NATURAL RESOURCES CONSERVATION SERVICE

CONSERVATION PRACTICE STANDARD

PUMPING PLANT

(No.)

CODE 533

DEFINITION

A facility that delivers water at a designed pressure and flow rate. Includes the required pump(s), associated power unit(s), plumbing, appurtenances, and may include on-site fuel or energy source(s), and protective structures.

PURPOSE

This practice may be applied as part of a resource management system to achieve one or more of the following purposes:

- Delivery of water for irrigation, watering facilities, wetlands, or fire protection
- Removal of excessive subsurface or surface water
- Provide efficient use of water on irrigated land
- Transfer of animal waste as part of a manure transfer system
- Improvement of air quality
- Reduce energy use

CONDITIONS WHERE PRACTICE APPLIES

This practice applies where conservation objectives require the addition of energy to pressurize and transfer water to maintain critical water levels in soils, wetlands, or reservoirs; transfer wastewater; or remove surface runoff or groundwater.

CRITERIA

Design, installation, and operation of a pumping plant shall comply with all federal, state, and local laws, rules and regulations. Laws and regulations of particular concern include those involving water rights, land use, pollution control, property easements, wetlands, preservation of cultural resources, and endangered species.

Colorado statutes govern the use of underground water. It is the responsibility of the landowner to comply with the applicable laws and regulations concerning applications and permits. The “Rules and Regulations for Water Well Construction, Pump Installation, Cistern Installation, and Monitoring and Observation Hole/Well Construction” (**Water Well Construction Rules**), 2 CCR 402-2, as set forth by the State of Colorado - State Board of Examiners of Water Well Construction and Pump Installation Contractors shall be followed.

General Criteria Applicable to All Purposes

Pump requirements. Design flow rate, range of operating heads, and pump type shall meet the requirements of the application.

Selection of pump materials shall be based on the physical and chemical qualities of the material being pumped and manufacturer's recommendations.

Well yield test. Prior to the design of the pump, for a pump that will be installed in a well, the yield and drawdown level of the well shall be determined by conducting a well yield test. The test shall show a stabilized production rate, where the flow rate and drawdown level do not change more than 10 percent during a period of at least one hour. Previous performance data for the well may be used in lieu of the pump test if the data is available, reliable, and within the range of the desired flow.

The yield of the well shall be adequate to serve the particular resource need for which the pump is to be designed. The pump discharge capacity shall not exceed the yield of the well as permitted by the State of Colorado.

Power units. Pump power units shall be selected based on the availability and cost of power, operating conditions, need for automation, and other site specific objectives. Power units shall match the pump requirements and be capable of operating efficiently and effectively within the planned range of conditions. The power unit shall be sized to meet the horsepower requirements of the pump, including efficiency, service factor, and environmental conditions.

Electric power units may include line power, photovoltaic panels, and wind or water powered turbines.

Electrical wiring shall meet the requirements of the National Electrical Code.

Renewable energy power units shall meet applicable design criteria in NRCS and/or industry standards, and shall be in accordance with manufacturer's recommendations.

Variable Frequency Drives. The owner shall inform the electric power provider that a Variable Frequency Drive will be installed prior to installation, and be responsible for following requirements of the electric power provider.

The Variable Frequency Drive shall be protected against overheating.

The Variable Frequency Drive control panel shall provide the read out display of flow rate or pressure.

Photovoltaic panels and photovoltaic (PV) powered systems. The photovoltaic array shall be sized based on average data for the location and the time of year pumping occurs, according to manufacturer's recommendations. The photovoltaic array shall provide the power necessary to operate the pump at the design flow rate, with the appropriate service factor considering a minimum panel degradation of 10 years. Fixed arrays shall be oriented to receive maximum sunlight. Panel tilt angle shall be based on the location latitude and time of year for power requirements. Panels shall be mounted securely to resist movement by environmental factors.

Photovoltaic (PV) powered pumping plants. An acceptable PV powered pumping plant shall include the following components:

- Photovoltaic array and mounting structure,
- Pump, including intake and outlet piping,
- Electrical System,
- Protective structures, and
- Provisions for water storage.

Float switches, timers or other monitoring devices shall be included to minimize the waste of water to the extent possible.

