# RENEWABLE DUBUQUE

## RENEWABLE ENERGY FOR A SMARTER SUSTAINABLE DUBUQUE

### The Nation’s First Comprehensive Urban Scale Renewable Energy Study and Policy Analysis

SUSTAINABLE DUBUQUE

THE UNIVERSITY OF IOWA School of Urban & Regional Planning

Greater Dubuque Development Corporation

Michael Beach, Nick Benson, Robyn Fennig, Adam Gebhart, Eric Isaacs, Yana Li, Hannah Papineschi, Michele Vitale, Andrew Bennett, Dr. Scott Spak

# PROJECT STATEMENT

As part of the Iowa Initiative for Sustainable Communities, the University of Iowa School of Urban and Regional Planning partnered with the City of Dubuque and the Greater Dubuque Development Corporation (GDDC) to better **understand how renewable energy can be incorporated into economic development in Dubuque, Iowa**. By combining geophysical-based renewable energy capacity mapping with return on investment, this project answers cutting-edge policy questions to **comprehensively evaluate how renewable energy can impact Dubuque's vision of sustainability**.

Available energy capacity for solar photovoltaic, solar hot water, wind, and ground-source heat pump (geothermal) systems were mapped using ArcGIS, to better understand the ability to produce energy on-site at the parcel level. Data from these maps were added to a spreadsheet that calculates return on investment using the best technology available on the market today. By understanding the economic feasibility of incorporating renewable to meet the demands of Dubuque's business community, the GDDC can help existing and potential businesses in identifying locations within Dubuque that are suitable for small scale renewable energy production.

These findings help Dubuque to explore three policy issues that arise from increased usage of renewable energy:

**Conflict between Historic Preservation and Renewable Energy**

As Iowa's oldest city, Dubuque has a large stock of historic buildings and sites. The City of Dubuque strongly desires to maintain its sense of place through historic preservation. Encouraging renewable energy development does not have to harming the historic character of the city.

**Critical Facilities Resiliency**

Eastern Iowa's climate is changing making Dubuque more vulnerable to flooding and other natural disasters. Renewable energy may be used to increase Dubuque's resiliency during natural and man-made disasters. If renewables are incorporated into critical facilities, they can help provide critical services during disasters.

**Relationship between Renewable Capacity and Demographics**

If renewable energy becomes increasingly used by Dubuquers, the city must be aware of potential inequities in the distribution of certain renewable capacity or suitability. If sites with highest capacity coincide with higher income or property values, Dubuque will need to mitigate inequalities to provide a more equal access.

# EXECUTIVE SUMMARY

Dubuque uses a definition of sustainability similar to the one made famous by the 1983 World Commission on Environment and Development, often referred to as the "Brundtland Commission." According to the City of Dubuque,

> **"Sustainability is defined by a community's ability to the environmental, economic, and social equity needs of today without reducing the ability of generations to meet their needs." [1]**

Through its Sustainable Dubuque Initiative, Dubuque is committed to a holistic approach to sustainability using the traditional "three-legged stool" approach. This approach weighs environmental and ecological integrity, economic prosperity, and social and cultural vibrancy equally to achieve its vision to be a viable, livable, and equitable community. This vision creates a sustainable legacy for future generations.

Its unique position along the Mississippi River, coupled with its natural resources, has provided the means for industry in Dubuque to grow and thrive. In order to achieve its goals of supporting a complete approach to sustainability, promoting economic growth and high standard of living, and providing reliable, cost-effective energy, it is essential for Dubuque to integrate renewable energies into present and future business operations

Increasing energy demand suggests that if Dubuque is to achieve its goal of becoming a sustainable community, it must incorporate reliable, clean, and safe alternatives into its community energy portfolio. This study enables residents and business owners to understand solar, wind, and ground source heat pump suitability on their parcels, and recommends means to improve conditions for renewable energy in the Dubuque community.

By not only disseminating the findings of this study, but also through implementation, Dubuque could poise itself to be a leader in the Midwest as an example of how to achieve a more sustainable future. It is our hope that through this first-ever comprehensive renewable energy study done at the urban scale in the United States, other communities will be able to follow Dubuque's dedication and initiative, and provide the same information for their residents

### What About Dubuque's Coal Plant?

Alliant Energy is studying the feasibility of taking its Dubuque coal-fired power plant off-line within the next few years. If this happens, Dubuque must import 100% of its energy to meet residential, industrial, and commercial energy demand. This poses challenges, as the City of Dubuque, Iowa has essentially been "in the energy business" since it was chartered for settlement in 1837.

1. City of Dubuque, "Dubuque's Approach," *Sustainable Dubuque*, http://www.cityofdubuque.org/index.aspx?NID=606.

# PROJECT PARTNERS

The Renewable Energy Mapping and Policy project brings four project partners together who are committed to better understand on-site renewable energy capacity and policy in the Dubuque area. All four project partners bring unique skills and perspectives to the project, ensuring that the project is truly holistic in scope.

## UNIVERSITY OF IOWA SCHOOL OF URBAN AND REGIONAL PLANNING

Home to one of the oldest continuously accredited graduate Urban and Regional Planning programs, the University of Iowa offers its students the opportunity to explore and analyze the built environment, leading to a career as a professional planner. Planners help to improve the quality of life in a range of communities of varying size and scope.

The University of Iowa School of Urban & Regional Planning

The School of Urban and Regional Planning offers a wide assortment of courses, ranging from fields such as transportation, housing, community development, economic development, land use, environmental planning and geographic information systems. One such required course is called “Field Problems in Planning,” which focuses on applying techniques learned in the classroom to help communities overcome planning-related challenges.[2]

Eight master’s degree students, one undergraduate student, and a faculty advisor were enlisted to define a project scope that combines innovative renewable energy capacity mapping methodologies at the urban scale, as well as policy analysis examining cutting-edge planning-related issues applied to Dubuque, Iowa. Participants from the School of Urban and Regional Planning include:

- Michael Beach, M.S. Urban and Regional Planning, 2012
- Nick Benson, M.S. Urban and Regional Planning, 2012
- Robyn Fennig, M.S. Urban and Regional Planning, 2012
- Adam Gebhart, M.S. Urban and Regional Planning, 2012
- Eric Isaacs, M.S. Urban and Regional Planning, 2012
- Yana Li, M.S. Urban and Regional Planning, 2012
- Hannah Papineschi, M.S. Urban and Regional Planning, 2012
- Michele Vitale, M.S. Urban and Regional Planning, 2012
- Andrew Bennett, B.S. Mechanical Engineering, 2012
- Dr. Scott Spak, Ph.D., Assistant Professor, Urban and Regional Planning

2. University of Iowa School of Urban and Regional Planning, “Purpose and Focus,” http://www.urban.uiowa.edu/content/purpose-and-focus.

**For more information about the University of Iowa School of Urban and Regional Planning, please visit: http://www.urban.uiowa.edu/**

## IOWA INITIATIVE FOR SUSTAINABLE COMMUNITIES

The University of Iowa School of Urban and Regional Planning began its Iowa Initiative for Sustainable Communities (IISC) in 2009 in order to help communities within the state address the problems and challenges they experience in enhancing their capacity to increase sustainability efforts. Specifically, the IISC focuses on challenges unique to communities in the State of Iowa. IISC achieves this goal by utilizing student and faculty knowledge and experience to perform outreach to communities, like Dubuque, so they are able to achieve a sustainable future.

This unique approach combines student-faculty-community collaboration on focused research and policy projects, engaging Urban and Regional Planning students in meaningful, hands-on planning-related projects. These projects also enable faculty members to advance their research. According to the IISC, "the end result will be to greatly enhance the University of Iowa's reputation for advancing sustainability scholarship, teaching, and community outreach."

**For more information about the Iowa Initiative for Sustainable Communities, please visit: http://www.urban.uiowa.edu/iowa-initiative-for-sustainable-communities**

## DAVID LYONS, PROJECT MANAGER WITH THE SMARTER-SUSTAINABLE DUBUQUE INITIATIVE

Shortly after the City of Dubuque created the Smarter Sustainable Dubuque Initiative, the City Council selected David Lyons to serve as its project manager. The former State of Iowa Economic Development Director and Insurance Commissioner brings numerous years of experience and knowledge of Iowa-specific policy to the Initiative. As project manager, Mr. Lyons strives to combine high levels of community engagement with the numerous partnerships that have been forged between the public and private sectors. Mr. Lyons helps Dubuque to join passionate community engagement with cutting-edge technology in order to effectively achieve its sustainability initiatives. His pioneering spirit has been contagious, helping to direct our group's passion and excitement to create a project that helps Dubuque work towards a more sustainable future.

**For more about the new Sustainable Dubuque Initiative managed by Mr. Lyons, please visit: http://www.cityofdubuque.org/index.aspx?NID=**

## GREATER DUBUQUE DEVELOPMENT CORPORATION

The Greater Dubuque Development Corporation (GDDC) aims to shape the City of Dubuque, Iowa into a place where businesses thrive through achieving their four main goals:

1. Business Retention and Expansion – Continually identify and assess needs of existing and future Dubuque-area businesses
2. Workforce Development – Recruit and retain a talented workforce

3. New Business Recruitment – Help to recruit new business by identifying and providing resources, information and services
4. Retail Expansion – Expand retail opportunities in a community of colleges and tourism

These four goals are integrated into its "Destination for Opportunity" campaign, a five-year initiative to achieve measurable objectives, such as 6% population growth, creation of 5,500 new jobs, and $16.00+ wage levels.[3]

This project helps the GDDC to better serve the needs of the existing business sector in Dubuque, by helping businesses to achieve greater degrees of energy independence and decrease operating costs, allowing businesses to thrive and expand. Additionally, this project will create a template shows which renewable energy technologies are best at the parcel level, helping to recruit new, sustainably-minded businesses to the Dubuque area,. This supports the development of high-skilled jobs, and a healthy local economy.

Our primary contacts at the GDDC, Executive Director and Chief Operating Officer, Mr. Rick Dickinson, and Vice President of Existing Businesses, Mr. Daniel McDonald, have helped the Renewable Energy Mapping and Policy Analysis Team (REMPAT) become acquainted with innovative, sustainability-minded businesses in Dubuque. Mr. McDonald and Mr. Dickenson have provided a wealth of data and information about the Dubuque business community, as well as afforded the REMPAT several opportunities to meet, network with, present the project to business owners, and create mutually-beneficial partnerships with local businesses. They also provided bi-weekly feedback to improve the project, ensuring that the products can directly help enhance Dubuque's existing and future business community. Mr. McDonald has also taken the time to seek out a group of businesses in different sectors to provide energy demand data for the REMPT to construct baseline data for the different industries.

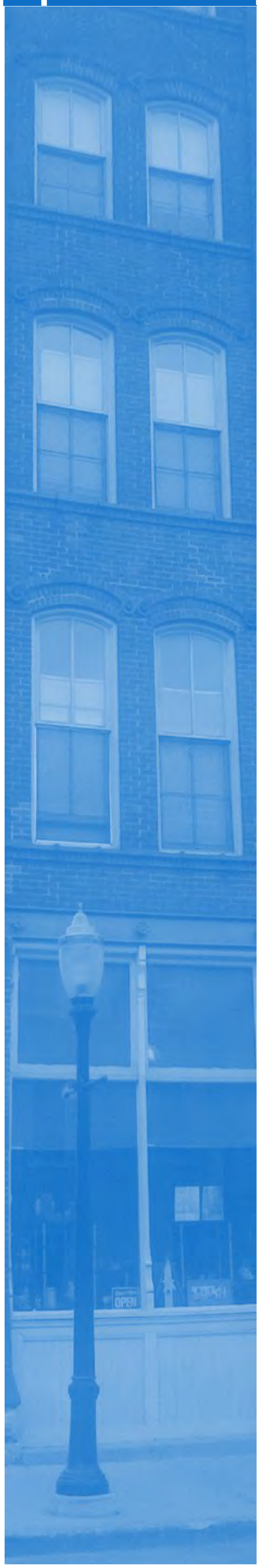
**For more information about the Greater Dubuque Development Corporation, please visit: http://www.greaterdubuque.org/**

**Figure 1: GDDC's advocates for businesses, like those shown above, in Dubuque, to ensure economic prosperity**

3. Greater Dubuque Development Corporation, "Who We Are," http://www.greaterdubuque.org/whoweare.cfm.

# DUBUQUE'S ENERGY HISTORY

By: Alejandra Ruales, Loras College



The U.S Electric Light and Power Company began operation on April 17, 1883 in Dubuque, Iowa after signing a three year contract with the city. Through the provision of two hundred arc lights for street illumination, which required fifty miles of wires within the city limits, Dubuque experienced its first use of electricity on November 17, 1883 when the Platt Brothers Clothiers were illuminated for five hours.[4] Though the capability existed, Dubuque residents still depended heavily on gas-powered lamps for lighting needs. This low level of community support resulted in a relatively slow development of the city's capacity for power generation.

**Figure 2 (Above): Development of electric power in Dubuque helped to fuel economic development in Downtown**

Although the U.S. Electric Light and Power Company intended to discontinue business in late 1884 due to low stock value, by March 15, 1890, Dubuque granted the company a larger contract. This new agreement included replacing one hundred twenty 2000-candlepower lamps with electric powered street lights.[5] Before the offer was accepted, the U.S. Electric Light and Power franchise was purchased by the Star Electric Company and merged with the Dubuque Electric Light Company and Dubuque Street Railway Company, both franchised by the Dubuque City Council, in December 1893.

On August 4, 1890, the Allen-Swiney Company signed a contract to supply street lights for three years with an annual cost of $75.00.[6] Later, Dubuque Light and Traction Company purchased the Dubuque Street Railway Company; however, by 1899 it was succeeded by the Home Electric Company due to financial problems. The arrangements of power generation remained complicated for nearly a decade as the City Council offered contracts to several different businesses until August 13, 1900, when the Union Electric Company was established as the main electric company in Dubuque. Union Electric Power was a consolidation between Romberg Line and the Allen & Sweeney Line railway systems, as well as the Star Electric Company.

At the time, Dubuque was the only city in Iowa boasting a ten minute normal service and five minute peak service. By 1916 the only service company remaining in Dubuque was Union Electric Company.[7]

Union Electric operated until 1924, when the Interstate Power Company took over the main electricity operations. The company expanded rapidly and spread to different locations in Iowa, parts of Illinois, Minnesota, Nebraska, North Dakota, Oklahoma, South Dakota, and the province of Manitoba, Canada.[8] However, the economic depression crushed the company's fortune. Consequently, as part of the company's reorganization process in 1973, the company sold Dubuque's bus system. The company became part of the Mid-Continent Area Power Pool (MAPP), which coordinated the planning and operation for power suppliers in Minnesota, Wisconsin, Montana, Iowa, Nebraska, North Dakota and South Dakota. By swapping power during times of peak demand, the Interstate Power Company's supply capability increased to 343,345 kWh, serving a total of 254 communities and 128,033 customers by 1966.[9] By 1975, the company met the demands of 252 communities and 141,000 electric and 41,000 natural gas customers.[10]

Other associations included a membership with MARCA, which was a regional reliability group of power suppliers that guaranteed reliability in the electric service.[11] Interstate Power Company showed a significant amount of capacity, compared to previous power plants that had a more local based production of energy. The capacity level was fundamental for the growth in agricultural, industrial and manufacturing production.

The energy supply for the company came predominately from coal-fired generators, of which, 97percent was extracted by domestic suppliers.[12] In 1978 the company's annual report indicated that "nearly two-thirds of coal requirements are covered by long term deliver contracts extending into 1996".[13] Sixty percent of the coal came from Wyoming and Montana, compared to the coal from Illinois mines. This western coal had a lower sulfur content. Consequently, most of the coal was transported by railroad and later by river barge to the power plans, which constituted one of the most significant coal costs.[14]

In as early as 1957, the company showed awareness of the environmental impact of its operations by creating an emission reduction program. In the annual report of 1967, the company mentions that due to Congressional and broad public awareness of the implications of particulate matters generated by coal, the company became equipped with dust removal equipment. During that year they installed an expensive electrostatic precipitator remove 98 percent of the particulate matter from gases generated at the Clinton, Iowa plant.[15]


**Figure 3 (Above): Dubuque's historic past makes way for a sustainable future. Image from the Mill Work District.**

In 2008, the Interstate Power Company became part of Alliant Energy Corporation, a public utility company incorporated in Madison, Wisconsin.[16] One aspect of Alliant Energy that compliments ongoing work in Dubuque is commitment to sustainability. The City of Dubuque expects that people understand the importance of this project and contribute in various tangible ways as sustainable becomes increasingly embedded into the community.

**SECTION ENDNOTES**

4. Lyon, Randolph W, "Union Electric Company," *Encyclopedia Dubuque,* Carnegie-Stout Public Library, 2008, http://www.encyclopediadubuque.org/index.php?title=UNION_ELECTRIC_COMPANY.
5. Ibid.
6. Ibid.
7. McCormick, John, "Early Struggles Recalled On 50th IPC Anniversary," *Telegraph Herald,* [Dubuque] 20 Apr. 1975. 8.
8. Lyon.
9. By 1991, the peak demand was 904MW.
10. Ibid.
11. *Interstate Power Company Annual Report 1967*. Rep. Dubuque, 1967.
12. *Interstate Power Company Annual Report 1984*, Rep. Dubuque, 1984.
13. *Interstate Power Company Annual Report 1978*, Rep. Dubuque, 1978.
14. *Interstate Power Company Annual Report 1980*, Rep. Dubuque, 1980.
15. *Interstate Power Company Annual Report 1967*, Rep. Dubuque, 1967.
16. Lyon.

# PLANNING PROCESS

Throughout the 2011-2012 academic year, the project was presented in its various phases from initial concept through final product for a wide range of audiences. These presentations allowed the group to interact with a broad array of stakeholders, address stakeholder questions, and incorporate new ideas. This section highlights each presentation and portions of the project highlighted.

## SUSTAINABLE DUBUQUE FIELD CAMP [DUBUQUE, IOWA]

Participants from the Iowa Initiative for Sustainable Communities (IISC) met at Hotel Julian in Dubuque, Iowa to develop the renewable energy capacity mapping and policy project from August 15-17, 2011. The Renewable Energy Mapping and Policy Analysis Team (REMPAT) became more familiar with the Dubuque community thanks to a citywide bus tour and presentations from several local officials, including Mayor Roy Buol and Sustainability Community Coordinator Cori Burbach. Students quickly learned the role that sustainability plays in guiding development and policy in Dubuque. Sustainability remains a principle that the city actively practices, having been recognized locally, regionally, and globally for taking a lead in implementing through its various public/private partnerships and sustainable initiatives.

Another key part of Sustainable Dubuque Field Camp was familiarizing REMPAT with project partners at the Greater Dubuque Development Corporation (GDDC). Both parties realized the vision that the others wished to accomplish through this project. REMPAT wanted to engage in meaningful, hands-on sustainability-focused research, while meeting the needs of the GDDC. During a meeting with the GDDC's Executive Director and Chief Operating Officer, Mr. Rick Dickinson, and Vice President of Existing Businesses, Mr. Daniel McDonald, the team was grasped what the GDDC was looking for: a better understanding of on-site renewable energy capacity and production potential, energy demand, and how to better integrate sustainability into the community, starting with businesses.

**Figure 4 (Above): On the bus tour REMPAT saw the site of "Complete Streets" project in the Millwork District increasing sustainability efforts in Dubuque**

Over the remaining day, the team, along with Faculty Advisor Dr. Scott Spak, outlined the basic methodology and final products to be delivered at the end of the 2011-2012 academic year (the timeline for project completion). On Wednesday August 17, 2011, Robyn Fennig and Nick Benson delivered an initial pitch to Mr. Dickinson and Mr. McDonald from the GDDC and rest of the project partners. Based on client feedback, the GDDC was pleased with the project deliverables and timeline for completion.

## REVISED PRESENTATION TO CLIENTS [IOWA CITY, IOWA]

On September 15, 2011, the Renewable Energy Mapping and Policy Analysis Team (REMPAT) delivered a revised presentation to all project partners, including the University of Iowa School of Urban and Regional Planning, participants in the Iowa Initiative for Sustainable Communities (IISC), the Greater Dubuque Development Corporation (GDDC), and other stakeholders on the University of Iowa campus. IISC participants and members of the GDDC who were not in attendance viewed the presentation through an online audio-visual distance learning program utilized by the University of Iowa called Adobe Connect. Feedback from online viewers was solicited through a conference telephone call and written forms. Project partners in Dubuque gained a better understanding of the project, and saw the progress made since Field Camp in August.

Yana Li and Adam Gebhart delivered this presentation, which featured a more refined project scope and methodology, as well as Gantt Chart that indicated key dates of completion for significant parts of the project

## BI-WEEKLY CONFERENCE CALLS WITH THE GREATER DUBUQUE DEVELOPMENT CORPORATION [IOWA CITY/DUBUQUE, IOWA]

Eric Isaacs served as the Renewable Energy Mapping and Policy Analysis Team's (REMPAT) primary contact to clients in Dubuque: the Greater Dubuque Development Corporation (GDDC) and the City of Dubuque. He called Mr. Dan McDonald from the GDDC and Mr. David Lyons, the project manager for the Smarter Sustainable Dubuque Initiative. Every other Friday morning, Eric reported on the group's progress made to date, as well as the potential challenges faced with gathering data or completion of tasks. These bi-weekly calls ensured that the project remained on task and held REMPAT accountable to completing all objectives laid out in the project timeline. Additionally, these calls helped to generate new ideas that aid in the completion of certain objectives. One example is the development of the business energy demand sampling methodology. Aside from these regularly scheduled calls, Eric made additional calls and sent emails to Mr. McDonald and Mr. Lyons as necessary to complete various tasks and objectives.

## WEEKLY RENEWABLE ENERGY MAPPING AND POLICY ANALYSIS TEAM MEETINGS [IOWA CITY, IOWA]

Throughout the Fall 2011 semester, the Renewable Energy Mapping and Policy Analysis Team (REMPAT) met every Monday afternoon at 1:30 pm. During the Spring 2012 semester, REMPAT met every Wednesday morning at 8:00 am. Hannah Papineschi created and sent out agendas prior to meetings, so that group members and instructors could prepare. These weekly meetings allowed each student the opportunity to update other group members on their weekly progress, detailing challenges and problems so that other group members could offer solutions or assistance. The meetings also allowed instructors, Dr. Paul Hanley and Dr. Charles Connerly, the opportunity to observe group dynamics and offer feedback and suggestions. Last, faculty advisor Dr. Scott Spak helped to solidify methodology and offer innovative solutions through his renewable energy and GIS mapping expertise. Collaboration among students and faculty proved valuable to the ability to complete work by deadlines and to the group's success.

## UTILITY BOARD CONSUMER ADVOCACTY STAKEHOLDER MEETING [DUBUQUE, IOWA]

On October 26, 2011 members of the Renewable Energy Mapping and Policy Analysis Team (REMPAT) attended a meeting with stakeholders, some with differing opinions, about energy regulations and policies. In attendance were representatives from the City of Dubuque, Greater Dubuque Development Corporation (GDDC), the Community Foundation of Greater Dubuque (CFGD), Alliant Energy, Black Hills Energy, the Iowa Utilities Board and state-approved Office of the Consumer Advocacy. The meeting highlighted various policies within the Smarter Sustainable Dubuque Initiative relating to the policies and regulations of each represented group. REMPAT networked and discussed opportunities for attendees to get involved with this project.

Mr. Dave Lyons, a project partner with REMPAT, discussed the Sustainable Dubuque Initiative, partnerships forged by the city, and ongoing pilot projects. Highlighted projects included smart metering for water, electricity, and natural gas. Mr. Lyons focused on how these technologies promoted healthy, sustainable choices in Dubuque. Following the presentation, Mr. Lyons facilitated a discussion centered on the need to engage community stakeholders with smart technology and to build and maintain public and private partnerships.

A forum was also held for groups to discuss ways to reduce existing regulatory barriers for renewable energy production. Specifically, each group discussed roles they play in the process. This session provided much insight into the barriers that prohibit widespread adoption of renewable energy and set the stage for public and private partnership collaboration within the Dubuque business community. In addition, it gave REMPAT an opportunity forge relationships with key players from both sectors and move the project forward.

## INNOVATIVE CONSORTIUM BREAKFAST [DUBUQUE, IOWA]

The Greater Dubuque Development Corporation (GDDC), invited Renewable Energy Mapping and Policy Analysis Team (REMPAT) members to present the project to local business owners. On October 28, 2011, the REMPAT attended a breakfast event with the Dubuque Innovative Consortium and introduced the project to the Dubuque business community. Consortium members, along with other Dubuque businesses, are the primary audience of the project, making it important to establish a familiarity with their efforts and goals.

