



Minimum Technical Requirements for the Renewable Energy Fund (REF)

All Rhode Island Renewable Energy Fund projects must demonstrate compliance with the Minimum Technical Requirements set forth in this document. These requirements are not intended to be all-encompassing, nor are they intended to be a substitute for engineering specifications, relevant codes and standards, or for safety requirements. Site-specific conditions and/or local regulations may stipulate additional requirements not contained in this attachment. Commerce RI reserves the right to withhold payment to any project that does not satisfy the Minimum Technical Requirements.

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Solar Photovoltaic (PV)

Required Inspection and Inspection Process

All installations are subject to a third-party inspection. Installers must submit Cadmus self-inspection reports along with the rest of the completion documents for all installations. Projects paired with energy storage must submit the PV + ESS-specific self-inspection report. Any commercial system with a system capacity greater than 30kW will be inspected via a virtual or on-site session. All other systems will begin as self-inspections and may be shifted to virtual or on-site at the discretion of the inspector, who will make determinations based on the clarity and comprehensiveness of the self-inspection report provided. The inspector will coordinate the site visit with the installer via email if an inspection is shifted to virtual or on-site.

An inspection report, and if required, a Correction Action Report (CAR), will be issued after each inspection. Projects that score a 4 or 5 will be approved for grant payment, however, any identified issues must be corrected. Projects that score a 3 or lower must have all corrections approved before grant payment is released.

Shading and Estimated Production Requirements

The PV project must be designed so that the estimated annual energy output is at least 80% of the default optimal output for a fixed PV project of the same capacity, as estimated by PVWATTS or a similar tool. Optimal parameters for purposes of a PVWATTS estimate are:

- 1) 0.89 DC to AC derate factor,
- 2) 42° array tilt, and
- 3) 180° (True South) azimuth. PVWATTS is available at the following website:
<http://pvwatts.nrel.gov>.

The PV project must have a measured total solar resource fraction (TSRF) of 0.8 or greater and is subject to TSRF verification by Solmetric SunEye (or equivalent shade measurement tool) during onsite inspection. TSRF is a measure of the actual expected irradiance divided by the total irradiance available to a system with optimal siting characteristics (tilt, azimuth, etc.). Note that shading losses are incorporated into the TSRF and that a low TSRF can be the result of shading, non-ideal orientation, or both.

Commerce RI has approved the Solmetric SunEye and Solar Pathfinder shading tools as program-compliant means of measuring and reporting TSRF for project applications. Bright Harvest, Scanify and Aurora desktop shading tools are also approved provided they utilize a method that measures all onsite obstructions within 100 feet east, south, and west of each array. HelioScope is approved only



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for commercial systems and must also model all onsite obstructions within a 100-ft radius. Should installers report TSRF via an approved desktop shading tool, but Cadmus challenges the accuracy of the report, an onsite Solmetric SunEye or Solar Pathfinder capture will be requested to verify TSRF as onsite measurement and verification takes precedence over the desktop tools' estimates.

When using Aurora, if LIDAR data is unavailable or incomplete for a specific location, an onsite SunEye or Pathfinder capture is required.

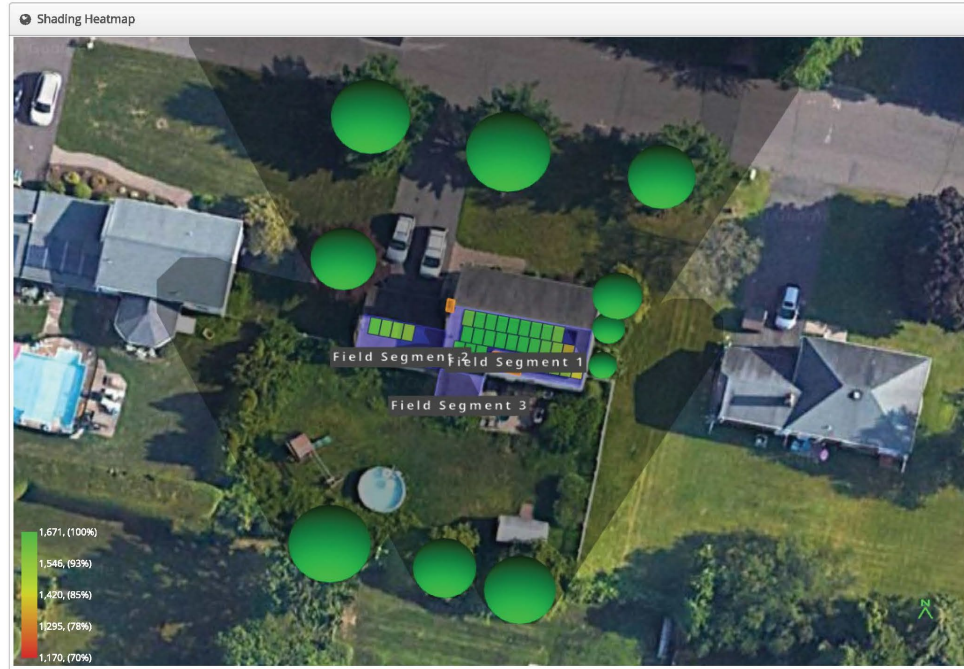
All other methods for reporting TSRF must be proposed to, and approved by, Commerce RI prior to submitting an incentive application. All shading reports edited to indicate the future removal of obstructions must submit proof of such removal.

