50% Energy Savings Toward a Net Zero Energy Building*.

Use an Integrated Design Approach

An integrated design approach, where all parties involved collaborate on the building design, was used to help each building in Greensburg reduce its energy consumption as much as possible. Integrated design was necessary because building systems have very

complex relationships and interactions; a small change in one system may lead to a significant increase in energy consumption of other systems.

The buildings featured in this brochure incorporated high performance building envelopes, exterior wall and roof constructions, and windows designed to have high insulation values to reduce the amount of heat loss during the winter and heat gain during the summer. The reduced heat transfer through the envelope had a direct impact on the heating and cooling systems; as a result, many of the buildings met their heating and cooling needs with energy-efficient ground-source heat pumps.

Incorporate Daylighting and Energy-Efficient Lighting

For many of the buildings in Greensburg, most of the energy savings came from implementing daylighting as much as possible to reduce the amount of electric lighting. Glazing systems were designed to optimize south- and north-facing daylighting while minimizing solar gain in the summer. Skylights, tubular daylighting devices, and clerestories were also used as common strategies for successful daylighting. Electric lighting systems, featuring efficient fluorescent and LED fixtures, are combined with occupancy and daylighting sensors, and a city-wide conservation mentality to ensure the lights are only on when needed.

Invest in Simple Building Systems

Oftentimes, when "high performance" buildings perform poorly, it is due to an overly complicated design. To combat this, many buildings in Greensburg incorporate simple building features that help passively save energy. Features that have been successful include:

- A north-south orientation
- Shading, daylighting, and high performance windows
- A quality thermal envelope (more airtight)
- Ground-source heat pumps, which were easy to implement because there are no condensers to maintain (like in conventional heating, ventilation, and air conditioning systems), and there are local zone level controls for the pumps.

Some buildings, such as the Kiowa County Memorial Hospital, required complex building systems to maintain the required indoor environment. In cases like this, outside expertise was retained to ensure continued good performance and maintenance of the building.

Keeping Greensburg Green

Going forward, the building owners and operators of Greensburg's buildings should periodically assess each building

Greensburg Buildings Performance Results

Architecture 2030 Challenge Goals

Established to reduce the energy consumption and associated energy costs of buildings, the Architecture 2030 Challenge (*http://architecture2030.org/*) takes a staged approach to reach a net-zero energy goal by 2030. It sets a current target of 60% energy savings relative to the regional or national average for a given building type. The savings targets then increase to 70% in 2015, 80% in 2020, 90% in 2025, and finally 100%, or net-zero energy, in 2030.

The annual savings, including renewables, for five of Greensburg's buildings exceed the current target of 60% savings; of the five, four of them exceed the 70% target of 2015. Six additional buildings are within 10% of meeting the 60% target.

LEED Goals

Eight of the 13 buildings analyzed are LEED Certified (five of the 13 are LEED Platinum). Three more Greensburg buildings are anticipated to achieve a LEED Platinum certification in the near future. By pursuing LEED certification and the city-wide initiative for sustainable design, these 13 buildings save a total of $200,000 per year in energy costs.

100% Renewable Energy, 100% of the Time

The Greensburg Wind Farm consists of ten 1.25 megawatt (MW) wind turbines that supply 12.5 MW of renewable power to the town—enough to power every house, business, and municipal building in Greensburg.

The town uses only about 1/4 to 1/3 of the power generated to reach its "100% renewable energy, 100% of the time" goal. Excess power is placed back on the grid and offered as renewable energy credits for other Kansas Power Pool and NativeEnergy customers.

The medium wind turbines in Greensburg were purchased with maintenance and service contracts. As Greensburg expands its wind energy production, it is vital that new wind turbines are also purchased with the necessary agreements in place and serviced appropriately to keep Greensburg green.

to ensure the sustainable and energy-efficient aspects are working properly by:

- Placing daylighting sensors in all spaces that receive abundant daylight
- Placing occupancy sensors in locations with electrical lighting
- Lowering setpoints (when appropriate) for all building controls during times when the building is unoccupied
- Turning off all electronics and other plug loads at night to prevent energy waste
- Reviewing utility bills annually and comparing the energy consumption to past years. This will help ensure a high level of performance by indicating when maintenance is needed.

More Information

Learn more about Greensburg's rebuilding efforts and the technical assistance provided by DOE and NREL at *www.eere.energy.gov/deployment/greensburg.html*.

For additional details on these and other Greensburg buildings, visit the Sustainable Buildings Database at *http://greensburg.buildinggreen.com/* or contact Greensburg GreenTown at *www.greensburggreentown.org*.

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This document is one in a series of documents outlining the options for and benefits of rebuilding green after a disaster. The series draws on lessons learned by teams from the U.S. Department of Energy and its National Renewable Energy Laboratory as they helped the townspeople of Greensburg, Kansas, rebuild green after a devastating tornado. To see the other documents in this series, visit eere.energy.gov/deployment/greensburg.html.

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