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Simple Cost-Benefit Analyses of Biogas Use and Tariff Options for an Existing Anaerobic Digester System on a New York State Dairy Farm

A Case Study

By

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Cornell PRO-DAIRY Dairy Environmental Systems Program

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Notice

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Executive Summary

New York State (NY) enacted the Climate Leadership and Community Protection Act[1] (CLCPA) in 2019. The CLCPA established a renewable energy program under public service law that distinguishes certain renewable energy systems from others included in the NY Clean Energy Standard[2] (CES) of 2016. Subsequent NY Public Service Commission (PSC) orders have resulted in multiple options for monetizing electricity generated by manure-based anaerobic digester gas (ADG)-to-electricity systems under the available electricity tariffs.

To begin to understand the economic value that the current NY electricity tariffs provide to owners of ADG-to-electricity systems, a simple cost-benefit analysis was conducted for each of the three available options (none with provisions for the environmental value) applied to a 2,000 cow NY dairy farm with an existing anaerobic digester system. Pertinent farm utility bills and ADG-to-electricity system performance data were provided by the farm. The option of producing renewable natural gas (RNG) was also analyzed because many NY dairy farmers with anaerobic digesters are looking at monetizing processed biogas under the California Low Carbon Fuel Standard[3] as an alternative to producing electricity. The options analyzed were:

- Option 1: Continue operating existing ADG-to-electricity system under the legacy net energy metering (NEM) tariff
- Option 2: Continue operating existing ADG-to-electricity system and elect Phase One Value Stack tariff
- Option 3: Continue operating existing ADG-to-electricity system and elect Phase One Value Stack tariff as Farm-Based Community Distributed Generation (CDG)
- Option 4: Replace existing electricity generation system with an RNG system owned and operated by a third party, with all farm and ADG-to-RNG system electricity purchased from utility

The annual electricity generation revenue was estimated to be up to $54,560 for Option 1 (average NEM rate of 4.54¢/kWh), $0 for Option 2 (average Value Stack rate of 3.98¢/kWh), and $121,600 for Option 3 (average Value Stack rate of 6.23¢/kWh, including the Community Credit[4]). However, the operation and maintenance expense exceeded the revenue in all three ADG-to-electricity options and produced no annual net income for the farm. Although the renewable electricity generated exceeded the onsite farm electricity usage by 77%, the lack of an environmental value in the tariffs prevented a net income opportunity. In contrast, Option 4 will generate a net income for the farm if the RNG revenue they receive from the third-party owner (farm confidential) exceeds their estimated annual cost of $190,900 for importing approximately 2,820,800 kWh for farm operations.

While the inclusion of the Community Credit (CC) available under Option 3 has the potential to generate more revenue than the legacy NEM tariff, the CC is subject to utility aggregate capacity limits and is set to decrease and be eliminated over time. In fact, at the time of this case study's release, the CC has already fallen to 2¢ per kWh. [5] Moreover, a CDG project requires establishing contracts with members, introducing additional risk.

[1] New York State Senate Bill S6599.
[2] NY Department of Public Service (DPS) Case 15-E-0302, Order Adopting a Clean Energy Standard (issued August 1, 2016).
[3] California Air Resources Board, https://ww2.arb.ca.gov/our-work/programs/low-carbon-fuel-standard.
[4] At the time of analysis, the Community Credit (CC) under the Phase One Value Stack tariff was 2.25¢/kWh.
[5] NY DPS Case 15-E-0751, Order Regarding Community Credit and Community Adder Allocations (issued March 19, 2020).

The Value Stack rate is low because no Environmental Value[6] is offered. NY dairy farms with ADG-to-electricity systems placed into service prior to 2015 are ineligible for the Environmental Value if they elect to opt into the Value Stack tariff due to the CES establishment of Tier 1 resources. Farms with ADG-to-electricity systems placed into service after 2014 that opt-in, and new systems that must use Value Stack, are no longer permitted to receive the Environmental Value unless they utilize fuel cell technology. [7] **The elimination of the Environmental Value from the Value Stack tariff for manure-based ADG-to-electricity systems that do not utilize fuel cells is the primary factor in the lack of net income potential from electricity generation.**

The Environmental Value component of the Value Stack accounts for the avoided greenhouse gas (GHG) emissions from offsetting grid electricity generation with renewable generation and is set to the higher of either the Tier 1 Renewable Energy Credit (REC) price or the U.S. EPA Social Cost of Carbon (SCC)-based calculation by the NY Department of Public Service (DPS). Adding the current Environmental Value to Option 3 would result in a net income to the farm of just over $100,000 annually. Given the uncertain future value and availability of the CC that is included in Option 3, the annual net income would drop to $1,570 if the CC were excluded.

Dairy farms that implement an anaerobic digestion system achieve *additional* GHG emission reduction associated with manure management that should be included in a true Environmental (E) value of the renewable electricity they generate. [8] Using this methodology, the obtainable E value was updated to 7.8¢ per kWh by applying the 2020 SCC value and the NY electricity grid GHG emission factor. [9] Including the true E value of 7.8¢/kWh in Option 3 for the case study farm increases the electricity generation value by $390,000 per year and the estimated annual net income under a CDG project format was $330,000 (including the CC) and $230,000 (excluding the CC). These net income values are believed to compare with those possible under Option 4 and may also produce a suitable ROI when the capital cost for a new system installation is included.

In Option 4, the RNG processing system for cleaning and compressing biogas for trucking to a pipeline injection point has an estimated electricity usage of 1,460,000 kWh per year, a 50% increase to the case study farm usage in the representative year analyzed. Furthermore, the conversion to producing RNG eliminates the source of "free" hot water to heat the anaerobic digester that was a harvested by-product of electricity generation from the engine-generator set, requiring a new boiler fueled by propane or utility natural gas that would consume an estimated 13,500 million BTU per year. Additional energy would be used in the trucking of RNG.

Despite this additional onsite and transportation energy usage assumed to be paid for by the third-party owner, Option 4 is able to produce an annual net income opportunity for the case study farm while the ADG-to-electricity options cannot under the current NY tariffs that lack an environmental value for the GHG emission reduction they achieve.

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[6] At the time of analysis, the Environmental (E) Value under the Phase One Value Stack tariff was 2.741¢/kWh.
[7] NY DPS Case 15-E-0751, Order Regarding High Capacity Factor Resources (issued December 12, 2019).
[8] Peter Wright and Curt Gooch, *Estimating the Economic Value of the Greenhouse Gas Reductions Associated with Dairy Manure Anaerobic Digestion Systems Located in New York State* (ASABE, July 2017), https://elibrary.asabe.org/abstract.asp?aid=47983.
[9] NY DPS Case 15-E-0751, E value calculation from Public Service Commission (issued March 13, 2018).

Introduction

Approximately 10 years ago, a 2,000 cow dairy farm in NY installed an anaerobic digester system to treat their manure incorporating a 600 kW combined heat and power (CHP) system that generates electric power and heat using an engine-generator set fueled by anaerobic digester gas (ADG). The anaerobic digester system is a horizontal plug-flow design that operates in the mesophilic temperature (approximately 100°F). The digester feedstock is only dairy manure generated from the farm's herd; no food waste is added.

The CHP system is a single reciprocating internal combustion engine-generator set that generates electricity and includes exhaust waste heat recovery and cooling water jacket heat recovery to heat a hot water loop. The hot water heating loop runs through piping within the anaerobic digester to maintain the design temperature.

The ADG-to-electricity system has and is currently participating in the NY legacy net energy metering (NEM) tariff for compensating electricity generated. A utility net meter is used to measure any imported utility electricity to the farm loads, and to measure any exported electricity that occurs when the system generates more power than the farm's demand. Under the legacy NEM methodology, in each billing period the total exported electricity receives a monetary compensation rate based on the farm's utility energy delivery rate. The energy rate is then converted into a monetary credit that is applied toward the farm's utility electric monthly charges, including fixed charges (e.g., a customer charge). Excess monetary credits carry over month to month and there is an annual true-up when the net excess, if any, is paid out to the farm.

The case study farm participates in remote NEM, which allows the farm to apply excess monetary credits from the farm utility account to other utility accounts under the same account owner name (if they are located in the same utility and NY ISO zone as the host farm). This allows the farm to offset some of the satellite location utility electricity costs. For this analysis, only the farm host site's utility bill impact was summarized because it represents the total value available, regardless of how it is distributed among the satellite utility accounts.

The simple cost-benefit analysis totaled the avoided utility cost from onsite generation and the revenue from excess electricity generation exported to the grid, and subtracted the average annual cost of operating and maintaining (O&M) the existing anaerobic digester, gas conditioning, engine-generator set, and heat recovery equipment owned by the farm. Annualized capital cost was not included in the analysis because the case study farm has already paid for the ADG-to-electricity system; however, annualized capital should be included for new systems. Additionally, the analysis did not include cost for significant future capital expenses, such as a major engine overhaul or replacement. Annual net income to the farm was calculated by subtracting the system O&M expense from the revenue generated.

