ENDEPENDENCE: RURAL ENERGY IN A RURAL COMMUNITY

by

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A THESIS

submitted in partial fulfillment of the requirements for the degree

MASTER OF LANDSCAPE ARCHITECTURE

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Approved by:

Major Professor
Mary C. Kingery-Page

Abstract

Rural Kansas communities are almost entirely dependent on large energy corporations. These corporations, in turn, are almost completely dependent on fossil fuels for energy production. Three major implications exist within these dependencies: 1) the dependence of rural communities on large corporations reduces the potential of a local economy to support itself; 2) the dependence on fossil fuels has severe environmental impacts; and 3) fossil fuels are non-renewable resources and will inevitably be exhausted.

A rural Kansas community has resources necessary to achieve and maintain energy independence in a renewable manner. The design of these systems in regard to economy, society, aesthetics, technology, and ecology will play a key role in sustaining these resources into the future. The intent of the project is to create a tool for rural communities to evaluate localized renewable energy potential using Washington, Kansas as an example.

Several questions were addressed to determine the capacity and feasibility of each local energy resource:

1) What renewable energy resources are available to a rural Kansas community and are they sufficient for the community to achieve energy independence?
2) How can the resource or its production be designed and maintained in regard to its environmental impact and long-term viability?
3) What are the implications of energy independence for the community's identity?

Because each question is dependent upon the answer to a previous question, a decision tree was the most viable method for the project's analysis and development. Research into the technology and science associated with each resource provided a general knowledge of the definitions associated with and processes necessary to determine the feasibility of the resource. For resources receiving a positive feasibility rating, analysis continued with a basic cost/benefit analysis that compares potential costs involving implementation and maintenance with the payback, offsets, and incentives involved in utilizing each resource.

Analysis of each feasible resource continued with site suitability analysis. The analysis of each resource resulted in resource maps showing potential implementation locations for three renewable resources studied: hydro, wind, and solar. The maps and accompanying graphics communicate the integration of renewable energy technologies into the existing community's identity.

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I'd like to acknowledge and extend my sincerest thanks to the following people...

to Katie for working through this project with me and allowing me to take it in my own direction. I don't know if you realize this but I've had you at some point for 4 of my 5 years here and I can't imagine college without you.

to Stacy and Stephanie for believing in this project from the very beginning.

to all of my professors.

to New Orleans for the experience of a lifetime.

to the 5th and 6th grade classes at Linn Elementary School for the ideas, excitement, and support...

to the RAM for providing much needed distraction from Seaton Hall, (especially Steiner, Young and Nathan) and for working with my hectic schedule...

to Amy for always making me laugh...

to Becky, Emily, and Lauren for kitten videos in times of distress and Auntie Mae's for celebration...

to my family for nodding their heads and agreeing with me (even though I think they secretly have no idea what Landscape Architecture is to this day)...

to Gary, for keeping Mom sane through all of this...

and finally, to my Mom, for countless hours and endless patience spent listening to my ramblings about absolutely everything while keeping me sane. I know it was exasperating at times but you never let me give up.

for mom and ethan

introduction

The purpose of this project is to create a tool for rural communities to utilize in considering renewable resource development. Because of this, analysis is a more substantial component of this project than in a typical design project. In place of the design phase, there is a necessity to make information and analysis accessible to rural communities. The conveyance of the results from research, synthesis, and the application is the critical final step that replaces design and makes the information accessible.

research

Research forms the project base. Synthesis, application, and conveyance stem from this initial base step.

synthesize

Synthesizes the information from the research into a methodology for application to individual resources. It also aids in establishing a relationship between renewable energy production and landscape architecture and looks toward their integration.

apply

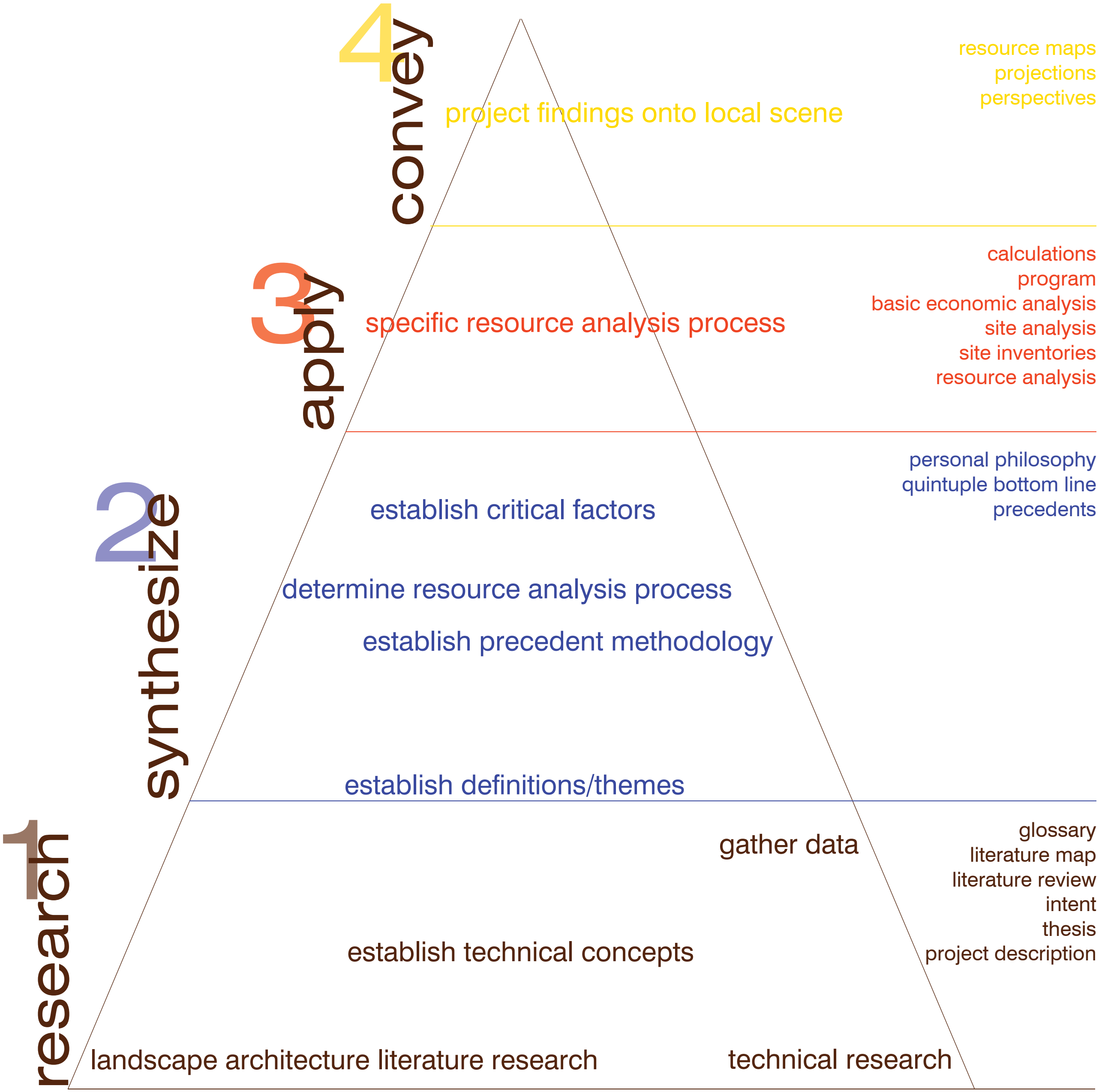
Interpretation of the synthesis for application to individual resources. It includes the facts, data, and particular knowledge gained from this interpretation.

convey

Convey replaces design as the final process phase. It is the means of communicating the knowledge gained as a direct result of the apply phase.

opposite page

f.1 **Process**


4 convey
project findings onto local scene
resource maps
projections
perspectives
3 apply
specific resource analysis process
calculations
program
basic economic analysis
site analysis
site inventories
resource analysis
2 synthesize
establish critical factors
determine resource analysis process
establish precedent methodology
establish definitions/themes
personal philosophy
quintuple bottom line
precedents
1 research
gather data
establish technical concepts
landscape architecture literature research
technical research
glossary
literature map
literature review
intent
thesis
project description


DO NOT
ENTER THE WATER
DO NOT
LAND OR LAUNCH BOATS
NO SWIMMING
NO FISHING NO WADING
THE LAKE SEDIMENT
CONTAINS HAZARDOUS SUBSTANCES
SMC 18.12.070


research

dilemma

The major dilemma shaping this project is that rural communities around the country are completely dependent on large energy corporations. The majority of these companies, in turn are completely dependent on fossil fuels for energy production. Three major implications exist within these dependencies.

1 The dependence of rural communities on large corporations creates a reduction in the potential job market of the community as well as a lack of self-sufficiency. Workforce in the energy sector ranges from construction to maintenance to management. Reinvesting in local energy production would allow the creation of these jobs. People holding these jobs are typically local and their money would most likely be put back into the local economy thus boosting community assets.

previous spread

f.2 **Sign at Gasworks Park in Seattle.** Sign reads “DO NOT ENTER THE WATER DO NOT LAND OR LAUNCH BOATS. NO SWIMMING NO FISHING NO WADING. THE LAKE SEDIMENT CONTAINS HAZARDOUS SUBSTANCES” (original image by author)

2 The dependence on fossil fuels has contributed to the global climate change. The burning of fossil fuels contributes to increases in carbon dioxide, a greenhouse gas, in the atmosphere. Greenhouse gases trap heat from solar radiation and are thought to be the cause of global increases in average temperature. Kansas has two thermoelectric generation plants ranked in the top 50 of Science Daily's "100 Highest CO2 Emitting Power Plants in the United States." A thermoelectric generation plant is any electric plant that uses steam for electrical power production. This steam can be produced through the burning of oil, coal, natural gas, or through nuclear means. (USDE 2006, 18) Jeffrey Energy Center at St. Mary's, Kansas is ranked #16 on the list for emitting 16.3 million tons of carbon dioxide annually in 2007. LaCygne Generating Station at LaCygne, Kansas ranked #46 on the list with 11.9 million tons (Science Daily 2007).

The burning of fossil fuels for power generation contributes to other environmental concerns in addition to the release of carbon dioxide. Thermoelectric generation plants require large amounts of water for production. According to Westar Energy's website, Jeffrey Energy Center uses 23,000,000 million gallons of water daily. While most of this water is returned, the water quality is reduced because of increased temperatures and pollutants (Congress 2006).

3 Finally, the simple fact exists that fossil fuels are costly and will inevitably be depleted. According to a report from the Union of Concerned Scientists (UCS), in 2008, Kansas imported more than 99% of its coal for energy production and spent $518 million out of state. The UCS report also states that Kansas has the potential to generate almost **79 times** its 2008 electricity needs from renewable energy sources (UCS 2010). This is money that could be put to other state needs such as education, infrastructure, and economic development.

With today's technological advances in the energy sector, renewable resources have the potential to become economic assets in rural communities and, in turn, solve some of the social, environmental, and aesthetic concerns within said communities.

thesis

A rural community in Kansas has resources necessary to achieve and maintain energy independence in a renewable manner.

The design of these systems in regard to economy, society, aesthetics, technology, and ecology will play the key role in sustaining these resources in a globally conscious way.

intent

The intent for the project is to create a tool for rural communities to use in considering opportunities for investment in renewable energy resource development while retaining their individual community identity. It is my hope that the communication of the findings of my research to community members will positively impact the way they consider the future of our rural communities.

With this project I am investigating the potential for investment in the energy sector in rural areas and the positive impacts energy independence would bring to a rural community. Community planning and investment in rural renewable energy systems would allow community members to interact and connect with the systems that impact and govern their daily lives. Investment in these systems would have numerous implications at the local, state, and national levels. The systems would create jobs and encourage investment in the local economy allowing the community to become less dependent on outside resources, reducing the cost of living while boosting community assets. Investment in renewable energy resources would reduce the need for state money spent on nonrenewable resource imports, money that could then be put into more pressing areas such as infrastructure, agriculture, environment, and education which provide the basis for the inherent pride and identity found in most rural communities. In addition to the monetary incentives, community interaction with these systems and their implementation has the potential to serve as a catalyst into other areas of sustainable design such as alternative stormwater management, conservation and waste management techniques.

key questions

what are the relationships between renewable energy and landscape architecture?

what renewable energy sources are available to a rural Kansas community?

are those resources sufficient for the community to achieve energy independence?

how can the resources be integrated into the existing community identity?

goals

Gain a basic knowledge of renewable resource technologies.

Establish connections between renewable energy and landscape architecture.

Develop a better understanding of the interactions and connections between energy systems, natural processes, and community identity.

objectives

Create a tool for rural communities to evaluate localized renewable energy potential using Washington, Kansas as an example.

Research and establish necessary site inventory and analysis for each resource.

Develop a process for evaluating the feasibility of a given renewable resource.

Calculate and determine feasible renewable resources.

Conduct site analysis to determine suitable sites for resource development.

Develop landscape architecture theory that incorporates technology into design considerations.

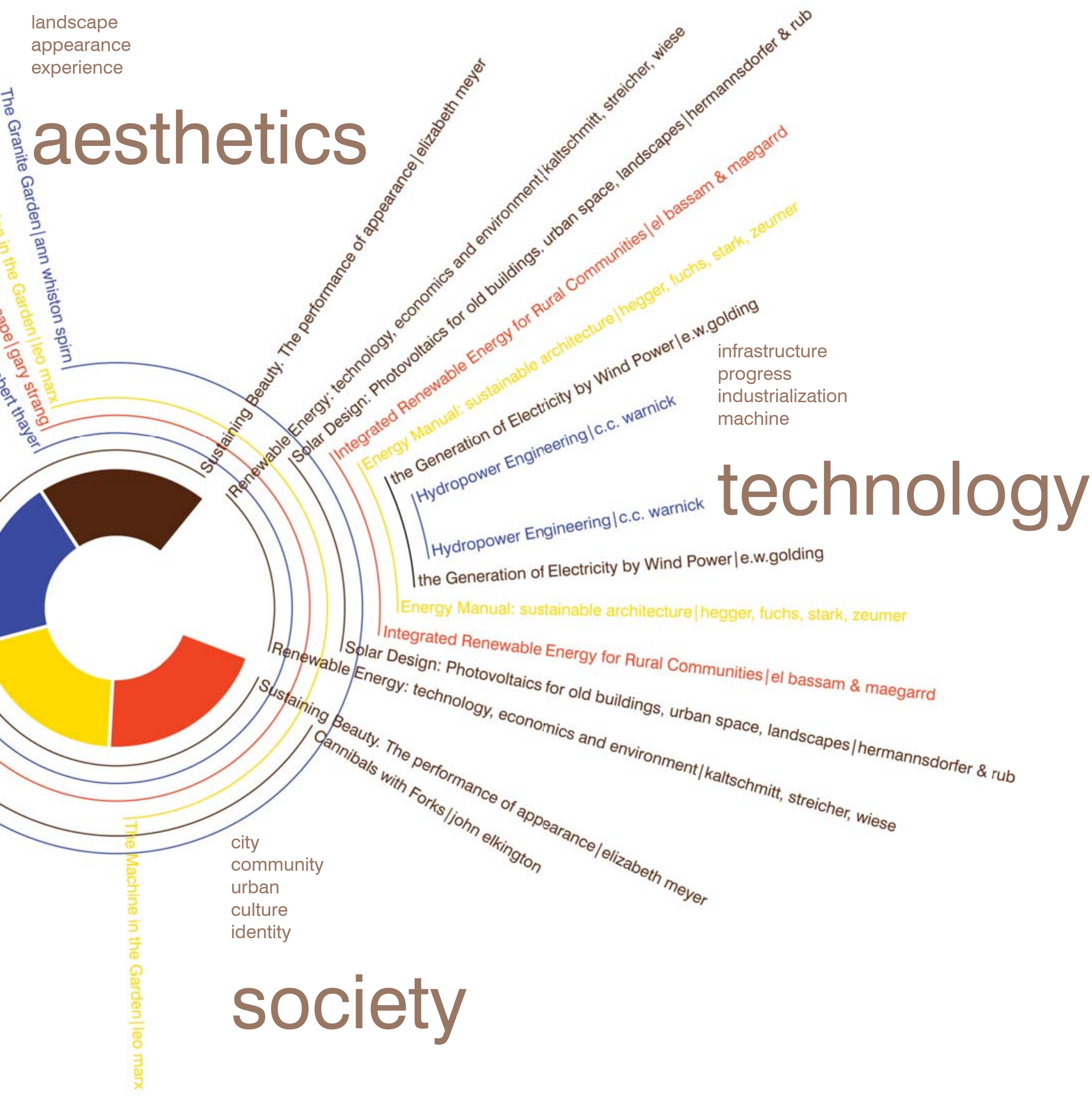
Communicate research and conclusions in a way that is highly accessible to a wide variety of people from community residents to landscape architects.

literature

The literature studied focuses on knowledge from different areas including landscape architecture, sustainability, aesthetics, and technology. (f.3) Further development of previous landscape architecture theories expands the field of sustainability and the triple bottom line to include technology and aesthetics. Literature from outside the landscape architecture profession provides critical supporting information and perspective on the addition of technology and aesthetics into the landscape. In addition to literature on landscape and sustainability, technical literature provides the basic equations and information necessary to move forward into Synthesis and Analysis.

f.3 **Literature Map**
Each partial ring represents a work of literature used to develop the Quintuple Bottom Line theory and technical synthesis. The location of each ring was determined by the concepts presented within that piece of literature. Example: Robert Thayer's **Gray World Green Heart** focuses on the concepts of ecology, society, technology, and aesthetics therefore the ring envelops those concepts.

Above each major division are terms from the literature interpreted to equate to the concepts of economy, ecology, society, technology, and aesthetics.



landscape
appearance
experience
aesthetics
The Granite Garden|ann whiston spirn
Sustaining Beauty. The performance of appearance|elizabeth meyer
Renewable Energy: technology, economics and environment|kaltschmitt, streicher, wiese
Solar Design: Photovoltaics for old buildings, urban space, landscapes|hermannsdorfer & rub
Integrated Renewable Energy for Rural Communities|el bassam & maegarrd
Energy Manual: sustainable architecture|hegger, fuchs, stark, zeumer
the Generation of Electricity by Wind Power|e.w.golding
Hydropower Engineering|c.c. warnick
infrastructure
progress
industrialization
machine
technology
Hydropower Engineering|c.c. warnick
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Energy Manual: sustainable architecture|hegger, fuchs, stark, zeumer
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Renewable Energy: technology, economics and environment|kaltschmitt, streicher, wiese
Sustaining Beauty. The performance of appearance|elizabeth meyer
Cannibals with Forks|john elkington
city
community
urban
culture
identity
society
The Machine in the Garden|leo marx

Further development of previous landscape architecture theories expands the field of sustainable design and the triple bottom line to include technology and aesthetics.

Sustaining Beauty
Elizabeth Meyer
adds aesthetic to create a quadruple bottom line of economy, ecology, society, and aesthetic

Gray World, Green Heart
Robert Thayer
suggests designing with technology as a consideration

The Granite Garden
Ann Whiston Spirn
city to country must be viewed as one system within nature

Literature from outside the landscape architecture profession provides critical supporting information for sustainability and perspective on the addition of technology and aesthetics to the landscape.

Cannibals With Forks
John Elkington
introduces Triple Bottom Line

The Machine in the Garden
Leo Marx
intrusion of “the machine” into the idealized rural American landscape

Technical literature provides the basic equations and concepts necessary to advance into synthesis and application.

Integrated Renewable Energy for Rural Communities
N. El Bassam
P. Maegaard
renewable energy basics
wind principles
solar principles
hydroelectric principles

Renewable Energy: Technology Economics and Environment
Martin Kalschmitt
Wolfgang Streicher
Andreas Wiese
renewable energy basics
hydroelectric generation principles

The Generation of Electricity by Wind Power
E.W. Golding
equations for estimating wind power potential
rated wind speed explanation

Energy Manual: Sustainable Architecture
Manfred Hegger
Matthias Fuchs
Thomas Stark
Martin Zeumer
relates energy consumption to architecture and human use

Hydropower Engineering
C.C. Warnick
hydrologic analysis principles

synthesize

...establish an understanding of the relationship between renewable energy production and landscape architecture and integrate the two...

quintuple bottom line

As landscape architects, we emphasize designs that connect people to place, forging positive interactions with the systems that envelop them and form their environment. My biggest concern as we move into the future is that technology governs more and more aspects of our daily lives, yet we have little to no understanding of or interaction with the energy grid or systems that make it possible for us to utilize these technologies. Even within the landscape architecture profession, we tend to overlook these energy systems or attempt to hide them within our designs. The systems have become such a large part of our daily lives that we should know and understand them as well as their impacts on the environment in which we live.

previous spread

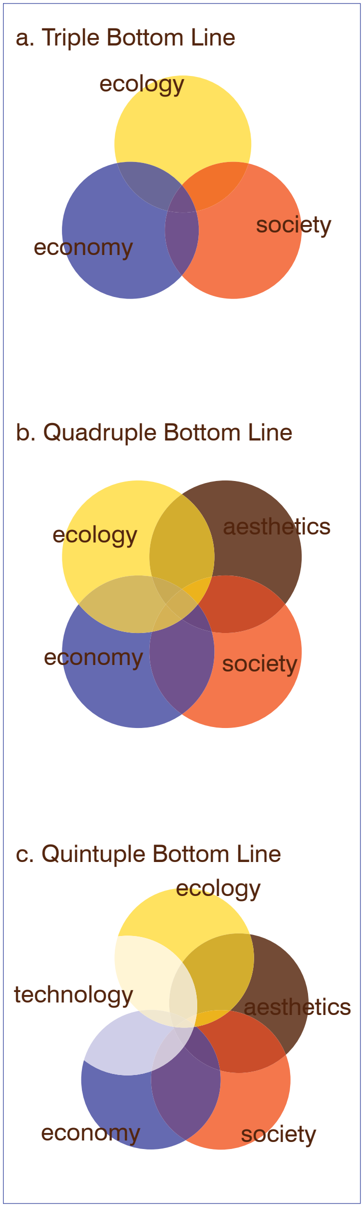
f.4 ***Love & Loss***
Roy McMakin. Seattle Olympic Sculpture Park. Signifies the love of the bucolic rural American landscape presented by Marx and the loss of that landscape to development and technology. (original image courtesy of Jeff Graham)

f.5 **Courthouse Square: Washington, KS**
(image by author)

I grew up in what Leo Marx would term the idealized rural American landscape. Nestled into the hills where the Smoky Hills meet the Flint Hills on the banks of Mill Creek, Washington's claim to fame involves the Mayor of Munchkinland from the Wizard of Oz and pie. The former is known to the locals, the latter to most of Central and Northeast Kansas, but neither are known on a national or even regional level. This does not make our story any less significant than that of New York or San Francisco. In fact, the opposite may be true. Rural communities, quite literally, provide the bread and butter for the United States, and in most cases, the world.

Our courthouse square (f.5) is the standard green lawn with tall shade trees, a large gun commemorating the World Wars, and a Statue of Liberty replica with the occasional wardrobe change. The square has served as a kickball field; sidewalk chalk art gallery; bottle rocket launch pad; and every Saturday morning from May to August, it is the venue for the morning farmer's market. This combination has created the place I know.

