SOLAR POWER 101
THE BASICS OF SOLAR ENERGY

Gary L. Hawkins, Ph.D.

University of Georgia – Tifton

Agent Training

29 May 2013

BASIC TERMINOLOGY

- Solar Electric
  - Uses Solar Panels or Photovoltaic (PV) Panels
- Solar Thermal
  - This is Solar Hot Water Heating

ADVANTAGES OF PV TECHNOLOGY

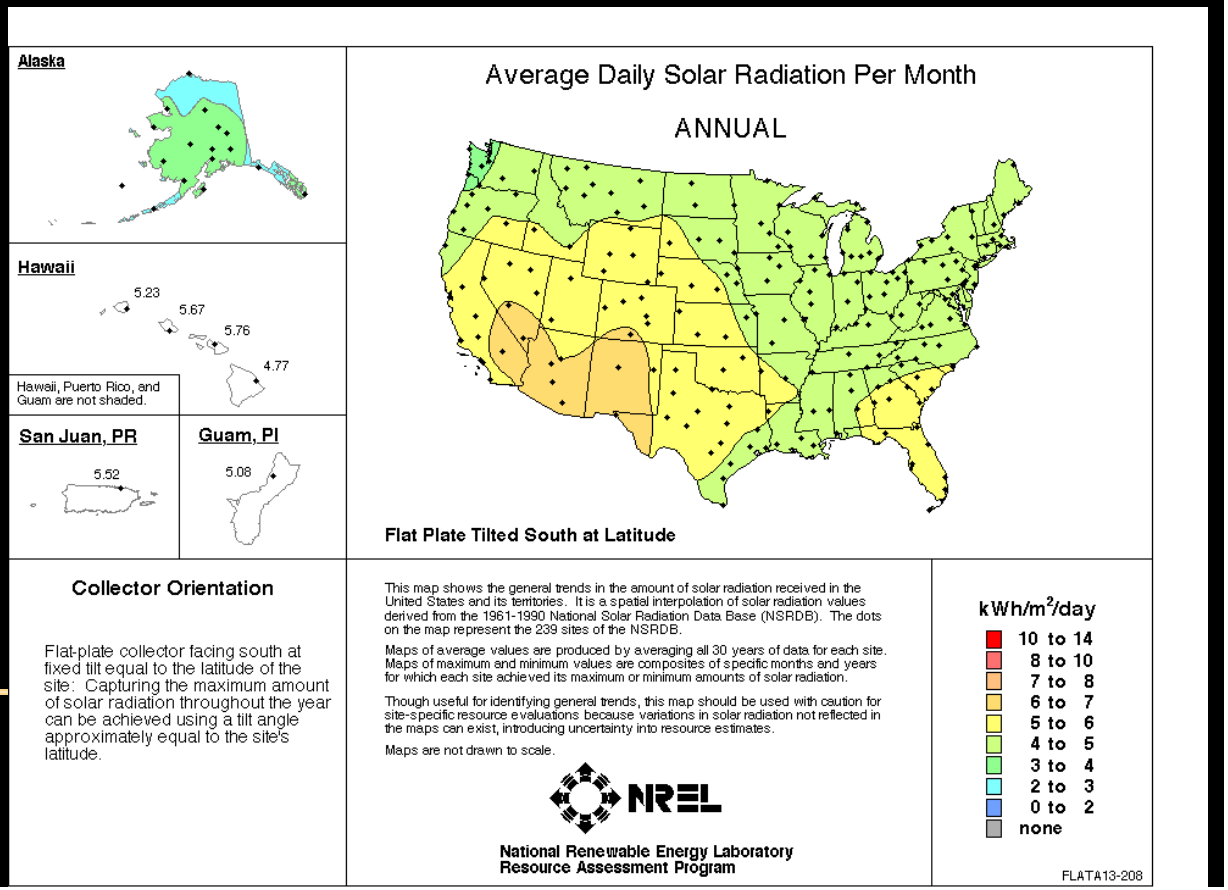
- Reliability
  - In harsh conditions the system has been shown to work
- Durability
  - Most modules are guaranteed for 25 years with production even after that
- Low maintenance cost
  - Systems require periodic inspection and occasional maintenance
- No fuel cost
  - No liquid fuel to deal with to produce power
- Reduced sound pollution
  - Only sound produced is from the pump and tracking system if used

ADVANTAGES OF PV TECHNOLOGY

- Photovoltaic modularity
  - Modules can be added to increase power
- Safety
  - No fuel required to be stored or used
- Independence
  - Based on the use, it system can be a stand alone system with no grid tied components
- Electric grid decentralization
  - For larger systems a small decentralized power station can reduce power outages

DISADVANTAGES OF PV TECHNOLOGY

- Initial Cost
  - The cost of a solar power system generally has to be expended up front and benefits received over time
- Variability of solar radiation



DISADVANTAGES OF PV TECHNOLOGY

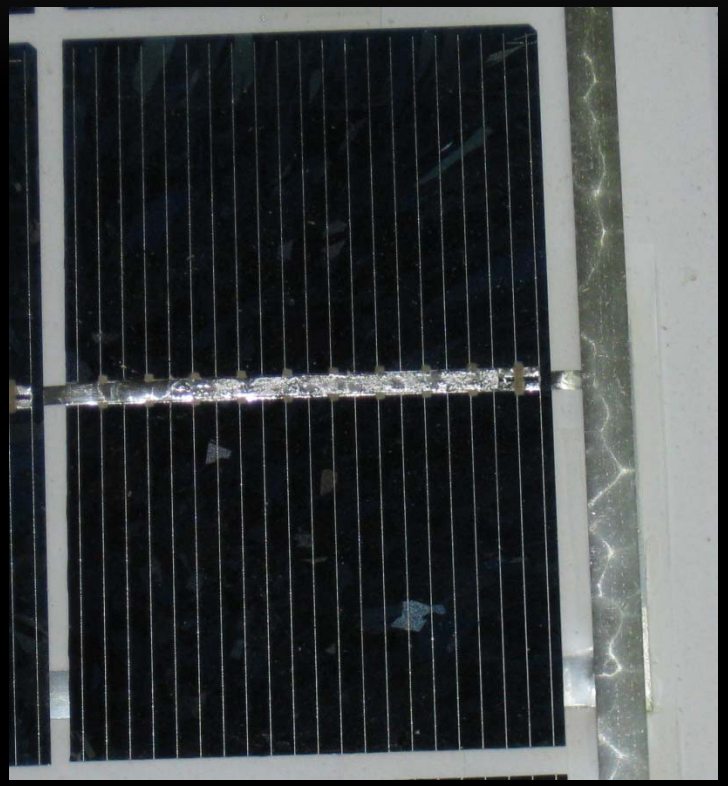
- Energy storage
  - If power is required outside daylight hours, then batteries are generally needed. These batteries are high amp-hours, seep cycle batteries. Cost can range from $250 - $500.
- Efficiency improvements
  - The use of solar power for home, office, barn, etc. use FIRST requires that energy conservation be practiced
- Education
  - Learning how solar systems are different from the electric grid is one of the first things that needs to be understood from potential users of the systems

OUTLINE

- PV System Components
- Terminology of Electricity
- Electric Circuits
- Designing a small PV system
- Sizing a system

