Colorado Energy Masters: Renewable Energy (Emphasizing Solar PV, Thermal & Small-Scale Wind)

Kurt M. Jones

County Extension Director

Chaffee County

Learning Objectives

- Evaluating the Solar Resource
  - Technical feasibility, permitting & zoning considerations
- How Solar Technology Works
  - Types of systems and equipment used
- Sizing Solar Systems
  - Evaluating electric and hot water loads
  - Determining offset
- Wind Energy Basics
- Financial Feasibility
  - Financing options, incentives, calculators
- Case Studies
- Trends
- Sources of Additional Information

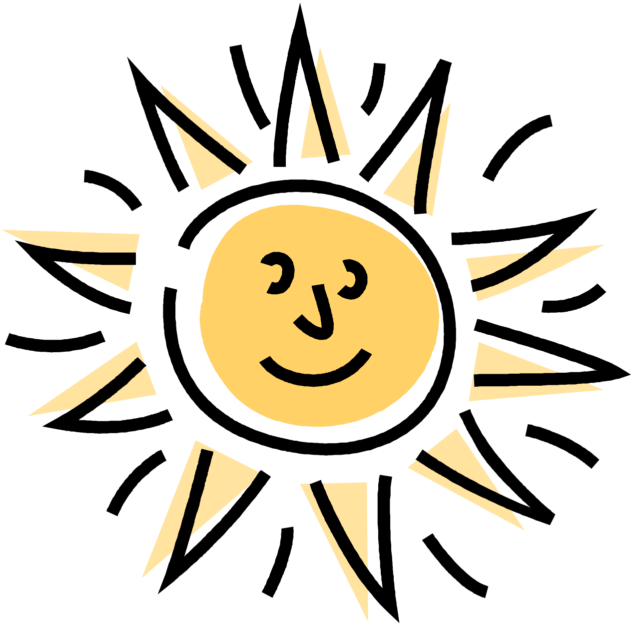
What to Expect from Today's Class

- Better understanding about solar energy technology
- Understand how to calculate energy loads
- Basic understanding of sizing solar systems
- Determining small-scale wind capacity and applicability to local conditions
- Understand costs/benefits from solar systems
- Where to go for additional information

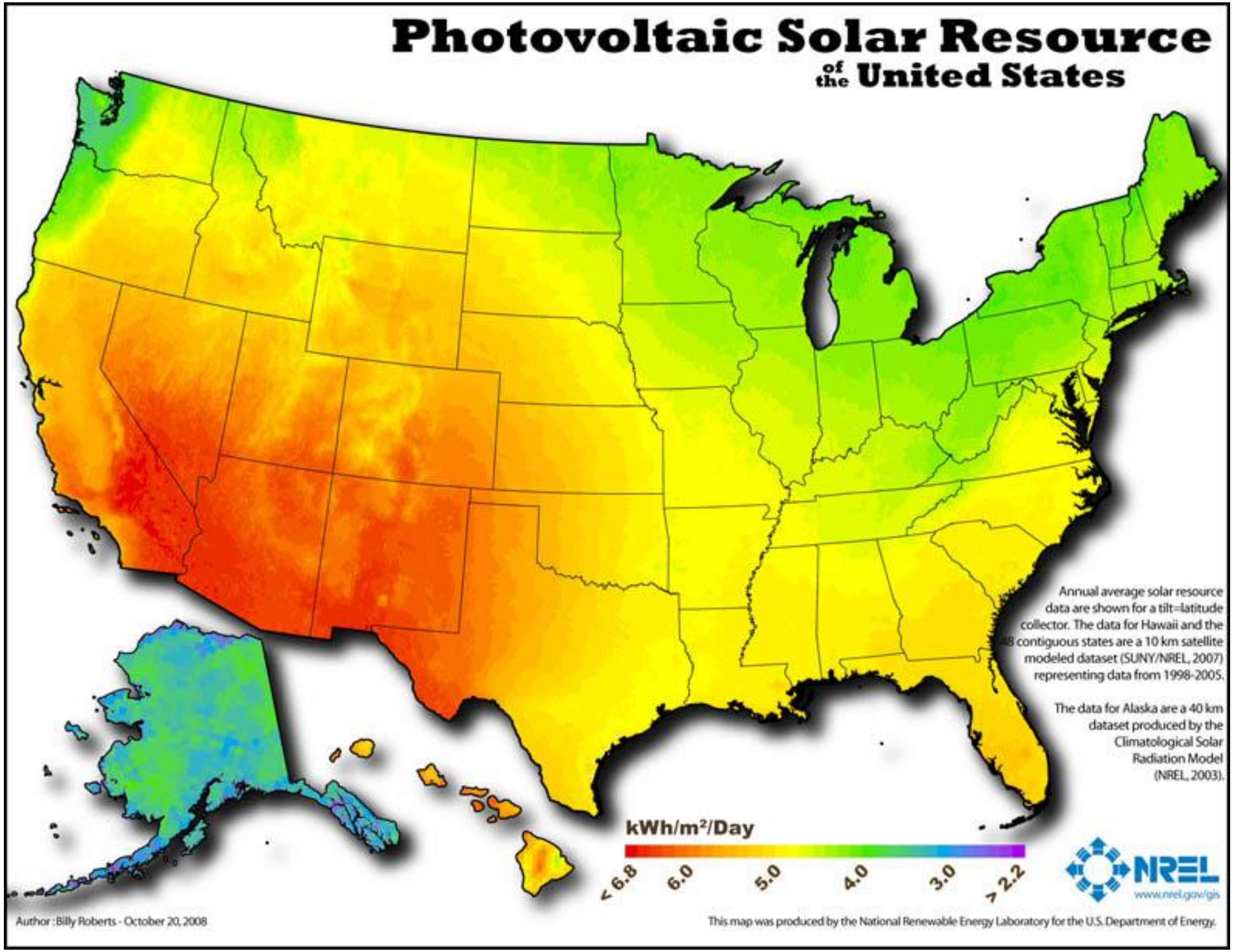
What NOT to Expect from Today's Class

- Design or build a solar system for electric or domestic hot water applications
- Provide advice on utility-scale solar or wind energy projects
- Become solar or wind energy "experts"

Evaluating the Solar Energy Resource



- Colorado enjoys copious amounts of sunshine per year
  - 300 days per year
- Unlike other renewable energy resources (example: wind), solar energy is relatively predictable
- Can be used for thermal or electric applications


Photovoltaic Solar Resource of the United States
kWh/m²/Day
< 6.8
6.0
5.0
4.0
3.0
> 2.2
Annual average solar resource data are shown for a tilt=latitude collector. The data for Hawaii and the 48 contiguous states are a 10 km satellite modeled dataset (SUNY/NREL, 2007) representing data from 1998-2005.
The data for Alaska are a 40 km dataset produced by the Climatological Solar Radiation Model (NREL, 2003).
NREL
www.nrel.gov/gis
Author : Billy Roberts - October 20, 2008
This map was produced by the National Renewable Energy Laboratory for the U.S. Department of Energy.

Peak Sun Hours

- Number of hours per day that the solar insolation equals 1,000 watts/square meter
- For example: 5 ½ hours of peak sun = 5.5 kWh/m^2
- Amount of solar insolation at a given location will vary due to season, elevation, weather, and potential shading

Measuring Solar Irradiance

- Solar irradiance meters can give site-specific information at a given time (useful for comparison with insolation data)
- Published solar energy tables available
- NREL PV-Watts calculator can give data via postal zip code

Tracking the Sun

- Tracking the sun's path is predictable, and is based on a site's latitude
- Colorado's latitude ranges from 37 degrees (NM border) to 41 degrees (WY border)

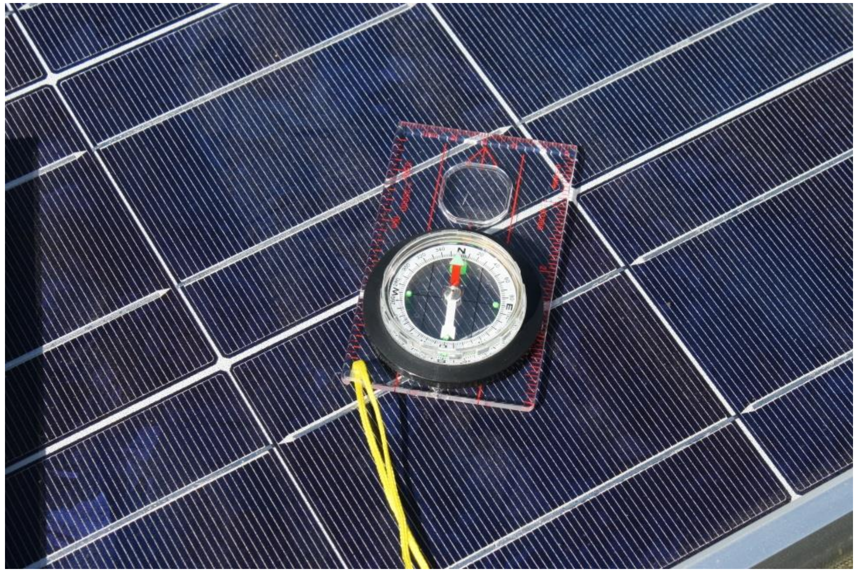
Tools for determining sun's path

- Solar Pathfinder – Useful tool which shows sun's path seasonally, but also shows potential shade issues and can calculate percent loss based on shading -- $300
- Free sun charts available from University of Oregon Sun Chart Program based on postal zip code or Lat./Long.

Azimuth

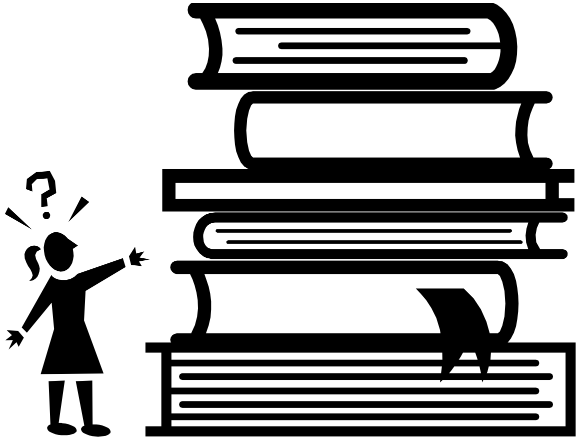
- The sun's apparent located east or west of true south is called azimuth
  - Measured in degrees east or west of true south
- Compasses align with magnetic fields which are not necessarily aligned with Earth's axis
  - Magnetic declination