This is our place yet with current population trends, this place has become threatened with extinction. To prevent this, the community must adapt and change. A general stereotype is that the attitudes of people within rural communities are not conducive to change. More often than not people are unaware of how to go about instigating changes that will positively impact the community without negative side effects and without completely altering their sense of community. To move into the future and preserve their place, these communities must adapt.



f.6 Sustainability Theories

In “Sustaining Beauty: The performance of appearance,” Elizabeth Meyer states: “While I do not believe that design can change society, I do believe it can alter an individual’s consciousness and perhaps assist in restructuring her priorities and values” (Meyer 2008, 10) The second part of that statement is exactly why I do believe design can change society. The environment in which we grow up helps shape our values and ethics. As designers, we have the power and ability to change the world we live in. As stewards of that environment, we have a responsibility to the earth and humankind to guide change for the better.

In The Machine and the Garden, Marx puts pen to the incongruity of the idealized American landscape aesthetic juxtaposed with industrialization, or the machine. According to Marx, “it is industrialization… that provides the counterforce in the American archetype of the pastoral design” (Marx 1964, 26). The idealized landscape is the attempt to retain the bucolic image that comes to mind when one mentions America, the “New World” (Marx 1964).

Recent landscape architecture works do not attempt to recreate this pastoral landscape but rather attempt to alter this aesthetic to one focused on the environmental systems and processes that created the original idealized landscape. Meyer shows a concern with appearance as a function of sustainability and the lack of aesthetic consideration in many of today’s designs. These designs are focused solely on replicating ecological processes with no thought toward the aesthetic, experiential qualities. She states that “a concern for beauty and aesthetics is necessary for sustainable design if it is to have a significant cultural impact” (Meyer, 2008). This presents a quadruple bottom line of society, economy, ecology, and aesthetic.

The quintuple bottom line stems from Meyer's concern with appearance as a function in "Sustaining Beauty" and Robert Thayer's concern for technology and infrastructure in *Gray World, Green Heart.* According to Meyer a concern for aesthetics has been lost in the search for sustainable solutions. Her belief is that "the experience of certain kinds of beauty - granted new forms of strange beauty - is a necessary component of fostering a sustainable community, and that beauty is a key component in developing an environmental ethic" (Meyer 2008, 9). This led me to a belief in the quadruple bottom line of social, economic, ecologic, and aesthetic concerns. (f.6.b)

My interest in energy resources led me to Robert Thayer's *Gray World, Green Heart*. His is a concern for the emotional attachment to the idealized landscape that leads to the disguise of technology within design. "Modern American life and culture are now primarily driven by science and technology, and that the landscape, as an object of culture, cannot help but reflect this technological determinism" (Thayer 1994, xvii).

This has led me to my belief that sustainability cannot be limited to three ideas and that the triple bottom line in a design context is a good starting point, but should not serve as the sole ideal. The quintuple bottom line (f.6.c) presents a model for sustainable design where ecological, social, economical, aesthetic, and technological concerns are all equal within the environment. The parts are designed to move and adapt to the needs of the individual project but all are given some consideration. For a design to be successful in the modern world, it must integrate all five aspects.

f.7 **Olympic Sculpture Park**: Seattle Art Museum, Seattle, WA
SAM's Olympic Sculpture Park successfully integrates technology (railroad and four-lane street) and aesthetics on a brownfield site on Puget Sound. (Image courtesy of the Seattle Times)

technical synthesis

The purpose of the Analysis Overview (f.8) is to provide a basic guide for all future resource analysis development. The process follows a decision tree sequence that begins with basic resource information such as the equations and data necessary to calculate the resource potential. If the resource potential exists, a process of site analysis for resource development follows. The individual research diagrams and processes vary due to the nature and qualities of the resources.

The entire process begins with a resource feasibility analysis divided into two branches, critical information and supporting information, to determine overall resource feasibility. The critical information branch involves equations and data necessary to determine the potential of available existing resources. The second branch, supporting information, is necessary to provide support for the conclusions on resource feasibility.

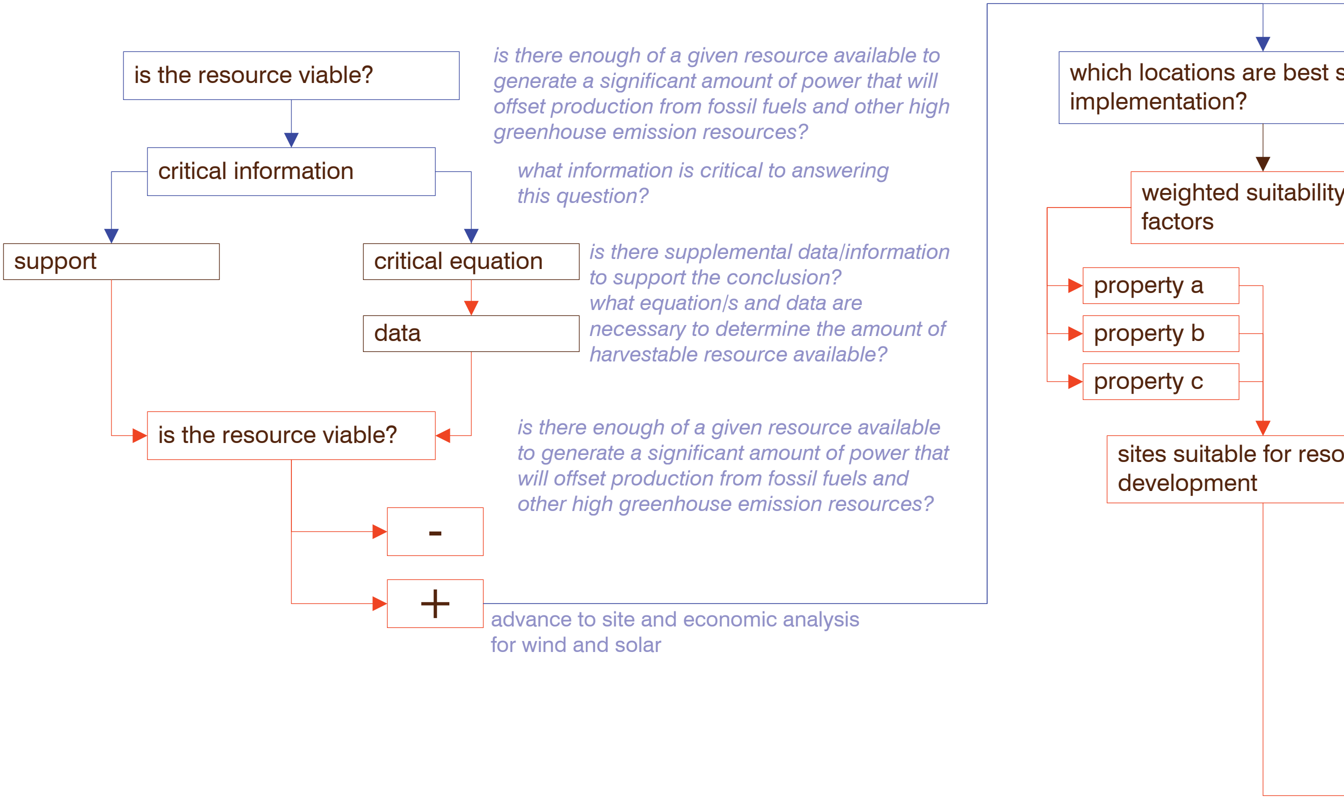
The bulk of the second branch is precedent studies; however, the precedent studies for this project differ from precedent studies for a typical design project. The ultimate goal of the precedent studies is to create a knowledge base that will help to establish an understanding of the relationship between renewable energy production and landscape architecture.

An understanding of processes is critical knowledge to a landscape architect. To be able to make the connections between landscape architecture and renewable energy production, the processes within renewable energy production must first be understood. As these connections have not been considered in-depth before, many of the precedents will be based on past, existing, or future renewable energy projects.

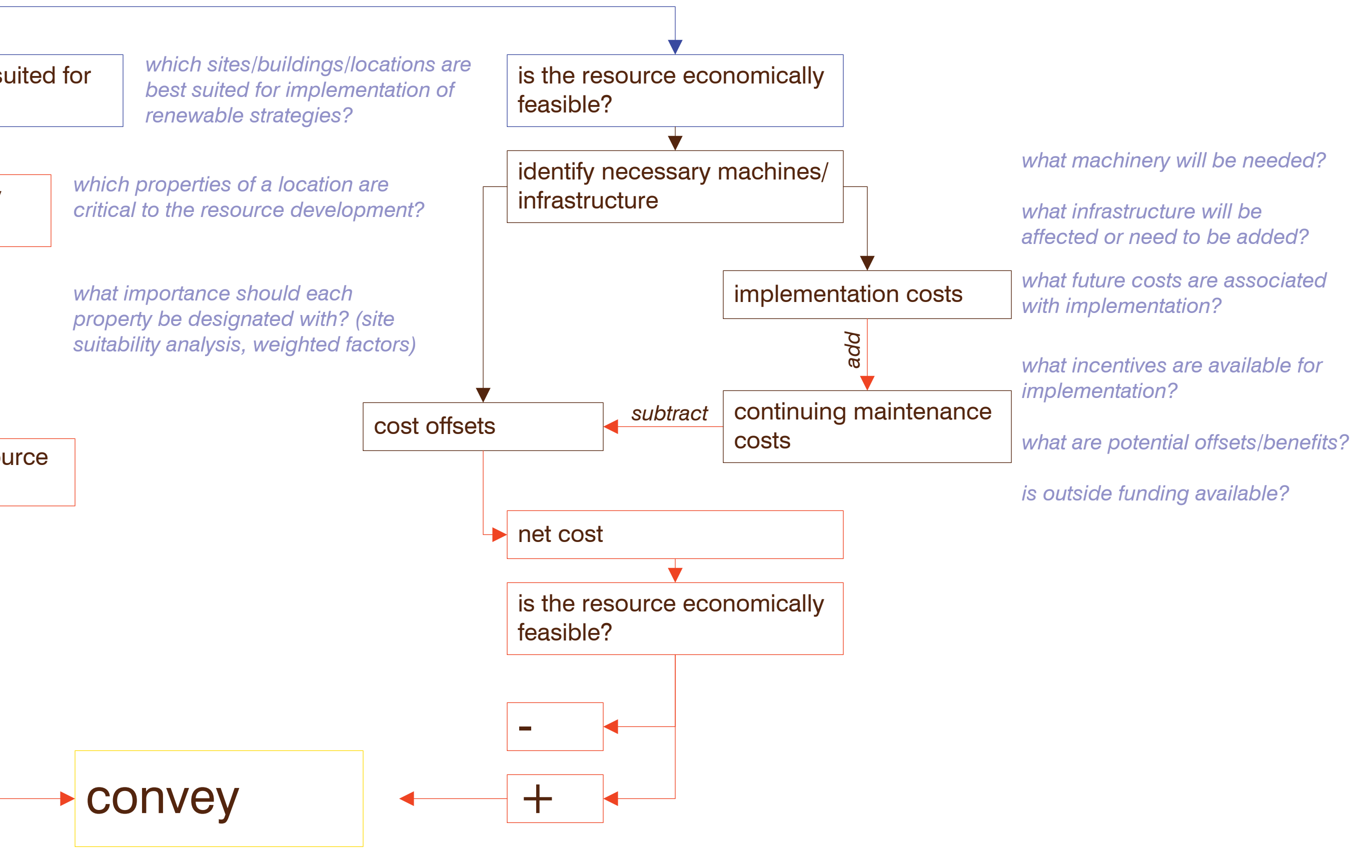
Following resource feasibility analysis, site analysis determines which sites or areas are best suited for resource development. This process eliminates sites unsuitable for resource development based on critical properties for each resource. The properties are weighted based on their importance to the resource development.

After the resource analyses is a basic economic analysis to determine basic costs and payback. An in-depth economic analysis would include the basic cost of necessary machines and infrastructure offset by potential incentives such as tax forgiveness, potential profit, and funding opportunities. This portion will be visible in the Convey phase of the project. For this project, the precedent project costs serve as a basis for cost estimation for Washington.

analysis overview



f.8 Analysis Overview Diagram
The color of the boxes and lines corresponds to the phases of the project: research, synthesize, apply, and convey.



suited for
which sites/buildings/locations are best suited for implementation of renewable strategies?
which properties of a location are critical to the resource development?
what importance should each property be designated with? (site suitability analysis, weighted factors)
urce
is the resource economically feasible?
identify necessary machines/ infrastructure
implementation costs
add
continuing maintenance costs
subtract
cost offsets
net cost
is the resource economically feasible?
-
+
convey
what machinery will be needed?
what infrastructure will be affected or need to be added?
what future costs are associated with implementation?
what incentives are available for implementation?
what are potential offsets/benefits?
is outside funding available?

precedent methodology

An understanding of processes is critical knowledge to a landscape architect. To make the connections between landscape architecture and renewable energy production, the processes within renewable energy production must first be understood.

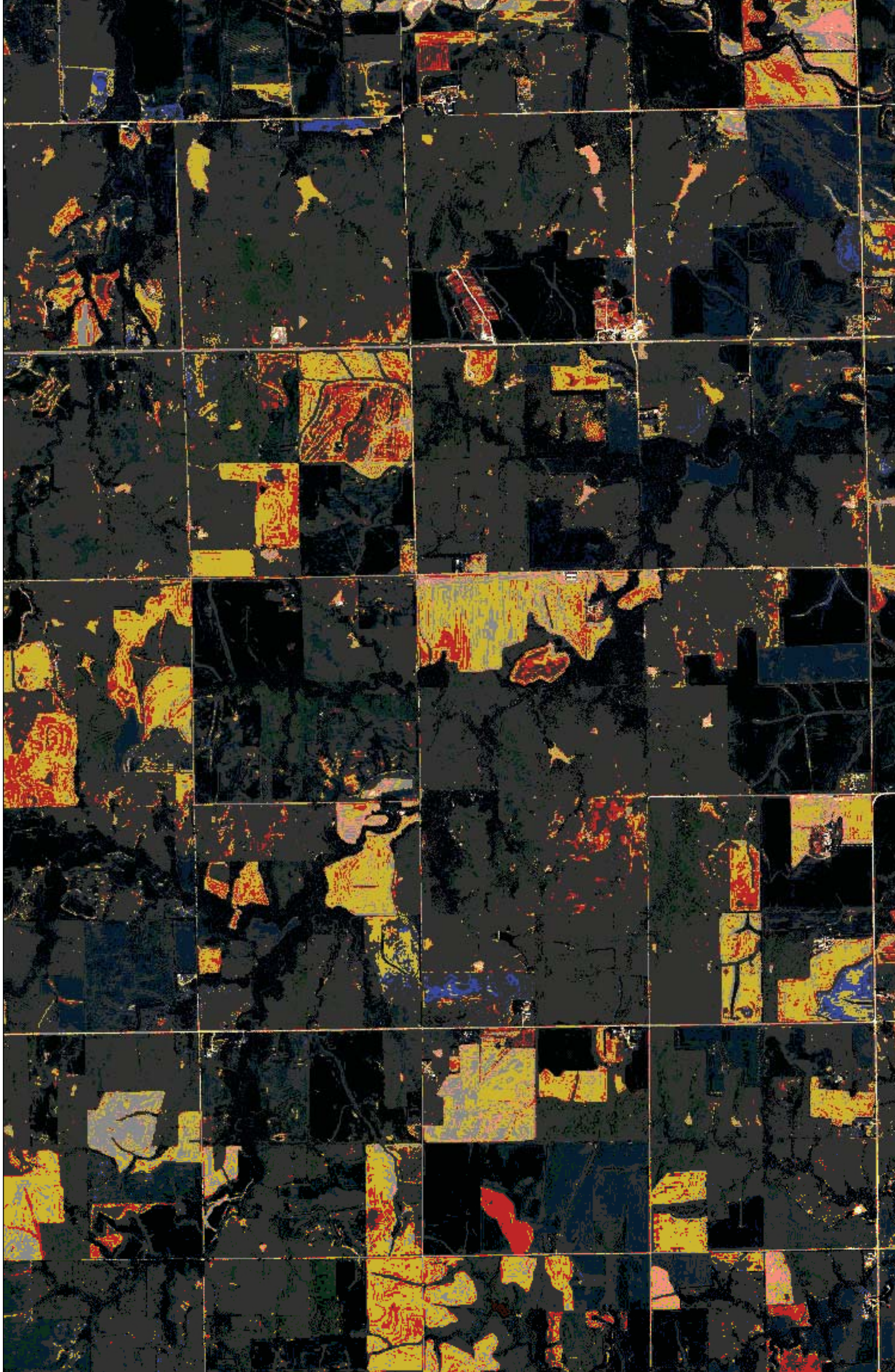
As these connections have not been considered in-depth before, many of the precedents will be based on past, existing, or future renewable energy projects. They were chosen from criteria based on recurring concepts such as physical site conditions and technical properties throughout the technical literature.

physical conditions
A project's location and the properties related to the location such as population, energy needs, topography, climate, and hydrology is the first criterion. Ideal projects are similar to the project site in most locational properties.

technical properties
Projects chosen as precedents must have certain physical attributes that contribute to the technical aspect of said project. For example, head is a requirement for the hydrologic precedents because is a critical factor in calculating power generation potential. Washington's dam falls into the low head category; therefore, dams with low heads were chosen as precedents.

	watertown dam	bowersock mill & power co.	greensburg wind farm	unalakleet wind farm	make it right foundation	washington, ks | current	washington, ks | potential
head	1.32	6	NA	NA	NA	3	3
average flow rate	8.7 cms	varies	NA	NA	NA	varies	varies
facility type	run-of-river	run-of-river	NA	NA	NA	run-of-river	run-of-river
classification	micro	micro				none	micro
generation potential	10 kW	2.35 mW	12.5 mW	600 kW	3kW/ system	none	> 3.75 mW
environmental impact	low	low	low	low	low	none	low
# of turbines			10	6		none	> 1
wind class			3 & 4	3 & 4		3 & 4	4 & 4
population served	small/office	large	small/ community	small/ community	small/ community	small/ community	small/ community
	hydro		wind		solar		

t.1 **Precedent Overview**
Overview shows the properties of each precedent that relate to small community resource development and how they relate to Washington.



apply

...interpret Synthesis for individual resources...

hydro power

Washington has an existing dam structure on Mill Creek. The dam is located next to the municipal power plant. This presented an opportunity to investigate micro-hydroelectric generation potential.

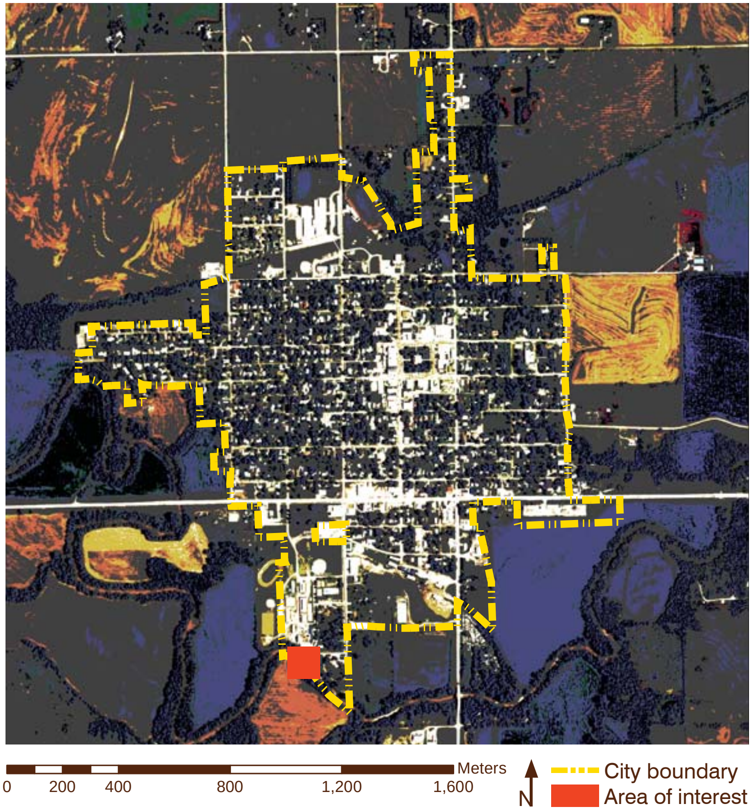
previous spread

f.9 **Map of Area Around Washington** (image by author)

left

f.10 **Washington City Dam** (image by author)

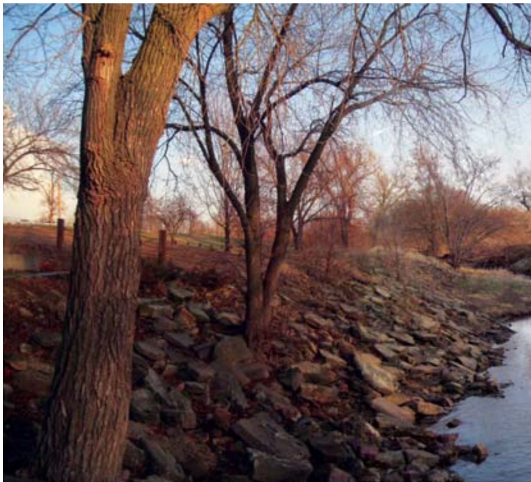
site



f.11 **City Context**
The dam is located within the Washington City Park adjacent to the municipal power plant.