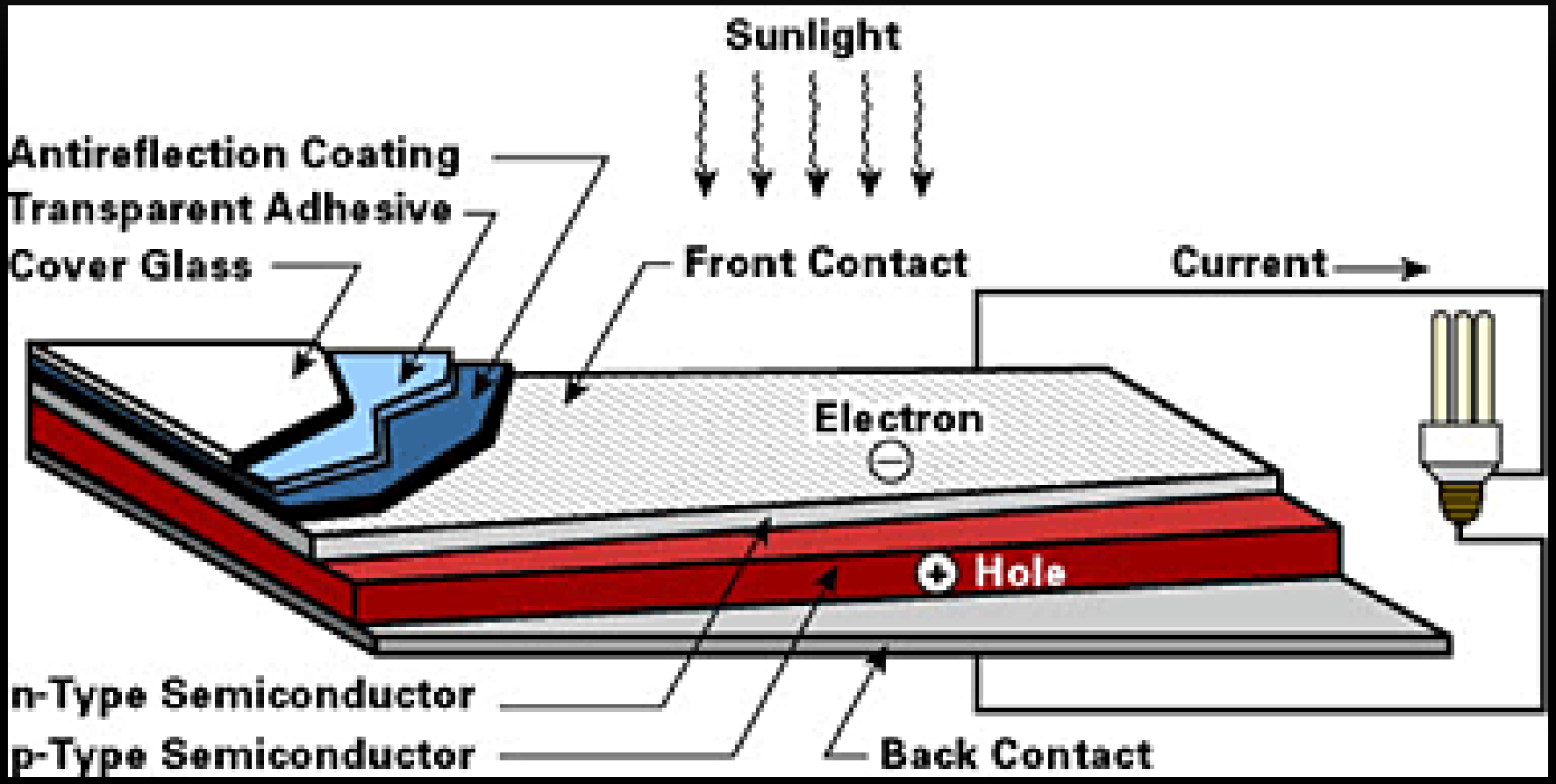
PV SYSTEM COMPONENTS

- Photovoltaic Cells



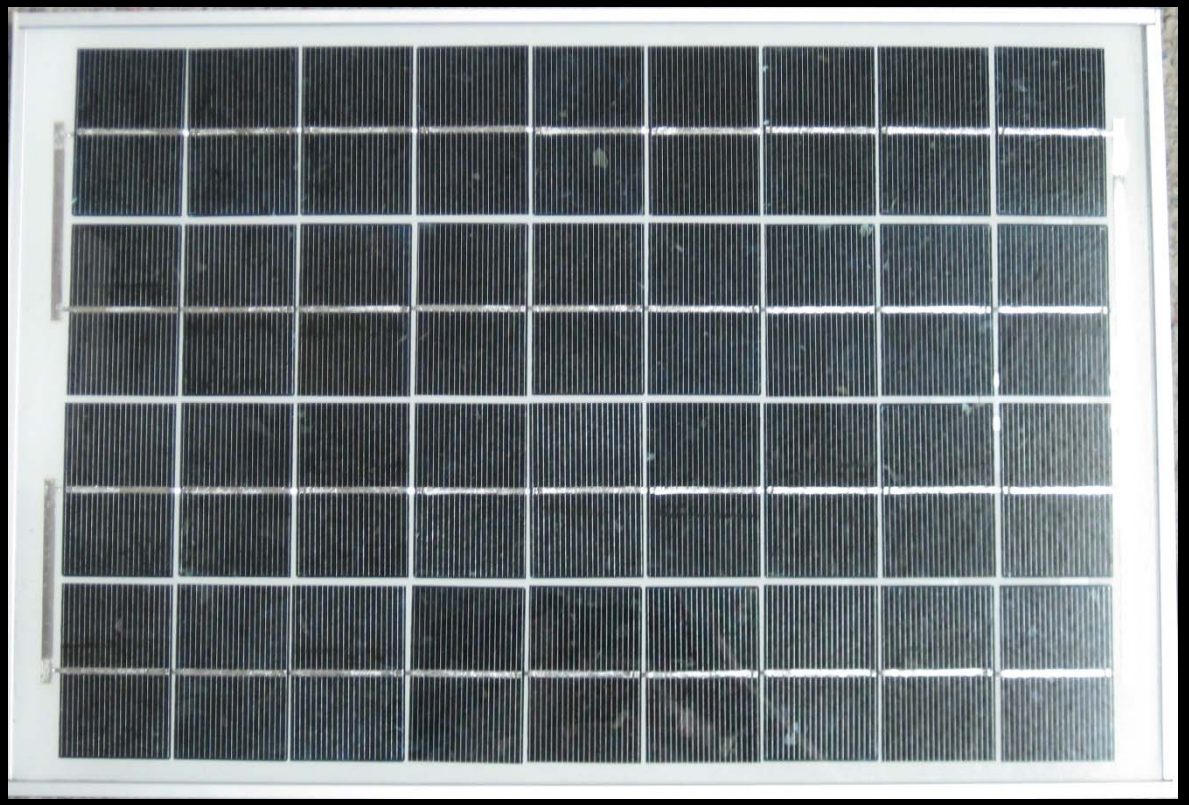
Picture from http://upload.wikimedia.org/wikipedia/commons/9/90/Solar_cell.png

SOLAR CELL CONSTRUCTION



PV SYSTEM COMPONENTS

- Module or Panel (generally interchangeable with each other)

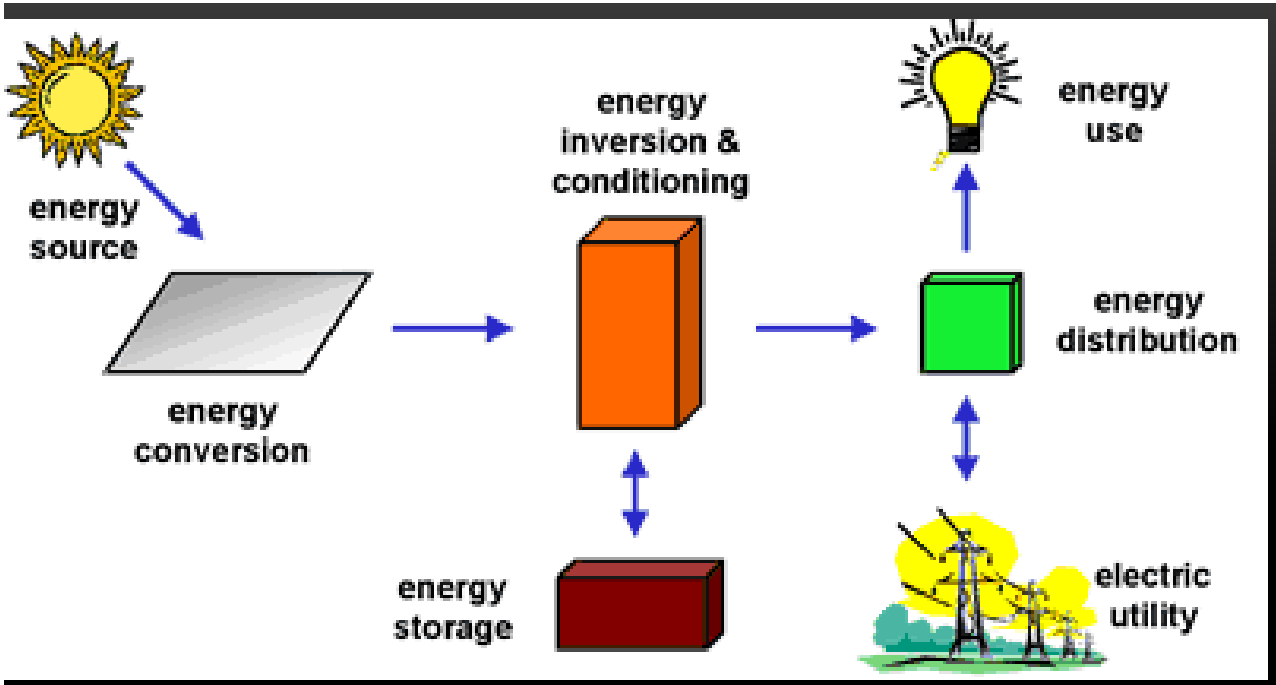


PV SYSTEM COMPONENTS

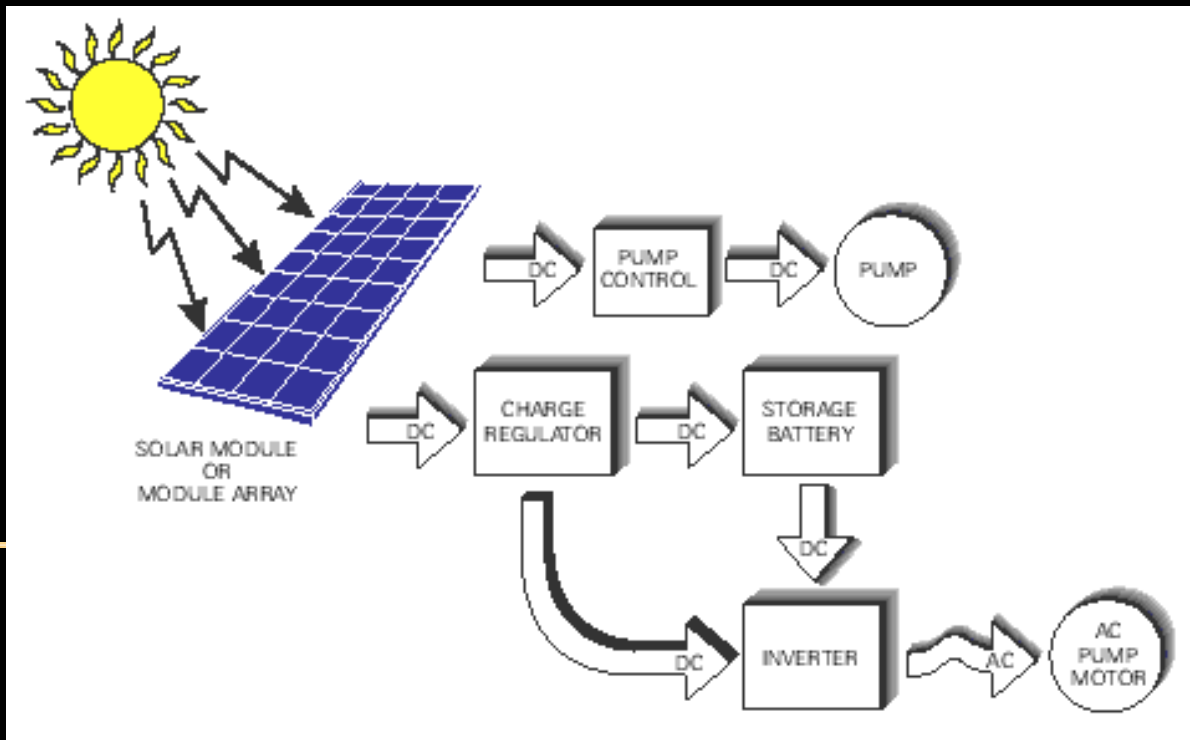
- Array – One or more panels joined together for a specific voltage or amperage

