Calculating and Projecting Energy and GHG Benefits

A Case Study of Solar Water Heaters and Anaerobic Digesters in Mexico

RESULTS AT A GLANCE: ANAEROBIC DIGESTERS

7,775 tCO_2e

mitigated from 2014 to 2030

estimated using CLEER Tool for reporting on EG. 12-7 Projected GHGs

786 tCO_2e

mitigated in 2014

estimated using CLEER Tool for reporting on EG. 12-6 Emissions Reduced

67,000 m^3

of biogas generated and utilized annually

1.25 years

average payback period for an anaerobic digester

Access the Clean Energy Emission Reductions (CLEER) calculators at cleertool.org.

This case study is one of a series being developed by the USAID Resources to Advance LEDS Implementation (RALI) project to demonstrate how to calculate USAID standard indicators for different types of clean energy activities. This case study calculates results achievable from solar water heater and anaerobic digester interventions, including potential greenhouse gas (GHG) emission reductions through 2030, which can be reported under USAID clean energy standard indicators.[1] Note: USAID does substantial work supporting clean energy reforms that are not easily quantified but may have a greater impact than the activities described here. RALI seeks to develop cost-effective methodologies for assessing the impact of the full range of clean energy assistance provided by USAID.[2]

ACCELERATING CLEAN ENERGY DEPLOYMENT IN MEXICO

Mexico is a leader in addressing climate change. With the passage in 2012 of the General Law for Climate Change, it became the first developing country to enact national legislation to reduce greenhouse gas (GHG) emissions.[3] This comprehensive law mandates actions for climate change mitigation and adaptation, as well as coordination across national and subnational government agencies. Mexico was also the first developing country to submit an Intended Nationally Determined Contribution—a document that lays out the steps that a country plans to take to address climate change—under the United Nations Framework Convention on Climate Change (UNFCCC). Despite these achievements, Mexico faces significant challenges in continuing to accelerate economic development while addressing its growing contribution to climate change.

Phase I of USAID's Mexico Low Emissions Development (MLED) program operated from 2011 to 2016. MLED's broad goals were to assist the Government of Mexico in implementing the General Law for Climate Change. MLED helped to develop human and institutional capacity for GHG inventory development; improved data collection, analysis, and modeling of economic and environmental impacts of low emissions development strategies; and assessed clean energy market potential. To accelerate clean energy deployment, MLED identified potential for high-impact, low-cost pilot interventions to showcase the feasibility for scale-up.

For this effort, MLED partnered with both local and international institutions, including Mexico's Environment and Natural Resources Ministry, the Energy Ministry, the National Electricity Commission, Cleantech Challenge Mexico, the U.S. National Renewable Energy Laboratory, and the U.S. National Association of Regulatory Utility Commissioners.

DEMONSTRATIONS TO CATALYZE SCALING UP OF CLEAN ENERGY

One pilot involved the installation of 58 square meters of solar thermal collectors at La Villa Pediatric Hospital in Mexico City, partially replacing two diesel-fueled boilers that supply hot water and steam for sterilization purposes and laundry. Conducted in partnership with the Ministry of Health and the Ministry of Environment of Mexico City, the intervention saved 12,000 liters of diesel fuel in its first year, resulting in annual cost savings of approximately US$9,000. These savings demonstrate that payback periods for similar systems could be as few as three years. It presents an attractive model that will be replicated in up to 26 hospitals and potentially in other facilities.

Generator from an anaerobic digester system at Amacuzac dairy farm in Morel, Mexico.

MLED also supported the installation of four anaerobic digester systems at dairy and swine farms in Mexico that house nearly 1,400 animals. Anaerobic digesters capture biogas generated from manure waste by microorganisms in anaerobic conditions. This biogas can then be used as a source of fuel for cooking, heating, electricity generation, and other applications. During the first year of operation, these farms generated over 67,000 cubic meters of biogas, avoiding methane (CH_4) emissions and reducing the need to purchase GHG-emitting sources of electricity and heat, such as liquefied petroleum gas (LPG). GHG reductions from these pilot interventions account for only a small part of the GHG mitigation from MLED clean energy actions.

GHG ESTIMATION METHODOLOGY AND ASSUMPTIONS

The USAID RALI project used the Clean Energy Emission Reduction (CLEER) tool to quantify GHG benefits through 2030. The calculations, detailed below, align with USAID indicators EG.12-6 (annual GHG emissions reduced) and EG.12-7 (projected future GHG emissions reduced).

Solar Hot Water Systems

STEP 1 - RALI obtained project information from the MLED Mission. The implementers provided data on the system and the quantity of diesel fuel saved.

