TEXAS A&M AGRILIFE EXTENSION

Renewable Energy for Landscape Irrigation Systems

Solar and Wind Pumping Workshop

Texas A&M School of Irrigation

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Agenda

- Current and Future Water Projections
- Projected Rise in Energy Cost
- Review of Irrigation System Hydraulics
- Determining Peak Water Requirements
- Solar Powered Pumping Plants
- Wind Mill Pumping Plants
- Limitations of Renewable Energy

2

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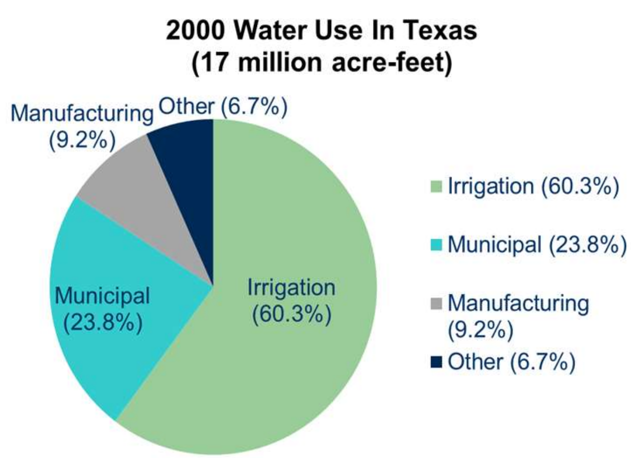

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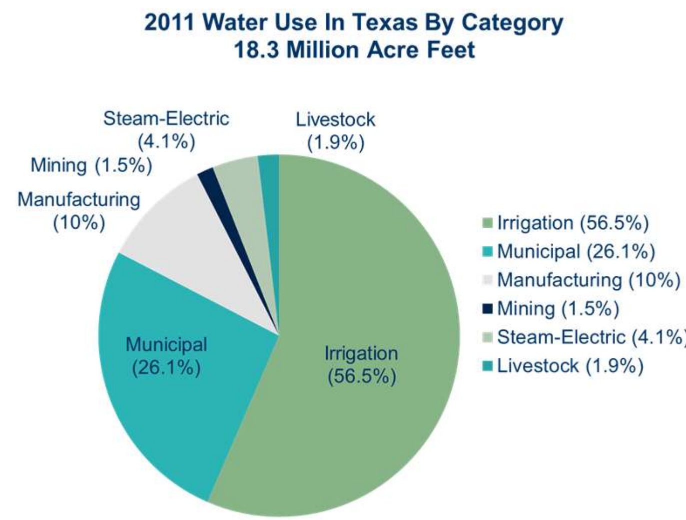

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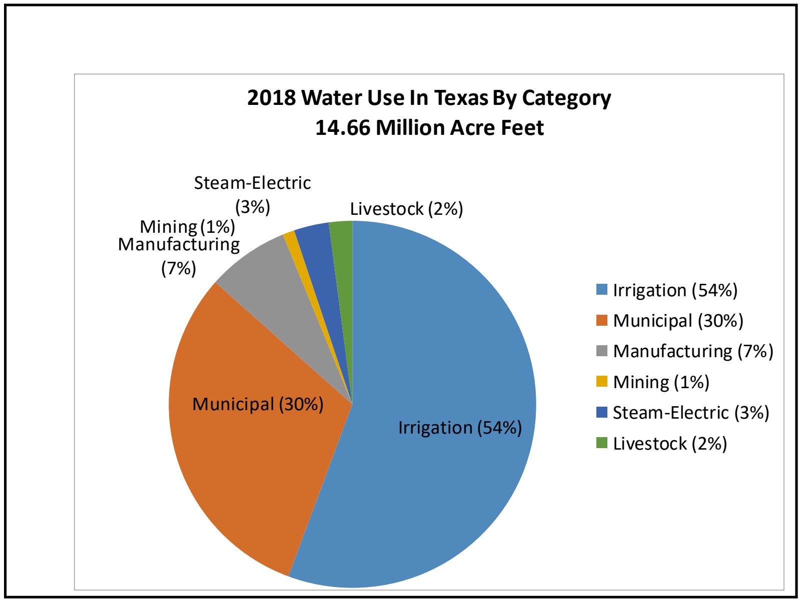
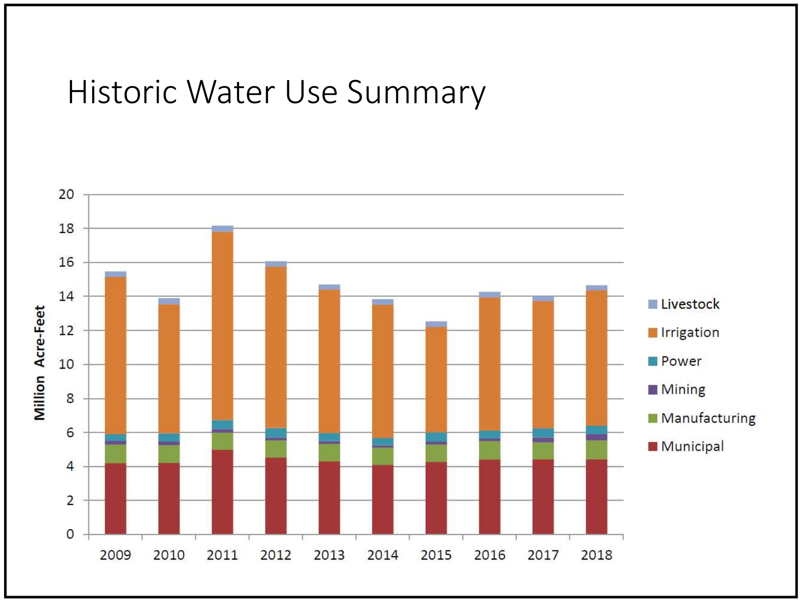
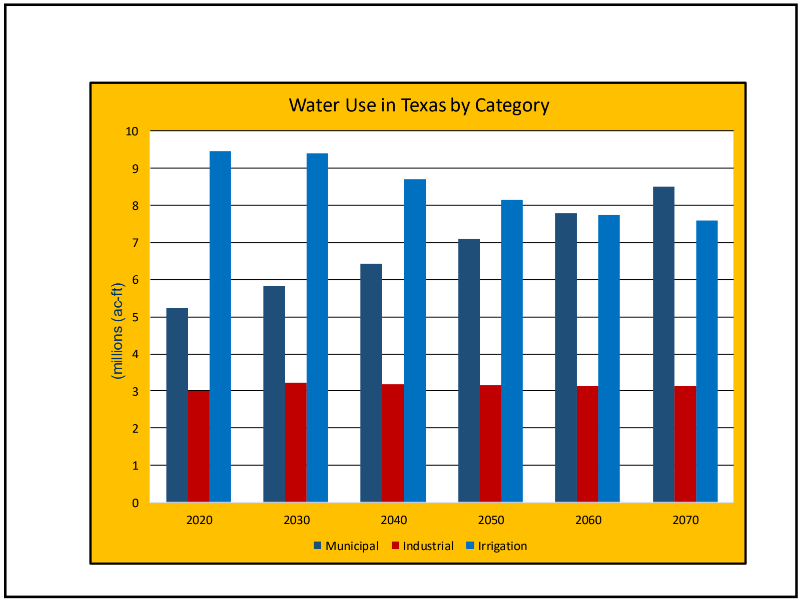

2018 Water Use In Texas By Category
14.66 Million Acre Feet
Steam-Electric (3%)
Livestock (2%)
Mining (1%)
Manufacturing (7%)
Municipal (30%)
Irrigation (54%)
Irrigation (54%)
Municipal (30%)
Manufacturing (7%)
Mining (1%)
Steam-Electric (3%)
Livestock (2%)

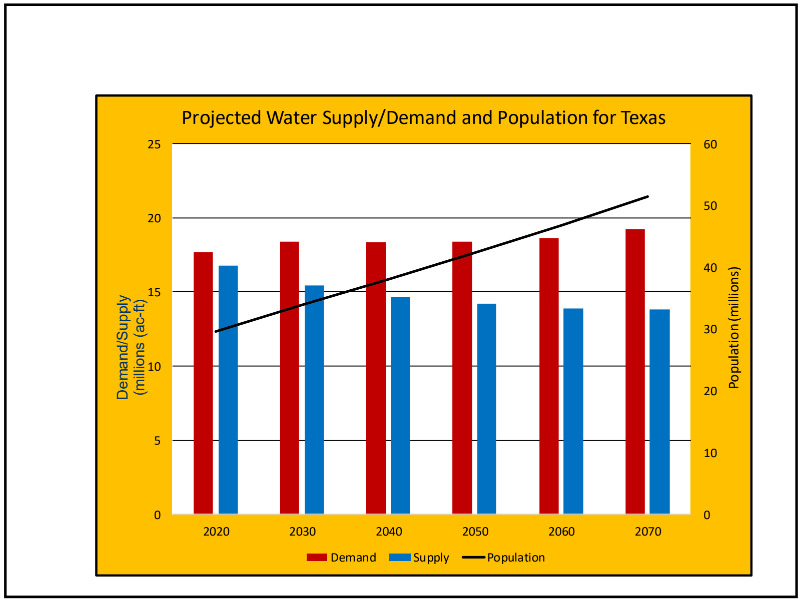
5


Historic Water Use Summary
Million Acre-Feet
20
18
16
14
12
10
8
6
4
2
0
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
Livestock
Irrigation
Power
Mining
Manufacturing
Municipal

6


Water Use in Texas by Category
(millions (ac-ft)
10
9
8
7
6
5
4
3
2
1
0
2020
2030
2040
2050
2060
2070
Municipal
Industrial
Irrigation

7


Projected Water Supply/Demand and Population for Texas
Demand/Supply (millions (ac-ft)
Population (millions)
25
20
15
10
5
0
60
50
40
30
20
10
0
2020
2030
2040
2050
2060
2070
Demand
Supply
Population

8

Water Planning in Texas

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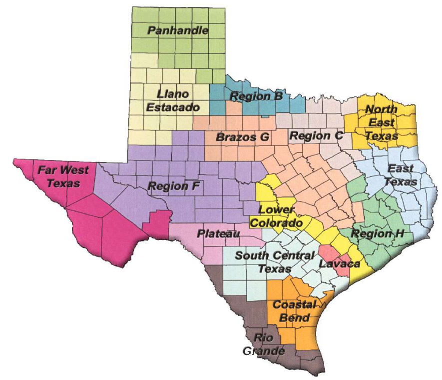
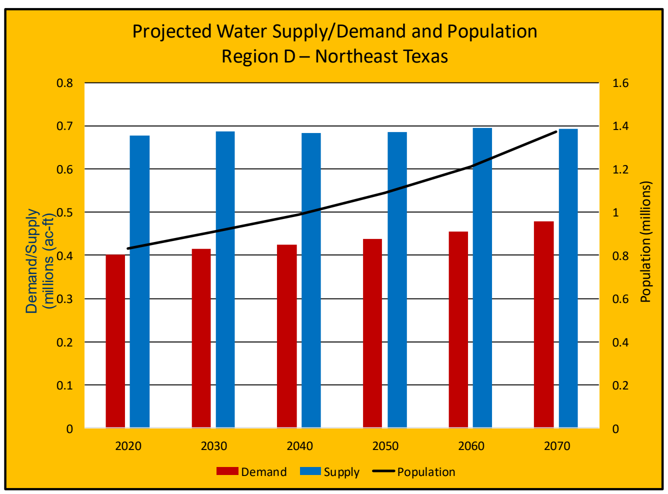
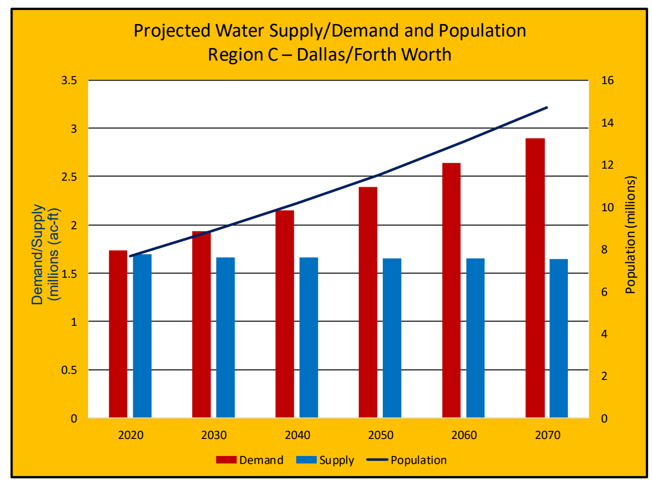
Figure 4-1: Location of the 16 regional water planning areas in Texas.