Solar insolation data. Site specific data, (energy received per unit area per day), are preferable for system design. Where site specific data is not available, solar insolation values may be estimated using data from tables 1, 2 & 3.

The solar insolation values for the period where the ratio of daily water requirement to average daily solar insolation is largest shall be used to size the PV array.

PV system components. Electrical components must be designed and installed in accordance with all applicable provisions of the National Electrical Code (NEC). All components shall be warranted against material and workmanship defects for a period of no less than one year from installation.

PV modules must have as a minimum, a manufacturer's warranty against power degradation in excess of 10% of the rated power for no less than ten years after installation. PV modules shall be individually labeled as described in NEC Article 690, and shall be listed by Underwriters Laboratories (UL) or another nationally recognized testing laboratory.

The array mounting structure may be fixed or portable. It must be designed with adequate anchors to maintain alignment under the normally expected loads and to support the array under extreme conditions.

A pump controller, inverter, fuses, surge protection and other electronic components shall be provided as recommended by the pump and PV module manufacturers, or as necessary to meet NEC requirements. Provisions shall be included to protect the pump from common pump faults, overload, electrical short circuits, and low water (dry running), as recommended by the pump manufacturer. A circuit breaker shall be provided as a means for disconnecting the array from the system. All electronic components shall be housed in a weather resistant enclosure (National Electrical

Manufactures Association (NEMA) 3R or equivalent). The system components shall be grounded as required by NEC articles 250 and 690.

Wiring materials and methods shall meet the requirements of NEC Articles 300 and 690. The length of wiring shall be minimized to the extent possible. All wiring shall be sized for a minimum of 125% of the maximum expected currents, and when feasible maintain the total distance voltage drop to less than 2.5%.

Photovoltaic (PV) powered pumps. The pump must be capable of delivering the design water requirement at the estimated total dynamic pumping head when solar power is available. Where the source of water is a well, depth, yield, static water level and draw down level at the design pumping rate must be determined.

The pump and fittings must be constructed from materials appropriate for the quality of water expected. Stainless steel, brass or plastic material shall be specified when total dissolved solids (TDS) in water are greater than 500 PPM. The pump intake must be adequately screened to prevent entrance of sand or other objectionable material. Pumps and required appurtenances must be installed in accordance with the current state and local regulations.

A minimum water storage volume equal to 3 days design water requirement shall be provided for all PV powered pumping systems.

When installed, the system shall pump at the design flow rate for a period no less than one hour, on a bright day, (800 watts per square meter solar irradiance, or more).

All components of the system shall be protected from damage by livestock or wildlife with fencing or other appropriate measures.

Windmills. Pumping units shall be sized according to pumping lifts and capacities, as specified by the manufacturer. The diameter of the mill shall be based on the stroke length and the average wind speed. Towers shall be proportioned to the mill diameter, with adequate height for efficient and safe operation.

Water powered pumps (hydraulic rams). Pumping units shall be sized according to flow rate, lift, fall, and efficiency. Bypass water shall be returned to the stream or storage facility, without erosion or impairment to water quality.

Suction and discharge pipes. To prevent cavitation, suction and discharge pipes shall be designed to account for suction lift, net positive suction head, pipe diameter and length, minor losses, temperature, and altitude. The size of suction and discharge pipes shall be based on hydraulic analysis, operating costs, and compatibility with other system components.

Appurtenances such as gate valves, check valves, pressure reducing valves, pressure gages, pipe connections, and other protective devices, shall be included to meet the requirements of the application.

Screens, filters, trash racks, or other devices shall be installed as needed to prevent the intake of sand, gravel, debris, or other objectionable material into the pump. Intake screens shall be designed according to applicable Federal and State guidelines, to avoid entrainment or trapping of aquatic organisms.

Backflow prevention devices shall be included according to Federal, State, and Local laws, to prevent contamination of water sources connected to the pumping plant. For State of Colorado rules regarding backflow prevention in pump systems and in chemigation systems, refer to Rule 11 of the State of Colorado “Water Well Construction Rules”, 2 CCR 402-2.

Buildings and accessories. Pumps shall be securely mounted on a solid foundation such as pilings or concrete. Foundations shall be designed to safely support the loads imposed by the pumping plant and appurtenances. Sheet piling or other measures shall be used, as required, to prevent piping beneath the foundation.