PV SYSTEM COMPONENTS

- Charge Controller
- Battery
- Inverter
- DC Load
- AC Load



A complete solar power system



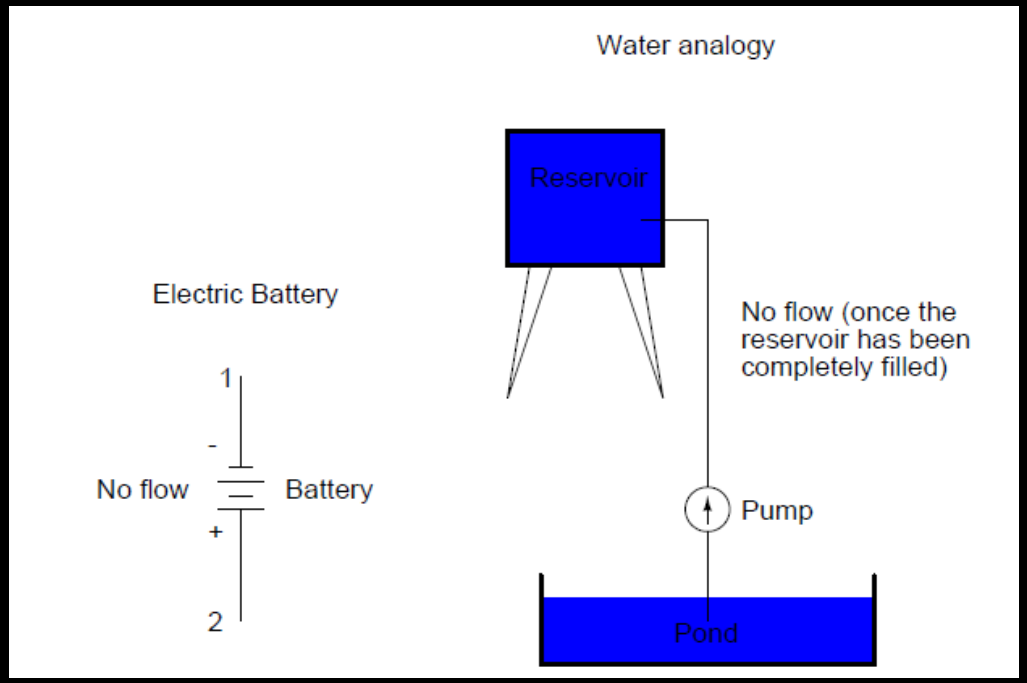
OUTLINE

- PV System Components
- Terminology of Electricity
- Electric Circuits
- Designing a small PV system
- Sizing a system

TERMINOLOGY

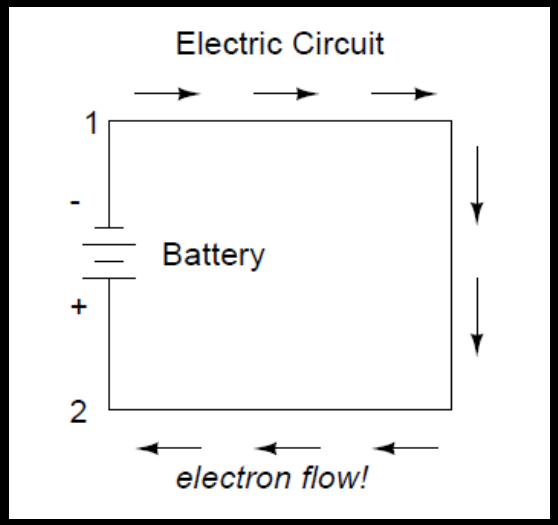
- Electricity
  - Flow of electrons through a circuit

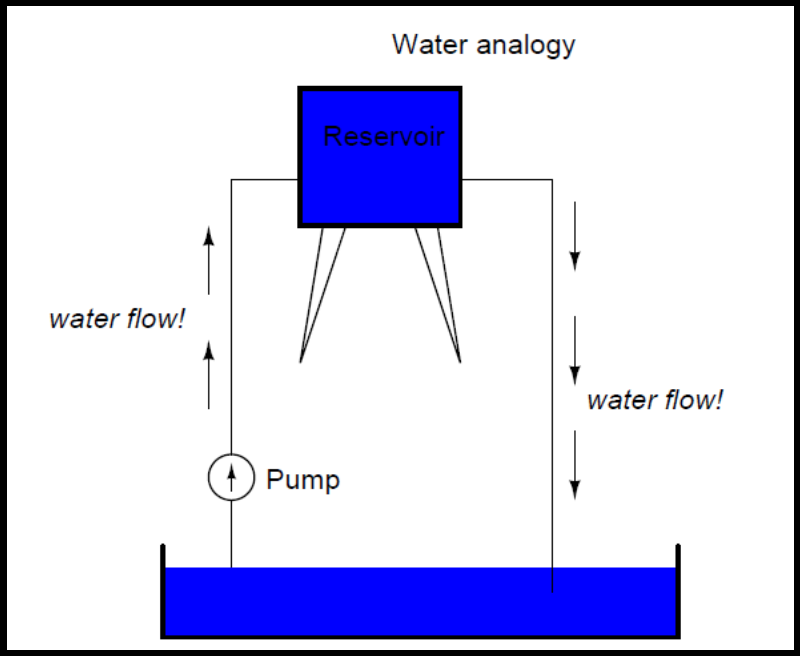
- Volt (V)
  - A unit of force (electric pressure) that has potential to cause electrons to flow in a wire



TERMINOLOGY

- Ampere or Amp (A)
  - Unit of electrical current flowing through a wire





- Watt
  - A unit of electrical power equivalent to a current of one amp under a pressure of one volt.

EQUATIONS

- Power = Watts (W) = Volts (V) X Amps (A)
  - 1000 watts = 1 kilowatt
- Energy = Watt-hours(Wh) = Watts X hours
  - 1000 Wh = 1 kilowatt-hr (kWh)
  - Amp-hour (Ah) = amps X hours

EQUATIONS

- Pop Quiz

  How much electrical energy is consumed if a 100 watt light bulb is used for 10 hours?

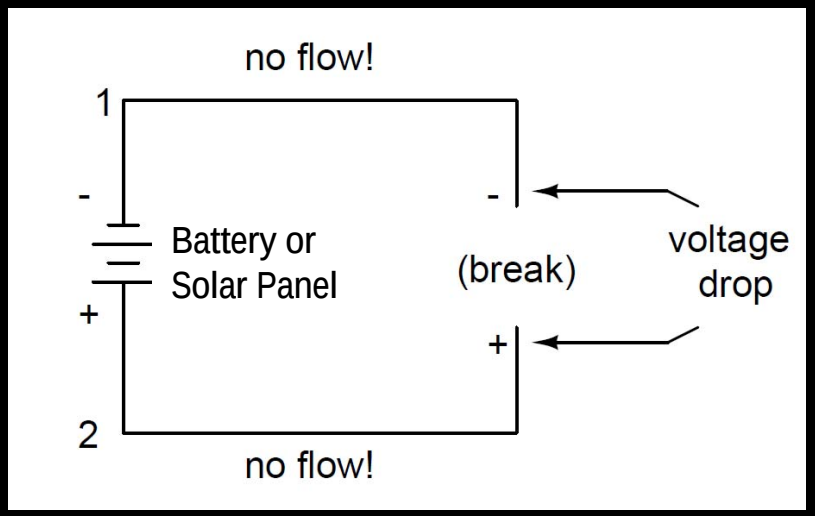
- 100 watt bulb X 10 hours = 1000 watt-hours or 1 kWh