10



11



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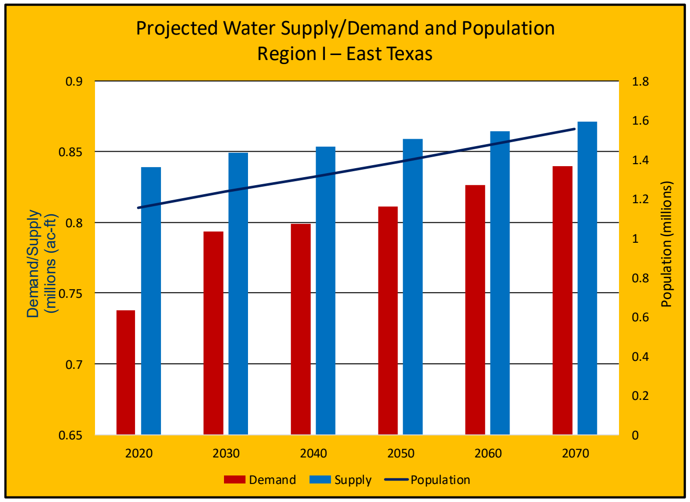
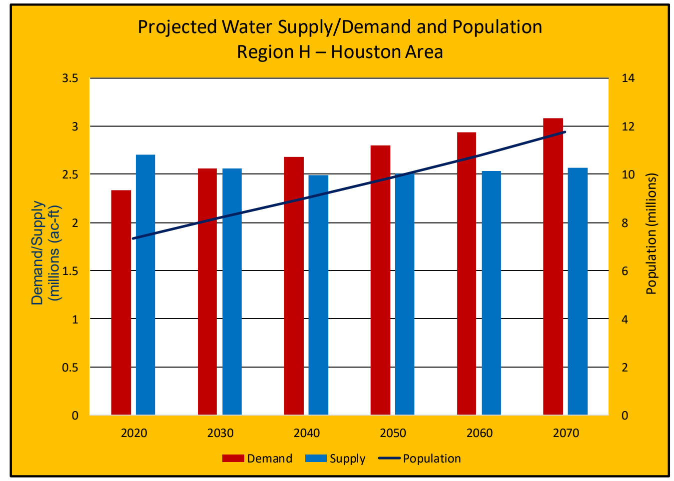


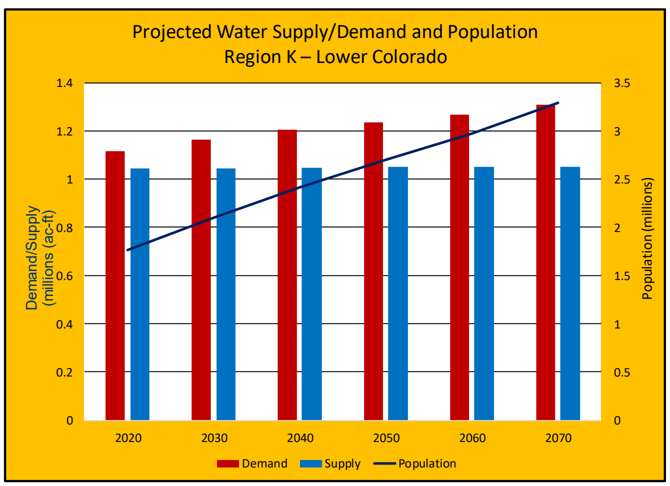
Projected Water Supply/Demand and Population
Region I – East Texas
Demand/Supply (millions (ac-ft)
Population (millions)
0.9
0.85
0.8
0.75
0.7
0.65
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
2020
2030
2040
2050
2060
2070
Demand
Supply
Population

13



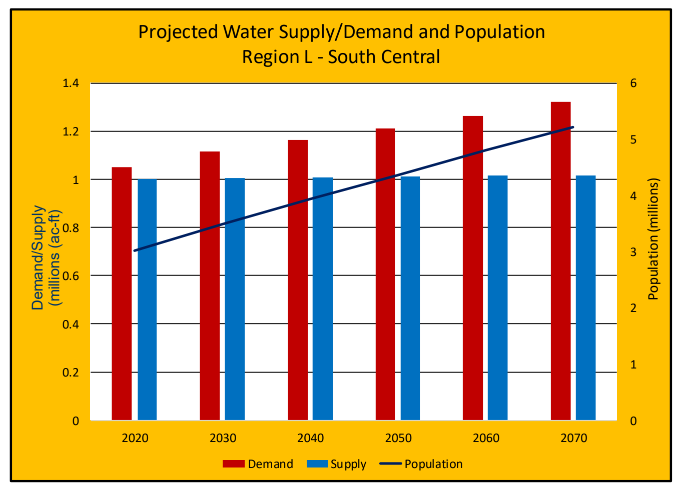
Projected Water Supply/Demand and Population
Region H – Houston Area
Demand/Supply (millions (ac-ft)
Population (millions)
3.5
3
2.5
2
1.5
1
0.5
0
14
12
10
8
6
4
2
0
2020
2030
2040
2050
2060
2070
Demand
Supply
Population

14



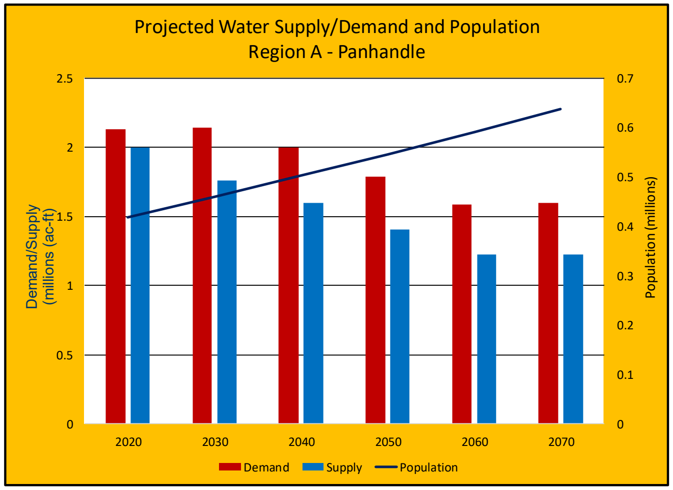
Projected Water Supply/Demand and Population
Region K – Lower Colorado
Demand/Supply (millions (ac-ft)
Population (millions)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
3.5
3
2.5
2
1.5
1
0.5
0
2020
2030
2040
2050
2060
2070
Demand
Supply
Population

15

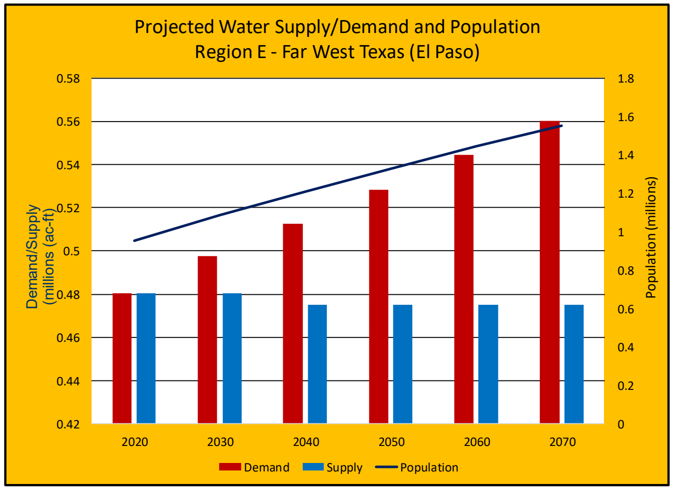


Projected Water Supply/Demand and Population
Region L - South Central
Demand/Supply (millions (ac-ft)
Population (millions)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
6
5
4
3
2
1
0
2020
2030
2040
2050
2060
2070
Demand
Supply
Population

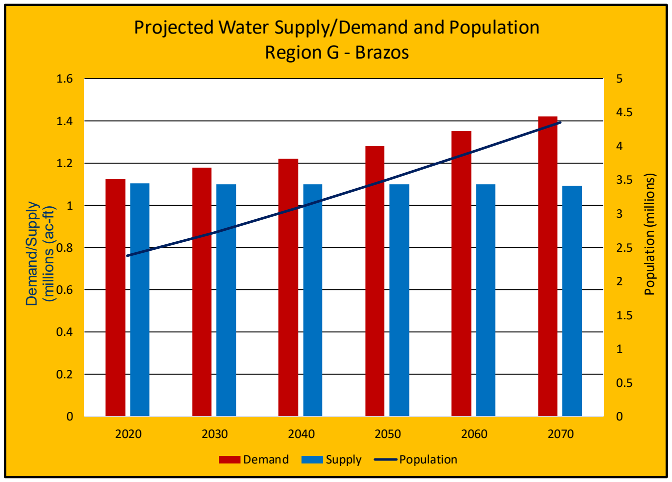
16


Projected Water Supply/Demand and Population
Region A - Panhandle
Demand/Supply (millions (ac-ft)
Population (millions)
0 0.5 1 1.5 2 2.5
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7
2020 2030 2040 2050 2060 2070
Demand Supply Population

17


Projected Water Supply/Demand and Population
Region E - Far West Texas (El Paso)
Demand/Supply (millions (ac-ft)
Population (millions)
0.42 0.44 0.46 0.48 0.5 0.52 0.54 0.56 0.58
0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8
2020 2030 2040 2050 2060 2070
Demand Supply Population

18


Projected Water Supply/Demand and Population
Region G - Brazos
Demand/Supply (millions (ac-ft)
Population (millions)
0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5
2020 2030 2040 2050 2060 2070
Demand Supply Population

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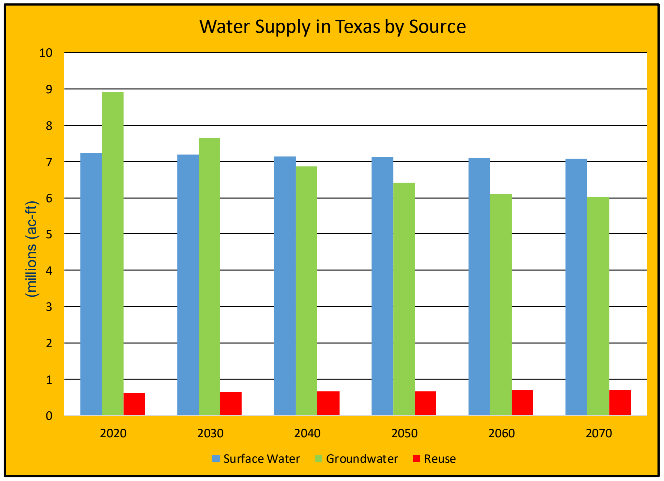
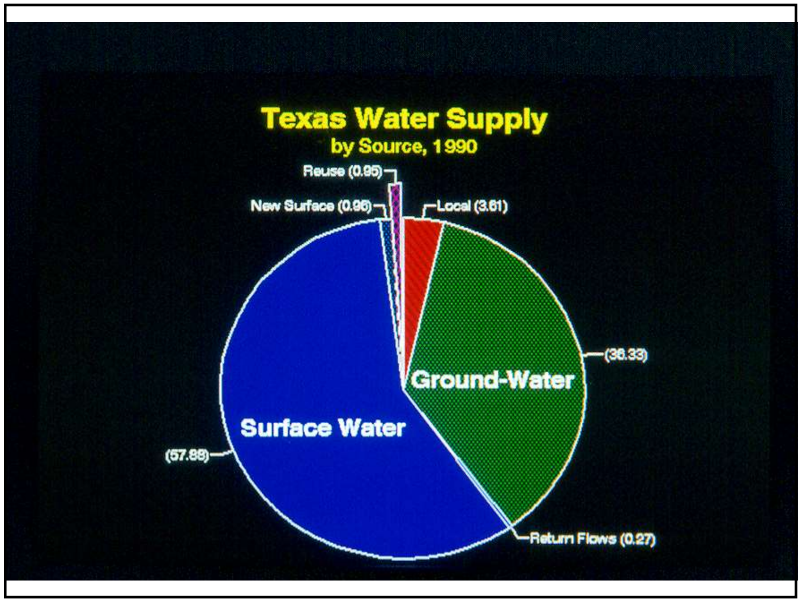
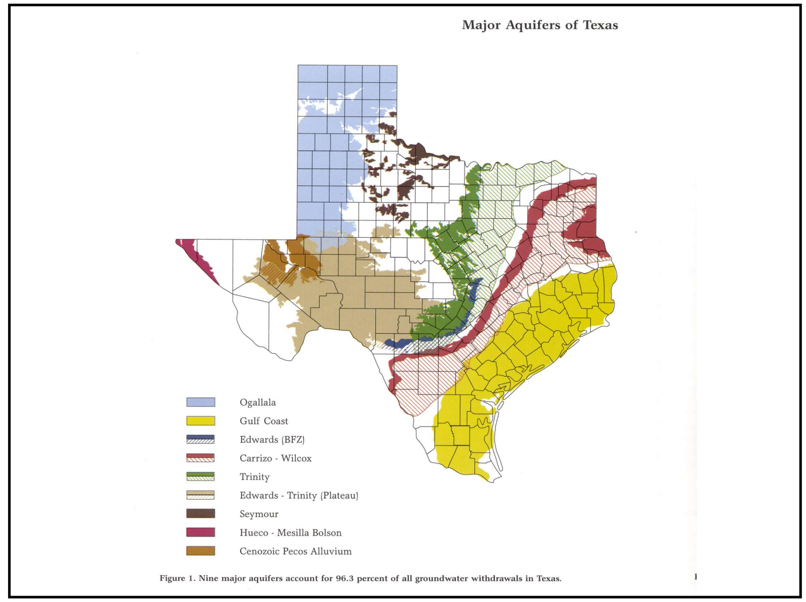

Water Supply in Texas by Source
(millions (ac-ft)
0 1 2 3 4 5 6 7 8 9 10
2020 2030 2040 2050 2060 2070
Surface Water Groundwater Reuse

20


Texas Water Supply
by Source, 1990
Reuse (0.95)
New Surface (0.96)
Local (3.61)
(36.33)
Ground-Water
Surface Water
(57.88)
Return Flows (0.27)

21


Major Aquifers of Texas
Ogallala
Gulf Coast
Edwards (BFZ)
Carrizo - Wilcox
Trinity
Edwards - Trinity (Plateau)
Seymour
Hueco - Mesilla Bolson
Cenozoic Pecos Alluvium
Figure 1. Nine major aquifers account for 96.3 percent of all groundwater withdrawals in Texas.