Options 1 through 3 estimated the electricity production revenue in both a representative year with a capacity factor (CF) of 0.77, based on actual performance data, and an attainable performance year with a CF of 0.95. Capacity factor is calculated as the total electricity generated in a year divided by, the total nameplate rating of the engine-generator set multiplied by 8,760 hours in a year. The CF is dependent on conditions including the variable biogas quantity and quality, and the availability of the system for producing electric power.

1.0 <u>Option 1</u>: Continue Operating Existing ADG-to-Electricity System under Legacy Net Energy Metering

1.1 System Performance and Electric Bill Impact for a Representative Year under Legacy NEM

A recent year, within the last 3 years, was selected as the representative year to analyze based on it having a complete data set. During this year, the existing ADG-to-electricity system had the following performance metrics.

- Average capacity factor (CF) = 0.77
- Uptime (percentage of hours the system was generating power) = 95%
- Electricity generated = 4,024,486 kWh
- On-farm electricity usage = 2,820,832 kWh
- Electricity exported to utility = 1,355,675 kWh
- Electricity imported from utility = 152,021 kWh

Utility import occurs when:

1) the ADG-to-electricity system is offline for maintenance, or
2) the farm power demand exceeds the engine-generator set power output at any point in time.

The monthly electricity used by the farm and the electricity generated by the CHP system during the representative year are shown in Figure 1.

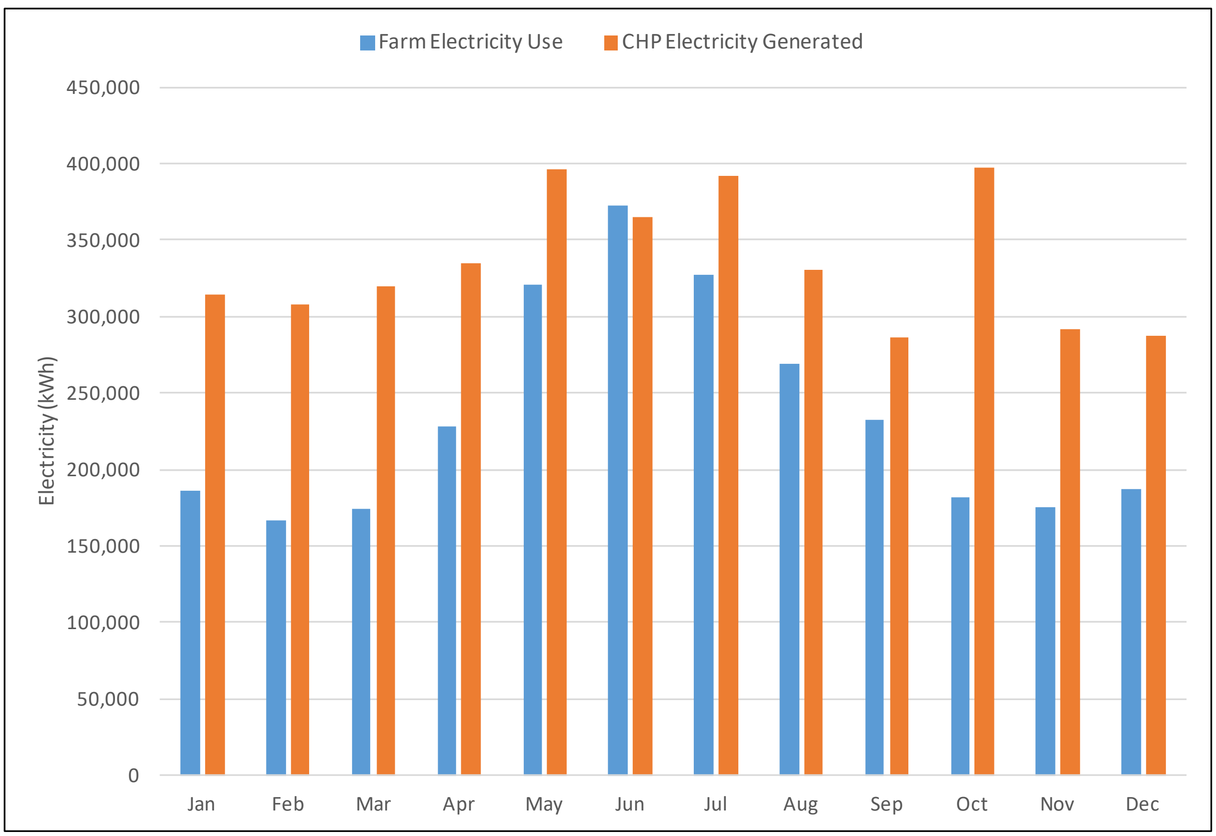

Figure 1. Monthly farm electricity usage and electricity generation from the ADG-to-CHP system.

The representative year utility bill average rates, charges, and credits are summarized below.

- Average exported electricity NEM adjustment rate = 4.54¢/kWh
- Total credit for exported electricity = $61,550
- Total charges for imported electricity = $50,800
- Average blended imported electricity rate = 33.42¢/kWh
- Percentage of imported electricity charges from monthly peak demand charges = 70%
- Average monthly peak demand rate = $7.40/kW

The cost of imported electricity includes several components: monthly peak demand charges ($/kW), imported electricity delivery and supply charges ($/kWh), and fixed charges ($). The monthly (or billing period) peak demand is measured as the highest average power imported during any 15-minute interval during the month. The peak demand measured by the utility meter and corresponding demand charge in each month of the year analyzed is shown in Figure 2. Given that the average farm load is 325 kW and a representative summer peak demand is 630 kW, Figure 2 illustrates that the single engine-generator set had periods of downtime in almost every month, causing significant power imports and associated demand charges from the utility.

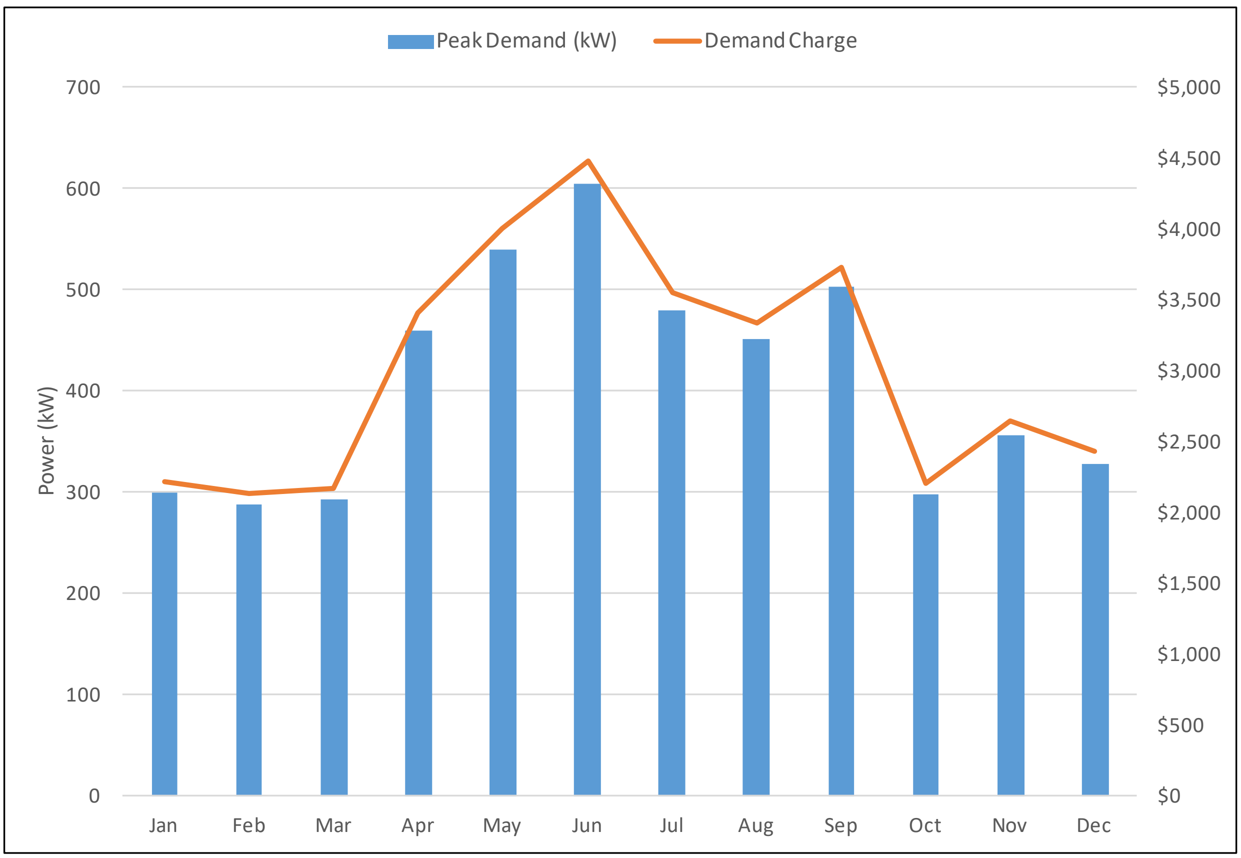

Figure 2. Monthly peak power demand and demand charge billed during a representative year when the ADG-to-CHP system is operating at a capacity factor of 0.77 and an uptime of 95%.