Where buildings are necessary to protect the pumping plant, provisions shall be included for adequate ventilation and accessibility for equipment maintenance, repairs, or removal.

Suction bays or sumps shall be designed to prevent the introduction of air at the intake.

The discharge bay or the connection to the distribution system shall meet all hydraulic and structural requirements.

Structures and equipment shall be designed to provide adequate safety features to protect operators, workers, and the public from potential injury. Drive shaft covers shall be required on all exposed rotating shafts.

Additional Criteria Applicable to Providing the Efficient Use of Water on Irrigated Land

Provisions for the connection of flow and pressure measurement devices shall be included in power plant system design.

Additional Criteria Applicable to the Improvement of Air Quality

Replacement pumping plants shall have lower total emissions of oxides of nitrogen and fine particulate matter, compared to the unit being replaced.

New, replacement, or retrofitted pumping equipment shall utilize a non-combustion power source, or cleaner-burning technologies or fuels.

Additional Criteria Applicable to Reduce Energy Use

For fossil fuel or electrical grid power sources, pumping plant installations shall meet or exceed the Nebraska Pumping Plant Performance Criteria, if applicable. Refer to NRCS National Engineering Handbook, Part 652, National Irrigation Guide, Table 12-2.

CONSIDERATIONS

When planning this practice, the following should be considered as applicable:

- The removal of surface water by a pumping plant can affect downstream flows or aquifer recharge volumes. Consider potential the long term impacts downstream of the pumping plant.
- If using a pumping plant to remove surface water or ground water flowing into a wetland, consider the potential impacts on existing wetland hydrology.
- The operation and maintenance of a pumping plant can involve the use of fuels and lubricants that when spilled may adversely affect surface or ground water quality. Consider measures to protect the environment from potential spills. In some cases, secondary containment of spilled fuel may be required by Federal and State laws or regulations.
- Pumping plants are often constructed in flood-prone areas or can be subject to other unexpected natural events. Consider how the pumping plant may be protected from extreme natural events and the consequences of damage or failure.
- Include protective sensors to detect low or stopped flow, or pressures that are too high or too low.
- The visual appearance of buildings or structures associated with the pumping plant should be compatible with the surrounding environment.
- When installing new or replacing existing combustion equipment, non-combustion and renewable energy sources, such as solar, wind, and water, should be considered.
- Properly maintained PV modules should have a service life in excess of twenty years. When feasible, other components of the pumping system, as well as the installation methods, should be of sufficient quality to maintain performance comparable to the modules.
- Solar trackers or storage battery units may be included as components of a PV powered pumping plant. When necessary, the batteries, battery enclosure, charge controller, and wiring design should be in accordance with the manufacturer recommendations and NEC articles 300, 480 and 690.
- In lightning prone areas consideration should be given to locating the system away from high points in the topography, installing lightning rods adjacent to the system, and including lightning surge protection in the system specifications.
- Where the pumping system is planned for a new well, consideration should be given to selection of the pump prior to the sizing the well casing diameter, to assure adequate space in the casing for the pump and related appurtenances.
- If practical, when the pump is planned for installation in a well, the well yield test should be made to include a range of

flows above and below the targeted flow rate to account for varying flow conditions and to better determine the potential performance of the well and the pump. Consideration should also be given to seasonal or long-term fluctuation of the water table in order to maintain desired flow rate and pressure.

- Consideration for economics of water storage, remoteness of the site, frequency of maintenance inspections, and importance of the water supply are necessary to determine the design water storage requirement. Such analysis may justify a larger water storage volume than the minimum 3-day supply requirement.
- All components of the water system in addition to the pumping plant should meet the requirements of applicable practice standards.

PLANS AND SPECIFICATIONS

Plans and specifications for constructing pumping plants shall be in accordance with this standard and describe the requirements for properly installing the practice to achieve its intended purpose. As a minimum, the plans and specifications shall include the following:

- A plan view showing the location of the pumping plant in relationship to other structures or natural features.
- Detail drawings of the pumping plant and appurtenances, such as piping, inlet and outlet connections, mounting, foundations, and other structural components.
- Written specifications that describe the site specific details of installation.
- A field test verifying that pumping plant performance meets system design criteria must be completed prior to approval and acceptance of the as-built system.