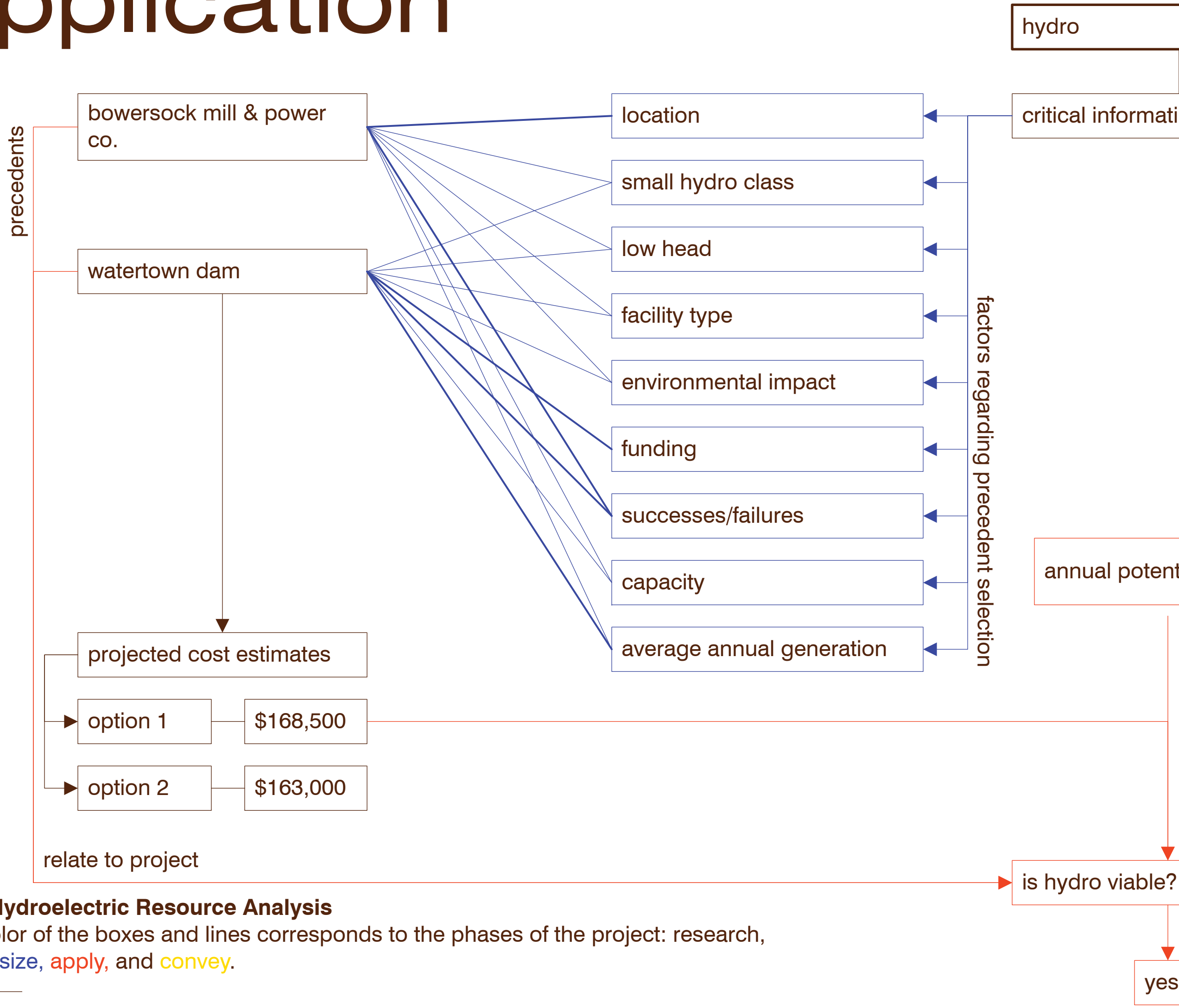
Located in the Washington city park (f.11), the Washington Water Reservoir Dam (f.12) on Mill Creek in the Big Blue River watershed is approximately 3 meters tall by approximately 36 meters wide and was previously used for the city's potable water supply. The area is currently used as a recreation area for local residents. However, with flooding during the summer of 2010, stream bank stability and safety have become major concerns for the site as the area is now posted with No Trespassing signs.

f.12 **Panorama of Dam Area**
(Image by author)

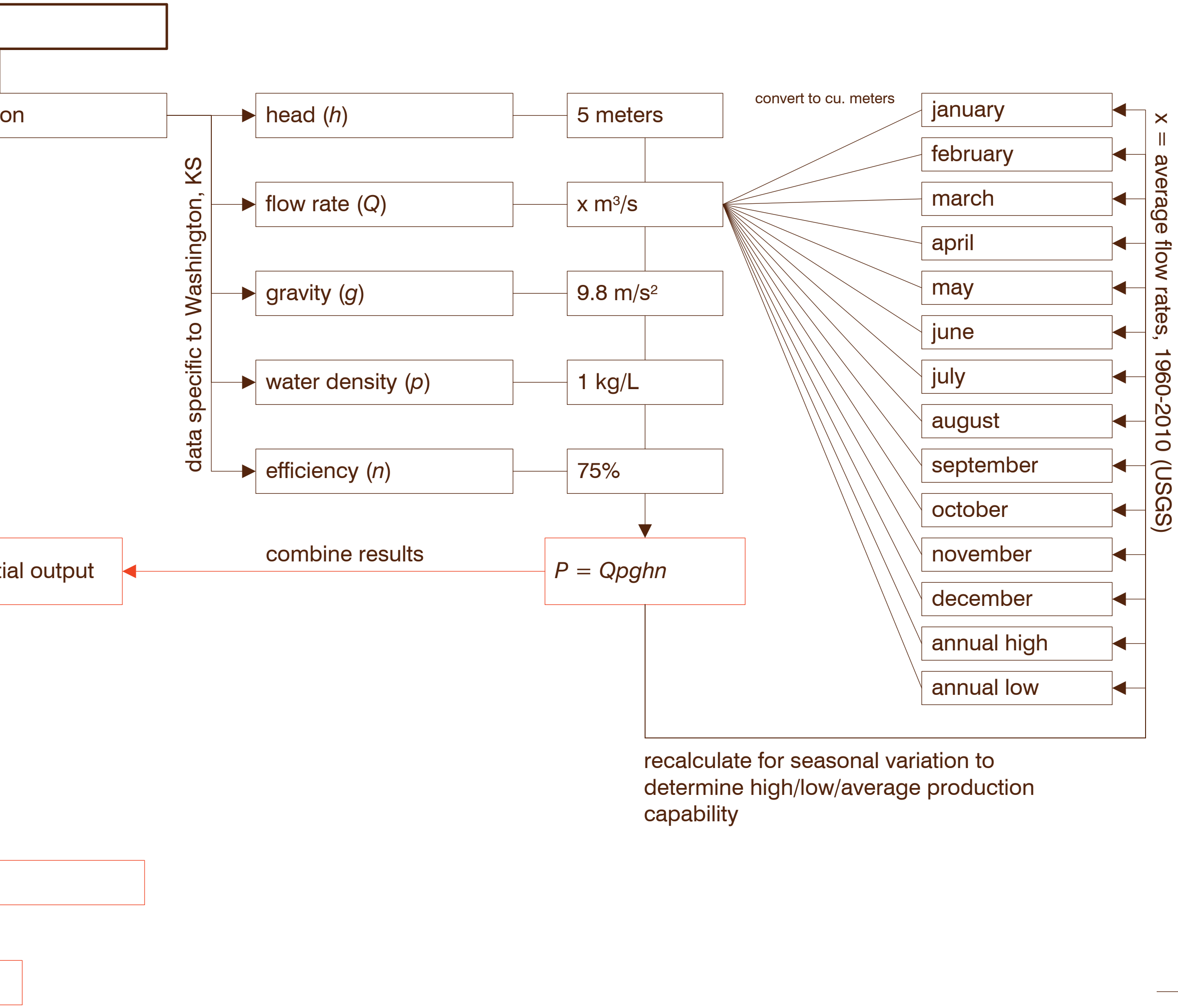


Investment in hydroelectric power generation infrastructure presents an opportunity for reinvestment in the area as a recreational asset to the community.

hydroelectric resource application

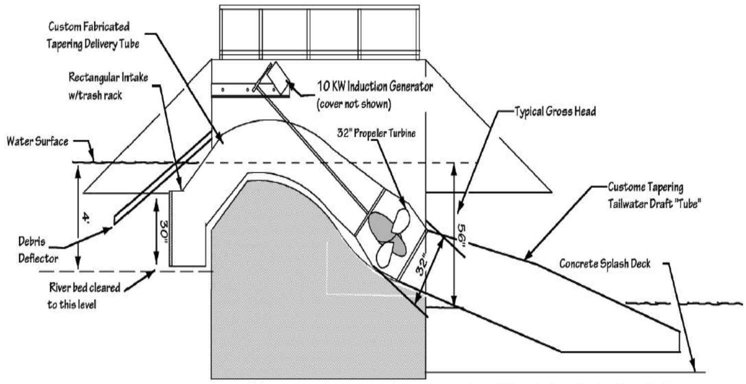


f.13 **Hydroelectric Resource Analysis**
The color of the boxes and lines corresponds to the phases of the project: research, synthesize, apply, and convey.


on
head (h)
5 meters
flow rate (Q)
x m³/s
gravity (g)
9.8 m/s²
water density (p)
1 kg/L
efficiency (n)
75%
data specific to Washington, KS
convert to cu. meters
january
february
march
april
may
june
july
august
september
october
november
december
annual high
annual low
x = average flow rates, 1960-2010 (USGS)
combine results
P = Qpghn
ial output
recalculate for seasonal variation to determine high/low/average production capability

precedents

watertown dam



f.14 **Hydroelectric Option 1**
(Courtesy of Anthony Fox and Sasaki & Associates)

In an effort to implement renewable energy systems at their Watertown, Massachusetts office, Sasaki & Associates hired a consultant to investigate the potential for implementing low-impact micro-hydro generation at the existing dam adjacent to their office, located on the St. Charles River.

The results of the study included two feasible design solutions for hydroelectric generation at the dam with little impact on the existing channel or dam structure. Because it was a private project for Sasaki, the firm decided to forego the project due to the high costs for licensing and permits.

economics

The Watertown Dam feasibility study serves as an example of a project that was not successful due to funding. A small community such as Washington would face similar funding dilemmas.

Two design options were presented within the Sasaki study. The first (f.14) was estimated at $168,500 and the second at $163,000 (Sasaki 2005). It can be concluded that similar costs could be expected for a project in Washington. Using the highest cost of $168,500 for a 10 kW generator this would amount to $17 per watt. Cost per watt is the unit used to determine cost feasibility for payback. This is the final result of the economic part of the resource analysis diagram. Potential funding opportunities and incentives are discussed in the conclusions.

f.15 **Watertown Dam**
(Courtesy of Anthony Fox and Sasaki & Associates)

precedents

bowersock mill & power co.

f.16 **Bowersock Dam**
(Courtesy of Bowersock Mills & Power Co.)

The Bowersock Mill & Power Co. hydroelectric plant was chosen because it is the only hydroelectric plant in Kansas still in operation today. Located on the Kansas River, it was originally constructed following an energy shortage in the early 1870s. It began as a project between a private business owner and the City of Lawrence to provide the city with a constant source of power. The initial construction was completed in 1874. The dam was rebuilt after flooding and ice flow damage several times throughout its history (Bowersock 2011).

The dam was originally built to provide the city of Lawrence with mechanical power and was refitted for electricity in 1888. Use of the mill diminished between 1941 and the 1960s until operations ceased in 1968; however, the oil crisis in the 1970s led to nationwide reinvestment in its power supply. The Public Utility Regulatory Policies Act of 1978 (PURPA) called for large utility companies to buy power from smaller producers. The Bowersock plant was recommissioned and equipped to supply 1000 homes with power and still operates today as a 2.5 mW electric plant. The plant is currently looking at an expansion that will include an additional powerhouse at the north end of the dam (Bowersock 2011).

This project serves as a precedent because of technical and physical properties similar to Washington. It has a low head and falls into the small hydroelectric class. Although it is greater in quantity, the flow rate of the Kansas River varies similarly to that of Mill Creek in Washington County.

f.17 **Flume View**
(Courtesy of Bowersock Mills & Power Co.)

calculations

hydroelectric resource application development (f.13)

mill creek discharge

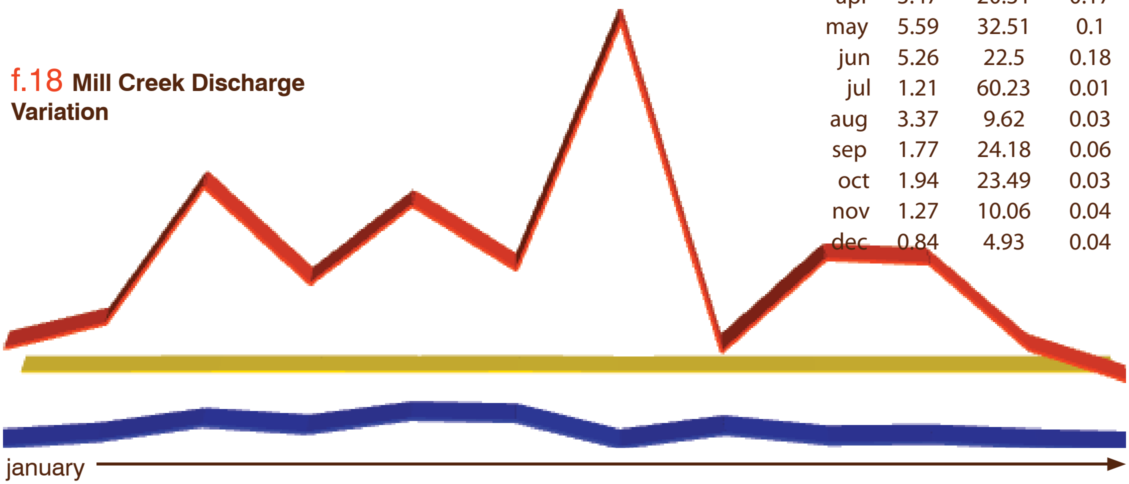
The United States Geological Survey (USGS) table of Monthly Statistics for Mill Creek at Washington, KS (USGS Station: 06884200) was imported into a Microsoft Excel workbook. The mean discharges for each month were calculated by dividing the sum of discharges per year and dividing by 50. (Full discharge tables can be found in Appendix) The minimum and maximum average discharges were derived from the data using the Excel formulas for minimum and maximum.

USGS measures discharge in the standard unit, cubic feet per second. Metric units are needed to calculate kilowatts using the theoretical water power equation; therefore USGS discharges were converted to metric units using a conversion of 1 cubic foot = .028 cubic meters. Table x summarizes the monthly discharge averages in cubic meters per second.

t.2 **Mill Creek Monthly Discharges** (cubic meters per second)

	mean monthly discharge	max average	min average
jan	1.22	10.28	0.03
feb	2.28	14.13	0.06
mar	4.56	35.39	0.16
apr	3.47	20.31	0.17
may	5.59	32.51	0.1
jun	5.26	22.5	0.18
jul	1.21	60.23	0.01
aug	3.37	9.62	0.03
sep	1.77	24.18	0.06
oct	1.94	23.49	0.03
nov	1.27	10.06	0.04
dec	0.84	4.93	0.04

f.18 **Mill Creek Discharge Variation**



potential power

The theoretical water power equation was used to determine potential monthly output. Monthly outputs were used to determine the theoretical water power equation: $P=Qpghn$ where

P = water power (kW)
Q = flow rate (cu. m/s)
p = density of water (kG/L) = 1kG/L
g = acceleration due to gravity (m/s sq.) = 9.8 m/s sq.
h = head = elevation of headwater - elevation of tailwater (m)
n = efficiency percentage

Values for h varied for the average, maximum, and minimum discharges because the head varies from very small at maximum discharge to very large at minimum discharge therefore the values assigned were:

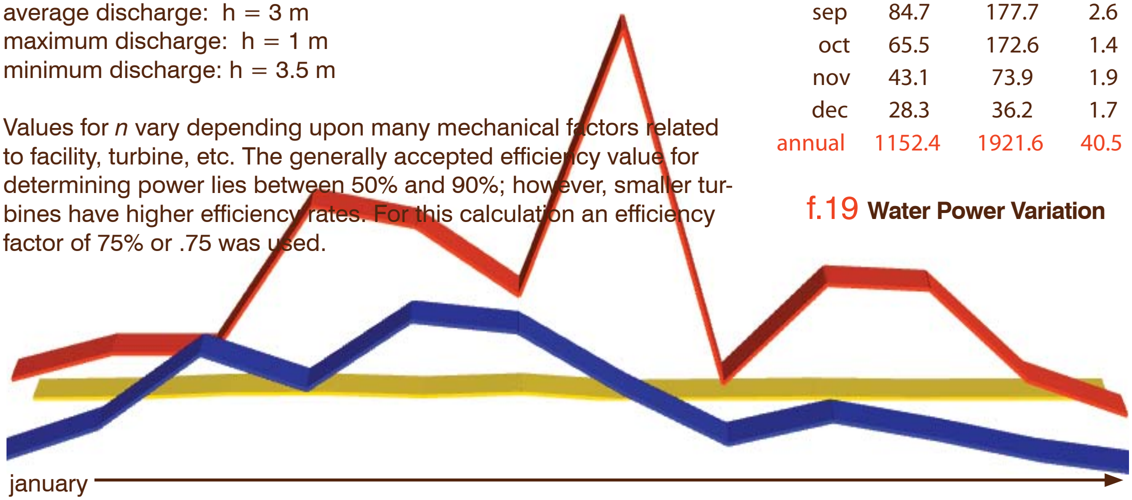
average discharge: h = 3 m
maximum discharge: h = 1 m
minimum discharge: h = 3.5 m

Values for *n* vary depending upon many mechanical factors related to facility, turbine, etc. The generally accepted efficiency value for determining power lies between 50% and 90%; however, smaller turbines have higher efficiency rates. For this calculation an efficiency factor of 75% or .75 was used.

t.3 Theoretical Water Power Calculations

	average kW	max kW	min kW
jan	41.4	75.5	1.3
feb	77.1	103.8	2.8
mar	154.3	103.8	7.2
apr	117.5	260.1	7.7
may	188.9	238.9	4.4
jun	177.7	165.4	7.9
jul	114.0	442.7	0.4
aug	59.9	70.7	1.4
sep	84.7	177.7	2.6
oct	65.5	172.6	1.4
nov	43.1	73.9	1.9
dec	28.3	36.2	1.7
annual	1152.4	1921.6	40.5

f.19 Water Power Variation

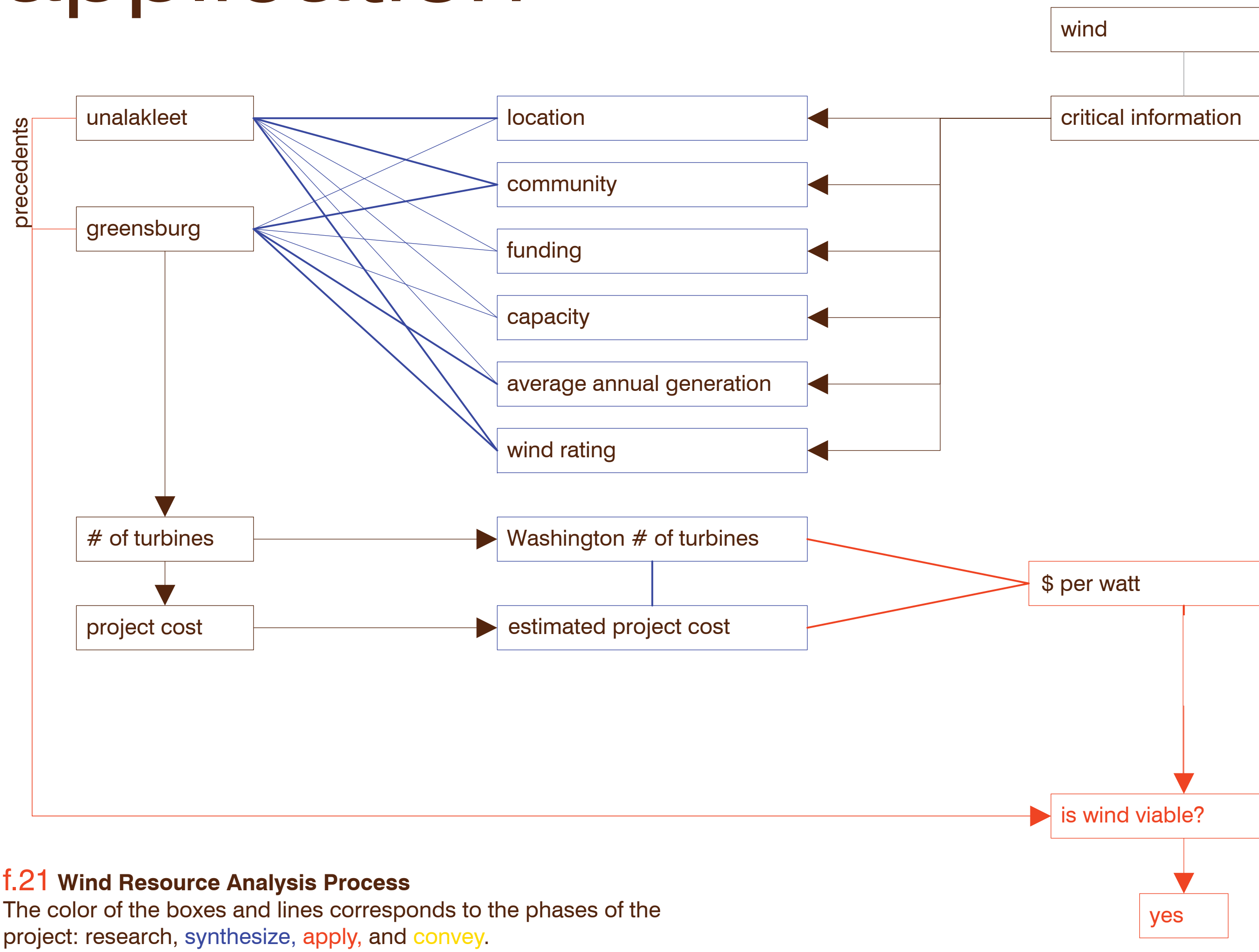


wind power

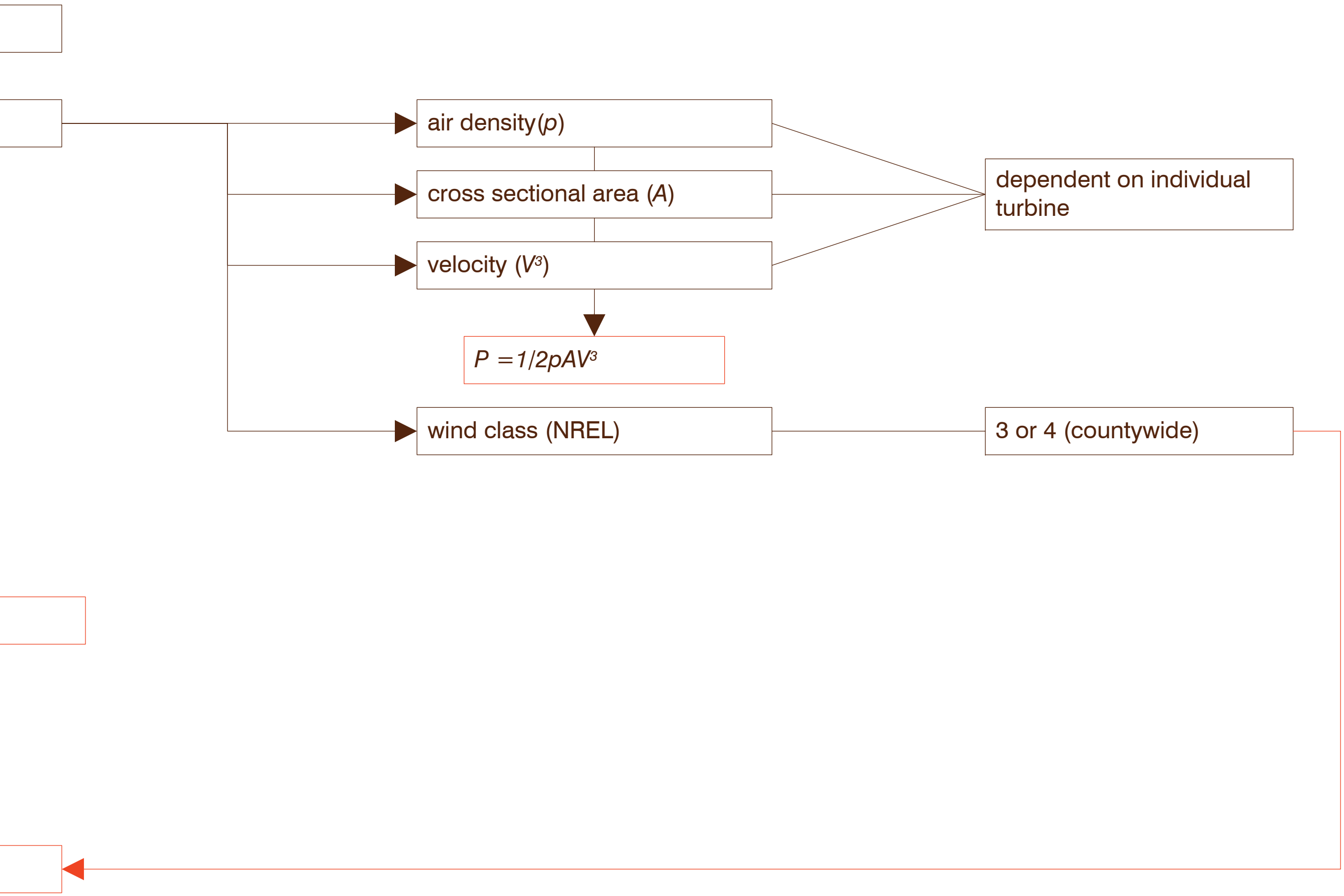
Kansas offers the third highest potential for wind energy in the U.S.
- U.S. Department of Energy, 2011

left
f.20 **Meridian Way Wind Farm, Cloud County** (Courtesy of Lawrence Journal World)

wind resource application



f.21 **Wind Resource Analysis Process**
The color of the boxes and lines corresponds to the phases of the project: research, synthesize, apply, and convey.


air density(p)
cross sectional area (A)
velocity (V3)
P =1/2pAV3
wind class (NREL)
dependent on individual turbine
3 or 4 (countywide)

precedents

unalakleet valley electric cooperative wind farm

Construction on the Unalakleet Valley Electric Cooperative (UVEC) wind farm began in Unalakleet, Alaska in the summer of 2009 and was completed in February 2010. The project involves six turbines capable of generating 100 kW each for total generation of 600 kW. The farm is expected to produce about 1.5 million kWh annually which equates to approximately 35% of the community's electrical needs (REAP 2010).

f.22 **Turbines at Unalakleet Wind Farm**
(Image courtesy of Renewable Energy Alaska Project)

According to the project's website, northernpower.kiosk-view.com/unalakleet, the system has generated a total of 1,065,721 kWh since November 2009 and has saved the community an estimated $213,144. The website also displays the environmental offset generated by the system. The amount generated is enough to power 333 houses annually. It has offset CO2 production by 1,664,129 lbs and saved 81,978 gallons of diesel fuel. In addition, the UVEC wind farm project has reduced and stabilized the cost of energy in the community (Northern Power Systems 2011).