Based on the average utility rates for imported electricity to the farm during the representative year analyzed, the total estimated cost of purchasing all the electricity needed for farm operations from the utility is $190,900/year, an equivalent blended rate of 6.77¢/kWh.

A diagram of the annual electricity generated and consumed on the farm, and imported and exported from the utility, is shown in Figure 3. In this representative year at a CF of 0.77, the net credit from the ADG-to-electricity system after applying the total credits to the billed charges was $10,750. This amount is the true-up payment the farm received from the utility under the legacy NEM tariff. In addition, they saved the expense of purchasing all their electricity from the utility ($190,900) resulting in a total economic benefit of $201,650 per year.

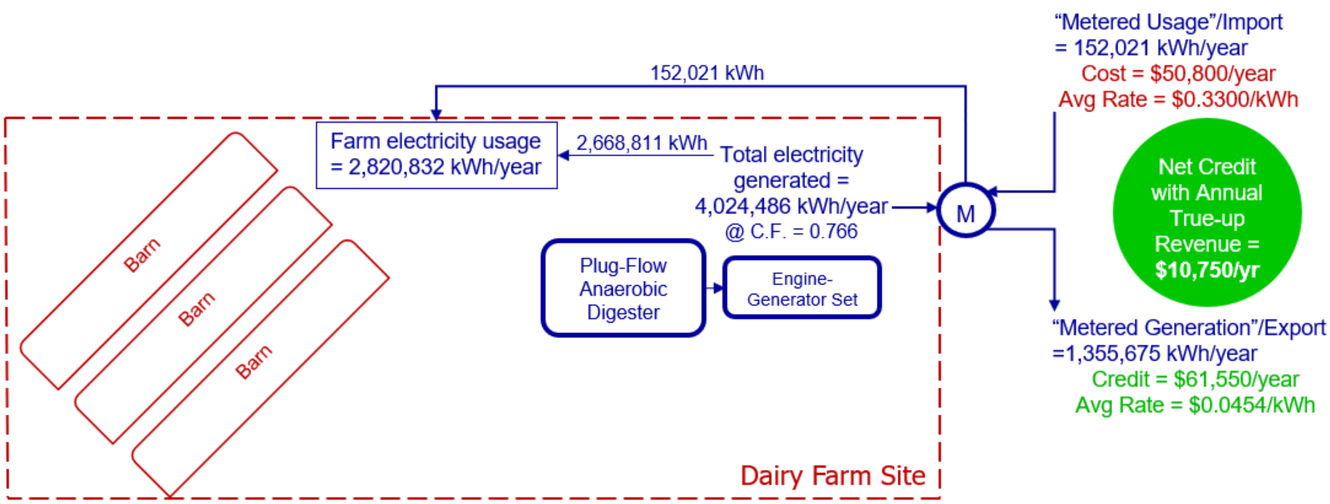

Figure 3. Diagram of Option 1 under a representative year operating capacity factor of 0.77.

1.2 Electric Bill Impact for the System Operating at an Attainable Capacity Factor under Legacy NEM

An annual capacity factor of 0.95 is realistic and attainable based on the uptime, or availability, of a single engine-generator set fueled by ADG (considering the system annual maintenance requirements). It is helpful to know what the maximum potential for savings under the legacy NEM tariff is by modeling the performance and electricity bill impact under a system CF of 0.95 (Figure 4).

With the ADG-to-electricity system producing more power and electricity, the monthly peak demand and total electricity imported from the utility is likely to decrease, however it is unknown by how much. The conservative assumption used was to maintain the import profile and cost of the representative year at the lower CF of 0.77, and apply the additional electricity generated to the total exported electricity amount.

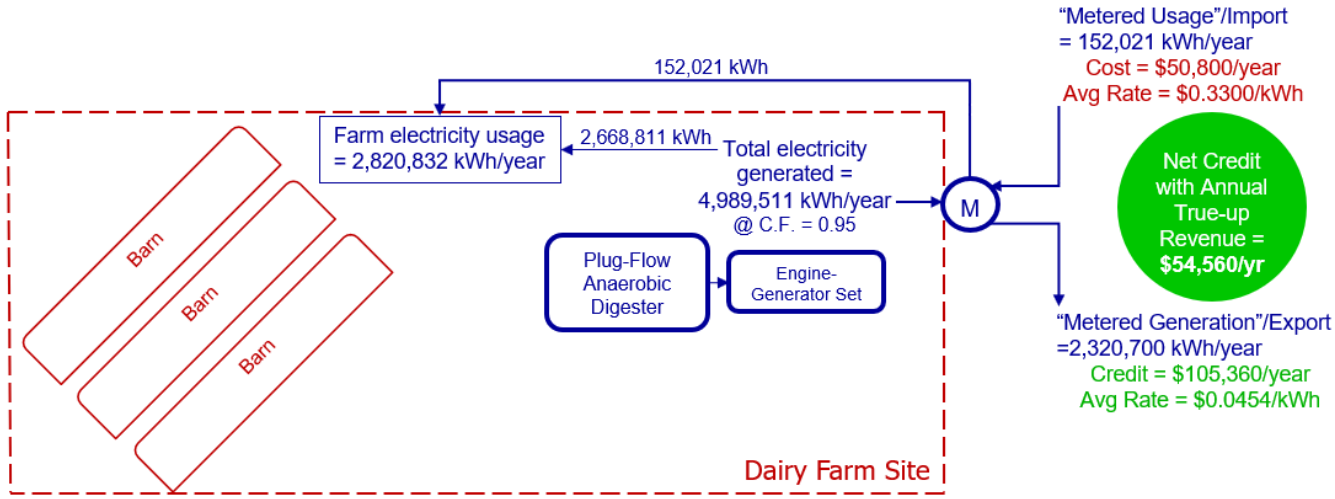

Figure 4. Diagram of Option 1 under an attainable operating capacity factor of 0.95.

In an attainable capacity factor year, the estimated system performance and associated utility bill credits and charges are summarized below.

- Average CF = 0.95
- Uptime = 95%
- Electricity generated = 4,989,511 kWh
- On-farm electricity usage = 2,820,832 kWh
- Electricity exported to utility = 2,320,700 kWh
- Electricity imported from utility = 152,021 kWh
- Total credit for exported electricity = $105,360
- Total charges for imported electricity = $50,800

The NEM tariff credit is 71% higher in the attainable capacity factor year than in the representative year analyzed. The net utility bill credit (annual true-up payment under the legacy NEM tariff) is $54,560, a five-fold increase over the representative year. Combining this monetary credit with the avoided cost of importing all electricity for the farm from the utility ($190,900) equals a total economic benefit of $245,460 per year.

2.0 Option 2: Continue Operating Existing ADG-to-Electricity System and Elect Phase One Value Stack

2.1 System Performance and Electric Bill Impact for a Representative Year under Value Stack

The Phase One Value Stack was first established[10] in March 2017 and is comprised of up to six parts (Figure 5). The blue boxes at the top of the stack denote the Phase One Value Stack tariff components that apply to all eligible distributed generation (DG) technologies, and all project types and locations. The orange boxes at the bottom of the stack denote the Value Stack components that apply only in

[10] NY DPS Case 15-E-0751, Order on Net Energy Metering Transition, Phase One of Value of Distributed Energy Resources, and Related Matters (issued March 9, 2017).

specific cases. Details of the Value Stack components and applicability are covered in Appendix A. For existing DG systems currently under the legacy NEM tariff, such as the case study farm, the newer Value Stack tariff is an option they can elect. The opt-in to Value Stack to replace legacy NEM is an irreversible decision.

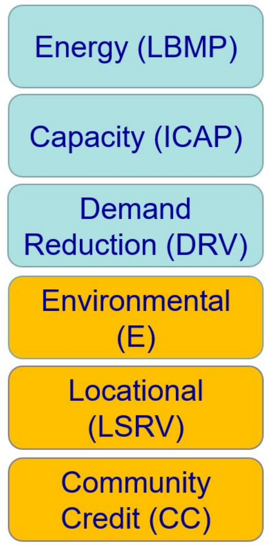

Figure 5. NY Phase One Value Stack tariff components.

The Phase One Value Stack for the case study farm was calculated using NYSERDA's VDER Value Stack Calculator version 2.3, designed for solar photovoltaic (PV) systems and solar PV paired with energy storage systems. [11] Although the calculator is not designed for an engine-generator set fueled by ADG, the inputs are customizable and the hourly power generation can be entered, along with the hourly onsite load. The E value was zeroed out due to the system's in-service date being prior to 2015 (and because it uses an engine-generator set and not a fuel cell). The LSRV also did not apply to the DG system site location on the utility grid. The CC was first created in the revised Value Stack compensation order[12] for Community Distributed Generation (CDG) projects located in certain NY utility territories. Existing projects under the legacy NEM tariff in these utilities that opt into the Value Stack tariff are eligible for the CC, if available at the time of opt-in. Section 3.0 covers the Option 3 case that includes the CC component in the Value Stack.