Azimuth



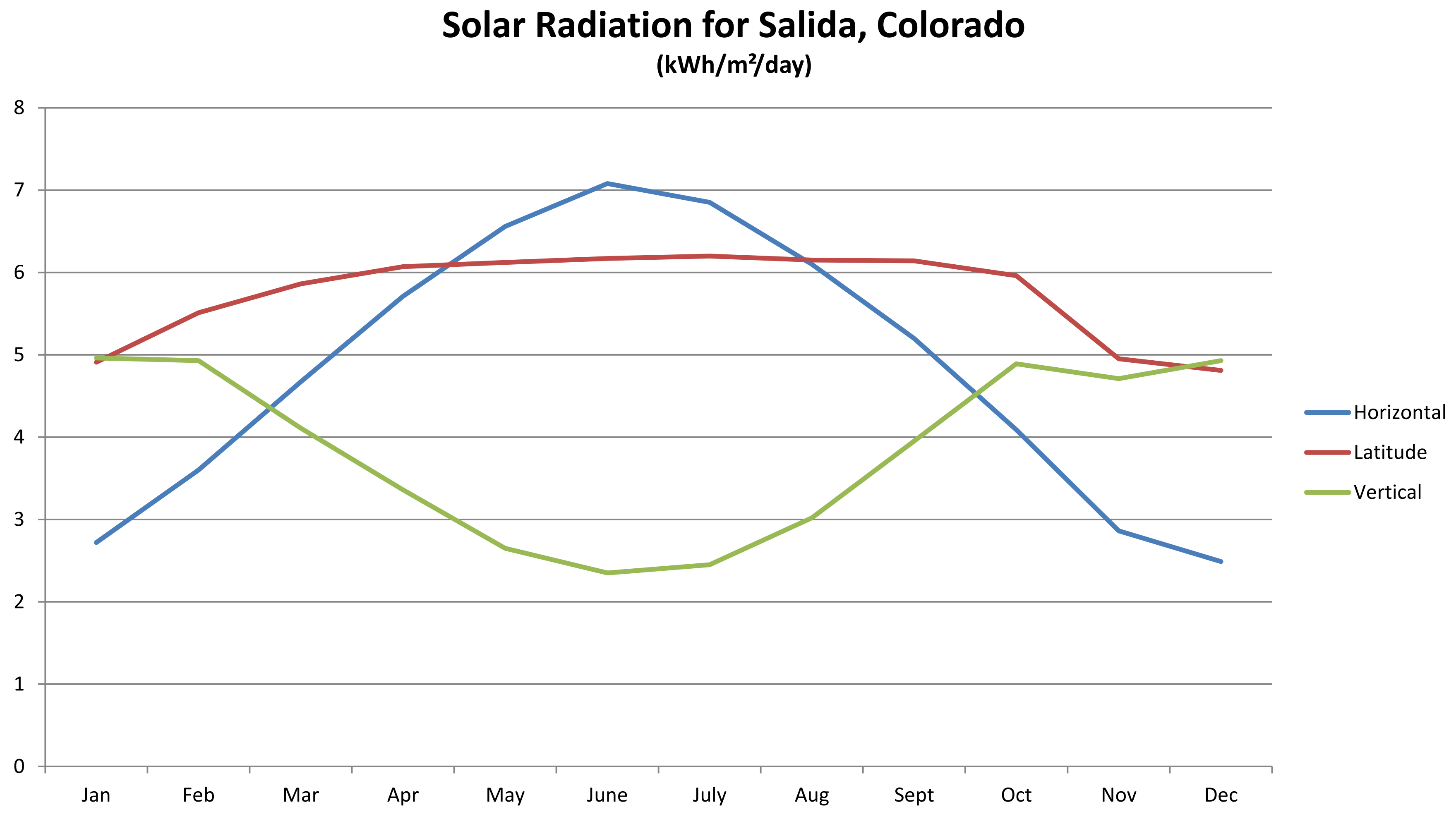
- Colorado’s magnetic declination ranges from about 10° east of magnetic south along the Kansas border to about 13° east of magnetic south in NW Colorado.
- Most use 11° as an average (169° on a compass) or correct on a Solar Pathfinder)

Who Cares?



- For optimum efficiency, we will orient the solar collector to capture the most solar radiance
  - True South
  - Perpendicular to the angle of the sun’s rays (depends on application)
  - In general, lack of potential shading within the sun’s annual path

Effect on Array Tilt Angles



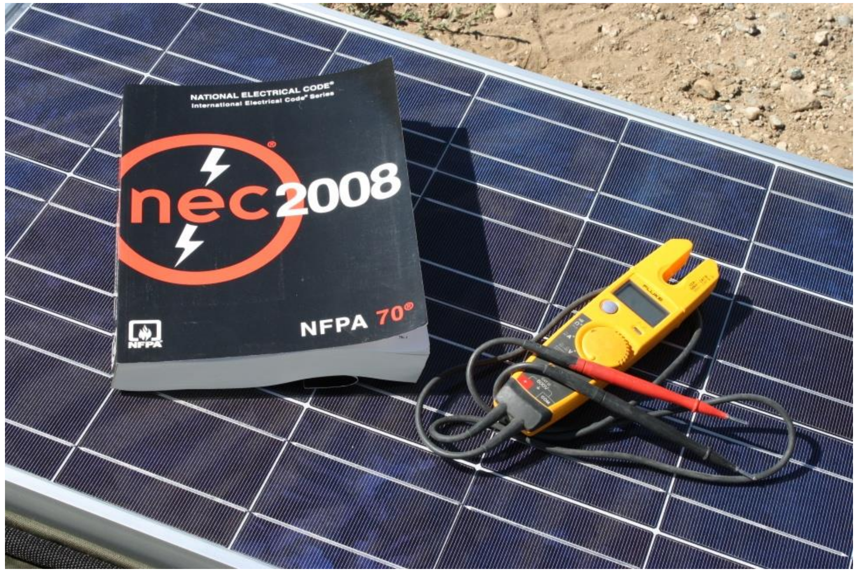
A Bit on Site Analysis

- Design month
  - If the load is consistent, the system is sized & oriented according to the month of lowest insolation.
  - If loads vary, the system is designed to meet the peak loads during the month of largest demand.

A Bit on Site Analysis

- Insolation data for site
  - PV Watts version 2 for site-specific (version 1 is still available for those less tech-savvy, but gives regional data)
- Potential Shading analysis
  - Picture at right was taken in May at about 3:30 pm (Aspen, CO)

Permitting & Zoning Issues



- Solar systems are regulated in most jurisdictions by building codes and building permits will likely be needed
- Photovoltaic system components must be UL listed and are governed by the National Electric Code
- Thermal systems “interact” with domestic water systems and have permitting requirements as well.
- Zoning requirements are different for each jurisdiction, check with local building department.

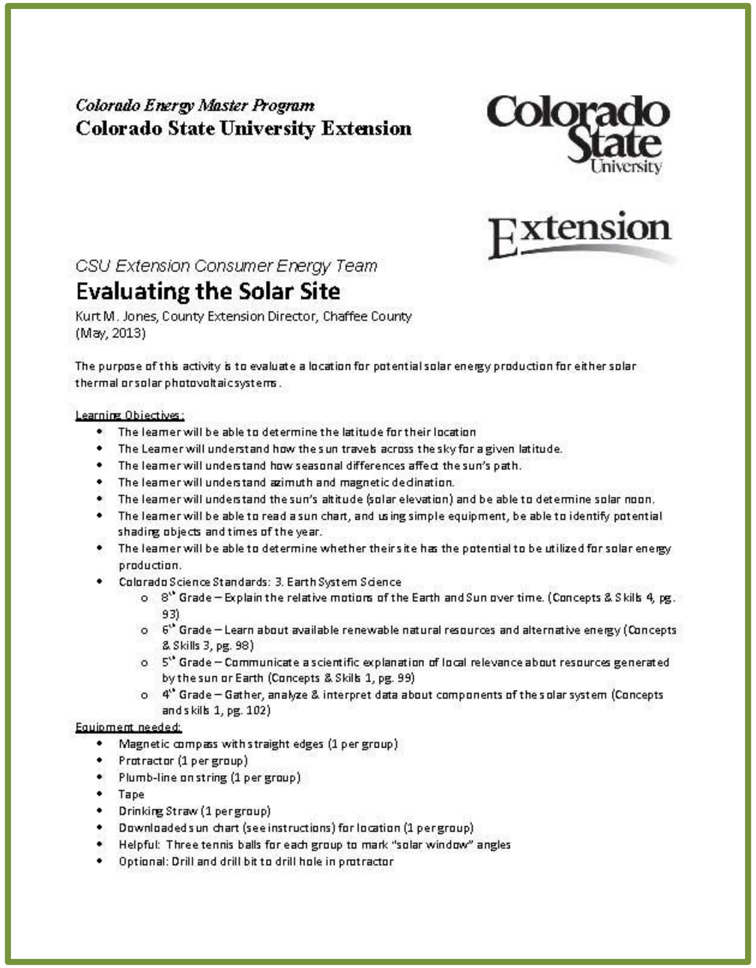
Is solar right for my property?

- Site analysis
  - Any covenant restrictions/viewsheds?
  - Roof mounted
    - Is my roof in good shape?
    - If work needs to be done in the next 10 years, may need to do that first.
  - Ground Mount
    - Do I have the space?
    - Aesthetics?

Solar Site Analysis Worksheet

- For those wanting to do a hands-on activity with youth or adults
- Inexpensive materials

- Need to do some prep work before speaking with the group!!


Colorado Energy Master Program
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CSU Extension Consumer Energy Team
Evaluating the Solar Site
Kurt M. Jones, County Extension Director, Chaffee County
(May, 2013)

The purpose of this activity is to evaluate a location for potential solar energy production for either solar thermal or solar photovoltaic systems.

Learning Objectives:

- The learner will be able to determine the latitude for their location
- The Learner will understand how the sun travels across the sky for a given latitude.
- The learner will understand how seasonal differences affect the sun's path.
- The learner will understand azimuth and magnetic declination.
- The learner will understand the sun's altitude (solar elevation) and be able to determine solar noon.
- The learner will be able to read a sun chart, and using simple equipment, be able to identify potential shading objects and times of the year.
- The learner will be able to determine whether their site has the potential to be utilized for solar energy production.
- Colorado Science Standards: 3. Earth System Science
  - 8th Grade – Explain the relative motions of the Earth and Sun over time. (Concepts & Skills 4, pg. 93)
  - 6th Grade – Learn about available renewable natural resources and alternative energy (Concepts & Skills 3, pg. 98)
  - 5th Grade – Communicate a scientific explanation of local relevance about resources generated by the sun or Earth (Concepts & Skills 1, pg. 99)
  - 4th Grade – Gather, analyze & interpret data about components of the solar system (Concepts and skills 1, pg. 102)

Equipment needed:

- Magnetic compass with straight edges (1 per group)
- Protractor (1 per group)
- Plumb-line on string (1 per group)
- Tape
- Drinking Straw (1 per group)
- Downloaded sun chart (see instructions) for location (1 per group)
- Helpful: Three tennis balls for each group to mark "solar window" angles
- Optional: Drill and drill bit to drill hole in protractor

What questions do you have about <u>solar site analysis or solar energy basics?</u>

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Types of Solar Systems

- Solar Thermal
  - Domestic Hot Water
  - Space Heating
  - Snow Melt
- Solar Photovoltaic
  - Grid-interactive
  - Off-grid
- Passive Solar Design

Solar Thermal Systems

- Batch systems
  - Water in high-volume collector…no freeze protection
- Thermosyphon
  - Water-storage above collector…natural convection water movement
- These are used in temperate climates…not for Colorado

Solar Thermal Systems

- Drainback
  - Frost protection to -10° to -20° F
  - Water drains back to conditioned space when water pump shuts off
  - Water storage must be below collectors
  - Will not overheat and damage system

Solar Thermal Systems

- Closed loop glycol
  - Propylene glycol (non-toxic) antifreeze mixed with water goes through panel for heating, then through a heat exchanger to transfer heat to domestic water system
  - Frost protection to -50° F
  - Most common type in Colorado (and US)
  - Propylene glycol can turn acidic in high temperatures, so cannot be stagnant in collector