When measuring TSRF, applicants must take measurements at all four corners of each proposed array location. Cadmus defines an array as a complete grouping of modules with the same azimuth and tilt and does not experience any direct obstruction. For example, an obstruction could be considered a dormer between modules on a roof with the same tilt and azimuth, or a rooftop HVAC system between modules on a roof with the same tilt and azimuth. The TSRF for each array is the mean of the readings taken at each of the four corners of the array. The overall TSRF is a weighted average of the individual array TSRF values, weighted by nameplate capacity. For example, a system with two arrays:

- Array 1: TSRF=90%, Capacity=5kW Array 2: TSRF = 70%, Capacity = 6Kw

This system would have an overall TSRF of $(0.9)(5kW) + (0.7)(6kW)$ divided by 11kW, or 0.79, and would therefore be ineligible for an incentive.

As a visual example, when submitting a copy of a shading report via HelioScope, the expectation is that each 'Field Segment' will represent one array. Though it's possible both arrays below are on the same tilt and azimuth, with the roofs at different heights, the potential variance in shading should be captured and reported by measuring both arrays.



Shading by Field Segment									
Description	Tilt	Azimuth	Modules	Nameplate	Shaded Irradiance	AC Energy	TOF ²	Solar Access	Avg TSRF ²
Field Segment 1	25.0°	190.8°	27	10.1 kWp	1,565.1 kWh/m ²	12.8 MWh ¹	97.8%	95.8%	93.7%
Field Segment 2	18.4°	191.0°	4	1.50 kWp	1,527.0 kWh/m ²	1.86 MWh ¹	96.2%	95.0%	91.4%
Totals, weighted by kWp			31	11.6 kWp	1,560.1 kWh/m²	14.7 MWh	97.6%	95.7%	93.4%

¹ approximates, varies based on inverter performance
² based on location Optimal POA irradiance of 1,671.0 kWh/m² at 38.0° tilt and 181.8° azimuth

Solar Access by Month												
Description	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec
Field Segment 1	97%	96%	96%	95%	95%	95%	95%	95%	97%	96%	97%	97%
Field Segment 2	95%	95%	95%	95%	95%	95%	95%	95%	95%	94%	95%	96%
Solar Access, weighted by kWp	97.1%	95.7%	95.8%	95.4%	95.2%	95.2%	94.9%	95.2%	96.3%	95.5%	96.7%	97.1%
AC Power (kWh)	891.5	1,028.9	1,258.9	1,339.1	1,452.9	1,442.2	1,609.5	1,488.4	1,360.6	1,112.3	840.5	880.1

Installation Requirements

All installations must follow the most **current adopted edition of the National Electrical Code** with the following changes, as noted below. In all cases where manufacturer instructions, third-party guides/handbooks, or other materials contradict the most current edition of any local, state, or federal code, the applicable code shall take precedence over such materials.



