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SIMULATIONS

What-If SAVi Simulations on a Sustainable Recovery 2020

Why Investing in Biogas Energy Generation and Compost Production Is a Pragmatic Recovery Plan for Rural Communities in Ghana

Andrea M. Bassi
Joseph Intsiful[1]
Ania Grobicki[2]
Georg Pallaske
Laurin Wuennenberg
Oshani Perera
Abigail Schlageter

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The Rationale for the What-If Sustainable Asset Valuation (SAVi) Simulations

Planning a sustainable recovery requires that we look ahead and forecast how spending today will play out in the national and global economy in the years to come. It is also important that the ongoing, unprecedented wave of public spending triggers a sustainable recovery, one that has the environment, climate, and social cohesion at its core. The Sustainable Asset Valuation (SAVi) What-If simulations are designed to inform this debate by helping us understand the economic and societal benefits that can be realized when public spending is targeted at sustainable infrastructure. Simulations are inspired by ongoing recovery plans and are based on authoritative data and real science.

[1] Dr. Joseph Intsiful, Senior Climate Information and Early Warning Systems Specialist, Green Climate Fund
[2] Dr. Ania Grobicki, Deputy Director of External Affairs, Green Climate Fund

Section 1. About This What-If Simulation

This simulation estimates the additional costs and benefits for a rural community in Ghana from investing in biogas energy generation and compost production based on pig manure reuse. It assesses if such investments could be targeted by sustainable recovery financing. To do so, we draw from preliminary work and simulations undertaken with the Green Climate Fund (GCF). We explored whether biogas energy generation and compost production could be considered by the GCF for (concessional) financing and/or other financial and non-financial support measures in the context of sustainable and climate-resilient communities in Ghana. This simulation hence evaluates whether investing in biogas energy generation and compost production would contribute to sustainable community development in light of the economic challenges posed by the COVID-19 pandemic.

The reuse of pig manure assumed in this simulation creates business opportunities for locals, thereby improving livelihoods in the long term. Further, biogas energy generation in rural communities could provide a new energy source and avoid some of the current community expenses for purchasing electricity. In addition, biogas energy generation reduces reliance on fossil fuels and mitigate negative climate and health impacts. Compost production based on pig manure could replace chemical fertilizers used in the project area and thus improve access to fertilizer in the community while sustainably increasing soil productivity. Moreover, pig manure use would prevent nutrients in excretions from running into freshwater bodies, hence reducing water treatment costs and avoiding human health impacts. These additional benefits associated with pig manure reuse would contribute to sustainable community development in Ghana.

Section 2. The SAVi Simulation Results

Overview

This SAVi assessment consists of:

- A valuation of the costs and benefits of investing in biogas energy generation based on reusing pig manure.
- A valuation of the costs and benefits of investing in compost production based on reusing pig manure to replace chemical fertilizer use.

The simulation is based on the following assumptions:

- The 4,047 ha project area serves to farm 10,000 pigs.
- 50% of the manure that is available for productive purposes will be used to produce biogas, generating 107,156 megawatt hours (MWh) of electricity over a 30-year period.
- The remaining 50% of manure available for productive purposes will be used for compost production.
- The 1,676 tons of compost produced will replace chemical fertilizers currently purchased and used on the 4,047ha project area.
- A project timeline of 30 years is assumed for both interventions.

Tables 1 and 2 present an overview of cost and benefit factors assessed in this simulation.

Table 1. Costs and benefits of biogas energy generation from pig manure reuse

Costs	• Capital costs for biogas energy generation plant • Operation and maintenance (O&M) costs
Benefits	• Avoided cost of purchasing electricity from the grid • Avoided social cost of carbon (SCC) due to reduced purchasing of electricity from carbon-intensive power from the grid

Table 2. Costs and benefits of compost production from pig manure reuse

Costs	• Compost production costs, primarily for a biogas digester • Added costs for local farmers to purchase compost compared to costs for chemical fertilizers
Benefits	• Revenues from compost sales • Avoided wastewater treatment costs due to avoided nitrogen runoff into local waterways from excreted pig manure left on open pastures

Table 3 provides an overview of the What-If simulation results for the first five years of implementing both pig manure reuse projects: the biogas energy generation and compost production. While the net results from a project owner´s point of view are slightly negative, the net societal results are already positive in the short term thanks to the additional societal-wide benefits generated by both projects. Table 4 presents the simulation results for a 30-year timeframe. The results demonstrate considerable positive net results from both the project owner and the societal standpoint. Over the lifetime of both assessed interventions, society will realize a net benefit of almost USD 14 million.