Flat Plate Solar Thermal Collector

Photo credit: US Department of Energy

Evacuated Tube Solar Thermal Collector

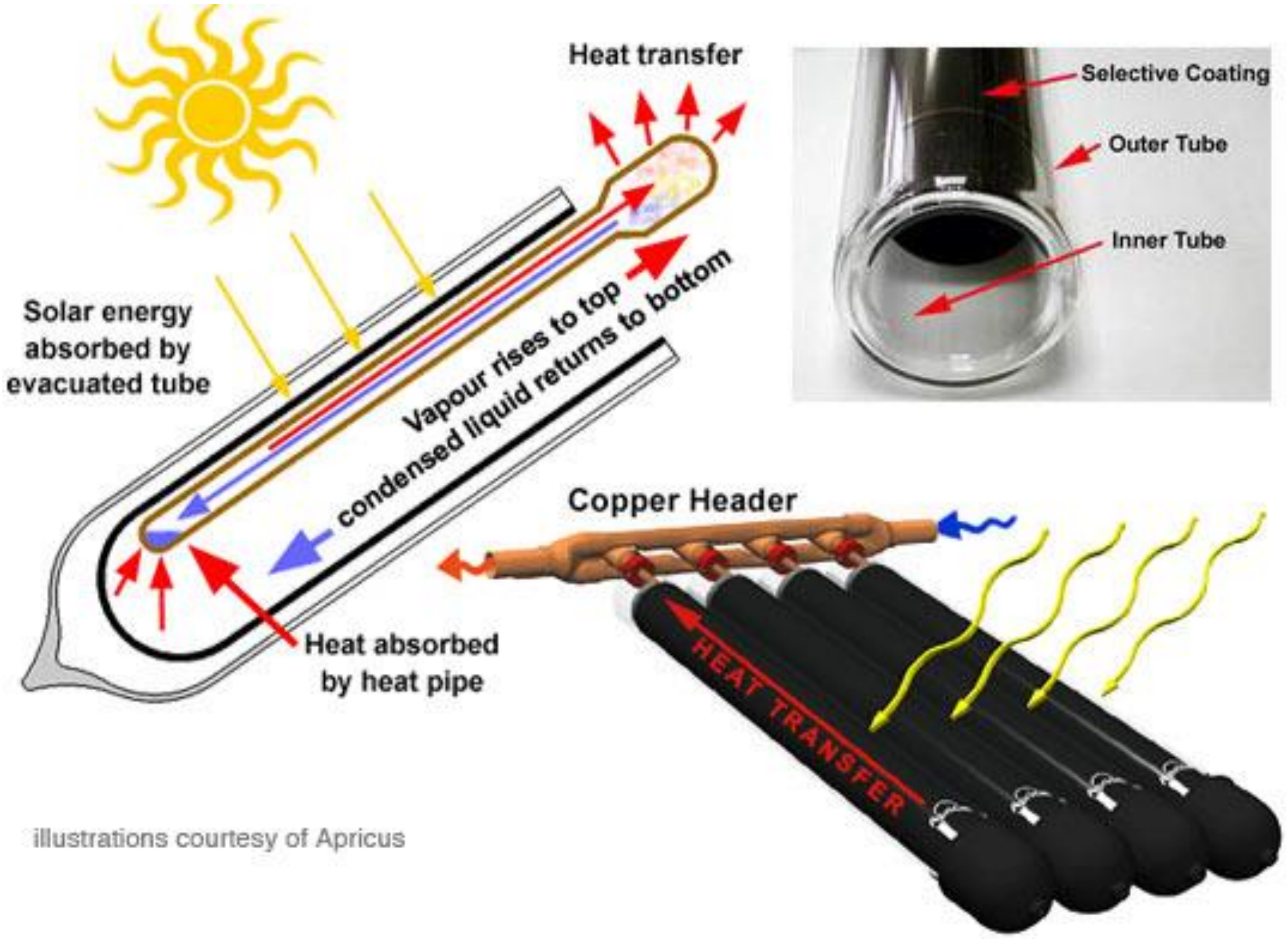


Photo credit: US Department of Energy

Which Type to Use?

- Depends on situation
- Lower-light applications show better efficiencies of evacuated tube collectors
- ET collectors are lighter…easier to install than a flat plate collector (75-85 pounds).
- ET tubes are cool to touch in full sun…won’t shed snow as quickly as flat plate

Additional Components

- Water storage tanks
  - Should be of sufficient size to accommodate hot water demand
- System controllers switch on water pumps or tempering valves based on programmed temperature sensor data
- Water pumps and plumbing components
- Backup heating (tankless water heaters or boilers)

Solar Photovoltaics

- Solar electric-generating panels are called photovoltaic panels
- Systems can be tied into the utility grid (grid-interactive or grid-tied), or can be off-grid, battery-based systems

Equipment for Solar System

Solar Cells

Solar Panel

Solar Array

- Ground Mounted
- Roof Mounted
- Pole Mounted

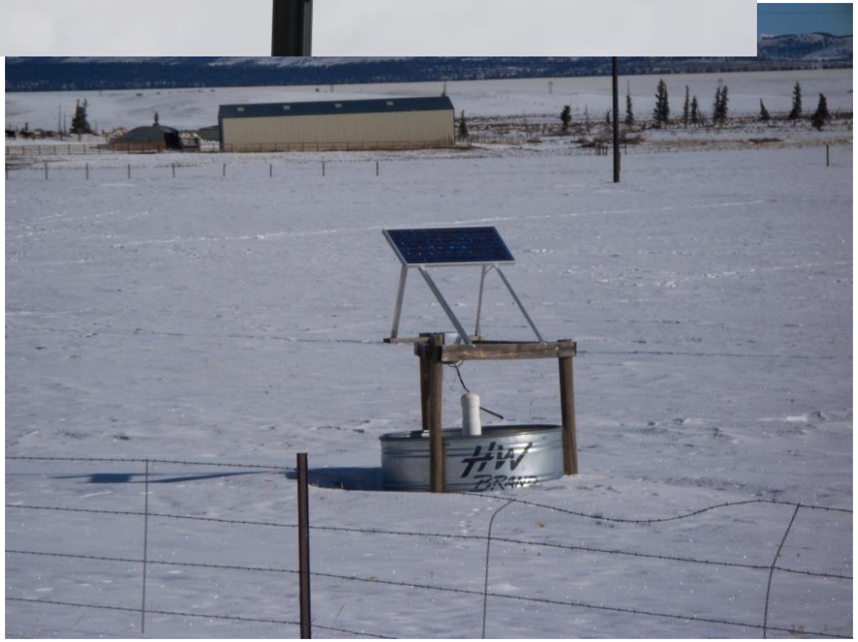
Equipment for Solar System

- Solar Panels assembled into an array…
- Balance of system components (everything else), including:

- Mounting System
- Wiring (sized for current, and temp.) in conduit
- Combiner box(es)
- Shutoffs
- Over-current protection
- Component & system grounding

- Inverter(s) (sized for maximum voltage/current)
  - Converts DC into AC
  - Provides ground-fault protection
- Off-grid also includes:
  - Charge controller
  - Battery system
    - Batteries & cables
    - Battery box

Photovoltaic applications



- Outdoor lighting
  - PV panel charges battery in sealed box (not shown) which powers a DC light
- Water Pumping
  - DC pump fills stock tank; simple float switches pump on/off
  - Panel can be mounted above or can be mounted on trailer which moves with animals to new pasture

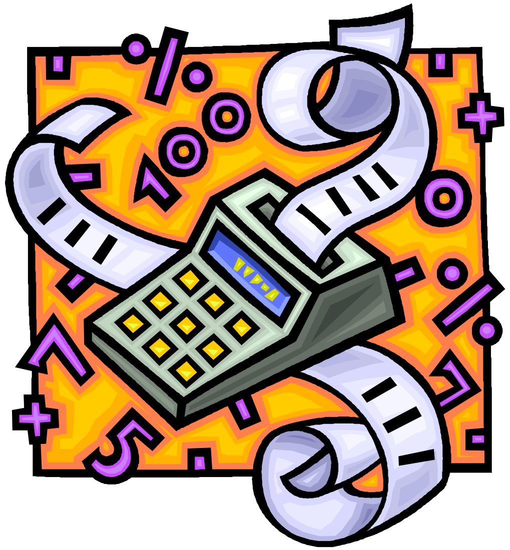
What questions do you have about <u>types of solar systems?</u>

Calculating size of system

- Various ways to calculate sizes of systems
- Most common is to evaluate demand and size accordingly

What size system do I need?

- Grid-tied systems-- User can evaluate their utility bills and determine the percentage of offset by solar.
- Off-grid systems – Will need to calculate their electrical load demands and size accordingly.



Sizing a Grid-Tied PV System

- Add up total energy usage for the year
- Divide by 365 for daily total
- Divide by 5.5 hours of solar insolation per day
- Factor in inefficiencies

Roof-Mounted System

- Can also calculate a system size based on available roof size
  - Calculate total roof area (square feet)
  - Multiply by 50-80% (allows for servicing & installing system)
  - Multiply by 10 watts/ft^2

Example

- Roof measures 14'x25'
- 14ft x 25ft = 350ft^2
- Has 250ft^2 usable space (71%)
- 250ft^2 x 10 watts/ft^2 = 2500 watts or a 2.5 kW system

Roof-mounted and building integrated systems are most aesthetically-pleasing

Sizing an off-grid system

- Calculate the anticipated loads (handout) for each room…compile for home
- Factor in days of autonomy
- Determine the size of the battery bank
- Determine the size of solar array to charge the battery bank

Load Analysis Worksheet

- Worksheet available from website which can help calculate energy loads for off-grid applications
- “Awareness” tool to show how much energy is demanded

Colorado State University Extension – Home/Business Electrical Load Analysis
Kurt M. Jones, Chaffee/Park County Extension Director
November, 2009

This worksheet can be used to conduct an energy usage assessment by evaluating electrical loads (lights, appliances, etc.) around the home or business. Electrical loads are classified as AC (Alternating Current) or DC (Direct Current). When sizing an off-grid alternative energy system, this analysis can help the designer size your system correctly. Every attempt should be made to be as energy efficient as possible prior to investing in an alternative energy system (Solar, Wind, etc.).

Location ____________________ Load Analysis AC or DC (Circle One...use additional sheet for DC load analysis)

Load	Volts		Amps		Watts		Quantity		Total Watts		Hours/Day Used		Days/Week Used		Days/ week		Avg. Daily Watt Hours
Example -- Bulbs		X		=	60	X	8	=	480	X	3.5	X	6	/	7	=	1,440
Ex. -- Water Heater	115	X	39.13	=	4500	X	1	=	4500	X	6	X	7	/	7	=	27,000
		X		=		X		=		X		X		/	7	=	
		X		=		X		=		X		X		/	7	=	
		X		=		X		=		X		X		/	7	=	
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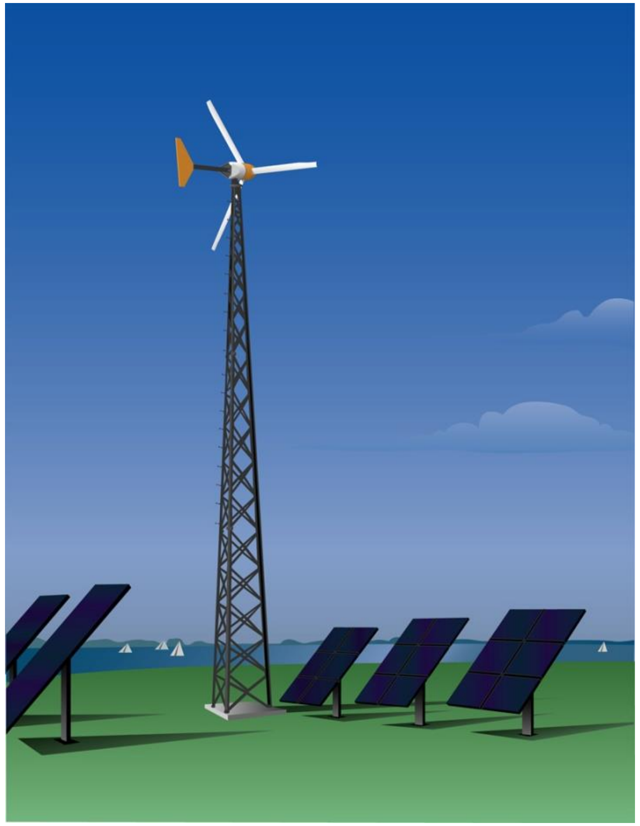
		X		=		X		=		X		X		/	7	=	
		X		=		X		=		X		X		/	7	=	
		X		=		X		=		X		X		/	7	=	
							Total Connected Watts								Total Daily Watt-Hours		

What about backup?