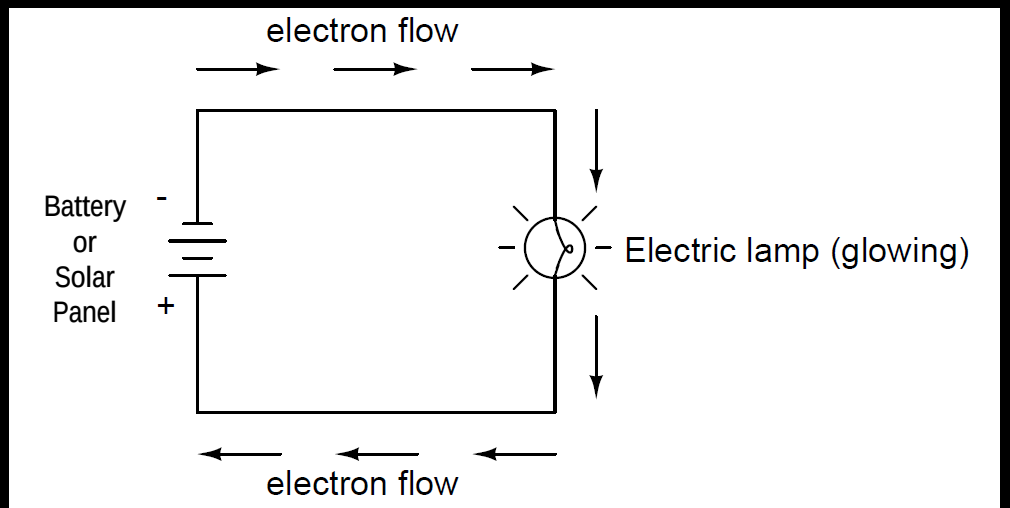
OUTLINE

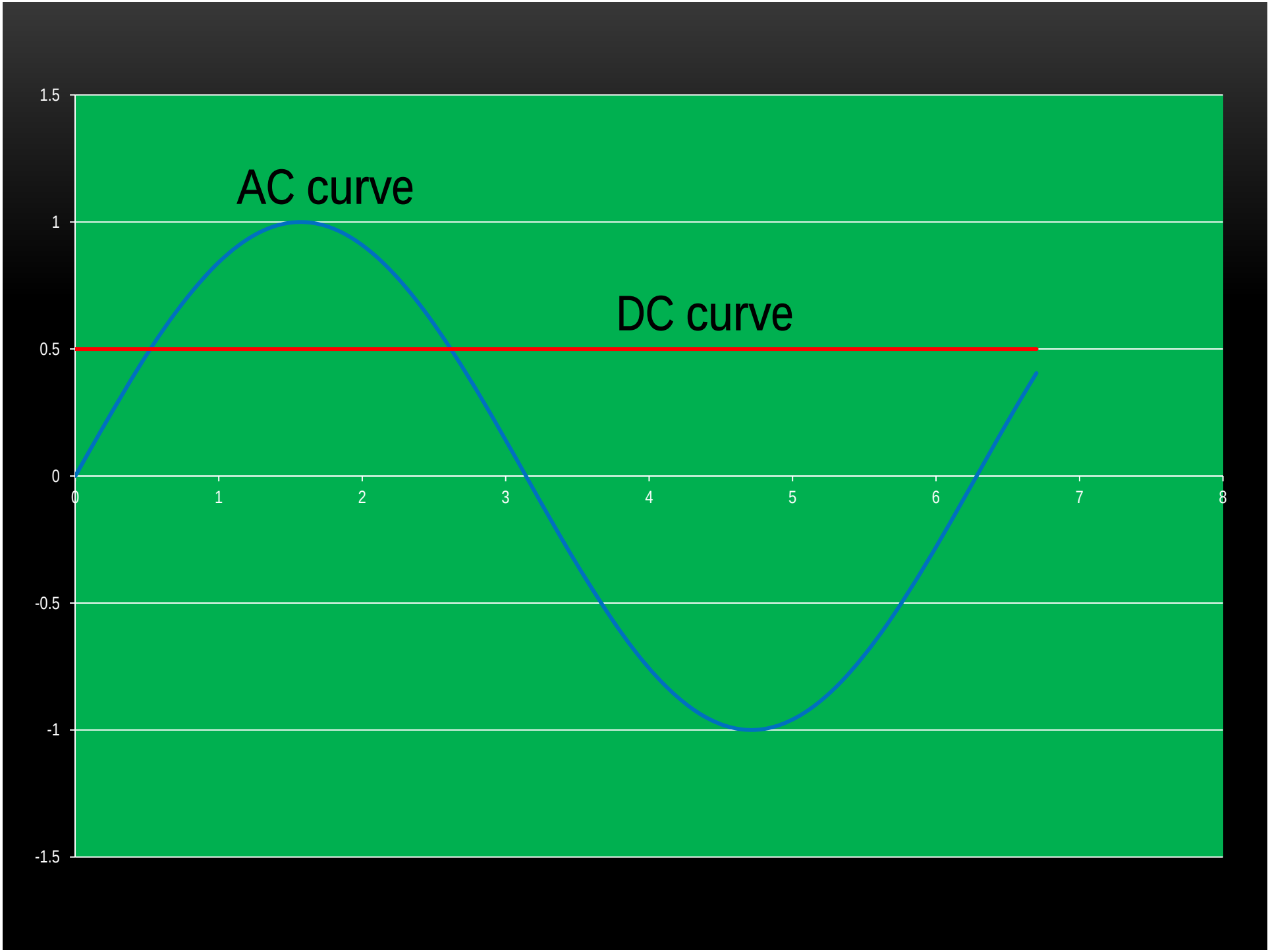
- PV System Components
- Terminology of Electricity
- Electric Circuits
- Designing a small PV system
- Sizing a system

ELECTRIC CIRCUITS

- Electric circuit is a continuous path of electron flow from a voltage source, such as a battery or PV panel, through a wire to the load and back.






AC curve
DC curve
1.5
1
0.5
0
-0.5
-1
-1.5
0
1
2
3
4
5
6
7
8

ELECTRIC CIRCUITS

- Series circuit is a circuit where the positive (+) end of each panel is connected to the negative (-) of the next panel.
- This configuration increases the voltage of the system but NOT the amperage.

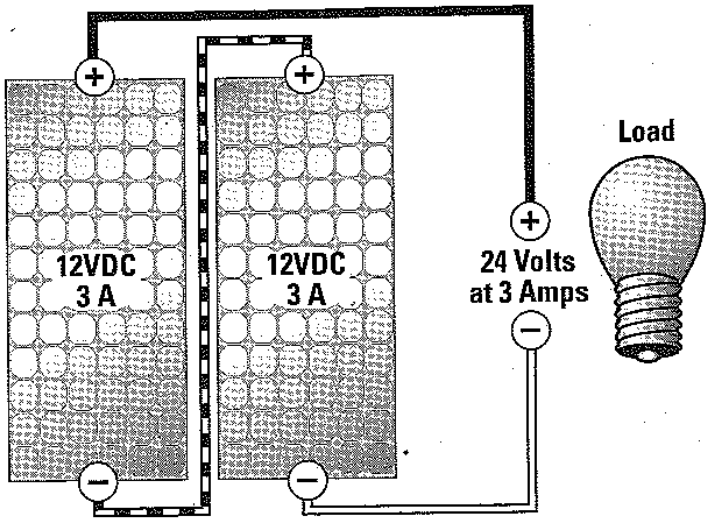


Figure 2-2
PV MODULES IN *SERIES*

ELECTRIC CIRCUITS

- Parallel circuit is a circuit where the positive (+) end of all panels are connected together.
- This configuration increases the amps but NOT the volts.

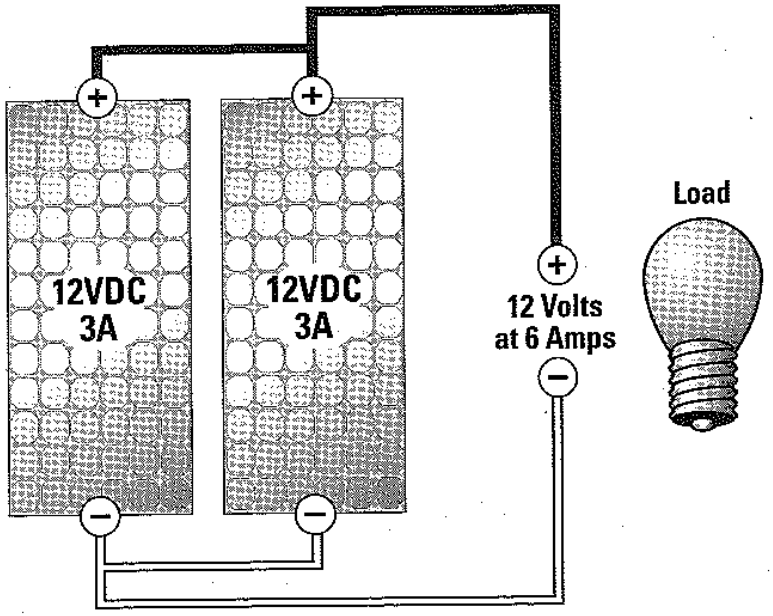


Figure 2-3

PV MODULES IN *PARALLEL*

ELECTRIC CIRCUITS

- Hybrid circuit is a circuit where part of the panels are connected in parallel and part are connected in series.
- This configuration increases both the amps AND volts.

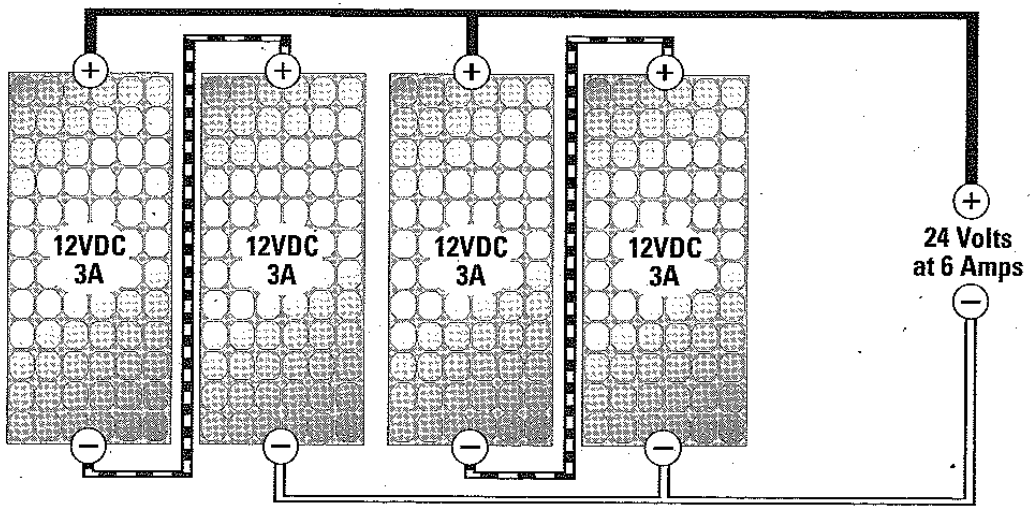


Figure 2-4

PV MODULES IN SERIES *AND* PARALLEL

OUTLINE

- PV System Components
- Terminology of Electricity
- Electric Circuits
- Designing a small PV system
- Sizing a system