The ICAP alternative 3 option was applied with an assumption that the CHP system would export 400 kW during the single hour system peak (two-thirds of its full load capacity). The calculator's average first operating year price per exported kWh was used in the analysis of the Value Stack option. NYSERDA's Value Stack Calculator is only to be used as a reference tool to estimate project revenues; actual monetary bill credits under the Value Stack are calculated by the utility.

[11] NYSERDA VDER Value Stack Calculator version 2.3, https://www.NYSERDA.ny.gov/All-Programs/Programs/NY-Sun/Contractors/Value-of-Distributed-Energy-Resources/Solar-Value-Stack-Calculator.

[12] NY DPS, Case 15-E-0751, Order Regarding Value Stack Compensation (issued April 18, 2019).

The same ADG-to-electricity system performance was assumed as in section 1.1 based on the representative year of actual data (Figure 6). The estimated average monetary credit rate for exported power was 3.98¢/kWh under the Value Stack. Because this value is less than both the blended rate of importing all electricity (6.77¢/kWh) and the total delivery and supply energy charges rate of 5.1¢/kWh on the farm utility bills, it is most valuable to continue to use the CHP system to offset the onsite load first before exporting any excess power.

[Note: The Value Stack calculator input included an hourly onsite load profile. Without having actual hourly load data, the farm's total electricity usage was entered in the calculator and a built-in Department of Energy commercial building reference load profile was used that aligned best with the known summer peak demand and monthly usage figures.]

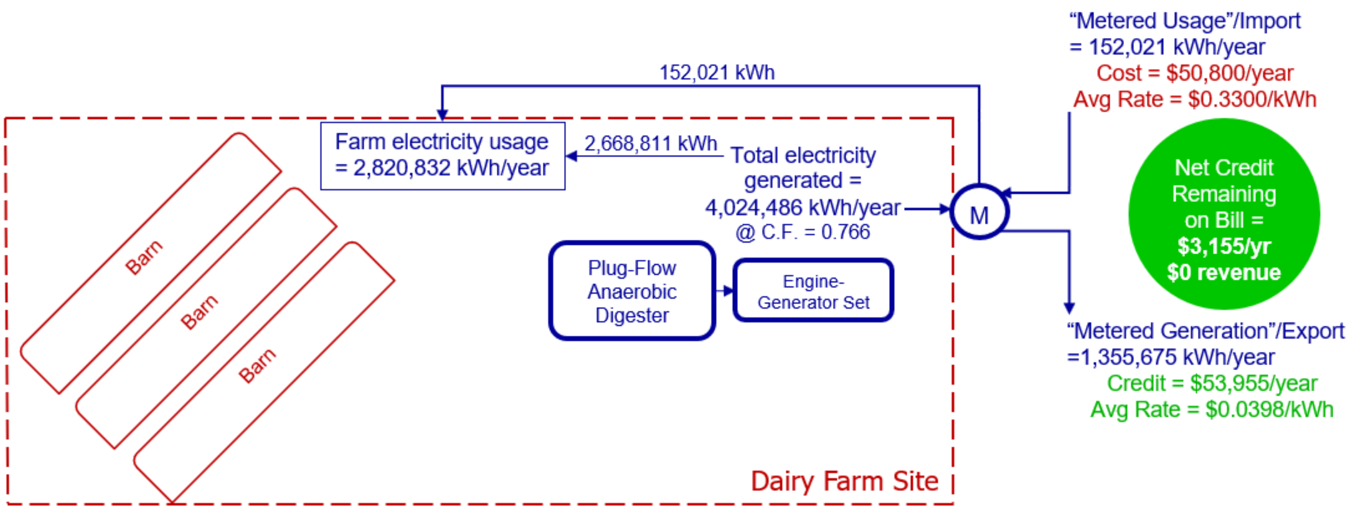

Figure 6. Diagram of Option 2 under a representative year operating capacity factor of 0.77.

In the representative year with capacity factor of 0.77 under the Value Stack tariff, the utility bill credits and charges were estimated to be:

- Total credit for exported electricity = $53,955
- Total charges for imported electricity = $50,800

The net monetary credit on the utility bill in the first year is therefore $3,155. Unlike the legacy NEM tariff, any excess credit is carried over indefinitely and can only be applied to future bill charges under the Value Stack tariff. There is no annual true-up payment, so the net credit paid to the farm is $0. The farm would realize an economic benefit of $190,900 per year from the avoided cost of importing all electricity needed for the farm.

2.2 Electric Bill Impact for the System Operating at an Attainable Capacity Factor under Value Stack

Using the same assumptions in section 1.2 to model the ADG-to-electricity system operating at an attainable CF of 0.95, the estimated Value Stack credit for exported electricity is over $92,000 in the first operating year (Figure 7). The net utility bill credit after the annual utility import cost of $50,800 would be approximately $40,000. However, this credit is not paid out to the farm and would remain on their bill, accumulating each year. The only opportunity to monetize this on-bill credit is to set up a Community Distributed Generation project (Option 3).

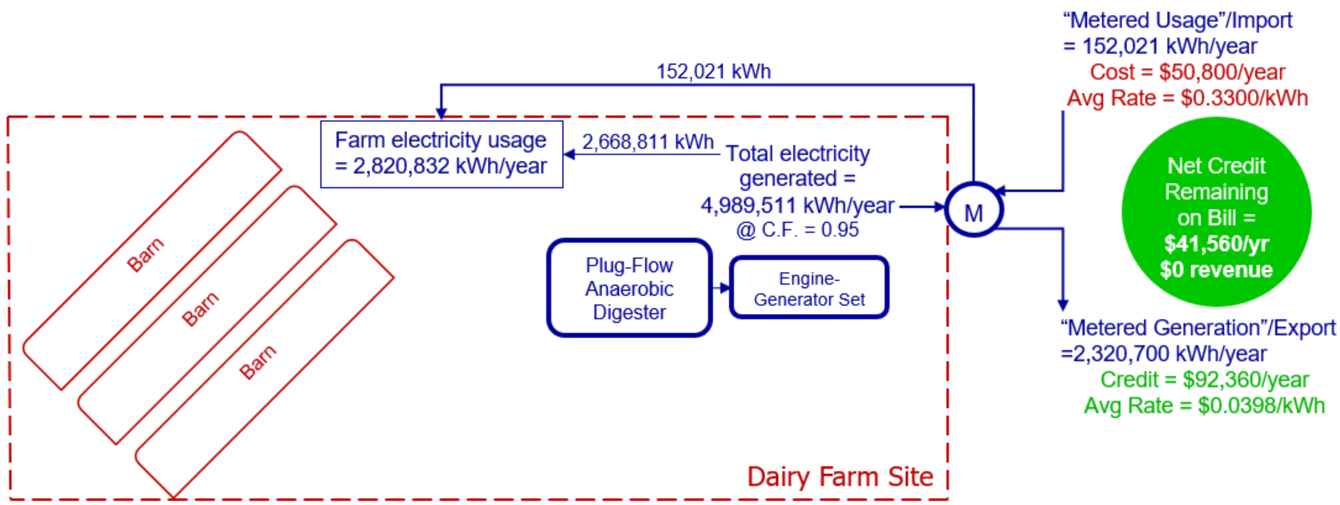

Figure 7. Diagram of Option 2 under an attainable operating capacity factor of 0.95.

3.0 <u>Option 3</u>: Elect Phase One Value Stack as Farm-Based Community Distributed Generation (CDG)

3.1 System Performance and Electric Bill Impact for a Representative Year under Value Stack as Farm-Based CDG

CDG is a project configuration that consists of a sponsor that hosts the DG system and community members that benefit from the electricity it generates. The graphic in Figure 8 illustrates how CDG works. The host site generates electricity with an eligible DG technology (i.e., those eligible for the Value Stack tariff, including certain ADG-to-electricity systems not previously eligible under the legacy NEM tariff). Electricity exported to the utility is valued using the Value Stack tariff structure that includes the Community Credit (CC) for those projects sited within National Grid, NYSEG, RG&E, or Consolidated Edison utilities, subject to aggregate capacity limits.

The Value Stack monetary credit is distributed to the participating CDG members on their utility bills, per the host's instructions on the allocated percentage of electricity generation to each member. The host's own site may use credits to offset its load. In exchange for the utility bill monetary credit (savings) that each member receives, they remit a membership payment back to the host. It is common practice for the membership payment to equal approximately 90% of the monthly utility bill credit received, but other arrangements determined by the CDG host are possible. This allows the host to monetize the electricity they are generating that exceeds their own usage under the Value Stack tariff.