- Most off-grid applications will incorporate a hybrid system (wind, generator, micro-hydro)
- Solar array is sized for daily loads (batteries do not assume full-charge on first day of sunshine)
- Lowers days of autonomy and increases solar radiation value



What questions do you have about <u>sizing PV solar systems?</u>

Sizing Domestic Hot Water

- As a general rule of thumb, each member of a household demands 20 gallons of hot water per day
  - Family of 4 = 80 gallons
- Key is to calculate the amount of energy needed to heat this supply of water from source temp to final temp

Sample Calculation

Scenario

- Conservative family of 4 in Fort Collins uses 60 gallons of hot water daily
- Source water temp is 45° F and desired temp is 120° F
- Designer decides to use Sun Earth EC-40 panels at latitude + 15° (55° tilt) facing south
- Designer assumes 15% heat losses throughout system

Calculations:

- Energy Formula
  - Energy= volume * density * specific heat * temp change
  - $Q = V * \rho * C * \Delta T$
  - Q = 60 gal * 8.33 lbm/gal * 1.0 Btu/lbm °F * 75° F
  - Q = 37,485 Btu
  - Q = 38 kBtu
- Next need to look at PV Watts to determine insolation values

Sample Calculation

- PV Watts for Fort Collins (80521 zip)
  - Best month Sept. 5.79 kWh/day
  - Worst Nov. 4.51 kWh/day
- Convert kWh/day into Btu/ft^2 day
  - Formula: kWh * 317 = Btu/ft^2 day
  - Best: 1835 Btu/ft^2 day
  - Worst : 1430 Btu/ft^2 day
- Utilizing testing data on chosen panel:
  - 44 kBtu/day in Sept
  - 16 kBtu/day in Nov

Sample Calculation

- Utilizing testing data on chosen panel:
  - 44 kBtu/day in Sept
  - 16 kBtu/day in Nov
- Factor in inefficiencies
  - 44 * .85 (15% losses) = 37 kBtu/day
  - 16 * .85 = 13.6 kBtu/day
- Demand is 38 kBtu/day
  - Sept. - 1 panel = 97% of demand
  - Nov. - 1 panel = 36% of demand

Sizing of storage tanks

- Generally looking at 1½ to 2 gallons of storage per square foot of collector
- Sun Earth EC-40 panel is about 41 ft^2
- So 1 panel requires 80 gallons of storage minimum, 2 panels require 160 gallons of storage capacity

Final Answer

- So in our scenario:
  - They can offset their hot water heating energy usage throughout the year with one panel and 80 gallons of storage

OR

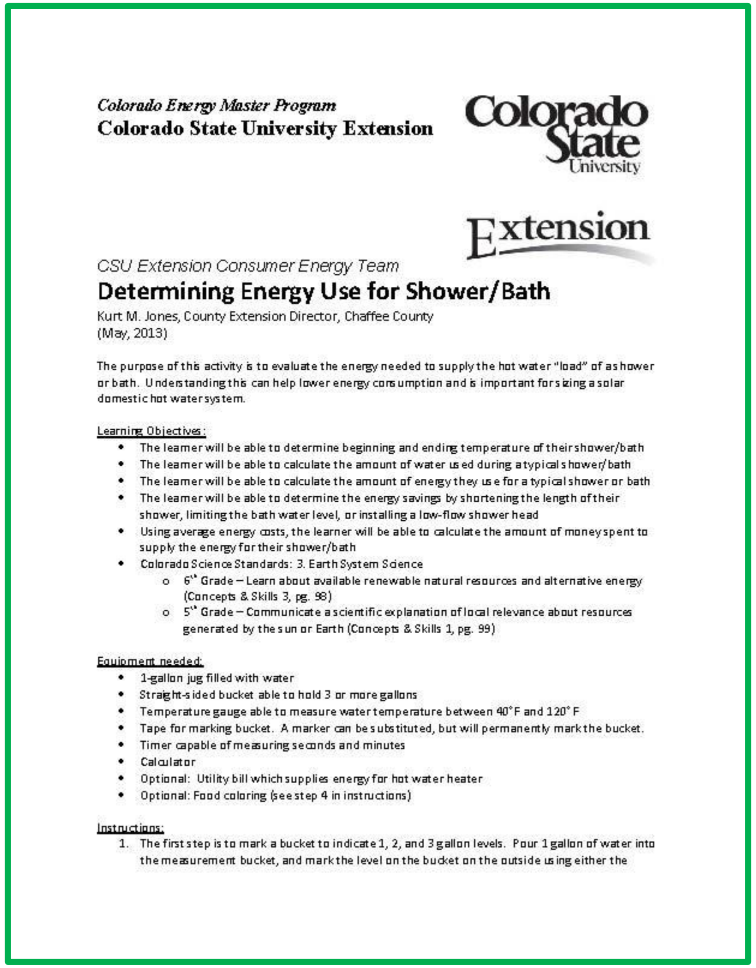
  - They can use two panels with 160 gallons of storage, overproducing in summer months and offsetting in the winter

OR

  - Play with tilt angles, collectors chosen, lower demand, explore partial shading of collector in summer months, or…

Shower/Bath Energy Use

- Hands-on activity for use with middle/high school students or adult community groups.
- Fun to predict and then compare the energy needed for the "typical" shower or bath of participants.



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Determining Energy Use for Shower/Bath

Kurt M. Jones, County Extension Director, Chaffee County
(May, 2013)

The purpose of this activity is to evaluate the energy needed to supply the hot water "load" of a shower or bath. Understanding this can help lower energy consumption and is important for sizing a solar domestic hot water system.

Learning Objectives:

- The learner will be able to determine beginning and ending temperature of their shower/bath
- The learner will be able to calculate the amount of water used during a typical shower/bath
- The learner will be able to calculate the amount of energy they use for a typical shower or bath
- The learner will be able to determine the energy savings by shortening the length of their shower, limiting the bath water level, or installing a low-flow shower head
- Using average energy costs, the learner will be able to calculate the amount of money spent to supply the energy for their shower/bath
- Colorado Science Standards: 3. Earth System Science
  - 6th Grade – Learn about available renewable natural resources and alternative energy (Concepts & Skills 3, pg. 98)
  - 5th Grade – Communicate a scientific explanation of local relevance about resources generated by the sun or Earth (Concepts & Skills 1, pg. 99)

Equipment needed:

- 1-gallon jug filled with water
- Straight-sided bucket able to hold 3 or more gallons
- Temperature gauge able to measure water temperature between 40°F and 120°F
- Tape for marking bucket. A marker can be substituted, but will permanently mark the bucket.
- Timer capable of measuring seconds and minutes
- Calculator
- Optional: Utility bill which supplies energy for hot water heater
- Optional: Food coloring (see step 4 in instructions)

Instructions:

1. The first step is to mark a bucket to indicate 1, 2, and 3 gallon levels. Pour 1 gallon of water into the measurement bucket, and mark the level on the bucket on the outside using either the

What questions do you have about <u>sizing thermal solar systems?</u>

Break!!

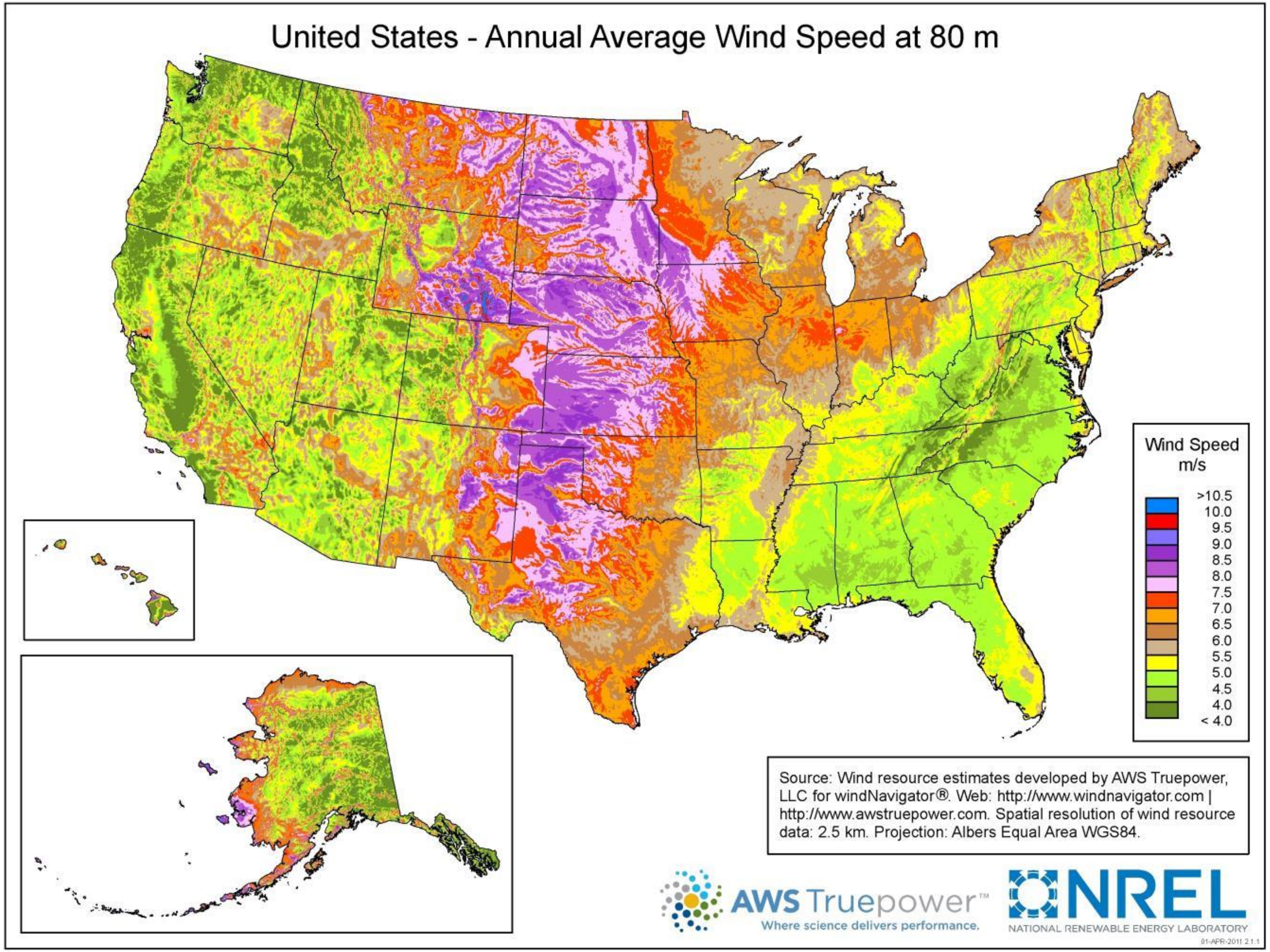
- Let's Take 10 minutes

Wind Energy

Irene Shonle
CSU Extension in Gilpin County

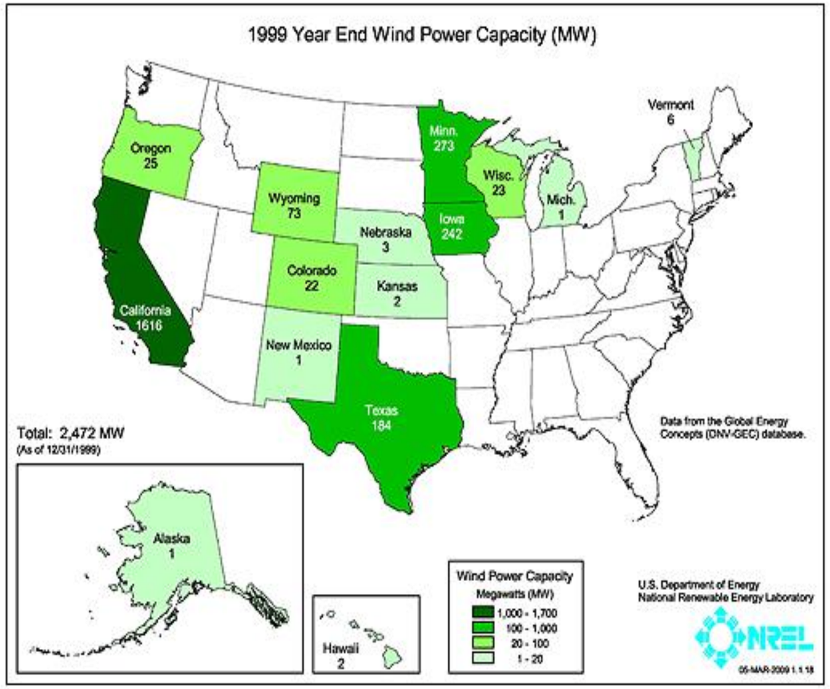
Why wind?