DESIGNING A SMALL PV SYSTEM

- Let's take a small cattle watering system:
  - How many cows are we watering? – 25 cows
  - How deep is the static water level in the well? – 40 feet
  - How far does the water have to be pumped? (this is the dynamic head) – 300 feet up hill 30 feet
  - What size pipe are we using? -- 1 inch pipe
  - Do we have a storage tank? – storage tank at top of hill, tank is 5 foot tall

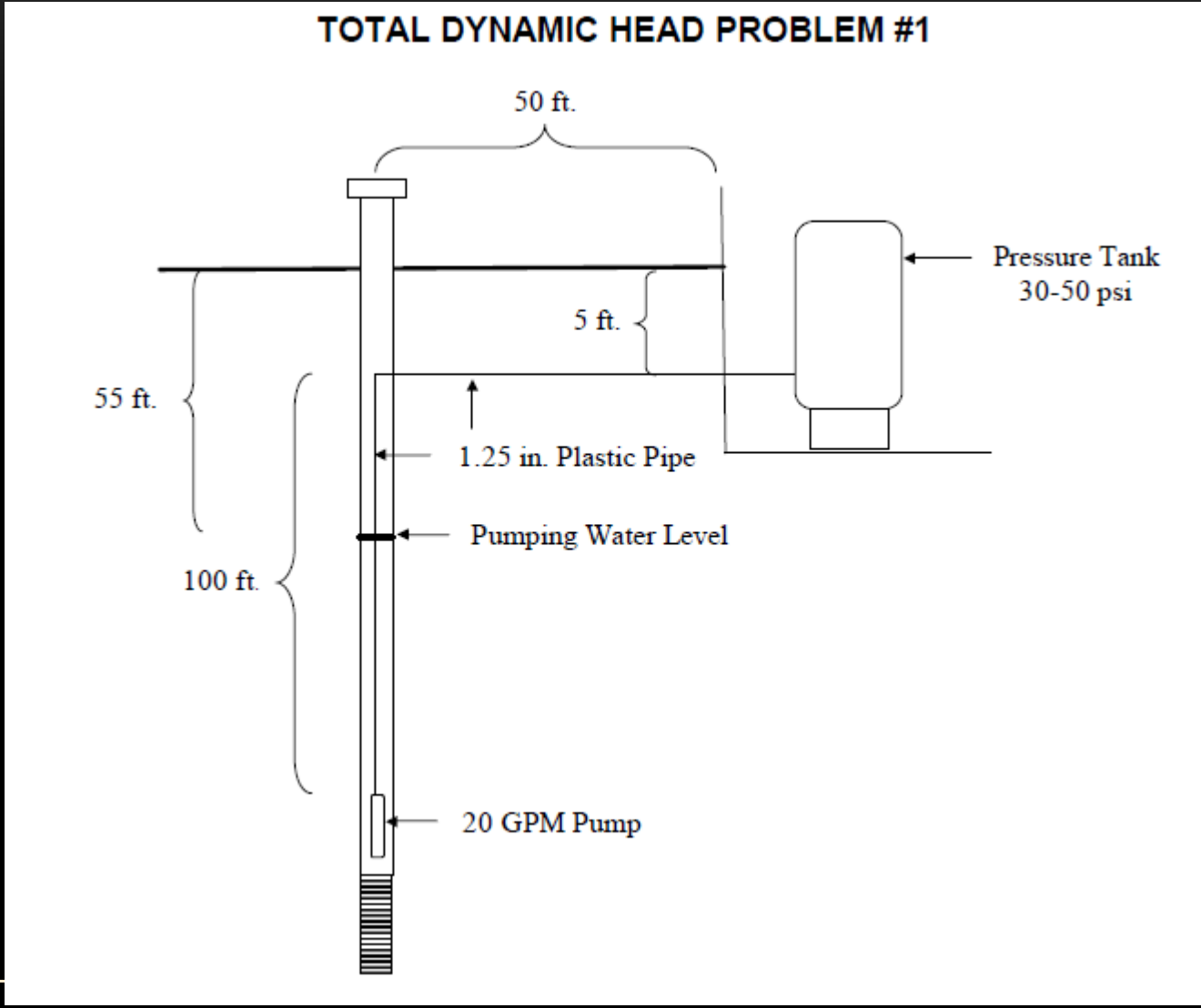
DESIGNING A SMALL PV SYSTEM

- Where to start?
  - Generally a lactating cow needs 20 gallons of water daily
    - Therefore with 25 cows we need 500 gallons of water DAILY
    - Assuming only 5 hours of sun daily (this should be very conservative figure)
    - Then we need 100 gallons per hour to be pumped
    - Or 1.7 gallons per minute to provide ample water for all cows

DESIGNING A SMALL PV SYSTEM

- What's next? – Designing the Dynamic Head requirement
  - How deep is the static water level in the well? – 40 feet
  - How far does the water have to be pumped? (this is the dynamic head) – 300 feet up hill 30 feet
  - What size pipe are we using? -- 1 inch pipe
  - Do we have a storage tank? – storage tank at top of hill, tank is 5 foot tall
  - All of this data will be used to determine the amount of head to pick a pump.

Total Dynamic Head Calculation



http://www.michigan.gov/documents/deq/deq-wb-dwehs-gwwfwim-section7_183032_7.pdf

FRICTION LOSS CHART

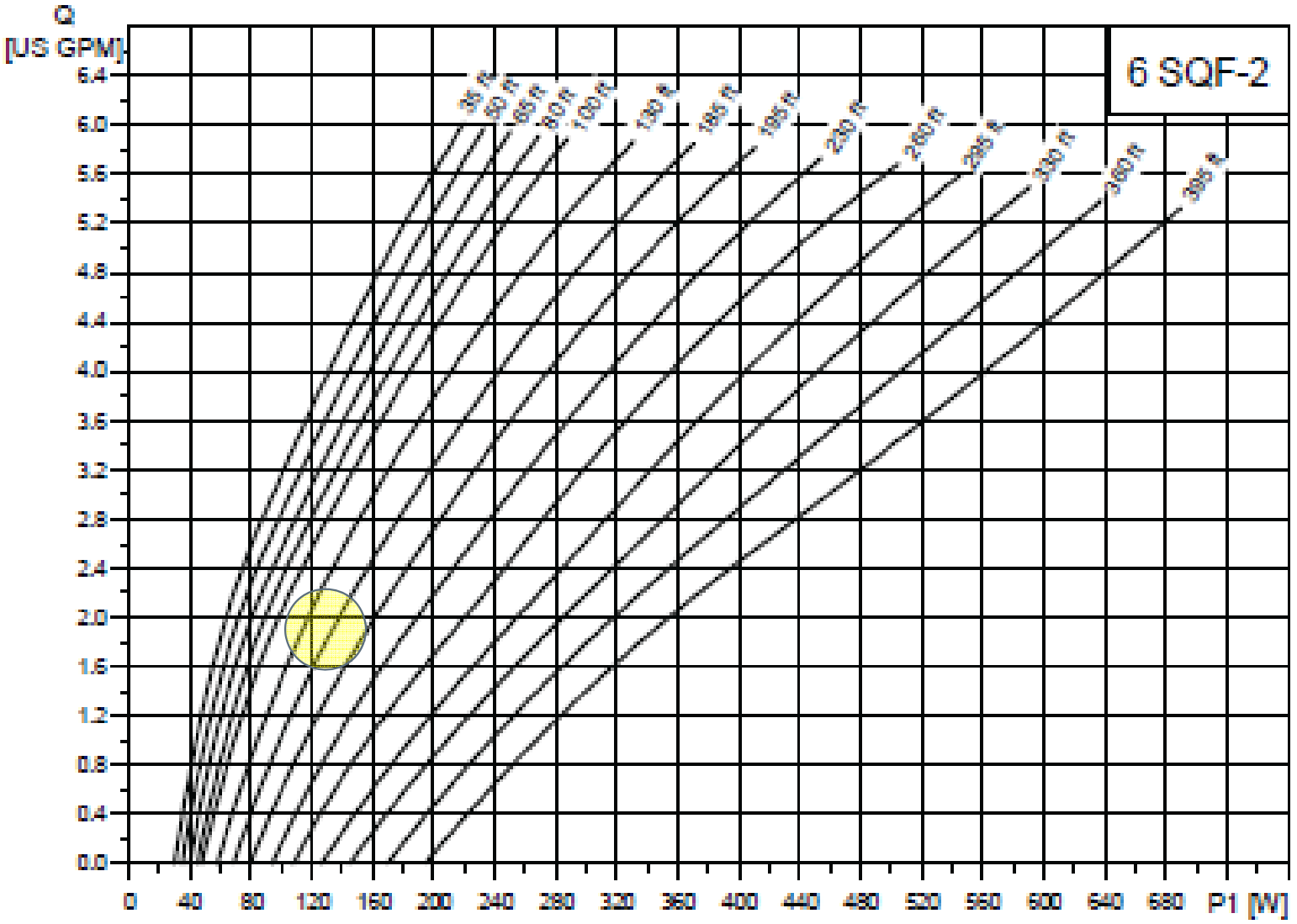
1 1/2 inch to 2 1/2 inch pipe and under 300 GPM