The project also uses the website as an educational tool to provide real-time data of the operation of each turbine. It illustrates how the electricity is being used in the community and a curriculum at the local school is being developed based upon the National Renewable Energy Laboratory's (NREL) Wind for Schools program (REAP 2010)

Funding for the project came from assistance from the Norton Sound Economic Development Corporation (NSEDC), the Unalakleet Native Corporation (UNC), and the Alaska Energy Authority (AEA) which oversees Alaska's Renewable Energy Fund Program (REAP 2010).

The Community of Unalakleet is located in an area similar to Washington in wind resources. The population was 688 at the 2010 census, about half the size of Washington but serves as a reasonable precedent because the community of Unalakleet and the community of Washington would face similar funding issues (ADCCED 2011).

f.23 **Construction of Unalakleet Wind Turbine**
(Image courtesy of Northern Power Systems)

precedents

greensburg wind farm

The Greensburg Wind Farm is part of the rebuilding effort by the community of Greensburg, KS following the 2007 tornado that devastated the community. Construction began in October 2009 and the project was completed in March 2010. The project includes 10 1.25 mW wind turbines which generate enough energy for 4000 homes (USDE 2011).

The project is owned by John Deere Renewables but was a collaboration between John Deere Renewables, *Native*Energy, Inc., US Department of Agriculture (USDA) Rural Development, Kansas Power Pool, and the city of Greensburg (John Deer Renewables 2009).

Funding for the $23 million project came from a $17.4 million loan from the USDA Rural Development and through investments from John Deere Wind Energy as well as gap funding from *Native*Energy, Inc. (USDE 2011).

Greensburg serves as a precedent because it was a grassroots community initiative. Community members took on the task of rebuilding the town sustainably. “As of August 2009 there are 4 LEED Platinum certified buildings, as well as 4 commercial buildings attempting LEED Platinum certification, and 1 attempting LEED Gold certification” within the city of Greensburg (Greensburg Greentown 2009). This initiative extended into the planning and construction of the Greensburg Wind Farm.

The scale of the Greensburg project is also a good precedent for a community scaled-wind resource development project. The wind farm produces enough energy for the community and is able to sell the excess to Kansas electrical companies.

Greensburg has many similarities to Washington. The population for the 2010 census was 777. However, this number is post-tornado. Pre-tornado, the 2000 population was 1,582 (US Census Bureau 2011). Washington's current population at 1,131 is smaller than Greensburg's in 2000 but greater than 2010's population (US Census Bureau 2011).

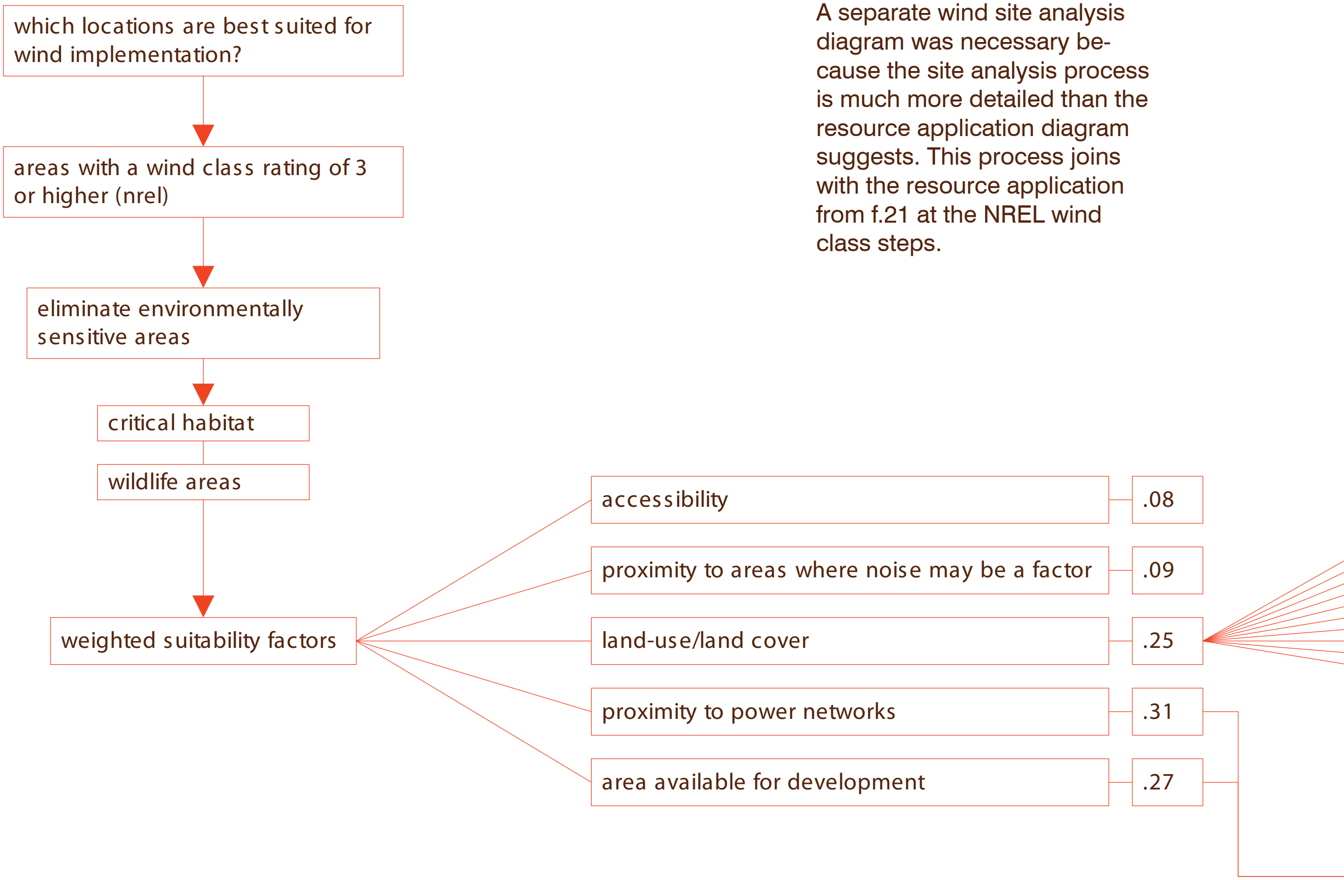
Both communities are located near or within areas designated with a 3 or 4 wind power classification rating (see Appendix, NREL 2011). Additional similarities lie between the two communities including being located within Kansas, having agricultural backgrounds, and having similar wind patterns.

economics

The total project cost for the Greensburg Wind Farm was $23 million. This was for ten, 1.25mW wind turbines (USDE 2011). Three similar turbines would complete Washington's energy independence. Assuming each turbine's construction costs about the same, three turbines would make up 30% of the Greensburg $23 million cost. Thirty percent is approximately $7 million or $1.87 per watt. Cost per watt is the unit used to determine cost feasibility for payback. This is the final result of the economic part of the resource analysis diagram. Potential funding opportunities and incentives are discussed in the conclusions.

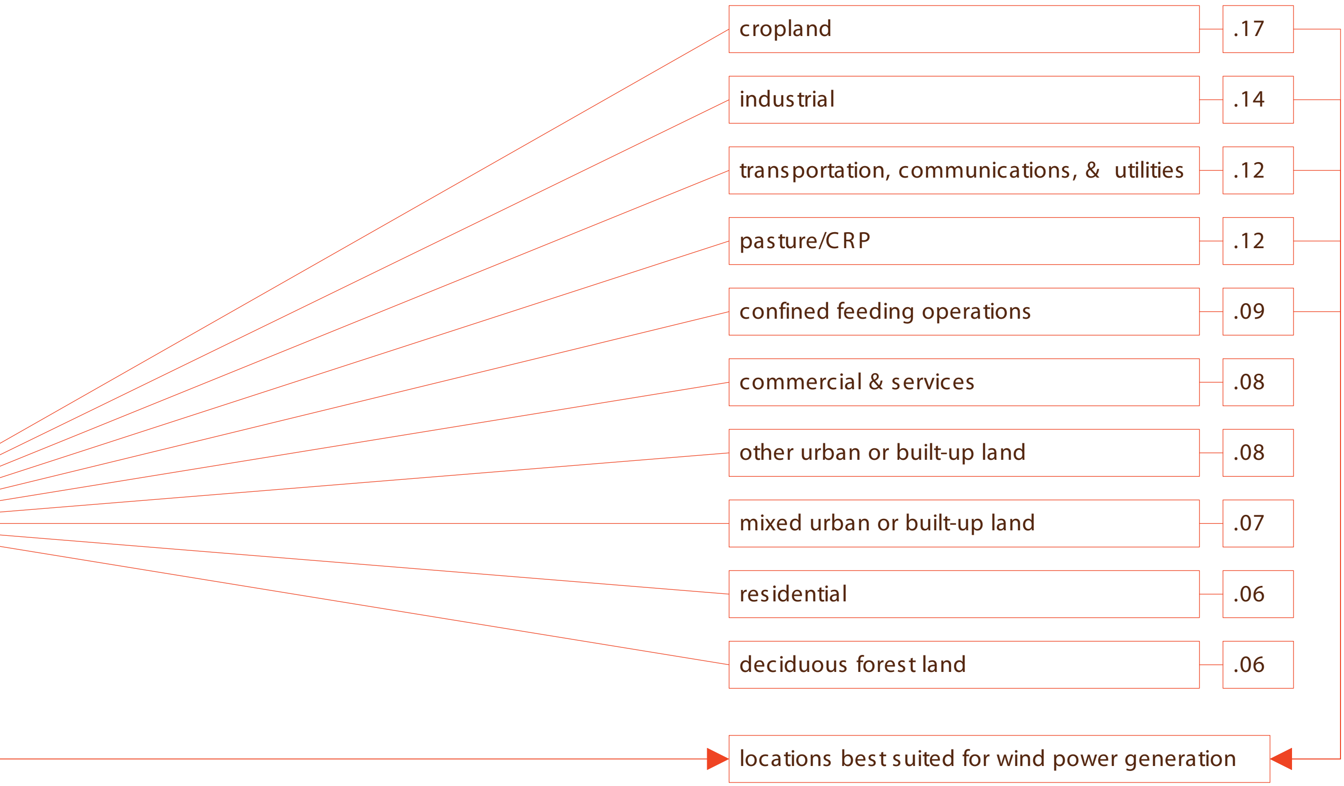
f.24 **Greensburg Wind Farm**
(Courtesy *Native*Energy, Inc.)

wind site analysis process



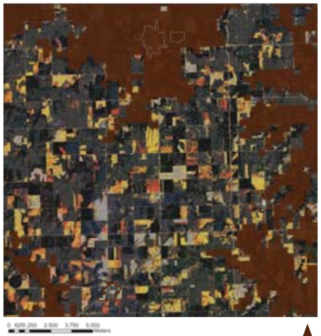
A separate wind site analysis diagram was necessary because the site analysis process is much more detailed than the resource application diagram suggests. This process joins with the resource application from f.21 at the NREL wind class steps.

f.25 **Wind Resource Site Analysis Process**


cropland
.17
industrial
.14
transportation, communications, & utilities
.12
pasture/CRP
.12
confined feeding operations
.09
commercial & services
.08
other urban or built-up land
.08
mixed urban or built-up land
.07
residential
.06
deciduous forest land
.06
locations best suited for wind power generation

wind site analysis development

wind class



wind class 3

wind class 4

N

f.26 **Wind Class**
The National Renewable Energy Laboratory (NREL) rates areas with a wind class rating of 3 or higher as suitable for wind resource development. (Source) Because most of Washington County has a rating of 3 or 4, 4 was chosen as the most suitable.

habitat

One of the largest concerns for wind resource development is destruction of critical habitat. This habitat is typically reserved or protected for threatened or endangered species. Most of Washington County is considered habitat for the Greater Prairie Chicken, *Tympanuchus cupido.* (See Appendix) Because much of this area is under cultivation, it is not ideal habitat. Ideal habitats of pasture and CRP land will later be eliminated in the Land Use/Land Cover suitability matrix.

suitability

The process for determining the weighting of site suitability factors for wind site analysis was derived from *Smart Land Use Analysis: the LUCIS Model*. (Carr, 2007) Qualities were determined to have the largest impact on the viability of resource development. These qualities were placed into a matrix (f.?) to evaluate and compare each characteristic.

1) Qualities from the vertical axis were compared with qualities on the horizontal axis based on a scale from 1 to 9.

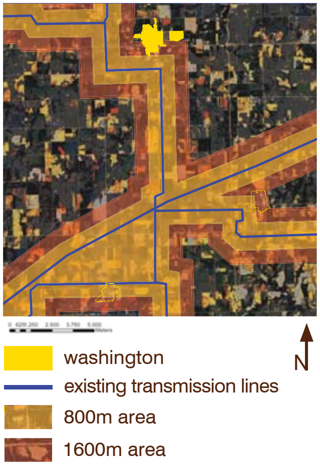
t.4 **Wind Suitability Matrix**

area available for develop
access
proximity to areas where noise may be a
proximity to power net

2) The total suitability rating number came from the sum of each comparison and this number was used as a percentage of the total possible.

	area available for development	accessibility	proximity to areas where noise may be a factor	proximity to power networks	LULC	total suitability rating	weight	weighted percentage
oment		9	9	4	5	27	0.27	27
sibility	1		5	1	1	8	0.08	8
factor	1	5		1	2	9	0.09	9
works	6	9	9		7	31	0.31	31
LULC	5	9	8	3		25	0.25	25
					total	100	1	100

transmission



f.27 Transmission
Transmission line construction is extremely costly at an estimated $1 million per mile; therefore proximity to existing power transmission networks is a critical consideration for wind resource development. An area of 800 meters on either side of existing transmission lines is most suitable while an extended area of 1600 meters (1 mile) on either side is suitable.

LULC

A matrix was again used to determine land use/land cover (LULC) suitability. The following results found cropland and pasture/CRP to be the most suitable.

t.5 LULC Suitability Results

residential	.06
commercial/services	.08
industrial	.14
transportation, communications, and utilities	.12
mixed urban/ built-up land	.07
other urban/built up land	.08
cropland	.17
confined feeding operation	.09
pasture/CRP	.12
deciduous forest land	.06

f.28.d *Most Suitable Areas*

cropland

f.28.c *Suitable Areas*

pasture/CRP

cropland

f.28.b *Wind Class Area*

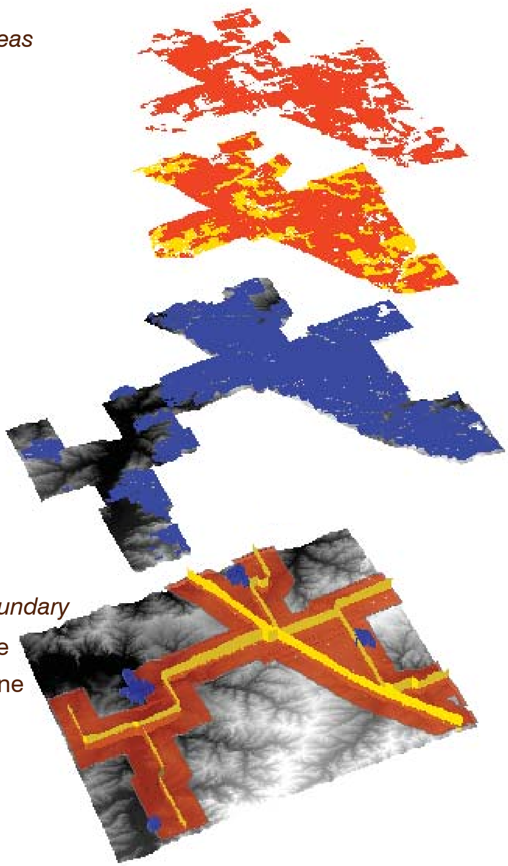
wind class 4

f.28.a *Transmission Boundary*

transmission line

transmission zone

city



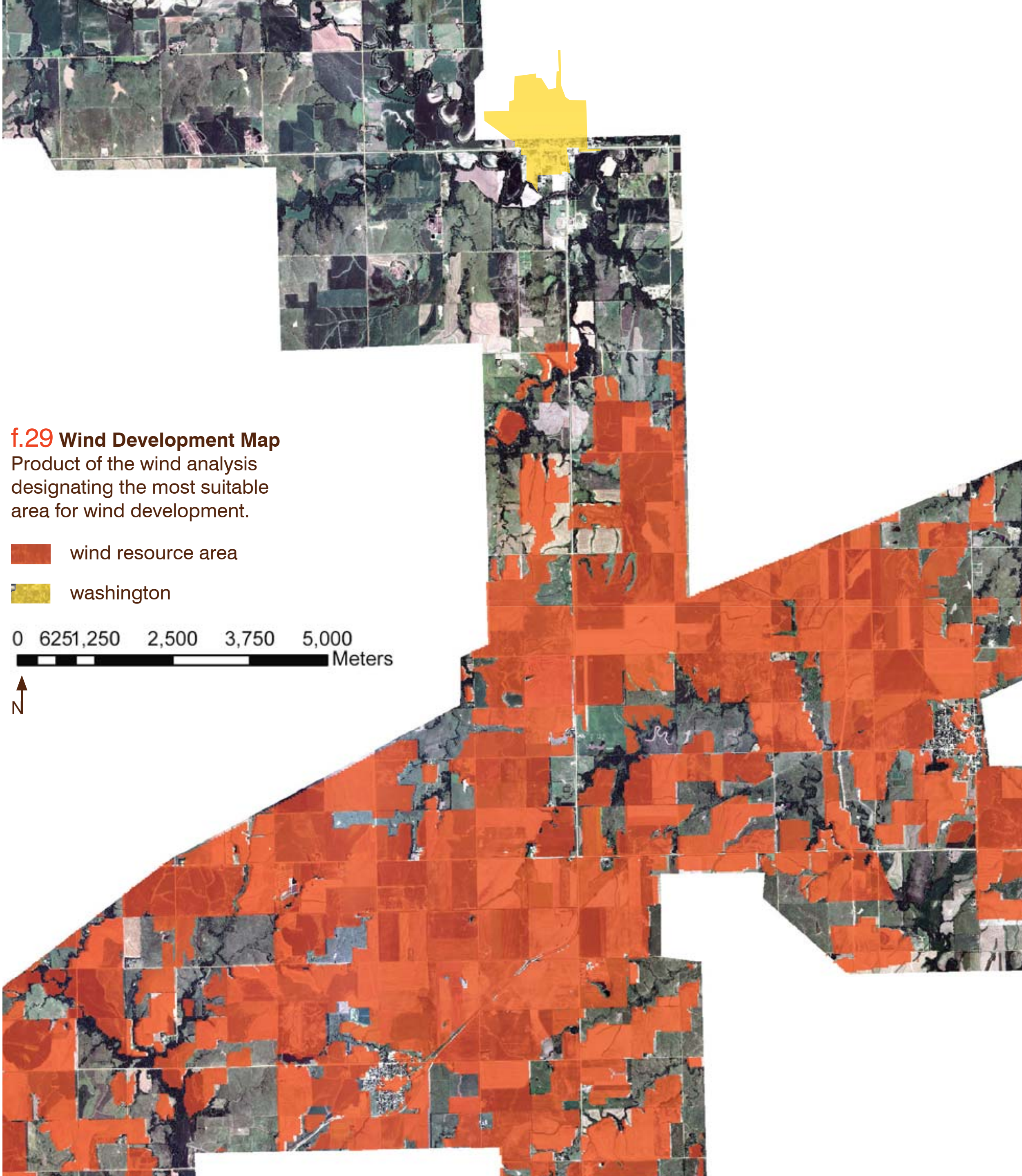
f.28 **Wind Development Area**
Layered diagram of the wind resource analysis process.

a. *Transmission Zone*
Transmission lines were added to a digital elevation model (DEM) of an area of Washington County including Washington, Greenleaf, Linn, and Morrowville. A 1600 meter zone on either side of the transmission lines was used to determine proximity to lines.

b. *Wind Class Area*
Areas within the transmission boundary with a wind class of 4 were extracted.

c. *Suitable Areas*
Cropland and pasture/CRP within the wind class area were determined suitable because there were no areas with industrial or transportation/communications/and utility use except along existing transmission lines.

d. *Most Suitable Area*
The most suitable land use was cropland therefore cropland was extracted from the overall land use suitability.



f.29 **Wind Development Map**
Product of the wind analysis designating the most suitable area for wind development.