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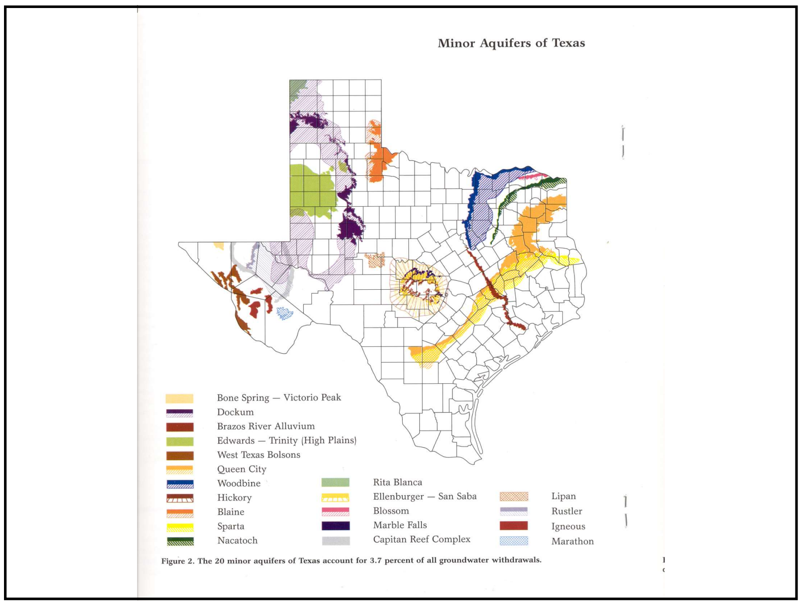
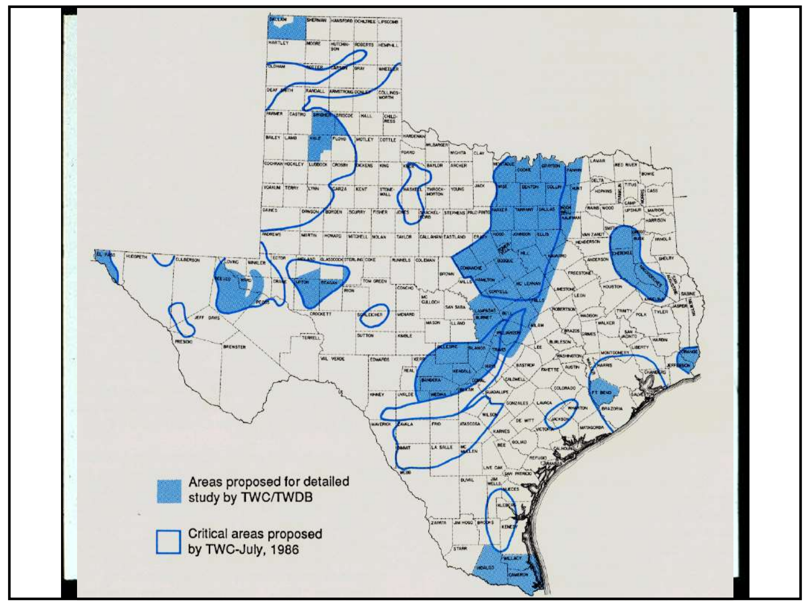

Minor Aquifers of Texas
Bone Spring — Victorio Peak
Dockum
Brazos River Alluvium
Edwards — Trinity (High Plains)
West Texas Bolsons
Queen City
Woodbine
Hickory
Blaine
Sparta
Nacatoch
Rita Blanca
Ellenburger — San Saba
Blossom
Marble Falls
Capitan Reef Complex
Lipan
Rustler
Igneous
Marathon
Figure 2. The 20 minor aquifers of Texas account for 3.7 percent of all groundwater withdrawals.

23


Areas proposed for detailed study by TWC/TWDB
Critical areas proposed by TWC-July, 1986

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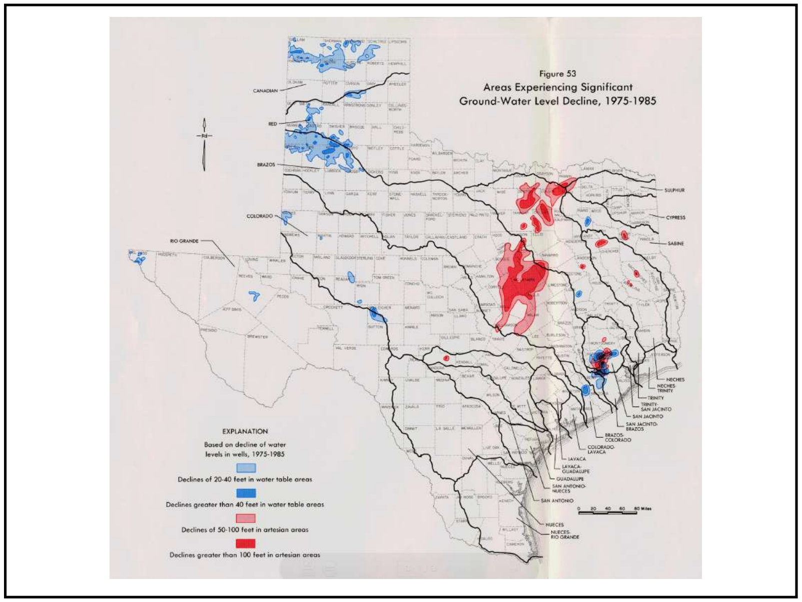
Figure 53
Areas Experiencing Significant Ground-Water Level Decline, 1975-1985
EXPLANATION
Based on decline of water levels in wells, 1975-1985
Declines of 20-40 feet in water table areas
Declines greater than 40 feet in water table areas
Declines of 50-100 feet in artesian areas
Declines greater than 100 feet in artesian areas

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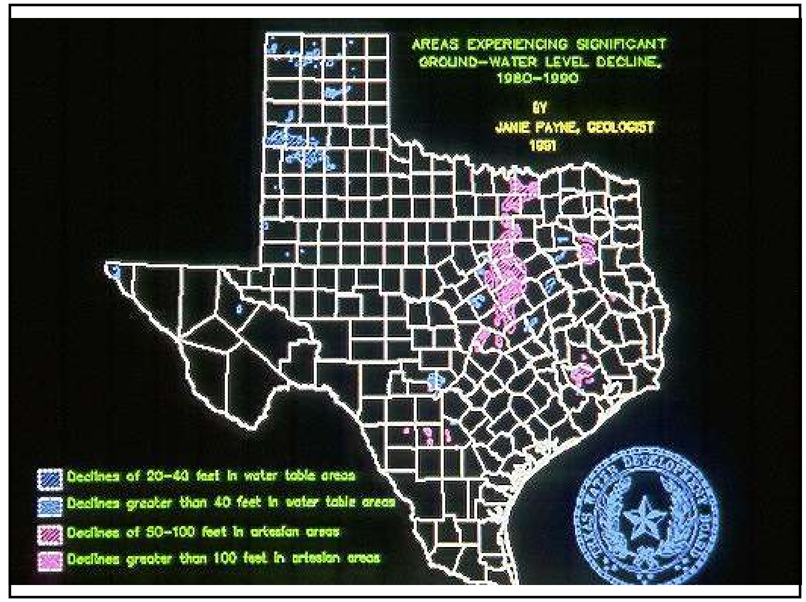
AREAS EXPERIENCING SIGNIFICANT GROUND-WATER LEVEL DECLINE, 1980-1990
BY
JANIE PAYNE, GEOLOGIST
1991
Declines of 20-40 feet in water table areas
Declines greater than 40 feet in water table areas
Declines of 50-100 feet in artesian areas
Declines greater than 100 feet in artesian areas

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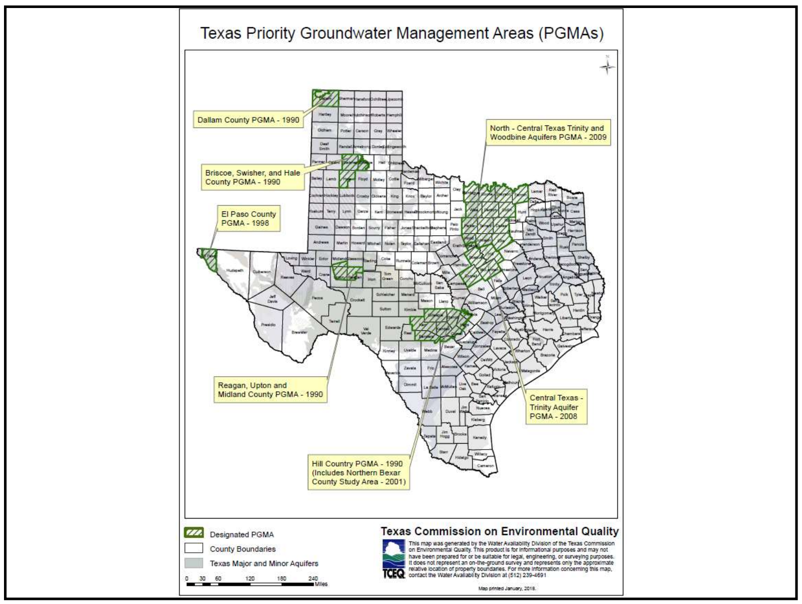
Texas Priority Groundwater Management Areas (PGMAs)
Dallam County PGMA - 1990
Briscoe, Swisher, and Hale County PGMA - 1990
El Paso County PGMA - 1998
North - Central Texas Trinity and Woodbine Aquifers PGMA - 2009
Reagan, Upton and Midland County PGMA - 1990
Central Texas - Trinity Aquifer PGMA - 2008
Hill Country PGMA - 1990 (Includes Northern Bexar County Study Area - 2001)
Designated PGMA
County Boundaries
Texas Major and Minor Aquifers
Texas Commission on Environmental Quality

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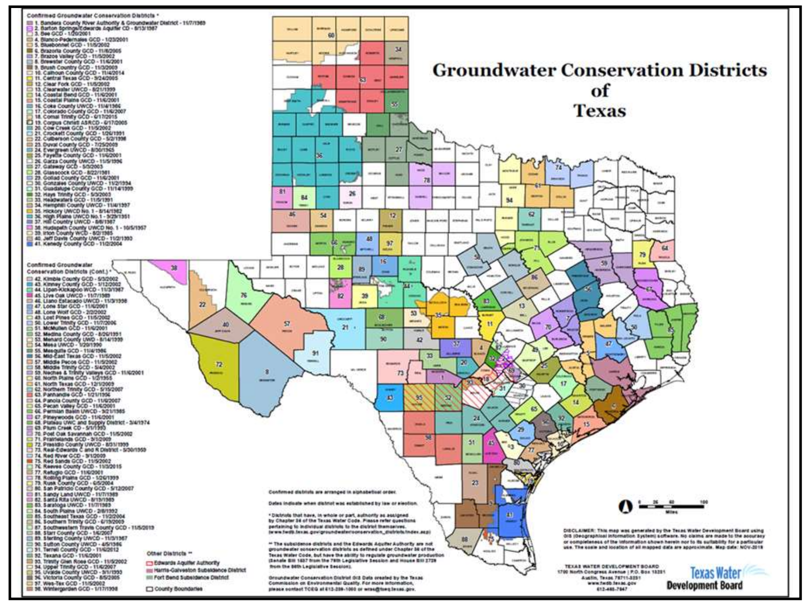
Groundwater Conservation Districts of Texas
Texas Water Development Board

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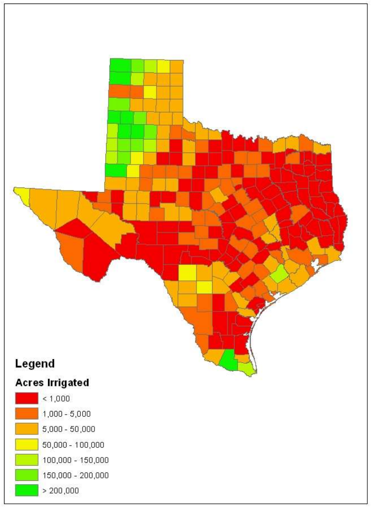
2009 Irrigated Acres By County



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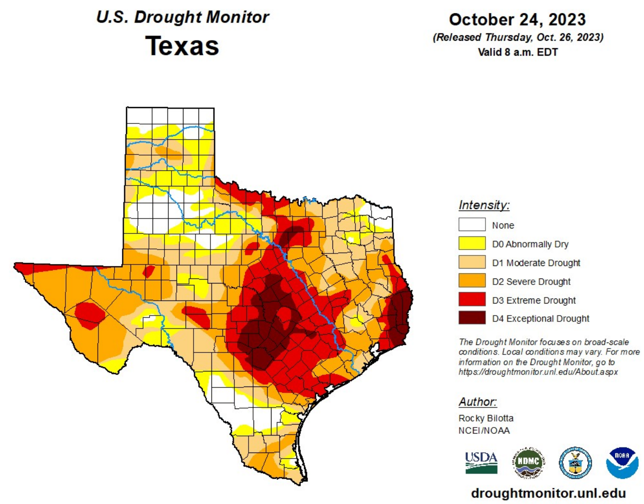
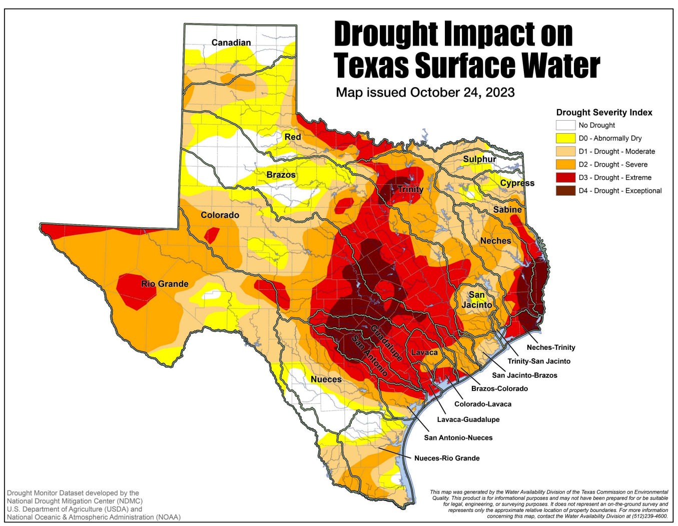


For Current Data, go to:
https://droughtmonitor.unl.edu/CurrentMap/StateDroughtMonitor.aspx?TX

30



For Current Map, go to:
https://www.tceq.texas.gov/downloads/response/images/drought-map.jpg

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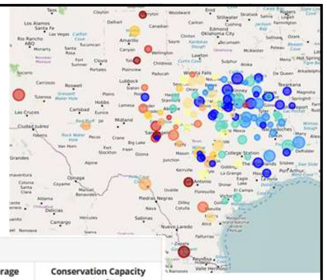
Texas Reservoir Status



Summary

	Date	Percent Full	Reservoir Storage (acre-ft)	Conservation Storage (acre-ft)	Conservation Capacity (acre-ft)
Today	2023-10-27	65.7	24,849,540	20,689,447	31,503,761
Yesterday	2023-10-26	65.2	24,683,587	20,532,858	31,503,761
2 days ago	2023-10-25	64.5	24,465,751	20,332,420	31,503,761
1 week ago	2023-10-20	64.7	24,530,516	20,378,510	31,503,761
1 month ago	2023-09-27	66.2	25,038,970	20,937,571	31,627,391
3 months ago	2023-07-27	73.5	27,899,076	23,249,544	31,627,391
6 months ago	2023-04-27	75.6	28,561,470	23,984,371	31,723,561
1 year ago	2022-10-27	67.3	25,583,397	21,195,714	31,503,761

* Percent Full is based on Conservation Storage and Conservation Capacity and doesn't account for storage in flood pool.