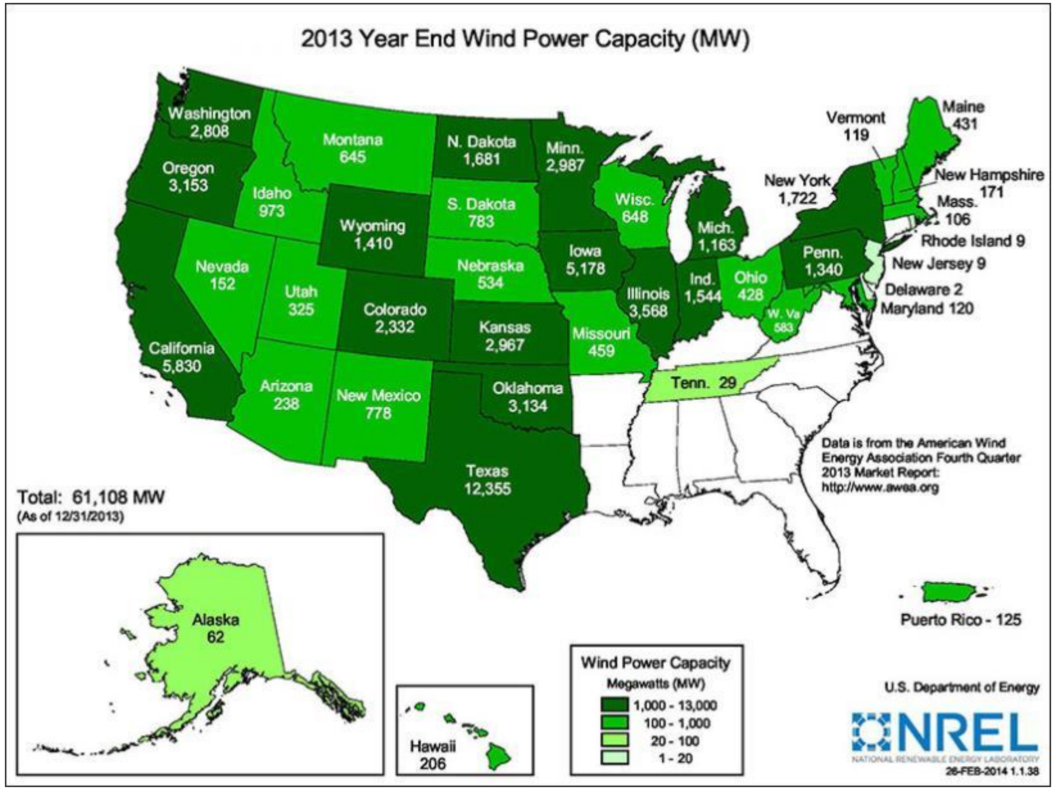
- Emissions-free, non-depleatable electricity
- Fuel cost will never increase
- Job creation/rural economic development
- Domestic power source



United States - Annual Average Wind Speed at 80 m
Wind Speed m/s
>10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
< 4.0
Source: Wind resource estimates developed by AWS Truepower, LLC for windNavigator®. Web: http://www.windnavigator.com | http://www.awstruepower.com. Spatial resolution of wind resource data: 2.5 km. Projection: Albers Equal Area WGS84.
AWS Truepower™
Where science delivers performance.
NREL
NATIONAL RENEWABLE ENERGY LABORATORY

1999-2013 installed wind capacities (2,500 MW- 61,108 MW)





Wind capacity

- Wind power was the #1 new sources for electricity generating capacity in 2012
  - wind power provided 42% of all new generating capacity installed.
- In 2013, wind provided 30% of new US generating capacity
  - But for the first time, solar outpaced wind in 2013 on global market

- Renewables currently produce about 13% of all electricity in US

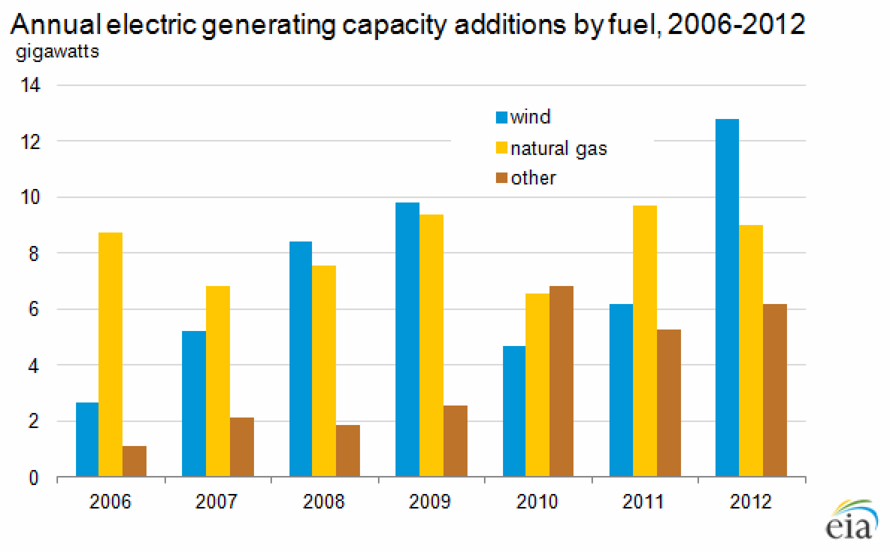


Chart from U.S. Energy Information Administration

Wind power today

- Wind energy installations power the equivalent of more than 15.5 million homes.
- American wind power reached major power generation milestones in 2013
  - 4% of U.S. electricity

National: 20% by 2030

(2008 report by DOE)

- US has affordable wind energy resources far in excess of those needed to enable a 20% scenario (no technological breakthroughs are needed)
- To implement:
  - new wind power installations would increase to more than 16,000 MW per year by 2018
  - continue at that rate through 2030

National: 20% by 2030

- The U.S. wind industry could support :
  - 500,000 jobs in the U.S.
    - > 150,000 workers directly employed by the wind industry
    - > 100,000 jobs in associated industries (e.g., accountants, lawyers, steel workers, and electrical manufacturing)
    - > 200,000 jobs through economic expansion based on local spending;
  - increase annual property tax revenues to more than $1.5 billion by 2030
  - increase annual payments to rural landowners to more than $600 million in 2030.

Major challenges to 20% wind

- Transmission systems for the increased supply
- Developing larger electric load balancing areas on regional basis
- Significant growth in the manufacturing supply chain
- Addressing potential concerns about local siting, wildlife, environmental issues, public acceptance

Credit: Warren Gretz, NREL
From EERE news

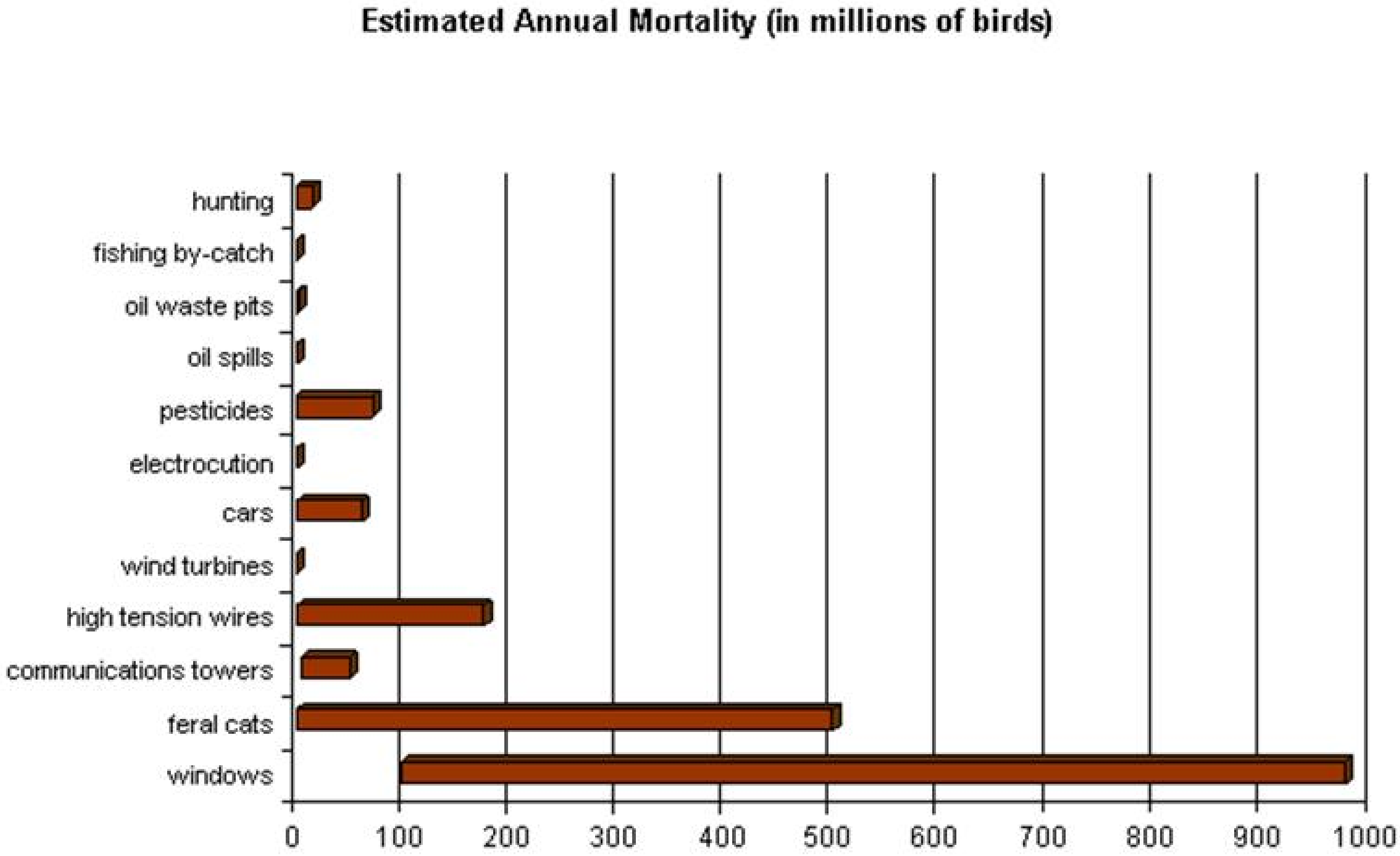
Growing public acceptance

- 10x as many positive attitudes towards wind energy than negative attitudes.
- Wind tourism on rise
  - People are paying to tour wind farms, hotels/b&bs are advertising their proximity to farms
  - (Ecotourism)

Birds and Bats

- Audubon Society supports properly sited wind power – the threat posed to birds by climate change is greater than turbines
  - Opposes new 30-year permits to kill and injure eagles
- Wind farms need to be planned, sited, and operated in ways that minimize harm to birds and bats
    - 2.9 - 8 birds are killed per turbine each year
    - Bigger turbines may have more impacts.
    - Impacts may increase as # turbines increase
- Reducing “cut in speed” during high risk times for bats may reduce mortality 50-87%