The positive results suggest that pig manure reuse is an economically attractive investment opportunity for farmers in rural communities as well as for the community as a whole. The investments would contribute to a sustainable recovery and enable long-term sustainable community development in the project area in Ghana. The slightly deficient net project results over the five-year time horizon might suggest that sustainable recovery financing provided by public funders and donors such as the GCF could be useful in the short term. These could be allocated in the form of concessional lending to cover part of the capital costs. Other financial support measures could be provided, such as guarantees for de-risking purposes to reduce commercial interest rates and the repayment burden and, moreover, crowd in commercial lenders and private investors for long-term financing of the projects.

Table 3. Overview of SAVi simulation short-term results

Cumulative results of biogas energy generation and compost production from pig manure reuse over five-year project timeline	Cumulative value after five years (USD)
Costs	
Total biogas energy generation costs	1,223,000
Compost production cost	353,000
(A) Total costs	**1,577,000**
Revenues	
Total revenues from household electricity demand	1,072,000
Total revenues from local sales of compost	353,000
(B) Total revenues	**1,425,000**
Net project results: (B)-(A)	**(152,000)**
Additional benefits and costs	
Avoided SCC due to reduced carbon-intensive electricity consumption	412,000
Additional cost of using fertilizer from compost	(87,000)
Avoided water treatment cost	1,232,000
(C) Total co-benefits	**1,557,000**
Net societal result: (B)+(C)-(A)	**1,139,000**

Table 4. Overview of SAVi simulation long-term results

Cumulative results of biogas energy generation and compost production from pig manure reuse over 30-year project timeline	Cumulative value after 30 years (USD)
Costs	
Total biogas energy generation costs	2,243,000
Compost production cost	2,120,000
(A) Total costs	**4,363,000**
Revenues	
Total revenues from household electricity demand	6,430,000
Total revenues from local sales of compost	2,120,000
(B) Total revenues	**8,550,000**
Net project results (B)- (A)	**4,187,000**
Additional benefits and costs	
Avoided SCC due to reduced carbon-intensive electricity consumption	2,471,000
Additional cost of using fertilizer from compost	(523,000)
Avoided water treatment cost	7,394,000
(C) Total co-benefits	**9,342,000**
Net societal result (B)+(C)-(A)	**14,052,000**

A Closer Look at the Simulation for Biogas Energy Generation

Table 5 presents the short-term results of the What-If simulation for biogas energy generation. Table 6 presents the long-term results.

First, total costs in Table 5 represent the capital costs of installing a biogas energy generation plant as well as the O&M costs over a period of five years. Given the assumptions that manure available will be sufficient to generate 3,572 MWh of electricity annually, a total of 107,156 MWh electricity can be generated over the assumed 30-year lifetime of the plant. The capital costs for a biogas energy generation plant with this capacity amounts to USD 1.019 million. The associated O&M costs for the first five years is USD 204,000.

Second, assuming an electricity sales price of USD 60 per MWh to local households, biogas production yields revenues of USD 1.072 million in the first five years. While from the project owner's standpoint this results in a net loss of USD 151,000 in the short term, accounting for related societal benefits leads to a positive short-term result.

Biogas energy generation reduces the use of coal for energy generation and thus reduces coal-related carbon emissions. Over 30 years, the cumulative reduction in emissions totals almost 79,724 tons carbon dioxide equivalent (CO_2eq). The SCC is applied to value the avoided carbon emissions in monetary terms. The SCC is a measure of the loss of human welfare that is caused by emitting one additional ton of CO_2e emissions (Nordhaus, 2017). Assuming SCC is USD 31/ton CO_2eq, over a period of 30 years the total avoided SCC from replacing a share of coal power generation by biogas power generation is projected at USD 412,000 in the short term. When the avoided SCC is incorporated in the analysis to reflect a societal standpoint, the short-term net result rises to USD 261,000.