By interacting with these stakeholders, members of the business community were able to contribute to the project. Innovative Consortium members recognized the groundbreaking research being performed by REMPAT members and expressed interest in forming partnerships with the team. In some cases, businesses owners provided the names of additional sources that could be of assistance to the project members. Several Consortium members directly provided information on annual, monthly, and peak electricity demand, enabling the group to produce accurate energy demand data for different business sectors. This data was used to help business and property owners determine how much of their energy needs may be satisfied through the use of renewable energy sources. Attending business owners were able to provide feedback on the project. It was imperative that the REMPAT, the GDDC, and the Innovative Consortium work together to further enhance the ability to implement the project's findings, as well as enhance efforts and goals of the Dubuque business community.

## END OF FIRST SEMESTER PROGRESS REPORT [IOWA CITY, IOWA]

On December 8, 2011, the Renewable Energy Mapping and Policy Analysis Team (REMPAT), represented by Michael Beach and Michele Vitale, delivered a final presentation, detailing work-to-date and the outlook for the remaining five months of the project. REMPAT unveiled preliminary solar, wind, and ground source heat pump maps, as well as preliminary policy analysis from the critical facilities and historic preservation planning questions.

## SECOND SEMESTER BEGINNING PROGRESS REPORT [IOWA CITY, IOWA]

Eric Isaacs and Hannah Papineschi delivered a progress report on February 7, 2012. Work-to-date, outlook for the remaining semester, and first drafts of all three technology maps were presented. New to the content, was the initial return on investment model methodology. The group fielded several questions specifically on the methodology from faculty members, project partners, and community members. These questions helped the group to refine the focus and methodology for the return on investment model for the rest of spring 2012.

## JAKOBSEN CONFERENCE [IOWA CITY, IOWA]

The Annual Jakobsen Conference at the University of Iowa brings together scholars, students, faculty, staff, and community members to engage in dialog about ongoing research. Robyn Fennig and Nick Benson represented REMPAT and presented the draft presentation for the American Planning Association's National Planning Conference in Los Angeles. The presentation highlighted methodology, maps, policy analysis, and preliminary outputs for return on investment. Presenting at the Jakobsen allowed us to field questions and explain how our project fits into a greater context of planning.

**The presentation may be viewed online at the following link:**
**[http://online.continuetolearn.uiowa.edu/p7y22oq8o20/?launcher=false&fcsContent=true&pbMode=normal0](http://online.continuetolearn.uiowa.edu/p7y22oq8o20/?launcher=false&fcsContent=true&pbMode=normal0).**

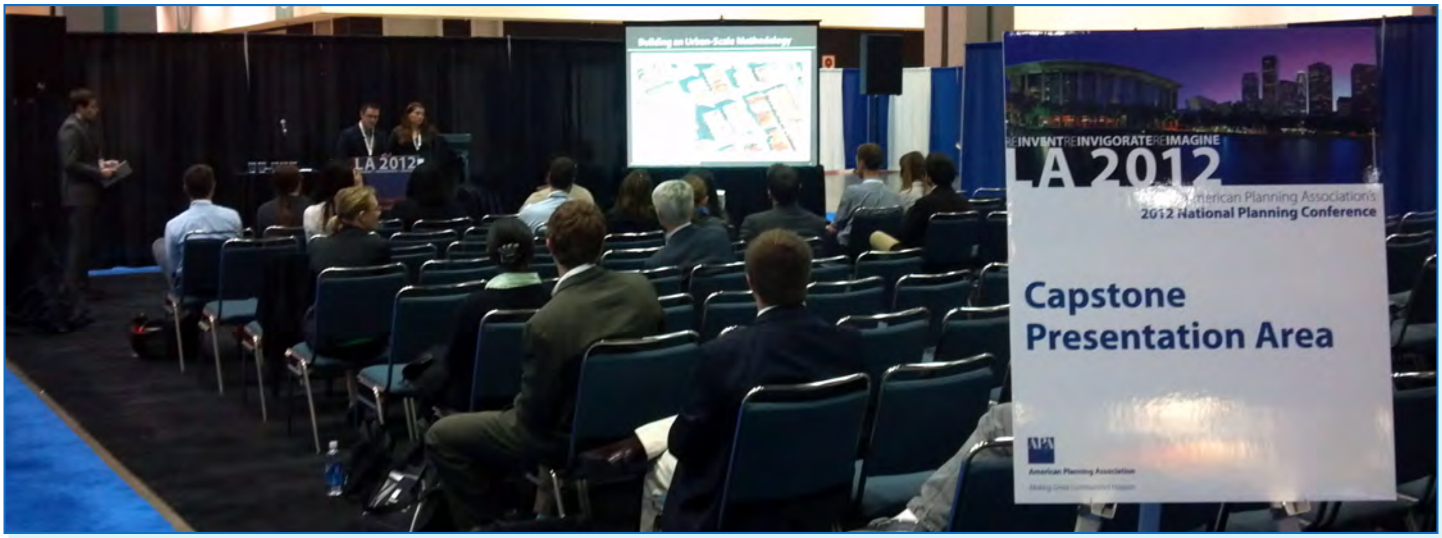



**Figure 5 (Above): Nick Benson and Robyn Fennig Present at the National Planning Conference in Los Angeles, California**

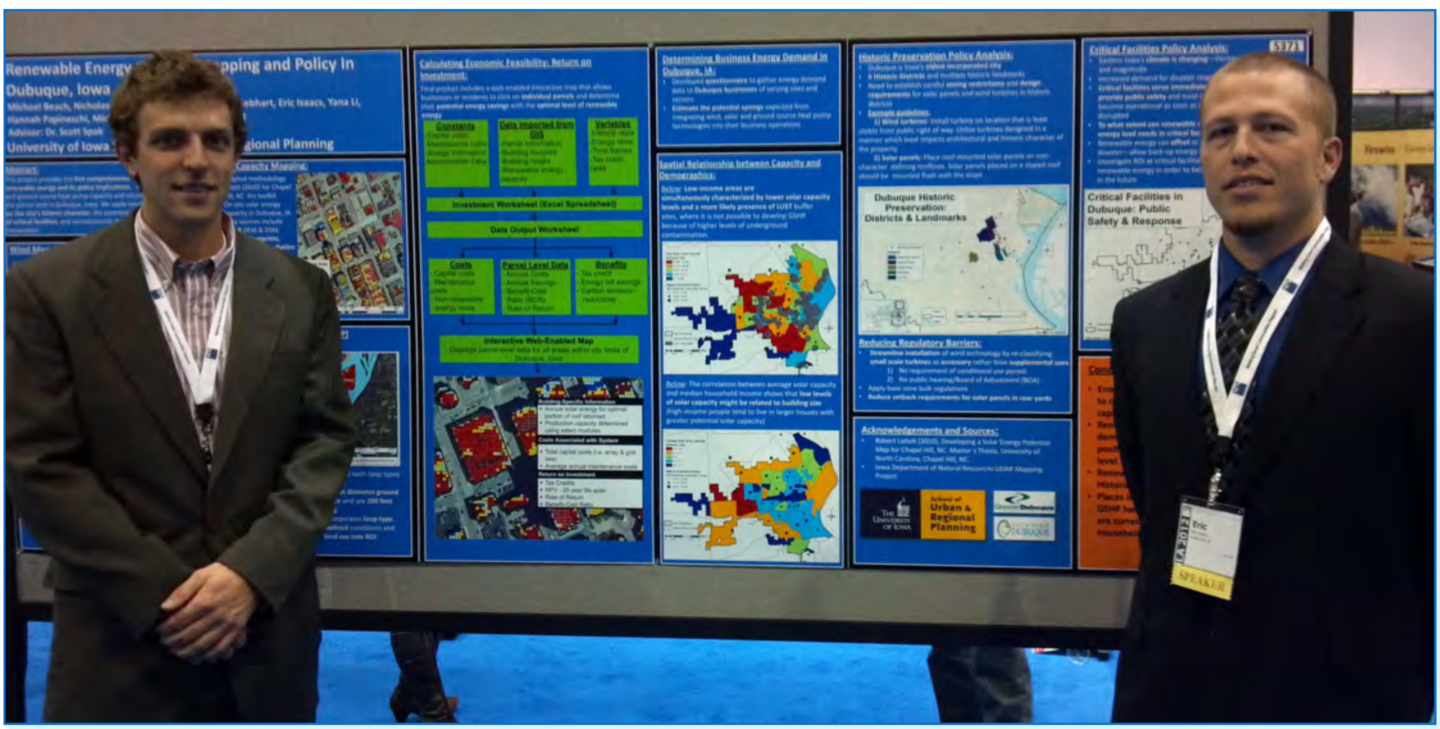



**Figure 6 (Above): Michael Beach (left) and Eric Isaacs (right) show the research poster at the National Planning Conference in Los Angeles, California**

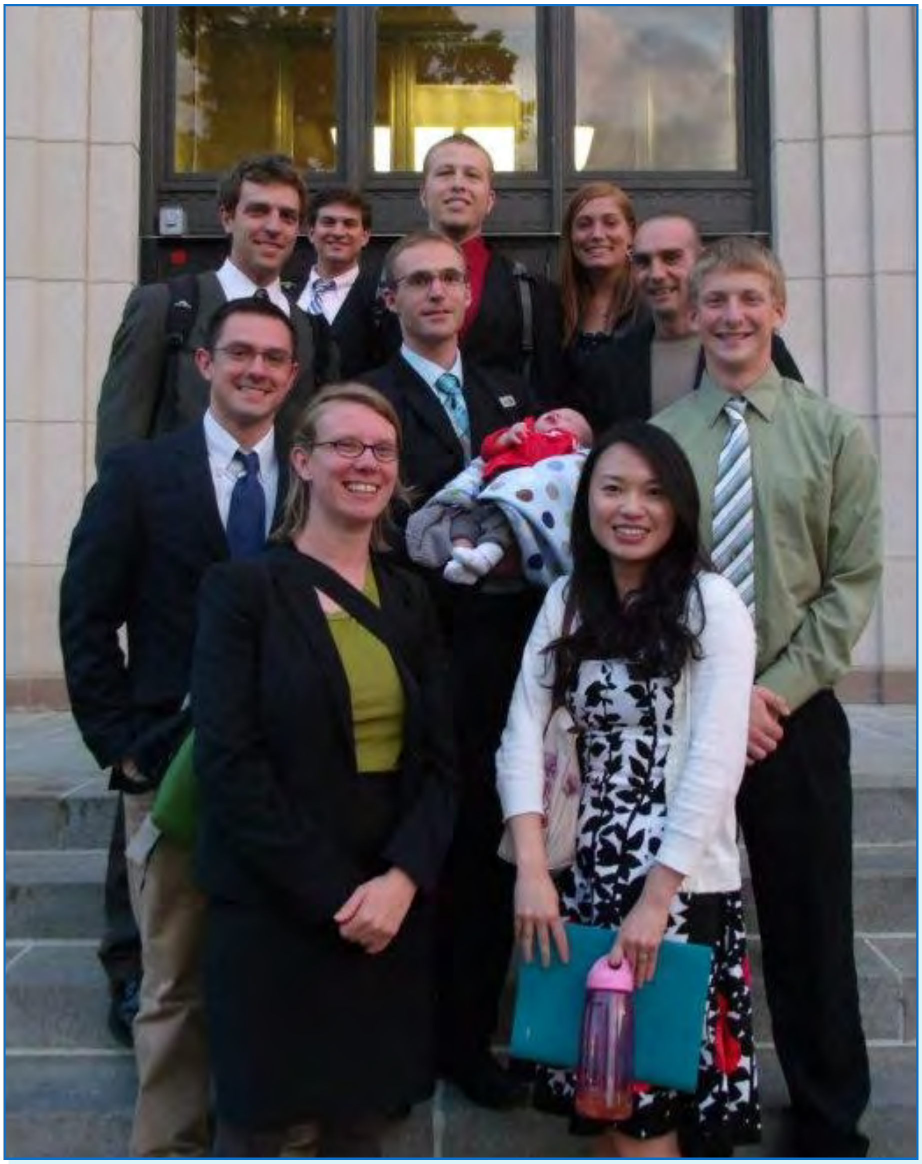
## AMERICAN PLANNING ASSOCIATION 2012 NATIONAL PLANNING CONFERENCE [LOS ANGELES, CALIFORNIA]

In September 2011, Robyn Fennig prepared and submitted an application to present at the 2012 National Planning Conference in Los Angeles, California. The Renewable Energy Mapping and Policy Analysis Team's (REMPAT) application was selected among a handful of student projects to present both a capstone presentation and a research poster by staff at the American Planning Association, as well as the Conference Host Committee in Los Angeles. Another task added to the project is securing travel grant funding to offset the costs of attending and presenting. Robyn oversaw the process, including seeking grant funding from the University of Iowa and School of Urban and Regional Planning, among other sources. REMPAT enjoyed the experience to represent all project partners, the University, and City of Dubuque in April 2012 in Los Angeles.

## FINAL PRESENTATION TO THE IOWA INITIATIVE FOR SUSTAINABLE COMMUNITIES [IOWA CITY, IOWA]

On April 24, 2012, Robyn Fennig and Nick Benson presented a final update to the project partners. This presentation built off of what the group showcased in Los Angeles, and presented findings of the Return on Investment Model. The group visually highlighted technologies with the highest return on investment, and indicated technologies that are an overall better investment.

**Figure 7 (Below): Student participants in the Iowa Initiative for Sustainable Communities with Dubuque Mayor Roy Buol n the Dubuque City Council Chambers.**



## PRESENTATION TO CITY OF DUBUQUE CITY COUNCIL [DUBUQUE, IOWA]

The group's made one last presentation to the Dubuque City Council on May 8, 2012 sharing all work completed in the project. New to this presentation was the web-enabled tool for residents and businesses to learn more about renewable energy on their parcels. The group also showcased the critical facilities policy analysis.

**Figure 8 (Left): REMPAT outside the Dubuque Historic Federal Building after the final presentation.**

**From left to right:**
**Bottom row: Hannah Papineschi, Yana Li**
**Second row: Nick Benson, Andrew Bennett**
**Third row: Adam Gebhart (and his son)**
**Fourth row: Mike Beach, Michele Vitale**
**Top row: Eric Isaacs, Robyn Fennig**

**This presentation may be viewed online, courtesy of the City of Dubuque, at:**
**http://cityofdubuque.granicus.com/MediaPlayer.php?view_id=2&clip_id=1257**

**(REMPAT's presentation starts at 22:00).**

# SOLAR CAPACITY MAPPING

One of the group's major tasks was to develop a solar capacity map to understand on-site energy production in Dubuque, Iowa. We were fortunate to find a capstone project completed by a Master's student at the University of North Carolina at Chapel Hill in 2010.[17] In this report, the author created a solar energy potential map for the city of Chapel Hill, North Carolina using ArcGIS, a geographical information system (GIS) software program. Using the general methodology outlined in this report and adapting it to our needs, we were able to create a raster file showing the incoming solar radiation for rooftops in Dubuque, Iowa. Ultimately, the findings of this capacity map were combined with knowledge about solar panel technology to complete a solar suitability payback analysis for photovoltaic and solar thermal energy systems.

## METHODOLOGY

In order to create the solar capacity map, we needed two main data items: Light Detection and Ranging (LiDAR) data and city building footprints. LiDAR data was acquired through the Iowa LiDAR Mapping Project as a raster file, which is an image file compatible for use with ArcGIS software, with elevation data of land, vegetation, and structures. The City of Dubuque provided the building footprint shapefile, a vector format used in ArcGIS, which was used to clip the final raster output to rooftops within the city. We also obtained National Renewable Energy Laboratory (NREL) Typical Meteorological Year 2 (TMY2) data, which aided in comparing our solar returns with known solar radiation data, providing for an additional check for accuracy in our data.

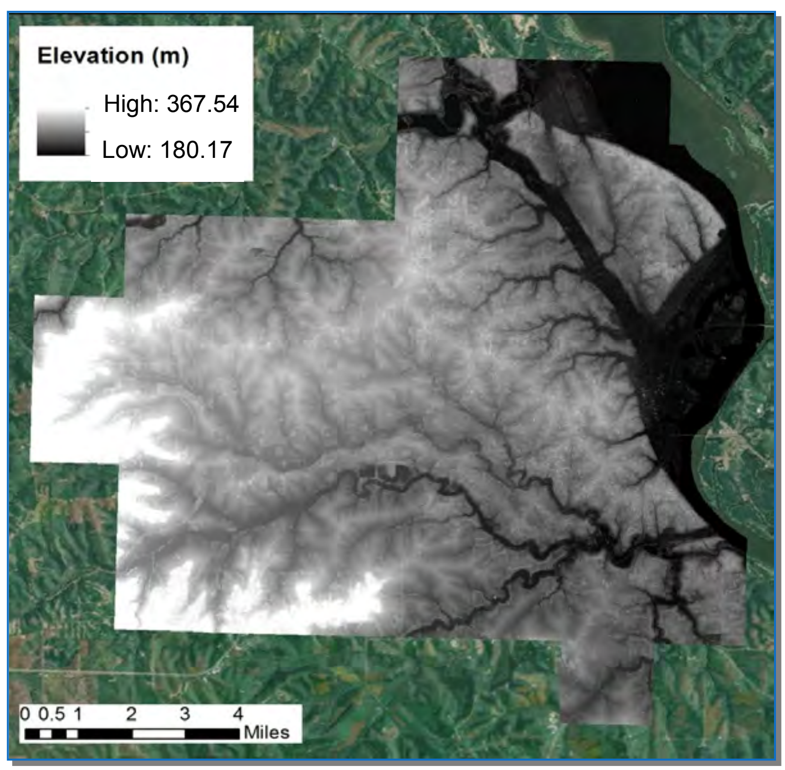



**Figure 9 (Above): Digital Elevation Model for Dubuque, Iowa**

Our first task was to create a Digital Surface Model (DSM). A DSM provides first-reflective topographic data of the earth`s surface containing cultural features (buildings, roads, and vegetation) and natural terrain features. In order to create a raster file, the raw LiDAR data was

17. Robert Leitelt (2010), Developing a Solar Energy Potential Map for Chapel Hill, NC. Master`s Thesis, University of North Carolina, Chapel Hill, NC.

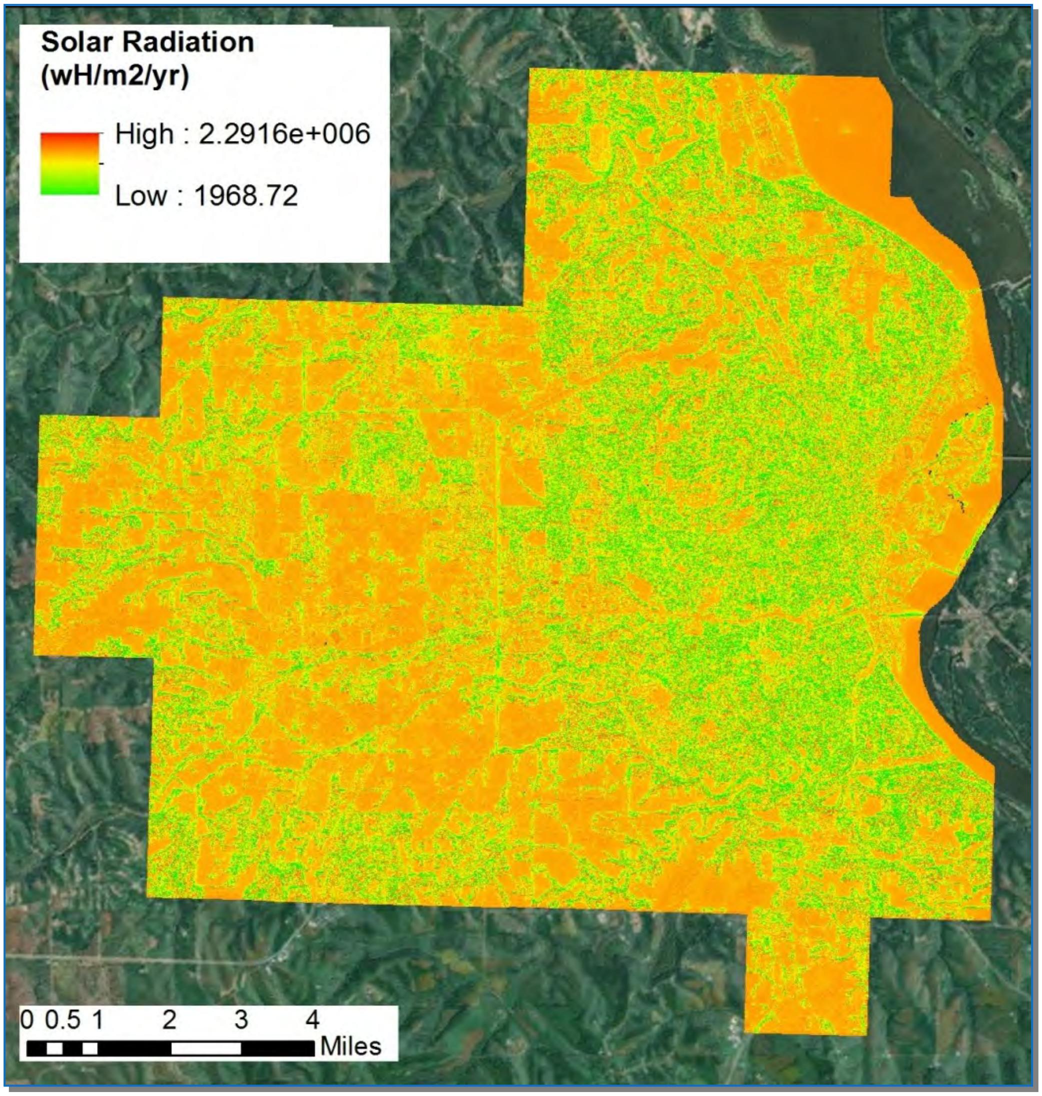



Figure 10 (Above): Area Solar Radiation for Dubuque, Iowa

downloaded as several LAS files.[18] These were processed into a multipoint file using the Point File Information and LAS to Multipoint tools within ArcGIS 3D Analyst. The multipoint file was then converted to a raster file with sixteen square meter cells and elevation assigned as the value field.

Because of the way LiDAR is created, there are often empty data cells in the raw data. We used a conditional expression that used the values of surrounding cells to fill these empty cells.[19], We applied the conditional expression four times, which allowed us to fill in most empty cells. The completed DSM layer provides a raster image with elevation data for land, vegetation, and structures. The DSM in its entirety for the City of Dubuque is displayed in *Figure 7*. In *Figure 7*, darker colors indicate lower elevation, while lighter colors indicate higher elevation.

After the DSM layer was created, we derived incoming solar radiation using the ArcGIS Spatial Analyst's Area Solar Radiation tool. We changed several inputs from the default settings to better fit the tool to our scenario. This included changing the sky size to 512, the time configuration to Multiple Days per Year, the year to 2011, the day and hour interval to one, the zenith and azimuth divisions to sixteen, the diffuse radiation to 0.2, and the transmittivity to 0.7. We chose these values because the output using these parameters compared well to NREL TMY2 data from Waterloo, Iowa, which was the closest city for which we had reliable data. Figure 8 shows the solar radiation return for Dubuque, Iowa in *Figure 8*. Warmer colors indicate higher incoming solar radiation.

Once we obtained our output from the solar radiation tool we separated the solar returns associated with buildings by extracting the solar raster to the City of Dubuque's building footprint shapefile. This removed all unnecessary solar returns from vegetation, roads, and bare terrain. We then converted the extracted solar raster to point data and the output value from Watt hours per square meter per year (Wh/m$^2$/year) to kilowatt hours per square meter per day (kWh/m$^2$/day), which is universally more useful. The final output is a point file extracted to buildings within the city with an average incoming solar radiation for each sixteen square meter area within the city, shown in *Figure 10*. Warmer colors (i.e. red and orange) in the map below indicate higher incoming solar radiation, while cooler colors (i.e. green and blue) indicate lower solar radiation. Zoomed images from the same map are included in Figures 11 and 12. As you zoom closer to a parcel, it becomes easier to see the variation within a single roof.

18. LAS stands for Log ASCII Standard, which is a format used for LiDar files.
19. Con(IsNull([input]),FocalStatistics([input],NbrRectangle(3,3),"Mean"),[input])
20. National Renewable Energy Laboratory. (1994, April). Solar Radiation Data Manual for Flat-Plate and Concentrating Collectors: Iowa Data Tables, http://rredc.nrel.gov/solar/pubs/redbook/PDFs/IA.PDF.