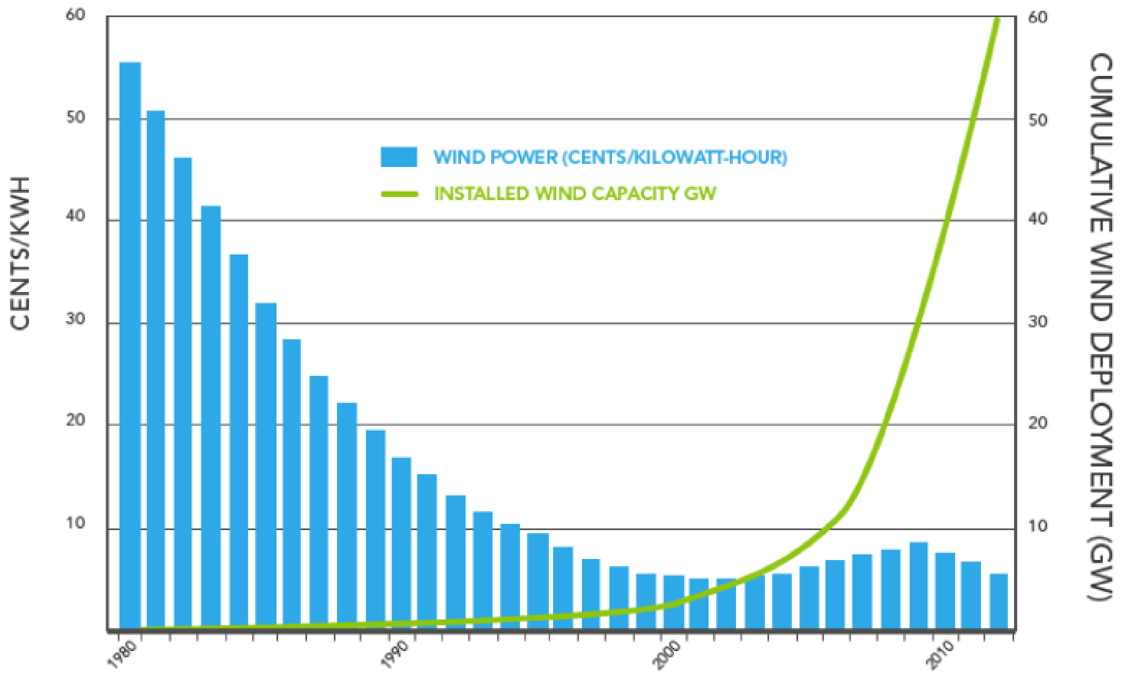
Causes of bird mortality



http://www.sibleyguides.com

Cost of wind declining

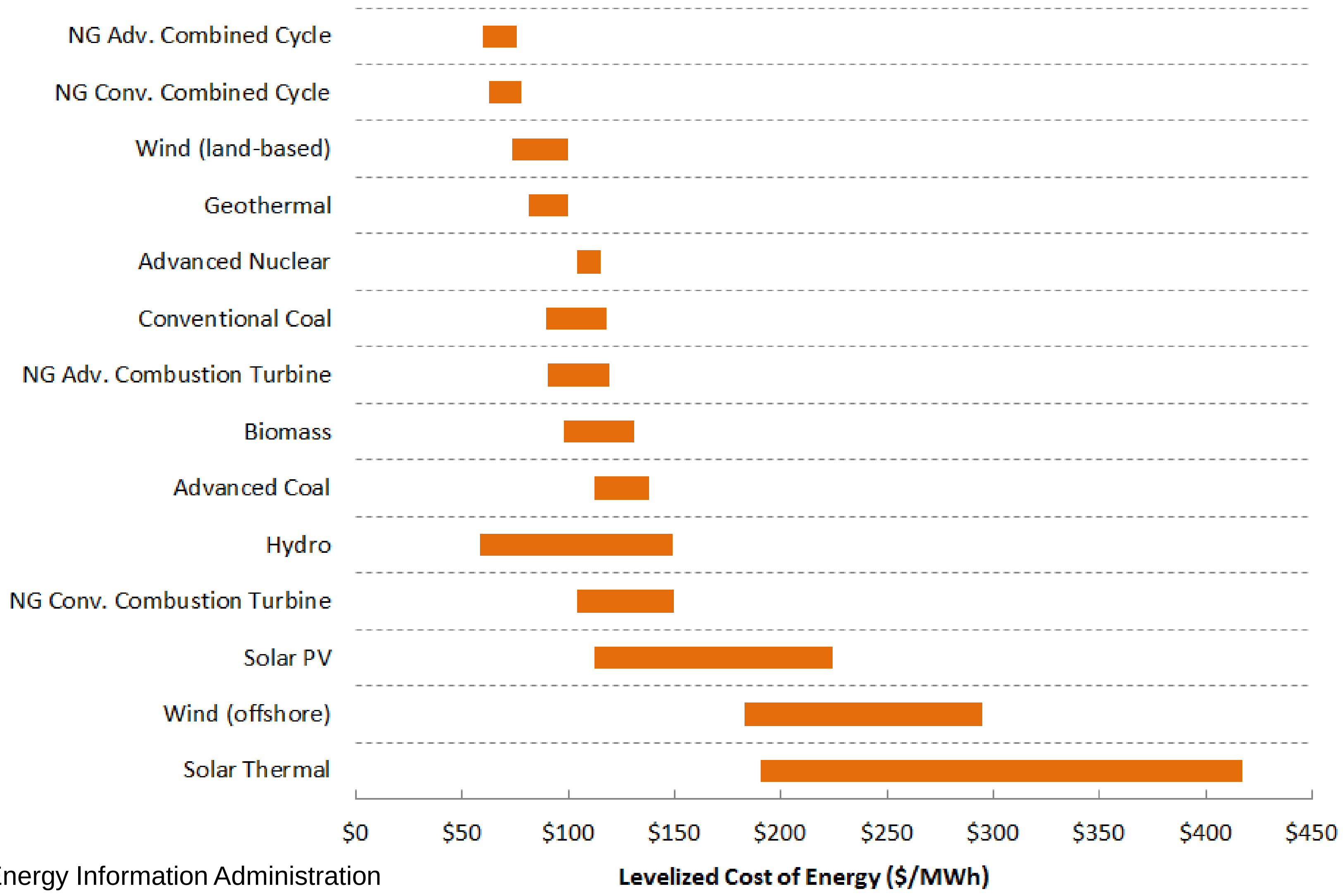
- Turbine prices have fallen 26 percent worldwide since 2009, 90% since 1980
  - wind power is within 5.5 percent of the cost of electricity from coal (source: Bloomberg. MidAmerican Energy Holdings Co.)



Utility perspective: wind as hedge

- *“Wind prices are extremely competitive right now, offering lower costs than other possible resources, like natural gas plants.* ***These projects offer a great hedge against rising and often volatile fuel prices***." - David Sparby, president & CEO of Xcel Energy’s Northern States Power announcing 600 MW of new wind power contracts on July 16, 2013.
- "*The latest addition of 150 megawatts of low-cost wind energy provides AECC with a* ***hedge against fluctuating natural gas energy prices*** *[…] We will continue to pursue energy options that allow AECC’s member cooperatives to provide reliable electricity at the lowest possible cost.”* - Duane Highley, president & CEO of Arkansas Electric Cooperative Corporation after signing a 150 MW contract July 22, 2013

Onshore wind energy & natural gas most affordable options for new electricity generation



The Energy Information Administration

Where wind power has shined!

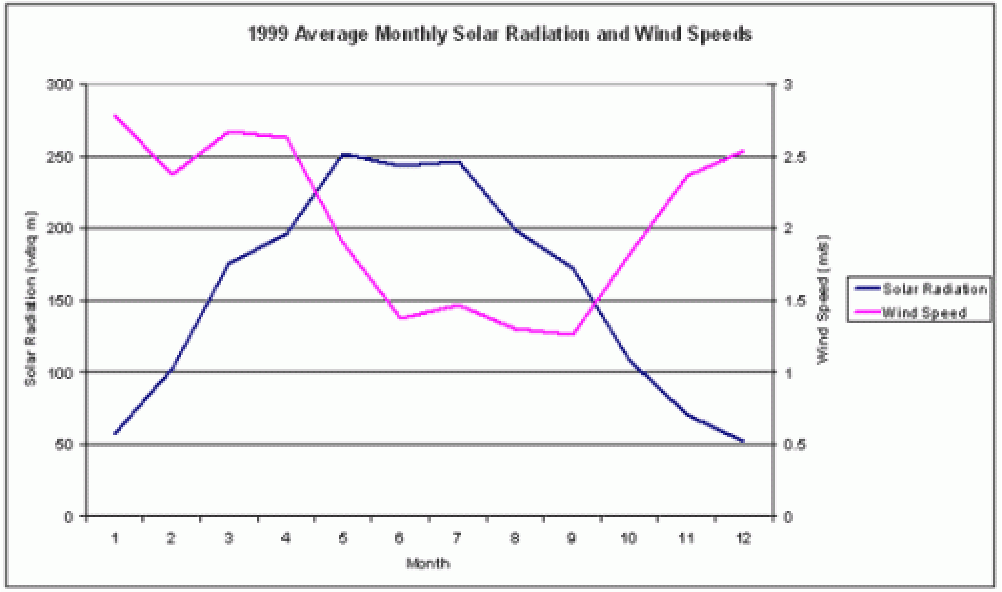
- Winter 2013-14 – record cold, natural gas shortages, power plant failures due to cold, record winter electricity demand
  - wind energy filled in supply gaps in regions with large wind energy capacity
  - At peak demand in late January, wind energy was saving $1.5 to $2 million per hour

Times when wind energy has flagged

- Texas heat 2011, 2012: record electrical demand (air conditioning)
  - high pressure systems stalled winds
  - Wind provided just 1.3% of demand, despite a 10% capacity

Wind and solar complementary

- Wind is often more productive in winter and at night
- Solar more productive in summer and during the day



Grid integration

- Wind energy can be ramped up or down to enhance system reliability
  - using wind farms to provide active power control is economically beneficial, negligible damage to the turbines
- Power plants can also be ramped up and down
  - The increase in plant emissions from cycling to accommodate variable renewables are more than offset by the overall reduction in CO_2, NO_x, and SO_2. In the high wind and solar scenario, net carbon emissions were reduced by one third.
    (NREL Western Wind and Solar Integration Study)

Distributed wind

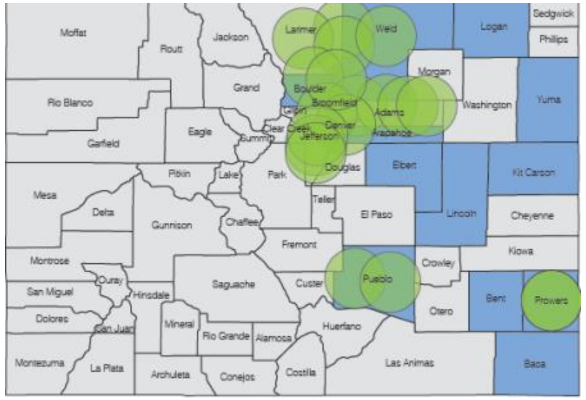
- 68 % (69,000 turbines, 812 MW) of all wind turbines in U.S. between 2003-2012 were distributed wind turbines
- 33% (3,800 turbines, 175 MW)of all wind turbines installed in the U.S. in 2012 were distributed wind turbines
  - 50 % decrease in distributed turbine installations but increase in power production of 62%

    -- Shift to larger turbines

Colorado – RE Bill 30% by 2020

- Colorado -- large utilities must obtain 30% of their power from renewable sources by 2020 (March 22, 2010)
- Electric cooperatives and municipal utilities (over 40,000 customers) must provide 10 percent of their retail electricity sales from renewables by 2020.

Colorado wind power 2013



- Currently online: 2,392 MW at 10 farms (870,000 homes)
- Percentage of electricity from wind 13.8% (up 2%)
- 10th highest % of power in US (down from 6th last year, wind resource is 13th)
- **Total direct and indirect jobs support in 2012**: 4000-5000.
- **Capital investment:** over $4.2 billion dollars
- **Annual land lease payments:** over $7,500,000
- 19 manufacturing facilities

Wind energy basics

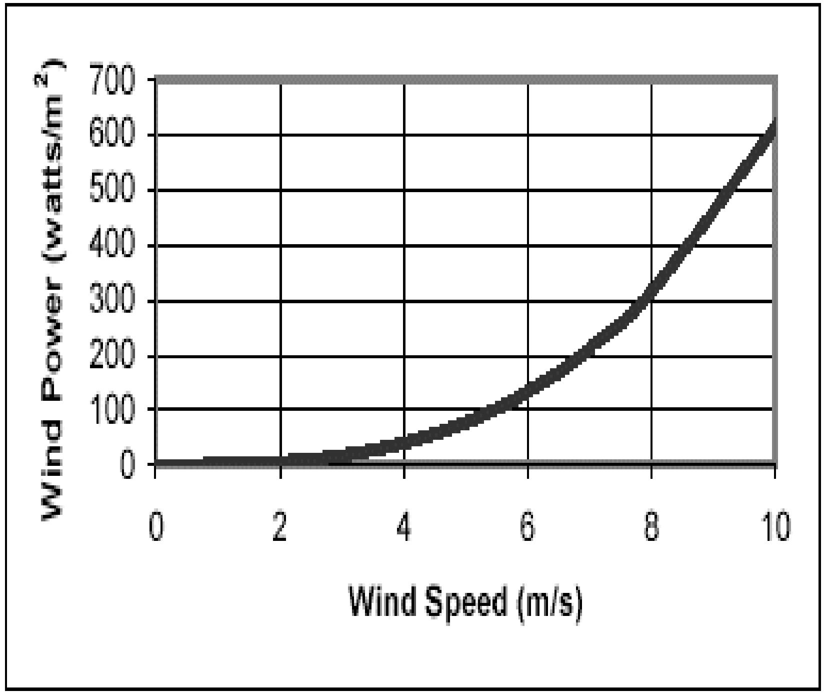
Power from the wind

Power in the Wind = $\frac{1}{2}\rho A V^3$

- Effect of air density, ρ
- Effect of swept area, A
- Effect of wind speed, V

Wind Speed (V)