Table 6 presents the simulation results over a 30-year timespan. The results suggest that in the long term, the project represents a net gain of USD 4.187 million from the project owner's standpoint. This suggests that the high capital costs of implementing a biogas energy generation plant will be covered in the long term by the revenues generated, making it an attractive long-term investment. When the additional benefits from the avoided SCC are accounted for, the long-term net benefits total USD 6.658 million, making the investment even more attractive from a societal standpoint.

The negative short-term result from a project owner's perspective might suggest that sustainable recovery support provided by public funders and donors, such as the GCF, could be useful to incentivize such investments. Financial support could allow producers to realize positive net results in the short and long terms. Further, pig manure reuse creates opportunities to improve the livelihoods of local people because of employment and additional income generation.

Table 5. Short-term results of the simulation for biogas energy generation

Results of biogas energy generation from pig manure reuse over five-year project timeline	Cumulative value after five years (USD)
Costs	
Capital costs of biogas energy generation	1,019,000
O&M costs of biogas energy generation	204,000
(A) Total costs	1,223,000
(B) Revenues: Total revenues from household electricity demand	1,072,000
Net project results (B)-(A)	**(151,000)**
(C) Additional benefits: Avoided SCC due to reduced carbon-intensive electricity consumption	412,000
Net societal result (B)+(C)-(A)	**261,000**

Table 6. Long-term results of the simulation for biogas energy generation

Results of biogas energy generation from pig manure reuse over 30-year project timeline	Cumulative value after 30 years (USD)
Costs	
Capital costs of biogas energy generation	1,019,000
O&M costs of biogas energy generation	1,223,000
(A) Total costs	**2,243,000**
(B) Revenues: Total revenues from household electricity demand	**6,430,000**
Net project results (B)-(A)	**4,187,000**
(C) Additional benefits: Avoided SCC due to reduced carbon-intensive electricity consumption	**2,471,000**
Net societal result (B)+(C)-(A)	**6,658,000**

A Closer Look at the Simulation for Compost Production to Replace Chemical Fertilizers

Table 7 presents short-term results for the What-If simulation of compost production. Table 8 presents the long-term results.

First, the simulation assumes that 1,676 tons of compost can be produced annually from the manure that is available. Assuming compost production costs are EUR 39 per ton (approximately USD 42), the total production costs are USD 353,000 for the first five years. The simulation assumes that compost is sold at the cost of production. Revenues from local compost sales are hence projected to be USD 353,000 in the first five years. This means that the producer will break even in the short term.

While there is neither a net gain nor loss from the producer's perspective, other benefit and cost factors can be considered from a societal point of view. Using compost instead of traditional chemical fertilizers would actually increase the farmer's input costs. Comparing the nutrient content in compost to that of chemical fertilizers, the 1,676 tons of compost produced annually has the potential to replace 190 tons of chemical fertilizer. Considering the cost of purchasing locally produced compost to be 42 USD/ton and the cost of chemical fertilizers to be 280 USD/ton, the additional annual cost from substituting chemical fertilizer with locally produced compost is USD 17,400. This amounts to USD 87,000 over the first five years. While this is an additional cost for local farmers, the local compost production guarantees continuous access to natural fertilizers and less dependency on availability of chemical fertilizers and potential market price fluctuations.

Moreover, using manure for productive purposes instead of leaving it on pastures prevents nitrogen from ending up in local waterways, which can be harmful to freshwater access and biodiversity. For the case of reusing manure, the simulation projects avoided nitrogen loadings to be around 49.6 tons per year. This can be valued in monetary terms by considering avoided water treatment costs. Assuming wastewater treatment cost of 5,100 USD per ton of nitrogen in local waterways, the reuse of manure will avoid a treatment cost of USD 1.232 million in the short term. When both of these societal impacts are considered, the additional fertilizer purchasing expenses by farmers and the avoided water treatment costs, compost production leads to a net gain of more than USD 1.1 million in the short term.