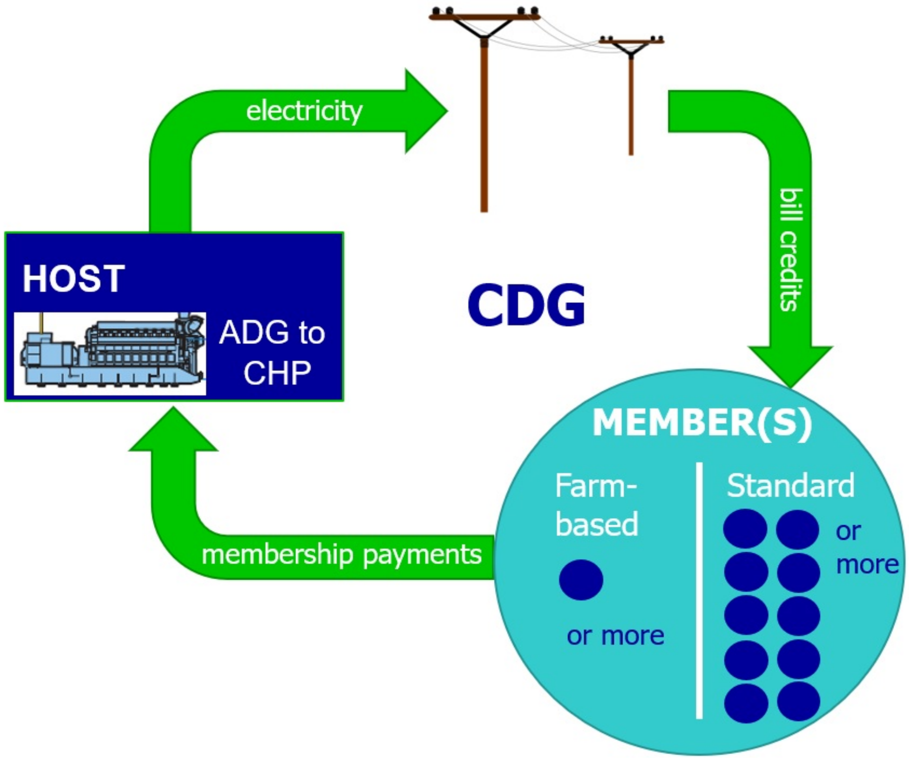

Figure 8. Community Distributed Generation (CDG) illustration.

CDG projects have become a popular format for large solar array installations in NY and in other states. At this time and to our knowledge, no ADG-to-electricity systems have used the CDG project format in NY, so there is some level of uncertainty in its success. Due to the need for membership agreements that are the host's responsibility, there will be a cost for creating and managing the associated contracts. An advantage that farms have is to use the "farm-based" CDG option instead of the "standard" to minimize the number of members and related contract management. More details on the farm-based and the standard CDG options are provided in Appendix A.

The estimated Value Stack rate in the first year is 6.23¢/kWh for this CDG project that uses the existing ADG-to-electricity system. This is equal to the Value Stack rate from section 2.0 plus the Community Credit[13]. Because the CDG Value Stack rate applied to exported electricity is close in value to the blended rate of importing all the electricity for farm operations from the utility (6.77¢/kWh), separately metering the two allows for the highest economic benefit. The farm can elect to add a new utility interval meter to the site that meters only the existing ADG-to-electricity generation, exporting all electricity generated to the utility grid. The farm loads would then be behind a separate meter (likely the existing utility meter), and subject to the utility rates for imported electric power. The cost of adding a second utility interval meter and adjusting the existing wiring was not assessed in this case study and would need to be understood to confirm the economic advantage.

[13] At the time of analysis, the Community Credit (CC) under the Phase One Value Stack tariff was 2.25¢/kWh.

If we assume the farm elects to host a farm-based CDG project, then they must allocate the electricity generated to at least one other farm operation-qualified member in addition to their own farm load account, and if desired, any other utility accounts in their name or those of their farm staff. All CDG members must be in the same utility territory. A possible farm-based CDG configuration assuming the same performance of the representative year with CF = 0.77 is shown in Figure 9.

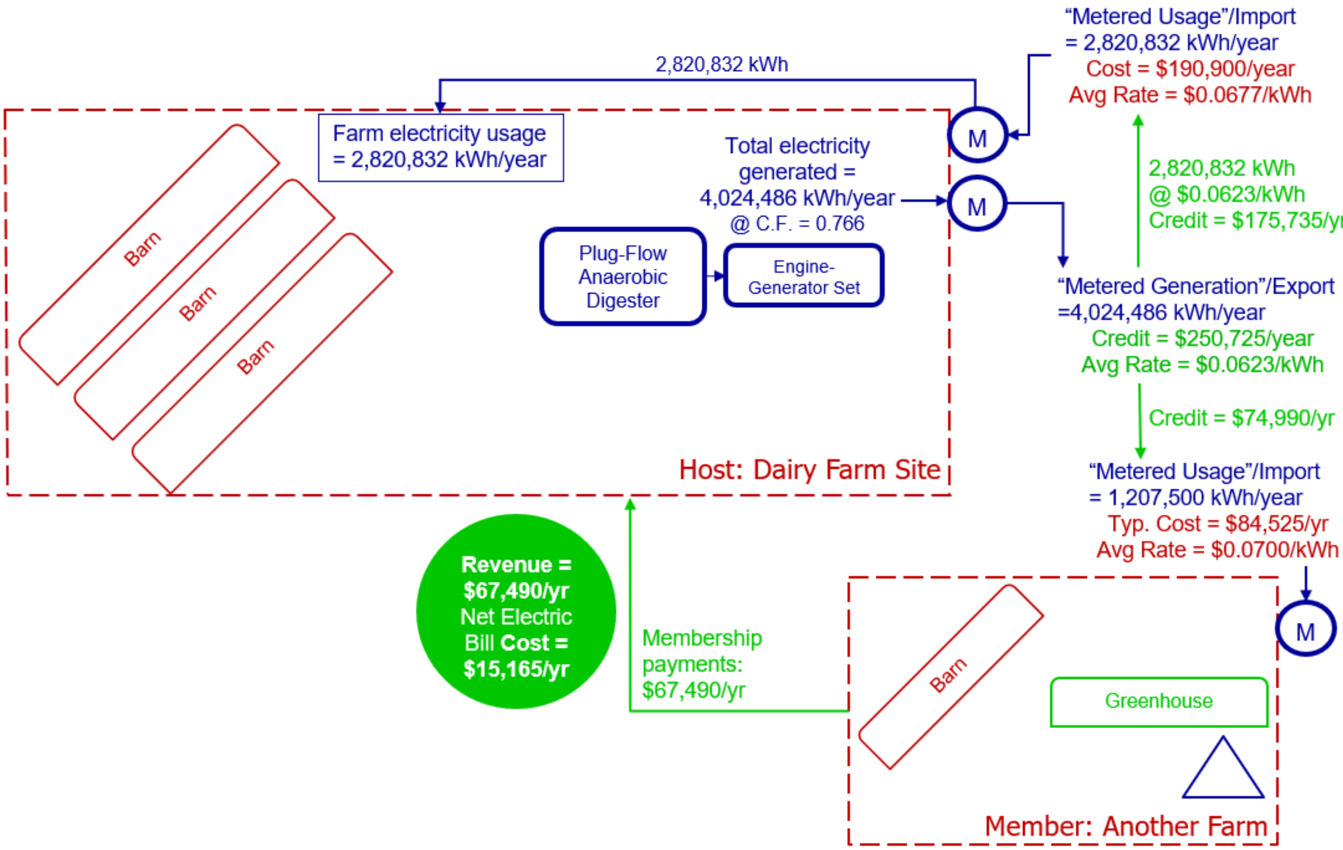

Figure 9. Diagram of Option 3 under a representative year operating capacity factor of 0.77.

In Option 3, 100% of the electricity generated is exported and receives the CDG Value Stack rate. The host can allocate up to 100% of the historical annual electricity usage of their farm to their farm utility import account, 2,820,832 kWh or 70% of the total generation in this case.

If we consider another farm operation that consumes at least 1,207,500 kWh annually, the remaining 30% allocation would be applied as a $74,990 credit against their annual electricity charges. At an assumed blended imported electricity rate of 7¢ per kWh for the member farm, their electricity bill cost after credit is estimated to be $9,535 (an 89% savings). The member farm would be required to make membership payments to the host farm each month, as utility bill credit is applied, in an amount less than the credit they receive. Assuming 90% of the credit is collected in membership payments, the member farm receives approximately 9% net savings on their annual utility electric cost.

A summary of the host farm annual utility electric bill impact is below.