** Water supply reservoirs include reservoirs which provide water for all beneficial purposes such as power generation, recreation, and municipal water supply. Today's total is subject to change as data are updated. See footnotes on individual lakes for cases where special conditions apply.

For Current Data, go to
http://waterdatafortexas.org/reservoirs/statewide

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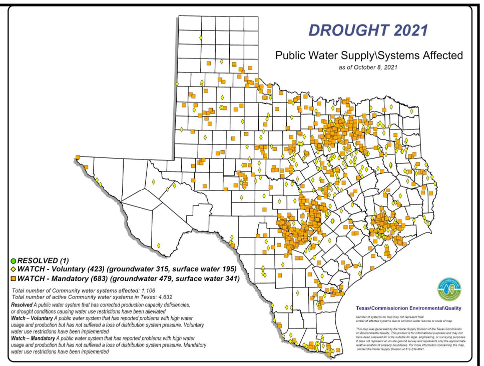

As of 10/27/23

TCEQ Drought Response, Water Restrictions Level	# PWS
Voluntary	116
Stage 1	235
Stage 2	84
Stage 3	92

*Note due to the number of Public Water Systems currently reporting restrictions, TCEQ no longer produces a map but maintains a weekly updated list on their website at https://www.tceq.texas.gov/drinkingwater/trot/droughtw.html

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Why Use renewable Energy?????

Solar and Wind Power

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Why Use Wind or Solar Power?

- May not have conventional power sources available at a site
- May want a "Green" solution for an irrigation system
  - Seeking LEED or WaterSense Accreditation for a site?

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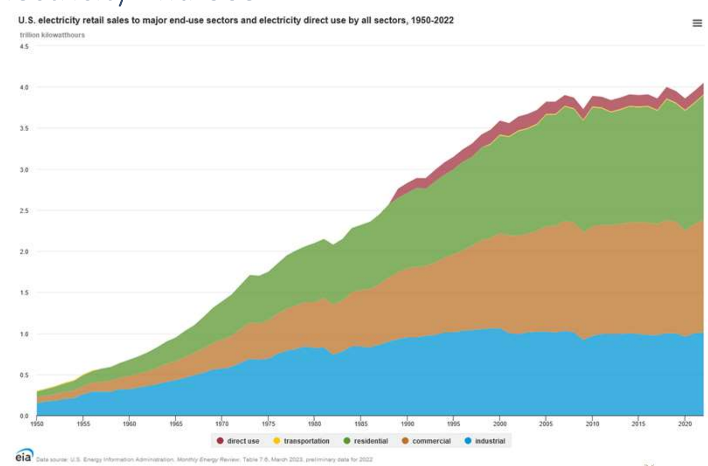
Electricity End Use



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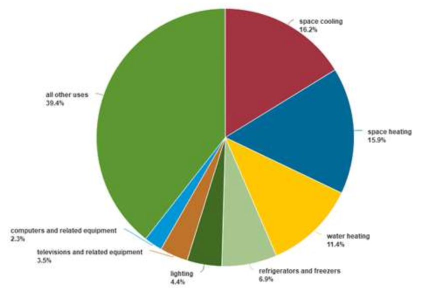
Electricity End Use

U.S. residential sector electricity consumption by major end uses, 2022



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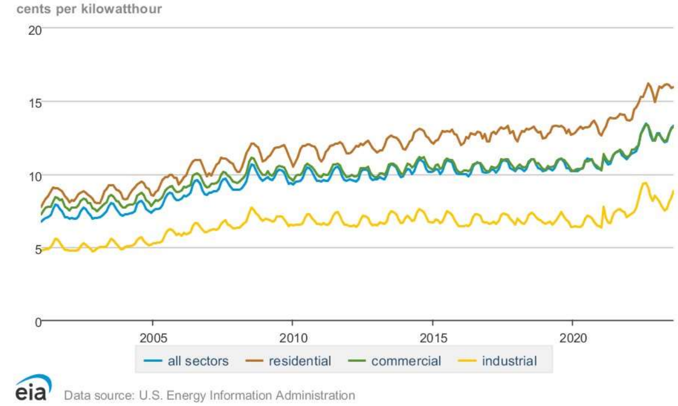
Average Retail Price of Electricity

Average retail price of electricity, United States, monthly



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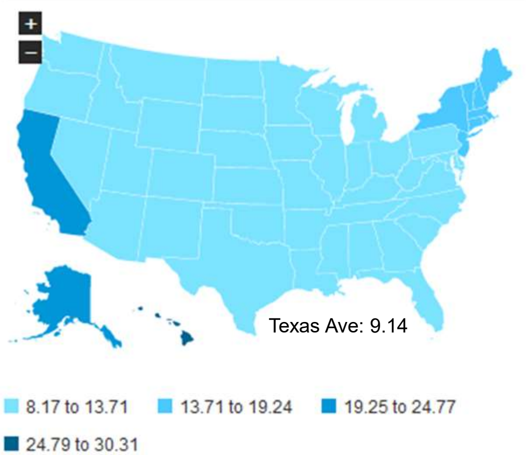
U.S. average retail price per kilowatthour is 11.10 cents



https://www.eia.gov/electricity/state/

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U.S. utility-scale electricity generation by source, amount, and share of total in 2022[1]
Data as of October 2023

Energy source	Billion kWh	Share of total
Total - all sources	4,231	
Fossil fuels (total)	2,553	60.4%
Natural gas	1,687	39.9%
Coal	832	19.7%
Petroleum (total)	23	0.5%
Petroleum liquids	16	0.4%
Petroleum coke	7	0.2%
Other gases[3]	12	0.3%
Nuclear	772	18.2%
Renewables (total)	901	21.3%
Wind	434	10.3%
Hydropower	255	6.0%
Solar (total)	144	3.4%
Photovoltaic	141	3.3%
Solar thermal	3	0.1%
Biomass (total)	52	1.2%
Wood	35	0.8%
Landfill gas	9	0.2%
Municipal solid waste (biogenic)	6	0.1%
Other biomass waste	2	<0.1%
Geothermal	16	0.4%
Pumped storage hydropower[4]	-6	-0.1%
Other sources[5]	11	0.3%

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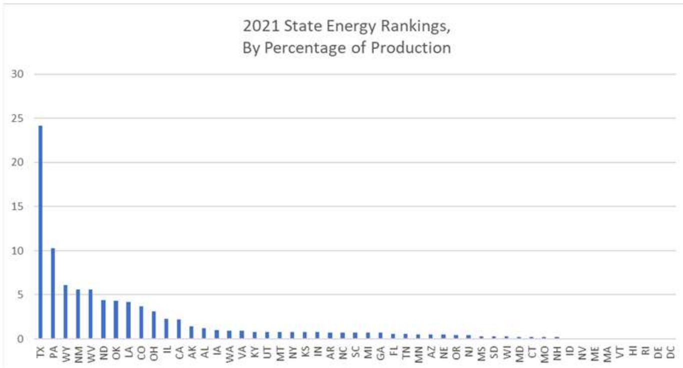
40



Texas is the largest producer of energy

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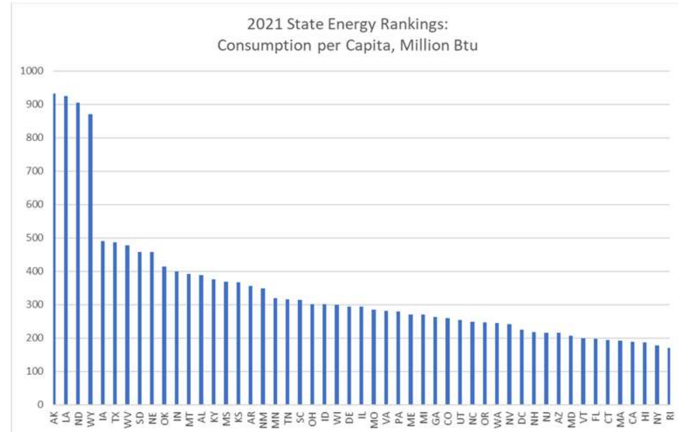

Texas ranks 6th in Consumption per Capita

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Calculating Peak Water Requirements

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What is Peak Water Demand?

- The maximum amount of water that is needed by a plant during peak use.
  - Important for planning pumping needs
- Estimated based on evapotranspiration for plants.

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Evapotranspiration, ET

- Measurement of the total water requirements of plants and crops
- The word **evapotranspiration** is a combination of the words "*evaporation*" and "*transpiration*"
- Very difficult to measure directly
- May be calculated using weather data

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ET Theory and Current Practice

- Penman 1949 first proposed the "energy balance method" for determining plant water requirements
- This method required daily or hourly weather data: solar radiation, temperature, wind, and relative humidity
- ET is calculated for a single plant/crop which is used as a reference for determining the water requirements of all other plants/crop

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Reference Evapotranspiration, ETo

- Alfalfa was the first reference crop used
- A cool season grass is now the standard reference plant
- The reference cool season grass is similar to a fescue, except that it is growing under ideal conditions

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Reference Evapotranspiration, ETo

- Also called "Potential ET (PET)"
- Used as a reference from which the water requirements of all other plants can be determined
- Note: ETo = PET
- *ETo is the potential evapotranspiration (PET) of a cool season reference grass growing 4-inches tall under well watered conditions*

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Reference Evapotranspiration, ETo

- ETo for Central/North Texas usually peaks in July between 0.24 and 0.28 inches per day
- Panhandle: peak ETo = 0.33 – 0.36 in/day
- West Texas: peak ETo = 0.5 – 0.6 in/day
- Gulf Coast: peak ETo = 0.23 - 0.26 in/day

May also be calculated based on historical monthly ETo data

Average Monthly ETo (PET)
(inches/month)

City	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Abilene	2.08	2.57	4.14	5.48	6.47	7.65	8.36	7.46	5.48	4.21	2.67	2.08	**58.65**
Amarillo	1.84	2.27	3.73	5.06	5.89	7.51	8.08	7.29	5.61	4.05	2.4	1.78	**55.51**
Austin	2.27	2.72	4.34	5.27	6.39	7.15	7.22	7.25	5.57	4.38	2.74	2.21	**57.51**
Brownsville	2.65	3.03	4.48	5.17	6.03	6.32	6.68	6.65	5.21	4.34	3.01	2.59	**56.16**
College Station	2.2	2.71	4.22	5.2	6.25	6.89	7.1	6.85	5.6	4.3	2.8	2.2	**56.32**
Corpus Christi	2.42	2.95	4.28	5.17	5.95	6.43	6.68	6.65	5.21	4.34	3.01	2.59	**55.68**
Dallas/Ft. Worth	2.0	2.46	3.96	5.14	6.21	7.06	7.40	7.25	5.49	4.19	2.59	2.10	**55.85**
Del Rio	2.47	3.01	4.76	6.01	6.98	7.41	7.57	7.41	5.77	4.35	2.91	2.36	**61.01**
El Paso	2.74	3.53	6.07	8.19	9.83	11.12	9.19	8.94	7.69	5.89	3.58	2.49	**79.26**
Galveston	2.2	2.6	4.1	5.0	6.11	6.6	6.2	6.0	5.5	4.2	2.8	2.3	**53.61**
Houston	2.36	2.83	4.32	5.01	6.11	6.57	6.52	6.08	5.57	4.28	2.9	2.35	**54.9**
Lubbock	2.35	2.63	4.41	5.53	6.93	7.73	7.63	7.2	5.54	4.19	2.61	2.33	**59.08**
Midland	2.2	2.78	4.46	5.91	7.21	8.2	9.23	8.62	6.95	4.31	2.78	2.16	**64.81**
Port Arthur	2.25	2.63	3.95	5.09	6.12	6.6	5.81	5.61	5.46	4.18	2.76	2.23	**52.69**
San Angelo	2.88	3.13	5.31	7.01	8.48	9.16	9.29	8.49	6.60	5.08	3.37	2.54	**71.34**
San Antonio	2.42	2.9	4.42	5.47	6.47	6.97	7.31	6.99	5.64	4.44	2.85	2.36	**58.24**
Uvalde	2.44	2.95	4.62	5.85	6.7	7.21	7.5	7.31	5.7	4.4	2.89	2.36	**59.93**
Victoria	2.35	2.87	4.29	5.77	6.39	6.7	6.92	6.7	5.36	4.41	2.93	2.33	**57.02**
Waco	2.13	2.62	4.03	5.31	6.45	7.15	7.40	7.5	5.7	4..41	2.7	2.17	**53.16**
Weslaco	2.5	2.57	3.96	4.9	6.12	6.53	7.0	6.58	4.79	3.96	2.85	2.29	**54.05**
Wichita Falls	1.94	2.46	4.07	5.50	6.7	7.54	7.97	7.72	5.79	4.3	2.62	1.95	**58.56**

Averages were computed using climatic data over the entire period of record available from the National Weather Service and compared to ETo rates based on the standardized Penman-Monteith equation where available. (August 2005)

Crop Coefficient (Kc)

- Crop coefficients (Kc) are used to relate ETo to the water requirements of specific plants and crops
- Represents a percentage of plant water use of ETo
- Sometimes referred to as the *plant coefficient*, *turf coefficient*, etc.