Table 8 presents the results for compost production over a 30-year timespan. While over the long term the producer is still breaking even, the net result from a societal standpoint amounts to USD 6.9 million. Considering that compost producers only break even but do not generate an attractive return on investment, the incentives for implementing the compost production project are not particularly high. Financial support by public funds such as the GCF could create incentives to implement this project and might be used to subsidize the purchasing price for local compost to make its purchasing less costly for local farmers. Local compost production is an attractive option for sustainable community development and sustainable recovery efforts because it enhances economic activities in the community, reduces the need for water treatment and protects the environment through decreased nitrogen loadings and lowered chemical fertilizer use.

Table 7. Short-term results of the simulation for compost production

Results of compost production from pig manure reuse over five-year project timeline	Cumulative value after five years (USD)
(A) Costs for compost production	353,000
(B) Revenues: from local sales of compost	353,000
Net project results (B)-(A)	**0**
(C) Additional benefits and costs:	
Additional cost of using fertilizer from compost	(87,000)
Avoided water treatment cost	1,232,000
Net societal result (B)+(C)-(A)	**1,145,000**

Table 8. Long-term results of the simulation for compost production

Results of compost production from pig manure reuse over 30-year project timeline	Cumulative value after 30 years (USD)
(A) Costs for compost production	2,120,000
(B) Revenues: from local sales of compost	2,120,000
Net project results (B)-(A)	**0**
(C) Additional benefits and costs:	
Additional cost of using fertilizer from compost	(523,000)
Avoided water treatment cost	7,394,000
Net societal result (B)+(C)-(A)	**6,871,000**

Section 3. Using the Results of This Simulation

This SAVi What-If simulation on biogas energy generation and compost production provides two key insights. First, the investment in pig manure reuse creates societal benefits by creating local economic activities, generating jobs, avoiding water pollution, and reducing carbon emissions. In addition, by providing access to locally produced fertilizers, it also supports land productivity and nutrition, outcomes to consider when investing in sustainable agriculture. This intervention allows rural communities to be more self-sufficient and generate employment opportunities using a circular economy approach.

Second, the value of this investment is not expressed by its profitability. In fact, it is assumed that if fertilizer and energy are locally produced and locally used they will not be sold at a premium price. Instead, this investment is an enabler for other interventions (such as sustainable agriculture practices) that can lead to higher profitability from crop production. Further, it leads to lower community costs (such as for wastewater treatment) or, if water is not treated, it reduces the impact of wastewater on human health and ecosystems.

In sum, investing in pig manure reuse options is an excellent complement to support the creation of sustainable and climate-resilient communities. Especially in the context of COVID-19, public donors and funders should consider providing sustainable recovery support for such circular economy opportunities to create entrepreneurship, realize community benefits, and protect the environment.

Section 4. The Design of the Simulation

Table 9. Simulation details

Manure use for biogas energy	
Capital cost	This estimate assumes pigs produce 8.630137 kg/head/day of manure based on Statistics Netherlands (2012) and assuming 25% of the manure produced is available for biogas energy generation. An estimated .51 MW required capacity was estimated based on the assumption that each ton of pig manure has an energy generation potential of 0.039 tonne of oil equivalent (TOE), which is equivalent to a potential electricity generation of 11.63 MWh per ton of manure, as estimated in an IEA study (IEA, 2020). Assuming there is a capital cost of EUR 2,000,000/MW, as estimated in Kost et al. (2018), this project has a capital cost of USD 1,019,368.
O&M cost (30 years)	According to Kost et al. (2018), the O&M costs of biogas generation are EUR 80,000/MW. We estimate that the O&M costs of this project would total USD 1,223,241 over the 30-year project lifetime.
Revenues from biogas electricity sales	Using local market sales prices of USD 60/MWh, we estimate that the project will lead to revenues totalling USD 6,429,600 by the end of the project lifetime.
CO_2e emissions compared to coal (ton)	Total amount of CO_2e avoided is estimated in comparison to coal power generation. Biogas energy generation can result in 79,710 tons of avoided CO_2 emissions by 2050 compared to coal.
Avoided SCC	Following Nordhaus (2017), we use an estimate of USD 31/ton of CO2 emitted for the SCC. Using the estimated 79,710 tons of CO2 emissions avoided from biogas energy generation, USD 2,471,444 in SCC can be avoided by 2050.