OPERATION AND MAINTENANCE

An Operation and Maintenance plan specific to the pumping plant being installed shall be prepared for use by the owner and responsible operator. The plan shall provide specific instructions for operating and maintaining facilities to ensure the pumping plant functions properly as designed. All component manufacturers' instructions appropriate for the specific equipment installed at the site shall be attached to the plan upon completion of the job. As a minimum, the plan shall address the following:

- Inspection or testing of all pumping plant components and appurtenances.
- Proper start-up and shut-down procedures for the operation of the pumping plant.
- Routine maintenance of all mechanical components (power unit, pump, drive train, etc.) in accordance with the manufacturer's recommendations.
- Procedures to protect the system from damage due to freezing temperatures.
- When applicable, procedures to frequently check the power unit, fuel storage facilities, and fuel lines, for leaks and repair as needed.
- Periodic checks and removal of debris as necessary from trash racks and structures, to assure adequate flow capacity reaching the pumping plant intake.
- Periodic removal of sediment in suction bays, to maintain design capacity and efficiency.
- Inspection and maintenance of anti-siphon devices, if applicable.
- Routine test and inspection of all automated components of the pumping plant, to assure the proper functioning as designed.
- Inspection and maintenance of secondary containment facilities, if applicable.
- Periodic inspection of all safety features, to ensure proper placement and function.
- Prior to retrofitting any electrically powered equipment, electrical service must be disconnected and the absence of stray electrical current verified.
- For PV powered pumping plants, adjust the tilt angle of the solar modules on a seasonal basis, if applicable.

REFERENCES

USDA-NRCS, National Engineering Handbook, Part 652, National Irrigation Guide.

State of Colorado - Rules and Regulations for Water Well Construction, Pump Installation, Cistern Installation, and Monitoring and Observation Hole/Well Construction (**Water Well Construction Rules**) 2 CCR 402-2 can be located at the following web address: http://water.state.co.us/boe

State of Colorado – Colorado Chemigation Act, Colorado Revised Statutes (CRS), Title 35 (Agriculture), Article 11 can be located at the following web address: http://www.colorado.gov/cs/Satellite/Agriculture-Main/CDAG/1184834153677

State of Colorado - 8 CCR 1203-8 RULES AND REGULATIONS PERTAINING TO THE ADMINISTRATION AND ENFORCEMENT OF THE COLORADO CHEMIGATION ACT can be located at the following web address: http://www.sos.state.co.us/CCR/Welcome.do

National Renewable Energy Laboratory. Solar Radiation Data Manual for Flat-Plate and Concentrating Collectors. National Renewable Energy Laboratory, Golden, CO, April, 1994.

Naval Facilities Engineering Command. Maintenance & Operation of Stand-Alone Photovoltaic Systems. Revised 1991. Photovoltaic Design Assistance Center, Sandia National Laboratories, Albuquerque, NM, March 1993.

Sandia National Laboratories. Stand-Alone Photovoltaic Systems: Handbook of Recommended Design Practices. Photovoltaic Design Assistance Center, Sandia National Laboratories, Albuquerque, NM, updated March, 1995.

Southwest Technology Development Institute. Photovoltaic Power Systems and the National Electrical Code: Suggested Practices, Sandia National Laboratories, Albuquerque, NM, December, 1996.

Stevens, John W., et al.. Photovoltaic Power As A Utility Service: Guidelines For Livestock Water Pumping. Photovoltaic Design Assistance Center, Sandia National Laboratories, Albuquerque, NM, March 1993

Table 1 Average Monthly Solar Insolation Data for Flat-Plate Collectors, Facing South at Fixed Tilt, (kWh/m^2/day),