STEP 2 - RALI estimated the GHG emission reductions from diesel savings using the following equation:

$$\text{Emissions Reduced } (\text{tCO}_2\text{e}) = \text{Diesel Savings (GJ)} \times \text{Emission Factor} \left(\frac{\text{tCO}_2\text{e}}{\text{GJ}}\right)$$

RALI estimated GHG savings from the solar hot water systems by using the quantity of diesel fuel saved. This GHG savings estimate aligns with the results based on in-situ measurements of diesel use at La Villa Pediatric Hospital. Emission factors refer to the amount of carbon dioxide (CO_2) emitted per unit of energy. The emission factor used for diesel was 0.074 tCO_2e/GJ, obtained from the Intergovernmental Panel on Climate Change (IPCC).[4] RALI assumed that no GHGs are emitted by the solar hot water system.

In order to estimate projected cumulative GHG emissions avoided for each year through 2030 from these interventions, RALI assumed that diesel savings would continue through 2030. RALI assumed a technology degradation rate of 0.3% per year (based on expert judgement).

Anaerobic Digester Systems

STEP 1 - RALI obtained project information from the MLED Mission. The implementers provided data on the system specifications, amount of biogas collected from the system, and livestock population. The systems were operational beginning in 2014.

STEP 2 - RALI calculated the amount of methane collected annually from the anaerobic digester systems using the following equation:

$$\text{CH}_4 \text{ Collected} \left(\frac{\text{tCH}_4}{\text{year}}\right) = \text{Biogas Produced} \left(\frac{\text{t}}{\text{year}}\right) \times \text{CH}_4 \text{ Fraction}(\%)$$

The amount of biogas produced and a methane fraction of 65% were provided by MLED implementers.

STEP 3 - RALI estimated the fugitive GHG emissions associated with the activity scenario using the following equation:

$$\text{Action Emissions}_{\text{Fugitive}} \left(\frac{\text{tCO}_2\text{e}}{\text{year}}\right) = \text{CH}_4 \text{ Collected} \left(\frac{\text{tCH}_4}{\text{year}}\right) \times \frac{\text{Fugitive Emissions Rate}}{1 - \text{Fugitive Emissions Rate}} (\%) \times \text{GWP}_{\text{CH}_4} \left(\frac{\text{tCO}_2\text{e}}{\text{tCH}_4}\right)$$

The CH_4 collected was calculated in Step 2. The fugitive emissions rate, which represents the amount biogas escaping the system, was estimated by MLED to be 10%. The 100-year global warming potential of CH_4 used is 25, as per IPCC.[5]

STEP 4 - RALI estimated the amount of energy that will be generated annually by the anaerobic digester system, based on the amount of biogas produced and captured. For systems that replace heat production, the following equation was used:

$$\text{Heat Generated} \left(\frac{\text{GJ}}{\text{year}}\right) = \text{CH}_4 \text{ Collected} \left(\frac{\text{tCH}_4}{\text{year}}\right) \times \text{Energy Content}_{\text{CH}_4} \left(\frac{\text{GJ}}{\text{tCH}_4}\right)$$

The energy content of CH_4 used was 54.9 GJ/t, which is based on estimates from U.S. EPA and Bracmort.[6,7]

For anaerobic digester systems that replace electricity, the following equation was used:

$$\text{Electricity Generated}\left(\frac{\text{kWh}}{\text{year}}\right) = \text{CH}_4\text{ Collected}\left(\frac{\text{tCH}_4}{\text{year}}\right) \times \text{Energy Content}_{\text{CH}_4}\left(\frac{\text{GJ}}{\text{tCH}_4}\right) \times \frac{1}{\text{Heat Rate}_{\text{ICE}}}\left(\frac{\text{kWh}}{\text{GJ}}\right)$$

The energy content of CH_4 used was assumed to be 54.9 GJ/t. Additionally, the heat rate of an internal combustion engine (ICE) was used to account for the loss of energy when generating electricity. The heat rate used in this case is 0.015 GJ/kWh, based on U.S. EPA statistics.[8]

STEP 5 - RALI estimated the GHG emissions from energy consumption associated with the baseline scenario, the scenario in which no anaerobic digester systems are installed. For anaerobic digester systems that replaced the consumption of fossil fuel for heat production, the following equation was used:

$$\text{Baseline Emissions}_{\text{Energy}}\left(\frac{\text{tCO}_2\text{e}}{\text{year}}\right) = \text{Heat Consumed}\left(\frac{\text{GJ}}{\text{year}}\right) \times \text{Emission Factor}_{Baseline\ fuel}\left(\frac{\text{tCO}_2\text{e}}{\text{GJ}}\right)$$