Manure use for fertilizer	
Compost production cost	This estimate assumes pigs produce 8.630137 kg/head/day of manure, as estimated by Statistics Netherlands (2012) and assuming 25% of the manure produced is available for compost production. This would lead to 7,875 tons of manure per year. Additionally, following Nolan et al. (2012), we estimate that the production cost of compost from manure is EUR 39/ton. We also calculate that compost yield is 21.3%. This would lead to a total compost production cost of USD 2,120,022.

Total revenues from local sales	From the same assumptions as above, we assume 7,875 tons of manure produced annually is used for compost production. Based on data from the Italian Composting and Biogas Association (CIC) (2017), we estimate that the sales price of compost is EUR 39/ton. This would lead to a total of USD 2,120,022 by 2050.
Avoided nitrogen loadings from pig manure (ton)	This value assumes application of fertilizer of 65 kg/ha/year. This calculation assumes the nitrogen content in pig manure is 19.825 kg N/head/year, as estimated by Velthof et al. (2015). It also assumes a 1.7% nitrogen share in compost, as estimated in Foged et al. (2012), and 15% nitrogen share in fertilizer as estimated in Quinn (2019). Foged et al. (2012) also estimated that the dry mass compost in pig manure is 47% and a study by Lorimor et al. (2004) estimates that the water compost in pig manure is 90%. Additionally, 8.82 ton of compost can replace one ton of chemical fertilizer. In total, this leads to an estimated 14,88 tons of nitrogen emissions avoided in nearby waterways.
Avoided cost of emitting nitrogen into water	Assuming 1,488 tons of nitrogen emissions are avoided, and assuming a cost of EUR 4.6 per kg per kg of nitrogen emitted into waterways as estimated by Hernandez-Sancho et al. (2009) the total avoided cost of emitting nitrogen into waterways is USD 7,394,095.
Total avoided cost of fertilizers	Assuming 1,675 tons of fertilizer can be produced from the available compost, the total amount of compost available over the 30 years is estimated to be 50,280 tons. This simulation assumes 8.82 tons of compost can replace every ton of chemical fertilizer, based on Foged et al. (2012), who note that the nitrogen content of compost is 1.7%, comparing this to the 15% that is typically found in chemical fertilizers. The simulation estimates that this will keep 189.9 tons of chemical fertilizers from being used, hence a total of 5,697 tons of fertilizer can be avoided in total over a 30-period. Considering the cost of chemical fertilizer to be 280 USD/ton, as estimated by Danso et al. (2005), the total avoided cost of this chemical fertilizer is USD 1,595,160 over 30 years. On the other hand, assuming a compost cost of 42 USD/ton, as estimated by a 2017 CIC report, the annual 1,676 tons of compost to replace these chemical fertilizers will cost USD 2,118,284 over a 30-year period. This means that the price of fertilizer from compost is USD 523,124 more than the cost of chemical fertilizers over the 30-year timespan.

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About SAVi

The SAVi is a simulation service that helps governments and investors value the many risks and externalities that affect the performance of infrastructure projects. It integrates best-in-class climate data from the EU Copernicus Climate Data Store.

The distinctive features of SAVi are:

- Valuation: SAVi values, in financial terms, the material environmental, social, and economic risks and externalities of infrastructure projects. These variables are ignored in traditional financial analyses.
- Simulation: SAVi combines the results of systems thinking and system dynamics simulation with project finance modelling. We engage with asset owners to identify the risks material to their infrastructure projects and then design appropriate simulation scenarios.
- Customization: SAVi is customized to individual infrastructure projects.

Check out the SAVi track record, on-line demo, and academy at www.iisd.org/savi.

For more information visit our website: iisd.org/sustainable-recovery