- Most important part of equation
- Power is a *cubic* function of wind speed
  - **<u>V</u>** <u>x</u> **<u>V</u>** <u>x</u> **<u>V</u>**
  - 20% increase in wind speed means 73% more power
  - Doubling wind speed means 8 times more power

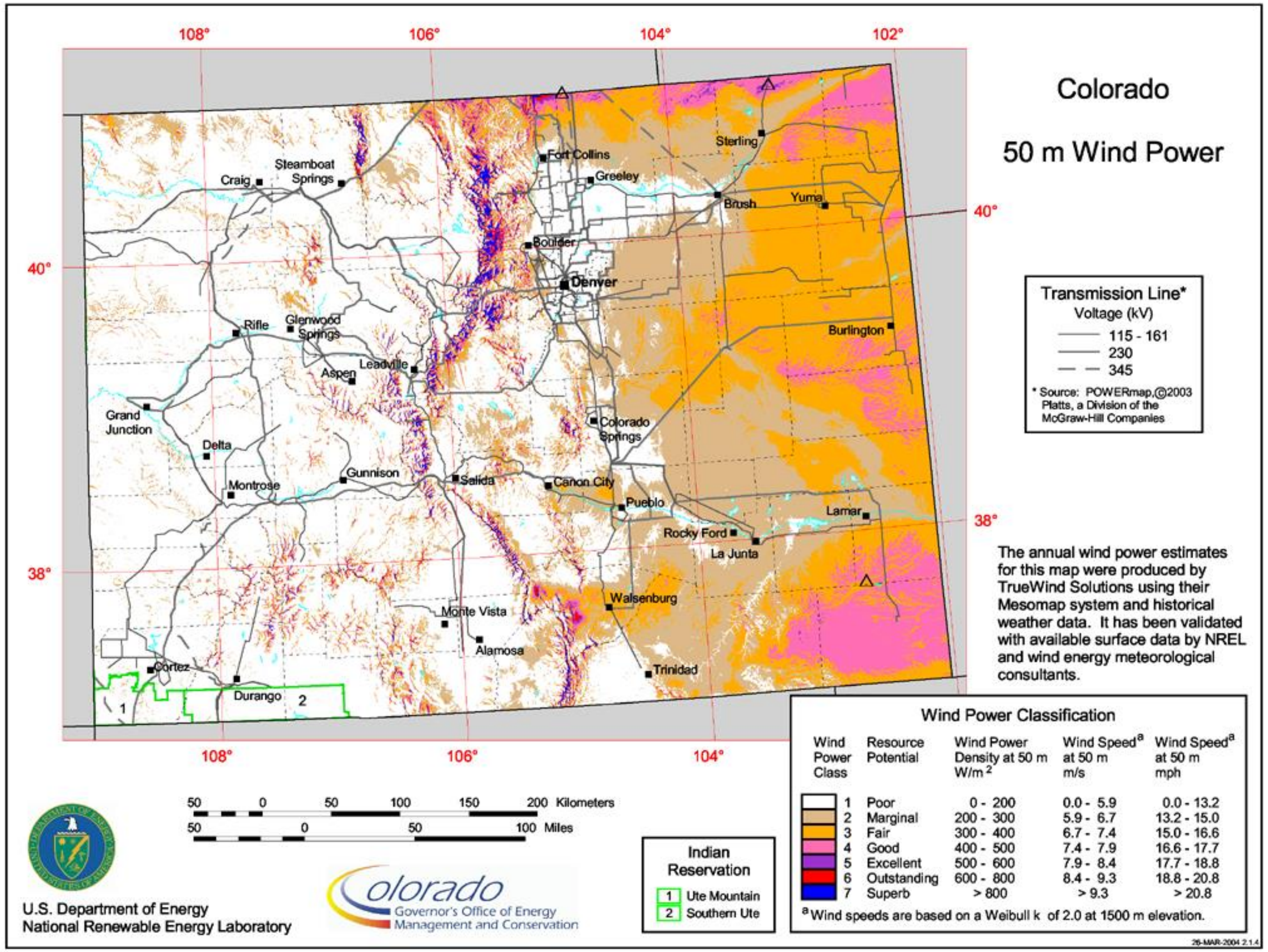


power =½ρAV^3

Effect of wind speed on production

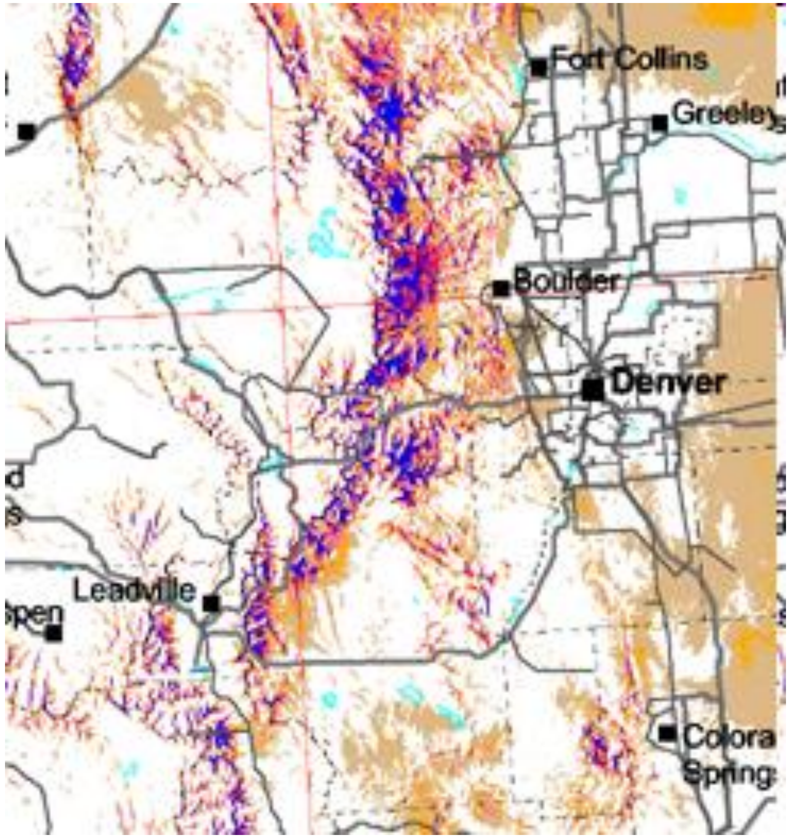
- Same turbine, two different wind regimes:
  - Yampa (8.3 mph)
    - 1200 kWh/year
  - Sheep Mtn: (18.4 mph)
    - 6,500 kWh/year

Take home lesson: put turbines in areas with a good wind regime



Colorado State University Extension Colorado Energy Master

Mountains have strong winds, but…



- Viewshed issues
- Roadless areas
- Forest Service issues
- Severe winter weather
- Costly to connect
- Difficult to access for maintenance

Economically viable projects:

Utility-scale projects: class 4+

Residential scale: class 2+

Wind Power Classes	10 m (33 ft)		50 m (164 ft)	
	Wind Power Density (W/m^2)	Average Wind Speed m/s (mph)	Wind Power Density (W/m2)	Average Wind Speed m/s (mph)
1	0-100	0-4.4 (0-9.8)	0-200	0-5.6 (0-12.5)
2	100-150	4.4-5.1 (9.8-11.5)	200-300	5.6-6.4 (12.5-14.3)
3	150-200	5.1-5.6 (11.5-12.5)	300-400	6.4-7.0 (14.3-15.7)
4	200-250	5.6-6.0 (12.5-13.4)	400-500	7.0-7.5 (15.7-16.8)
5	250-300	6.0-6.4 (13.4-14.3)	500-600	7.5-8.0 (6.8-17.9)
6	300-400	6.4-7.0 (14.3-15.7)	600-800	8.0-8.8 (17.9-19.7)
7	400-1,000	7.0-9.4 (15.7-21.1)	800-2,000	8.8-11.9 (19.7-26.6)

On-grid vs off grid needs

- On-grid: should have winds of 9-12 mph
- Off-grid 6 or 7mph

Estimating your wind resource

- People make very poor anemometers.
- Use projected or real data

Sources of Projected Wind Data

Wind Maps (Static and interactive)

• State wind maps: http://www.windpoweringamerica.gov/windmaps/residential_scale.asp

•Wind map US 30 m http://www.nrel.gov/gis/images/30m_US_Wind.jpg
•US wind map 80m http://www.nrel.gov/gis/images/80m_wind/USwind300dpe4-11.jpg

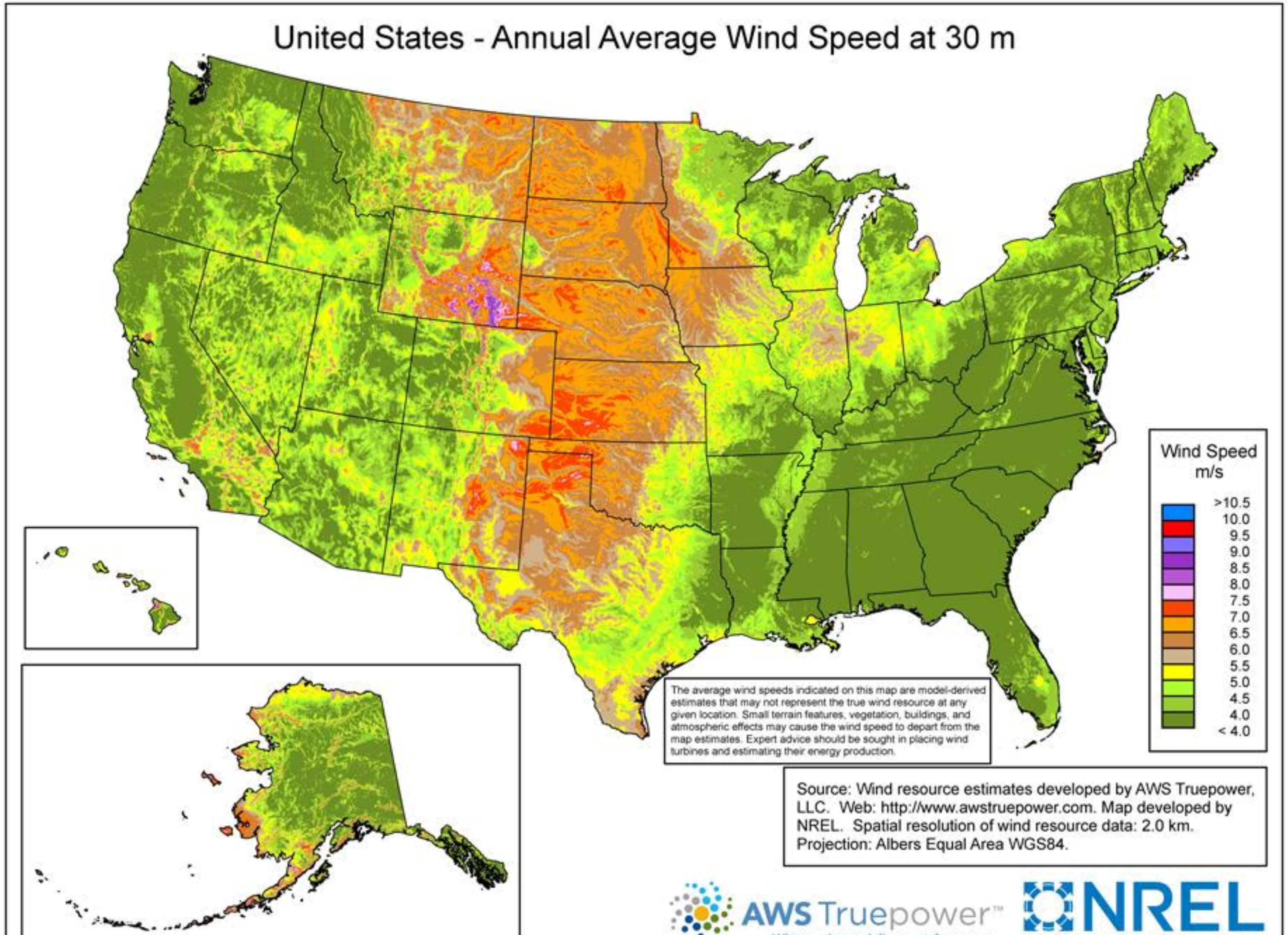
Sites that charge:

•3TIER First Look: http://firstlook.3tiergroup.com/

•AWS Truewind Wind Navigator: http://navigator.awstruewind.com/

The values assume good exposure to the wind

New! Wind speeds at lower hub heights for residential scale



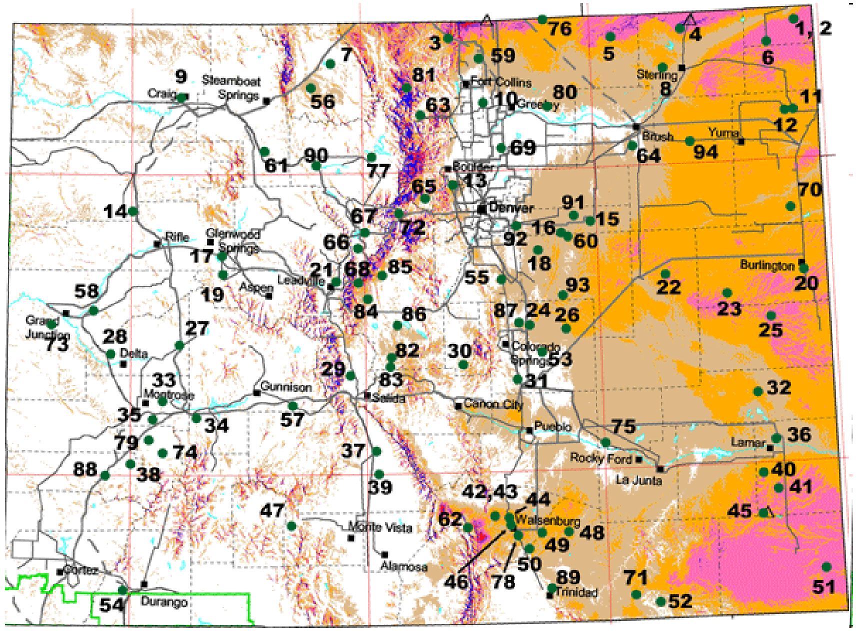
Extension
Colorado Energy Master

Realities of wind assessment with free projected data

- They use publicly available data
  - Accuracy varies
  - Difficult to know which data were used
  - May not know hub height of collection
  - Seasonality calculations can be off for mountainous regions
- Provide a “guesstimate” --uncertainties in the average wind speed values are significant!
  - could be off by a wind class or two (viable → not viable)

Sources of reliable data

- Anemometer loan program in Colorado run by CSU
- On-site “reality check” with an anemometer recommended if your project is 50-100kW



Colorado ALP program has data from 104 sites

Sticker Shock??

- As with any renewable energy investment, best return on dollars is on demand side of the equation rather than supply side
- Becoming energy-efficient is the first step in renewable energy
- Solar systems can be expanded upon later, provided initial installation accounts for future expansion

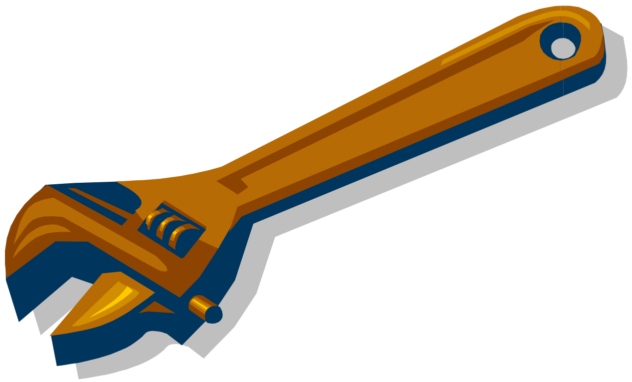
Financing the solar investment

- Grid-tied systems
  - Utility company rebates
  - Federal Income Tax credit (30%)
    - Dec. 31, 2016 expiration
  - Local incentives (sales/property tax exempt?)

Financing the solar investment (continued)

- Off-grid systems
  - Federal Income Tax credit (30%)
  - Local incentives (sales/property tax exempt?)
- http://www.dsireusa.org lists most of the incentive programs available. Easily searchable via postal zip code.

Evaluating the solar investment



- Tool is currently available
  - Revision underway
- Evaluates costs/benefits of a grid-tied solar system
- Customizable

Data needed prior to using…

PV Watts

Click on the site where you want to use PVWATTS to calculate the electrical energy produced. Choose the site nearest to your location that has similar topography. If near a state border, you may wish to review site locations in the adjacent state.

Colorado

- Annual Electricity usage
- Proposed system size
- Installed price quote (or can use $4-6.00/watt)
- Rebate info from utility company
- Anticipated solar electrical generation data (NREL-PVWatts)

PV Watts example 4.89kW system

AC Energy & Cost Savings

Cautions for Interpreting the Results

Station Identification	
City:	Boulder
State:	Colorado
Latitude:	40.02° N
Longitude:	105.25° W
Elevation:	1634 m
PV System Specifications	
DC Rating:	4.9 kW
DC to AC Derate Factor:	0.770
AC Rating:	3.8 kW
Array Type:	Fixed Tilt
Array Tilt:	40.0°
Array Azimuth:	180.0°
Energy Specifications	
Cost of Electricity:	8.4 ¢/kWh

Results			
Month	Solar Radiation ($kWh/m^2/day$)	AC Energy (kWh)	Energy Value ($)
1	4.43	522	43.85
2	4.89	511	42.92
3	6.05	689	57.88
4	6.09	647	54.35
5	5.99	640	53.76
6	6.08	612	51.41
7	6.06	614	51.58
8	6.24	634	53.26
9	6.25	631	53.00
10	5.67	615	51.66
11	4.60	514	43.18
12	4.29	505	42.42
Year	5.56	7133	599.17

FINANCIAL & ECONOMIC BENEFITS

PHOTOVOLTAIC GRID-TIED SYSTEM (Utility Based Rebate Formula)

This calculator may be used to determine the financial and economic benefits (or costs) of installing a photovoltaic grid-tied sytem to a residence. It relates only to grid-tied solar photovoltaic systems without battery systems. The calculator should not be used as the only aid in deciding whether or not to purchase and install a photovoltaic grid-tied system.

INSTALLATION COSTS

Size of System (Watts)	4,890
Installation Price ($/Watt)	$ 6.00
Rebate ($/Watt)	$ 1.75
Federal Incentive Rate	30%
Expected Life of System (years)	20
Cost of Installation	$ 29,340
Rebate	$ 8,558
Federal Tax Incentive	$ 6,235
Net Installed cost	$ 14,548

See Instructions Below

ANNUAL BENEFITS

Amount of Electricity Produced (kWH)	7,133	
Amount of Electricity Used (kWH)	8,002	
Cost Savings by Generating Electricity		$ 792
Electricity Savings (kWH)	7,133	
Rate ($/kWH)	$ 0.1110	
Revenues from Sales of Excess Electricity		$ -
Amount Sold (kWH)	0	
Rate ($/kWH)	$ 0.0280	
Net Annual Benefits		$ 792

ANNUAL CASH OUTFLOWS

Change In (Home) Insurance Premiums		$ 82
Rate	0.2800%	
Debt Payments (or Opportunity Costs)		$ 2,081
Amount Borrowed	$ 15,000	
Interest Rate	6.90%	
Term (Years)	10	
Monthly Payment	$ 173.39	
Total Annual Cash Outflows		$ 2,163

COST/BENEFIT ANALYSIS (life of system)

Net Installation Costs		$ 14,548
Maintenance Costs		$ 1,467
Percent of Initial System Cost	5.00%	
Additional (Home) Insurance Premiums		$ 2,207
Rate of Inflation	3.00%	
Total Interest Paid on "Loan"		$ 6,258
Total Costs		$ 24,480
Total Benefits		$26,180
Rate of Inflation	5.00%	
Net Financial Benefits		**$1,700**

This amount shows the return on investment over the system's useful life.

Increased Value of Home Due to System		$ 7,133
Rate of Increase ($/kWH Produced)	$ 1.00	
Net Economic Benefits		**$ 8,833**

This amount shows the return on investment plus the added value of the property realized at the sale of the property. It should be noted that the value of the system will decrease based on the age of the system and remaining useful life.

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Colorado State University is the land-grant university in Colorado. CSU Extension is the front door to the university providing information and education and encouraging the application of research-based knowledge in response to local, state, and national issues affecting individuals, youth, families, agricultural enterprises, and communities of Colorado. Extension has a presence in all 64 Colorado counties.

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See Instructions Below

ANNUAL BENEFITS

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Rate ($/kWH)	$ 0.0280	
Net Annual Benefits		$ 792

ANNUAL CASH OUTFLOWS

Change In (Home) Insurance Premiums		$ 82
Rate	0.2800%	
Debt Payments (or Opportunity Costs)		$ 1,608
Amount Borrowed	$ 15,000	
Interest Rate	6.90%	
Term (Years)	15	
Monthly Payment	$ 133.99	
Total Annual Cash Outflows		$ 1,690

COST/BENEFIT ANALYSIS (life of system)

Net Installation Costs		$ 14,548
Maintenance Costs		$ 1,467
Percent of Initial System Cost	5.00%	
Additional (Home) Insurance Premiums		$ 2,207
Rate of Inflation	3.00%	
Total Interest Paid on "Loan"		$ 9,548
Total Costs		$ 27,770
Total Benefits		$26,180
Rate of Inflation	5.00%	
Net Financial Benefits		**($1,590)**

This amount shows the return on investment over the system's useful life.

Increased Value of Home Due to System		$ 7,133
Rate of Increase ($/kWH Produced)	$ 1.00	
Net Economic Benefits		**$ 5,543**

This amount shows the return on investment plus the added value of the property realized at the sale of the property. It should be noted that the value of the system will decrease based on the age of the system and remaining useful life.

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Evaluating Other Technologies

- Evaluating off-grid investment is difficult
  - No other alternatives for comparison
  - Battery care is essential for long-term usefulness, replacement is expensive
- Solar Domestic Hot Water calculations are extensive and variable. Cost comparison depends on fuel source price.

What questions do you have about evaluating financials?

Trends

- Difficult to predict – Technology innovations and economics changing rapidly
- "Things I'm watching"
- CSU Extension Energy Face Book page – share current trends

Economies of Scale

- Solar on parity with coal-fired electrical generation
  - Power Purchase Agreement announced - $.04/kWH
- Larger Solar Systems
  - Moapa Southern Paiute, 250 MW (Nevada)
  - Sun Edison expansion (San Luis Valley)

Net-Metering Debate

- Current law states that customers receive full-credit for energy produced by grid-interactive systems
- Utilities making argument that the actual value is less than full retail
- If successful, this will greatly affect financial feasibility for distributed energy production

Tighter Financial Incentives

- Many utilities will meet their renewable energy portfolio standards ahead of schedule
- Many financial incentives are being scaled back
- Many argue the affordability of solar systems is due to these subsidies (both leased and customer-owned systems)

Research

- MIT – developed solar cell that shows higher efficiency (40%+)
- Battery efficiencies and reduced weight
- Innovations in system components

Explore the DIY calculator

- Navigate to http://www.ext.colostate.edu/energy/diy.html
  - Home Energy Audit
  - Ag Energy Audit
  - Solar PV
  - Wind

Sources of additional information

- Fact Sheets
  - 10.624 Harvesting Energy from the Sun: Photovoltaics
  - 10.627 Intro to Domestic Hot Water Systems
  - 10.623 Wind Energy for Colorado Home Owners, Farmers and Small Businesses
  - Coming: Off-Grid Solar Photovoltaic Systems
- Website

http://www.ext.colostate.edu/energy/solar.html

"Friend" us on Face Book: Colorado State University Extension -- Energy

Questions??

- Kurt Jones, 719-539-6447, kurt.jones@colostate.edu
- CSU Extension energy website http://www.ext.colostate.edu/energy/index.html