RALI assumed that the anaerobic digester system installations did not change consumption habits, and thus the electricity consumed is equal to the electricity generated, calculated in Step 4. Emission factors refer to the amount of CO_2 emitted per unit of energy. The emission factors used were fuel specific and from IPCC.[4]

For anaerobic digester systems that replaced electricity production, the following equation was used:

$$\text{Baseline Emissions}_{\text{Energy}}\left(\frac{\text{tCO}_2\text{e}}{\text{year}}\right) = \text{Electricity Consumed}\left(\frac{\text{kWh}}{\text{year}}\right) \times \text{Emission Factor}\left(\frac{\text{tCO}_2\text{e}}{\text{kWh}}\right) \times \frac{1}{(1-\text{Line Loss Factor})}(\%)$$

RALI assumed that the anaerobic digester system installations did not change consumption habits, and thus the electricity consumed will be equal to the electricity generated, calculated in Step 4. The grid electricity emission factor utilized is a national-level combined marginal emission factor. This factor is a national average of all combined marginal emission factors used by registered Clean Development Mechanism (CDM) projects (2004-2015), which are based on the CDM methodology.[9] The line loss factor accounts for additional energy needed to be produced in order to deliver the required amount of electricity. The line loss factor was derived from International Energy Agency (IEA) data, and adjusted to remove non-technical line loss (such as theft of electricity).[10]

What is a combined marginal emission factor?

A *combined marginal emission factor* takes into account both operating margin and build margin. Operating margin reflects avoided emissions from existing power infrastructure (i.e., power plants or sources that already supply electricity to the country's electric grid). Build margin reflects avoided emissions from new infrastructure (i.e., new power plants or sources that would need to be built to meet additional electricity needs).

CLEER uses combined marginal emission factors to better reflect the emissions likely to be reduced or avoided as a result of clean energy interventions.

STEP 6 - RALI estimated the fugitive GHG emissions associated with the baseline scenario, the scenario in which no anaerobic digester systems were installed, using the following equations:

$$\text{Baseline Emissions}_{Fugitive\ CH_4}\left(\frac{\text{tCO}_2\text{e}}{\text{year}}\right) = \text{Livestock Population (head)} \times \text{Volatile Solids}\left(\frac{\text{kg VS}}{\text{head}\cdot\text{year}}\right) \times \text{Production Capacity}_{\text{CH}_4}\left(\frac{\text{tCH}_4}{\text{kg VS}}\right) \times \text{GWP}_{\text{CH}_4}\left(\frac{\text{tCO}_2\text{e}}{\text{tCH}_4}\right)$$

The fugitive emissions in the baseline scenario represent the emissions associated with the manure management practice in the absence of the anaerobic digester systems. The volatile solids value represents the rate at which each animal produces organic compounds, and the production capacity represents the amount of CH_4 present in the volatile solids. Both values are dependent on the type of animal and the farm region, and the values used are from IPCC.[4] The 100-year global warming potential of CH_4 used is 25, as per IPCC.[5]

In addition to the baseline CH_4 emissions, RALI also accounted for baseline nitrous oxide (N_2O) emissions. The nitrogen excretion value represents amount of N_2O emitted per animal. This value, which is dependent on the animal type and the region, is from IPCC.[4]

$$\text{Baseline Emissions}_{Fugitive\ N_2O}\left(\frac{tCO_2e}{year}\right) = \text{Livestock Population (head)} \times \text{Nitrogen Excretion}\left(\frac{tN_2O}{head}\right) \times GWP_{N_2O}\left(\frac{tCO_2e}{tN_2O}\right)$$

STEP 7 – RALI calculated the total GHG emissions reduced:

$$\text{Emissions Reduced}\left(\frac{tCO_2e}{year}\right) = \text{Baseline Emissions}_{\text{Energy}}\left(\frac{tCO_2e}{year}\right) + \text{Baseline Emissions}_{\text{Fugitive } CH_4}\left(\frac{tCO_2e}{year}\right) + \text{Baseline Emissions}_{\text{Fugitive } N_2O}\left(\frac{tCO_2e}{year}\right) - \text{Action Emissions}_{\text{Fugitive}}\left(\frac{tCO_2e}{year}\right)$$

RALI does not consider emissions from the combustion of biogas in the action scenario, because the emissions are biogenic. Therefore, the total emissions reduced are equal to the baseline energy consumption emissions plus the baseline fugitive emissions minus the action fugitive emissions.