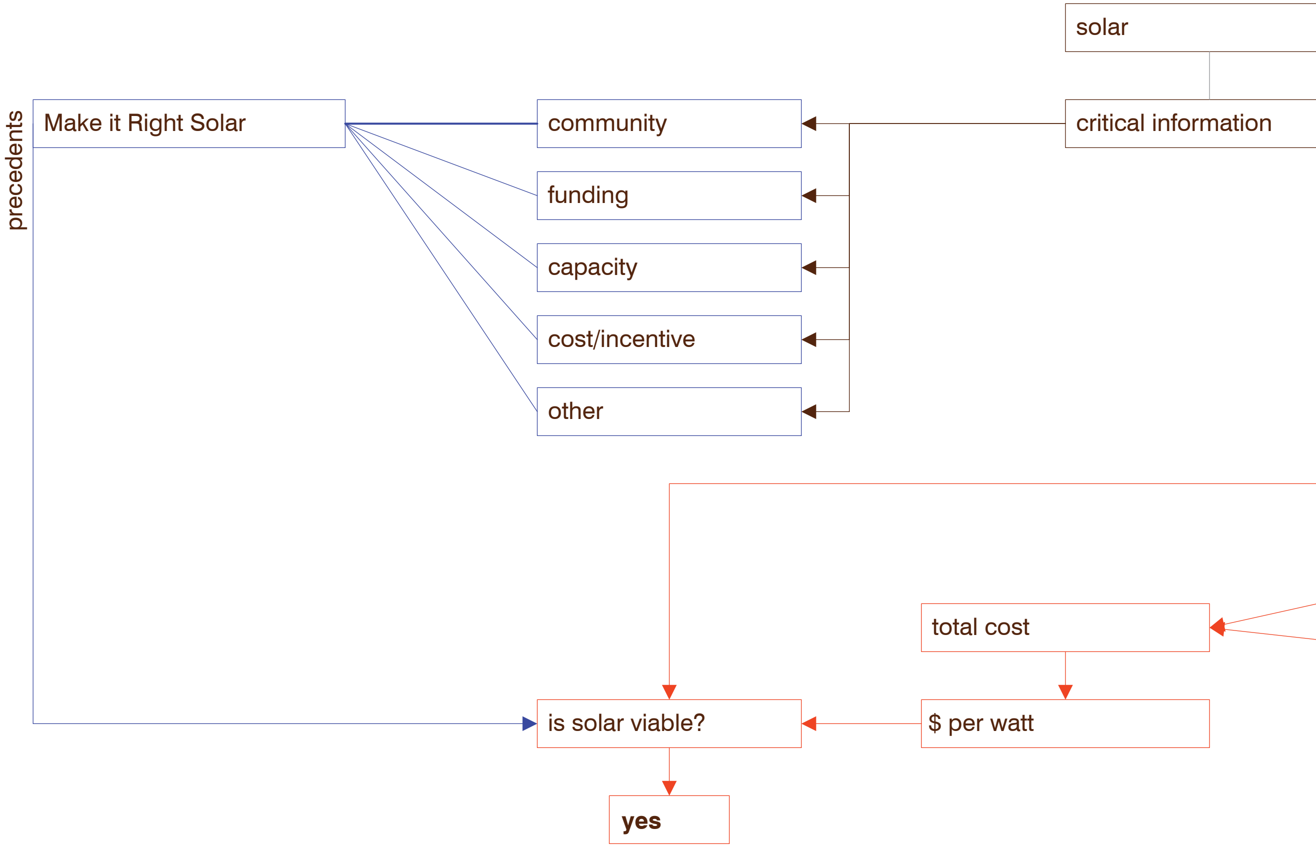
solar power

"The average annual solar energy falling on one square mile in central Kansas is about four billion kWh or fifteen trillion Btu, the equivalent of two and one-half million barrels of oil. About 70 square miles receive solar energy equal to Kansas's annual energy consumption."
--Kansas Corporation Commission, 2005

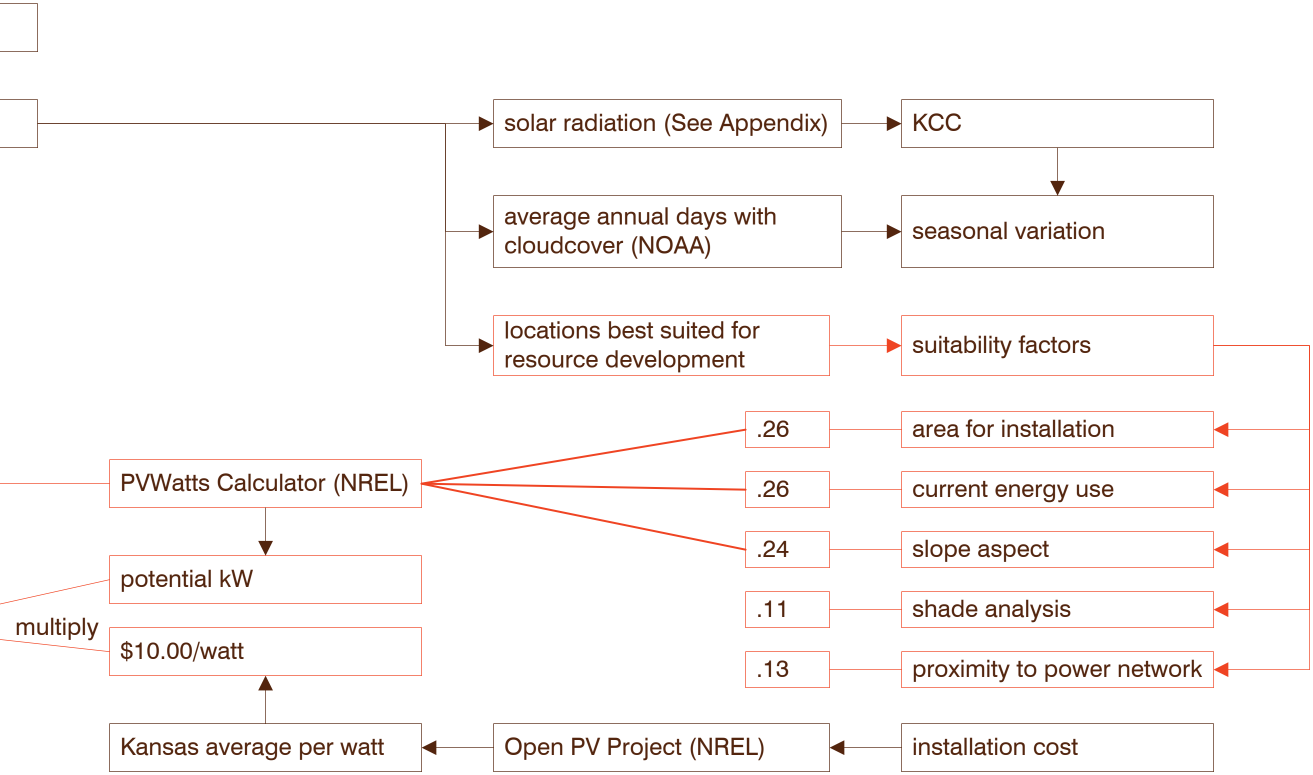
Washington County is approximately 900 square miles.

left
f.30 **Washington County Sunset**
(Image by author)

solar resource application



f.31 **Solar Resource Analysis Process**
The color of the boxes and lines corresponds to the phases of the project: research, synthesize, apply, and convey.


solar radiation (See Appendix)
KCC
average annual days with cloudcover (NOAA)
seasonal variation
locations best suited for resource development
suitability factors
.26
area for installation
PVWatts Calculator (NREL)
.26
current energy use
.24
slope aspect
potential kW
.11
shade analysis
multiply
$10.00/watt
.13
proximity to power network
Kansas average per watt
Open PV Project (NREL)
installation cost

precedents

make it right foundation

f.32 **Solar Panels**
(Courtesy of Make It Right Foundation)

The Make It Right Foundation (MIR) was created by Brad Pitt in response to the lack of rebuilding initiative in New Orleans' Lower Ninth Ward following Hurricane Katrina. The mission of the foundation is "to be a catalyst for redevelopment of the Lower Ninth Ward, by building a neighborhood comprised of safe and healthy homes that are inspired by Cradle to Cradle thinking, with an emphasis on a high quality of design while preserving the spirit of the community's culture."

This is done through the construction of highly sustainable homes. Two of these sustainable qualities pertaining to energy are that the homes are tightly sealed to prevent heating/cooling leakage and are furnished with Energy Star rated appliances. These qualities greatly reduce the need for electrical energy within the home and the associated costs.

f.33 **Solar Panels on an MIR Residence**
(Courtesy of Make It Right Foundation)

Each MIR home is equipped with a photovoltaic system that generates between 2.7 and 3.0 kW of energy (Make It Right Foundation 2009). Because the homes are efficiently designed and constructed, the systems often over-generate and excess power is put into the city's power grid. This excess power counts as credits toward the homeowner and greatly reduces, if not occasionally eliminates, monthly energy bills.

Entergy, New Orleans' energy company, was initially reluctant to allow homeowners to put energy back into the grid. The energy generated by the home solar systems is now used as a credit toward energy bills. Entergy was not looking to add sustainable resources, however, Westar Energy is looking to add 500 mW of additional renewable energy to their generation portfolio (Westar 2009). This may provide an opportunity for Westar and small communities to work together.

solar resource application development

The following is the actual development of the solar resource application diagram from page 58 (f.31).

suitability

Sites were selected based upon the results of a suitability matrix (f.34) in which roof area, current energy use, and slope aspect were deemed the most important characteristics. The process for determining the weighting of suitability factors for was derived from *Smart Land Use Analysis: the LUCIS Model*. (Carr, 2007) Qualities were determined to have the largest impact on the viability of resource development. These qualities were placed into a matrix to evaluate and compare each characteristic.

1) Qualities from the vertical axis were compared with qualities on the horizontal axis based on a scale from 1 to 9.

2) The total suitability rating number came from the sum of each comparison and this number was used as a percentage of the total possible.

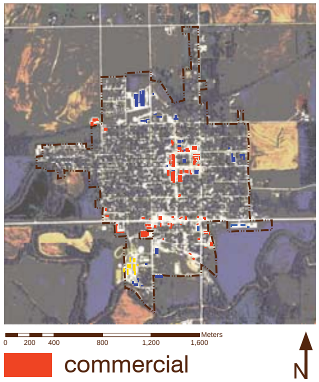
t.6 **Solar Suitability Matrix**

	slope aspect	shade	proximity to power network	area for installation	current energy use	total suitability rating	weight	weighted percentage
slope aspect		9	8	5	2	24	0.24	24
shade	1		3	2	5	11	0.11	11
proximity to power network	2	7		2	2	13	0.13	13
area for installation	5	8	8		5	26	0.26	26
current energy use	8	5	8	5		26	0.26	26
					total	100	1	100

building

city boundary

f.34 Building Roofs
Buildings with the largest roof area were selected from an aerial image and inventory. The approximate roof area footprints of these buildings were placed into GIS.



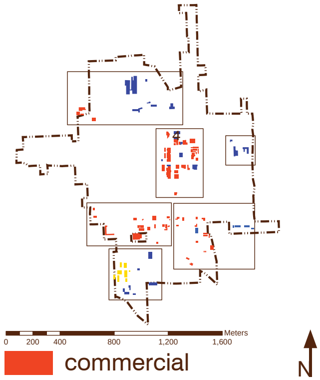
commercial

government/service

other

city boundary

f.35 Building Uses
Current energy use based on data from the City of Washington showed buildings with the highest energy use included schools; retail and commercial; city, county, and state government; and service related. Thus, the roof areas were categorized according to building use. Smaller buildings associated with these uses were added to the roof area diagram.



commercial

government/service

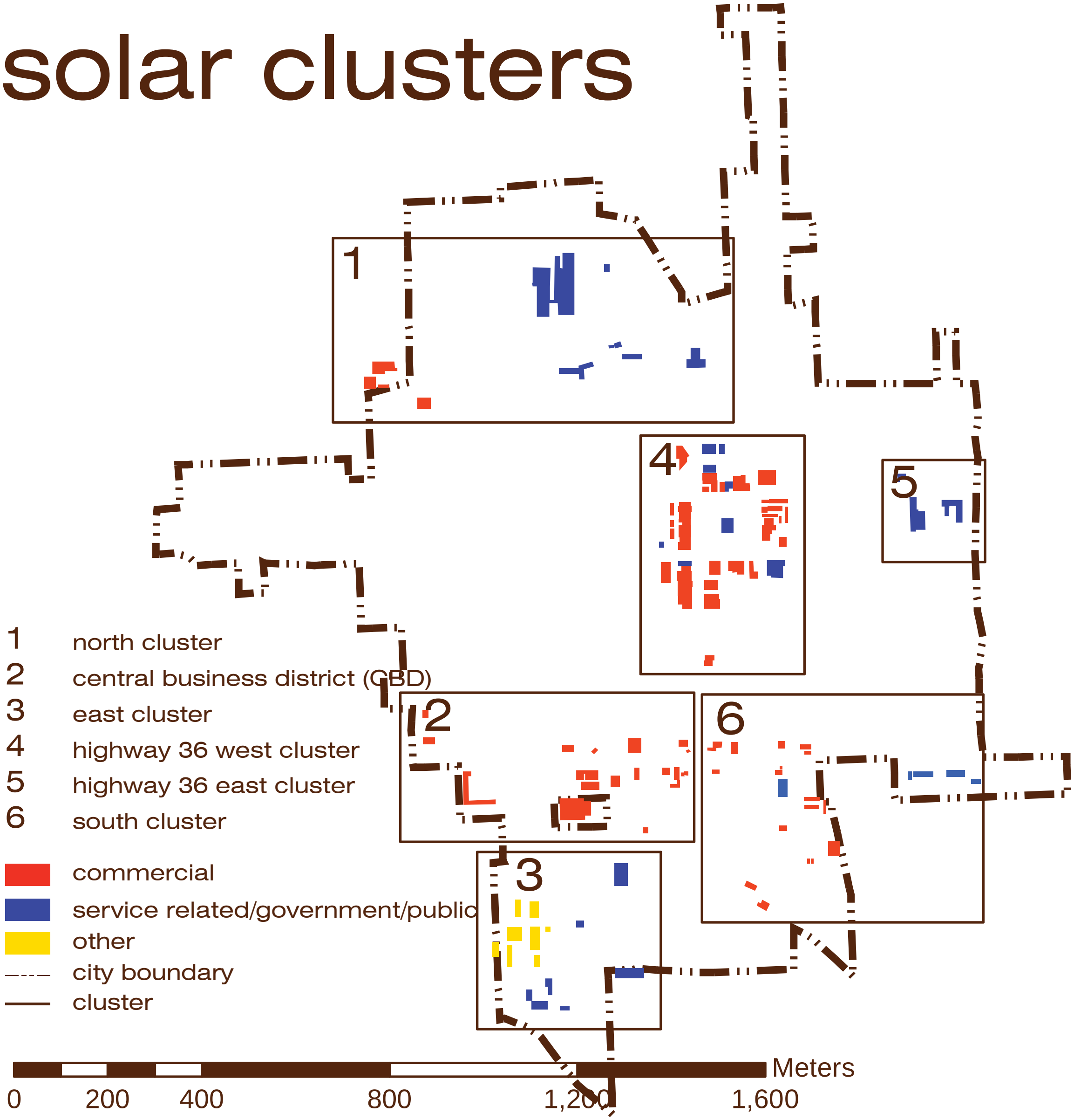
other

city boundary

cluster

f.36 Clusters
Upon building selection, the majority of usable buildings fell into six visible clusters. These clusters were used for calculating resource potential.

solar clusters



f.37 **Solar Clusters**

1 The total building footprints for the four building uses within each cluster were calculated and divided in half to account for roof area that may not be suitable for solar implementation due to structure, slope, shade, or other conflicts. This number was converted to a DC rating by dividing the roof area by 8.75, the area needed to generate 1 kW of power.

2 To calculate AC energy in kWh, this number was then inserted into the National Renewable Energy Laboratory's (NREL) PVWATTs calculator, an online resource for calculating solar potential using a set of general constants for the state of Kansas and the area for solar cell installation. (See Appendix)

3 The results of these calculations were placed back into a spreadsheet to calculate total generation for each building use within a cluster as well as the cluster totals.

total potential: 5,319,705 kWh (5.32×10^6) = $1,020,391.94 saved annually

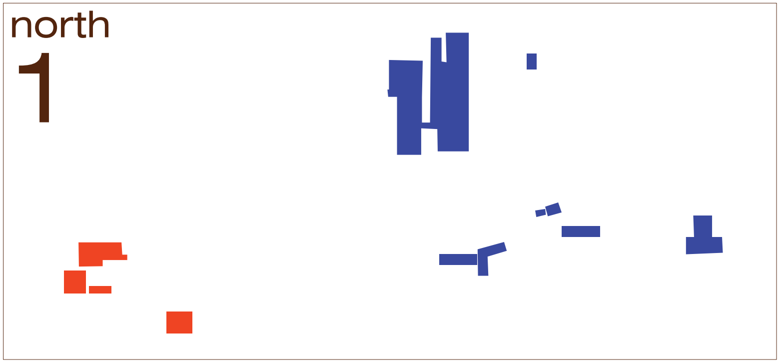
payback: 38 years

t.7 Cluster Calculations

building type		total roof area (m2)	usable roof area (sq. m)	DC rating	AC energy (kWh)	energy savings ($)
north						
commercial		2,622.42	1,311.21	150	206,778	19,122.83
USD 108		11,637.41	5,818.71	665	916,715	84,777.80
	total	14,259.83	7,129.92	815	1,123,493	103,900.63
highway 36 west						
commercial		9,886.84	4,943.42	565	778,863	72,029.25
	total	9,886.84	4,943.42	565	778,863	72,029.25
south						
government		4,488.17	2,244.09	256	352,901	32,636.28
other		4,397.17	2,198.58	251	346,008	31,998.82
	total	8,885.34	4,442.67	508	698,909	64,635.10
CBD						
commercial		17,851.15	8,925.57	1,020	1,406,089	130,035.11
government		4,150.11	2,075.05	237	326,709	30,214.05
	total	22,001.26	11,000.63	1,257	1,732,798	160,249.16
east						
medical		3,253.09	1,626.54	186	256,405	23,712.33
	total	3,253.09	1,626.54	186	256,405	23,712.33
highway 36 east						
commercial		5,590.76	2,795.38	319	439,748	40,667.90
government		2,130.33	1,065.17	122	168,179	15,553.19
other		1,532.12	766.06	88	121,310	11,218.75
	total	9,253.20	4,626.60	529	729,237	67,439.84

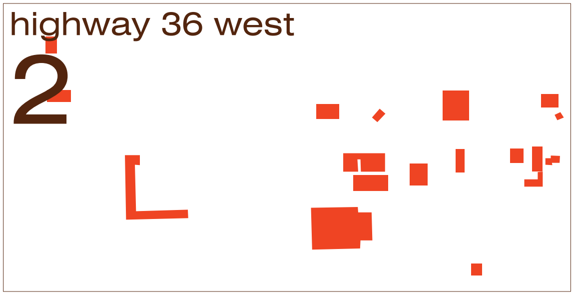
following spread
f.38 **Cluster Calculation Diagram**

5.32 x 10^6 kWh



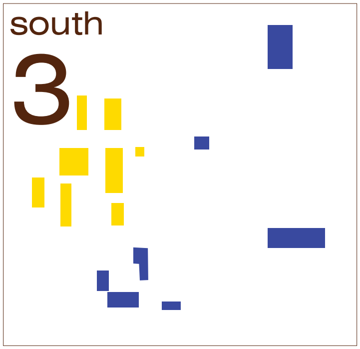
1,311 sq m
5,818 sq m

1,123,493 kWh



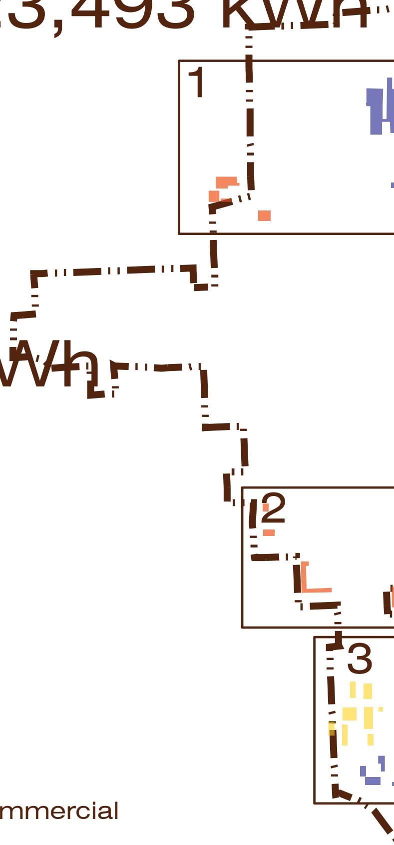
4,943 sq m

778,863 kWh

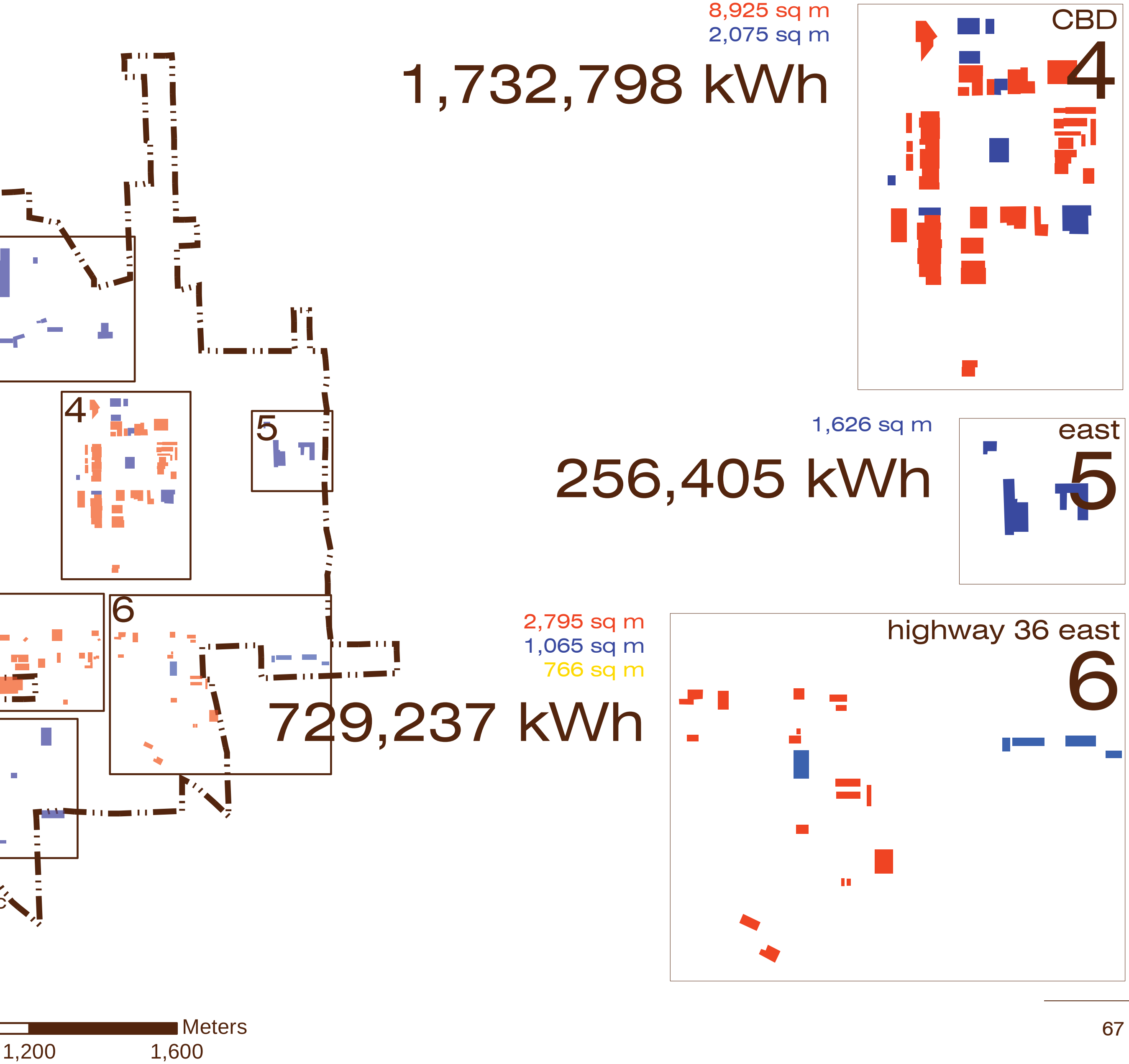


2,244 sq m
2,198 sq m

698,909 kWh



- commercial
- service related/government/public
- other
- city boundary
- cluster


8,925 sq m
2,075 sq m
1,732,798 kWh
CBD
4
1,626 sq m
256,405 kWh
east
5
2,795 sq m
1,065 sq m
766 sq m
729,237 kWh
highway 36 east
6
4
5
6
Meters
1,200
1,600

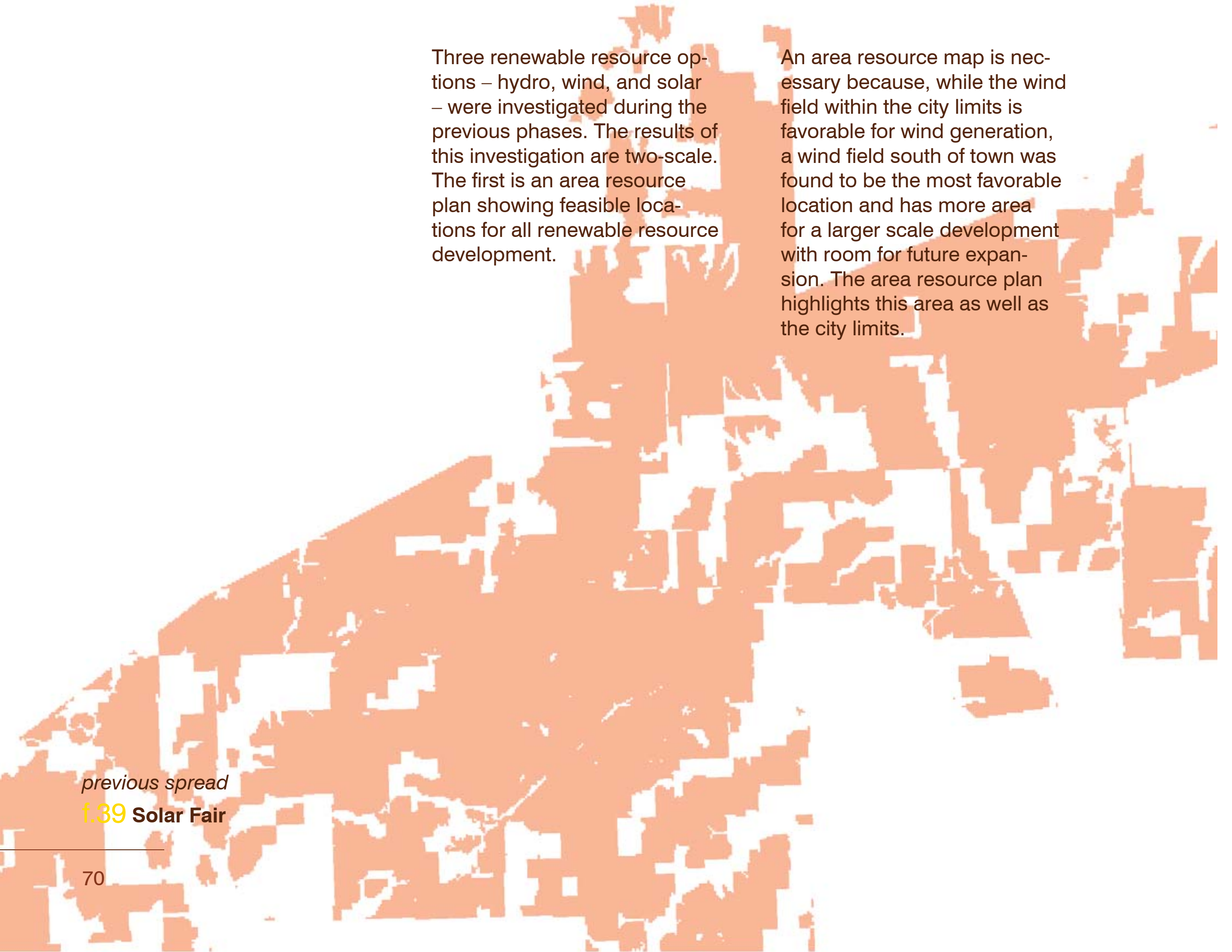
convey

...project application results onto local scene...

two scales

Three renewable resource options – hydro, wind, and solar – were investigated during the previous phases. The results of this investigation are two-scale. The first is an area resource plan showing feasible locations for all renewable resource development.