Crop Coefficient (Kc)

Kc varies depending on the type of plant/crop and growth stage

Kc may also be adjusted for such factors as:

- ☐ Plant density
- ☐ Desired plant quality
- ☐ Level of allowable stress
- ☐ Site conditions
- ☐ Micro-climates
- ☐ etc.

Turf Coefficient, Tc

- A factor used to relate ETo to the actual water use by a specific type of turf
- Reflects the percentage of ETo that a specific turf type requires for maximum growth

Turf Coefficients	
Warm Season	0.6
Cool Season	0.8
Sports Turf	0.8

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Plant Water Requirement (WR)

- WR = ETo x Kc, or
- WR = ETo x Tc, or
- WR = PET x Kc, or
- WR = PET x Tc
- WR, ETo, and PET may be in in/day, in/week, or in/mo

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Water Requirements

Example 1: What is the peak daily water requirement (ET) for warm season grass in College Station, TX?

Peak Monthly ETo = July = 7.1 inches

$ETo_{Daily} = ETo_{monthly}$ / # of days in month

ETo_{Daily} = 7.1 in/month / 31 days

ETo_{Daily} = 0.23 in/day

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Water Requirements

- Once ETo_{Daily} is known we can calculate peak plant water requirements.

ETo_{Daily} = 0.23 in/day

Kc = 0.6 (warm season grass)

$ET_{Peak\ Daily} = ETo_{Daily} \times Kc$

$ET_{Peak\ Daily}$ = 0.23 in/day x 0.6

$ET_{Peak\ Daily}$ = 0.14 in/day

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Water Requirements

Example 2: What are the daily and weekly peak water requirements (ET) for warm season turf in El Paso, Texas?
ETo_{Daily} = 0.38 inches/day

<u>Daily</u>

$ET_{Peak\ Daily} = ETo_{Daily} \times Kc$

$ET_{Peak\ Daily}$ = 0.38 in/day x 0.6

$ET_{Peak\ Daily}$ = 0.23 in/day

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Calculating Weekly Water Requirement

- Irrigation scheduling is usually done on a weekly basis.
- It may be necessary to determine weekly water requirements

$ET_{Peak\ Weekly} = ETo_{Peak\ Daily} \times 7$ days/week

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Storage and Pumping Capacity

- Many irrigation systems, such as gravity fed, requires on-site water storage
- Pumps may not be able to operate "on-demand"
  - Ex. Need sun or wind?
- Most pumping plants are designed to supply peak daily water requirements
- Calculating Irrigation Volumes requires knowing irrigated area
  - acres, square feet, etc.

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Determining Irrigated Area

- Best to calculate area in square feet, ft^2
  - Area of a Circle: $A = \pi r^2$ or $A = \frac{\pi d^2}{4}$
  - Area of a Triangle: $A = \frac{length \times width}{2}$
  - Area of a Square or Rectangle: $A = length \times width$

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Irrigated Area

- In flood and sprinkler irrigation, the irrigated area is the entire field or bed
- For drip under plastic mulch, the irrigated area is usually estimated as the
  - Width of the row x
  - Length of the row

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Irrigated Area – Example Problems

Example Problem

For a row width of 1 ft and row length of 400 ft, what is the irrigated area?

1.0 ft x 400 ft = 400 ft^2

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Calculating Storage

- In situations where irrigation water maybe stored onsite, storage volume must be calculated.
  - Harvested Rainwater
  - AC Condensate
  - Other Recycled/Reclaimed Sources
- Storage volume is based on peak plant water demand and irrigated area

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Calculating Storage - Feet

V = D* x A x 7.48

Where:

V = Storage volume, gallons

D = Peak plant water demand, ft*

A = Area, ft^2

7.48 = Constant, converts ft^3 to gallons

*Need to convert inches to feet

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Calculating Storage - Inches

V = D x A x 0.623

Where:

V = Storage volume, gallons

D = Peak plant water demand, inches

A = Area, ft^2

0.623 = Constant, converts to gallons

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Storage Example

- A turf zone is 30 ft x 60 ft and has a peak demand of 0.25 in/day. What is the minimum storage volume needed?
- Step 1: Determine Irrigated Area
  - Area = Length x Width
  - Area = 30 ft x 60 ft
  - Area = 1800 ft^2

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Storage Example (continued)

- Step 2: Calculate Daily Storage Volume
  - V = D x A x 7.48
    - Where:
      - D = 0.25 inches ÷12 inches/foot = 0.02 ft
      - A = 1800 ft^2
  - V = 0.02 ft x 1800 ft^2 x 7.48
  - V= 269.3 gallons

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Storage Example (continued)

- Step 3: Calculate Total Storage Volume
- Irrigation is usually scheduled on a weekly basis:
  - V= 269.3 gallons/day
  - V= 296.3 gpd x 7 days
  - Total Volume = 2074.1 gallons per week

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Storage Example (continued)

- Step 4: Do you have enough stored??
  - Total Volume = 2074.1 gallons per week

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Irrigation System Runtime

- Precipitation Rate – defines how fast an irrigation system applies water (in inches per hour)

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Irrigation System Runtime

RT = WR÷PR

RT – Station runtime (hours)

WR – Water requirement (inches)

PR – Precipitation rate (inches per hour)

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Irrigation System Runtime

Example: A drip irrigation system has a precipitation rate of 0.50 in/hr. How long must the irrigation system operate to apply a peak water requirement of 1.57 in/week?

$$RT = \frac{WR}{PR}$$

RT = 1.57/ 0.50

RT = 3.14 hours or 189 minutes

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Introduction to Pumps

Steps to Pump Selection

1. What type of pump is needed?
2. What are the power sources available?
3. What is the preference on power source?
4. What is the flow requirement?
5. Will a water storage tank or pond be used?
6. Will the pump provide water for a pressurized irrigation system?
7. What is the diameter of the pipeline to be connected to the pump?

What type of pump is needed?

- Pump Options:
  - Centrifugal
    - Most Common in Landscape Irrigation
    - Often referred to as a "Booster Pump"
  - Submersible
  - Turbine
    - Not typically used for landscape irrigation
- Why use a specific pump?

Common Irrigation Pumps

- 3 Most Common Types of Pumps used in Irrigation
  - Centrifugal
  - Submersible
  - Turbine

Pump Selection

- Whichever is more cost effective for the application based on pumping depth (or Total Head) and required flow rate
- Choose a quality pump
  - Use major manufacturers
  - Only use pumps that have a pump curve
- Choose a pump based on projected maintenance needs

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Pump Selection – Pump Curves

- Any manufactured pump should have a pump performance curve
  - Often performance is graphed but may also be listed as a table
- Reading a pump curve requires irrigation system hydraulics knowledge:
  - Required Pumping Head
    - Feet of Head or PSI
  - Required Flow Rate
    - Gallons/Minute or Gallons/Hour

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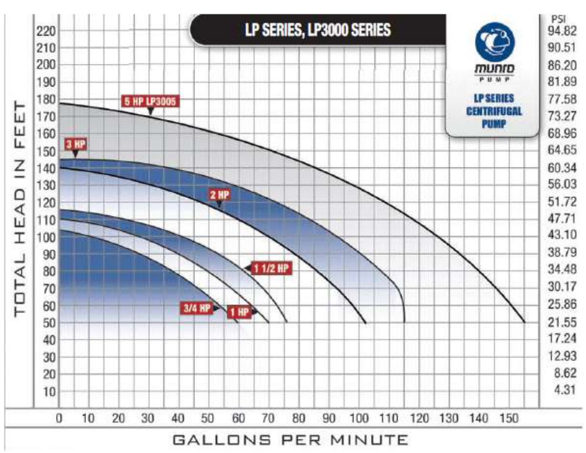
Understanding Pump Curves

Pump Performance Curve



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Understanding Pump Charts: Table Example

Pump Performance Chart

Model Number	Phase	HP	Suction Lift Feet	Capacity - U.S. Gallons Per Minute Discharge Pressure (PSI) 10	15	20	25	30	35	40	45	Shut Off Pressure PSI	Suction Pipe Tap	Discharge Pipe Tap
LP075B	1	3/4	1.5	56	48	42	37	29	21			41	2"	1-1/2"
LP100B	1	1	1.5	58	53	48	43	38	32	23	11	48	2"	1-1/2"
LP150B	1	1-1/2	2	78	77	71	70	62	53	43	30	47	2"	1-1/2"
LP200B	1	2	2	86	84	81	77	71	62	52	40	50	2"	1-1/2"
LP300B	1	3	2	102	101	101	97	91	85	76	62	63	2"	1-1/2"
LP075B	3	3/4	2	56	48	42	37	29	21			41	2"	1-1/2"
LP100B	3	1	2	58	53	48	43	38	32	23	11	48	2"	1-1/2"
LP150B	3	1-1/2	2	78	77	71	70	62	53	43	30	47	2"	1-1/2"
LP200B	3	2	2	86	84	84	77	71	62	52	40	50	2"	1-1/2"
LP300B	3	3	2	102	101	101	97	91	85	76	68	63	2"	1-1/2"

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What are the power sources available?

- Power Options
  - Electricity
  - Diesel
  - Gasoline
  - **Solar or Wind**??
- Is the power option reliable/dependable?
- Is the power option *economical*?

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What is the flow requirement?

- What are the expected water uses?
  - Irrigation
  - Water Features
    - Fountains/Pools
  - Other
- What is the expected peak flow rate needed?
  - Peak Crop Consumptive Use?
- Can the well/water source provide this flow rate?

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Will a water storage tank or pond be used?

- What will be the maximum storage volume?
- Will a second pump be used to pump out of the storage tank or pond?
- If a second pump is used, what type of pump?
  - Boost Pressure

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Will the pump provide water for a pressurized irrigation system?

- What type of pressurized system?
  - Sprinkler
    - High Pressure
  - Drip
    - Low Pressure
- What is the systems pressure requirement?

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What is the Pressure/Head Requirement?

- Suction Head
  - For Centrifugal Pump Only:
    - Elevation change from the pump inlet to the pump
- Pumping Head
  - For all Pump:
    - Elevation change from Pump to Delivery Point
    - Includes friction loss
- Operating Head
  - Also referred to as the operating pressure of a pressurized irrigation system such as sprinklers or drip

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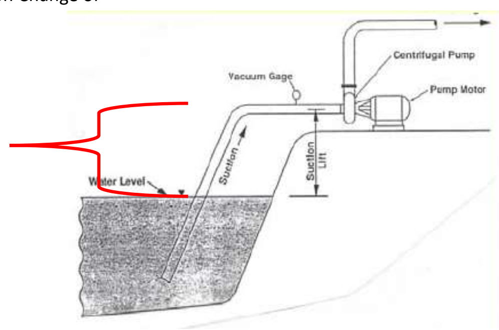
Suction Head

- Is limited based on the size of the centrifugal pump
- Rule of Thumb:
  - Maximum of Elevation Change of 6-15 feet
  - Friction Loss in Pipe



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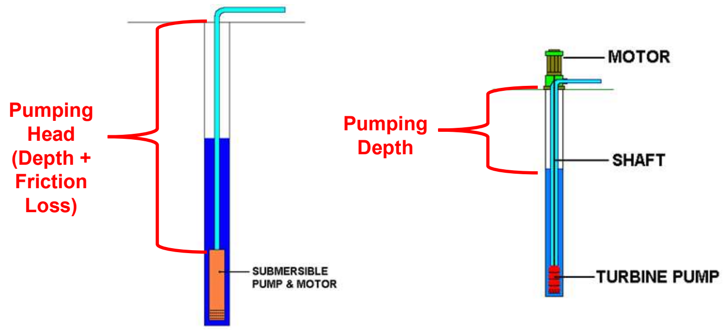
Pumping Depth vs Head

- Elevation Change from Water to the Surface



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Operating Head

- Usually based on the operating requirement of a sprinkler or drip emitter
- Refer to Manufacturers Specification Literature for requirements
- Maybe listed as PSI

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Typical Pressures and Flows for Sprinkler Irrigation

Sprinkler Type	Radius of Throw	Pressure Ranges	Flow Ranges
Spray	5 to 16 ft.	15 to 30 psi	Up to 4 gpm
Small Rotors	15 to 30 ft.	25 to 55 psi	Up to 6 gpm
Medium Rotors	30 to 50 ft	25 to 65 psi	Up to 10 gpm
Large Rotors	50 ft. +	50 to 120 psi	10 to 40+ gpm
Guns	100 ft. +	100 psi +	80 gpm +

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Typical Pressures and Flows for Drip Irrigation

Drip Type	Pressure Ranges	Flow Ranges
On-line Drip Emitters	10 to 50 psi	0.5 to 24 gph
Inline Drip Emitters	10 to 50 psi	0.4 to 0.9 gph
Mini sprays/ Spitters	10 to 50 psi	0 to 30 gph
Drip Tape	8 to 20 psi	10 to 60 gph per 100 ft. of tape

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What is the Pressure/Head Requirement?

- Need Total Dynamic Head to complete pump selection
- Total Dynamic Head
  - Pumping Depth + Operating Head+ Elevation Changes + Friction losses

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What is the diameter of the pipeline to be connected to the pump?

- Will the pipeline be large enough for the flow requirement?
- Will there be excessive friction loss?
  - Use larger pipe to minimize friction loss?
- Remember not to exceed 5ft/s velocity

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Using Renewable Energy Systems

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Renewable Energy Systems

- Typically refer to Solar and Wind Powered Systems
- Offer opportunities to utilize non potable water sources for irrigation
  - Example: Harvested Rainwater
  - *Note* Purple Pipe use with non potable water

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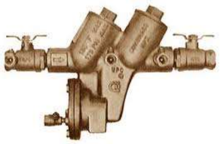
Renewable Energy Systems

- TCEQ Regulations still apply to irrigation systems using alternative energy sources if connected to a potable water supply.
- If cross connecting potable and non potable water sources for irrigation, use RPZ or Air Gap backflow prevention



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Solar Powered Pumping Plants

Electricity Review

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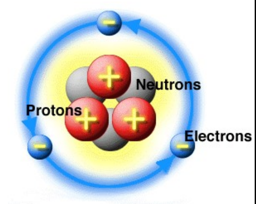
Electricity Review

- Electricity is the flow (movement) of electrons through a material.
- All materials in nature are made of atoms, nature's building blocks. Atoms consist of protons, neutrons, and electrons.
- The inner part of the atom (nucleus) contains protons and neutrons.
- Electrons orbit the nucleus.