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- Twist-on wire connectors (wire nuts) shall not be used in any outdoor enclosure unless listed to UL 486D for use in damp/wet locations. Proof of listing will be required during inspection if applicable. (See Article 110.28 for more information)
- Interconnections on the utility side of service disconnecting means are considered a second “set” of service-entrance conductors as permitted in Article 230.40, Exception 5 and 230.82(6), but not considered an “additional service.”
 - PV system disconnect must be suitable for use as service equipment, in accordance with Article 230.70.
 - Utility conductors must always be on the line terminals of the disconnect, otherwise fuses will remain energized when disconnect is in open (off) position.
 - Article 230.79(D) requires a minimum rating of 60A, OCPD AIC rating follows 110.9 & 110.10.
 - Service-entrance conductor set required to be sized to disconnect rating, in accordance with Article 230.42(B).
 - Wiring methods for conductors on the utility side of disconnect shall follow Article 230.43.
- Residential installations of ground- and pole-mounted arrays must have a disconnect switch as described in Article 690.17 exception two, located at the array to isolate all DC current carrying conductors. This is not required where the ground- or pole-mounted array consists entirely of AC modules, DC-DC converters (optimizers), or microinverters.
- Areas where wiring passes through ceilings, walls, or other areas of the building must be properly restored, booted, and sealed. Thermal insulation in areas where wiring is installed must be returned to “as found or better” condition.
- Commerce RI requires that photos be taken of the following system components for all rooftop solar arrays, including: array and PV modules, DC disconnect, string inverters (including transformerless units), microinverter/DC optimizer, AC disconnect/AC combiner, and interconnection (supply side and load side). These photos shall be kept on record with the primary installer and made available to Commerce RI upon request.
- An owner’s manual of operating and maintenance instructions must be provided to the PV project owner and preferably also posted on or near the PV project. The owner’s manual should include manufacturer’s specifications, serial numbers, warranty policies, etc.



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- Owners must be provided with, at minimum, a basic training orientation that includes maintenance instructions, troubleshooting, meter reading, and electric production reporting instructions.
- Solar PV projects designed to be installed on pitched, non-flat roofs, are required to have an azimuth that is the same as the roof azimuth, in order to be eligible to receive a rebate.

Roof Requirements

PV arrays shall not be installed on any roof that is expected to be replaced within 10 years, or that contains damage that may require repair or early replacement.

Common Installation Violations Found During Onsite Inspections

- Grounding electrode conductor is missing or undersized, in violation of NEC Articles 690.47(C), 250.66, 250.122, and 250.166.
- Grounded (neutral) conductor is not properly bonded to PV service disconnect enclosure using a listed grounding bus or terminal, or the grounded conductors are not properly bonded to the Grounding Electrode Conductor (GEC), in violation of NEC Article 250.24(C).
- Circuit conductors are sagging and/or not supported and secured at least every 4.5' and within 12" of every outlet box, junction box, cabinet, or fitting, in violation of NEC Articles 338.10(B)(4) and 334.30.
- Conduit is missing an approved internal sealant at penetrations between conditioned and unconditioned spaces to prevent condensation in violation of NEC Article 300.7(A).
- Permanent plaque or directory denoting location of all power sources and location of disconnects on premise at each service equipment location is missing, incomplete, or unsuitable for the environment, in violation of NEC Articles 705.10, 690.56 and/or 110.21
- Indoor-rated twist-on wire connectors (wire nuts) shall not be used in outdoor enclosures. Article 110.28 indicates this area can be a damp or wet location, and such installation may violate the listing of the product, see also Article 110.3(B).
- NM-B cable (Romex®) shall not be sleeved in outdoor raceways. Article 300.9 defines the interior of such raceways as a wet location and Article 334.12(B)(4) prohibits this cable to be installed in a wet location.



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- Article 300.7(A) requires raceways passing from the interior to the exterior of a building be filled with an approved material to prevent the circulation of warm air to a colder section of the raceway.
- Article 250.24(A)(5) prohibits a grounded (neutral) conductor to be connected to ground at any location downstream of the service disconnecting means. Common violations include this connection in a PV meter enclosure or an AC combiner panelboard.
- Terminal ratings and conductor size/limitations must be followed per Article 110.3(B). Common violations include multiple conductors under a terminal listed for a single conductor, or conductors undersized for the terminals, such as inside a meter enclosure.

Energy Storage

Technology Requirement

Energy storage technologies that satisfy all technical eligibility criteria of National Grid’s Connected Solutions^[1] program are eligible for this program.

^[1] <https://www.nationalgridus.com/RI-Home/ConnectedSolutions/BatteryProgram>

Solar Hot Water

System Warranties and Certifications:

SHW systems must be whole systems (tanks, collectors, controls, and plumbing). Components must be new, and collectors must be certified to the OG-100 or OG-300 standard by an accredited testing laboratory, such as the Solar Rating and Certification Corporation (“SRCC”) or the International Association of Plumbing and Mechanical Officials (“IAPMO”). SHW systems must be backed by a minimum 10-year manufacturer’s warranty for collectors, two (2)-year warranty for other system components, and a two (2)-year comprehensive installation warranty.