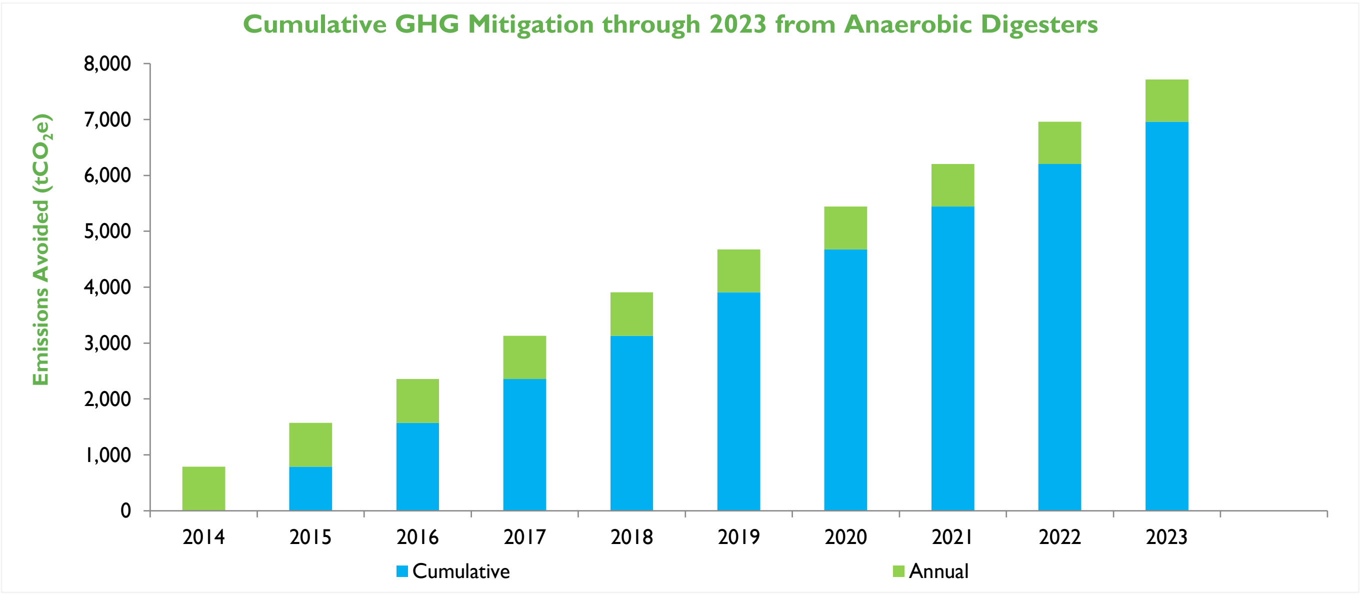
In order to estimate projected cumulative GHG emissions avoided for each year through 2030 from these interventions, RALI assumed that the resulting energy impacts from the interventions would continue through 2030. RALI assumed a technology degradation rate of 0.5% per year (based on expert judgement). The technology degradation rate affected each emission value differently – action fugitive emissions are assumed to increase 0.5% annually as the system degrades, the baseline energy consumption is assumed to decrease 0.5% annually as less baseline energy is offset as the system degrades, and baseline fugitive emissions remain constant annually as the livestock population is assumed to remain constant over time. Finally, based on advice from MLED implementers, it was assumed that each anaerobic digester system has a 10 year lifetime.

GHG CALCULATIONS AND RESULTS

Solar hot water system impacts: RALI estimates that in 2014, these interventions produced approximately 423.3 gigajoules (GJ) of energy and avoided 32 metric tons of CO_2-equivalent (tCO_2e) emissions. From 2014-2030, these solar water heaters are expected to avoid 534 tCO_2e. If these systems are successfully implemented in the 26 additional hospitals in 2016, the additional GHG savings through 2030 will reach approximately 12,276 tCO_2e.

Anaerobic digester system impacts: The anaerobic digester systems produce approximately 600 GJ of energy per year, avoiding roughly 786 tCO_2e annually by offsetting the consumption of LPG, wood, diesel, and grid electricity, and by avoiding emissions from traditional animal waste management processes. From 2014-2023, the anaerobic digester systems are projected to avoid 7,775 tCO_2e.

Total: In total, these MLED interventions avoided 818 tCO_2e in 2014, and are expected to reduce GHG emissions by a total of 8,309 tCO_2e from 2014 through 2030. Both the solar hot water and anaerobic digester systems are pilot interventions, so the success of these interventions can create opportunities for further emission reducing interventions in the future.



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