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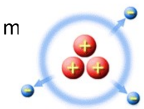
Electricity Review

- Protons and electrons have physical "charges".
  - Protons = Positive charge
    Electrons = Negative charge
- These "charges" act similar to the magnetic poles of a m



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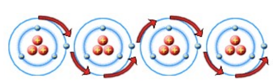
Electricity Review

- The unlike charges between a positively charged proton and a negatively charged electron produce an attractive force that holds the electron in orbit around the nucleus.
- When electrons move from one atom to another, *electricity* flow has occurred.



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Types of Electricity

- There are two types of electricity
  - Direct Current (DC)
    - Electrons flow in only one direction
  - Alternating Current (AC)
    - Electrons periodically cycle their direction of flow. The electrons move first in one direction and then move back in the opposite direction.

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Terminology: Voltage

- Voltage (V) is the electrical force that pushes the electrons from atom to atom through a material
- Scientifically represented by symbol “E”
- Voltage in a wire is analogous to water pressure in a piping system

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Terminology: Current

- Measured in amps, current is the rate of flow of electrons through a material
- Scientific symbol is “I”
- Current in a wire is analogous to flow rate (gpm) in a piping system

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Terminology: Resistance

- Measured in ohms, defines how loosely or tightly a material holds on to its electrons.
  - Low resistance = Good conductor
  - High resistance = Bad conductor
- Scientific Symbol is “R”
- Resistance in a wire is analogous to friction loss in a piping system.

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Terminology: Watt

- Electrical power is a measure of the rate of work and electric current or device can accomplish
- Manufacturers indicate how much electrical power an appliance consumes in units of watts (Scientific symbol “P”).
- Sometimes referred to as “volt-amps” or “VA” (common for solenoid valves)

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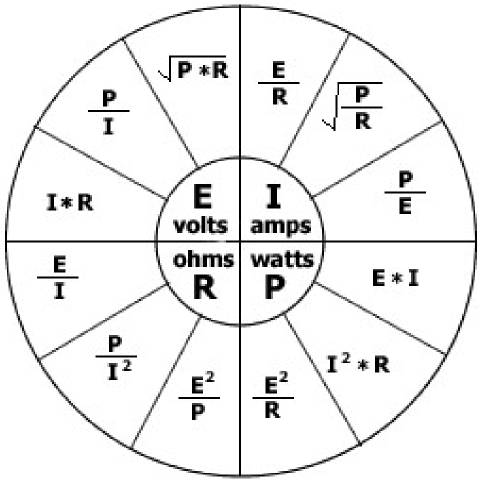
Electrical Relationships



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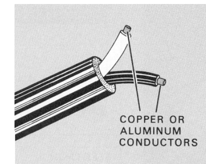
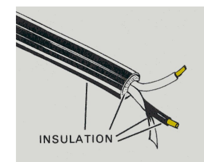
Wire

- Wire generally comprised of conductors and insulators
- Conductors are materials made up of atoms which readily allow electrons to be transferred from atom to atom
- Insulators are materials made up of atoms with electrons tightly bound to the nucleus preventing the flow of electricity





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Wire

- Good Insulators
  - Glass
  - Rubber
  - Porcelain
  - Plastic
- Good Conductors
  - Gold
  - Copper
  - Aluminum

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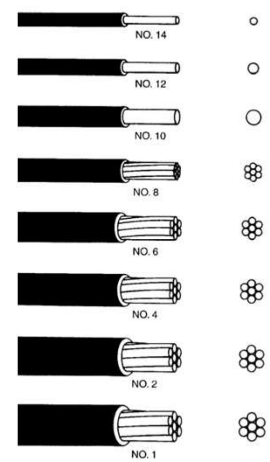
Wire Size

- In the American Wire Gauge System, as the wire number gets smaller, the diameter of the wire gets larger.
- Can come solid or stranded



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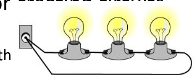
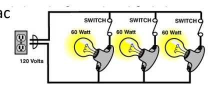
Wiring Circuits

- 2 Basic Types of wiring patterns for creating circuits
  - Series
    - Contains only one path from the source th... ad fails then all loads stop



  - Parallel
    - Contains separate, individual path for eac... continue operating



Solar Powered Pumping Plants

Solar Power

Solar Power

- Solar power is the conversion of sunlight (solar energy) into electricity (DC current)
- Solar energy can be captured by either using:
  - Photovoltaic's (PV)
    - System of solar cells that convert sunlight into electric current
  - Concentrated Solar Power (CSP)
    - System of lenses or mirrors that focus a large area of sunlight into a small beam

Photovoltaic Cells

- Also known as Solar Panels or Solar Cells
- Made of special semiconductors such as silicon

How Solar Panels Work

- When light is absorbed into the semiconductor, the energy knocks electrons loose, allowing them to flow freely.
- The electric field that acts to force electrons free causes a current to flow in a certain direction.
- By placing metal contacts on the top and bottom of the cell we can draw the current off for external use.

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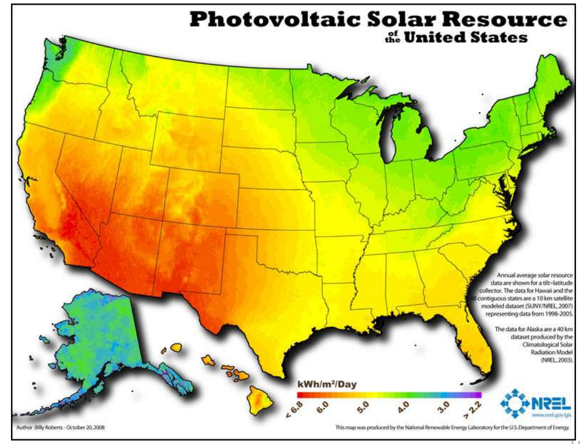
Solar Distribution Across the US



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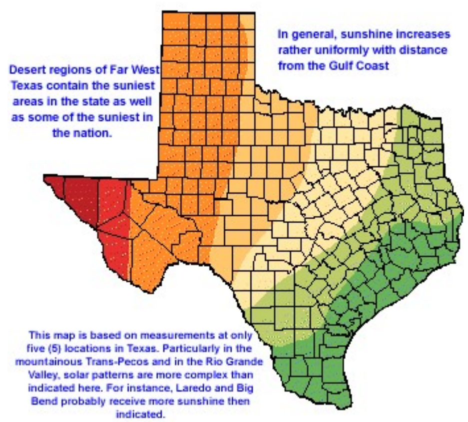
Solar Distribution Across Texas



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Types of Solar Energy (Radiation)

- 2 Types of Solar Energy
  - Direct Radiation
    - Energy that avoids atmospheric scattering and arrives at the earth's surface in an unbroken line
  - Diffused Radiation
    - Energy that is deflected by cloud cover, humidity, pollution and dust.
    - Cannot be effectively focused and generally not useful for power conversion

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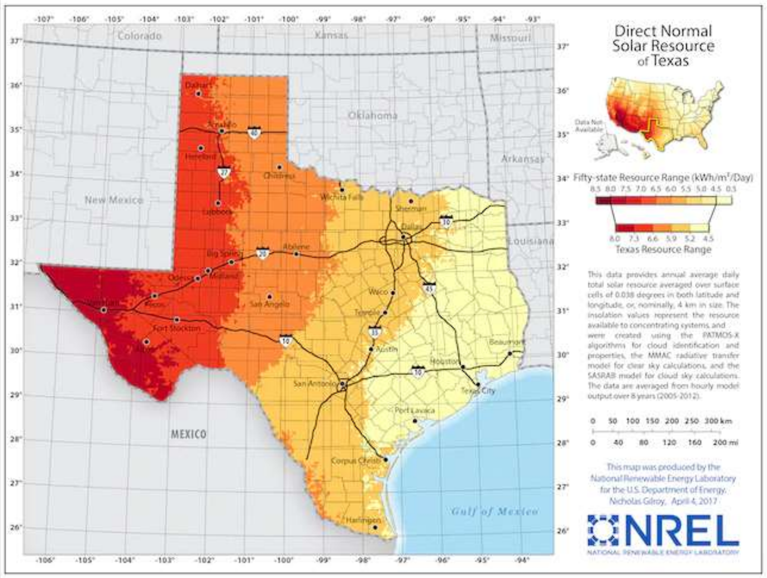

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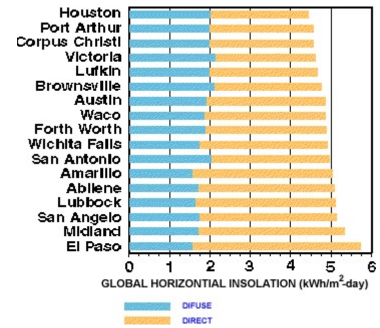
Global Radiation

- Insolation is the total amount of solar radiation that strikes a particular location over a given time period, typically a day



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Average Direct Solar Hours in Texas

- East Texas
  - 4.5 Sunny Hours Per Day
    - Beaumont, Houston, Corpus Christi
- East Central Texas
  - 4.8-5.5 Sunny Hours Per Day
    - Dallas, Austin, San Antonio, Harlingen
- West Central Texas
  - 5.8-6.2 Sunny Hours Per Day
    - Childress, Abilene, San Angelo
- West Texas
  - 6.3-6.8 Sunny Hours Per Day
    - Amarillo, Lubbock, Midland, Fort Stockton

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Solar Powered Pumping Plants

Systems Components

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Components of Solar Pumping Systems

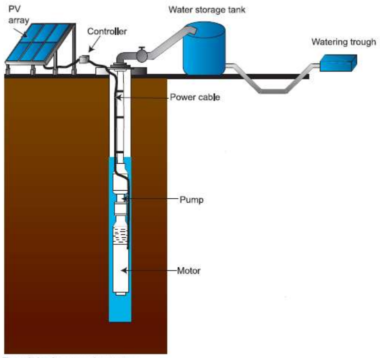

Figure 2. A solar-powered water pump.

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Components of Solar Pumping Systems

- PV Array (solar panels)
- Motor
- Pump
- Controller
- Power cable
- Batteries (if applicable)
- Storage tank (if applicable)
- Accessories
  - Dry well probe sensor
  - Pressure switches

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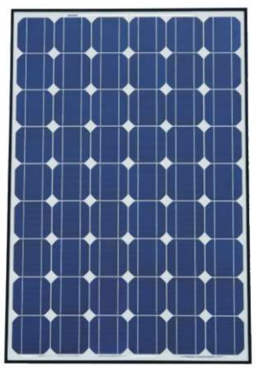
Solar Panels

- Sized according to output wattage
- Typical sizes include:
  - 90W – 12V
  - 110W – 24V
  - 175W – 24V
- Newer "higher efficiency" panels are available in 200-300W



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Wiring Solar Panels

- Solar panels must be wired to meet the power demand of the selected pump/motor configuration
- 3 Wiring Options
  - Series
  - Parallel
  - Series-Parallel

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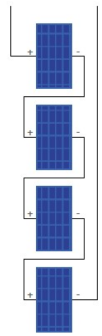
Series Wiring Diagram

- If wired in series, total the watts & volts from each panel
- Example:

  Each Panel is 175W-24V

  - In Series, Add the Watts and Volts
  - Total Output is 700W-96V



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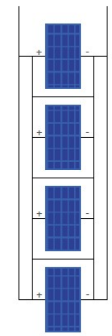
Parallel Wiring Diagram

- If wired in parallel, total watts but volts remain the same
- Example:

  Each Panel is 175W-24V

  - In Parallel, Add Watts not Volts
  - Total Output is 700W-24V



126

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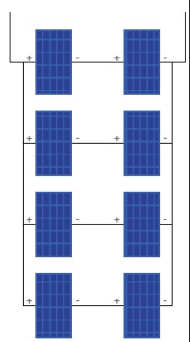
Series-Parallel Wiring Diagram

- If wired series-parallel, total the watts of all panels but only total volts for one set of parallels
- Example:

  Each Panel is 175W-24V

  - Series/Parallel, Add all Watts
    and only add the number of Parallels
  - Total Output is 1400W-48V



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Panel Wiring

- When designing your solar panel wiring diagram, panels may be oversized to provide extra watts but should not provide extra volts
- Ex: If 1200W-48V is needed, you may provide 1400W-48V but not 1400W-72V
- Increasing watts will allow for earlier start time and longer operating time

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Motors

- Typically Use DC Motors
  - Usually 12V, 24V, 36V or 48V
- May use AC Motors
  - A solar pump inverter is needed and there is power lost in the conversion



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Pump

- 2 Types of Pumps
  - Submersible
    - Set under water either vertically or horizontally
    - Typically has a high pumping capacity
  - Surface (Booster)
    - Typically used to increase pressure
    - Connected to an existing water supply above ground


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Controller (Control Units)

- Allow for management of the pumping systems
- Contain ports/controls to be used with:
  - Time based irrigation controllers
  - Dry Well Probe/Water Level Probe
  - Motor speed adjustments
  - Batteries


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Power Cables

- Cables size and length is based upon power requirement
- Most manufacturers will have charts to help determine size and max length

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Example Wire Sizing Table

Wire Sizing Table (Controller to Motor)			
MAX FEET	System Watts – Wire Size AWG		
	70W	150W	300W
17	#14	#14	#14
33	#10	#10	#10
50	#10	#10	#10
65	#10	#10	#10
80	#10	#10	#8
Cable is sized for maximum 6% voltage loss			

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Example Wire/Panel Chart

Cable sizing chart

Panels	Power (Wp)	Volts (Vmp)	Amps (Imp)	Volts (Voc)	Amps (Isc)	14 AWG	12 AWG	10 AWG	series	parallel
1	80	33	2.4	42	2.6	82	130	207	1	
2	160	67	2.4	83	2.6	164	261	415	2	
3	240	100	2.4	125	2.6	246	391	622	3	
4	320	133	2.4	166	2.6	328	522	829	4	
5	400	167	2.4	208	2.6	410	652	1037	5	
6	480	200	2.4	249	2.6	493	783	1244	6	
7	560	233	2.4	291	2.6	575	913	1451	7	
8	640	266	2.4	332	2.6	657	1044	1659	8	
8	640	133	4.8	166	5.2	164	261	415	4	2
9	720	100	7.2	125	7.8	82	130	207	3	3
10	800	167	4.8	208	5.2	205	326	518	5	2
12	960	200	4.8	249	5.2	246	391	622	6	2
14	1120	233	4.8	291	5.2	287	457	726	7	2
15	1200	167	7.2	208	7.8	137	217	346	5	3
16	1280	133	9.6	166	10.4	82	130	207	4	4
18	1440	200	7.2	249	7.8	164	261	415	6	3

Note: max. cable length in feet; uses a max. 3 % voltage drop

Max. cable length between CU200 and SQF = 650 ft.

