Trash to Treasure: Policy considerations for successful implementation of anaerobic digestion in the Global South -

Azmery Afnan, Emily Schabert and Victor Igwe (The State University of New York, College of Environmental Science and Forestry, United States)

Key Messages

- Anaerobic digestion is a sustainable way to manage waste and produce clean energy simultaneously, but is underutilized worldwide.
- Dependence on anaerobic digestion will increase in coming decades to mitigate the climate effects of fossil fuels; this provides a green window of opportunity for countries not currently investing in anaerobic digestion.
- Policies that encourage the use of anaerobic digestion, such as feed-in tariffs, improved industry standards-setting, and educational initiatives, are needed for more successful implementation of the technology.
- Public and private entities can work in synergy on both large- and small-scale initiatives to create successful implementation of anaerobic digestion technologies.

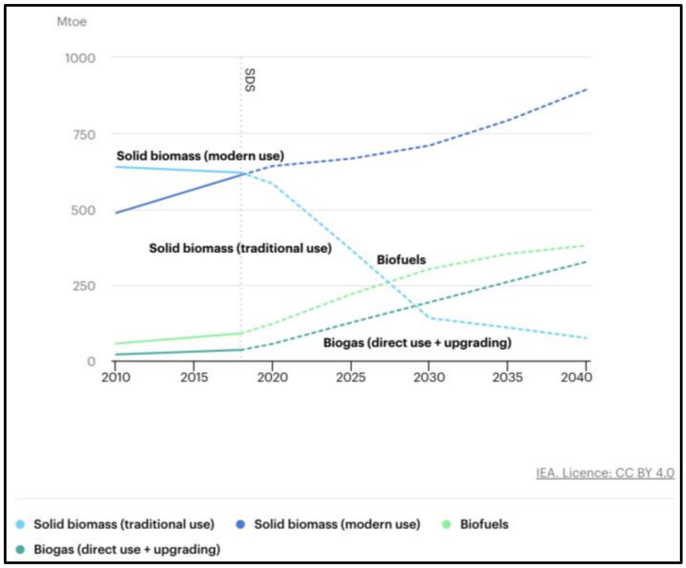
Rising population, especially in urban areas, has heightened the need for effective waste management processes. Due to rising populations and increasing levels of personal consumption, global annual waste generation is expected to increase by 73% from current levels to about 3.9 billion tonnes in 2050.[1] In rural areas of the Global South, a lack of waste management infrastructure can lead to practices like open burning and waste dumping which has significant public health consequences.[2]

Waste-to-energy (WTE) technologies are efficient ways to manage organic waste while at the same time producing clean energy and promoting efficient waste management. There are a variety of WTE technologies available, but not all are created equal. Pyrolysis and gasification, for example, heat organic waste at extremely high temperatures to turn it into biochar, bio oil, and syngas,[3] which can then be used as fuel sources. However, small inconsistencies in the pyrolysis process can lead to incomplete combustion, which releases greenhouse gases and particulate matter into the air.[4] Pyrolysis also requires energy to heat the waste to high temperatures, and recycling the syngas and bio oil products for this purpose can significantly reduce the overall energy output of the system.[5].

Anaerobic digestion (AD), on the other hand, decomposes waste using microorganisms in the absence of oxygen.[6] This method does not pose the same risk of greenhouse gas release, and is a relatively simple chemical process that requires no energy input. When properly optimized, AD can turn any type of biomass - such as human or animal excrement, food waste, or agricultural waste - into three main products: biogas, a liquid digestate, and a fibrous-solid component - with minimal odor and a small land footprint.[7] The biogas product can be burned cleanly as a cooking fuel or can be injected into natural gas pipelines for use in municipal energy production, and the liquid and fibrous-solid products can be used as high-quality fertilizers. The biogas product can also be further refined for use in combustion engines, such as those used in transportation.[8]

While the production of biogas using AD is not a new technology, it is significantly underutilized in nearly all areas of the world. The International Energy Agency (IEA) reports that current global biogas usage is around six million cubic meters of natural gas equivalent, and this usage is concentrated mainly in North America and Europe.[9] The same report notes that in order for the world to maintain a global temperature rise below 2°C, global usage of biogas as an energy source will likely need to increase to nearly 370 billion cubic meters of natural gas equivalent by 2040; this information is also shown in the graph below.[9] Broader adoption of AD outside of North America and Europe will be necessary in the next decade in order to mitigate climate change and achieve the Sustainable Development Goals.

Figure 1. Global bioenergy demand necessary for maintaining less than 2°C global temperature rise[9].



Adoption of this technology would contribute to the renewable energy share of global energy production, promote efficient waste disposal and better air quality conditions, eliminate public health concerns from storage of waste in landfills or open dumping practices, reduce threats to groundwater contamination due to water contamination, and mitigate threats to the climate due to greenhouse gas emissions and fine particulate matter formulation from the burning of wood and fossil fuels.