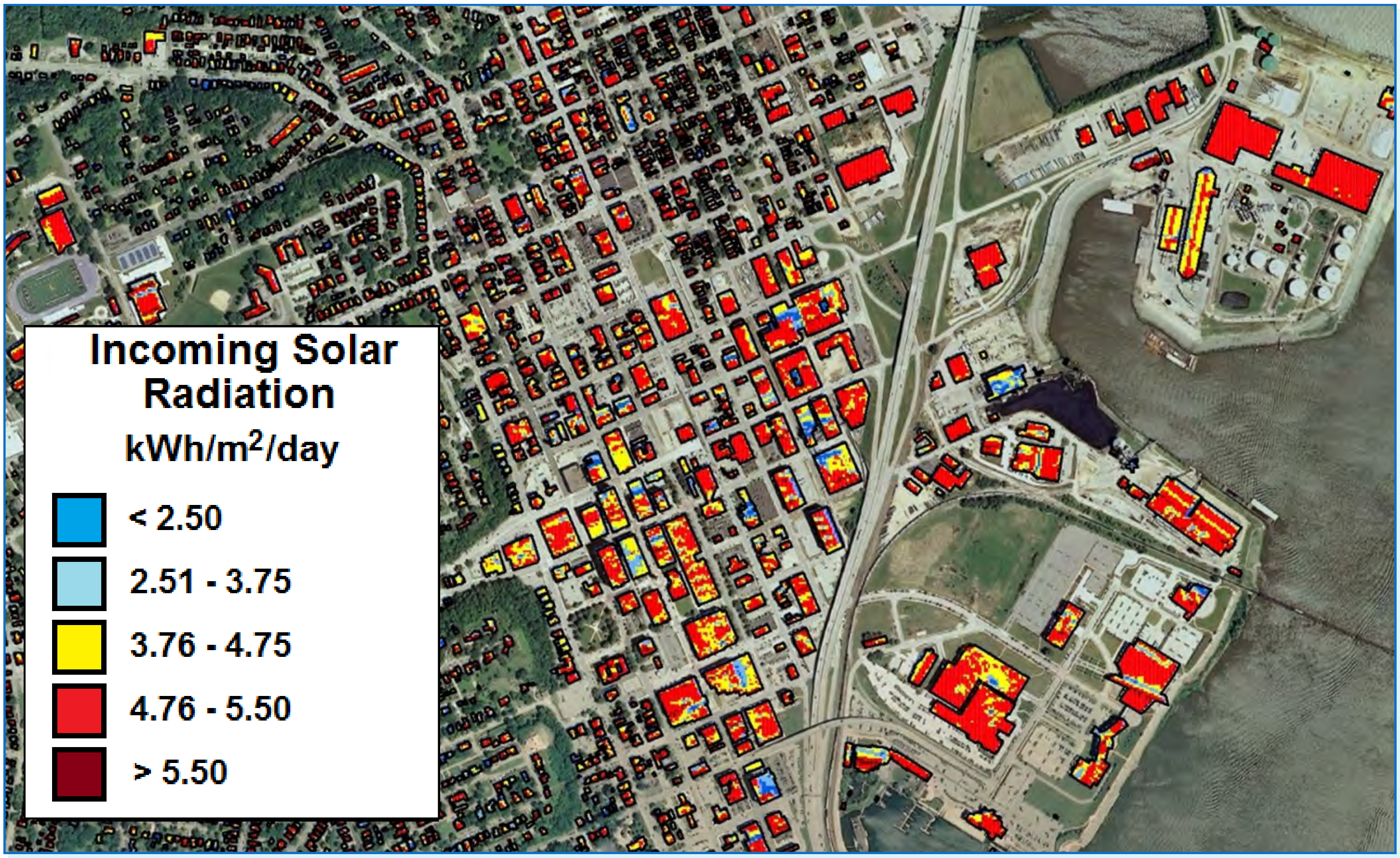



Figure 11 (Above): Incoming Solar Radiation in Dubuque, Iowa focused on Downtown Dubuque


Figure 12 (Above): Incoming Solar Radiation in Dubuque, Iowa focused on Downtown Dubuque (Zoomed)

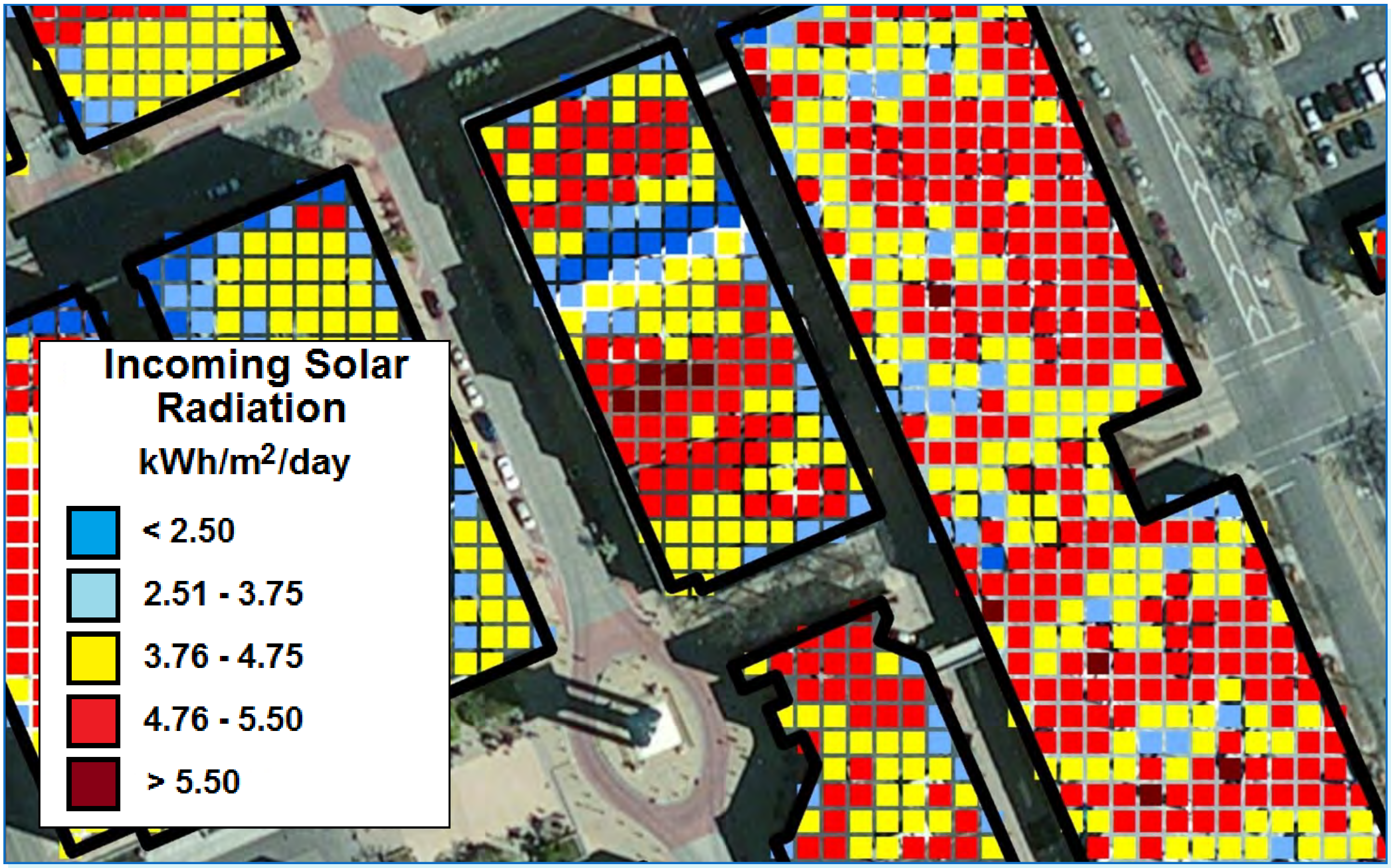



Figure 13 (Above): Incoming Solar Radiation in Dubuque, Iowa Zoomed Closer to Downtown Dubuque

# GSHP SUITABILITY MAPPING

The temperature of the earth below the frost zone remains at a relatively constant temperature year-round, typically about 55°F. When the ground temperature is higher than the ambient temperature, a ground source heat pump (GSHP) uses the earth as a hot reservoir from which it is able to pull heat for a building. Likewise, the system can be reversed in the summertime so that heat can be pulled out of a home and dumped into earth because it is cooler than the ambient temperature. GSHP systems are sized by the 'ton' of heating capacity, and the size of the system is determined by numerous factors including the tightness of the building envelope, building materials, size and use. System sizing is discussed in greater detail in the next section of this report.

There are two types of GSHP systems, *open-loop* and *closed-loop* systems. *Open-loop* systems are often called 'pump-and-dump' systems because they pump groundwater up though a heat exchanger on the surface before returning it underground. *Closed-loop* systems circulate the same fluid through the ground loop, using the ground as a heat exchanger. We chose to investigate only closed loop systems because of open-loop system environmental concerns such as the drawing down of the aquifer and potential contamination.

The most useful guide for the citizens of Dubuque is a map that identifies the maximum system size that each parcel can support. In the return on investment model, discussed in the next section of this report, this information is paired with an estimated system size per parcel to determine feasibility. Per Iowa Department of Natural Resources regulations, certain sites were immediately deemed unsuitable and eliminated:

- Sites within 1,000' of wastewater treatment facilities
- Sites within 1,000' of solid waste facilities
- Sites within 1,000' of leaking underground storage tanks (LUST sites)

Using GIS data from the Iowa DNR, bedrock conditions were included in the suitability map. Once a parcel was deemed suitable according to the aforementioned criterion, we evaluated the maximum system size it could support. The capacity of each parcel was determined by the number of bore holes which could fit on the property, for two different drilling configurations. In both horizontal and vertical drilling, pipes require a minimum of 15' between one another. The general consensus among local GSHP experts is that each 200' section of pipe has a heating capacity of one ton. It is also important to note that most non-residential sites drill up to 300' per loop, but only 200' loops were used in this analysis.

Horizontal loops require that the total surface area of the parcel be divisible into 15' by 200' rectangles. In this scenario, installers are able to stack three, 200'-long pipes at incremental depths of 15', 30' and 45'. In this manner, each 15' by 200' rectangle of surface area has a total of 600' of pipe, equivalent to roughly 3 tons of heating ca-

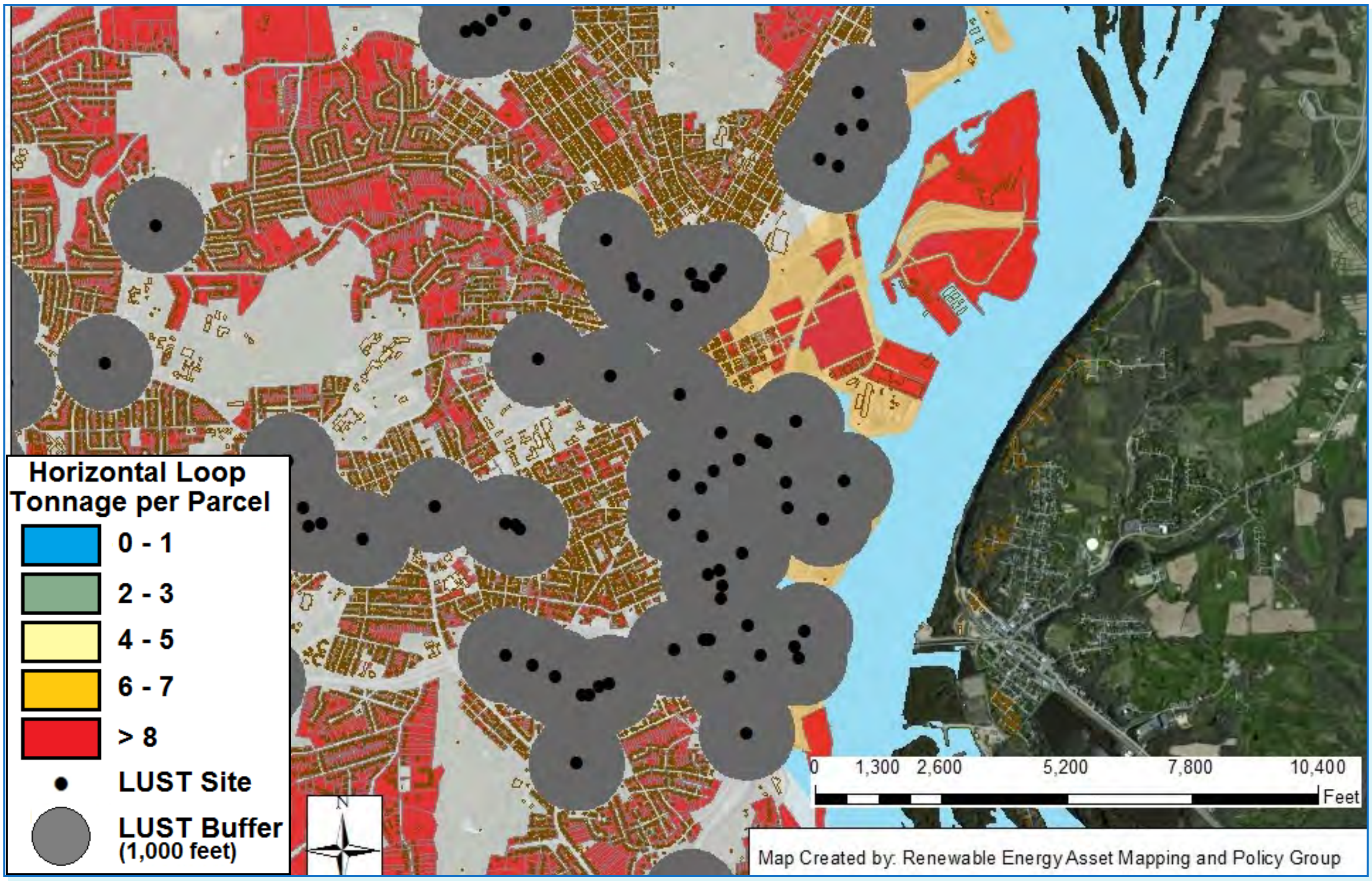



**Figure 14 (Above): Horizontal Loop GSHP System Suitability in Dubuque, Iowa (focused on Downtown Dubuque)**

pacity. Horizontal loops typically cost less to install, but cannot be used if the bedrock is limestone. One main advantage is that it is possible to drill horizontally underneath an existing building or parking lot, so although the surface area requirement is large, it does not need to be un-built. Outside of the buffer zones, all parcel's demand can be met with either a horizontal, vertical or both. Thirty-three percent of parcels were eliminated because they were in a buffer zone and the remaining sixty-seven percent of all parcel's demand was satisfied using a combination of horizontal and vertical loop.

Figure 14 shows the horizontal loop GSHP suitability map. Warmer colors indicate a higher GSHP capacity, while the gray circles around black dots represent the buffer required by the DNR around LUST sites. Most of these sites are along the industrial/ commercial corridors of the city.

The vertical loop capacity of a parcel was determined by dividing the open surface area by 180 $ft^2$, the footprint required to maintain 15' in between each bore hole. Vertical systems are more expensive, but can be drilled into limestone. Figure 15 provides a close-up look at the vertical loop GSHP capacity for a section of downtown Dubuque. The gray areas in the upper and lower left-hand corners are buffer zones around nearby LUST sites.

Numerous experts were consulted in order to make this map as accurate as possible; their information is included in the Acknowledgements. GSHP systems are incredibly site-specific, so contacting an experienced professional is absolutely necessary to verify the findings in this report. The purpose of this map, and the entire project, is to

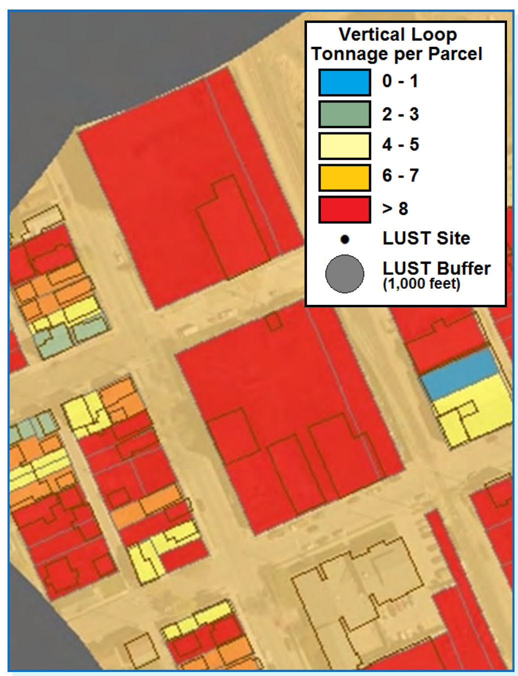



**Figure 15 (Above): Vertical System Suitability in Dubuque, Iowa**


**Figure 16 (Above): Vertical Loop GSHP System Suitability in Dubuque, Iowa**

give people an idea of the renewable energy capacity for their parcel and encourage them to take a serious look at these technologies.

Thank you to the following individuals for contributing to the GSHP research:

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# WIND CAPACITY MAPPING

Mapping wind capacity in the City of Dubuque was the most challenging part of the project. Vegetation, buildings, and topography in urban areas lead to turbulent wind patterns, which cause less predictability in wind speed. Detailed and reliable meteorological data was not easy to obtain. This, in turn, affected our ability to reliably model wind speed and direction throughout the city.

Despite these challenges, the group was able to develop maps showing mean annual wind speed and power curves for all parcels in Dubuque. Additionally, we generated energy capture reports to develop the return on investment template.  The group used five steps to complete the wind capacity map and ROI calculations :

1) Researched existing wind capacity studies and methodology used in those studies
   - Determined which methods are applicable to our project
2) Identified potential wind power curve data sources
   - Requested data and additional references
3) Obtained data and perform quality assurance and quality control (QA/QC)
   - Determined suitability of data
   - Checked accuracy of observations using National Weather Service data
4) Used openWind mapping software and best available data to map capacity
   - Revised parameters to obtain best resolution
5) Used openWind energy reports in ROI estimates
   - Entered selected turbine models and specifications in openWind
   - Generated power curves at designated height(s) for turbines

## METHODOLOGY

### RESEARCH

We first reviewed wind mapping reports and studies. There were numerous reports available on this topic; however, few of them analyzed wind at the urban scale. Most reports focused on mapping utility-scale wind energy. The few studies conducted at the urban scale investigated potential wind energy at a single site but did not detail how to map potential capacity at the community level. Most studies, whether urban or utility scale, suggested that a user install an anemometer on-site for six months to one year in order to obtain an accurate wind power curve, which would not be useful four our study.

### IDENTIFY DATA SOURCES, OBTAIN DATA, QA/QC

Next, we identified potential sources to obtain wind speed data. Group members contacted agencies, such as the Iowa Energy Center, Iowa Farm Bureau, and the Iowa Wind Energy Association, in hopes of finding urban scale wind speed data for Dubuque. Unfortunately, these agencies did not have data, but suggested others who could potentially assist the project. Interacting with these groups increased the visibility of our project in the wind energy community.

In October, Steve Brown, a City of Dubuque engineer, provided a dataset containing anemometer readings from twelve locations throughout the city. It included:

- anemometer model
- wind speed
- temperature
- time of reading

In November we performed quality assurance on the data and found that readings from some locations were problematic. Most anemometer recorded wind speed over different times periods and at different time intervals.
For instance, readings taken one site showed observations taken once daily from April 2010 to November 2011, while observations at another site were collected every five-minutes from August, 2006 to March, 2007. Additionally, some anemometers had errant or inconsistent readings (i.e. negative wind speed).

Initially, group members determined that only observations from the City Hall Annex were suitable for use in openWind, the wind speed modeling program chosen for this project. This dataset was sufficient since it offered the longest, continuous time period measured (August, 2006 to March, 2007), the shortest intervals for measurements (five minutes), and the largest number of worthwhile measurements (after QA/QC) at 65,500.

While one location might be sufficient to predict wind speed in some cities, data from additional sites was needed to more accurately predict wind speed in Dubuque. This was due largely to the variations in urban wind patterns and the topography of the Dubuque. The City Hall Annex is located in downtown Dubuque, which also encompasses a portion of the Mississippi River valley. This compares to areas west boundary of downtown, marked by steep bluffs, separating downtown from the rest of the city. This created at least two different zones for which modeling needed to account.

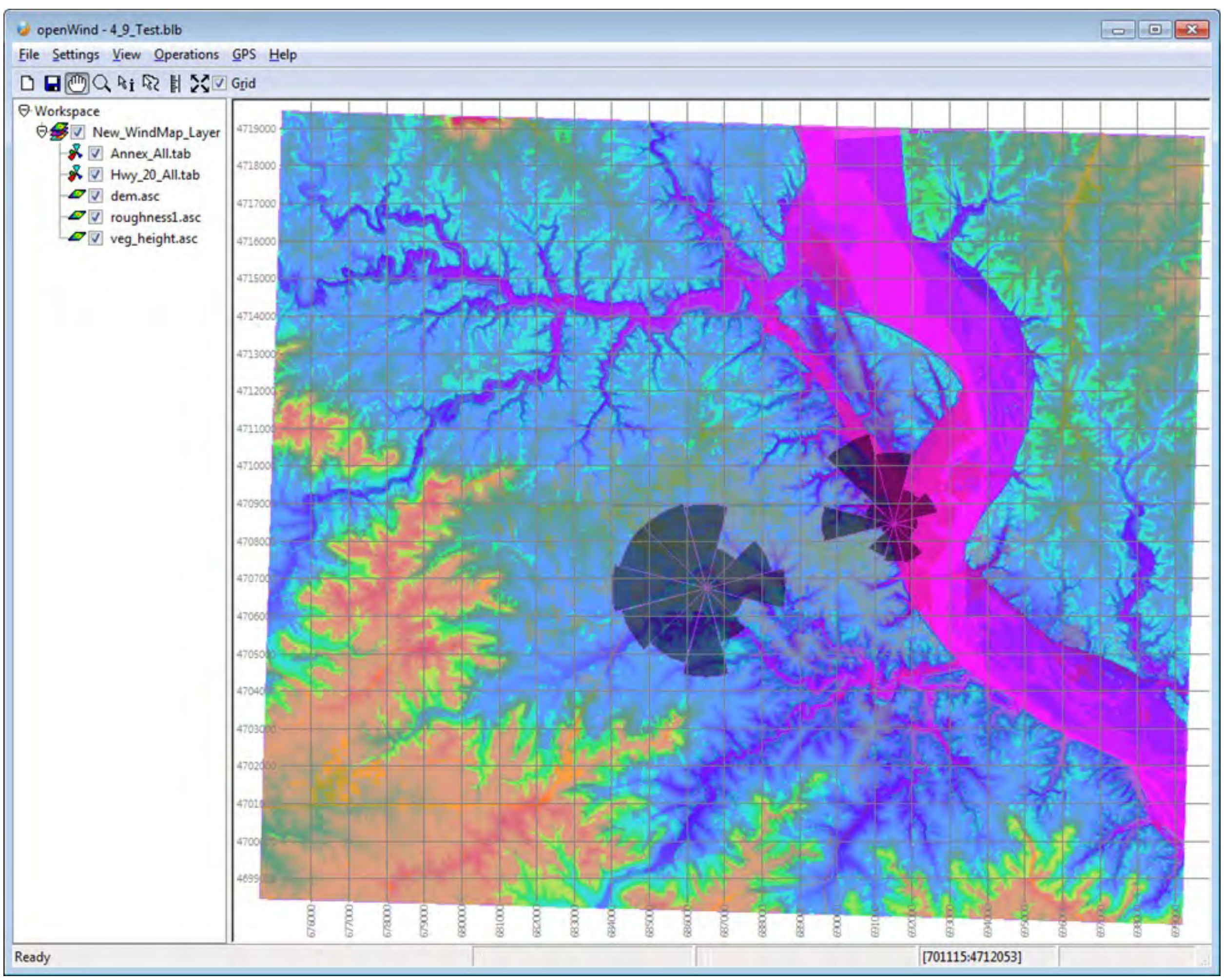



**Figure 17 (Left): Screenshot of initial AWS OpenWind test run with both the City Hall Annex and Highway 20 anemometer sites (locations highlighted by wind rose images).**

**It is easy to see the ArcGIS-like interface used by the program.**

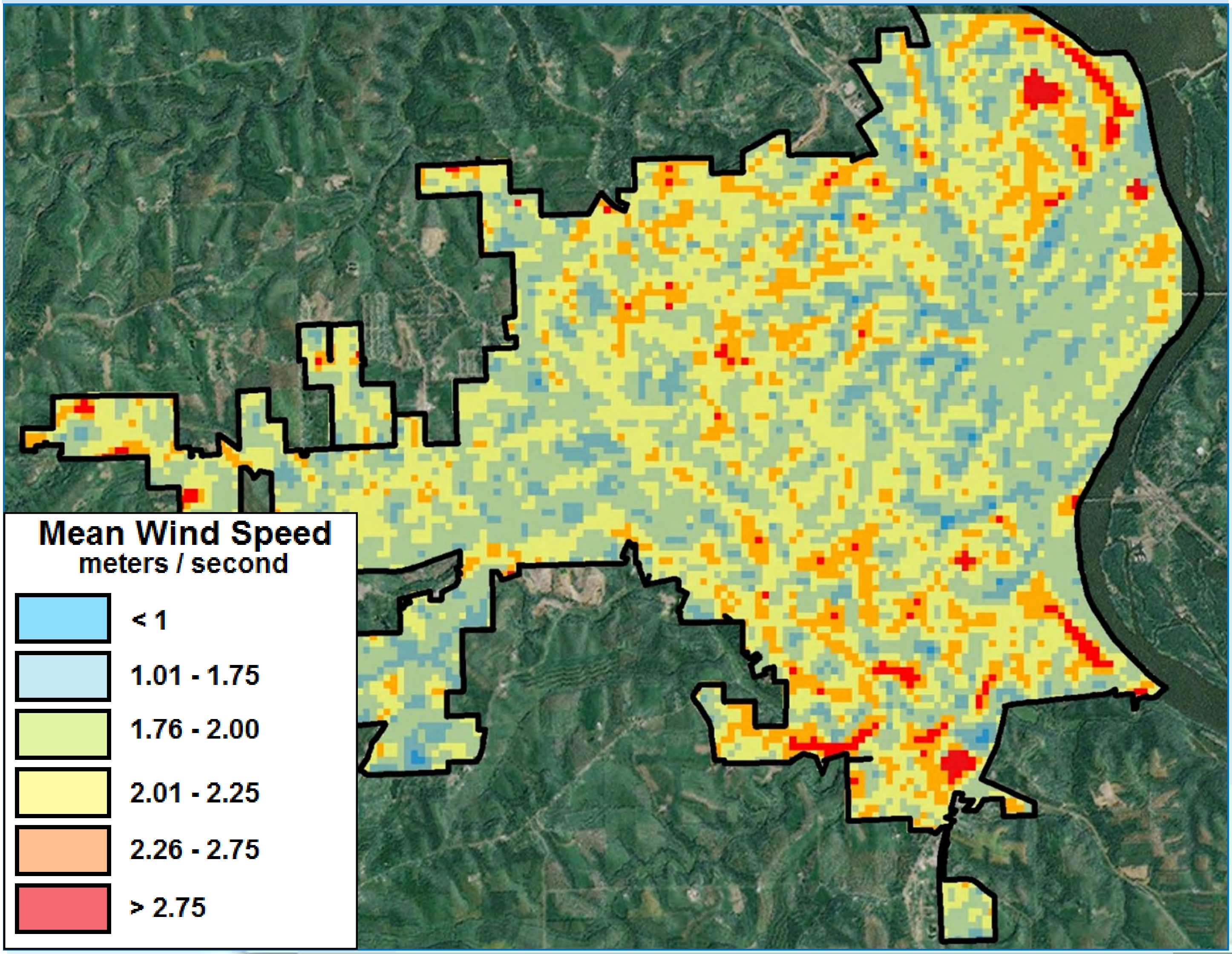



**Figure 18 (Above): Wind capacity map generated with OpenWind using both anemometer site readings at 90m resolution.**

In December, the Iowa Environmental Mesonet (see website at : http://mesonet.agron.iastate.edu) provided additional wind speed data. This site provided free access to meteorological data recorded at hundreds of sites and on multiple networks throughout the State of Iowa. Among all networks with a measurement station in Dubuque, only one location was identified that had wind speed data to complement the City Hall Annex.