Location	Tilt Angle	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Flagstaff, AZ	Lat. -15º	4.4	5.2	5.9	6.8	7.2	7.4	6.2	6.1	6.1	5.6	4.7	4.2	5.8
35.13 N, 111.67	Latitude	5.2	5.8	6.2	6.7	6.7	6.7	5.8	5.9	6.3	6.1	5.4	4.9	6.0
elev. 7,005 ft.	Lat +15º	5.6	6.1	6.2	6.2	5.9	5.7	5.0	5.4	6.0	6.3	5.8	5.4	5.8
Alamosa, CO	Lat. -15º	4.7	5.5	6.2	6.9	7.1	7.4	7.0	6.8	6.5	5.9	4.9	4.4	6.1
37.45N, 105.87W	Latitude	5.5	6.2	6.5	6.8	6.6	6.8	6.5	6.5	6.7	6.4	5.6	5.2	6.3
elev. 7,536 ft.	Lat +15º	6.0	6.5	6.4	6.3	5.8	5.7	5.6	5.9	6.4	6.5	6.0	5.7	6.1
Boulder, CO	Lat. -15º	3.8	4.6	5.4	6.1	6.2	6.6	6.6	6.3	5.9	5.1	4.0	3.5	5.4
40.02N, 105.25W	Latitude	4.4	5.1	5.6	6.0	5.9	6.1	6.1	6.1	6.0	5.6	4.6	4.2	5.5
elev. 5,361 ft.	Lat +15º	4.8	5.3	5.6	5.6	5.2	5.2	5.3	5.5	5.8	5.7	4.8	4.5	5.3
Co. Springs, CO	Lat. -15º	4.0	4.7	5.5	6.2	6.2	6.7	6.6	6.4	6.0	5.4	4.2	3.7	5.5
38.82N, 104.72W	Latitude	4.6	5.2	5.7	6.1	5.9	6.2	6.1	6.1	6.1	5.8	4.8	4.4	5.6
elev. 6,171 ft.	Lat +15º	5.0	5.4	5.6	5.6	5.2	5.3	5.3	5.6	5.9	5.9	5.1	4.8	5.4
Eagle, CO	Lat. -15º	3.7	4.6	5.3	6.1	6.4	7.0	6.9	6.5	6.1	5.2	3.8	3.4	5.4
39.65N, 106.92W	Latitude	4.3	5.2	5.6	6.0	6.0	6.4	6.3	6.3	6.2	5.6	4.3	3.9	5.5
elev. 6,512 ft.	Lat +15º	4.6	5.4	5.5	5.6	5.3	5.5	5.5	5.7	5.9	5.7	4.5	4.3	5.3
Grand Jct., CO	Lat. -15º	3.8	4.7	5.5	6.5	7.0	7.5	7.3	7.0	6.5	5.4	4.1	3.6	5.7
39.12N, 108.53W	Latitude	4.4	5.2	5.7	6.4	6.6	6.8	6.7	6.7	6.6	5.9	4.6	4.1	5.8
elev. 4,839 ft.	Lat +15º	4.7	5.4	5.6	6.0	5.8	5.8	5.8	6.1	6.4	6.0	4.9	4.5	5.6
Pueblo, CO	Lat. -15º	4.1	4.9	5.7	6.5	6.7	7.2	7.1	6.9	6.3	5.6	4.4	3.9	5.8
38.28N, 104.52W	Latitude	4.8	5.4	6.0	6.4	6.3	6.6	6.6	6.6	6.4	6.0	5.0	4.6	5.9
elev. 4,721 ft.	Lat +15º	5.2	5.6	5.9	6.0	5.6	5.6	5.7	6.0	6.2	6.2	5.3	5.0	5.7
Goodland, KS	Lat. -15º	3.9	4.6	5.4	6.2	6.4	7.0	7.0	6.7	6.0	5.3	4.0	3.6	5.5
39.37N, 101.70W	Latitude	4.5	5.1	5.7	6.1	6.0	6.4	6.5	6.4	6.1	5.7	4.6	4.2	5.6
elev. 3,688 ft.	Lat +15º	4.9	5.3	5.6	5.7	5.3	5.5	5.6	5.8	5.8	5.8	4.8	4.6	5.4
North Platte, NE	Lat. -15º	3.6	4.3	5.1	5.8	6.1	6.7	6.8	6.4	5.7	4.9	3.6	3.3	5.2
41.13N, 100.68W	Latitude	4.1	4.7	5.3	5.7	5.7	6.1	6.3	6.1	5.7	5.3	4.1	3.8	5.3
elev. 2,785 ft.	Lat +15º	4.4	4.9	5.2	5.3	5.1	5.3	5.5	5.6	5.5	5.3	4.3	4.1	5.0
Albuquerque, NM	Lat. -15º	4.6	5.4	6.3	7.3	7.7	7.8	7.4	7.2	6.6	5.9	4.8	4.3	6.3
35.05N, 106.62W	Latitude	5.3	6.0	6.5	7.2	7.2	7.1	6.9	6.9	6.8	6.5	5.5	5.0	6.4
elev. 5,312 ft.	Lat +15º	5.8	6.2	6.5	6.6	6.3	6.1	6.0	6.3	6.5	6.6	5.9	5.5	6.2
Tucumcari, NM	Lat. -15º	4.3	5.1	5.9	6.8	7.0	7.2	7.1	6.8	6.2	5.6	4.5	4.0	5.9
35.18N, 103.60W	Latitude	5.0	5.6	6.2	6.7	6.6	6.6	6.6	6.5	6.3	6.1	5.2	4.8	6.0
elev. 4,039 ft.	Lat +15º	5.4	5.9	6.1	6.2	5.8	5.7	5.7	5.9	6.1	6.2	5.5	5.2	5.8
Salt Lake City, UT	Lat. -15º	2.9	4.0	5.0	5.9	6.6	7.2	7.3	7.0	6.3	5.0	3.3	2.5	5.2
40.77N, 111.97W	Latitude	3.2	4.3	5.2	5.8	6.2	6.6	6.7	6.7	6.4	5.4	3.7	2.9	5.3
elev. 4,226 ft.	Lat +15º	3.4	4.4	5.1	5.4	5.5	5.6	5.8	6.1	6.1	5.5	3.9	3.1	5.0
Cheyenne, WY	Lat. -15º	3.6	4.4	5.3	5.9	6.0	6.5	6.6	6.3	5.8	5.0	3.8	3.3	5.2
41.15N, 104.82W	Latitude	4.1	4.9	5.5	5.8	5.6	6.0	6.1	6.1	6.0	5.4	4.3	3.9	5.3
elev. 6,142 ft.	Lat +15º	4.5	5.1	5.5	5.4	5.0	5.1	5.3	5.5	5.7	5.5	4.6	4.2	5.1
Rock Springs, WY	Lat. -15º	3.5	4.4	5.3	6.0	6.5	7.0	7.1	6.9	6.3	5.2	3.7	3.2	5.4
41.60N, 109.07W	Latitude	4.0	4.8	5.5	5.9	6.1	6.4	6.6	6.6	6.4	5.6	4.1	3.7	5.5
elev. 6,745 ft.	Lat +15º	4.3	5.1	5.5	5.5	5.4	5.5	5.7	6.0	6.1	5.7	4.4	4.1	5.3