Required Inspection and Inspection Process

Installed systems must meet all applicable state and local laws and ordinances. The Installer must attest that the Project has received a building and/or plumbing permit and has completed a satisfactory plumbing inspection by the local authority. All installations are subject to a third-party



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inspection. Prior to the inspection taking place, the installer will be notified via email of the inspection. The installers should make all reasonable attempts to attend the inspection. An inspection report will be issued after each inspection. All corrections must be approved before grant payment is released.

Shading and Estimated TSRF Requirements

Solar Hot Water project must have a measured total solar resource fraction (TSRF) of 0.8 or greater and is subject to TSRF verification by Solmetric SunEye (or equivalent shade measurement tool) during onsite inspection. TSRF is a measure of the actual expected irradiance divided by the total irradiance available to a system with optimal siting characteristics (tilt, azimuth, etc.). Note that shading losses are incorporated into the TSRF and that a low TSRF can be the result of shading, non-ideal orientation, or both. When measuring TSRF, applicants must take measurements at all four corners of each proposed array location. The TSRF for each array is the mean of the readings taken at each of the four corners of the array. The overall TSRF is a weighted average of the individual array TSRF values, weighted by nameplate capacity. For example, a system with two arrays:

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This system would have an overall TSRF of $(0.9)(5kW)+(0.7)(6kW)$ divided by 11kW, or 0.79, and would therefore be ineligible for an incentive.

Commerce RI has approved the Solmetric SunEye and Solar Pathfinder shading tools as program-compliant means of measuring and reporting TSRF for project applications. Helioscope, Bright Harvest, Scanifly and Aurora shading tools are also approved provided they utilize a method that measures onsite obstructions. All other methods must be proposed to, and approved by, Commerce RI prior to submitting an incentive application. All shading reports edited to indicate the future removal of obstructions must submit proof of such removal.

System Minimum Technical Requirements

Systems must include the installation of solar thermal collectors that transfer the absorbed solar radiation to a fluid passing through the collectors.

- Collector area and mounting:
 - Collectors must SRCC OG-100 certified
 - Collector tilt must follow manufacturer specifications.
 - Orientation must be between ninety (90) degrees and two hundred seventy (270) degrees true.

- Collectors must be secured according to manufacturer’s recommendations.
- Storage:
 - All systems must follow the manufacturer’s recommendations regarding storage capacity;
 - The storage tank should be at least as large (in gallons) as the Project Site’s estimated daily use (in gallons per day); and
 - The storage tank’s volume (in gallons) should hold approximately one and a half (1.5) gallons per square foot of collector area.
- Plumbing:
 - All systems shall include one of the stagnation methods:
 - Advanced controller with vacation or holiday mode;
 - Advanced controller with thermal cycling function;
 - Heat dump radiator;
 - Steam back;
 - Pressure stagnation protection; or
 - Other (requiring approval by REF)
 - All systems shall include one of the freeze protection methods
 - Direct forced circulation (open loop): Automatic freeze drain valve;
 - Indirect forced circulation (closed loop): Active closed-loop glycol;
 - Indirect forced circulation (closed loop): Closed-loop glycol or water drainback;
 - Thermosiphon: Closed-loop glycol;
 - Glycol drainback; or
 - Other (requiring approval by REF)
 - The Primary Installer shall provide assurances for freeze protection to at least negative twenty-seven (-27) degrees Fahrenheit in the case of pressurized systems, or nine (9) degrees Fahrenheit for drainback systems.
- Insulation: All systems must have insulation on all exposed and accessible hot water piping. Underground circulation lines must be below the frost line.
- System Labeling:
 - Drain and Fill Valves
 - Pipe label showing direction of flow
 - Pipe Label indicating fluid temperature Hot(Red), Cold(Blue)
 - Pipe Label showing what type of Heat Transfer Fluid and/or glycol mixture ratio
 - Tank Bypass/isolation valve labels



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Solar Hot Water arrays shall not be installed on any roof that is expected to be replaced within 10 years, or that contains damage that may require repair or early replacement.