- Average CF = 0.77
- Uptime = 95%
- Total credit for exported electricity = $250,725
- Total charges for imported electricity = $190,900
- Portion of credit applied to farm utility import account = $175,735
- Net annual utility bill charges = $15,165
- CDG membership payments to farm = $67,490

Combining the $67,490 annual membership payment with the $175,735 utility bill credit received, the total annual economic benefit to the host farm for Option 3 is $243,225. This is approximately 20% higher than the economic benefit they are achieving with their legacy NEM tariff under an operating system capacity factor of 0.77. However, the farm-based CDG project format enables the host farm to collect over 6 times more revenue from the electricity their ADG-to-electricity system is producing than their legacy NEM tariff permits.

3.2 Electric Bill Impact for the System Operating at an Attainable Capacity Factor under Value Stack as Farm-Based CDG

In the case of the ADG-to-electricity system operating at an attainable capacity factor of 0.95, the CDG project performance and estimated electricity values are shown in Figure 10 and summarized below.

- Average CF = 0.95
- Uptime = 95%
- Total credit for exported electricity = $310,850
- Total charges for imported electricity = $190,900
- Portion of credit applied to farm import utility account = $175,735
- Net annual utility bill charges = $15,165
- CDG membership payments to farm = $121,600

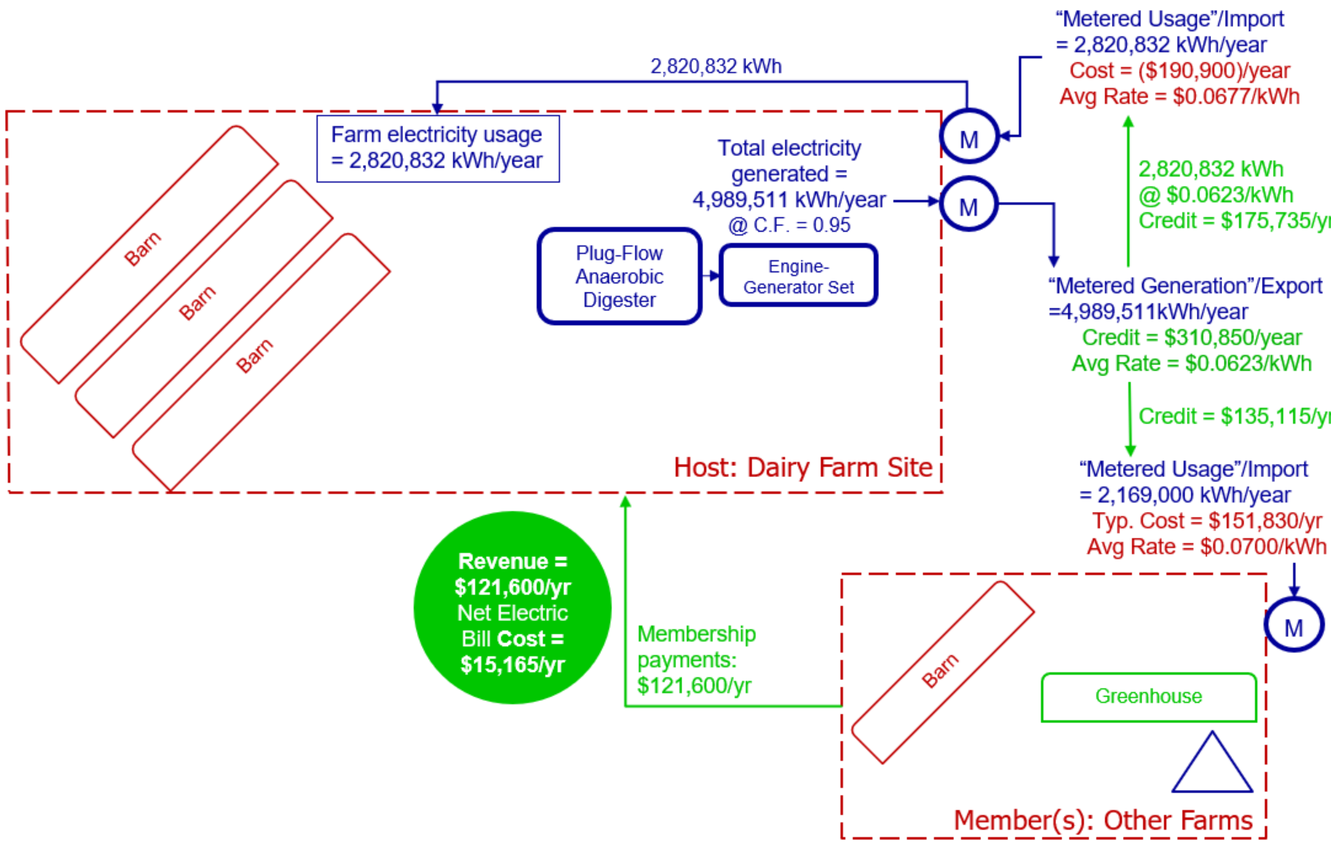

Figure 10. Diagram of Option 3 under an attainable operating capacity factor of 0.95.

Combining the $121,600 total membership revenue with the $175,735 utility bill credit received, the economic benefit to the host farm is $297,335 in the first operating year. This benefit is also over 20% higher than the legacy NEM tariff benefit under the attainable capacity factor assumption of 0.95. In this case, the farm receives over two times the revenue from the electricity generated using a CDG project format under the Value Stack tariff than it does under its legacy NEM tariff.

4.0 Option 4: Replace Existing ADG-to-Electricity System with an RNG System and Purchase Utility Electricity

4.1 Electricity Usage and Utility Cost of ADG-to-RNG System

The existing anaerobic digester electricity usage, including pumps for moving manure and digestate, is included in the farm operations electricity usage. Also included in the farm's electricity usage are the digester gas conditioning equipment loads used to support the existing engine-generator set system. Under Option 4, these loads would be taken offline and a new raw digester gas conditioning system would be added to produce renewable natural gas (RNG).

For this analysis, the assumption is that the RNG system will produce pipeline quality natural gas that will be loaded into a tanker truck for transport to a pipeline injection point located elsewhere. In general, to produce pipeline quality RNG, hydrogen sulfide (H_2S), moisture (H_2O), and carbon dioxide (CO_2) must be removed from the raw biogas, and the gas must be compressed to a higher pressure. The final product gas must meet the gas pipeline injection specification. The example RNG processing system assumed in this analysis contains three main components that consume power: a glycol chiller used for moisture removal, a stage one gas compressor prior to CO_2 removal, and a stage two gas compressor for further compression of the product gas for tanker truck loading.

The estimated RNG processing system main component power demand and annual electricity usage at an assumed maximum biogas flow rate of 250 scfm is summarized below.

- Glycol chiller average power = 38 kW
- Stage one gas compressor power = 72 kW
- Stage two gas compressor power = 65 kW
- Uptime (percentage of hours the system was operating) = 95%
- Total RNG processing system electricity usage = 1,460,000 kWh/year

The RNG system electricity usage increases the total annual electricity usage at the farm site by 50%, to a total of 4.28 million kWh (Figure 11). ADG-to-RNG systems are being developed by companies who may own and operate the system, rather than the farm owner taking this role. In this format, the RNG system owner is typically responsible for paying for the electricity use of the system. It may be behind a new utility service and meter, adjacent to the existing farm utility meter. Applying the same utility rate structure that the farm site has to the RNG system usage, the annual cost is estimated to be $100,000.

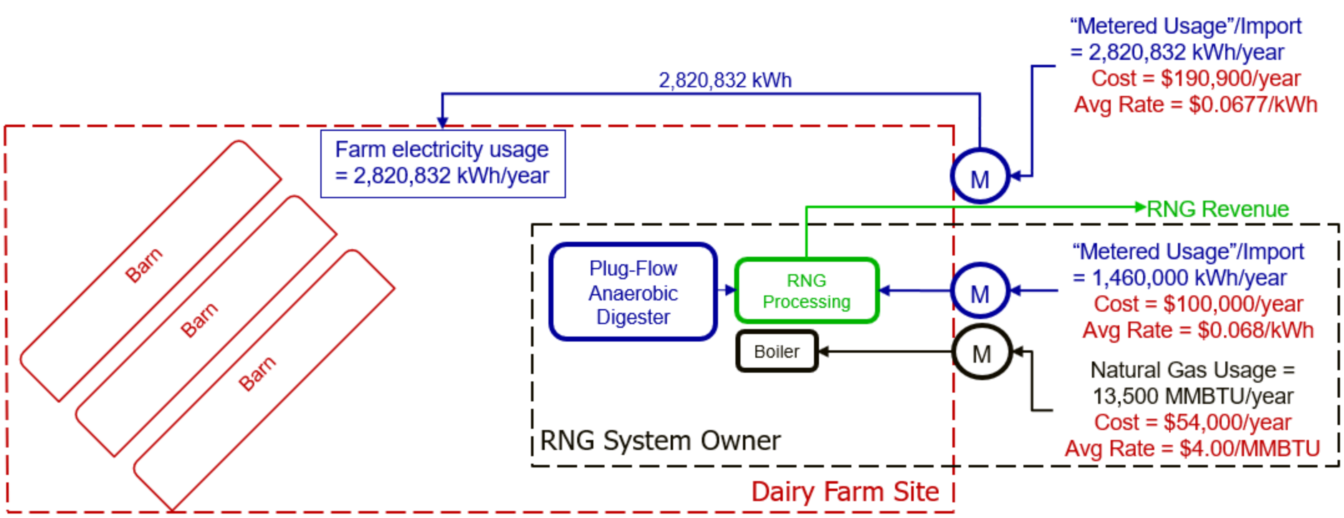

Figure 11. Diagram of Option 4.