Loss of Head in Feet, Due to Friction Per 100 Feet of Pipe

1 1/2 INCH				2 INCH				2 1/2 INCH			
GPM	Steel C=100 ID=1.61"	Copper C=130 ID=1.60"	Plastic C=140	GPM	Steel C=100 ID=2.067"	Copper C=130 ID=2.062"	Plastic C=140 ID=2.067	GPM	Steel C=100 ID=2.469"	Copper C=130 ID=2.50"	Plastic C=140 ID=2.469"
4	0.267	0.1[illegible]5	0.144	10	0.431	0.268	0.233	20	0.654	0.375	0.353
6	0.565	0.3[illegible]8	0.305	15	0.916	0.569	0.495	30	1.39	0.792	0.75
8	0.962	0.611	[illegible]	20	1.55	0.962	0.839	40	2.36	1.35	1.27
10	1.45	0.923	0.785	25	2.35	1.45	1.27	50	3.56	2.04	1.92
12	2.04	1.29	1.1	30	3.29	2.03	1.78	60	4.99	2.86	2.69
14	2.71	1.71	1.46	35	4.37	2.71	2.36	70	6.64	3.82	3.58
16	3.47	2.2	1.87	40	5.6	3.47	3.03	80	8.5	4.88	4.59
18	4.31	2.75	2.33	45	6.96	4.31	3.76	90	10.6	6.06	5.72
20	5.24	3.31	2.83	50	8.46	5.24	4.57	100	12.8	7.37	6.9
25	7.9	5	4.26	55	10.1	6.22	5.46	110	15.3	8.8	8.25
30	11.1	7	6	60	11.9	7.34	6.44	120	18	10.3	9.71
35	14.7	9.35	7.94	70	15.8	9.78	8.53	130	20.9	12	11.3
40	18.9	12	10.2	80	20.2	12.5	10.9	140	23.9	13.7	12.9
45	23.4	14.9	12.63	90	25.1	15.6	13.6	150	27.3	15.6	14.7
50	28.5	18.1	15.4	100	30.5	18.9	16.5	160	30.7	17.6	16.6
55	34	21.5	18.35	110	36.4	22.5	19.7	170	34.3	19.7	18.5
60	40	25.3	21.6	120	42.7	26.6	23.1	180	38.1	21.9	20.6
65	46.4	29	25.1	130	49.6	30.7	26.8	190	42.1	24.2	22.7
70	53.2	33.8	28.7	140	56.9	35.2	30.6	200	46.3	26.6	25
75	60.4	38	32.6	150	64.7	40.1	35	220	55.3	31.8	29.8
80	68.1	43.1	36.8	160	72.8	45.1	39.3	240	66.4	37.4	35.8
85	76.2	47.6	41.2	170	81.4	50.5	44	260	75.3	43.3	41.6
90	84.7	53.6	45.7	180	90.5	56.1	48.9	280	86.3	49.4	46.6
95	93.6	58.8	50.5	190	100	62	54	300	98.1	56.8	52.9
100	103	65.1	56.6	200	110	68	59.4				

Note: The area above the heavy line is recommended for normal operation based on a maximum flow velocity of 5 ft./sec.

6 SQF-2


6 SQF-2
Q
[US GPM]
6.4
6.0
5.6
5.2
4.8
4.4
4.0
3.6
3.2
2.8
2.4
2.0
1.6
1.2
0.8
0.4
0.0
35 ft
50 ft
65 ft
80 ft
100 ft
130 ft
165 ft
195 ft
230 ft
260 ft
295 ft
330 ft
360 ft
395 ft
0
40
80
120
160
200
240
280
320
360
400
440
480
520
560
600
640
680
P1 [W]

TOTAL DYNAMIC HEAD WORKSHEET

Determine Total Elevation Head

1. How many vertical feet is it from the pumping water level to the pressure tank?
   _____ ft. 80 feet

Determine Friction Head

2. What is the pump capacity flow rate through pipe? _____ gpm 6 gpm

3. What is the diameter and material type of the water service line from the well to the pressure tank? Diameter _____in. Material _____ 1.5 inch PVC

4. Apply the answers to questions 2 and 3 to a friction loss chart to find the friction head per 100 feet of water service line. _____ ft./100 ft. .305 feet/100 ft

5. What is the length of the water service line? _____ ft. 300 feet

6. What is the friction head for the water service line (multiply the answers for questions 4 and 5).
   _____ ft. 1 foot

   Example: Friction loss chart shows that 1 inch diameter plastic pipe at 10 gpm flow rate has a friction head loss of 6.3 ft. per 100 ft. $\frac{6.3}{100}$ ft. x pipe length = friction head

   Water service line is 200 ft. in length.

   $\frac{6.3}{100}$ ft. x 200 ft. = 12.6 ft. friction head

7. What is the diameter and material type of the drop pipe from the pump to the pitless adapter?
   Diameter _____in. Material _____ 1.5 inch PVC

8. Apply the answers to questions 2 and 7 to a friction loss chart to find the friction head per 100 feet of pump drop pipe. _____ ft./100 ft. .305 feet/100 ft

9. What is the length of the pump drop pipe? _____ ft. 80 feet

10. What is the friction head for the water service line? (multiply the answers for questions 8 and 9 – see example in #6 above). _____ ft. 0.2 foot

11. What is the total friction head? _____ ft. 82 feet

Determine Pressure Head

12. What is the pressure switch pump cut-out setting? _____ psi 50 psi

    Example: The pump cut-out setting is the pressure at which the pump will shut off at the end of the pump operating cycle. If the pressure switch setting is 30-50 psi, the pump cut-out setting is 50 psi.

13. Determine the pressure head by converting the answer from question 12 from pound per square inch to feet of head by multiplying it by 2.31 ft./psi. _____ ft.

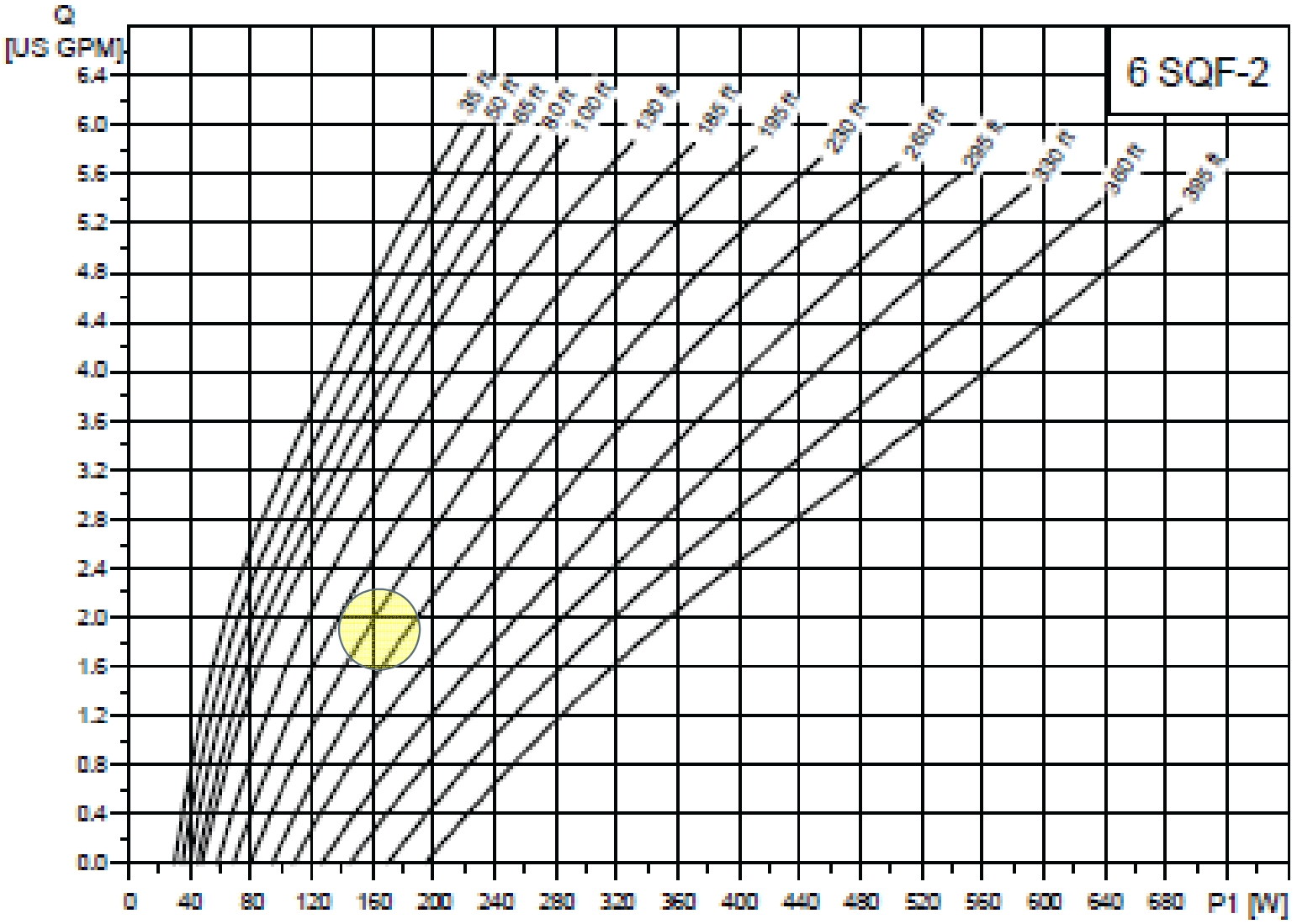
    Example: 50 psi x 2.31 ft./psi = 115.5 ft. 115.5 feet