The Roadway Weather Information Systems (RWIS), part of the Iowa Department of Transportation's effort to monitor pavement and weather conditions along Iowa's major roads, has one location in western Dubuque. The station station, located near the southeast corner of U.S. Highway 20 and Menard Court, provided a second dataset of meteorological observations that were exposed to a different wind pattern. Data from this station was available from February 2000 to the present on ten-minute intervals. To remain consistent with City Hall Annex data, only observations from August 2006 to March 2007 (a total of 30,550 observations) were used for modeling wind speed in Dubuque.

## OUR SOFTWARE: OPENWIND

Phase 1 openWind

To map wind capacity, we used an open-source program called openWind. Provided by AWS Truepower, openWind features an ArcGIS-like interface and was developed "as an aid for the design, optimization, and assessment of wind power projects" to model wind speed in an a selected area based on meteorological measurements, elevation, vegetation and structure height, and surface roughness .[27]

Data used and sources included:

- Meteorological measurements (MetMasts)
  MetMasts came from anemometer observations at both City Hall Annex (City of Dubuque) and Highway 20 (RWIS).
- Elevation and vegetation height rasters
  These rasters were generated for solar capacity mapping. Elevation data came from a county digital elevation model (DEM) and vegetation height came from subtracting the DEM from Li-DAR data using the Raster Calculator within ArcGIS.
- Surface roughness
  This was derived from 2006 National Land Cover Database (NLCD) files. Specific roughness values, according to the Davenport-Wieringa roughness-length classifications (see: http://www.shodor.org/os411/courses/_master/tools/calculators/moninobukhov/roughness.html), were applied to NLCD land cover types. Finally, all rasters were converted to ASCII files in ArcGIS for use in openWind.

OpenWind incorporated these files into the calculation and allowed us to select the desired measurement height and output raster cell size, or resolution. The primary raster outputs showed mean annual wind speed, inflow angles, and elevation. Group members used a computer with 12GB RAM to run the software. This which was necessary due to the extensive nature of input data and the high resolution outputs.

Group members sought a desired resolution of 10 meter cells for the entire city to help account for fluctuation in wind speeds caused by an urban environment and varying topographic features. However, this proved difficult as the software would not complete the calculation despite using computers with 12GB RAM. After several weeks of trial and error, we were able to create wind maps with resolutions of 90 meters by incorporating observations from both MetMast locations. A resolution of 20 meters was obtained for the downtown area

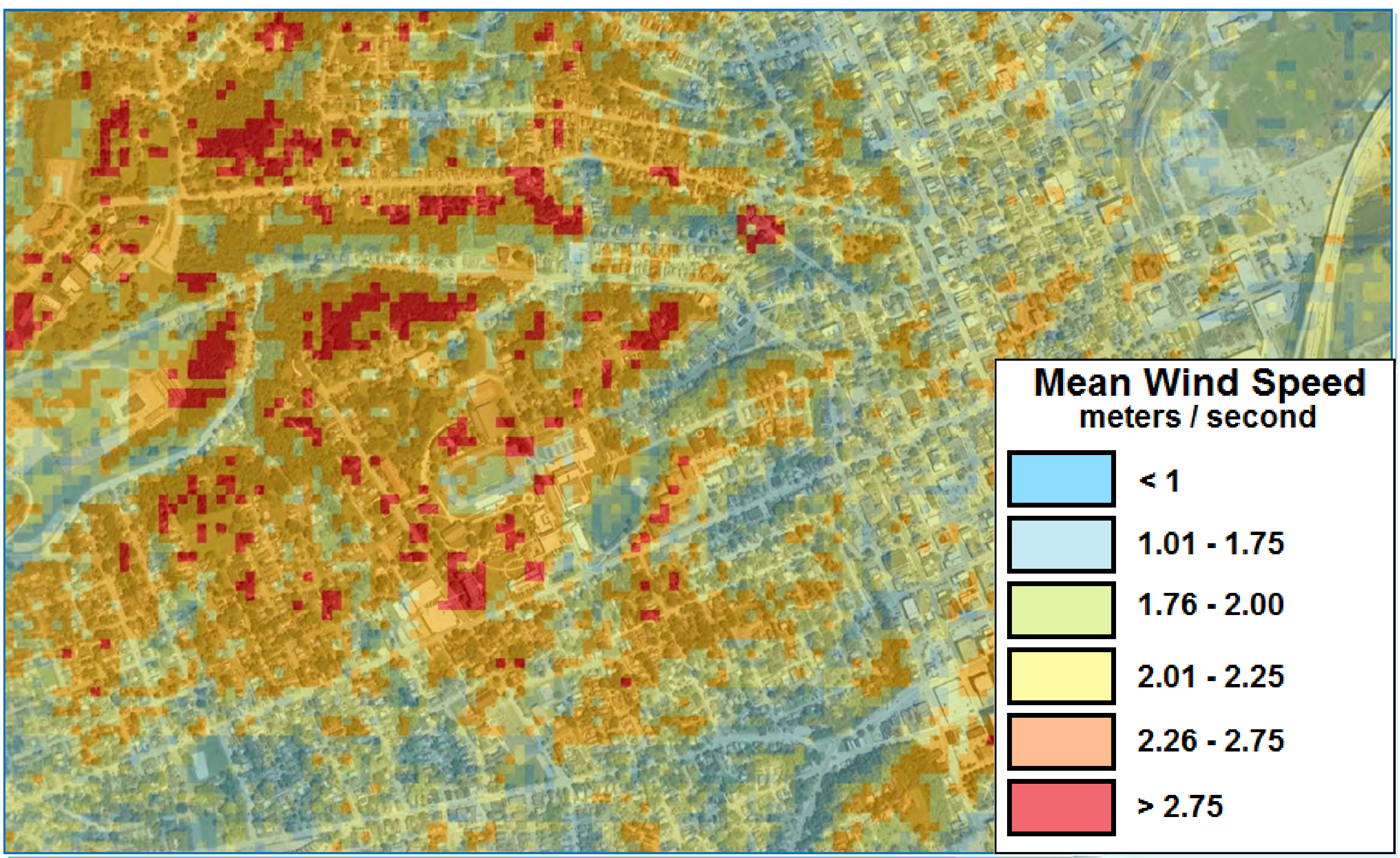



**Figure 19 (Above): Wind capacity map generated with OpenWind using both anemometer site readings, at the 20 meter resolution**

using *only* the City Hall Annex MetMast. Because openWind restricted wind speed height measurements to a minimum of 10 meters, we used these calculations as our base data.

Phase II openWind

The second phase of openWind consisted of using energy capture reports and mean annual wind speed outputs to assist with the ROI template. Group members identified three turbine models (**see models and specs in ROI section**) suited for the urban environment for which an ROI value would be calculated on each parcel. Each model's estimated power curve and specifications were entered into openWind and a turbine was placed in an output cell for mean wind speed range of 0-1, 1-2, 2-3, 3-4, and 4-5 meters per second. The Energy Capture report was created for each turbine showing its annual capacity when subjected to the mean wind speed ranges above.

We first attempted to use the openWind *Hours per Year* report to predict the total hours per year that each parcel or grid cell would see winds in the ranges listed above. Upon closer inspection, the *Hours per Year* report only reflects observations from the first MetMast listed in the Wind Map Layer, not each output grid cell, and thus was not useful for our purposes.

Next, we decided to place turbines at random locations throughout the city in order to find power curves for those locations. This proved ineffective for two reasons. First, we could not randomly place turbines on every parcel in the city because of the memory required for such a task. Second, random placement of turbines in the city would not necessarily provide any indication of variation in power curves because we did not take wind speed differences into account.

In the final attempt at calculating power output at the parcel level, we incorporated the results from the first phase of the wind mapping to create new turbine models in openWind. We created turbine models in openWind and entered the manufacturer's design specifications. Then, we identified locations in ArcGIS that experienced the mean annual wind speeds in the categories listed above. These coordinates were used to posi-

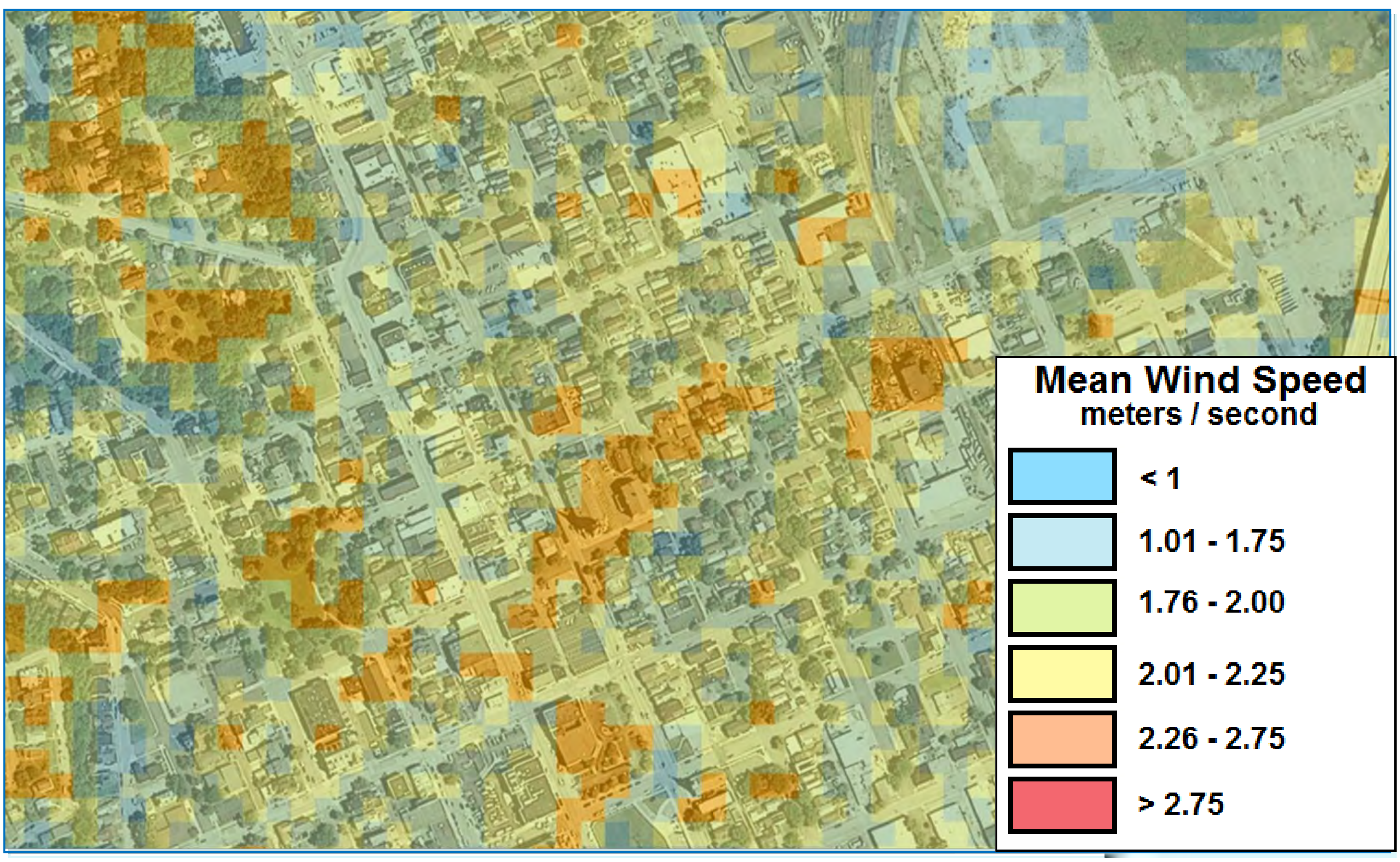



**Figure 20 (Above): Wind capacity map focused on Downtown Dubuque at a higher, 10 meter resolution**

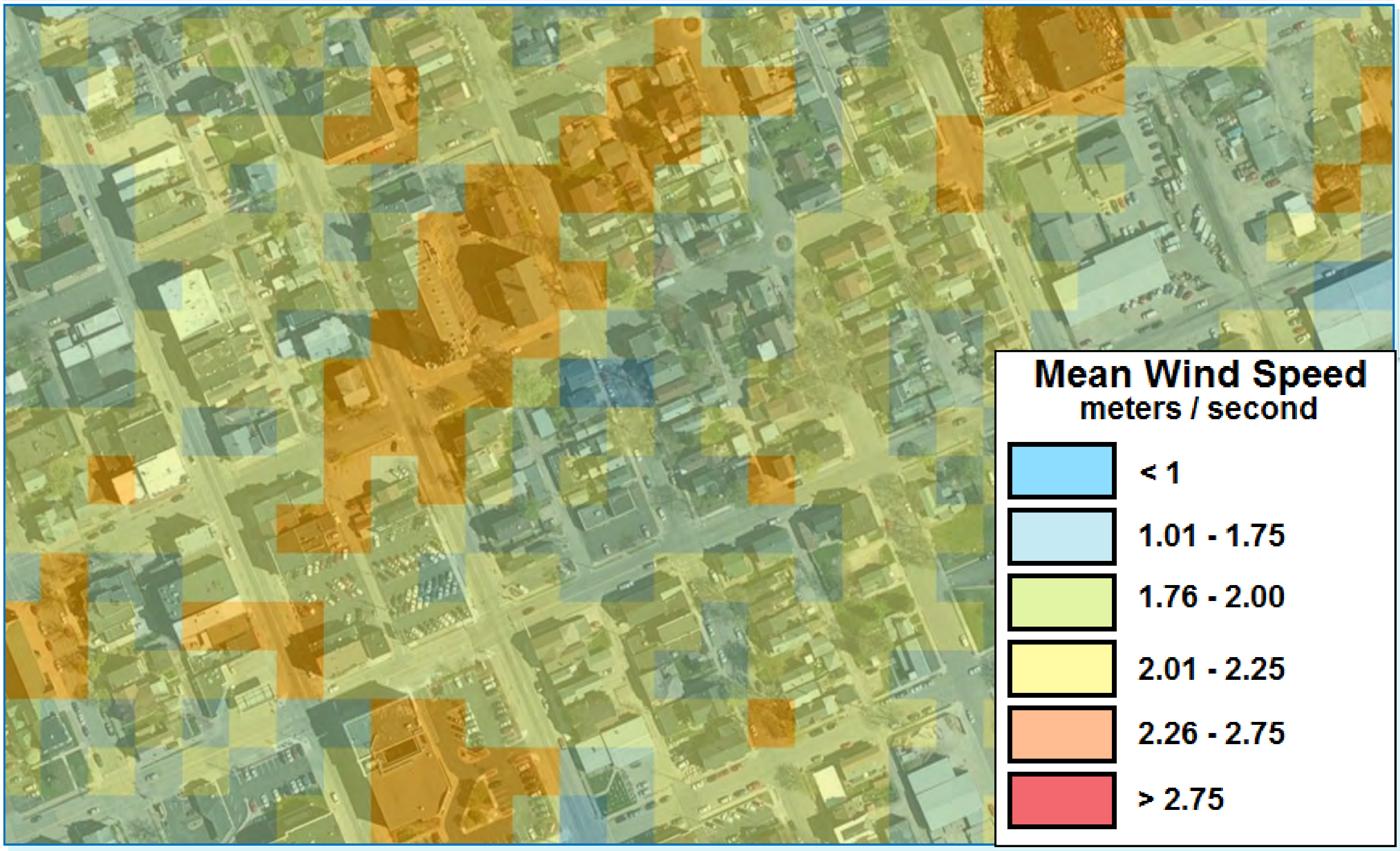



Figure 21 (Above): Wind capacity map focused on downtown at 10 meter height, zoomed in for higher resolution

# RETURN ON INVESTMENT

Disseminating information about renewable energy capacity is an important first step to enabling Dubuque home and business owners better understand their options for renewable energy. However, if installing renewable energy is not cost-effective, it cannot be implemented. Our group seeks to not only give capacity information, but help Dubuquers understand potential savings and return on investment.

## SOLAR THERMAL TECHNOLOGY RETURN ON INVESTMENT

Both residential and commercial buildings can benefit from a solar thermal system. In cold climates like the upper Midwest, a glazed collector is used because it is able to produce hot water even when the ambient temperature is below freezing. Heated glycol circulates through the glazed solar collector and exchanges heat with a building's water supply to produce hot water. The ROI model assumes that each residential parcel has one solar hot water collector located on the part of the roof with the highest solar radiation. The average residence uses 70 gallons of hot water per day, per person.[21] According to the Iowa Renewable Energy Association, a properly sized system can easily meet this requirement four to six months of the year, and provide preheated water for the remainder of the year.[22]

Using the solar map, which calculates incoming solar radiation, we determined the amount of daily hot water produced by our selected collector. The Heliodyne Gobi 408 001 solar thermal energy collector was used in our analysis. This system features two 4' by 8' collector panels with an efficiency of 70%.

Water temperature depends on the inlet and ambient temperature. In order to estimate total annual production, the inlet temperature was assumed to be 55˚ Fahrenheit (i.e. tap water) and average ambient temperature to be 60˚ Fahrenheit. We also assumed that temperature for heated household applications is 120˚ F. The following inputs were used in calculations:

- Desired temperature of water (i.e. 120˚ F)
- Incoming solar radiation (determined from solar map)
- Specific heat of glycol mixture in solar collector (i.e. amount of energy it takes to raise glycol by one degree Celsius) = 3.85 kJ per Kg—˚ C (i.e. kJ: kilo Joules per kilo Gram degrees Celsius)

We combined the above inputs with the output of the ArcGIS solar map, where energy is displayed in kWh per square meter. Using conversions, the output was in gallons per square meter. Inefficiencies in the systems reduced the overall peak output. We assumed 50% efficiency for water heating systems and 95% efficiency in heat exchange between the glycol mixture and water. Each solar collector, in a location with an average radiation of 4.5 (kWh/$m^2$/day), will produce 54.4 gallons of hot water with these assumptions. After calculating the daily hot water production the collector

21. *Investing in a Solar Hot Water System*. Retrieved from the Vermont Energy Investment Corporation, http://www.rerc-vt.org/shw_investing.htm
22. *Solar Domestic Hot Water*. Retrieved from the Iowa Renewable Energy Association (IRENEW), http://www.irenew.org/IRETC_SDHW.html


**Figure 22 (Above): Solar Thermal Benefit-Cost Ratio compared to conventional gas water heaters at the parcel level in Downtown Dubuque, Iowa**

**Figure 23 (Below): Solar Thermal Benefit-Cost Ratio compared to high efficiency gas water heaters at the parcel level in Downtown Dubuque, Iowa**