SQ Flex is most efficient at 120V and above. Grundfos recommends combining panels to produce 120 or above.

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Batteries

- Pumping may be required during times when solar energy is not available (such as night) or for extended periods of cloudy days.
- Batteries should be wired correctly to provide the necessary Watts and Volts
- Deep Cycle batteries should always be used

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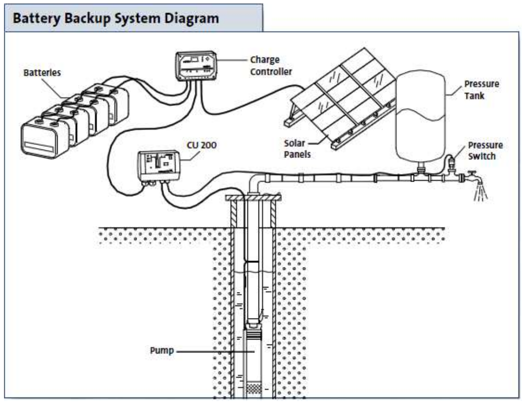
Battery Backup System



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Systems Accessories

- Dry Well Probes- can be set
  - Normally Open
    - Turns on when wet
  - Normally Closed
    - Turns off when wet
- Pressure Switches
  - Turns on the pump when pressure drops



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Systems Accessories

- Irrigation Controllers
  - Irrigation Controllers can be connected to solar pumping systems to allow for user defined pumping
  - Connects to controller just like a master valve or pump relay
  - Solar Powered Irrigation equipment is available.
    - DC latching solenoids, battery controllers, etc.


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Example Solar Landscape Irrigation

- Hunter
  - Solar Kit for XC Hybrid Controllers
- DIG
  - LEIT Solar Powered Controller
  - LEIT Solar Valve Kit
- Baseline – DC Irrigation
- Weathermatic – Smartline Solar




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Solar Powered Pumping Plants

Designing Pumping Systems

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Example Problem

- Given: Rainwater is harvested from a commercial building roof in Austin. When full, the storage tank holds 1000 gallons and is used for irrigating flowers beds. The irrigation zone applies 2.5 GPM at 10 PSI.
- Required: Design the solar pumping plant.

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Example Problem

- Most pumps are sized by Pumping Head
  - Feet (Ft) or Meters (M)
- First Determine Pumping Head
  - 10 PSI = ?ft
  - 10 PSI x 2.31 Ft/PSI
  - 10 PSI = 23.1 feet of head (vertical lift)

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Example Problem

- Select pump and read manufacturers specs

Total Lift		PS150 BOOST 60			PS150 BOOST 125			PS150 BOOST 240		
Feet	Meters	L/h	US-G/h	Watts	L/h	US-G/h	Watts	L/h	US-G/h	Watts
17	5	260	69	35	475	125	50	900	238	65
33	10	257	68	40	470	124	55	895	236	90
50	15	254	67	45	470	124	62	890	235	105
65	20	252	67	55	469	124	70	880	232	120
83	25	250	66	63	460	122	80	875	231	135
100	30	248	66	72	450	119	90	870	230	150
132	40	246	65	80	448	118	105	865	229	200
150	45	244	64	85	447	118	112	860	227	225
165	50	242	64	90	446	118	120			
200	60	240	63	95	425	112	140			
231	70	239	63	110	419	111	160			
265	80	238	63	125	409	108	185			
300	90	236	62	140	407	108	200			
330	100	234	62	165						
400	120	228	60	185						
460	140	222	59	220						

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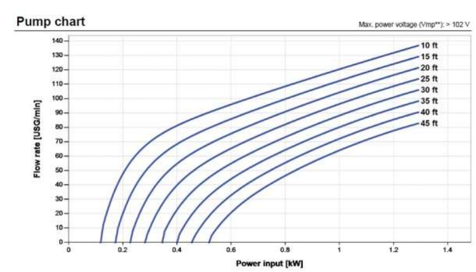
Reading Manufacturers Specs-Pumps

- Sometimes Manufacturers Use Pump Curves
- Follow Curve for Head to needed Flow Rate



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Example Problem

- Manufacturers specs report flow in gallons per hour, will need to convert to flow.
- Irrigation System = 2.5 GPM
  - 2.5 GPM = 150 GPH
- Revisit chart to determine model pump needed and total Watts
  - Need 23.1 Ft & 150 GPH

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Example Problem

- Select Model and Watts
  - Need 23.1ft and 150 GPH
  - <u>PS150 BOOST 240, 90W</u>

Total Lift		PS150 BOOST 60			PS150 BOOST 125			PS150 BOOST 240		
Feet	Meters	L/h	US-G/h	Watts	L/h	US-G/h	Watts	L/h	US-G/h	Watts
17	5	260	69	35	475	125	50	900	238	65
33	10	257	68	40	470	124	55	895	236	90
50	15	254	67	45	470	124	62	890	235	105
65	20	252	67	55	469	124	70	880	232	120
83	25	250	66	63	460	122	80	875	231	135
100	30	248	66	72	450	119	90	870	230	150
132	40	246	65	80	448	118	105	865	229	200
150	45	244	64	85	447	118	112	860	227	225
165	50	242	64	90	446	118	120			
200	60	240	63	95	425	112	140			
231	70	239	63	110	419	111	160			
265	80	238	63	125	409	108	185			
300	90	236	62	140	407	108	200			
330	100	234	62	165						
400	120	228	60	185						
460	140	222	59	220						

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Example Problem

- What solar panel configuration is needed (90 Watts)?
  - 1-90W-12V Panel in Series or greater

PS150 PANEL CONFIGURATIONS (MAXIMUM OPEN CIRCUIT VOLTAGE - 50V)

Panel Model	# of Panels	Panel Wtg.	Nominal Voltage	Open Circuit Voltage	Total Wtg.	Total Series Nominal Vltg.	Total Series Open Circuit Vltg.	Total Parallel Nominal Vltg.	Total Parallel Open Circuit Vltg.	Total Series-Parallel Nominal Vltg.	Total Series-Parallel Open Circuit Vltg.
LA-90-12V	1	90	12	21.4	90	12	21.4				
LA-110-24V	1	110	24	47.2	110	24	47.2				
LA-175-24M	1	175	24	44.7	175	24	44.7				
LA-90-12V	2	90	12	21.4	180	24	42.8	12	21.4		
LA-110-24V	2	110	24	47.2	220	~~48~~	~~94.4~~	24	47.2		
~~LA-90-12V~~	~~3~~	~~90~~	~~12~~	~~21.4~~	~~270~~	~~36~~	~~64.2~~				
LA-175-24M	2	175	24	44.7	350	~~48~~	~~89.4~~	24	44.7		
~~LA-110-24V~~	~~3~~	~~110~~	~~24~~	~~47.2~~	~~330~~	~~72~~	~~141.6~~				
~~LA-120-12V~~	~~3~~	~~120~~	~~12~~	~~23.8~~	~~360~~	~~36~~	~~71.4~~				
LA-90-12V	4	90	12	21.4	360	~~48~~	~~85.6~~	12	21.4	24	42.8
LA-110-24V	4	110	24	47.2	440	~~96~~	~~188.8~~	24	47.2	~~48~~	~~94.4~~
~~LA-90-12V~~	~~5~~	~~90~~	~~12~~	~~21.4~~	~~450~~	~~60~~	~~107~~				
~~LA-175-24M~~	~~3~~	~~175~~	~~24~~	~~44.7~~	~~525~~	~~72~~	~~134.1~~				
LA-90-12V	6	90	12	21.4	540	~~72~~	~~128.4~~	12	21.4	~~36~~	~~64.2~~
~~LA-110-24V~~	~~5~~	~~110~~	~~24~~	~~47.2~~	~~550~~	~~120~~	~~236~~				
~~LA-90-12V~~	~~7~~	~~90~~	~~12~~	~~21.4~~	~~630~~	~~84~~	~~149.8~~				

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Designing Solar Pumping Systems

- Most manufacturers & dealers have pump design software
- Software requires
  - Required pumping head or pressure
  - Desired flow rate
  - Location (solar reference for panel needs)
- Software/dealer will assemble a pump package with the correct pump and solar array

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owered Pumping Plants

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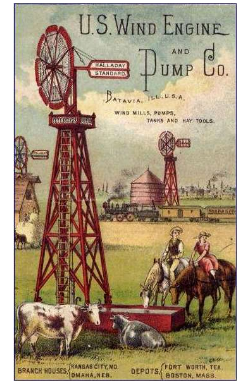
History of WindMills

- The first American water windmill was designed by David Halladay in 1854.
- Very popular during the Mid-Late 1800's as settlers moved west.



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History of WindMills

- Windmills helped supply water for human consumption, livestock and irrigation.
- Between 1850 and 1970 over 6 million windmills were installed in the U.S. alone.

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Reality Check

- The wind does not blow all the time
- Wind may only blow a few hours a day
- Wind pumps require a minimum wind speed of 7 mph to operate
- Crops require large amounts of water
- The deeper the well, the less water a wind pump will produce
- Water storage tanks are expensive

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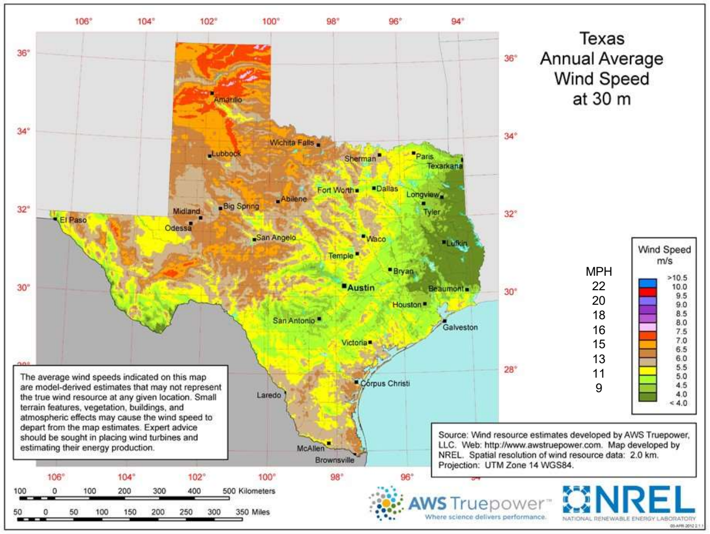

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Wind Speed Units and Conversion Factors

	m/s	Km/hr	mph	knots
1 m/s	1.000	3.600	2.337	1.994
1 km/hr	0.278	1.000	0.622	0.540
1 mph	0.447	1.609	1.000	0.869
1 knot	0.514	1.853	1.151	1.000

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Wind Speed Classification

- Light Winds: 7-9 mph
  - causes movement of small branches and leaves
- Fair Winds: 10-16 mph
  - raises dust, blows litter on the ground
- Strong Winds: 17-24 mph
  - causes small trees to sway
- Above 25 mph
  - Most windmills have an automatic regulation system that turns the wind wheel out of the wind in strong winds and storms

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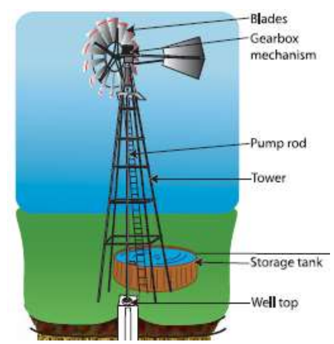
Wind Pumping Components

- Wind pumps may be purchased from certain manufacturers as a complete package that includes
  - The wind mill (Mast/Blades)
  - Gear box
  - Pump rod
  - Tower/Structure
  - Pump



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Sucker Rods

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Wind Mill Head

- Head Includes:
  - Basic Motor
  - Vane
  - Tail Assembly
  - Furl Brake Kit
  - Mast Complete
  - Wheel Complete
- 702 Model Head

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Gearbox

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Cylinders

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WindMill Pumping Video

https://youtu.be/3AA8s3Jtetg?si=dD3qywCiZ4s5iG4c

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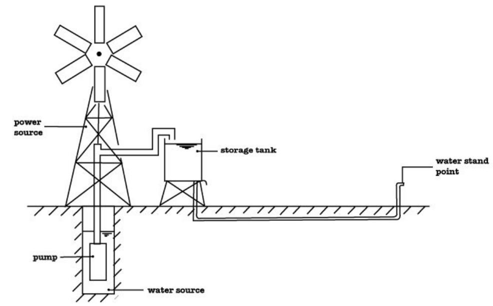

- This illustration shows a wind pump set-up
  - The power source (wind mill)
  - Pump
  - Storage tank
  - Pipe line

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- Wind pumps may also be set-up to use surface water such as ponds, canals, rivers, etc.
- Appropriate regulatory authority should be contacted prior to withdrawing water from these sources
  - River Authority, Corp of Engineers, etc.