Common Installation Violations

- System missing labels.
- Dissimilar metals in direct contact promoting galvanic corrosion.
- Missing, damaged or compromised pipe insulation exposing pipe to environment.
- Missing or incorrectly installed tank Pressure and Temperature emergency relief valve discharge pipe.
- Inadequate piping support.
- System pressure is below standard operating levels.

Wind Technology

Estimated Production Requirements

Estimated annual electricity generation for wind energy projects must be made using a bin analysis method, such as NREL’s WindCAD model or an equivalent tool that combines a wind speed probability distribution with a wind turbine power curve and includes relevant adjustments for local terrain, vegetation, and turbine operational characteristics. Key inputs shall include:

- Wind Speed: Annual mean wind speed shall be obtained from a reputable data source with a minimum spatial resolution of 2.5km x 2.5km
- Anemometer Height: The reference height accompanying the annual mean wind speed. Standard heights include 30m, 50m, and 80m
- Wind Shear: The wind shear is used to adjust wind speeds to match the proposed tower height and reflect, generally, how rough the local terrain is. Commerce RI recommends the following wind shear values based on general nearby terrain:
 - Grass: 0.15
 - Cropland/agricultural: 0.22
 - Scattered trees and hills: 0.29
 - Sparse forest/buildings: 0.34
 - Dense forest/urban setting: 0.44
- Tower Height: The proposed height of the tower
- Adjusted Hub Height: The anticipated hub height of the wind turbine, less the mean canopy height, where mean canopy height is the average height of densely packed obstructions within 10 rotor diameters of the tower location. For example, a 140ft tall tower surrounded by 40ft average canopy height forest would have an adjusted hub height of 100ft. Adjustments to canopy height based on packing density may be made at Commerce RI’s discretion.

Commerce RI also recommends including a wind rose, to indicate the directionality of the site wind resource.

For projects with rated generator output, at 11 m/s, greater than 1MW must estimate annual generation based on at least 6 months of onsite meteorological data and a measure-correlate-predict (MCP) analysis correlating short-term monitoring with long-term local weather conditions.



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Installation Requirements

All wind energy projects must be installed per Article 694 Wind Electric Systems of the current edition of the National Electric Code, as well as all relevant equipment installation instructions and engineering specifications. In addition, Commerce RI has the following specific requirements:

- The bottom of the rotor swept area must be at least 30ft above all surrounding obstructions within 500ft of the tower base
- Applicants seeking grant funding for wind energy projects installed on parcels less than 5 acres in size shall include signed letters of support from all abutting neighbors as attachments to the grant application. These letters must indicate that neighbors have been made aware of all possible acoustic and aesthetic impacts and have no opposition to the proposed project.

Common Installation Violations

- Wind energy projects are frequently sited incorrectly with relation to the available site wind resource. It is important to use the most accurate wind data possible and to position the wind turbine to minimize obstructions to wind flow. Though this is particularly important in the windward direction, obstructions downwind of the wind turbine can also negatively impact the available wind resource.
- All towers and associated equipment must be properly grounded to minimize the risk of lightning strikes

Anaerobic Digestion

Estimated Production Requirements

Installers shall comply with the following production/yield validation methods:

Biogas production estimates will be conducted using the following calculation, unless REF approves an alternative method.

$$Annual\ Biogas\ (ft^3) = \frac{A \times B \times C \times D \times E \times 365\ days}{F}$$

Where:

- A Number of animals (Agricultural) or gallons of influent per day (industrial)
- B Pounds of organic material per day
- C Percentage of organic material collected in influent (less spillage and other losses)
- D Digester efficiency
- E COD¹ conversion factor (ft³ methane per pound of organic matter)
- F Percent methane in biogas

Because the energy production from anaerobic digestion is highly dependent on feedstock, operating conditions and selected digestion process, the feedstock to the AD system should meet the following values for methane gas production:

Methane Gas Production by Feedstock*

Feedstock	Total Solids	CH ₄ Yield
	(%)	(ft ³ per pound)
WWTP sludge	**	**
Livestock manure	3-12	0.224-0.288
Food waste	10-30	0.962-1.754
Organic MSW	15-35	0.8-1.515

¹ Chemical Oxygen Demand is a measure of the amount of oxygen required to aerobically digest a substance into CO₂ and H₂O and is used to measure the heat content available from the reverse reaction converting methane and oxygen into water, carbon dioxide, and energy.