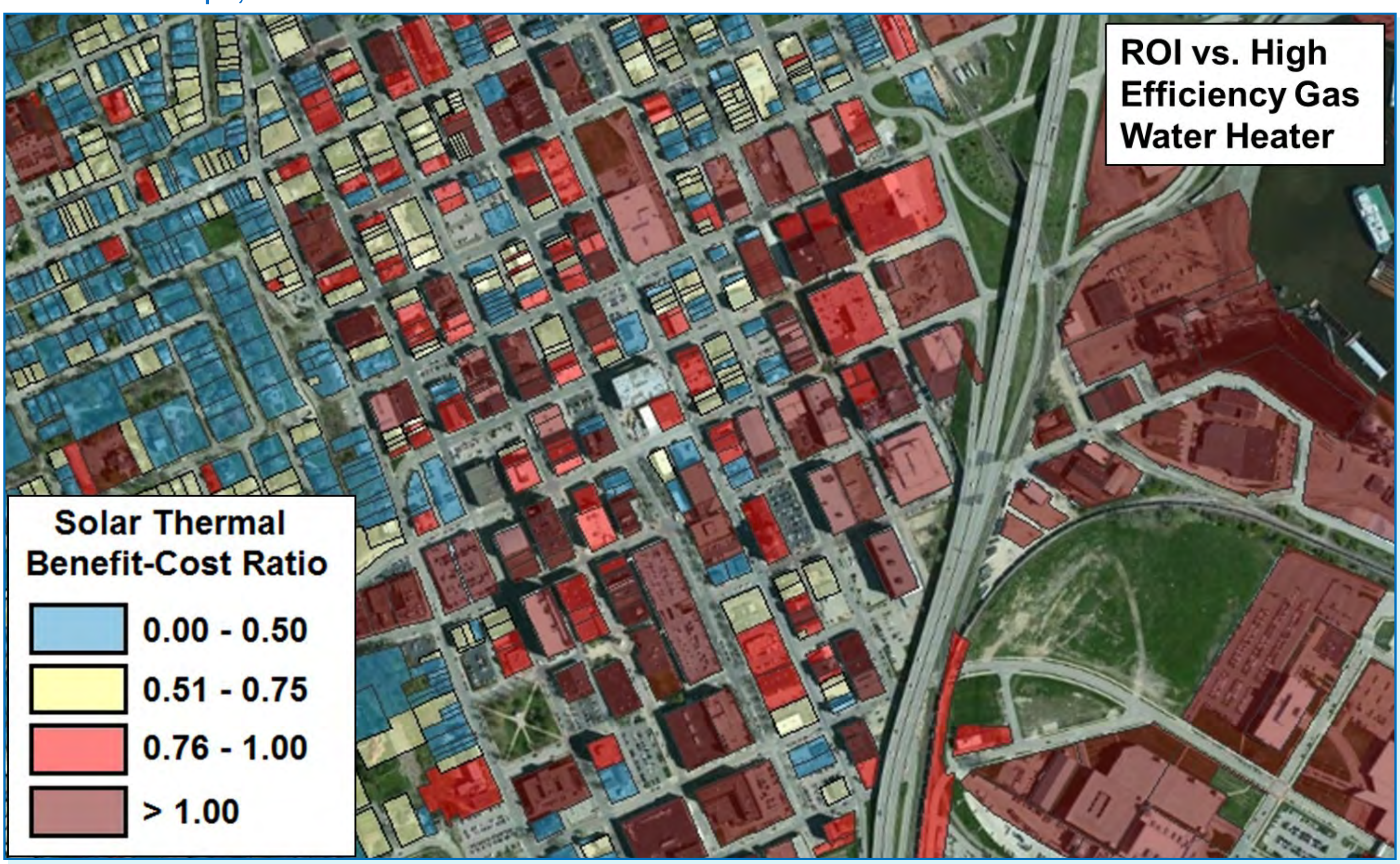
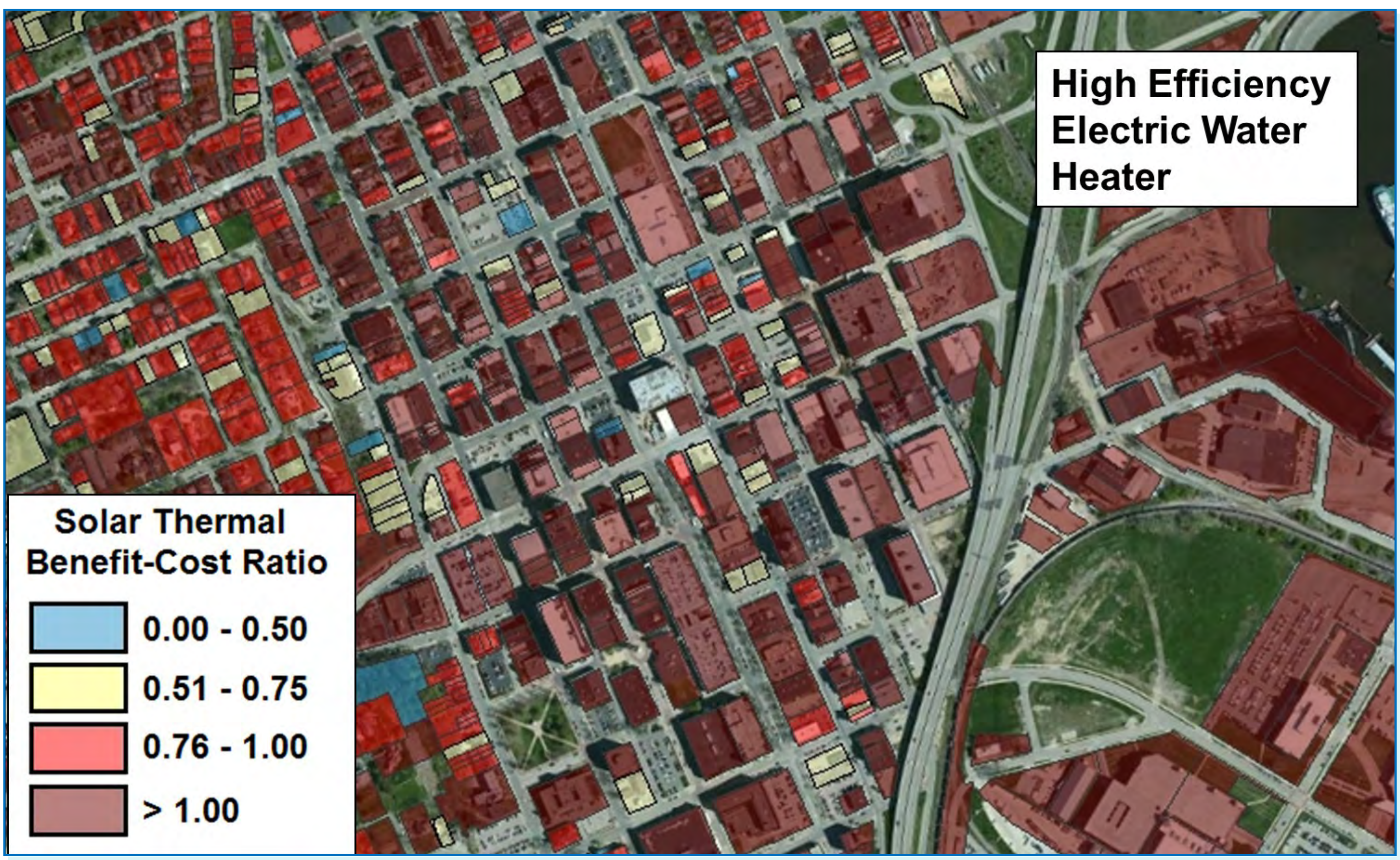



Figure 24 (Above): Solar Thermal Benefit-Cost Ratio compared to conventional electric water heaters at the parcel level in Downtown Dubuque, Iowa

Figure 25 (Below): Solar Thermal Benefit-Cost Ratio compared to high efficiency electric water heaters at the parcel level in Downtown Dubuque, Iowa



system, we were able to calculate electricity savings, based on calculations that determined amount of electricity required to heat the same amount of water. Offsets were calculated using four types of water heating systems:

- Conventional gas (60% efficiency)
- High efficiency gas (65% efficiency)
- Electric (90% efficiency)
- High efficiency electric (95% efficiency)

Setting a rule to determine the estimated hot water demand for each building proved to be difficult. For example, office buildings with a cafeteria use much more hot water than an office building without, and there is no way to capture this difference with the ArcGIS data. The hot water demand for buildings in commercial and industrial zones was estimated to be one system per 6000 square feet. Of course, there is a large margin of error in this estimate. With no way to differentiate between building uses and water use, a warehouse with the same footprint as a water-intensive manufacturing facility will have the same assumed demand. The benefit of this type of system is that it is modular, and the system output and capital cost can easily be scaled for buildings that know their hot water consumption.

As previously stated, many sources estimated daily hot water usage for a single family home to be approximately 70 gallons. Each residential parcel was limited to one system, estimated to meet nearly 100% of the demand in the summer, and preheat the water in the winter time.

Based on our findings, solar thermal sees relatively high return on investment as compared to all four technologies (i.e. conventional gas, high efficiency gas, electric, and high efficiency electric). Figures 22 and 23 highlight the ROI as compared to conventional gas and high efficiency gas water heaters. Figures 24 and 25 show the ROI compared to conventional and high efficiency electric water heaters. It is easy to see that overall, solar thermal systems see a higher ROI when compared to electric systems, due in part to the lower cost of natural gas.

## SOLAR PHOTOVOLTAIC TECHNOLOGY RETURN ON INVESTMENT

Solar PV is arguably the simplest of the renewable energies investigated in this report; installation is straightforward and the electricity produced feeds directly into the home or business. Solar PV systems typically last 25-30 years with minimal maintenance, though their power output does decrease slightly. This ROI model makes the distinction between residential and commercial PV systems. On residential parcels, it is assumed that 25% of the roof surface is facing south, and that all roofs have a slope of 27° (pitch of 1:2). The slope of the roof is important because in a residential situation the panels will be mounted parallel to the roof line, and the panels will receive about 10% more energy from the sun if oriented at a 30° pitch instead of flat. It is often the case in small arrays that nearby obstructions will cast shadows across the array at some point during the day over the course of the year, which cuts off power production in typical arrays. To address this issue, we have chosen to use one Enphase inverter on each module. These produce power independently from one another, are easy to monitor remotely, and are cost effective. They also limit the power output to 215 watts per panel, so relatively inexpensive 225 and 230 watt modules can be used without consequence; typically a PV installer would look for the best balance between cost and energy production per square feet. Using the UniRac Solar online array configuration tool, a price-per-module was determined from various array configurations. In the ROI model, it was assumed that eight modules could fit in each four meter by four meter grid cell. This may be an overestimation or an underestimation, depending on how many adjacent cells are available for solar. A grid tie inverter is needed to sync the solar power with the grid power.

Commercial systems are designed in a similar manner, except it was assumed that all commercial and industrial zoned buildings have flat roofs. Two types of roof-mounted systems exist for flat-roofed buildings. If the roof is corrugated metal, the array can be bolted directly into the existing roof structure. This is lightweight, typically 3-5 pounds per square foot, and less expensive than a ballasted system. If the roof is coated with a waterproof membrane, however, a non-penetrating design is preferred. In this ROI analysis, it was assumed that all commercial buildings would use a non-penetrating system. A quote from Cooper B-Line was used to determine a cost per watt for the racking, and one cement paver (ballast) is needed per module. These systems are larger, so a Fronius CL 44.4 inverter was chosen, which can handle up to 200 modules. Multiple inverters can be used in series for large installations. Unlike residential arrays, flat roof arrays use rows of modules laying in landscape and propped up at a 30° angle. The second row has to be set back a distance of 0.4 meters from the row to the South in order to avoid its shadow, so the maximum number of panels per grid cell is assumed to be six.

In both cases, the amount of incident energy from the sun for a particular grid cell is multiplied by the total area of the grid cell covered with solar PV. Solar cells can convert about 13% of the incident solar energy into electricity, so the total amount of energy is multiplied by this efficiency factor to determine the actual electrical output of the array.

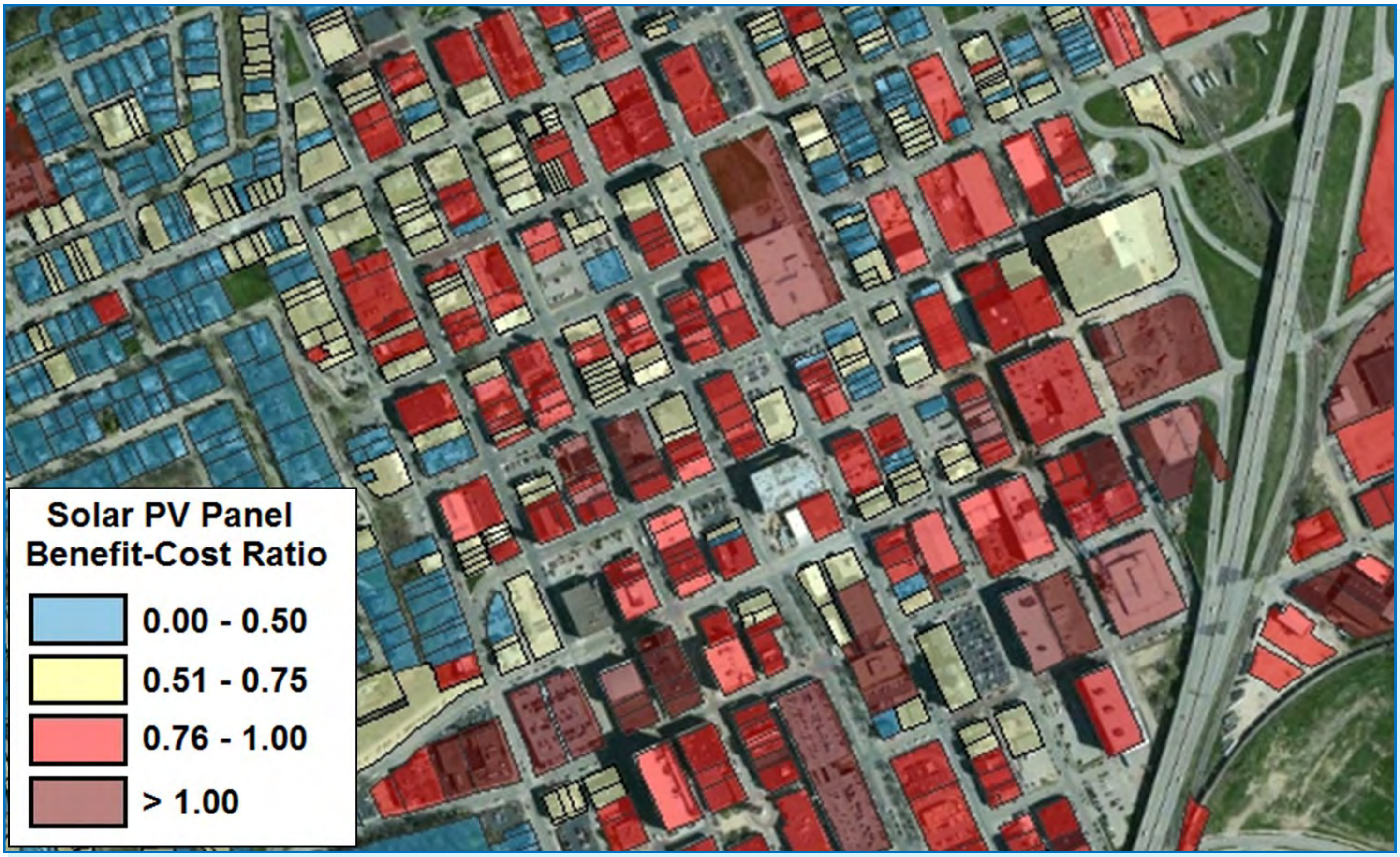



**Figure 26 (Above): Solar PV Return on Investment by Parcel for Dubuque, Iowa**

Solar PV return on investment is displayed in *Figure 26*. Blue parcels indicate those that experience a higher return on investment based on the technology used in this analysis.

## WIND TECHNOLOGY RETURN ON INVESTMENT

REMPAT selected six different wind turbines to be used for different applications at various heights, where zoning permits. Our turbines consisted four horizontal axis, more “traditional” turbines, and two vertical axis sail-shaped turbines. Vertical axis turbines tend to be more expensive and produce less power, but have a lesser impact on the aesthetics and historic character of a building. The six turbines selected were:

- Honeywell WT6500; 1.5 kW peak power output (Horizontal Turbine)
- Skystream 3.7; 2.4 kW peak power output (Horizontal Turbine)
- Bergey Excel 5; 6.2 kW peak power output (Horizontal Turbine
- Bergey Excel 10; 10 kw peak power output (Horizontal Turbine)

- Helix Wind S322; 2 kW peak power output (Vertical Turbine)
- Helix Wind S594; 4.5 kW peak power output (Vertical Turbine)

The Honeywell was chosen for its low cut-in speeds, which means it produces power at a lower wind speed relative to the other turbines. It can be used at lower heights, making it a candidate for residential power production. On the other end of the spectrum, the Bergey Excel 10 produces more power, but must be placed at a higher height. Since its power outputs were computed at heights of 30 and 36 meters, it may not be suitable for all zoning designations, such as residential areas. In other words, this wind turbine will likely be used in commercial applications.

The wind portion of the return on investment template required the use of OpenWind, the software used in the capacity mapping stage of the project. Specifically, we used the OpenWind energy capture reports. Several attempts were made to accomplish this. The first attempt was to use the *Hours per Year* report to determine the number of hours per year, per grid cell that we should see wind speeds within a given range. After calculating mean annual wind speed at each resolution, it was determined that the *Hours per Year* report only produces “hours per year” for the first MetMast listed in the OpenWind Wind Map Layer.

A second attempt included the random placement of turbines throughout the city to find power curves for those locations.  This proved ineffective for two reasons. First, we would not be able to randomly place turbines for every parcel in the city as that would require too much memory to run at one time. Second, randomness would not necessarily provide any indication of variation in power curves.

The third and final attempt incorporated the results from the first phase of capacity mapping and the creation of new turbine models in OpenWind. The idea was that by taking mean annual wind speed from the 90 meter resolution and 10 meter height raster outputs, we could estimate the power curve(s) for based on a specific turbine model used in the return on investment template. This meant that we had to create turbine models in OpenWind and enter the manufacturer’s design specifications. Then, the raster outputs were used to identify locations where turbines could be placed mean annual wind speed ranges of 0-1, 1-2, 2-3, and 3-4 meters/second.

This process was completed for each turbine type at a height of 10 meters and for the wind speed ranges mentioned above.  The results showed that as wind speed range increased, so did power.  Said power could then be adjusted accordingly to show power curve(s) at a height of 2 meters and 5 meters

Using these templates, we were able to create turbines in OpenWind with the same characteristics as the four horizontal turbines selected by our group. (Manufacturers of each turbine provide power curves for wind speeds ranging from 0 to 25 meters per second) In OpenWind a turbine must be “placed” in a grid cell to determine that particular cell’s power output. Instead of placing a turbine on each of the thousands of parcels in Dubuque, we identified cells deemed representative for a particular wind speed and placed each of the six selected turbines in that cell. In order to be considered representative, we chose non-boundary cells in a well-developed area adjacent to cells with similar wind speeds, near the Met Masts. We acknowledge that two cells with the same average wind speed will have different power outputs; however, this is an appropriate approximation because we use the entire wind density curve to determine power output at any given cell, not just average wind speed.

- Skystream and  Honeywell models were run at 10 meter heights, since they are used in residential zoning designations, where height is restricted.
- The Bergey 5 and Bergey 10 were run at 18 and 30 meters, respectively, as they are used in commercial applications where the height restrictions are not as stringent.

Using modified templates on representative grid cells, we ran Detailed Energy Reports in the OpenWind Energy Capture function. In this function, OpenWind aggregates the wind speed from the two anemometer locations (Highway 20 and City Hall Annex) to create a probability of hours per year that the wind is at a certain speed. This is called a Wind Frequency Table. Multiplying the Wind Frequency Table by the power output of the various wind turbines at the same speed, OpenWind produces a profile of power production for an entire year.

This annual power output is what drives the return on investment model.

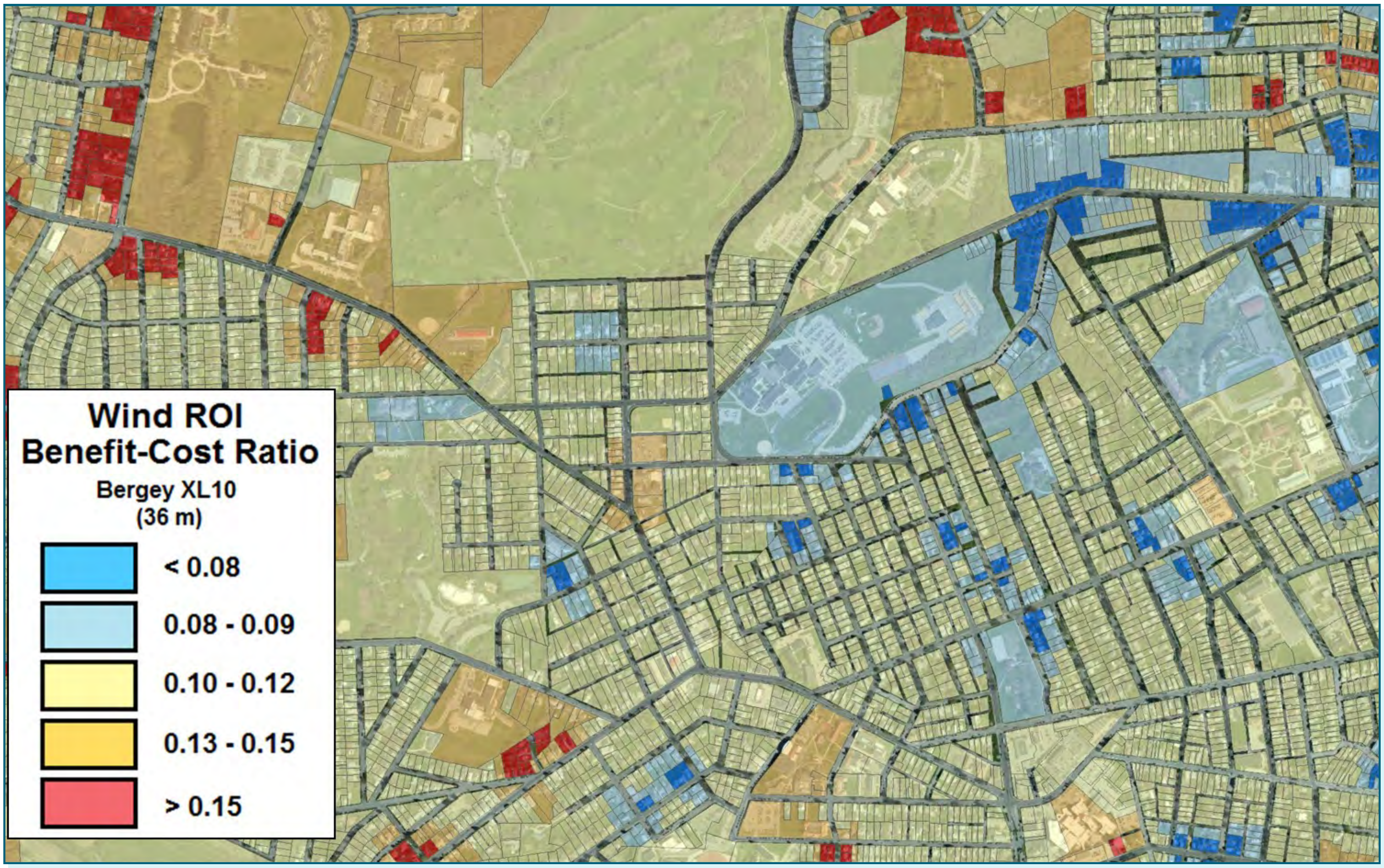



**Figure 27 (Above): Wind ROI for the Bergey XL10 at a 36m height in Dubuque, Iowa. This map highlights that the Benefit-Cost Ratio for wind is much lower, relative to the solar technologies, throughout the city.**

## GROUND SOURCE HEAT PUMP TECHNOLOGY RETURN ON INVESTMENT

Commercially available ground source heat pump units were sized by the ton, which corresponds to a heating capacity of 12,000 BTUs per hour. Three key variables used to determine the required system size, included:

- Number of Heating Degree Days (HDD) in Dubuque
- Square footage of the building
- Average energy factor for the specific building type

Simply put, HDDs count how many degrees away from a set temperature, in this case 65°F, the ambient temperature varied over the course of a day. RETScreen, the Canadian energy authority, provided monthly totals for heating and cooling degree days. In general, heating load dominated in the North Central Midwest, and systems were sized accordingly. However, cooling degree day information was necessary to determine the energy used by the system during the summer months and was important for large commercial structures.

Zoning information and total square footage was taken from the GIS data for each parcel. The energy factors, which were in units of $BTU/ft^2/HDD$, were determined from annual energy usage data compiled by the US Energy Information Administration. If the building was residential, its square footage fell into one of the nine size ranges for which the EIA tabulated average annual energy intensity in $BTU/ft^2$.[23]

23. Energy Information Administration (2005). *Residential Energy Consumption Survey*. Retrieved from http://www.eia.gov/consumption/residential/data/2005/hc/hc5spaceheatingindicators/pdf/tablehc12.5.pdf

For commercial structures, distinctions were made between office, educational, retail and service, healthcare and food service buildings. All data was based on an average building of each type; the amount of energy used for space conditioning is given as a percentage of the total energy intensity of each building, in BTU/ft$^2$.[24] From the EIA regional data, it was determined that buildings in the North Central Midwest use approximately 22.75% more energy than the national average, and the annual BTU consumption data was adjusted accordingly. The energy intensity values for each size of residential building and type of commercial building were divided by the local HDDs to determine the specific energy factors. Due to the wide variety of manufacturing processes included in industrial zones and the reduced heating load due to excess process heat, the average energy factor was determined to be 5 BTU/ft$^2$/HDD. [25]

Demand, a function of building square footage, usage type, heating degree days and cooling degree days, was coupled with bedrock conditions and loop type to determine return on investment.

| | STRATA | |
|---|---|---|
| **TYPE** | **Wet and Sandy** | **Limestone** |
| Vertical Bore Hole | $10-12 per ft per borehole | $15-$20 per ft per borehole |
| Horizontal Bore Hole | $6.90 per ft per borehole | null |

Unfortunately the analysis we ran on the return on investment for GSHP was not meaningful enough to include in our report. There are a wide number of ground truths that could not included in our analysis like the age of a building, the intensity of the use and the efficiency of a pre-existing furnace. These other factors are extremely important in determining energy efficiency and building seal, which play a huge role in determining ability to heat or cool a structure.

Also, natural gas prices are relatively cheap in Iowa making the switch less then attractive. According to the EIA, the price per cubic foot of natural gas has steadily dropped since August of 2008 ($21.50/thousand cubic foot) to most recently reported peak that occurred in August 2011 ($17.27/thousand cubic foot). In general, Dubuque is well positioned to site a ground source heat pump system and an increase in natural gas prices would only makes this more attractive.

## ROI SPREADSHEET METHODOLOGY

In order to estimate energy demand, we split all parcels in Dubuque into two groups – residential and commercial/other. To estimate the energy demand for residential parcels, we used data from the Energy Information Administration's 2005 residential energy consumption survey. The survey estimates energy consumption based on region, ours being the East North Central region. It estimated energy use at 47.4 thousand BTU per square foot, which is equivalent to 13.89 kWh per square foot.

For the commercial/other category, we used the results of our Dubuque business energy demand survey to estimate energy consumption. The eleven respondents were grouped into five categories based on zoning classification and usage. Taking the furnace efficiency into account (assuming AFUE-annual fuel utilization efficiency is 90%),[26] we converted gas usage into kWh per year. The total energy consumption is the sum of annual electricity usage and annual gas usage converted to kWh. The energy consumption rate for each parcel was calculated as the total annual energy consumption divided by the estimated floor area in square feet. The energy consumption rates are shown in Table 1.