Ref: NREL TP-463-5607

Table 2 Average Monthly Solar Insolation Data for 1-Axis Tracking Flat-Plate Collectors, N-S Axis at Fixed Tilt, (kWh/m^2/day),

Location	Tilt Angle	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Flagstaff, AZ	Lat. -15º	5.8	6.9	8.0	9.5	10.2	10.7	8.6	8.4	8.5	7.6	6.2	5.4	8.0
35.13 N, 111.67W	Latitude	6.4	7.4	8.3	9.4	9.9	10.3	8.3	8.3	8.6	8.0	6.7	6.0	8.1
elev. 7,005 ft.	Lat +15º	6.8	7.6	8.2	9.1	9.4	9.6	7.8	7.9	8.4	8.1	7.0	6.4	8.0
Alamosa, CO	Lat. -15º	6.1	7.4	8.4	9.6	10.1	10.7	9.8	9.4	9.0	8.0	6.4	5.7	8.4
37.45N, 105.87W	Latitude	6.8	7.9	8.7	9.6	9.8	10.3	9.5	9.2	9.1	8.4	7.0	6.3	8.5
elev. 7,536 ft.	Lat +15º	7.2	8.1	8.6	9.2	9.3	9.6	8.9	8.8	9.0	8.5	7.3	6.7	8.4
Boulder, CO	Lat. -15º	4.8	5.9	7.0	8.1	8.4	9.1	9.1	8.6	7.9	6.7	5.0	4.4	7.1
40.02N, 105.25W	Latitude	5.2	6.2	7.2	8.0	8.1	8.8	8.7	8.4	7.9	7.1	5.5	4.9	7.2
elev. 5,361 ft.	Lat +15º	5.5	6.4	7.1	7.7	7.7	8.2	8.2	8.0	7.8	7.1	5.7	5.2	7.1
Co. Springs, CO	Lat. -15º	5.1	6.1	7.2	8.3	8.5	9.3	9.0	8.6	8.1	7.1	5.4	4.7	7.3
38.82N, 104.72W	Latitude	5.6	6.5	7.4	8.3	8.2	9.0	8.7	8.5	8.1	7.4	5.8	5.3	7.4
elev. 6,171 ft.	Lat +15º	5.9	6.6	7.3	7.9	7.7	8.4	8.1	8.1	8.0	7.5	6.1	5.6	7.3
Eagle, CO	Lat. -15º	4.6	5.9	6.9	8.2	8.9	9.9	9.6	9.0	8.3	6.8	4.7	4.2	7.3
39.65N, 106.92W	Latitude	5.1	6.3	7.1	8.1	8.6	9.5	9.3	8.8	8.4	7.2	5.1	4.6	7.3
elev. 6,512 ft.	Lat +15º	5.3	6.5	7.1	7.8	8.1	8.9	8.7	8.4	8.2	7.2	5.3	4.9	7.2
Grand Jct., CO	Lat. -15º	4.7	6.0	7.1	8.7	9.6	10.6	10.1	9.5	8.9	7.1	5.1	4.4	7.7
39.12N, 108.53W	Latitude	5.2	6.4	7.3	8.7	9.3	10.1	9.8	9.4	9.0	7.5	5.6	4.9	7.8
elev. 4,839 ft.	Lat +15º	5.4	6.6	7.2	8.3	8.8	9.5	9.2	8.9	8.8	7.5	5.8	5.2	7.6
Pueblo, CO	Lat. -15º	5.3	6.3	7.5	8.9	9.1	9.9	9.7	9.3	8.5	7.4	5.6	4.9	7.7
38.28N, 104.52 W	Latitude	5.8	6.7	7.7	8.8	8.8	9.5	9.4	9.1	8.6	7.7	6.1	5.5	7.8