* adapted from Cenex, June 2009

** For WWTP Sludge the following table applies:

Feedstock	CH ₄ Yield
	(f ³ per pound volatile solids)
Primary Sludge	5-6.25
Secondary Sludge	3.03-3.846

* adapted from IEA Bioenergy, Bachmann et al., 2015

Biogas generation shall be converted into energy savings metrics such as electricity (kWh) or natural gas (therms) savings. Ultimately, the energy savings to be evaluated will be driven by a range of factors but the primary output, biogas, will be converted to the appropriate units for evaluation purposes.

The efficiency of the overall AD system depends on the selected energy conversion technology. The selected technology energy efficiency values must fall within these ranges noted in the table below, unless the applicant can supply sufficient justification for an alternative assumption:

Technology	Net Electrical Efficiency		Net Thermal Efficiency		Size Range kW
	Range %	Typical %	Range %	Typical %	
Internal Combustion Engine	25 – 45	33	40 – 49	40	50 – 5K
Internal Combustion Engine – Lean Burn		37			
Gas Turbines	23 – 36	30	40 – 57	40	250 – 250K
Microturbines	24 – 30	27	30 – 40	35	30 – 250
Steam Turbine	20 – 30	25	20 – 45	45	500 – 1,300K
Stirling Engine	25 – 30	27	45 – 65	60	1 – 50

Reprinted with permission from the Water Environment Federation, MOP 32, 2009.

Installation Requirements

Depending on the proposed technology (low or high solid, single stage/multistage, mesophilic, thermophilic), the anaerobic digestion system must be installed in accordance with the manufacturer instructions and design engineer specifications.

- For the design of the digester and gas components, installer shall provide adequate safety measures and install components in accordance with standard engineering practice for handling a flammable gas. Safety and best practice standards should comply with NRCS Practice Standard 366, Anaerobic Digester², [EPA guidelines and applicable permitting requirements](#)³.
- An owner’s manual of operating and maintenance instructions must be provided to the AD project owner and preferably also posted on or near the AD project. The owner’s manual should include, at a minimum:
 - Manufacturer’s specifications, serial numbers, and warranty policies
 - Proper loading rates of the digester and total solids content of the influent
 - Operating procedures for the digester
 - Description of the planned startup procedures, normal operation, safety issues, and normal maintenance items
 - Instructions for safe use and flaring of biogas

Owners must be provided with, at minimum, a basic training orientation that includes maintenance instructions, troubleshooting, meter reading, and reporting instructions.

System Requirements

All installations must follow the most **current edition of the National Electrical Code** with the following additions as noted below. In all cases where manufacturer instructions, third-party guides/handbooks, or other materials contradict the most current edition of any local, state, or federal code, the applicable code shall take precedence over such materials.

- Installer shall measure, track, and document the feedstock type and quantity used in the digester design. Digester design must take into account varying feedstock properties. Depending on the system design, extraneous material may need to be removed, reduced, or otherwise handled.

² <https://efotg.sc.egov.usda.gov/references/public/NY/nyps366.pdf>

³ <https://www.epa.gov/agstar/guidelines-and-permitting-livestock-anaerobic-digesters>



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- Digester cover, materials, anchorage, and appurtenances shall be designed to capture and convey biogas to the gas collection system. The digester cover and materials shall meet the requirements of NRCS Practice Standard 367, Waste Facility Cover⁴.
- Above or below grade tanks must be equipped with an overhead exhaust/ventilation system to capture gaseous emissions and route them to an odor control system.
- All odorous areas should be vented to appropriate abatement. Acceptable abatement treatments include: biofilters, carbon filters, chemical scrubbers, and thermal oxidizers.
- Emission Controls:
 - Nutrient Management Plans must account for how all waste components will be utilized. All participating farms must follow a nutrient management plan that complies with the 2015 NRCS 590 Nutrient Management Standard.⁵
 - Installers or operators should implement an environmentally responsible digestate management plan.

Installers must install and maintain a gas meter and provide measurements of total biogas produced, including the amount of methane produced⁶. The amount of methane content in biogas may vary, but typically ranges from 60%-70%.

Common Installation Violations

As noted above the design and construction of anaerobic digestion depends on the process configuration.

The construction contractor/installer must comply with all local permit requirements.

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⁴ https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=nrcseprd340709&ext=pdf

⁵ https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1192371.pdf

⁶ An example of one meter that may be suitable for automatic methane monitoring:

<http://www.co2meter.com/products/50-co2-100-ch4-meter-nema4>