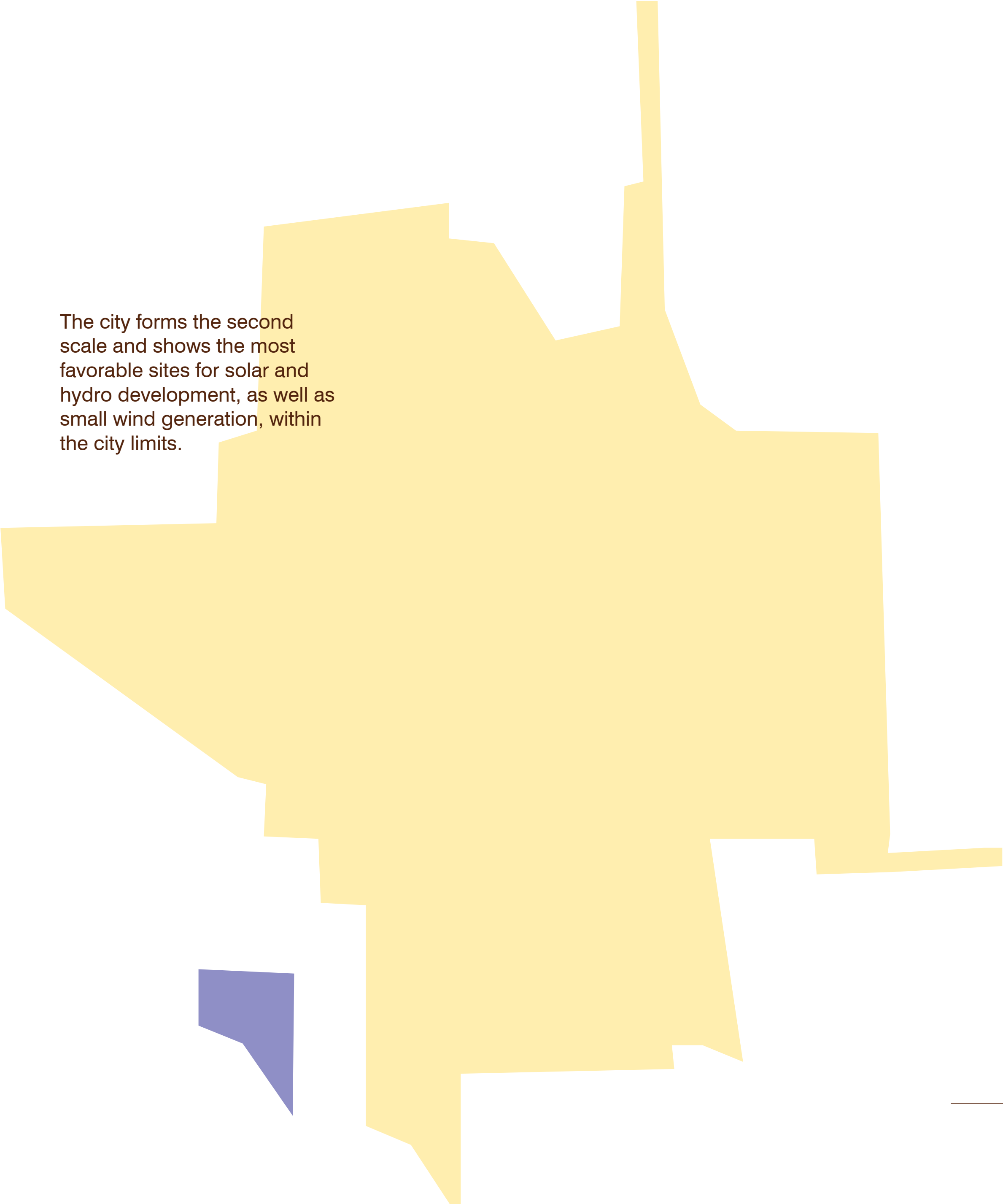
An area resource map is necessary because, while the wind field within the city limits is favorable for wind generation, a wind field south of town was found to be the most favorable location and has more area for a larger scale development with room for future expansion. The area resource plan highlights this area as well as the city limits.



previous spread

f.39 **Solar Fair**

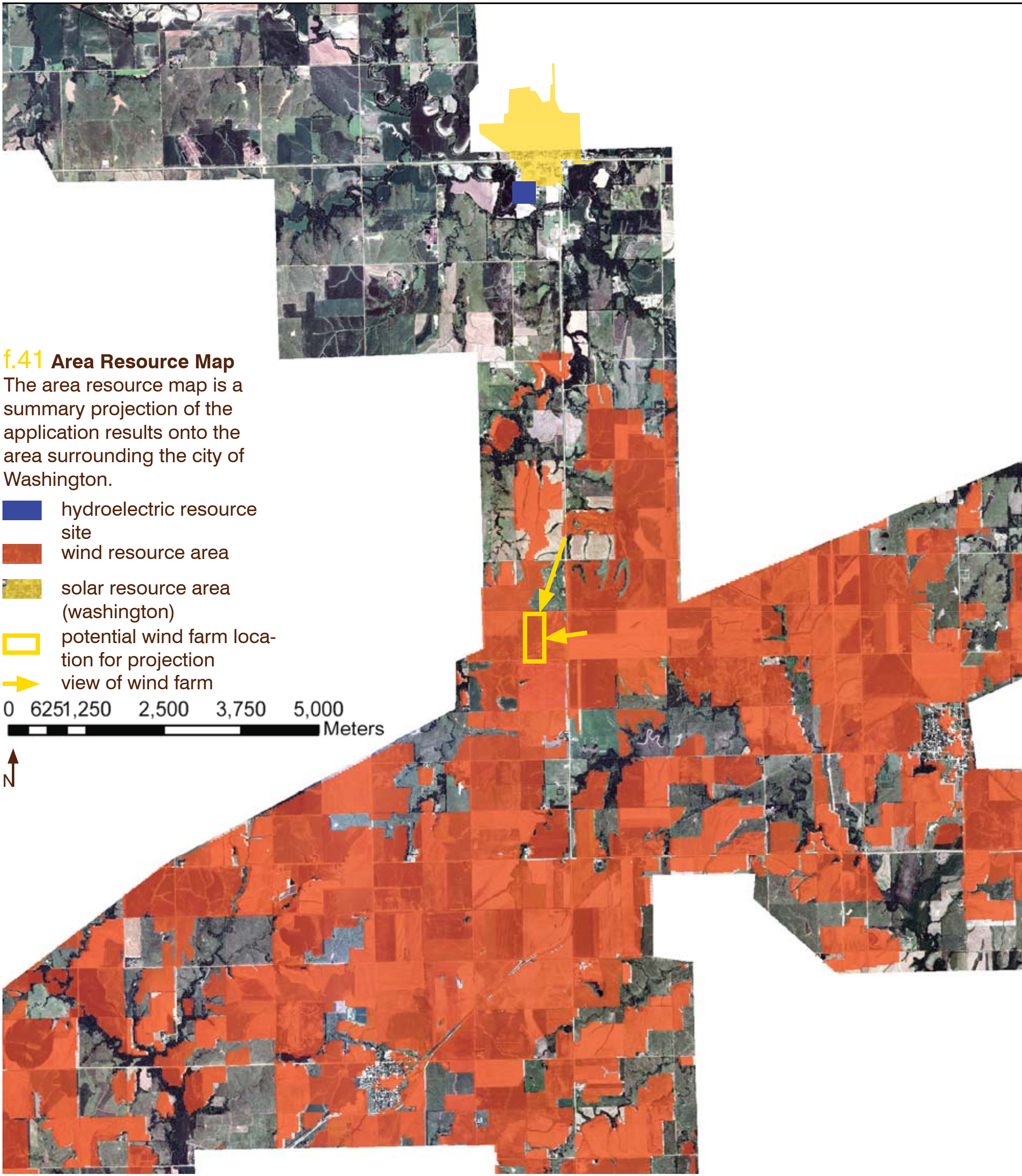
The city forms the second scale and shows the most favorable sites for solar and hydro development, as well as small wind generation, within the city limits.



area resources

One of the largest issues facing wind farm development is concern for the intrusion of wind turbines onto the existing landscape. These images project the implementation of wind farms onto the existing visual landscape along the KS Highway 15 corridor between Washington and Linn.

f.40 **Projection of Wind Farm South of Washington**
Three turbines were used for the research calculations. Eight turbines are shown in this image to assess the visual impact of a larger wind farm. The approximate farm location is on the map on the following page.



f.41 **Area Resource Map**
The area resource map is a summary projection of the application results onto the area surrounding the city of Washington.

f.42 Wind Farm
Projection of wind farm driving south on K15. Calculations for the research account for 3 wind turbines that would meet Washington's energy load. Eight turbines are shown here to assess the visual impact of a potentially larger wind farm.

city resources

These images depict the implementation of hydro-electric and solar power generation onto the existing visual landscape within the city of Washington.

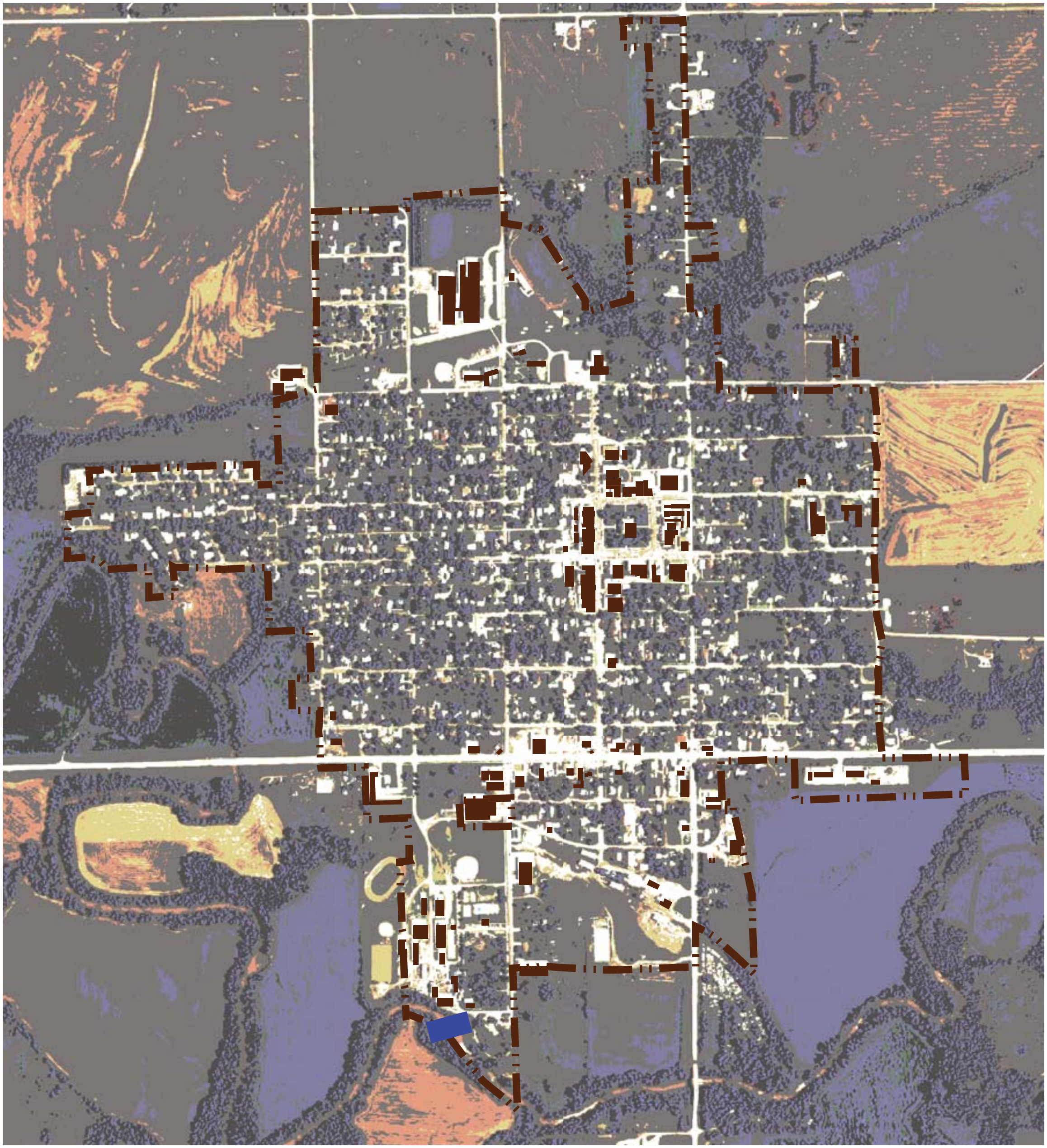
opposite page

f.43 **City Resource Map**
The city resource map is a summary projection of the solar and hydro application results onto the city of Washington.

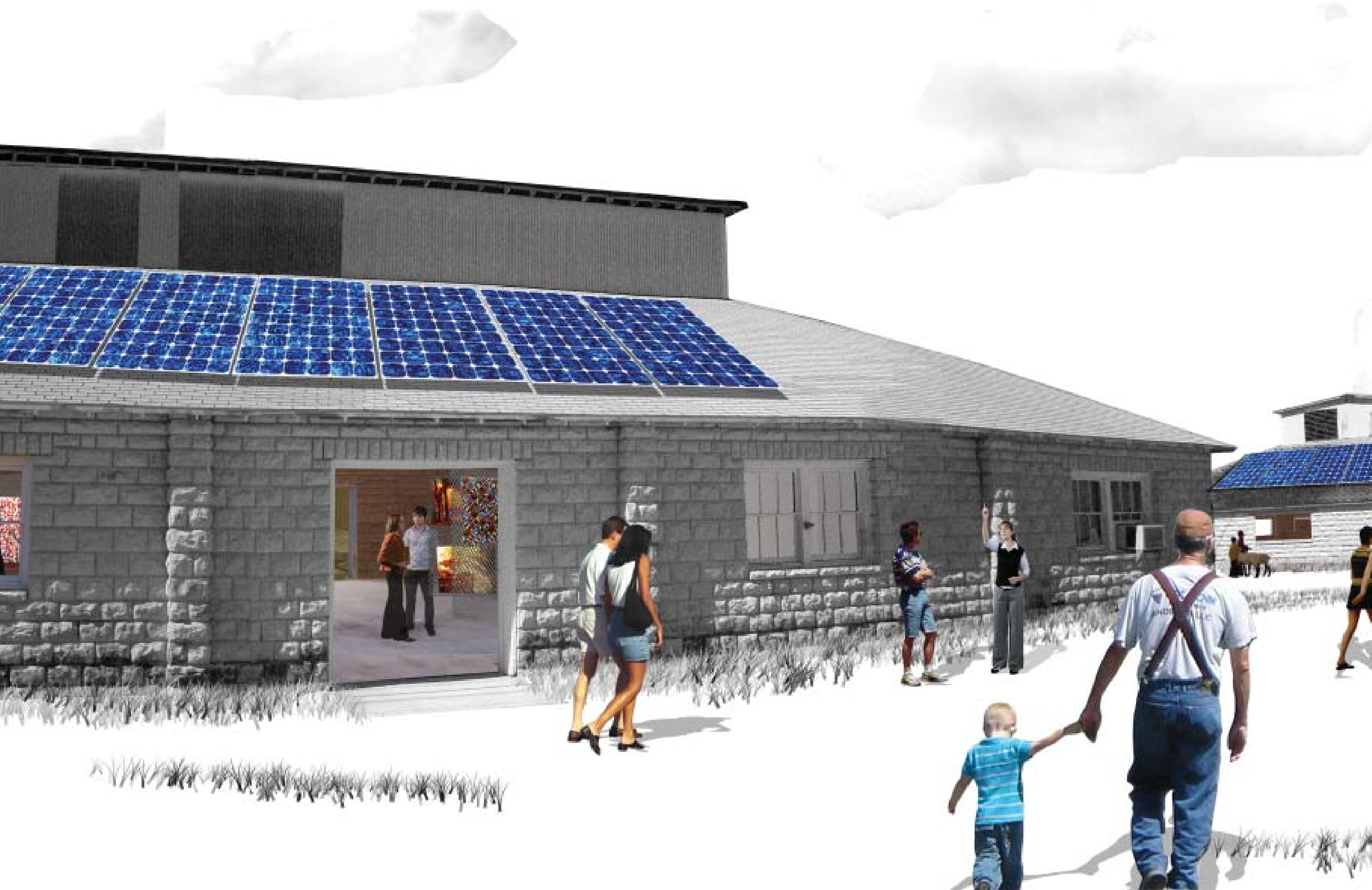
dam site for hydroelectric

solar resource site

city boundary



f.44 **Solar Fair**
Projection of solar energy system onto the Washington County Fair Scene. System interactions are delineated with color.

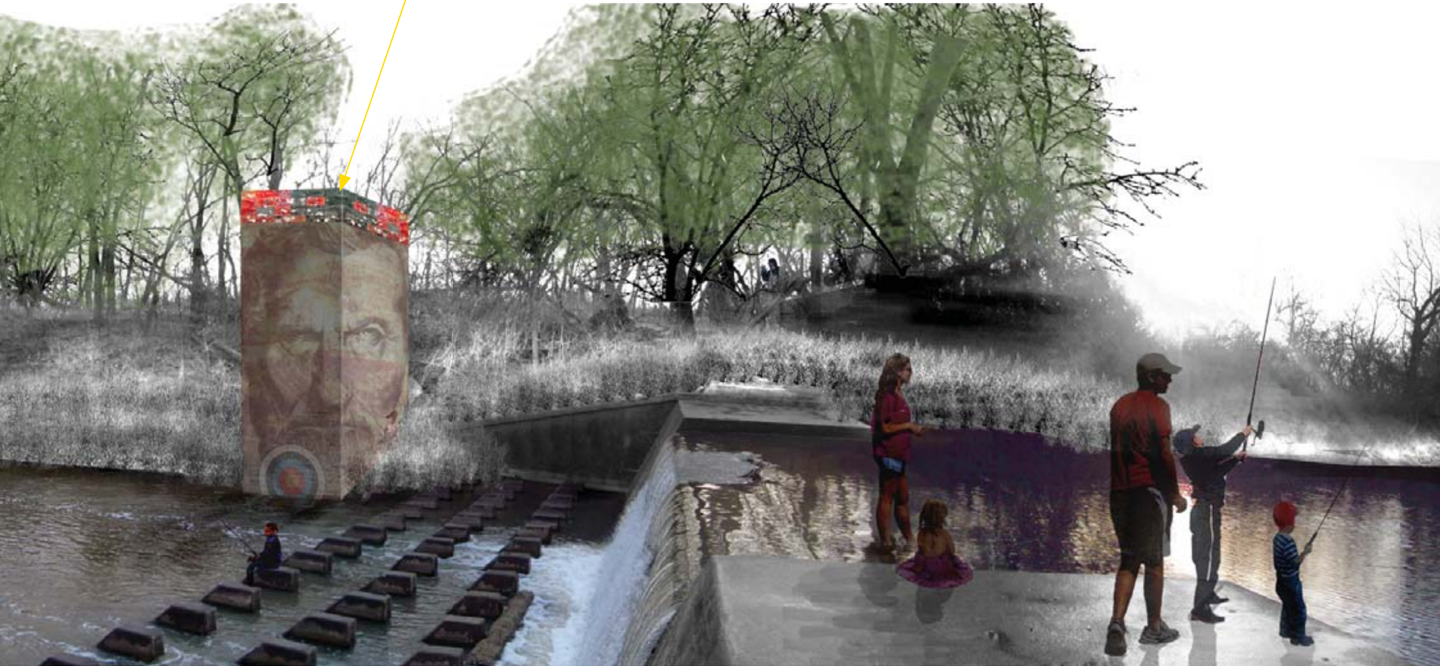


f.45 **Washington City Dam**
Projection of hydroelectric infrastructure onto existing dam scene

site improvements allow for more accessible interaction with the site

tower serving as a turbine house. *Many different options exist for micro-hydroelectric turbine placement and construction. The tower was used because it is the most visible and the most intrusive onto the existing landscape. This intrusion reveals the presence of the hydropower system.*

This type of structure also has the potential to serve as a canvas for Washinton's culture. 'Old Man River' is shown in this rendering as a tribute to the stream and a target pays tribute to the fact that many children learn to skip rocks in this location. It could also serve as a venue/gallery for local artists.



conclusion

Washington's highest peak load from 2002 to August 2010 was 4500 kW (4.5mW) in 2006 (Leck 2010).