elev. 4,721 ft.	Lat +15º	6.1	6.9	7.7	8.5	8.3	8.9	8.8	8.7	8.4	7.8	6.3	5.8	7.7
Goodland, KS	Lat. -15º	4.9	5.9	7.1	8.3	8.6	9.6	9.7	9.1	8.0	6.9	5.0	4.5	7.3
39.37N, 101.70W	Latitude	5.4	6.3	7.3	8.3	8.3	9.2	9.4	8.9	8.0	7.2	5.5	4.9	7.4
elev. 3,688 ft.	Lat +15º	5.7	6.4	7.2	8.0	7.8	8.6	8.8	8.5	7.9	7.3	5.7	5.3	7.3
North Platte, NE	Lat. -15º	4.4	5.4	6.5	7.8	8.1	9.1	9.3	8.6	7.5	6.3	4.5	4.0	6.8
41.13N, 100.68W	Latitude	4.9	5.7	6.7	7.7	7.8	8.8	9.0	8.5	7.5	6.6	4.8	4.4	6.9
elev. 2,785 ft.	Lat +15º	5.1	5.9	6.6	7.4	7.4	8.2	8.4	8.1	7.4	6.6	5.0	4.7	6.7
Albuquerque, NM	Lat. -15º	5.9	7.1	8.3	10.0	10.6	10.8	9.9	9.5	8.8	7.9	6.3	5.5	8.4
35.05N, 106.62W	Latitude	6.5	7.5	8.6	9.9	10.3	10.4	9.5	9.3	9.0	8.3	6.8	6.1	8.5
elev. 5,312 ft.	Lat +15º	6.9	7.7	8.5	9.5	9.7	9.7	8.9	8.9	8.8	8.4	7.1	6.5	8.4
Tucumcari, NM	Lat. -15º	5.5	6.6	7.9	9.3	9.5	9.9	9.6	9.1	8.3	7.5	5.9	5.2	7.9
35.18N, 103.60W	Latitude	6.0	7.1	8.1	9.2	9.3	9.5	9.3	9.0	8.4	7.9	6.4	5.7	8.0
elev. 4,039 ft.	Lat +15º	6.3	7.2	8.0	8.9	8.7	8.9	8.7	8.5	8.2	7.9	6.6	6.1	7.8
Salt Lake City, UT	Lat. -15º	3.4	4.8	6.3	7.7	8.9	10.0	10.2	9.6	8.5	6.5	4.0	3.0	6.9
40.77N, 111.97W	Latitude	3.7	5.1	6.5	7.7	8.7	9.6	9.8	9.4	8.6	6.8	4.3	3.3	7.0
elev. 4,226 ft.	Lat +15º	3.8	5.2	6.4	7.4	8.2	9.0	9.2	9.0	8.4	6.9	4.5	3.4	6.8
Cheyenne, WY	Lat. -15º	4.5	5.7	6.9	7.9	8.1	9.0	9.2	8.7	7.8	6.6	4.8	4.1	6.9
41.15N, 104.82W	Latitude	4.9	6.0	7.1	7.8	9.3	8.7	8.9	8.6	7.9	6.9	5.2	4.6	7.0
elev. 6,142 ft.	Lat +15º	5.2	6.2	7.0	7.5	8.7	8.1	8.3	8.2	7.7	6.9	5.4	4.9	6.9
Rock Springs, WY	Lat. -15º	4.3	5.6	6.9	8.0	9.0	10.0	10.1	9.6	8.5	6.8	4.6	3.9	7.3
41.60N, 109.07W	Latitude	4.7	6.0	7.1	8.0	8.7	9.6	9.8	9.4	8.6	7.1	4.9	4.4	7.4
elev. 6,745 ft.	Lat +15º	5.0	6.1	7.0	7.7	8.2	9.0	9.2	9.0	8.5	7.2	5.1	4.6	7.2