24. Energy Information Administration (1995). *A Look at Principle Building Activities*. Retrieved from http://www.eia.gov/emeu/consumptionbriefs/cbecs/pbawebsite/contents.htm
25. Energy Information Administration (1998). *Consumption of Energy for All Purposes*. Retrieved from http://www.eia.gov/emeu/mecs/mecs98/datatables/contents.html#enduse
26. See http://www.energysavers.gov/your_home/space_heating_cooling/index.cfm/mytopic=12530

### Table 1: Energy consumption rate

| | Average rate(kWh/y/sqf) | Standard deviation |
|---|---|---|
| **Commercial** | 18.46413249 | 6.853860333 |
| **Industrial** | 19.68002536 | 17.34916052 |
| **Heavy Industrial** | 20.67663816 | 3.409228387 |
| **Institutional** | 38.6517669 | 23.17127158 |
| **Office** | 20.73898305 | 7.93 |

In order to assign these energy consumption rates to each parcel, we used the ArcGIS Dubuque parcels layer to identify each parcel's zone. We then multiplied the floor area of the buildings in each parcel by the energy consumption rate for each zone. Parcels that were not in any of the zones listed in Table 3 were coded as "Other," and the energy consumption was calculated using EIA data.

We used ArcGIS to calculate the number of panels that would fit on each rooftop based on the roof area, and input that into the spreadsheet along with the average incoming solar radiation. Capital costs for solar technology was taken from manufacturer's websites and known figures. A Visual Basic (VBA) Module was applied to the number of panels and incoming solar radiation using known values for solar technology. This provided us with the total energy output from the panels.

To ensure that the solar photovoltaic system was not larger than necessary for each building, we compared the energy demand to the potential output and resized those systems that were exceeding demand. Using another VBA Module, we created a resizing index that forced energy output to equal energy demand. The result gave us the number of panels needed to match output and demand. We then recalculated capital cost and energy output.

Calculating the benefit-cost ratio for each parcel required that we compute equivalent annual cost (EAC) using the capital recovery factor, capital cost, and an interest rate of 7 percent. The benefit-cost ratio is the annual energy savings divided by the EAC. We used three different tax credit scenarios to recalculate the benefit-cost ratio. The first (described above) assumed no tax credit. The second assumed a 30 percent tax credit on capital cost. The third assumed a 1 cent credit per kWh generated from a renewable energy source.

# WEB-ENABLED TOOL

Group members developed a web map application to further enhance the quality of the project and provide yet another valuable tool for the GDDC and the people of Dubuque to work towards a more sustainable future.  Available on the World Wide Web at [http://urbansrv01.iowa.uiowa.edu/flexviewers/REAMPAT/](http://urbansrv01.iowa.uiowa.edu/flexviewers/REAMPAT/), this application was built using ArcGIS Viewer for Flex Application Builder.  The final product is a web application that is informative, user-friendly, and interactive.

The web application serves a couple primary purposes.  First, it gave group members a chance to apply what they learned in a Spatial Analysis in Planning course to a real-world project.  Second, and most importantly, it provides an easy way for the GDDC to better serve its constituents and for the people of Dubuque to view their potential on-site renewable energy capacity.

Opening the application the user is greeted by a *splash screen* that provides an introduction to the site and its intended use.

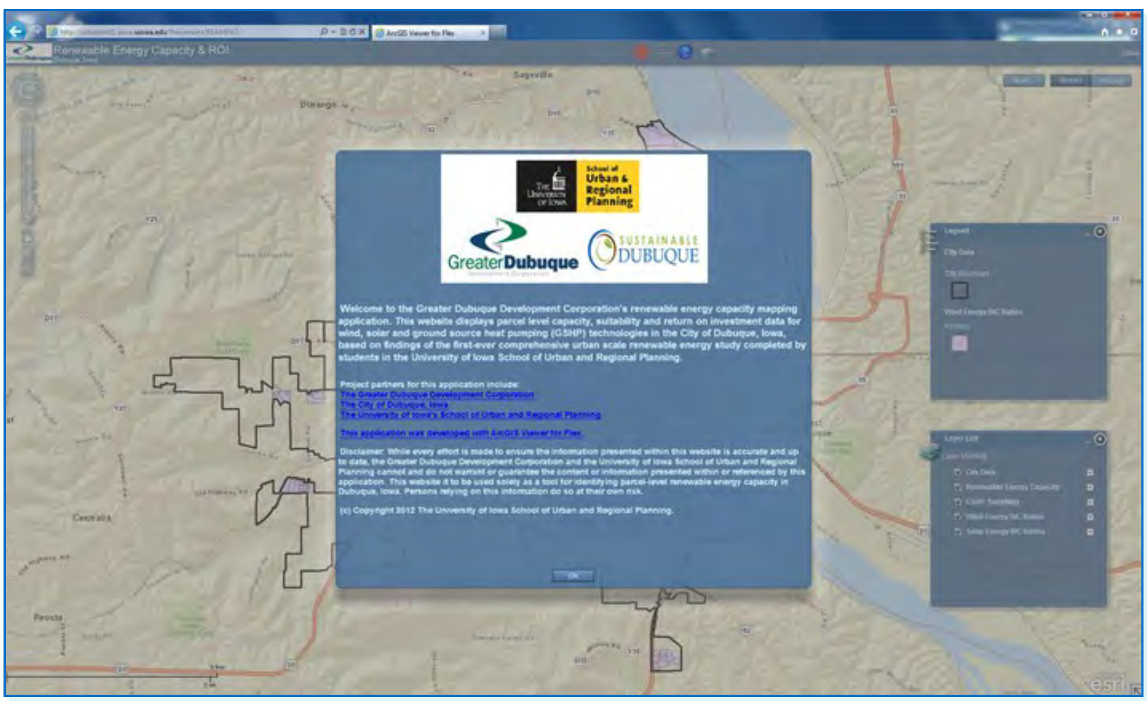



**Figure 28 (Above): Welcome screen of Web-Enabled Tool**

Map layers available on the application include layers developed by the group such as mean annual wind speed, daily incoming solar radiation, and benefit/cost analysis ratios.  In addition, building footprints and parcels (as of September, 2011) provided by the City of Dubuque are available. The initial extent shows the City of Dubuque and a streets base map provided by Application Builder.

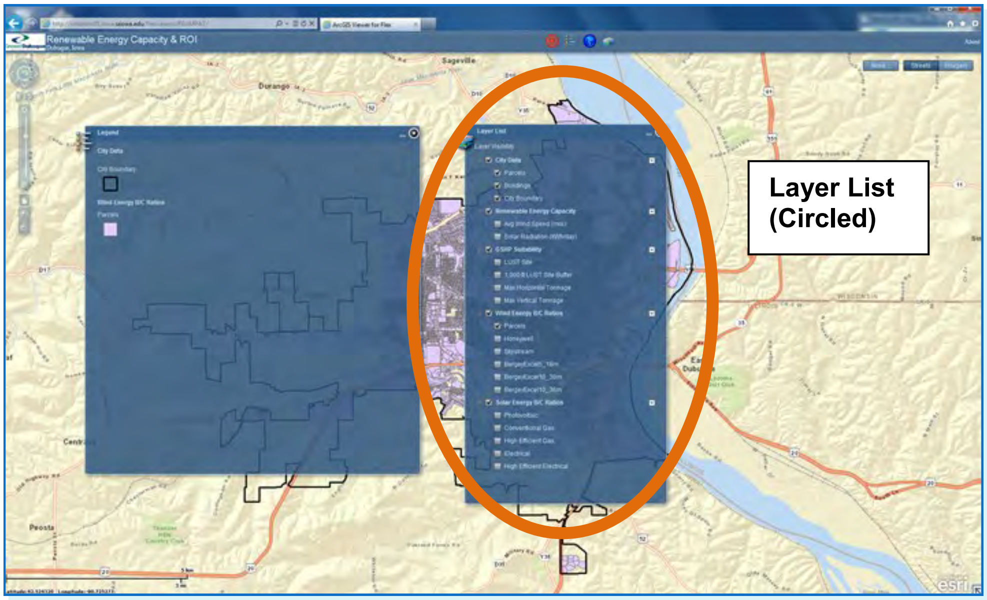



**Figure 29 (Above): Screenshot of the Web-Enabled Tool highlighting the layer list.**

The Layer List window allows the user to turn specific layers on and off while a built-in transparency tool permits the user to compare multiple layers at one time by adjusting each layer's transparency. Additionally, navigation tools on the left side of the viewer enable the user to zoom in or out, as well as move (pan) within the viewer window. An imagery (aerial photo) base map is also available.

Perhaps the most exciting features of the application are the *widgets*, located on the title bar at the top and center of the webpage, provided by Application Builder. For instance, the Query widget allows the end user to search for a specific parcel by parcel number or site address. This tool is titled Find an Address and can be seen in the screenshot pictured on the next page in Figure 31.

The Identify widget allows the user to select a feature within a layer and view a list of pre-defined attributes of that feature. Attributes include parcel ID number, capacity information, benefit/cost values and percent of to-

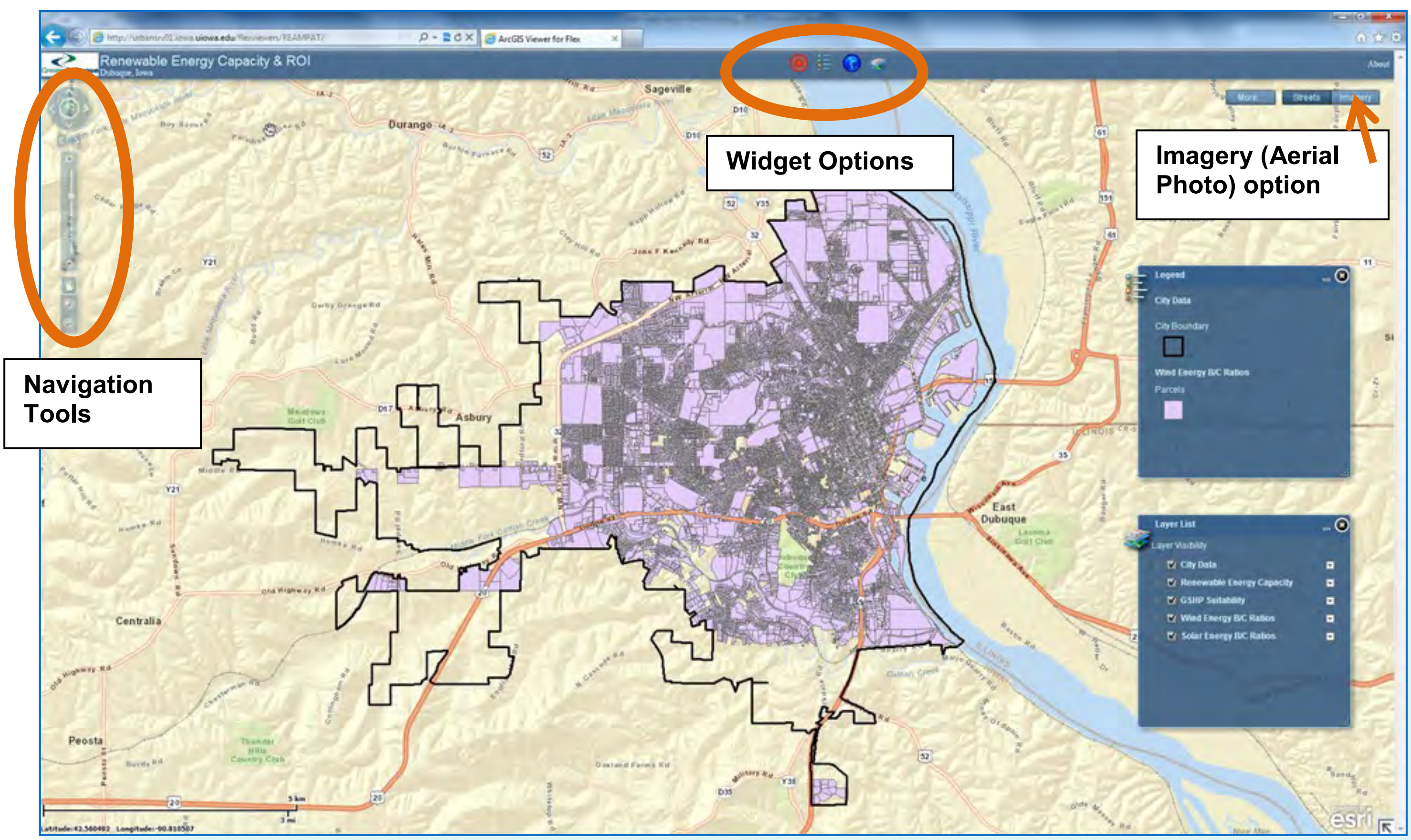



**Figure 30 (Above): Screenshot of the Web-Enabled Tool highlighting the navigation tools, widgets, and imagery options.**

tal energy demand met by wind for different turbines at different heights, just to name a few.  As seen in the following screenshot, this tool is titled Renewable Energy Information by Parcel.

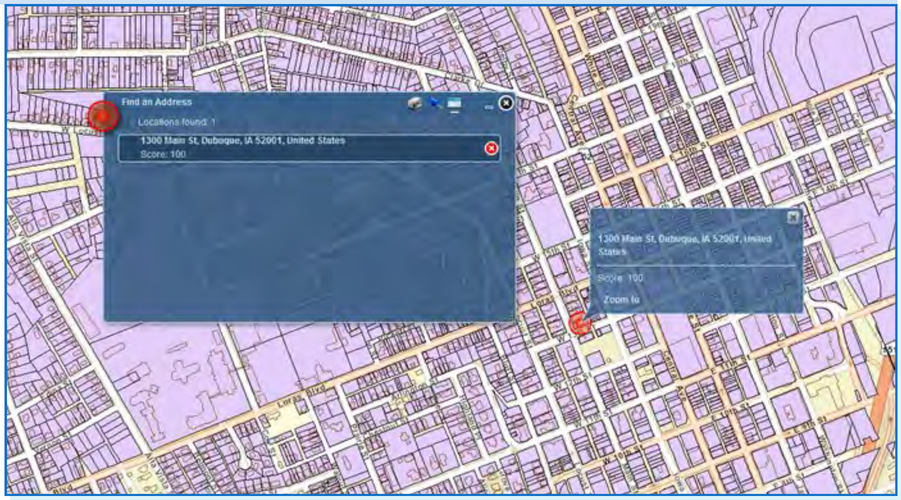



Figure 31 (Above): Screenshot of the Web-Enabled Tool highlighting the "Find an Address" function.

Figure 32 (Below): Screenshot of the Web-Enabled Tool display of parcel-specific energy information, including capacity and return on investment for each technology examined.


Despite having many useful tools and providing the ability to view a variety of different layers exhibiting various data, this web map does have limitations.  In terms of usability, it is fairly intuitive to operate, especially if the user has previous experience using other mapping applications.  However, if the user is not familiar with online mapping applications, specifically ArcGIS Flexviewer applications, that person may need to practice operating the site to gain a better understanding of its capabilities.  Additionally, there currently are not any definitions offered to assist the user with interpreting the layers or results in the widget windows.  Finally, as mentioned on the splash screen, students in the University of Iowa School or Urban and Regional Planning and the GDDC cannot and do not warrant the information provided in this application.  While steps were taken to ensure accuracy, the user must remember they are using the information presented in this application at their own risk.

The GDDC has agreed to take on operation and upkeep of this application.  For the benefit of the GDDC, as well as the people and business owners of Dubuque, the following suggestions are recommended for the long-term viability of this application:

- Cache the application layers to increase functionality and speed.  Currently the layers are loaded via streaming, which increases download time.
- Set up popup description windows for different layers (similar to what exists for parcel layer)
- Add help functions to assist the user.
- Generate metadata for all layers.
- Create new widgets that generate reports and tables to provide results in a more meaningful manner.
- Modify widget windows as needed to make the results more intuitive or easy to interpret.

# RENEWABLES IN HISTORIC DUBUQUE

A significant policy issue identified early-on in our project was the potential conflict between historic preservation and renewable energy in Dubuque. Dubuque is the oldest city in Iowa and has one of the largest inventories of historic structures in the state.[27] As such, Dubuque has cultivated a strong historic preservation ethic, with a historic preservation ordinance, a conservation district ordinance, 5 historic districts, 9 historic conservation districts, numerous National Historic Landmarks and National Register of Historic Places, a variety of historic preservation incentives and an active Historic Preservation Commission.[28] At the same time, Dubuque is committed to sustainability, and in particular integrating renewable energy resources like wind, solar and GHSP into city businesses' energy supply. The conflict between historic preservation and renewable energy arises due to the fact that wind turbines or solar panels are not historic structures, and as such, would typically not be allowed on a historic property or building. Geothermal systems do not pose the same problem as they are installed underground and typically do not damage the historic nature of the property.

**Figure 33 (Above): The Fenelon Place Elevator adds to Dubuque's historic character**

This project evaluated current Dubuque city ordinances, including the historic preservation ordinance and the general land use and zoning ordinances (Title 16, Unified Development Code (UDC)),[29] reviewed national resources on renewable energy zoning, including other municipalities' zoning codes, and utilized GIS generated capacity maps to determine what potential city ordinance amendments or additions could be made to encourage renewable energy development in Dubuque while continuing to support the city's character. This section will first review the overall zoning regulations for solar and wind energy conversion systems in Dubuque and make recommendations on how the city can encourage greater use of renewable energy. The second section reviews historic preservation regulations for solar and wind energy conversion systems and makes recommendations on how the city can integrate renewable energy into historic districts more effectively. These recommended amendments to both the general zoning ordinances of the UDC, as well as the Historic Preservation ordinance, were discussed on two occasions with City of Dubuque planning staff, including Laura Carstens, Planning Services Manager, Associate Planner Kyle Kritz, who specializes in the zoning code and wrote the current ordinances, and Assistant Planner Dave Johnson, who is the staff planner for Historic

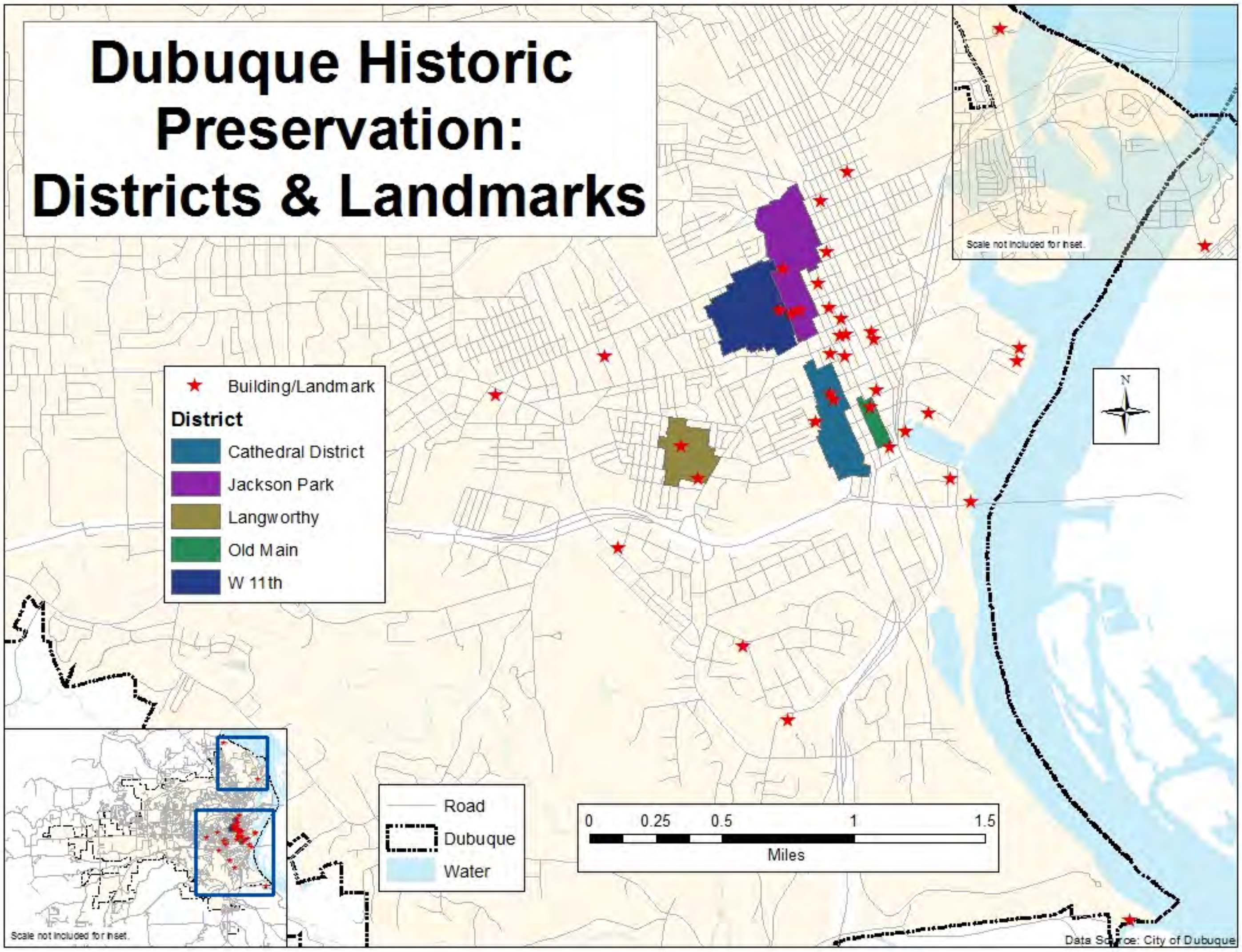



Figure 34 (Above): Historic Districts and Landmarks in Dubuque, Iowa

Preservation Commission.

## SOLAR ENERGY SYSTEMS

Solar panels are more easily regulated than wind energy conversion systems because they can be installed with less impact on surrounding properties than wind turbines. In Dubuque, solar panels are currently regulated as accessory uses under the UDC, and as such, are not required to be submitted to the Board of Adjustment for a conditional use permit.[30] Rather, solar panels can currently be placed in any zone – e.g. residential, industrial or commercial – as long as the solar panel follows the bulk requirements of that zone, as well as the requirements of an accessory use. For example, in a single-family residential zone, R-1, a solar panel may be installed as long as it does not exceed the zone's height limit of 30 feet and is set back 20 feet from the front, 6 feet from the side and 20 feet from the rear yard, among the other bulk regulations of the R-1 zone.[31]

In addition, Dubuque already encourages solar as a renewable energy source through their Solar Subdivision provision. New residential subdivisions in the City of Dubuque must obtain a sustainability score of 40 points before the subdivision can be approved. The developer can achieve 30 out of the 40 points by making a Solar Subdivision, defined as a development that includes 70 percent "solar lots" that have a minimum north-south dimension of 75 feet and a front line orientation that is within 30 degrees of the true east-west axis.[32]

Our recommendations for the City of Dubuque in regards to solar collectors are to 1) reduce the rear yard setback in order to allow easier placement of solar panels in backyards and 2) provide some guidance as to where to place solar collectors on properties. The following is a recommended text amendment to Dubuque's Unified Development Code Art 3 – 7. Sec. 1., relating to the R-1 zone. We recommend this text amendment apply to all applicable zones.

**Recommended Amendments to Unified Development Code Art. 3 – 7, Sec. 1 (as well as applicable accessory use provisions in other zones)**

A. *Solar collectors may be installed within the required rear yard setback but shall not be closer than 2 feet to any abutting property line.*
B. *Solar collectors shall be installed in the location that is least visible for the abutting public right of way, so long as installation in that location does not significantly diminish energy performance*
C. *Significantly decrease energy performance: defined as decreasing the expected annual energy production by more than 20 percent.*

## WIND ENERGY CONVERSION SYSTEMS

Stand- alone wind energy conversion systems are regulated in Dubuque as a supplemental use, rather than an accessory use under Section 2, Art. 7-3 of the UDC. Building-mounted wind energy conversion systems are considered an accessory use in all zones and must comply with the bulk requirements of the base zone.[33] For stand-alone systems as a supplemental use, a conditional use permit is required in all zones, and means the applicant must go through the Board of Adjustment. Supplemental use wind energy conversion systems are classified as two types: Residential Wind Energy Conversion Systems (RWECS) and SWECS(Small Wind Energy Conversion Systems). RWECS regulations allow wind energy conversion systems in all residential and office zones up to a maximum height of 80 feet, along with other regulations.[34] SWECS regulations allow wind energy conversion systems in all other zones, including industrial and agricultural zones, up to a maximum height of 120 feet, along with other regulations.[35]

However, a significant restraint on the current regulation of stand-alone wind turbines is that they can only be installed on properties greater than or equal to 1 acre in size.[36] Utilizing our GIS maps, we calculated that this regulation limits the percentage of residential parcels that are able to install wind turbines to around 5 percent of the entire city. Out of a total of 19,678 residential parcels, only 1,023 are 1 acre or larger, meaning 95 percent of all residential parcels are not currently able to install stand-alone wind turbines. In addition, requiring a conditional use permit for all wind turbines means the installer must go through the Board of Adjustment, which costs at least $300 per application, can be a lengthy process, and requires a public hearing that in the end, may result in the denial of the permit altogether.