The Washington dam could support micro-hydroelectric power generation. Using the Watertown Dam from Sasaki as an example, the Washington dam could provide 10kW of power as a base load with a potential for more based on specific engineering of turbine size and type.

At least three 1.25 mW wind turbines could provide the leftover load needed to support the community.

The potential exists for over 1500 kW of solar power to be installed on buildings designated with commercial, public, government, and service related uses. This implementation would cut energy purchases by almost one third of current purchases. These calculations do not include additional potential residential solar installations.

.01mW + 3.75mW + 1.5mW

hydro + wind + solar

A rural community has the resources necessary to achieve energy independence.

5.26 mW
total power

cost

The following provides base data and implementation cost based on existing data and previous projects.

The Watertown Dam serves as the cost precedent for hydroelectric generation. The most expensive option for a 10kW system was estimated at $168,500 (Sasaki 2005). Hydroelectric is the second most expensive at almost $17,000 per kW or $17 per watt. This number could drop depending on the turbine size.

Washington has the wind resources for a small-scale or utility-scale wind farm. The Greensburg Wind Farm provides the cost precedent for this resource. Thirty percent of the total Greensburg project cost of $23 million for 10 turbines was used to calculate the cost for 3 turbines in Washington (US Department of Energy 2011). This came out to be just under $7 million. Wind was also the least expensive with a startup of $1870 per kW.

The startup cost of 1500kW of solar at the existing Kansas state average of $10 per watt ($1000/kW) would equate to approximately $38 million without loans or deductions (NREL 2011). Solar is the most expensive renewable energy option at over $25,000 per kW. As the most expensive option, it is not the most feasible. Smaller experimentational projects on local businesses and residences may be a more viable option.

funding

With declining population and infrastructure concerns, Washington could also face a lack of local funding. However, funding and incentives are available through many government agencys including the USDA, Environmental Protection Agency, and Internal Revenue Service. Because Westar Energy is looking to add more renewable energy sources to their portfolio, additional support and funding may be available.

The Database of State Incentives for Renewables and Efficiency (DSIRE) from the US Department of Energy provides information on state and federal initiatives for renewable energy and building efficiency funding. One of the most applicable sources of funding for rural Kansas is the Rural Energy for America Program (REAP) which was created to assist farmers, ranchers and rural small businesses. "All agricultural producers, including farmers and ranchers, who gain 50% or more of their gross income from the agricultural operations are eligible... Rural electric cooperatives may also be eligible to apply" (USDA 2011).

Other funding opportunities area available through various organizations such as NativeEnergy in the Greensburg precedent. Other incentives include tax deductions and credits at both the state and local levels. Table ? provides the basic initial cost for solar, hydro, and wind projects with REAP loans of 60 - 85% of the project cost, the REAP grant of $500,000, and a tax credit of 30% of the startup cost.

t.8 **Basic Project Economic Analysis**

	cost w/out deductions	**REAP loan**	**REAP grant**	**tax credits**	**total w/ deductions**
solar	38,594,035.00	23,156,421.00	500,000.00	11,578,210.50	3,359,403.50
hydro	168,500.00	134,800.00	500,000.00	50,550.00	-516,850.00
wind	6,990,000.00	4,893,000.00	500,000.00	2,097,000.00	-500,000.00
grand totals	*45,752,535.00*	*27,451,521.00*	*500,000.00*	*13,725,760.50*	*4,075,253.50*

total cost without deductions: $45,752,535
total cost with deductions: $4,075,253

community

The final concern facing renewable resource development in rural communities is the community itself. This is a major concern because rural communities differ from urban communities in numerous ways. While renewable energy development impacts everyone on the grid, the most impact is in the rural backyards where the renewable resources are actually developed. In Kansas, this means the fields and pastures that form the rural visual landscape.

Community engagement will play a key role in investing in these resources. Engagement must include education on the topics of wind, solar, and hydroelectric. Community input on issues such as landscape intrusions from wind turbines would provide valuable insight for the planning of these resources into the future.

The largest obstacles facing renewable energy system implementation in rural areas are:

1. Funding
2. Transmission & Sellback
3. Community

reflection

This project was a journey. What began as a dam retrofit became energy independence for an entire community. The transition to complete use of renewable resources from fossil fuels which we are currently reliant upon has interested me since Kathleen Sebelius refused to sign a piece of legislation enabling an addition to the coal-operated power plant in Holcomb, KS. While in New Orleans, I saw the effects of the Deepwater Horizon oil spill firsthand. When I began getting headaches from the smell of oil every day, I was fed up.

As architects, we tend to leave energy infrastructure to the engineers. I came to realize that we are just as responsible. Much of the controversy surrounding renewable energy stems from societal concern. Solving societal and environmental problems is in our job description so I had to ask myself, ‘what if we were to take a stand for renewable energy?’

Entering into the project I knew very little about anything that goes into renewable energy. Throughout the process I gained the understanding I set out to establish, a basic understanding of renewable energy technology.

While I was able to provide basic cost estimates based on previous projects, I would have liked to have gone into more detail with the economic aspect of renewable resource development. That, however, is an entirely different research project in itself. I also would have liked to involve community members in the process to receive their input. This too presents a project in itself.

While the project took a different turn than I had originally anticipated, I am proud of the result. I set out to develop a tool for communities to use in consideration of renewable resources and I believe the project serves as a good starting point.

moving forward

Using research from my hometown of Washington, I hope to move forward in continuing research into community energy resource development as well as education and meetings for rural community members about the topic. Continuing research would involve travel to and study of successful community energy projects around the United States and Europe. Funding would also be put towards the creation of materials for community meetings and charrettes. These meetings are critical to preserving the culture and pride that exists in rural communities while advancing into new areas of technology and infrastructure.

appendix

washington city peak loads

	2002	2003	2004	2005	2006	2007	2008	2009
January	1971	2179	2309	2415	2318	2568	2672	2129
February	1988	2161	2205	2414	2359	2538	2612	2064
March	2036	2210	2047	2260	2226	2372	2484	2106
April	2307	1991	1960	2172	2336	2350	2372	1821
May	3000	2499	2543	2776	3047	2923	2435	2027
June	3600	3398	3070	3861	3443	3316	3481	3657
July	4300	3900	3817	4400	4500	3970	3910	3451
August	3614	3848	3390	3900	4300	4309	3572	3100
September	3502	2585	3366	3400	2530	3503	2794	2275
October	2816	2170	2219	3018	2707	2708	2627	1929
November	2126	2225	2364	2369	2516	2358	2304	1900
December	2105	2224	2464	2565	2534	2210	2175	2129
Annual Max	*4300*	*3900*	*3817*	*4400*	*4500*	*4309*	*3910*	*3657*

(Leck 2010)

mill creek discharges

News updated April, 2011

USGS Surface-Water Monthly Statistics for Kansas

The statistics generated from this site are based on approved daily-mean data and may not match those published by the USGS in official publications. The user is responsible for assessment and use of statistics from this site. For more details on why the statistics may not match, click here.

USGS 06884200 MILL C AT WASHINGTON, KS

Available data for this site Time-series: Monthly statistics GO

Washington County, Kansas
Hydrologic Unit Code 10270207
Latitude 39°48'49", Longitude 97°02'14" NAD27
Drainage area 344 square miles
Contributing drainage area 344 square miles
Gage datum 1,261.56 feet above NGVD29

Output formats
HTML table of all data
Tab-separated data
Reselect output format

YEAR	00060, Discharge, cubic feet per second, Monthly mean in cfs (Calculation Period: 1959-10-01 -> 2010-09-30) Calculation period restricted by USGS staff due to special conditions at/near site											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1959										166.9	9.48	7.78
1960	44.7	164.1	616.4	182.4	141.5	217.9	48.6	17.5	6.25	3.84	5.65	6.33
1961	6.12	10.5	39.9	69.3	461.9	239.6	15.8	3.20	594.2	453.0	209.7	44.5
1962	367.1	164.4	261.7	57.3	118.0	181.1	14.3	24.7	29.8	48.0	9.74	11.0
1963	13.0	20.4	66.6	70.0	19.4	69.3	5.59	7.16	140.5	11.6	6.21	5.04
1964	6.76	7.98	8.81	31.5	9.99	37.5	0.326	2.37	25.6	1.43	2.87	2.40
1965	2.47	115.2	227.3	29.2	68.5	167.0	107.2	11.0	132.5	10.6	5.03	7.52
1966	6.18	33.4	8.48	6.23	3.54	21.4	8.15	8.79	71.8	1.11	1.50	1.39
1967	1.06	2.23	5.81	43.5	8.78	803.7	59.2	16.8	101.6	33.0	9.16	8.94
1968	9.42	10.7	9.46	47.4	19.7	40.7	26.9	343.6	77.9	160.2	20.9	16.5
1969	174.0	504.6	197.7	79.7	247.3	84.3	102.1	42.4	10.3	6.15	11.0	10.1
1970	8.44	12.0	16.2	24.4	27.8	265.9	4.08	5.43	43.6	54.0	18.3	6.87
1971	8.04	231.0	198.9	30.3	701.7	203.3	68.9	5.21	2.79	6.34	79.7	16.5
1972	10.2	13.1	12.1	22.3	236.4	18.1	65.1	285.3	133.9	18.5	359.2	130.2

(USGS 2011)

1973	247.9	155.8	816.8	509.0	357.2	68.9	205.5	38.5	863.6	838.8	128.9	151.3
1974	297.0	122.4	76.5	66.6	100.6	36.8	6.30	6.12	4.15	4.37	7.87	9.27
1975	16.7	52.2	111.5	47.9	56.9	313.5	19.8	5.24	3.89	2.05	8.39	8.69
1976	9.55	14.5	58.7	215.9	51.5	17.2	36.4	2.29	14.4	3.12	3.52	3.45
1977	5.39	10.2	14.5	9.20	267.9	74.7	6.32	282.2	90.6	26.5	58.3	25.3
1978	16.0	46.9	646.6	150.6	496.2	82.1	83.0	55.8	159.0	11.0	21.2	17.0
1979	12.7	192.6	1,264	110.9	85.4	120.1	130.1	18.6	5.04	24.6	44.6	20.5
1980	20.4	48.7	284.0	253.0	49.7	73.6	5.94	4.17	2.10	7.00	4.46	7.59
1981	6.34	8.45	7.85	7.75	23.4	30.9	203.3	86.8	37.3	9.37	48.8	49.8
1982	11.9	194.3	164.7	54.0	473.7	320.1	178.9	22.7	16.5	14.0	15.3	23.1
1983	39.5	164.8	113.3	182.4	143.4	740.3	36.8	7.67	12.2	14.7	19.0	12.3
1984	122.7	83.7	160.1	615.6	264.0	722.9	79.6	11.8	7.69	11.3	14.3	92.1
1985	30.0	154.5	34.9	43.9	95.1	144.3	55.7	124.4	78.5	187.7	59.0	42.2
1986	25.8	66.2	71.0	121.2	235.2	45.6	272.2	145.3	353.8	445.5	101.4	129.7
1987	71.5	55.2	894.9	725.3	645.9	451.6	76.2	44.3	28.9	20.3	46.5	33.1
1988	29.5	64.5	32.3	38.4	31.1	86.9	75.0	2.23	3.28	2.45	5.05	6.65
1989	7.78	6.05	12.6	8.02	7.88	17.7	102.3	135.1	390.4	8.02	7.70	8.15
1990	12.6	10.7	34.8	21.1	299.4	416.3	39.9	55.3	3.61	4.25	5.44	5.86
1991	5.55	12.1	11.5	128.8	25.3	17.7	1.65	1.15	5.29	5.59	8.90	8.00
1992	6.30	5.56	6.05	24.7	8.92	41.7	694.7	262.7	180.6	212.4	230.7	176.1
1993	51.7	478.6	496.7	304.1	419.7	593.7	2,151	201.2	289.0	71.1	52.9	46.9
1994	39.7	40.6	85.5	57.5	82.5	496.9	215.2	44.7	10.8	11.9	20.5	26.6
1995	29.8	29.2	56.0	46.6	1,161	314.0	98.5	36.2	31.3	14.3	19.1	21.2
1996	23.1	28.6	20.5	21.2	419.0	209.9	43.6	60.7	41.7	17.1	200.6	64.2
1997	54.0	62.5	56.5	94.5	53.9	68.3	9.43	3.58	6.90	10.4	6.46	17.1
1998	26.9	89.1	251.7	420.3	60.7	166.3	104.8	31.6	27.0	53.5	240.8	39.5
1999	44.2	38.5	33.0	256.1	270.8	184.6	41.2	40.1	9.77	6.80	13.8	18.1
2000	19.0	23.2	22.8	19.3	13.0	6.38	78.3	3.59	2.08	3.02	4.69	5.44
2001	5.29	66.1	199.8	82.4	194.8	361.8	114.7	55.2	61.6	20.7	18.9	18.9
2002	20.4	25.0	20.7	24.5	170.1	51.4	4.15	4.44	2.35	4.07	5.27	5.99
2003	7.70	9.37	9.46	11.5	47.8	209.8	19.8	10.2	79.2	5.66	19.3	9.00
2004	7.59	54.0	246.0	33.6	83.7	74.4	38.1	5.05	2.28	2.43	3.90	5.71
2005	6.14	16.1	8.99	86.9	35.2	64.3	77.2	200.8	26.1	8.33	8.28	8.89
2006	8.94	7.74	11.4	31.6	16.8	11.6	13.9	88.1	94.3	5.11	4.88	18.4
2007	48.3	218.5	61.5	122.2	788.5	129.5	17.0	146.5	97.9	356.9	39.9	64.3
2008	115.4	96.8	58.7	376.0	256.5	159.6	139.0	132.9	37.9	208.5	38.4	28.9
2009	25.5	29.6	23.9	187.6	122.4	109.5	19.1	15.2	20.2	41.2	96.4	46.5
2010	151.5	90.5	285.1	259.5	299.9	908.8	374.7	47.8	96.1			
Mean of monthly Discharge	46	82	165	127	202	202	125	63	90	72	47	30

** No Incomplete data have been used for statistical calculation

DISCHARGE, CUBIC FEET PER SECOND
WATER YEAR OCTOBER 2009 TO SEPTEMBER 2010
DAILY MEAN VALUES
[e, estimated]

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	5.0	103	38	e45	e141	e101	136	1,880	62	149	44	465
2	4.4	51	37	e41	e142	e87	120	354	1,120	141	41	672
3	3.9	36	35	e37	e133	e113	106	218	711	133	38	738
4	3.7	30	29	e35	e130	e162	94	164	165	2,450	51	197
5	4.1	26	e28	e33	e127	e202	90	137	90	2,530	159	69
6	4.7	24	34	e31	e127	e215	139	116	66	667	84	42
7	4.2	23	e35	e30	e121	e220	104	649	53	e1,090	50	32
8	4.9	24	e31	e29	e119	e162	87	823	137	e1,560	41	27
9	7.0	23	e29	e29	e105	e406	80	238	291	e404	37	26
10	6.3	21	e33	e30	e104	1,270	75	591	105	e268	34	25
11	5.4	20	e36	e31	e95	852	71	624	64	e209	32	26
12	5.5	20	e36	e32	e85	447	67	305	53	e173	29	25
13	6.0	20	e36	e36	e76	266	65	208	92	158	27	25
14	8.0	21	e36	e38	e74	189	62	203	190	147	25	26
15	9.9	21	e36	e45	e68	150	67	127	137	225	24	27
16	10	27	e36	e55	e66	128	990	103	67	193	24	26
17	9.7	55	e35	e60	e66	114	676	96	55	120	25	25
18	7.8	216	e35	e74	e65	106	210	93	54	102	26	23
19	6.5	207	e39	e97	e65	101	137	87	136	91	25	22
20	5.9	261	e42	e151	e65	96	113	310	3,950	84	26	22
21	6.6	206	e43	e195	e66	91	102	523	8,710	85	25	22
22	16	159	e43	e279	e68	91	104	249	e6,650	98	24	21
23	81	164	e67	e1,440	e65	93	541	138	2,000	92	23	24
24	150	721	e87	e558	e60	92	793	102	721	73	61	49
25	73	152	e91	e270	e59	109	248	133	462	64	218	72
26	36	73	e87	e201	e62	88	176	234	330	59	142	48
27	24	54	e80	e176	e72	677	130	223	244	56	49	36
28	19	48	e73	e164	e109	1,360	114	142	204	51	30	26
29	61	44	e66	e155	---	467	109	90	181	49	24	24
30	351	41	e58	e152	---	221	1,980	73	163	49	21	22
31	337	---	e51	e149	---	163	---	64	---	47	23	---
Mean	41.2	96.4	46.5	152	90.5	285	260	300	909	375	47.8	96.1
Max	351	721	91	1,440	142	1,360	1,980	1,880	8,710	2,530	218	738
Min	3.7	20	28	29	59	87	62	64	53	47	21	21
Ac-ft	2,530	5,730	2,860	9,320	5,030	17,530	15,440	18,440	54,080	23,040	2,940	5,720

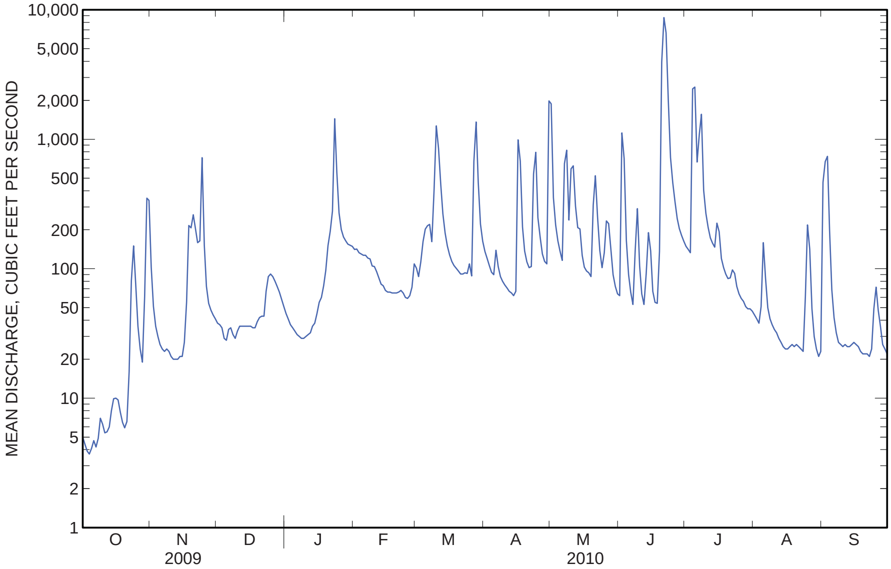
STATISTICS OF MONTHLY MEAN DATA FOR WATER YEARS 1960 - 2010, BY WATER YEAR (WY)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Mean	71.9	46.7	30.4	45.8	81.3	165	127	202	202	125	63.0	89.6
Max	839	359	176	367	505	1,264	725	1,161	909	2,151	344	864
(WY)	(1974)	(1973)	(1993)	(1962)	(1969)	(1979)	(1987)	(1995)	(2010)	(1993)	(1968)	(1973)
Min	1.11	1.50	1.39	1.06	2.23	5.81	6.23	3.54	6.38	0.33	1.15	2.08
(WY)	(1967)	(1967)	(1967)	(1967)	(1967)	(1967)	(1966)	(1966)	(2000)	(1964)	(1991)	(2000)

06884200 MILL CREEK AT WASHINGTON, KS—Continued

SUMMARY STATISTICS

	Calendar Year 2009		Water Year 2010		Water Years 1960 - 2010	
Annual mean	61.2		225		104	
Highest annual mean					468	1993
Lowest annual mean					12.7	1964
Highest daily mean	2,450	Apr 27	8,710	Jun 21	10,000	Jul 7, 1993
Lowest daily mean	3.7	Oct 4	3.7	Oct 4	0.00	Jun 29, 1963
Annual seven-day minimum	4.3	Oct 2	4.3	Oct 2	0.00	Jun 29, 1963
Maximum peak flow			10,300	Jun 21	14,600	Jul 7, 1993
Maximum peak stage			25.10	Jun 21	29.35	Jul 7, 1993
Instantaneous low flow			3.6	Oct 3	0.00	many years
Annual runoff (ac-ft)	44,330		162,700		75,470	
10 percent exceeds	82		422		172	
50 percent exceeds	26		74		19	
90 percent exceeds	7.1		23		3.5	

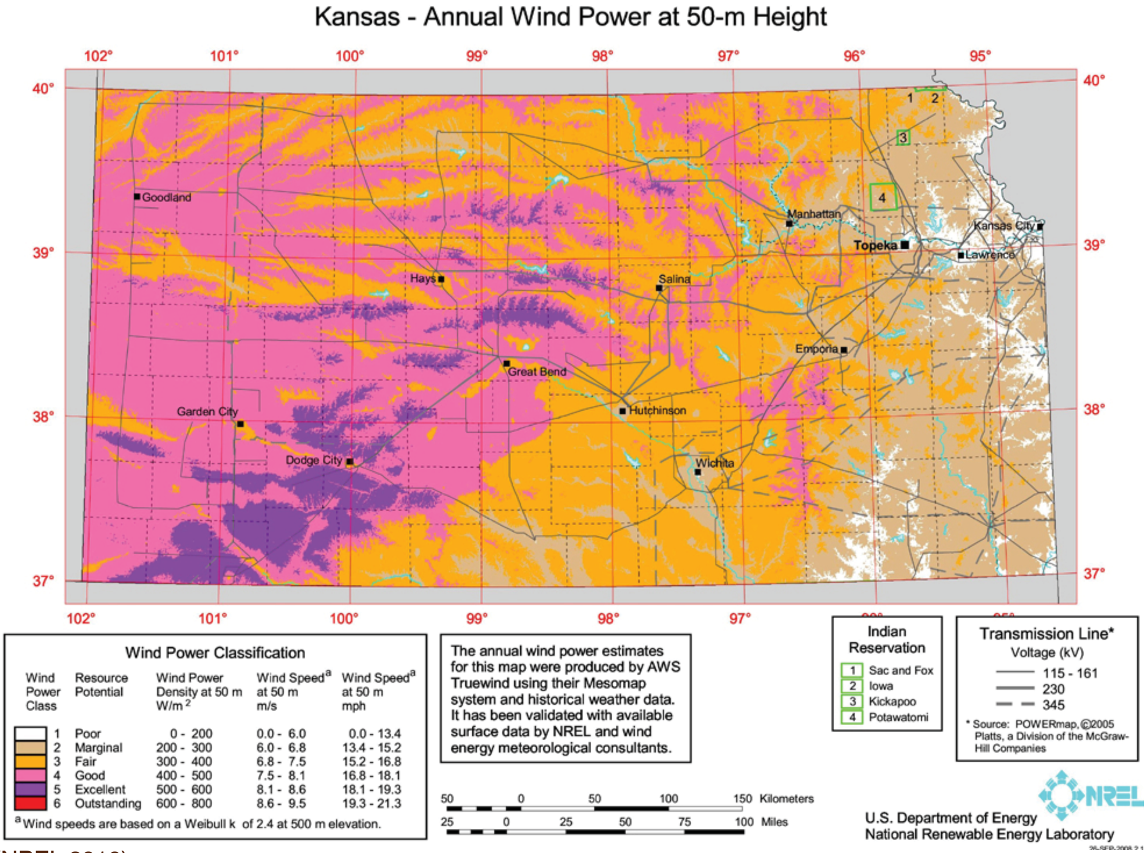


All discharge tables and data from USGS data for USGS 06884200 MILL C AT WASHINGTON, KS.