Ref: NREL TP-463-5607

Table 3 Average Monthly Solar Insolation Data for 2-Axis Tracking Flat-Plate Collectors, N-S Axis, (kWh/m^2/day),

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Flagstaff, AZ	4.7	5.5	6.4	7.3	7.9	8.5	8.4	8.0	6.9	6.4	4.9	4.3	6.6
Alamosa, CO	7.2	8.1	8.7	9.7	10.2	11.0	10.0	9.4	9.2	8.5	7.3	6.8	8.8
Boulder, CO	5.6	6.4	7.2	8.1	8.5	9.4	9.2	8.6	8.0	7.1	5.7	5.3	7.4
Co. Springs, CO	5.9	6.7	7.4	8.4	8.6	9.6	9.2	8.6	8.2	7.5	6.1	5.7	7.7
Eagle, CO	5.4	6.5	7.1	8.2	9.0	10.2	9.8	9.0	8.4	7.3	5.4	5.0	7.6
Grand Jct., CO	5.5	6.6	7.3	8.8	9.7	10.8	10.3	9.6	9.0	7.6	5.8	5.2	8.0
Pueblo, CO	6.2	6.9	7.8	8.9	9.2	10.2	9.9	9.3	8.6	7.8	6.4	5.9	8.1
Goodland, KS	5.7	6.4	7.3	8.4	8.7	9.9	9.9	9.1	8.1	7.3	5.7	5.3	7.7
North Platte, NE	5.2	5.9	6.7	7.8	8.2	9.4	9.5	8.7	7.6	6.7	5.0	4.7	7.1
Albuquerque, NM	6.9	7.7	8.6	10.0	10.8	11.1	10.0	9.5	9.0	8.4	7.2	6.6	8.8
Tucumcari, NM	6.4	7.2	8.1	9.3	9.6	10.1	9.8	9.2	8.4	8.0	6.7	6.2	8.3
Salt Lake City, UT	3.9	5.2	6.5	7.8	9.1	10.3	10.4	9.6	8.6	6.9	4.5	3.5	7.2
Cheyenne, WY	5.2	6.2	7.1	7.9	8.2	9.3	9.3	8.8	7.9	6.9	5.4	4.9	7.3
Rock Springs, WY	5.0	6.1	7.1	8.1	9.1	10.3	10.3	9.6	8.7	7.2	5.2	4.7	7.6