4.2 Heating Usage and Utility Cost of ADG-to-RNG System

In addition to the electricity cost of the RNG system, without the ADG-fueled CHP system generating electricity and heat, there is a need for a new heating source to heat the digester to maintain its operating temperature of 100°F. A gas-fueled hot water boiler is assumed to be added to the site to supply hot water heating to the anaerobic digester.

The digester heating needs vary throughout the seasons, with peak demands reaching approximately 2.0 million BTU/hour in the winter and year-round average demand of 1.25 million BTU/hour for the case study farm. The annual cost of heating the digester is $54,000 at an estimated natural gas rate of $4.00 per million BTU (supply and delivery costs), assuming that a utility natural gas supply can be brought to the farm site to supply an 81% average efficiency boiler. If a natural gas supply cannot be brought to the farm site, a propane-fueled hot water boiler would cost $377,000 per year to fuel at an estimated rate of $2.58 per gallon.

The RNG product has such a high value that it does not make *economic* sense to use a portion of it onsite to fuel the hot water heating boiler needed to maintain the anaerobic digester operating temperature. However, it is uncommon for rural farms in NY to have access to natural gas pipelines, and propane or other fossil fuels may be the only current economical option to supply the necessary digester heating when RNG is produced from the biogas instead of electricity and heat.

5.0 Summary of Farm Cost-Benefit Analysis by ADG Use Option

5.1 Electricity Generation Revenue and Total Economic Benefit by ADG-to-Electricity Option

Among the three electricity generation options, the largest opportunity for revenue generation is to structure the project as a farm-based Community Distributed Generation (CDG) system. Revenue from electricity sales to the farm-based CDG members are estimated to be up to $67,490 per year under an operating capacity factor of 0.77 and up to $121,600 per year under a capacity factor of 0.95. The farm will also offset either all or much of its utility electricity cost estimated at $190,900 annually, adding to the overall electricity generation benefit, shown in the last column of Table 1 and Table 2.

Table 1. Electricity Generation Calculated Revenue and Economic Benefit in a Representative Year (Capacity Factor = 0.77).

Option	Option Description	Electricity Generation Revenue (year 1)	Total Electricity Generation Economic Benefit (year 1)
Option 1	Legacy Net Energy Meter (NEM)	$10,750	$201,650
Option 2	Phase One Value Stack [a]	$0	$190,900
Option 3	Phase One Value Stack as CDG	$67,490	$243,225

[a] An excess credit of $3,155 in year 1 is estimated, which must roll over into the following year. This excess is not included in the total electricity generation economic benefit because it cannot offset any real costs in year 1.

Table 2. Electricity Generation Calculated Revenue and Economic Benefit in an Attainable Year (Capacity Factor = 0.95).

Option	Option Description	Electricity Generation Revenue (year 1)	Total Electricity Generation Economic Benefit (year 1)
Option 1	Legacy Net Energy Meter (NEM)	$54,560	$245,460
Option 2	Phase One Value Stack [a]	$0	$190,900
Option 3	Phase One Value Stack as CDG	$121,600	$297,335

[a] An excess credit of $41,560 in year 1 is estimated, which must roll over into the following year. This excess is not included in the total electricity generation economic benefit because it cannot offset any real costs in year 1.

5.2 Cost-Benefit and Net Income of ADG Use Options

The energy-related revenue and expenses of the different ADG use options were compared to help the case study farm decide which option can provide the highest net energy-related income (or lowest net operating cost). The ADG-to-electricity use options have an expense to the farm for operating and maintaining (O&M) the anaerobic digester, gas conditioning, and engine-generator set CHP system. The average annual O&M cost including parts and labor is estimated to be $128,300 based on the farm historical records. The simple cost-benefit comparison among Options 1 through 3 is shown in Table 3; the actual annual economic benefit is less when *all* costs are included, such as annualized capital.

Table 3. Simple Annual Cost-Benefit of ADG-to-Electricity Options with CF = 0.95.

Option	Option Description	Economic Benefits – Costs
Option 1	Legacy Net Energy Meter (NEM)	$117,160
Option 2	Phase One Value Stack	$62,600
Option 3	Phase One Value Stack as CDG	$169,035

The annual net income to the farm of each ADG use option is calculated by subtracting the O&M expense from the electricity or RNG generation revenue (Table 4). All ADG-to-electricity options produce a net operating cost instead of a net income but offer a lower net operating cost than the baseline case of the farm not employing an anaerobic digester system.

For the option of using the ADG to produce RNG, the expectation is that a third party assumes ownership of the RNG system, including the anaerobic digester, and is responsible for the O&M cost (not identified in this analysis) as well as the electricity and digester heating fuel costs associated with the RNG processing equipment on the site. Under this assumption, the farm is responsible for the cost of their own electricity usage imported from the utility and has no other electrical or heating energy-related expenses associated with the farmstead.

Table 4. Calculated Annual Net Income by ADG Use Option (CF = 0.95 for Options 1, 2, and 3).

Option	Option Description	Energy Revenue – Expenses
Baseline	No anaerobic digester system in place	−$190,900
Option 1	ADG-to-Electric under Legacy NEM	($73,740)
Option 2	ADG-to-Electric under Phase One Value Stack	($128,300)
Option 3	ADG-to-Electric under Phase One Value Stack as CDG	($21,865)
Option 4	ADG-to-RNG	RNG revenue[a] – $190,900

[a] The estimated revenue to the farm from RNG production is confidential and not included in this analysis.

If the revenue that the case study farm receives from RNG production using their dairy manure (farm confidential) exceeds the estimated expense of $190,900 for purchasing utility electricity for their farm operations, then a more thorough review of all annual costs associated with this option is warranted to determine the actual net economic cost-benefit. Indications are that this option will produce a net income to the farm, based on strong private sector activity in proposed ADG-to-RNG systems.

***The elimination of the Environmental (E) Value from the Value Stack tariff for manure-based ADG-to-electricity systems that do not utilize fuel cells is the primary factor in the lack of net income potential from electricity generation*.**

Discussion

The simple cost-benefit analyses conducted for the case study farm illustrate that there is a net benefit to operating an ADG-to-electricity system up to an estimated $169,035 annually. This economic benefit is utility bill savings from what the farm would otherwise spend to power their farm operations. In this case study, the farm can generate up to 77% more electricity with the manure-only ADG-to-electricity system than it uses onsite; yet under the current NY tariffs and the CLCPA, there is no opportunity to generate a net income from this significant excess renewable electricity generation. In contrast, the farm does have an opportunity to generate significant net income if they convert their existing ADG-to-electricity system to an ADG-to-RNG system, due to the environmental value provided to these systems through the California Low Carbon Fuel Standard.

A summary of the net income potential under different electricity generation Environmental (E) Value scenarios applied to the case study farm is shown in Table 5. These scenarios are 1) no E Value per the current Value Stack tariff, 2) including the E Value currently available for "renewable energy systems" as defined in the CLCPA (e.g., the same value that solar PV systems are provided), and 3) including a true E Value that quantifies the total GHG emission reduction of the ADG-to-electricity system.

Although only ADG systems that generate electricity using fuel cells (of which, to our knowledge, there are currently no installations existing in NY) are eligible to receive the E Value under the Value Stack tariff, we reviewed how the E Value component impacts the opportunity for net income from the case study farm electricity generation. Including the current E Value of 2.741¢/kWh in the Value Stack calculation in Option 3 resulted in an estimated annual net income to the farm of $102,740 (including the Community Credit).

An anaerobic digester is an effective manure management tool that allows farms to receive several benefits, including significant reduction in GHG emissions. The GHG emissions of the manure itself are reduced through anaerobic digestion, in addition to the grid GHG emissions offset by using the biogas to generate renewable electricity. A method for calculating the total GHG emission reduction from an ADG-to-electricity system on a NY dairy farm and producing a true E Value for the electricity generated is presented in the paper by Wright et al. (2017). [14] Applying this method using the 2020 U.S. Environmental Protection Agency (EPA) Social Cost of Carbon ($52.14 per MT CO_2e) and the NY electricity grid GHG emission factor of 0.5017 MT CO_2e/MWh resulted in an obtainable true E Value of 7.835¢/kWh. Adding this true E Value to the Value Stack calculation in Option 3 produced an estimated annual net income to the farm of $330,000 (including the CC) and $230,000 (excluding the CC). These annual net income values are believed to be comparable with those possible under Option 4.