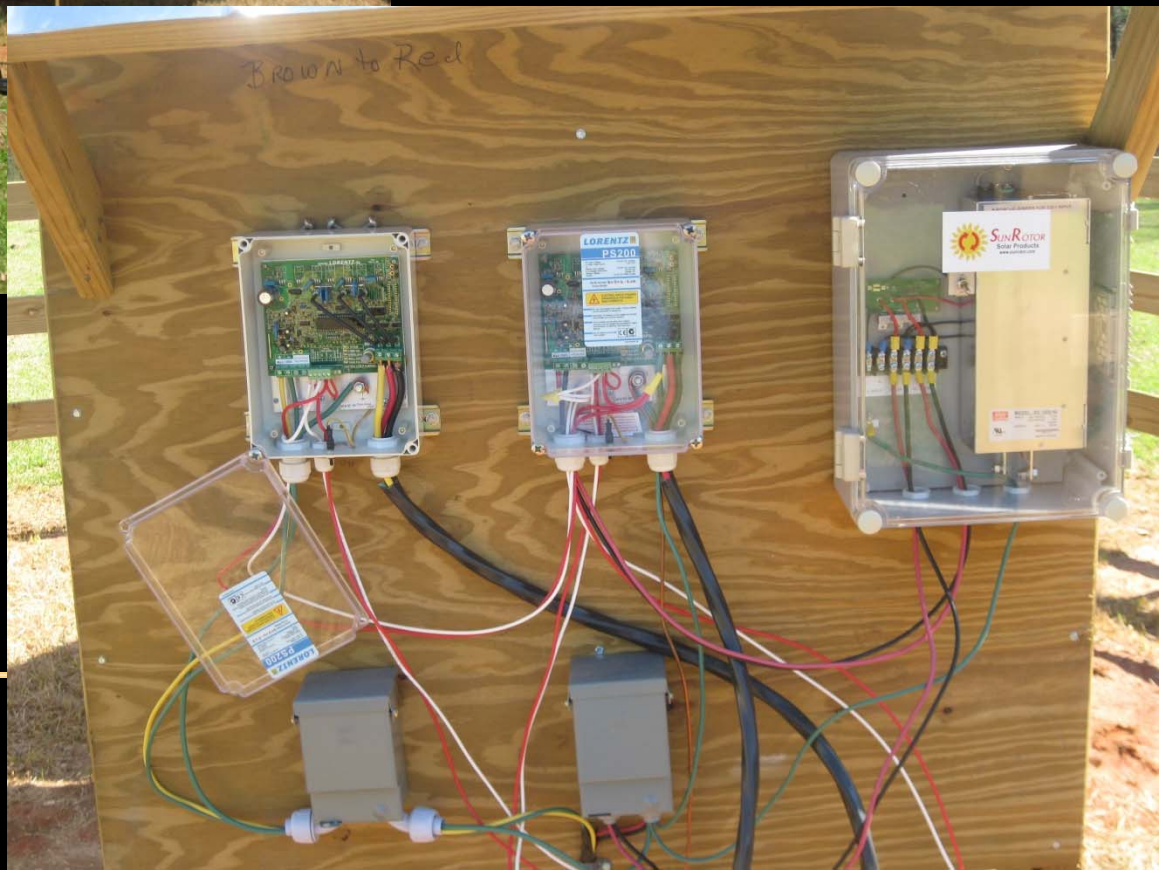
Determine Total Dynamic Head

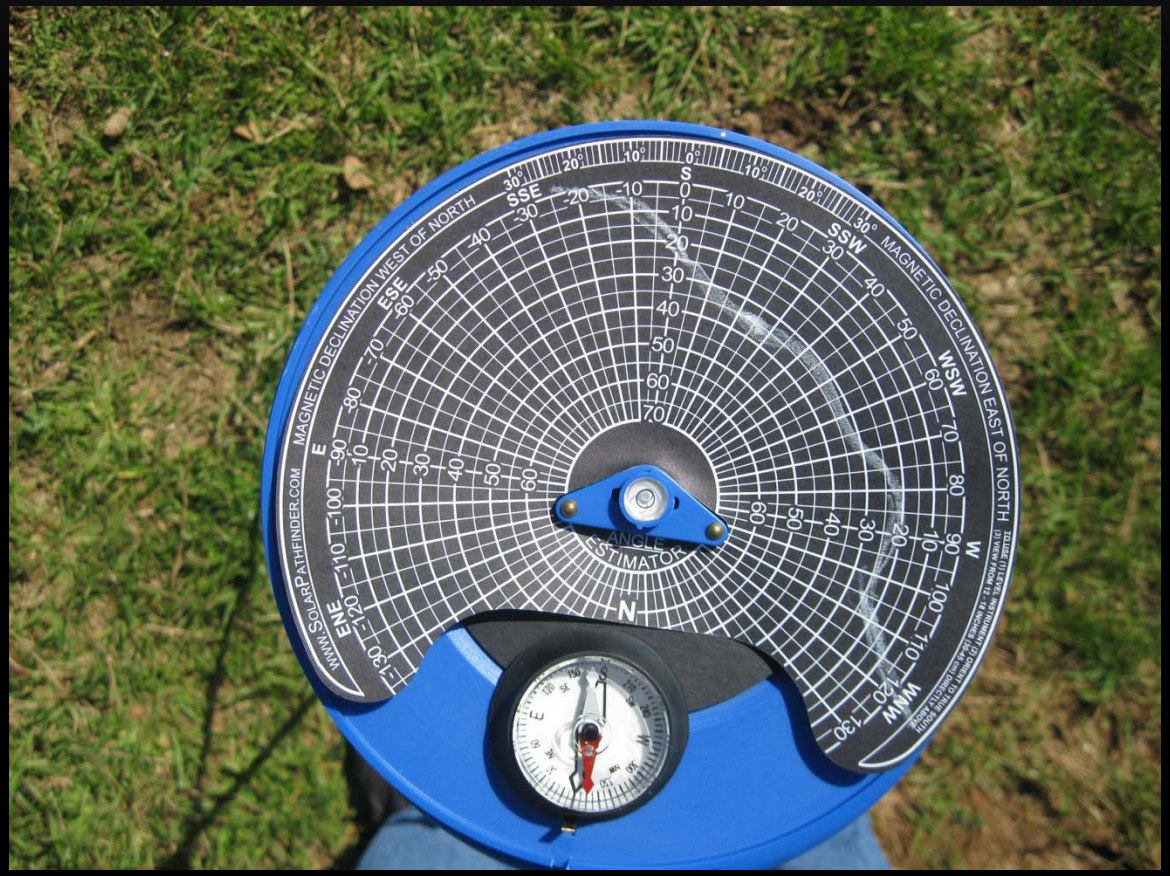
14. Determine TDH by adding answers for questions 1, 11, and 13.

    Total dynamic head = _____ ft 197.5 feet

6 SQF-2


Q
[US GPM]
6 SQF-2
35 ft
50 ft
65 ft
80 ft
100 ft
130 ft
165 ft
195 ft
230 ft
260 ft
295 ft
330 ft
360 ft
395 ft
6.4
6.0
5.6
5.2
4.8
4.4
4.0
3.6
3.2
2.8
2.4
2.0
1.6
1.2
0.8
0.4
0.0
0
40
80
120
160
200
240
280
320
360
400
440
480
520
560
600
640
680
P1 [W]


Brown to Red
LORENTZ
PS200
SUNROTOR
Solar Products


WWW.SOLARPATHFINDER.COM
MAGNETIC DECLINATION WEST OF NORTH
MAGNETIC DECLINATION EAST OF NORTH
S
SSE
SSW
ESE
WSW
E
W
ENE
WNW
N
ANGLE
ESTIMATOR


08/10/2010

RENEWABLE AND ENERGY EFFICIENCY REBATES, TAX INCENTIVES, REFUNDS

HTTP://WWW.DSIREUSA.ORG/

DSIRE™

Database of State Incentives for Renewables & Efficiency

U.S. Department of Energy | Energy Efficiency & Renewable Energy

North Carolina Solar Center

IREC

Home | Glossary | Links | FAQs | Contacts | About Us

DSIRE SOLAR

solar policy information

Resources

- Summary Maps
- Summary Tables
- Library
- Search
- What's New?