Our recommendation for the City of Dubuque is to supplement the current wind energy conversion system regulations with an additional regulation that allows small, on-site wind energy conversion systems (AWECS) to be categorized as accessory, rather than supplemental. The reasoning behind this additional regulation is that property owners, particularly residential property owners, may want to install small wind turbines that fit into the bulk requirements of the underlying zone, and it makes little sense to require these property owners to obtain a conditional use permit. Rather, as long as the wind turbine satisfies the bulk requirements of the base zone, and complies with the same design and noise restrictions of the RWECS and SWECS, then the property owner should be allowed to install a wind turbine after a simple administrative review.

Based on our GIS map calculations, this supplemental regulation for on-site accessory wind energy conversion systems increases the number of AWECS - eligible residential parcels from 1,023 to 11,241 parcels, or about 57% of all residential parcels in Dubuque. This calculation includes a recommended setback requirement for AWECS equal to 100 percent of the height of the turbine. Building footprints were eliminated based on the fact that stand-alone turbines cannot be placed within a building. Parcels that did not contain enough remaining land to satisfy a 30 foot setback (i.e. allow the placement of a 30 foot tall AWECS) were also eliminated in order to assure conservative calculations. Although this calculation provides an accurate estimation of where on-site accessory wind energy conversion systems *could* be placed, more detailed, site-specific analysis must be completed to determine where AWECS *should* be placed on residential zones. The following is a recommended text amendment to the Unified Development Code for on-site accessory wind energy conversion systems.

**Recommended Amendment to Art. 7-3, Sec. 2 (Wind Energy Conversion Systems):**

*On-Site Accessory Wind Energy Conversion Systems (AWECS): A system is considered an on-site accessory wind energy system only if it supplies electrical power solely for on-site use, except that when a parcel on which the system is installed also receives electrical power supplied by a utility company, excess electrical power generated and not presently needed for on-site use may be used by the utility company. AWECS shall be considered accessory uses in all zones, requiring only administrative review by the Building Inspection Department and/or the Planning Department, as long as the requirements of this section are met.*

*Zoning Districts: Residential, PUD, Office, Commercial, AG, ID*
*Minimum setback: 100% of total system height*
*Maximum height:*

1. *Residential: 30 feet*
2. *Office: 35 feet*
3. *Commercial: 45 feet*
4. *Industrial: 75 feet*
5. *Agricultural: 75 feet*
6. *PUD: pursuant to PUD*

A. *The requirements for siting and construction of all On-Site Accessory Wind Energy Conversion Systems regulated by this section shall include the following:*
    1. *Wind energy towers shall to the extent possible blend into the surrounding environment and architecture, including painting to reduce visual obtrusiveness. The City Planner may require a photo of an AWECS system of the same model that is the subject of the landowner's application adjacent to a building or some other object illustrating scale (e.g., manufacturer's photo).*
    2. *AWECS shall not be artificially lighted unless required by the FAA or appropriate authority.*
    3. *No tower should have any sign, writing, or picture that may be construed as advertising.*
    4. *AWECS shall not exceed 60 decibels, as measured at the closest property line. The level, however, may be exceeded during short-term events such as utility outages and/or severe windstorms.*
    5. *The applicant shall provide evidence that the proposed height of the AWECS does not exceed the height recommended by the manufacturer or distributor of the system.*
    6. *The applicant will provide information demonstrating that the system will be used primarily to offset on-site consumption of electricity.*

A. *Compliance with the International Building Code: Building permit applications for an AWECS shall be accompanied by standard drawings of the wind turbine structure, including the tower base, and footings. An engineering analysis of the tower showing compliance with the International Building Code and certified by a professional engineer licensed in the State of Iowa shall also be submitted.*

B. *Compliance with National Electric Code: Building permit applications for an AWECS shall be accompanied by a line drawing of the electrical components in sufficient detail to allow for a determination that the manner of installation conforms to the National Electric Code. This information may be supplied by the manufacturer.*

This recommended amendment does not circumvent Sec. 2, Art. 7-3, but rather provides an additional route for a property owner to install a wind energy conversion system on their property. If the property owner chooses to abide by the height restrictions, bulk limitations and design restrictions, then they can obtain a wind energy conversion system through administrative review. If not, then the property owner can go through the conditional use permit process and potentially install larger wind energy conversion systems on their property.

## HISTORIC PRESERVATION AND RENEWABLE ENERGY

The conflict between historic preservation and renewable energy has gained nation-wide attention over the last five to ten years. Numerous cities and counties have dealt with on-site wind turbines and solar panels conflicting with historic preservation ordinances, and a large utility-scale wind turbine farm in historic Nantucket Sound, Massachusetts went through significant opposition and litigation before being approved last year.[37] As such, there are multiple city and county ordinances that this project has looked to for examples on how to regulate wind and solar systems in a manner that protects historic preservation and also advances sustainability. In addition, publications from the Department of Interior, the National Trust for Historic Preservation and the National Renewable Energy Laboratory provide general guidance on how to integrate wind turbines and solar panels into historic properties. The state of Michigan has also taken the lead on establishing general siting guidelines for wind energy systems; however the state's greatest emphasis is on utility-scale systems, not urban-scale wind turbines.[38]

Currently Dubuque's Historic Preservation ordinance, codified in the UDC, requires any owner of a historic property seeking to install a wind energy conversion system or a solar panel to obtain a Certificate of Appropriateness from the Historic Preservation Commission (HPC). The HPC utilizes general national standards, including the "Secretary Of Interior's Standards and Guidelines for Archaeology and Historic Preservation", the "Secretary of Interior's Standards and Guidelines for the Treatment of Historic Properties", and the "Secretary of the Interior's Standards for Rehabilitation and Guidelines for Rehabilitating Historic Buildings", codified as 36 CFR 68, as guidelines when reviewing Certificate of Appropriateness applications. Local standards, including the "Architectural Guidelines for Historic Structures in the Historic Districts of the City of Dubuque, Iowa;" the "Streetscape and Landscape Guidelines for the Historic Districts of the City Of Dubuque, Iowa," also guides the HPC.[39]

We do not recommend changing the Certificate of Appropriateness requirement; this serves as a necessary gatekeeper for potential conflicts that arise between renewable energy installations and historic properties. However, we do recommend providing greater guidance within the code for the HPC to specifically address design issues that arise when siting wind turbines or solar panels on historic properties. A lack of upfront guidance could deter property owners seeking to install these renewable energy systems on historic properties, and providing greater structure to the HPC's review will help to streamline the process.

Through first semester research, multiple cities' ordinances were identified as having potential zoning language by which to draft historic preservation amendments for the City of Dubuque that would provide clear guidance for customers looking to implement wind turbines and/or solar panels on historic properties. Five cities in particular that have extensive code language on renewable energy and historic preservation include: Eureka Springs, Arkansas, Boulder, Colorado, Bayfield, Wisconsin, Grand Rapids, Michigan, and Santa Monica, California. From these example cities as well as other resources, including the national publications mentioned above, we developed guidelines for placement of solar panels and wind energy conversion systems in historic districts that could be incorporated into Dubuque's Historic Preservation ordinance.

### Recommended Solar Collector Amendments to Unified Development Code Art. 10

*The following recommendations shall supplement the previous standards of review for the Historic Preservation Commission's determination of whether to issue a Certificate of Appropriateness for an application to place a solar energy system in a Historic District or on a Historic Landmark:*

1. *Roof-mounted solar panels should not visible from a public right of way. Solar singles may be added to a roof surface visible from a public right of way if low or non-reflective shingles are used.*
2. *Solar panels shall be placed on a non-character defining roofline of a non-primary elevation (not readily visible from public streets). Solar panels shall be run parallel to the original roofline.*
3. *Solar panels shall be set back from the edge of a flat roof to minimize visibility. Panels may be set at a pitch and elevated if not highly visible from the public right of way.*
4. *Solar panels and all related mechanical equipment and mounting structures should be of a non-reflective finish such as an adonized finish.*
5. *Mechanical equipment attached to the building fascia shall be painted the same color as the fascia in order to blend into the building.*

6. *Detached solar energy systems shall be placed in the side yard and screened from the public view if screening does not significantly decrease the energy performance of the solar energy system.*
   - *Significantly decrease energy performance: defined as decreasing the expected annual energy production by more than 20 percent.*

## Recommended Wind Energy Conversion System Amendments to Art 10.

1. *Wind energy conversion systems shall be installed in the location on the property that is least visible from the public right of way*
2. *Wind energy conversion systems shall be designed in a manner which least impacts the architectural and historical character of the property.*
   - *Potential mechanisms for blending wind energy conversion systems with the properties historic and architectural character include painting or finishing the column and blades, utilizing unique blade designs, and screening of the wind energy conversion system, so long as the screening does not significantly decrease the energy performance of the system, as defined as decreasing the expected annual energy production by more than 20 percent.*

## SECTION ENDNOTES

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28. Ibid.
29. City of Dubuque Municipal Code, Title 16, Unified Development Code (UDC), Articles 7 and 10, http://www.cityofdubuque.org/DocumentView.aspx?DID=1828.
30. See UDC, Art. 5-2.7, http://www.cityofdubuque.org/DocumentView.aspx?DID=1828.
31. See UDC, Art. 5-2.7 for a full list of the bulk regulations in the Single-Family Residential Zone, http://www.cityofdubuque.org/DocumentView.aspx?DID=1828.
32. UDC, Art. 11-10, Sustainable Development Tools, Solar Subdivisions, http://www.cityofdubuque.org/DocumentView.aspx?DID=1828.
33. See UDC, Art. 5, stating that building-mounted wind turbines are an accessory use in all zones.
34. See UDC Art. 7-3, Sec. 2 for the full list of regulations pertaining to RWECS and SWECS, http://www.cityofdubuque.org/DocumentView.aspx?DID=1828.
35. Ibid
36. Ibid.
37. Drash, Wayne. “Nation’s first offshore wind farm approved for Nantucket Sound,” CNN.com., April 28, 2010, http://www.cnn.com/2010/TECH/04/28/cape.cod.wind.farm/index.html.
38. Michigan Siting Guidelines for Wind Energy Systems, Michigan Department of Labor and Economic Development, March 5, 2007, http://www.michigan.gov/documents/Wind_and_Solar_Siting_Guidlines_Draft_5_96872_7.pdf.
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# RENEWABLES AND RESILIENCY

Evidence collected by the Iowa Climate Change Impacts Committee suggests that Eastern Iowa experiences more precipitation today than it did 100 years ago.[40] Increased incidence of rain, combined with increased humidity and summer temperatures, produces stronger summer storm systems with higher storm magnitude.[41] Ultimately this matters because higher storm magnitude tends to coincide with higher damages incurred and increased likelihood for people to rely on publically provided services to help them cope in the time of a disaster. Dubuque witnessed this phenomenon in late July 2011, when it experienced rainfall totals of seven to fifteen inches within a time period of twelve hours, resulting in flash flooding.[42] Dubuque, the hardest hit area, sustained over $7 million in reported property damages from the flooding and tornadoes that occurred during the storms. This event resulted in Presidential Disaster Declaration DR-4018, declared in late August 2011.

“A changing Iowa climate will create greater demands for disaster-response services,” placing a greater demand for critical facilities in Iowa to stay operational, despite increased hazard events.[43] In other words, when citizens rely most on disaster-response and public safety, increased strain is placed on the systems that provide these services. When catastrophic hazard events occur, Dubuque’s critical facilities must maintain services, or at the very least, become operational as soon as possible if service is disrupted. The guiding question is to what extent can renewable energy help meet or offset energy demand in these critical facilities if a disaster were to occur? This question will be answered based on the findings of the renewable energy capacity mapping and return on investment findings, as presented in this report. If Dubuque is able to utilize renewable energy in critical facilities, community-wide vulnerability decreases, thus, increasing resiliency to hazard events.

## DEFINING CRITICAL FACILITIES AND VULNERABLE POPULATION CENTERS

The State of Iowa defines critical facilities as, “those structures from which essential services and functions for victim survival, continuation of public safety actions, and disaster recovery are performed or provided.”[44] This includes facilities such as health care, jails, police and fire stations, critical records storage facilities, schools, environmental health facilities, public utilities, etc. Dubuque also has numerous vulnerable population centers which are places with concentrated numbers of people requiring increased assistance during disasters, such as children and senior citizens. This includes place sites like apartment complexes, assisted living homes, and senior living centers.[45] Total, Dubuque’s critical facilities and vulnerable population centers list includes 97 facilities total.

*Figure 12* highlights locations of critical facilities used for public safety and immediate disaster response, based on the 97 facility list provided by the Dubuque County Emergency Management Agency and Hazard Mitigation Plan.

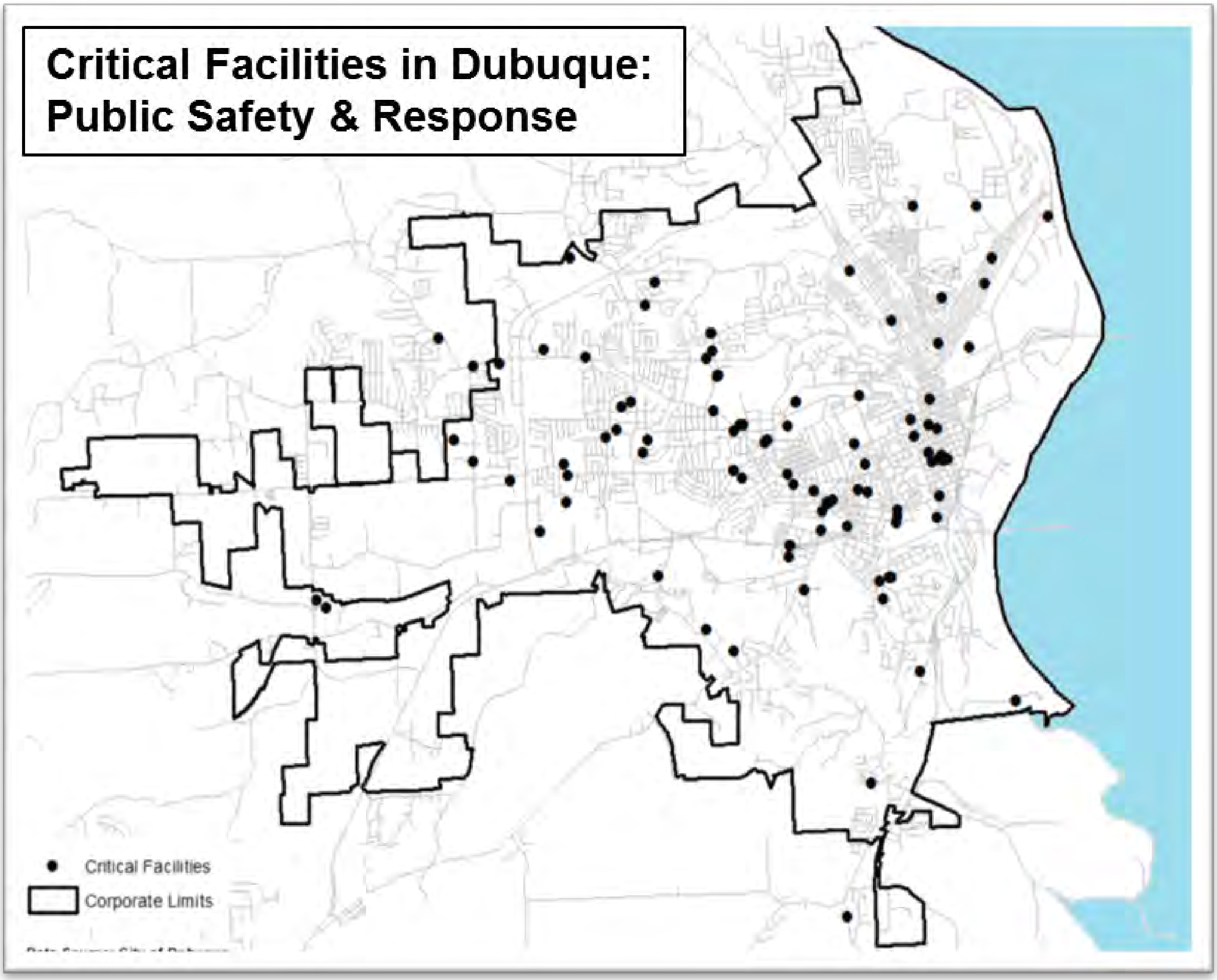


Figure 35 (Above): Critical Facilities for Public Safety and Immediate Response in Dubuque, Iowa

## DUBUQUE'S VULNERABILITY

Based on Dubuque County's local hazard mitigation plan, the community is most vulnerable to severe winter storms, windstorms, thunderstorms and lightning, flooding (flash flooding and riverine flooding), and tornadoes. These hazards pose challenges to the placement of renewable energy. For instance, providing renewable energy in flood prone areas goes against principles of cost-effective risk mitigation, which would suggest siting investment out of floodplains to decrease risk of hazard exposure. Another example would be the use of permanent renewable energy technology as the key means to provide energy for a critical facility. The technology may not offer suitable resiliency against a windstorm or tornado, but may be used to offset generator capacity if used in addition to a traditional means of providing power.

## CAN WE INCREASE RESILIENCY IN DUBUQUE?

Based on the findings of the return on investment model, Dubuque's potential for urban scale wind is not very high. This is due largely to the intermittent pattern of wind energy and relatively low wind speed overall. Because wind turbines do not produce as much energy, relative to the return for the solar technologies, and because wind turbines are vulnerable to damage during windstorms, severe storms, and tornadoes, this analysis focuses only on solar energy as a means to provide resiliency to community critical facilities.

## SOLAR PHOTOVOLTAIC SYSTEMS

The return on investment model incorporates data from the City of Dubuque and the solar capacity maps to calculate the system capacity for a building's given rooftop. Specifically, by taking square footage of the building, and combining it with average demand per square foot from the return on investment model (based on Energy Information Administration survey data), we were able to compare demand to capacity of the system placed on the facility's roof.

Using the critical facilities outlined in the Dubuque Multi-Hazard Mitigation Plan, we found that many facilities in Dubuque could meet energy demand using solar PV systems. A table displaying the extent to which demand can be met by solar PV systems at Dubuque critical facilities A can be seen in ***Appendix B.***

**% Demand Met by Solar PV at City Service Facilities**

| Facility Name | % Demand Met |
|---|---|
| Police Station | 100% |
| Jail | 100% |
| 911 Dispatch Center | 100% |
| Five Flags Civic Center | 53% |
| Youth Detention Center | 34% |
| City Hall | 30% |
| Court House | 23% |
| Grand River Center | N/A |
| Federal Building | N/A |

Solar PV Systems and City Services
Based on lack of data in the return on investment model, data for the Grand River Center and Historic Federal Building could not be calculated.

Overall, three of the facilities performing "city services" could use solar to offset electricity demand, as shown in the table to the left This is particularly promising, since the police station and 911 Dispatch Center are crucial to maintain operation in time of a disaster.

Of the remaining four facilities, solar photovoltaic systems could be explored to offset day-to-day operating costs, or peak demand if funding becomes available.

**% Demand Met by Solar PV at Facilities Providing Medical Services**

| Facility Name | # of Facilities with Data | # Facilities with 100% Demand Met |
|---|---|---|
| Paramedic Stations | 4 | 3 |
| Blood Donation Centers | 3 | 0 |
| Hospital | 2 | 1 |

Solar PV Systems at Medical Services Facilities
Of the nine medical services facilities that had data available for, four of them could meet electricity demand with solar pv systems, according to the EIA survey data.

**% Demand Met by Solar PV at School Facilities**

| Facility Name | # of Facilities with Data | # Facilities with 100% Demand Met |
|---|---|---|
| Pre-Schools | 20 | 6 |
| Elementary Schools | 17 | 4 |
| Middle Schools | 7 | 3 |
| High Schools | 5 | 2 |

Solar PV Systems and Dubuque Schools
After a disaster, Dubuque may be able to more quickly return to a sense of normalcy if school service can be restored as quickly as possible. Based on the EIA data, fifteen schools have the ability to meet energy demand with solar PV systems. Most of these facilities provide educational services for younger children. Children in pre-schools and elementary schools are particularly vulnerable in times of a disaster, since younger children require additional considerations in the disaster response process.

**% Demand Met by Solar PV at Other Vulnerable Populations Centers**

| Facility Name | # of Facilities with Data | # Facilities with 100% Demand Met |
|---|---|---|
| Retirement Homes | 15 | 2 |
| Mental Health Centers | 3 | 0 |

Solar PV and Other Vulnerable Population Centers
Only a few of the vulnerable population centers in Dubuque have the ability to meet 100% of electricity demand using solar PV systems. These facilities should first focus on improving energy efficiency before they explore installing solar panels.

## SOLAR THERMAL SYSTEMS

Calculating demand differed in this part of the methodology, since each building usage has a more specific demand for hot water, based on the facility. Average demand was obtained using the U.S. Department of Buildings Energy Data Book (see: http://buildingsdatabook.eren.doe.gov/CBECS.aspx). The Energy Index for Commercial Buildings allows a user to select building types by Census Division and Climate. Dubuque, Iowa fell under the "West North Central" Census Division and "Zone 2" Climate Zone, which signifies less than 2,000 cooling degree days and between 5,500 and 7,000 Heating Degree Days. Building types that most closely match the actual function were also selected (i.e. energy required to heat water consumed by the Dubuque Police Station was obtained by selecting the "Public Safety" category). Each building category provided an average BTU per thousand square foot (i.e. BTU/1,000 sq.ft.)required for hot water.

By taking this average BTU/1,000 sq. ft, multiplying it by 1,000 and by the building square footage, the energy demand for heating water was obtained. This number was compared to the system capacity calculated in the return on investment spreadsheet to see whether or not if the building's rooftop could meet the demand for the facility. The system was assumed to be the size of the entire rooftop to determine the capacity. Note, that this means that the solar thermal system is NOT optimizes with the solar PV system, found in the previous section. This was an exercise to see if demand could be met if the entire roof was used only for solar thermal. A table displaying the extent to which demand can be met by solar thermal systems at Dubuque critical facilities A can be seen in ***Appendix C.***

**% Energy Demand Met for Heating-Water at City Facilities**

| Facility Name | % Demand Met |
|---|---|
| Five Flags Civic Center | 4724% |
| Police Station | 3772% |
| 911 Dispatch Center | 1320% |
| Youth Detention Center | 466% |
| Court House | 198% |
| Jail | 86% |
| City Hall | 25% |
| Grand River Center | N/A |
| Federal Building | N/A |

Solar Thermal Systems at City Facilities

Five city critical facilities produce an excess of capacity using solar thermal systems. Many of these buildings tend not to require a lot of hot water demand, and thus do not require a lot of energy to heat water. These facilities should not dedicated their entire rooftops to solar thermal, but rather size the system to meet demand.

Solar Thermal Systems at Medical Services Facilities

Even though medical services require more hot water for processes, all but one facility could meet its demand, based on the EIA data. Both hospitals could decrease operating costs significantly if they transfer to a solar thermal water heating system. Only one paramedic station, with a smaller roof area, would be unable to meet energy demand through solar thermal.

**% Demand Met by Solar Thermal at Facilities Providing Medical Services**

| Facility Name | # of Facilities with Data | # Facilities with 100% Demand Met |
|---|---|---|
| Paramedic Stations | 4 | 2 |
| Blood Donation Centers | 3 | 3 |
| Hospital | 2 | 2 |

Solar Thermal Systems at School Facilities

Almost every single school has the potential to meet demand for hot water using solar thermal systems. Only one pre-school is unable to meet demand.

**% Demand Met by Solar Thermal at School Facilities**

| Facility Name | # of Facilities with Data | # Facilities with 100% Demand Met |
|---|---|---|
| Pre-Schools | 20 | 19 |
| Elementary Schools | 17 | 17 |
| Middle Schools | 7 | 7 |
| High Schools | 5 | 5 |

Solar Thermal Systems at Other Vulnerable Populations Centers

Though most critical facilities could meet needs, retirement homes and mental health centers do not have the same capacity as other facilities, overall. However, slightly over half of all retirement homes could meet their demand. Again, this is key, because as a vulnerable population, senior citizens require additional considerations and resources during disaster response.

**% Demand Met by Solar Thermal at Other Vulnerable Populations Centers**

| Facility Name | # of Facilities with Data | # Facilities with 100% Demand Met |
|---|---|---|
| Retirement Homes | 15 | 9 |
| Mental Health Centers | 3 | 1 |

## RECOMMENDATIONS

Among Midwestern communities, those that have been able to best incorporate renewable energy have been done so in the recovery from catastrophic disasters. Several Midwestern case studies will provide the greatest amount of data and recommendations for incorporating renewable energy into disaster recovery, as these communities are subject to similar natural hazards as Dubuque, Iowa. Specific examples include:

- **Soldiers Grove, Wisconsin** – This small village in southwestern Wisconsin who utilized passive solar and photovoltaic energy to power development after relocating its central business district out of a floodway. Soldiers Grove became the nation's "First Solar Village" and is the first time that renewables were incorporated into community-wise recovery efforts.
- **Valmeyer, Illinois** – Valmeyer gained nation-wide attention in its incorporation of sustainable technologies into the town's design of its relocation site after devastating flooding in 1993. After securing Federal assistance, passive solar design and ground-source heat pumps were integrated into houses and businesses.
- **Greensburg, Kansas** – In its long-term community recovery efforts, Greensburg has incorporated renewable energy and energy efficiency into recovering from an EF5 magnitude tornado that wiped out the entire town.