Table 5. Summary of Estimated Annual Net Income Potential under Different Environmental (E) Values (applied to Option 3 at CF = 0.95 and shown with and without the CC value).

Value	Current Value Stack tariff	Including current NY E Value	Including true E value for GHG emission reduction
Environmental (E) Value	0¢/kWh	2.741¢/kWh	7.835¢/kWh
Annual Net Income, with CC	($21,865)	$102,740	$330,000
Annual Net Income, without CC	($129,250)	$1,570	$230,000

[14] Ibid., 2.

Appendix A. Details of Value Stack Tariff and Community Distributed Generation

Value Stack Tariff

The Value of Distributed Energy Resources (VDER) is a NY Department of Public Service (DPS) proceeding established in March of 2017 to provide a more granular tool for compensating distributed generation (DG) exported to the electric grid, to replace the net energy metering (NEM) monthly value method. The concept of VDER is to assign the appropriate value to the electric power exported to the grid at each individual hour of the day throughout the year and include the societal benefits of the power source (e.g., emissions reduction, community access to clean electricity, etc.). VDER is the overarching NY DPS proceeding, and the Value Stack refers to the specific compensation structure that applies to a given DG system size and type. Phase One Value Stack applies to all the DG systems that were eligible for net metering at the time of its issue in March 2017, including farm waste ADG-to-electricity systems that are 5 MW or smaller, and was expanded to include CES Tier 1 eligible resources as well.

The Phase One Value Stack is comprised of up to six parts described below. Parts 1, 2, and 3 apply to every eligible DG project, while parts 4, 5, and 6 apply only in specific cases.

- Part 1. Energy value ("LBMP"): the day-ahead hourly wholesale NYISO energy rate for the zone where the DG system is located. LBMP stands for locational-based marginal price.
- Part 2. Capacity value ("ICAP"): one of three calculation alternatives, but only alternative 3 applies to ADG-to-electricity systems. Alternative 3 is a "capacity tag" approach because it multiplies the monthly ICAP capacity prices by the power exported at the time of the single hour system peak.
- Part 3. Demand reduction value ("DRV"): equal to the utility's dollar per kW-year rate, applied evenly over the applicable peak demand hours for that utility (except Consolidated Edison utility, the applicable hours are 13:00 to 18:00 on non-holiday weekdays 6/24 through 9/15; if NYSEG utility, add the hours 17:00 to 19:00 on non-holiday weekdays in January). The DRV rate is locked in for the first 10 years of the project, and then transitioned to the current rate.
- Part 4. Environmental value ("E"): defined as the higher of 1) the latest Clean Energy Standard Tier 1 REC procurement price or 2) the Social Cost of Carbon (SCC) calculated by the NY DPS. Currently, the SCC-based value is higher at 2.741¢/kWh that is exported to the grid by the eligible DG system. Eligibility for the E value was revised in December 2019 under a NY PSC order[15] that restricted it to only those systems defined as "renewable energy systems" in the NY CLCPA[16] passed in July 2019. The "renewable energy systems" definition in the CLCPA includes "fuel cells which do not utilize a fossil fuel resource in the process of generating electricity" but does not include farm waste ADG-to-electricity systems in general.
- Part 5. Locational system relief value ("LSRV"): applied to projects located in specific areas of a utility where system relief is needed. These areas are continually updated on utility-provided maps and final qualification for LSRV is determined at the time of interconnection approval. Payment is based on the exported power during at least 10 peak-period events per year lasting between 1 and 4 hours each and given a 21-hour advance notice. This value can be significant because it is equal to

[15] Ibid., 2.
[16] Ibid., 1.

the utility's dollar per kW-year rate divided by 10 and applied to the lowest hourly power injection during each event. The LSRV, if applicable, is also fixed for the first 10 years and then transitioned to the current rate.

- Part 6. Community credit ("CC"): applied only to NEM-eligible DG systems structured as Community Distributed Generation (CDG) projects and located within National Grid, NYSEG, RG&E, or Consolidated Edison utility territories (subject to aggregate CDG maximum capacity limits). Currently, the CC is 2.25¢/kWh for exported electricity to the grid, however the value is lower for fuel cell systems due to their high capacity factor. Fuel cell CDG projects receive 16% of the CC value[17], or 0.36¢/kWh.

A key difference between the newer Value Stack tariff and the legacy NEM tariff is the way that excess on-bill monetary credit is handled. Legacy NEM permits an annual true-up resulting in any excess credit to be paid out to the farm by the utility. The Value Stack tariff permits no true-up for excess bill credit, either annually or at the end of the 25-year term. Any excess utility bill credits rollover from month to month and year to year under the Value Stack. Electing a Community Distributed Generation (CDG) project format is a way to monetize the excess bill credit by applying it to CDG member bills and collecting a membership payment equal to a percentage of the member bill credit.

Community Distributed Generation (CDG)

Community Distributed Generation is a DG project format that consists of a sponsor that hosts the DG system and community members that benefit from the electricity it generates. The host site generates electricity with an eligible DG system (those systems eligible under Phase One VDER are eligible for CDG), typically without load behind the utility meter, but there may be load if desired. Electricity generated that is exported to the utility is valued using the Phase One Value Stack compensation structure that includes the CC value for those projects sited within National Grid, NYSEG, RG&E, or Consolidated Edison utility territories. Note that only the historically NEM-eligible DG system types are eligible to receive the CC value under Value Stack.

The Value Stack monetary credit is then distributed to the participating CDG members on their utility bills, per the host's instructions on the allocated percentage of electricity generation to each member. The host's own site may also be a member of the CDG project. In exchange for the utility bill monetary credit (savings) that each member receives, they remit a membership payment back to the host. It is common practice for the membership payment to equal approximately 90% of the monthly utility bill credit received, but other arrangements determined by the CDG host are possible. This format allows the host to monetize the electricity they are generating that exceeds their own usage under the Value Stack.

<u>Standard CDG</u>

The standard CDG format requires a minimum of 10 members. A single "large customer" member or group of large customers participating in the standard CDG project may be allocated up to 40% of the DG system electricity output at a maximum. A large customer is defined as one within the jurisdictional utility's non-residential demand-based or mandatory hourly pricing service classification. The remaining percentage of the CDG electricity output (60% or more) shall be allocated to mass-market customers in an amount of at least 1,000

[17] NY DPS Case 15-E-0751, Order Regarding High Capacity Factor Resources (issued December 12, 2019).

kWh annually per member. Mass-market customers are defined as those within the jurisdictional utility's residential or small commercial service classification that are not billed based on peak demand. The members may be any utility customer of the same utility as the host site, even if they are not within the same NYISO load zone. The host meter, where the DG system is interconnected, must be a non-residential meter. The maximum allocation to any member must not exceed their historical average annual electricity (kWh) usage.

Farm-Based CDG

In April of 2018, the NY PSC issued an order that established waivers for those CDG projects serving only farm operations and residences of individuals who own or are employed by the served farm operations. Farm operations is defined as "the land and on-farm buildings, equipment, manure processing and handling facilities, and practices which contribute to the production, preparation and marketing of crops, livestock and livestock products as a commercial enterprise…" and "may consist of one or more parcels of owned or rented land, which parcels may be contiguous or noncontiguous to each other". [18]

The ten-member minimum is waived, enabling farm-based CDG projects to serve 1 or more members. The 40% maximum electricity allocation for a large customer or group of large customers is also waived, enabling the farm-based CDG project to allocate as much electricity to both themselves and/or another large customer farm operation as desired. As in standard CDG, the maximum allocation to any member must not exceed the historical average annual electricity (kWh) usage of that member.

From the case study farm analysis and others conducted, it is clear that farm-waste ADG-to-electricity systems are often capable of generating significantly more electricity than the farm site consumes, making them ideal candidates for a CDG project format under the new Value Stack tariff. For existing systems under the legacy NEM tariff, if the Value Stack compensation rate for a CDG project is higher than the historical NEM rate, a careful assessment of the additional economic benefit to opting into the Value Stack should be made. The challenges with a CDG project include finding suitable member(s) within the same utility provider and developing a contractual agreement for mutually acceptable membership payments in exchange for utility bill savings.

Fuel Cell Systems under CDG

In the order issued on December 12, 2019, the NY PSC adopted an adjustment factor to the Community Credit (CC) for a fuel cell CDG system, as a high-capacity-factor resource. The adjustment factor adopted is equal to the average capacity factor of a solar PV system (0.14) divided by a fuel cell's average capacity factor (0.87), which equals 0.16. This means that fuel cell CDG systems will receive 16% of the CC in the Phase One Value Stack, regardless of whether they are standard or farm-based, fueled by natural gas or fueled by ADG. Reciprocating internal combustion engine and gas turbine systems that are eligible Value Stack technologies when fueled by farm-waste ADG are not subject to this CC adjustment factor and will receive the full CC value.

[18] NY DPS Case 15-E-0751, Order Regarding Farm-Based Distributed Energy Resources (issued April 20, 2018).