myDSIRE

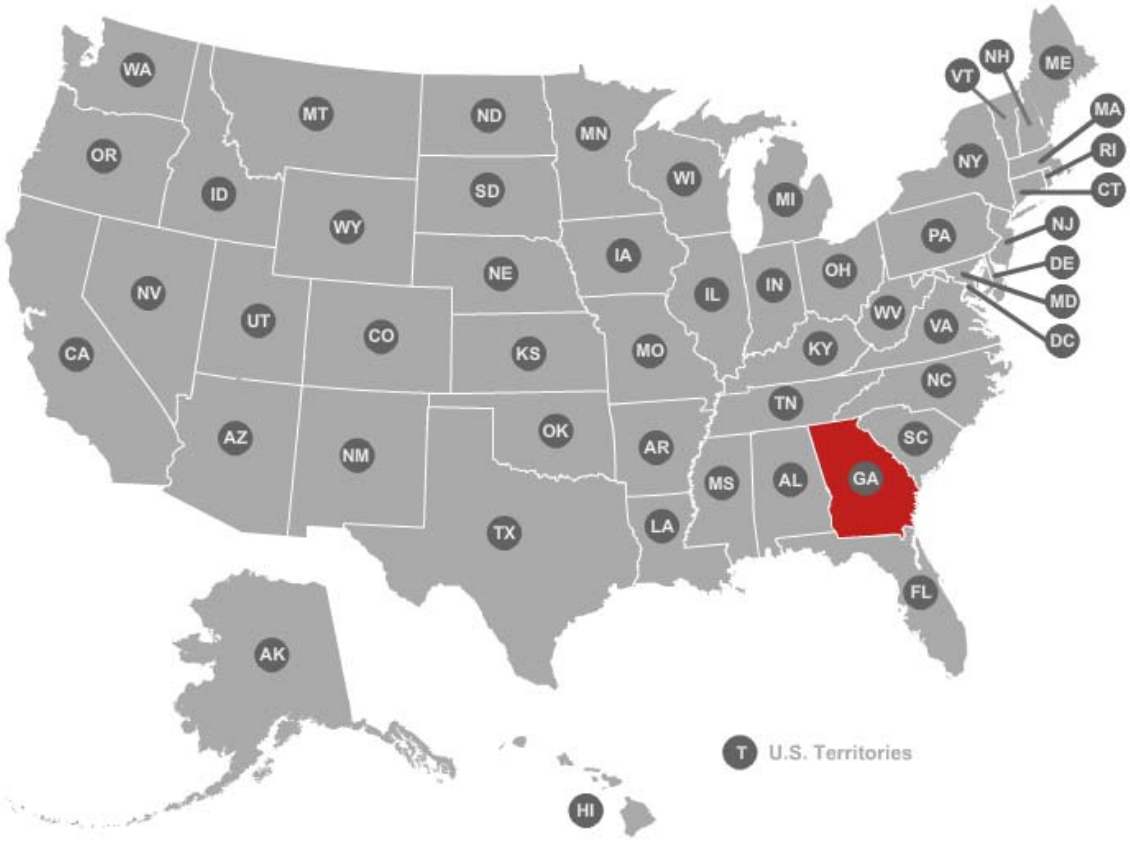
customize DSIRE for your organization

DSIRE is a comprehensive source of information on state, local, utility and federal incentives and policies that promote renewable energy and energy efficiency. Established in 1995 and funded by the U.S. Department of Energy, DSIRE is an ongoing project of the N.C. Solar Center and the Interstate Renewable Energy Council.

Choose one or both databases:

☑ Renewable Energy ☑ Energy Efficiency

Federal Incentives



Resources
Summary Maps
Summary Tables
Library
Search
What's New?

GEORGIA

Incentives/Policies for Renewables & Efficiency

Printable Version

See Federal Incentives
See All Summaries
See Residential Incentives Only

Financial Incentives

Corporate Tax Credit
- Clean Energy Tax Credit (Corporate)

Local Rebate Program
- Atlanta - Sustainable Home Initiative for a New Economy (SHINE) Program

Other Incentive
- Georgia Green Loans Save & Sustain Program

PACE Financing
- Local Option - Special Improvement Districts

Performance-Based Incentive
- Georgia Power - Solar Buyback Program
- TVA - Generation Partners Program

Personal Tax Credit
- Clean Energy Tax Credit (Personal)

Sales Tax Incentive
- Biomass Sales and Use Tax Exemption

State Rebate Program
- Georgia - Residential Energy-Efficient Appliance Rebate Program

Utility Loan Program
- Amicalola EMC - Energy Resource Conservation (ERC) Loan
- Coweta-Fayette EMC - Energy Advantage Loan Program
- Habersham EMC - Energy Efficient Loan Program
- TVA Partner Utilities - *energy right* Heat Pump Program
- Walton EMC - Prime PowerLoan Program

Utility Rebate Program

- Atlanta Gas Light - Energy Efficiency Incentive Program
- Blue Ridge Mountain Electric Membership Corporation - Water Heater Rebate Program
- Central Georgia EMC - Photovoltaic Rebate Program
- Central Georgia EMC - Residential Energy Efficiency Rebate Program
- Cobb EMC - Solar Rebate Program
- Coweta-Fayette EMC - Geosystem Rebate Program
- Diverse Power - Energy Efficient New Construction Rebate Programs
- Energy Power Board - Energy Efficiency Rebate Program
- Georgia Power - Energy Efficiency Home Improvement Rebates
- Georgia Power - Energy Star New Home Builder Rebate Program
- GreyStone Power - Photovoltaic Rebate Program
- GreyStone Power - Sun Rays Power Program
- Habersham EMC - Energy Efficiency Rebate Program
- Jackson EMC - Right Choice for Builders Rebate Program
- Jackson EMC - Right Choice Sun Power Rebate Program
- Marietta Power & Water - Residential Water Heater and Heat Pump Rebate
- Sawnee EMC - Commercial Energy Efficiency Rebate Program
- Sawnee EMC - Residential Energy Efficiency Rebate Program
- Sawnee EMC - Solar Photovoltaic Rebate Program
- TVA Partner Utilities - *energy right* New Homes Program
- TVA Partner Utilities - *energy right* Water Heater Program
- Walton EMC - Residential Solar and Efficiency Rebate Programs

Rules, Regulations & Policies

Building Energy Code

- Georgia State Energy Code for Buildings

Energy Standards for Public Buildings

- Atlanta - Sustainable Development Design Standards
- Chamblee - LEED Requirement for Public and Commercial Buildings
- Georgia Governor's Energy Challenge 2020

Interconnection

- Interconnection Guidelines

Net Metering

- Georgia - Net Metering

Solar Access Law/Guideline

- Solar Easements

Related Programs & Initiatives

Alternative Fuels and Advanced Vehicles Data Center
The U.S. Department of Energy's Alternative Fuels and Advanced Vehicles Data Center (AFDC) provides a wide range of information and resources to enable the use of alternative fuels and other petroleum-reduction options, such as advanced vehicles, fuel blends, idle reduction and fuel economy. The AFDC site offers a database of state and federal laws and incentives related to alternative fuels and vehicles, air quality, fuel efficiency, and other transportation-related topics.

Green Power Network
The U.S. Department of Energy's Green Power Network provides news and information on green power markets and activities, including opportunities to buy green power. This site provides state-by-state information on green power marketing and utility green power programs. In addition, the site lists marketers of renewable energy credits (RECs), also known as green tags or renewable energy certificates, which represent the environmental attributes of the power produced from renewable energy projects.

Weatherization Assistance Program
The U.S. Department of Energy's Weatherization Assistance Program (WAP) enables low-income families to reduce their energy bills by making their homes more energy-efficient. Through this program, weatherization service providers install energy-efficiency measures in the homes of qualifying homeowners free of charge. The WAP program web site offers a state-by-state map of opportunities, projects and activities.

Wind Powering America
The U.S. Department of Energy's Wind Powering America site provides state-by-state information on wind projects and activities, including wind working groups, validated wind maps, anemometer loan programs, small wind guides, state-specific news, wind for schools, workshops and web casts.

NC STATE UNIVERSITY

GEORGIA
Incentives/Policies for Renewables & Efficiency

Printable Version

Resources
- Summary Maps
- Summary Tables
- Library
- Search
- What's New?

Clean Energy Tax Credit (Personal)

Last DSIRE Review: 04/16/2010

Program Overview:

State:	Georgia
Incentive Type:	Personal Tax Credit
Eligible Renewable/Other Technologies:	Solar Water Heat, Solar Space Heat, Photovoltaics, Wind, Geothermal Heat Pumps
Applicable Sectors:	Residential
Amount:	35%
Maximum Incentive:	Solar hot water: $2,500 PV, active space heating, wind energy: $10,500 Energy Star-certified geothermal heat pump: $2,000
Equipment Requirements:	Solar thermal collectors must meet SRCC certification OG-100 or FSEC-GO-80. Solar thermal residential systems must meet SRCC OG-300 or FSEC-GP-5-80.
Carryover Provisions:	Excess credit may be carried forward for five years from the close of the taxable year in which the clean energy property was installed.
Program Budget:	$2.5 million annually
Program Start Date:	7/1/2008
Program Expiration Date:	12/31/2012
Web Site:	http://www.gefa.org/Index.aspx?page=423
Authority 1:	O.C.G. § 48-7-29.14
Date Enacted:	5/14/2008
Date Effective:	7/1/2008
Expiration Date	12/31/2012

Summary:

In May 2008, Georgia enacted legislation establishing personal and corporate tax credits for clean energy equipment installed and placed into service. For clean energy property installed for single-family residential purposes, the tax credit is equal to 35% of the cost of the system (including installation). The credit is subject to various ceilings depending on the type of system.

The following credit limits for various technologies and sectors apply:

- A maximum of $2,500 per residence for domestic solar water heating
- A maximum of $10,500 per residence for photovoltaics (PV), active space heating and wind energy systems
- A maximum of $2,000 per installation for Energy Star-certified geothermal heat pumps.

Leased systems are eligible for the credit. (In the case of a leased system, the cost is considered to be eight times the net annual rental rate, which is the annual rental rate paid by the taxpayer less any annual rental rate received by the taxpayer from subrentals.)

Before claiming the credit, the taxpayer must submit an application to the Georgia tax commissioner for tentative approval, as the aggregate amount of tax credits -- both personal and corporate credits -- taken may not exceed $2,500,000 in a given year. Tax credits are granted on a first come, first served basis and may not exceed the taxpayer's liability for that taxable year. The credit must be taken for the taxable year in which the property is installed. Excess credit may be carried forward for five years from the close of the taxable year in which the installment of the clean energy property occurred.

Solar hot water systems must be certified for performance by the Solar Rating Certification Corporation (SRCC), the Florida Solar Energy Center (FSEC) or a comparable entity approved by the tax authority. The equipment must meet the certification standards of SRCC OG-100 or FSEC-GO-80 for solar thermal collectors and/or SRCC OG-300 or FSEC-GP-5-80 for solar thermal residential systems.

This tax credit is in effect from July 1, 2008, until December 31, 2012. For more information, review the guidelines for the tax credit issued by the Department of Revenue.

Contact:

Taxpayer Services Division
Georgia Department of Revenue
1800 Century Center Blvd, NE
Atlanta, GA 30345-3205
Phone: (404) 417-4480
E-Mail: taxpayer.services@dor.ga.gov
Web Site: https://etax.dor.ga.gov/

QUESTIONS?

Gary L. Hawkins

University of Georgia

Tifton Campus

229-386-3377

ghawkins@uga.edu