Looking to these communities can provide examples about pre-disaster recovery planning. If a plan is put into place before a disaster occurs, Dubuque can set forth recovery projects in a timely fashion. If Dubuque was to suffer a catastrophic disaster event, jumpstarting long-term community recovery with a renewable focus simplifies efforts in the future. Having a recovery plan in place helps to make finding funding straightforward, and demonstrates commitment to sustainable recovery, increasing the chances to secure competitive grant funding. This case was clearly demonstrated in Soldiers Grove, Wisconsin.[46]

One document that Dubuque should look to is the U.S. Department of Energy's model guidelines document that outlines integrating energy efficiency and renewable energy into emergency planning. Though this document is aimed primarily at states, many of its suggestions can be applied at the county and local levels to help provide a baseline to create a disaster-resistant community, from a facilities perspective. Additionally, the Department of Energy provides information on case studies through its "Operation Fresh Start," to help highlight successful best practices in other communities that can be incorporated in Dubuque.

If Dubuque incorporates renewables after a catastrophic disaster, funding options will be more available from state and federal sources, decreasing the amount of money necessary for a local match. In fact, Valmeyer, Illinois, Greensburg, Kansas and Soldiers Grove, Wisconsin all offer relevant examples on how to secure creative funding packages, ranging from Federal, state, and regional grant funds, as well as using tax increment financing and planned unit developments to fund and zone recovery to accompany for renewable energy. On the other hand, funding options differ if Dubuque chooses a more proactive approach to mitigate disaster effects. Though at the time of writing, Congress was deciding about the final reorganization of emergency management related grants—the current proposal places mitigation grant funding into a larger "emergency management" grant pool. Dubuque should investigate whether or not it can use Pre-Disaster Mitigation and Hazard Mitigation Grant Program (HMGP) funding awards, if they are still in in future fiscal years.

### SECTION ENDNOTES

40. Tackle, Eugene S, "Climate Changes in Iowa," in *Climate Change Impacts on Iowa 2010,* Iowa Climate Change Impacts Committee, http://www.iowadnr.gov/portals/idnr/uploads/air/environment/climatechange/complete_report.pdf?amp;tabid=1077, 8.
41. Ibid.
42. National Climatic Data Center, "Event Record Details, Dubuque County, 27 Jul 2011, 20:00:000 PM EST" http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~ShowEvent~886535.
43. Swenson, Dave, "Climate Change Consequences for Iowa's Economy, Infrastructure, and Emergency Services," in *Climate Change Impacts in Iowa 2010*, Iowa Climate Change Impacts Committee, 29.
44. Iowa Department of Homeland Security and Emergency Management, "Iowa's Rural Electric Cooperatives' Annex to the State of Iowa hazard Mitigation Plan," *State of Iowa Mulit-Hazard Mitigation Plan 2010*, 19. http://www.iowahomelandsecurity.org/documents/hazard_mitigation/HM_StatePlan_1-2_AnnexC_RECMitigPlan.pdf
45. East Central Intergovernmental Association, *City of Dubuque Hazard Mitigation Plan,* 2011, 8-13.
46. Becker, William S., "Come Rain, Come Shine: A Case Study of a Floodplain Relocation Project at Soldiers Grove, Wisconsin," *Wisconsin Department of Natural Resources*, http://dnr.wi.gov/org/water/wm/dsfm/Flood/Documents/ComeRainComeShine.pdf.

# RENEWABLES AND SOCIAL JUSTICE

A project labeled as 'sustainable' must go beyond the conservation of the local natural environment and the protection of the historical character of a city. Social justice issues must also be considered if Dubuque is to attain its vision of sustainability. During this semester, the Renewable Energy Mapping and Policy Analysis Team (REMPAT) investigated the association between renewable energy sources and socio-demographic and economic data. Understanding the extent to which renewable energies are geographically accessible to low-income groups and minorities can help the City of Dubuque overcome disparities that exist in the community.

## METHODOLOGY

To spatially illustrate this relationship, REMPAT compared energy capacity and socio-demographic data by considering 2010 American Community Survey data at the census block group level. Solar capacity and electricity demand have been estimated by considering only residential buildings (there are 21,365 residential buildings within the city limits).

The Zonal Statistic as Table tool in ArcMap has been used to summarize solar capacity by block groups from the previously created solar capacity raster file. Electricity demand has been predicted by multiplying each building area by 6.88 Kw/hours/square foot. We obtained this energy consumption rate from the GSHP map data, which had done an estimate for the residential areas using a survey of 1,900 residences. The national average is approximately 5 Kw/Hours/SQF for residential buildings.

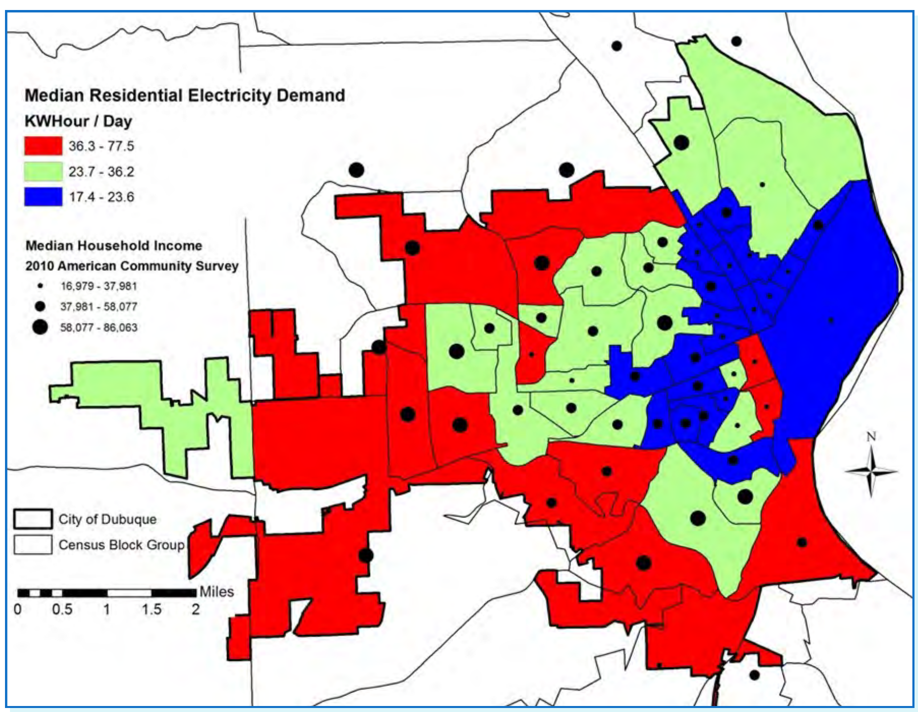


Figure 36 (Above): Residential Energy Demand in Dubuque, Iowa

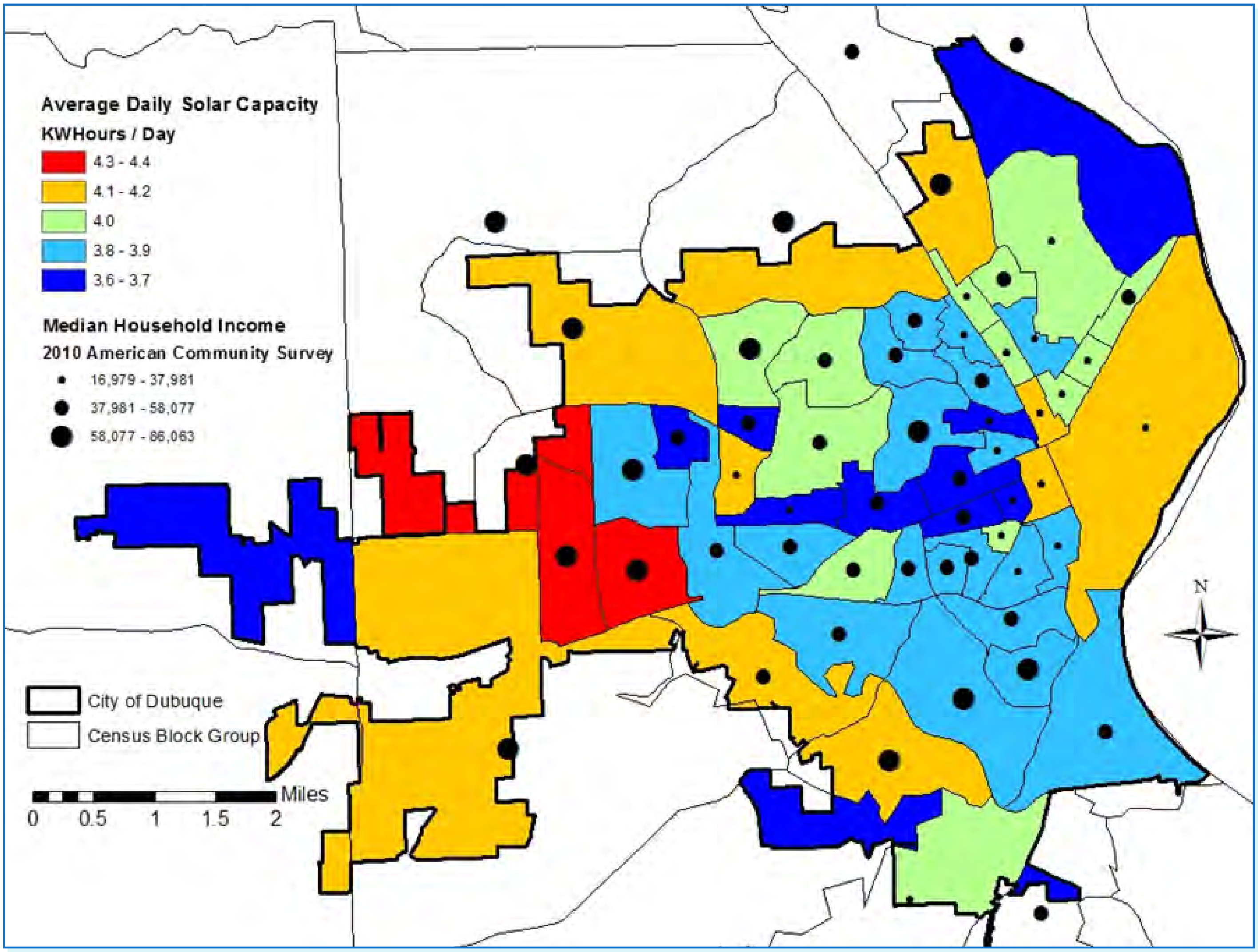


**Figure 37 (Above): Average Daily Solar Capacity Compared to Median Household Income**

## FINDINGS

First of all, we explored spatial patterns of residential energy use and realized that electricity consumption substantially varies across the City of Dubuque, following a low-to-high East-West trend from the downtown area along the Mississippi river to the more peripheral suburbs. This pattern seems to be strongly correlated with income inequalities. As shown in Figure 36, the inner city center (in blue color) is simultaneously characterized by the lowest median household income and the smallest energy consumption. On average, low-income families use less energy per household, partially because higher-income households are more likely to live in larger houses (Figure 36).

House size (especially in terms of roof size) is also one the most important factors able to determine potential solar capacity. Thus, it is not surprising that the wealthier suburbs in the outskirts of the city represent the census block groups where the average potential solar capacity is the highest, while the buildings in the poorer downtown area have a lower solar potential (Figure 37). However, low-income groups could be the ones that might benefit the most by adopting solar panels, since on average an higher percentage of their overall energy demand could be met by solar as a source of alternative energy. In fact, solar capacity does change across space but not as much as electricity demand, which differs more significantly by block groups (Figure 38).

Spatial disparities become even more clear when considering multiple renewable energies at a time. Figure 38 identifies the locations of Leaking Underground Storage Tank (LUST) sites, where it is not possible to de-

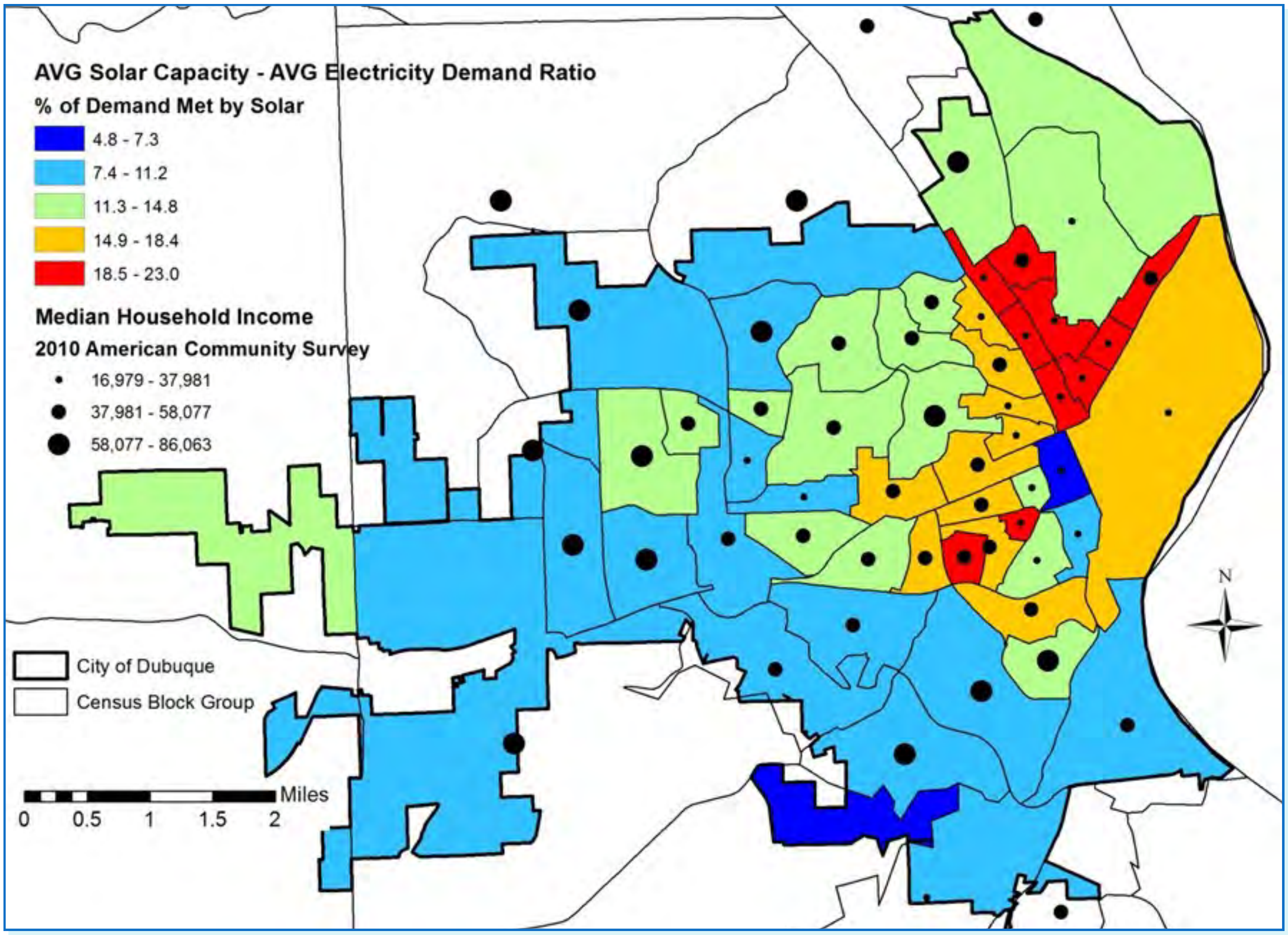


**Figure 38 (Left): Solar Capacity / Electricity Demand Ratio**

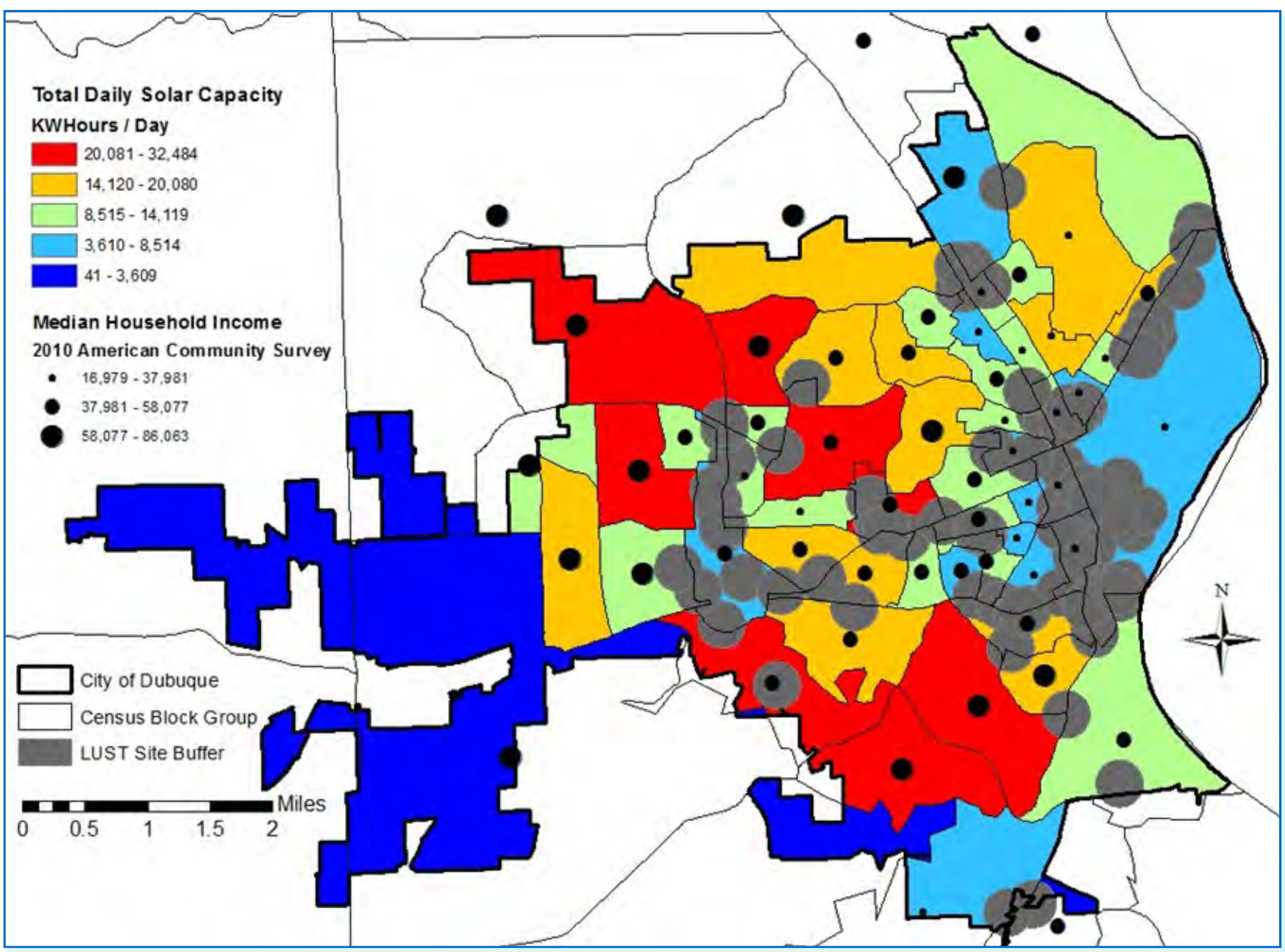


**Figure 39 (Left): Solar Capacity, LUST Buffer Sites, and Median Household Income**

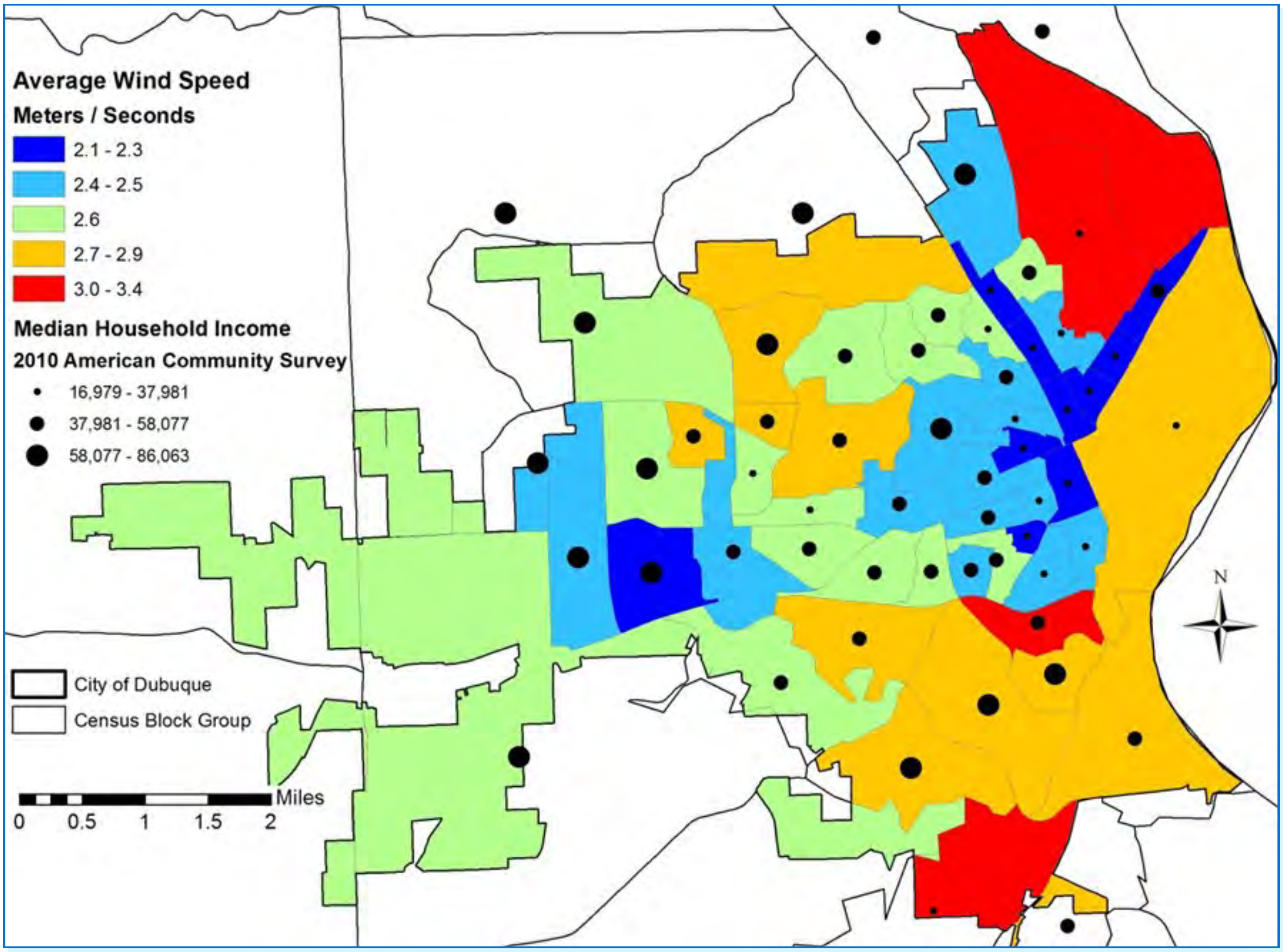


Figure 40 (Above): Digital Elevation Model for Dubuque, Iowa

velop ground source heat pumping systems due to soil contamination. These sites are predominantly clustered in the downtown area and along the Highway 20 East-West corridor, which are typically low-income areas; only few LUST sites are located in high-income block groups. Besides solar and ground source heat pumping, also wind appears to be a renewable energy source not equally accessible to all Dubuque residents.

In terms of wind capacity, as expected, average wind speeds are higher along the Mississippi river, but they are the lowest in the downtown area where lower terrain altitude and high density development tend to limit the overall wind energy power that low-income groups could develop. Instead, high-income families are more likely to take advantage of wind as an alternative energy source, since they tend to live in larger residential lots located in low-density suburban areas, where wind turbines might capture more wind power (Figure 40).

## CONCLUSIONS

Our spatial and demographic analysis suggests a potentially unequal distribution of benefits from renewable energy development to the city of Dubuque. On average, the downtown area is characterized by a lower natural ability to generate renewable capacity. Smaller building roof size, underground soil contamination, lower terrain altitude, and high density development limit the potential overall energy production from solar, ground source heat pumping, and wind. At the same time, similarly to many other American cities, the Dubuque inner city center is where low-income families and minorities tend to reside, creating a spatial mismatch between renewable energy potential and disadvantaged groups. From a social justice point of view, these challenges need to be addressed and mitigated in order to avoid that the incorporation of renewable energy into economic development of the city could further exacerbate the rich-poor local divide.