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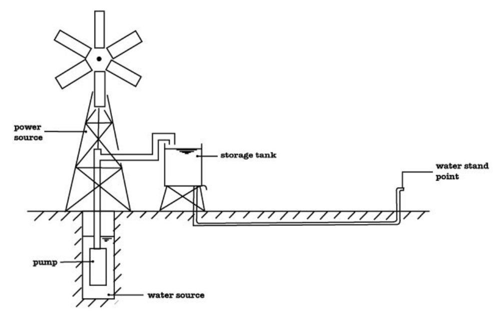

- The wind pump is designed to lift the water into the storage tank
- The storage tank is constructed at the proper height to provide sufficient head (pressure) to operate the irrigation system

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Manufacturers Specification Sheets

- The size of the wind mill is based on the diameter of the wind wheel and the cylinder (well) diameter
- The pumping rate (gph) and the total elevation that the water can be lifted is listed for each:
  - wind wheel and cylinder diameter
  - average wind speed range

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Pumping Elevation

- Pumping elevation includes the depth to the water and height of the storage tank

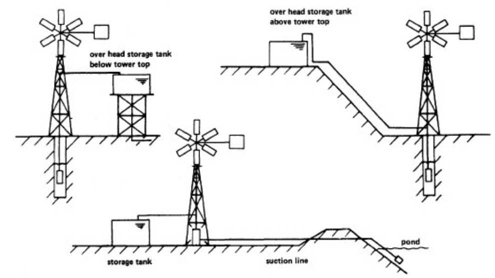

Figure 6.1. Typical wind pump system layouts.

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Portion of the Iron Man Wind Pump Specification Sheet for 6 M (20 ft) Wind Wheel

Elevation Feet - Meters	LIGHT WINDS Cylinder Diameter Inches - MM	LIGHT WINDS Water Pumped per Hour Gallons - Cu M	FAIR WINDS Cylinder Diameter Inches - MM	FAIR WINDS Water Pumped per Hour Gallons - Cu M	STRONG WINDS Cylinder Diameter Inches - MM	STRONG WINDS Water Pumped per Hour Gallons - Cu M
10 - 3	16 - 400	7470 - 28.3	18 - 460	13860 - 52.5	18 - 460	18900 - 71.6
16 - 5	14 - 350	5700 - 21.6	16 - 400	10960 - 41.5	16 - 400	14915 - 56.5
23 - 7	12 - 300	4200 - 15.9	14 - 350	8370 - 31.7	14 - 350	11432 - 43.3
33 - 10	10 - 250	2900 - 11	12 - 300	6150 - 23.3	14 - 350	11432 - 43.3
50 - 15	8 - 200	1875 - 7.1	10 - 250	4277 - 16.2	12 - 300	8236 - 31.8
66 - 20	7 - 180	1505 - 5.7	8 - 200	2745 - 10.4	10 - 250	5834 - 22.1
100 - 30	6 - 150	1055 - 4	7 - 180	2218 - 8.4	8 - 200	3722 - 14.1
130 - 40	5 - 130	790 - 3	6 - 150	1530 - 5.8	7 - 180	3088 - 11.5
165 - 50	4 3/4 - 120	660 - 2.5	5 - 130	1162 - 4.4	6 - 150	2112 - 8

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Example Problem

Under "Fair Winds", how much water will a 6 M Iron Man pump for an elevation of 50 ft?

4277 gallons per hour

How much water will the be pumped in 2 hours?

8554 gallons

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Portion of the Iron Man Wind Pump Specification Sheet for 6 M (20 ft) Wind Wheel

Elevation Feet - Meters	LIGHT WINDS		FAIR WINDS		STRONG WINDS	
	Cylinder Diameter Inches - MM	Water Pumped per Hour Gallons - Cu M	Cylinder Diameter Inches - MM	Water Pumped per Hour Gallons - Cu M	Cylinder Diameter Inches - MM	Water Pumped per Hour Gallons - Cu M
10 - 3	16 - 400	7470 - 28.3	18 - 460	13860 - 52.5	18 - 460	18900 - 71.6
16 - 5	14 - 350	5700 - 21.6	16 - 400	10960 - 41.5	16 - 400	14915 - 56.5
23 - 7	12 - 300	4200 - 15.9	14 - 350	8370 - 31.7	14 - 350	11432 - 43.3
33 - 10	10 - 250	2900 - 11	12 - 300	6150 - 23.3	14 - 350	11432 - 43.3
50 - 15	8 - 200	1875 - 7.1	10 - 250	4277 - 16.2	12 - 300	8236 - 31.8
66 - 20	7 - 180	1505 - 5.7	8 - 200	2745 - 10.4	10 - 250	5834 - 22.1
100 - 30	6 - 150	1055 - 4	7 - 180	2218 - 8.4	8 - 200	3722 - 14.1
130 - 40	5 - 130	790 - 3	6 - 150	1530 - 5.8	7 - 180	3088 - 11.5
165 - 50	4 3/4 - 120	660 - 2.5	5 - 130	1162 - 4.4	6 - 150	2112 - 8

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Example Problem

What size of water storage tank will I need to hold 8554 gal?

8554 gal ÷ 7.48 gal/ft^3 = 1144 ft^3

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Example Problem: Design a Wind pump – Drip Tape System

Select a wind pump and design the water storage tank for the following:

- A Garden
  - 20 rows, each row 1ft wide and 20ft long
  - Deep rooted vegetable with a peak water use of .25 in/day
- Wind pump
  - An Iron Man 6m wind wheel
  - “Light Wind” conditions
  - Depth to the water table: 50 ft
- Drip System
  - Drip Product: .5 GPM/100ft, 12 inch emitter spacing, in-let pressure of 8 PSI
  - Main Line: 100 ft of 1”PVC Class 200

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- Step 1: Calculate peak daily water use
  - 400ft^2 x (.25in/12in) x 7.48 gal/ft^3 = 52.3 Gallons
  - *Note: this is the minimum capacity of the water storage tank*
- Step 2: Calculate total flow rate of drip tape
  - total length of drip tape: 20 rows x 20 ft = 400 ft
  - total flow rate .5 GPM/100ft x 400 ft = 2 GPM

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- Step 3: Determine the total head needed for the irrigation system
  - in-let pressure: 8 PSI = 18.5 Feet of Head
  - friction loss in main line: Using Chart C2 for 1 inch pipe and 2 gpm ➔ .07 psi = .03 ft
  - Add at least 10% for losses through fittings/valves ➔ 0.1
  - minimum head required to operate irrigation system:
    18.5 ft + 0.03 ft + 0.1 ft = 18.63 ft

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- Step 4: Determine minimum height of water storage tank
  - 18.63 ft to the bottom of tank
  - Based on the availability of materials/tank sizes, determine the height of the tank (bottom of tank to the top of tank)
  - Note that the minimum storage volume of the tank must be 52.3 Gallons

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- Step 5: Calculate total pumping elevation
  - depth to water table = 50 ft
  - minimum height of bottom of tank = 18.63 ft
  - height of tank = 4 ft (assumption)

  Total pumping elevation: 50 + 18.63 + 4 = 72.63 ft

4ft Height of Tank

18.63 Ft to Tank

50 Ft to Water Table

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- Step 6: Select Wind pump from Iron Man chart (Light Winds, 72ft head)
  - A cylinder of with a diameter of 6 inch will meets our requirements. Pumping rate under light winds will be about 1055 GPH

Elevation Feet - Meters	LIGHT WINDS		FAIR WINDS		STRONG WINDS	
	Cylinder Diameter Inches - MM	Water Pumped per Hour Gallons - Cu M	Cylinder Diameter Inches - MM	Water Pumped per Hour Gallons - Cu M	Cylinder Diameter Inches - MM	Water Pumped per Hour Gallons - Cu M
10 - 3	16 - 400	7470 - 28.3	18 - 460	13860 - 52.5	18 - 460	18900 - 71.6
16 - 5	14 - 350	5700 - 21.6	16 - 400	10960 - 41.5	16 - 400	14915 - 56.5
23 - 7	12 - 300	4200 - 15.9	14 - 350	8370 - 31.7	14 - 350	11432 - 43.3
33 - 10	10 - 250	2900 - 11	12 - 300	6150 - 23.3	14 - 350	11432 - 43.3
50 - 15	8 - 200	1875 - 7.1	10 - 250	4277 - 16.2	12 - 300	8236 - 31.8
66 - 20	7 - 180	1505 - 5.7	8 - 200	2745 - 10.4	10 - 250	5834 - 22.1
100 - 30	6 - 150	1055 - 4	7 - 180	2218 - 8.4	8 - 200	3722 - 14.1
130 - 40	5 - 130	790 - 3	6 - 150	1530 - 5.8	7 - 180	3088 - 11.5
165 - 50	4 3/4 - 120	660 - 2.5	5 - 130	1162 - 4.4	6 - 150	2112 - 8

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- Step 7: Calculate the minimum numbers of hours the pump will need to operate to supply the irrigation water requirement

The peak irrigation water requirement is 52.3 gallons/day

Pumping rate is 1055 gallons/hr

time to fill tank → 52.3 gallons ÷ 1055 gal/hr = .05 hours = 3 minutes

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- Step 8: Reality Check

Do you have wind enough wind during the peak water use period?

IF not, then you will need more wind pumps or need to reduce the size of your irrigation system!

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What about wind turbines?

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Wind Turbines

- Wind Turbines use wind power to produce electricity
- Combines basic principles previous discussed for wind and solar
- Can offer flexibility by providing AC or DC Power

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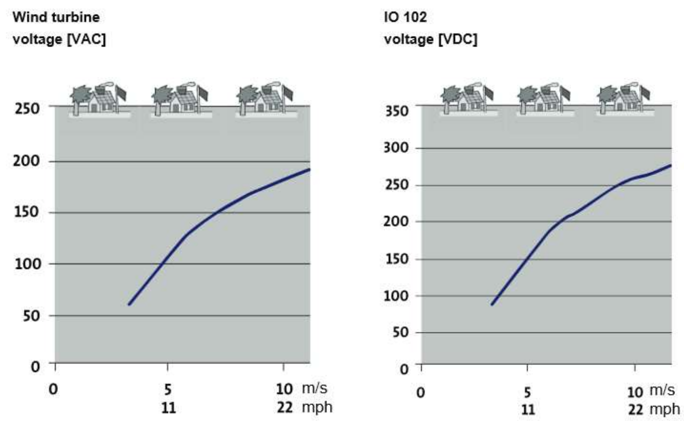
Wind Turbine Power



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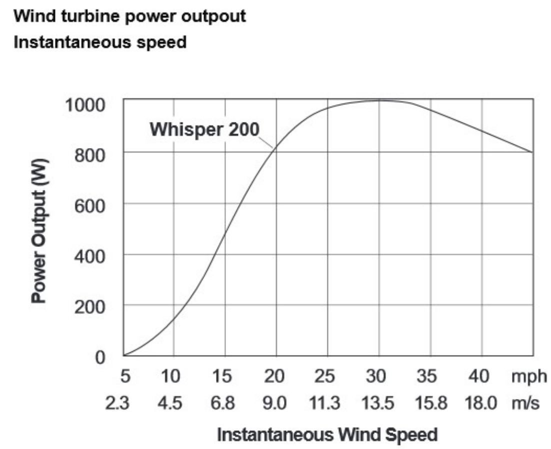
Wind Turbine Power Output



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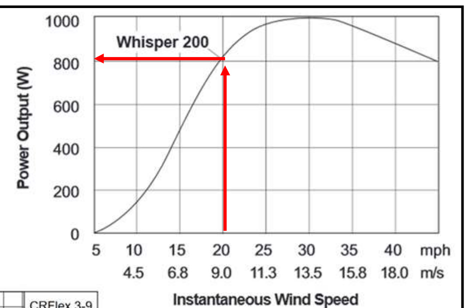
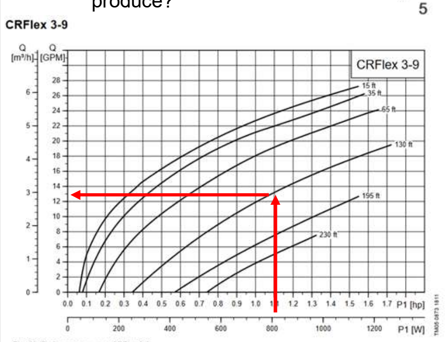
Example:
Your Location can maintain 20 mph winds

If your sprinkler system requires 55psi, How much flow will the pump below produce?





20MPH = ~800 Watts of Power Output

55 PSI = 127 ft of head

800 Watts will pump ~13 GPM @ 130ft of Head

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Limitations of Renewable Energy

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Solar Systems

- Advantages
  - Favorable Weather
    - Pump consistently all year
  - Portability
    - can be portable to move
  - Lifetime
    - Around 20 years
  - Maintenance
    - Limited Maintenance

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Solar Systems

- Disadvantages
  - Stormy Weather
    - Panels can be damaged by hail
    - Cloudy Weather and short days reduce energy
    - Lightening Strike damage if not properly grounded
  - Cost
    - High initial start up cost
    - Batteries are expensive and only last about 5 years

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Wind Systems

- Advantages
  - Favorable Weather
    - Steady winds are most productive
  - Lifetime
    - Can exceed 50 years with proper maintenance
  - Cost
    - Lower initial cost

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Wind Systems

- Disadvantages
  - Stormy Weather
    - High Winds wear parts more rapidly
    - Destructive winds can ruin system
  - Wind Requirement
    - Pump production slows or stops when wind speeds are low, which occur in July and August when water is needed most
  - Maintenance Cost
    - Requires periodic maintenance to moving parts

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Reality Check

- Wind Solar pumping systems are going to be most feasible for low flow/low pressure irrigation systems such as Drip Irrigation.
- Renewable systems offer the “Green” solution to water conservation practices such as rainwater harvesting.

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