wind resource

	10 m				50 m			
	wind power density (W/m^2)		speed m/s		wind power density (W/m^2)		speed m/s	
	Min	Max	Min	Max	Min	Max	Min	Max
1	0	100	0	4.4	0	200	0	5.6
2	100	150	4.4	5.1	200	300	5.6	6.4
3	150	200	5.1	5.6	300	400	6.4	7
4	200	250	5.6	6	400	500	7	7.5
5	250	300	6	6.4	500	600	7.5	8
6	300	400	6.4	7	600	800	8	8.8
7	400	1000	7	9.4	800	200	8.8	11.9

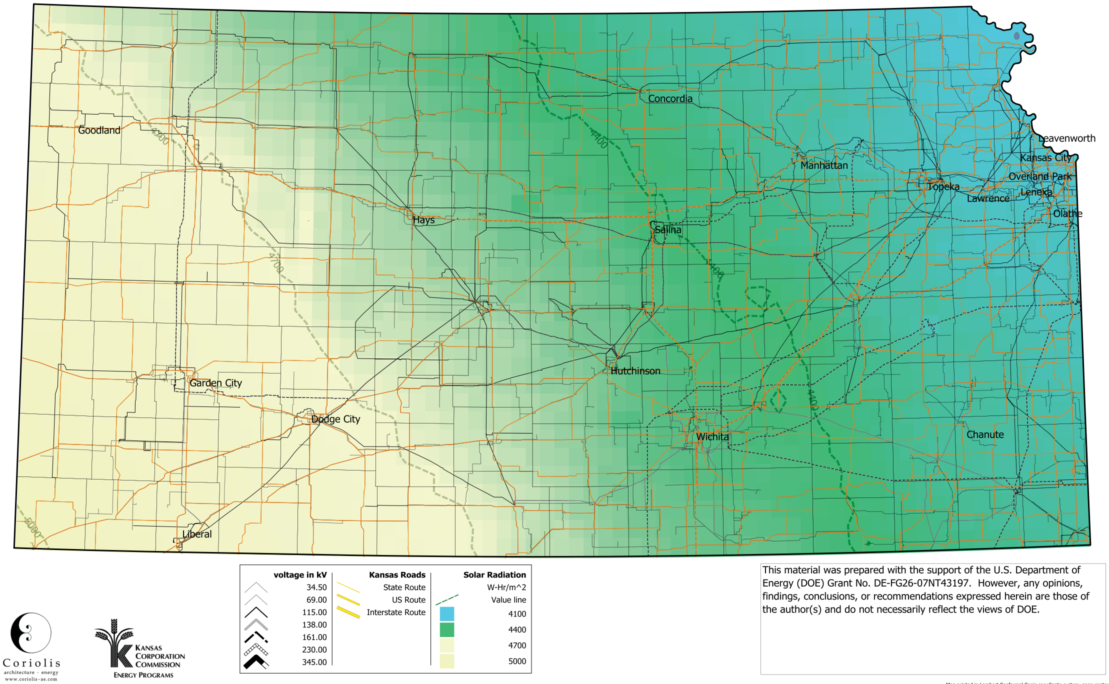
(NREL 1986)


Kansas - Annual Wind Power at 50-m Height
102°
101°
100°
99°
98°
97°
96°
95°
40°
39°
38°
37°
Goodland
Hays
Salina
Manhattan
Topeka
Kansas City
Lawrence
Emporia
Great Bend
Hutchinson
Garden City
Dodge City
Wichita
Wind Power Classification
Wind Power Class
Resource Potential
Wind Power Density at 50 m W/m 2
Wind Speed a at 50 m m/s
Wind Speed a at 50 m mph
1 Poor 0 - 200 0.0 - 6.0 0.0 - 13.4
2 Marginal 200 - 300 6.0 - 6.8 13.4 - 15.2
3 Fair 300 - 400 6.8 - 7.5 15.2 - 16.8
4 Good 400 - 500 7.5 - 8.1 16.8 - 18.1
5 Excellent 500 - 600 8.1 - 8.6 18.1 - 19.3
6 Outstanding 600 - 800 8.6 - 9.5 19.3 - 21.3
a Wind speeds are based on a Weibull k of 2.4 at 500 m elevation.
The annual wind power estimates for this map were produced by AWS Truewind using their Mesomap system and historical weather data. It has been validated with available surface data by NREL and wind energy meteorological consultants.
50 0 50 100 150 Kilometers
25 0 25 50 75 100 Miles
Indian Reservation
1 Sac and Fox
2 Iowa
3 Kickapoo
4 Potawatomi
Transmission Line*
Voltage (kV)
115 - 161
230
345
* Source: POWERmap, ©2005 Platts, a Division of the McGraw-Hill Companies
NREL
U.S. Department of Energy
National Renewable Energy Laboratory

(NREL 2010)

solar radiation

Kansas Solar Resource Map



This material was prepared with the support of the U.S. Department of Energy (DOE) Grant No. DE-FG26-07NT43197. However, any opinions, findings, conclusions, or recommendations expressed herein are those of the author(s) and do not necessarily reflect the views of DOE.

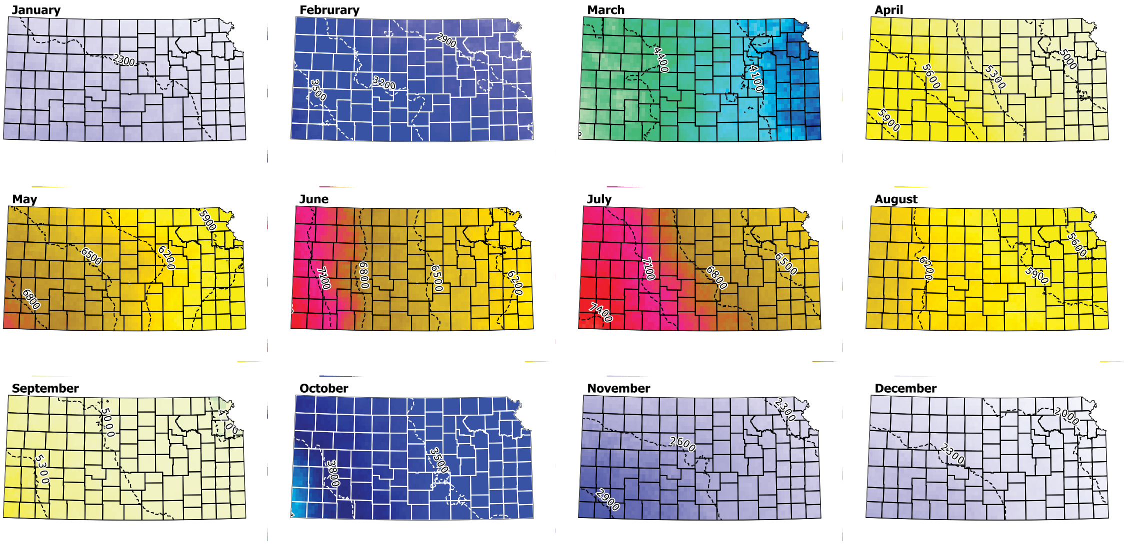
Map printed in Lambert Conformal Conic coordinate system. page center:-98.33

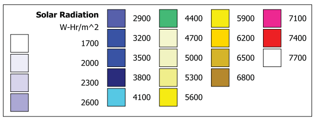
Coriolis architecture · energy www.coriolis-ae.com

Kansas Corporation Commission Energy Programs

(KCC 2010)

Kansas Solar Resource Map





The average annual solar energy falling on one square mile in central Kansas is about four billion KWh or fifteen trillion Btu, the equivalent of two and one-half million barrels of oil. About 70 square miles receive solar energy equal to Kansas's annual energy consumption. Plants using photosynthesis might convert 1% or lessof this energy to biomass. Solar thermal systems might convert 30-40% to useful heat, and solar photovoltaic systems might convert 5-20% to high value electricity. Matching the availability of the resource to the demand for energy is an important factor in making solar energy systems feasible, technically and economically. The maps above show monthly solar energy in Watt-hours per square meter for Kansas.

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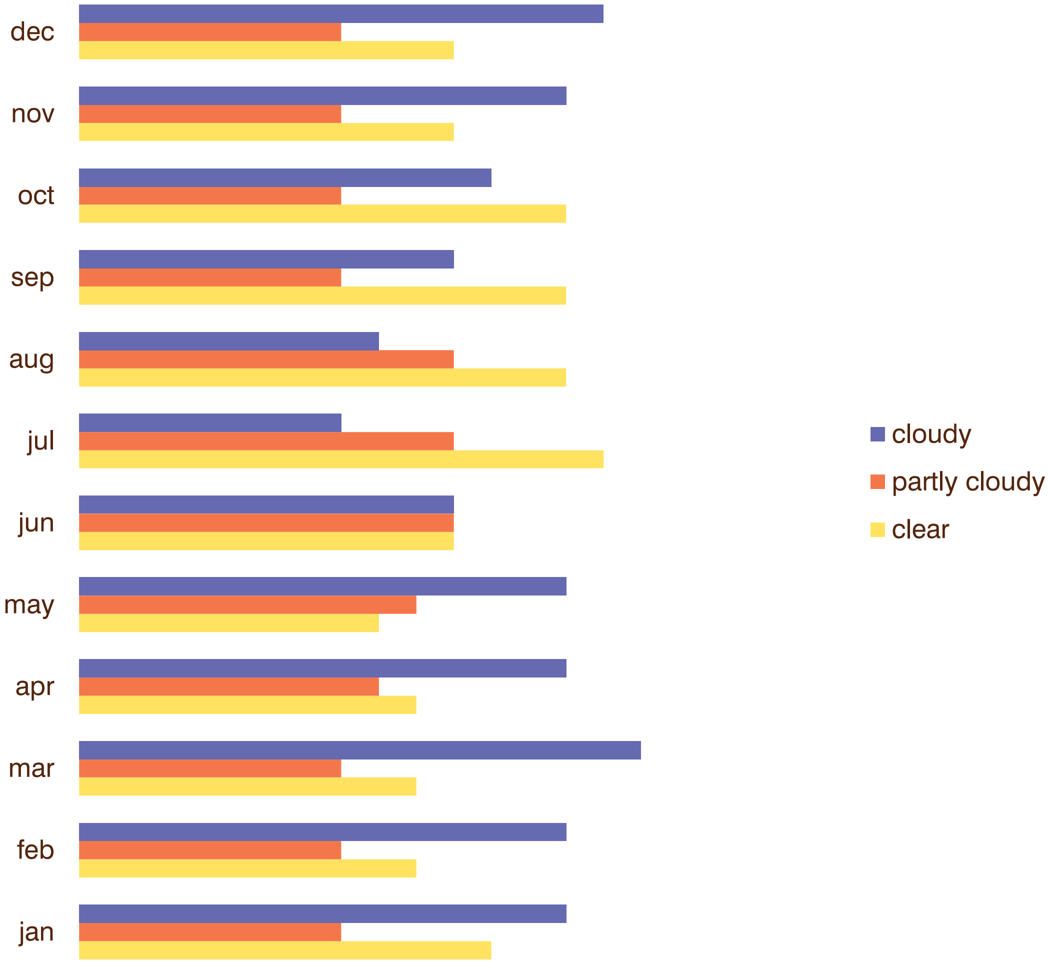
Energy Programs

(KCC 2010)

cloudcover

	Concordia			Topeka		
	clear	partly cloudy	cloudy	clear	partly cloudy	cloudy
jan	11	7	13	10	6	15
feb	9	7	13	8	6	14
mar	9	7	15	7	7	16
apr	9	8	13	8	8	14
may	8	9	13	7	10	14
jun	10	10	10	8	10	11
jul	14	10	7	11	11	9
aug	13	10	8	12	10	9
sep	13	7	10	12	8	10

Cloudcover based on data from the National Oceanic and Atmospheric Association.


dec
nov
oct
sep
aug
jul
jun
may
apr
mar
feb
jan
cloudy
partly cloudy
clear

PVWatts - North

North - Commercial

Station Identification	
Cell ID:	0222368
State:	Kansas
Latitude:	39.9 ° N
Longitude:	97.2 ° W
PV System Specifications	
DC Rating:	150.0 kW
DC to AC Derate Factor:	0.770
AC Rating:	115.5 kW
Array Type:	Fixed Tilt
Array Tilt:	39.9 °
Array Azimuth:	180.0 °
Energy Specifications	
Cost of Electricity:	9.2 ¢/kWh

Results			
Month	Solar Radiation ($kWh/m^2/day$)	AC Energy (kWh)	Energy Value ($)
1	4.31	15897	1470.15
2	4.57	14894	1377.40
3	5.34	18706	1729.93
4	5.89	19382	1792.45
5	5.74	18774	1736.22
6	6.01	18451	1706.35
7	6.17	19220	1777.47
8	5.96	18893	1747.22
9	5.86	18384	1700.15
10	5.04	16733	1547.47
11	4.02	13864	1282.14
12	3.73	13580	1255.88
Year	5.22	206778	19122.83

North - USD 108

Station Identification

Cell ID:	0222368
State:	Kansas
Latitude:	39.9 ° N
Longitude:	97.2 ° W
PV System Specifications	
DC Rating:	665.0 kW
DC to AC Derate Factor:	0.770
AC Rating:	512.0 kW
Array Type:	Fixed Tilt
Array Tilt:	39.9 °
Array Azimuth:	180.0 °
Energy Specifications	
Cost of Electricity:	9.2 ¢/kWh

Results

Month	Solar Radiation ($kWh/m^2/day$)	AC Energy (kWh)	Energy Value ($)
1	4.31	70476	6517.62
2	4.57	66032	6106.64
3	5.34	82929	7669.27
4	5.89	85926	7946.44
5	5.74	83232	7697.30
6	6.01	81800	7564.86
7	6.17	85209	7880.13
8	5.96	83759	7746.03
9	5.86	81502	7537.31
10	5.04	74184	6860.54
11	4.02	61463	5684.10
12	3.73	60205	5567.76
Year	5.22	916715	84777.80

PVWatts - CBD

CBD - Commercial

Station Identification	
Cell ID:	0222368
State:	Kansas
Latitude:	39.9 ° N
Longitude:	97.2 ° W
PV System Specifications	
DC Rating:	1020.0 kW
DC to AC Derate Factor:	0.770
AC Rating:	785.4 kW
Array Type:	Fixed Tilt
Array Tilt:	39.9 °
Array Azimuth:	180.0 °
Energy Specifications	
Cost of Electricity:	9.2 ¢/kWh

Results

Month	Solar Radiation ($kWh/m^2/day$)	AC Energy (kWh)	Energy Value ($)
1	4.31	108099	9997.00
2	4.57	101282	9366.56
3	5.34	127199	11763.36
4	5.89	131796	12188.49
5	5.74	127664	11806.37
6	6.01	125467	11603.19
7	6.17	130696	12086.77
8	5.96	128472	11881.09
9	5.86	125010	11560.92
10	5.04	113785	10522.84
11	4.02	94274	8718.46
12	3.73	92345	8540.07
Year	5.22	1406089	130035.11

CBD - Government

Station Identification	
Cell ID:	0222368
State:	Kansas
Latitude:	39.9 ° N
Longitude:	97.2 ° W
PV System Specifications	
DC Rating:	237.0 kW
DC to AC Derate Factor:	0.770
AC Rating:	182.5 kW
Array Type:	Fixed Tilt
Array Tilt:	39.9 °
Array Azimuth:	180.0 °
Energy Specifications	
Cost of Electricity:	9.2 ¢/kWh

Results

Month	Solar Radiation ($kWh/m^2/day$)	AC Energy (kWh)	Energy Value ($)
1	4.31	25117	2322.82
2	4.57	23533	2176.33
3	5.34	29555	2733.25
4	5.89	30623	2832.02
5	5.74	29663	2743.23
6	6.01	29153	2696.07
7	6.17	30368	2808.43
8	5.96	29851	2760.62
9	5.86	29046	2686.17
10	5.04	26438	2444.99
11	4.02	21905	2025.77
12	3.73	21457	1984.34
Year	5.22	326709	30214.05

PVWatts - East

East - Medical

Station Identification	
Cell ID:	0222368
State:	Kansas
Latitude:	39.9 ° N
Longitude:	97.2 ° W
PV System Specifications	
DC Rating:	186.0 kW
DC to AC Derate Factor:	0.770
AC Rating:	143.2 kW
Array Type:	Fixed Tilt
Array Tilt:	39.9 °
Array Azimuth:	180.0 °
Energy Specifications	
Cost of Electricity:	9.2 ¢/kWh

Results			
Month	Solar Radiation (kWh/m²/day)	AC Energy (kWh)	Energy Value ($)
1	4.31	19712	1822.97
2	4.57	18469	1708.01
3	5.34	23195	2145.07
4	5.89	24033	2222.57
5	5.74	23280	2152.93
6	6.01	22879	2115.85
7	6.17	23833	2204.08
8	5.96	23427	2166.53
9	5.86	22796	2108.17
10	5.04	20749	1918.87
11	4.02	17191	1589.82
12	3.73	16839	1557.27
Year	5.22	256405	23712.33

PVWatts - HWY 36 West

HWY 36 W Commercial

Station Identification	
Cell ID:	0222368
State:	Kansas
Latitude:	39.9 ° N
Longitude:	97.2 ° W
PV System Specifications	
DC Rating:	565.0 kW
DC to AC Derate Factor:	0.770
AC Rating:	435.0 kW
Array Type:	Fixed Tilt
Array Tilt:	39.9 °
Array Azimuth:	180.0 °
Energy Specifications	
Cost of Electricity:	9.2 ¢/kWh

Results

Month	Solar Radiation ($kWh/m^2/day$)	AC Energy (kWh)	Energy Value ($)
1	4.31	59878	5537.52
2	4.57	56103	5188.41
3	5.34	70458	6515.96
4	5.89	73005	6751.50
5	5.74	70716	6539.82
6	6.01	69499	6427.27
7	6.17	72395	6695.09
8	5.96	71163	6581.15
9	5.86	69246	6403.87
10	5.04	63028	5828.83
11	4.02	52220	4829.31
12	3.73	51152	4730.54
Year	5.22	778863	72029.25

PVWatts - South

South - Government

Station Identification	
Cell ID:	0222368
State:	Kansas
Latitude:	39.9 ° N
Longitude:	97.2 ° W
PV System Specifications	
DC Rating:	256.0 kW
DC to AC Derate Factor:	0.770
AC Rating:	197.1 kW
Array Type:	Fixed Tilt
Array Tilt:	39.9 °
Array Azimuth:	180.0 °
Energy Specifications	
Cost of Electricity:	9.2 ¢/kWh

Results

Month	Solar Radiation ($kWh/m^2/day$)	AC Energy (kWh)	Energy Value ($)
1	4.31	27131	2509.07
2	4.57	25420	2350.84
3	5.34	31925	2952.42
4	5.89	33078	3059.05
5	5.74	32041	2963.15
6	6.01	31490	2912.20
7	6.17	32802	3033.53
8	5.96	32244	2981.93
9	5.86	31375	2901.56
10	5.04	28558	2641.04
11	4.02	23661	2188.17
12	3.73	23177	2143.41
Year	5.22	352901	32636.28

South - Other

Station Identification	
Cell ID:	0222368
State:	Kansas
Latitude:	39.9 ° N
Longitude:	97.2 ° W
PV System Specifications	
DC Rating:	251.0 kW
DC to AC Derate Factor:	0.770
AC Rating:	193.3 kW
Array Type:	Fixed Tilt
Array Tilt:	39.9 °
Array Azimuth:	180.0 °
Energy Specifications	
Cost of Electricity:	9.2 ¢/kWh

Results			
Month	Solar Radiation ($kWh/m^2/day$)	AC Energy (kWh)	Energy Value ($)
1	4.31	26601	2460.06
2	4.57	24923	2304.88
3	5.34	31301	2894.72
4	5.89	32432	2999.31
5	5.74	31415	2905.26
6	6.01	30875	2855.32
7	6.17	32161	2974.25
8	5.96	31614	2923.66
9	5.86	30762	2844.87
10	5.04	28000	2589.44
11	4.02	23199	2145.44
12	3.73	22724	2101.52
Year	5.22	346008	31998.82

PVWatts - HWY 36 East

HWY 36 E Commercial

Station Identification	
Cell ID:	0222368
State:	Kansas
Latitude:	39.9 ° N
Longitude:	97.2 ° W
PV System Specifications	
DC Rating:	319.0 kW
DC to AC Derate Factor:	0.770
AC Rating:	245.6 kW
Array Type:	Fixed Tilt
Array Tilt:	39.9 °
Array Azimuth:	180.0 °
Energy Specifications	
Cost of Electricity:	9.2 ¢/kWh

Results			
Month	Solar Radiation (kWh/m^2/day)	AC Energy (kWh)	Energy Value ($)
1	4.31	33807	3126.47
2	4.57	31676	2929.40
3	5.34	39781	3678.95
4	5.89	41219	3811.93
5	5.74	39926	3692.36
6	6.01	39239	3628.82
7	6.17	40874	3780.03
8	5.96	40179	3715.75
9	5.86	39096	3615.60
10	5.04	35586	3290.99
11	4.02	29484	2726.68
12	3.73	28880	2670.82
Year	5.22	439748	40667.90

HWY 36 East Government

Station Identification	
Cell ID:	0222368
State:	Kansas
Latitude:	39.9 ° N
Longitude:	97.2 ° W
PV System Specifications	
DC Rating:	122.0 kW
DC to AC Derate Factor:	0.770
AC Rating:	93.9 kW
Array Type:	Fixed Tilt
Array Tilt:	39.9 °
Array Azimuth:	180.0 °
Energy Specifications	
Cost of Electricity:	9.2 ¢/kWh

Results			
Month	Solar Radiation ($kWh/m^2/day$)	AC Energy (kWh)	Energy Value ($)
1	4.31	12930	1195.77
2	4.57	12114	1120.30
3	5.34	15214	1406.99
4	5.89	15764	1457.85
5	5.74	15270	1412.17
6	6.01	15007	1387.85
7	6.17	15632	1445.65
8	5.96	15366	1421.05
9	5.86	14952	1382.76
10	5.04	13610	1258.65
11	4.02	11276	1042.80
12	3.73	11045	1021.44
Year	5.22	168179	15553.19

HWY 36 East Other

Station Identification	
Cell ID:	0222368
State:	Kansas
Latitude:	39.9 ° N
Longitude:	97.2 ° W
PV System Specifications	
DC Rating:	88.0 kW
DC to AC Derate Factor:	0.770
AC Rating:	67.8 kW
Array Type:	Fixed Tilt
Array Tilt:	39.9 °
Array Azimuth:	180.0 °
Energy Specifications	
Cost of Electricity:	9.2 ¢/kWh

Results

Month	Solar Radiation ($kWh/m^2/day$)	AC Energy (kWh)	Energy Value ($)
1	4.31	9326	862.47
2	4.57	8738	808.09
3	5.34	10974	1014.88
4	5.89	11371	1051.59
5	5.74	11014	1018.57
6	6.01	10825	1001.10
7	6.17	11276	1042.80
8	5.96	11084	1025.05
9	5.86	10785	997.40
10	5.04	9817	907.88
11	4.02	8133	752.14
12	3.73	7967	736.79
Year	5.22	121310	11218.75

All Solar calculations were created using NREL's PVWatts calculator.

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figure references

f.1 **Process**. Author. 2011

f.2 **Sign at Gasworks Park**. Author. 2009

f.3 **Literature Map**. Author. 2011

f.4 **Love & Loss**. Jeff Graham. 2009

f.5 **Courthouse Square**. Author. 2011

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