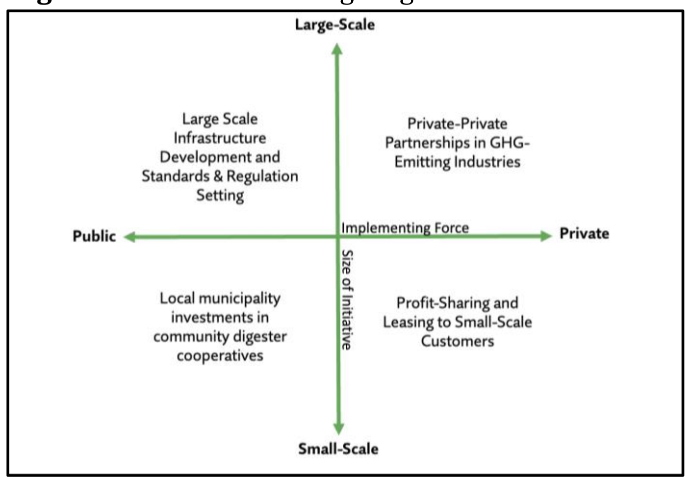
The outcomes of existing and past attempts at implementing AD in the Global South have been varied; however, AD has great potential for positive impact if implemented alongside supportive policies. The objective of this brief is to establish potential methods of implementing AD in the Global South, highlighting political, economic, and social factors to be taken into consideration.

Scenario Building Analysis

Based on expert interviews and academic and institutional research, two critical factors influencing the implementation of AD in developing countries were chosen to perform a scenario-building exercise. The institutional implementing force was identified as one critical factor due to the important role that institutions play in implementing waste management and energy infrastructure. The roles for the public sector involve the encouragement of technology adoption through policy implementation as well as creating conditions and opportunities for industry players to participate and collaborate. Private sector roles involve the provision of direct investment of resources and time in AD programs, production of AD systems, and collaboration with both public and other private entities through partnerships. The size of the implementing initiative was chosen as the second critical factor due to the different benefits and challenges of specific AD initiative sizes.

Four potential scenarios for implementing successful AD initiatives were developed using public and private institutional implementing forces and large- and small-scale initiative sizes.

Figure 2. Scenario building diagram



Scenario 1: Large-Scale Public Initiatives

In the large-scale public initiative scenario, national government entities invest in large-scale infrastructure development and regulation setting. The infrastructure development component would involve developing the physical digestion plants, pipelines, and utility connections for large portions of the population - such as in municipal wastewater treatment plants or near existing landfills. This also may include improved logistical infrastructure - such as roads or railways - for transporting the liquid and fibrous-solid products to farms or other areas in need of these fertilizers.

A large-scale public investment in AD would also require adapting the national regulatory environment for waste-to-energy technologies to be conducive to their use. For example, standards regarding the quality of biogas must be based on the final composition of the gas itself, not based on the type of feed from which the gas was produced. Creating quality standards based on the feed to the digester and not on the final quality of the gas has created a regulatory environment not conducive to biogas use in the United States.[10]

Lastly, the large-scale public initiative scenario may also include national-level policies such as tax credits, financial penalties for carbon emissions, and/or government initiatives to educate the public on the benefits of AD and encourage the private sector and the general public to adopt AD technologies.[11]

This scenario can be beneficial in the long-run as it creates the infrastructure necessary to continue the expansion of AD in the longer term and can reach a greater number of people; however, this scenario requires significant financial and personnel investments from national governments, which can be very difficult on short timelines. This type of initiative may need to be implemented in smaller pieces over a longer period of time, in which case it may be best to pair this scenario with an additional, privately implemented or smaller-scale scenario that shows benefits for citizens in the short- to medium-term.

Case Study: Senegal's National Biogas Program (PNB-SN)

A largely unsuccessful initiative by the Senegalese government aimed to install 8,000 biodigesters in rural Senegal in the late 2000s. By the end of the program, fewer than 600 digesters were installed, and of those, fewer than 200 were functional. The main challenge faced by this program was the significant upfront cost of the digesters, which consumed 70-117% of a household's annual income on average, depending on the region of the country[18]. This program aimed to be a large-scale initiative but fell short due to a lack of social programming, such as educating buyers on how to operate and maintain the digesters and educating skeptics on the benefits of biogas, as well as a lack of financial support for buyers. The latter could have been remedied through higher government subsidies or through public-private partnerships with companies willing to lease their digesters (as described in Scenario 4).

Scenario 2: Large-Scale Private Initiatives

In the large-scale private initiative scenario, larger entities adopt the technology through partnerships with private companies in the AD industry. These large entities may include public utilities, such as municipal waste management departments, or companies whose processes lead to the generation of large amounts of organic waste. These entities would partner with private AD companies to convert organic wastes to energy to supplement current energy sources. For example, a large paper mill could enter a partnership with an AD company to efficiently use the cellulosic waste byproducts from the papermaking process.[12]

This scenario relies heavily on private companies taking the initiative to identify potential partners and implementing these systems. This scenario may work best when run in parallel with a large-scale public initiative, as the public version could include creating national policies that encourage these private-private partnerships.[11]

Scenario 3: Small-Scale Public Initiatives

The small-scale public initiative scenario includes forming partnerships between local or municipal governments and communities interested in using their waste for AD. Local government entities are often well-equipped to connect constituents to resources that would assist in the implementation of AD, including finding financing opportunities for the cost of the digester(s), forming networks with AD companies and other people knowledgeable about AD processes, and assisting with community-level education initiatives about AD technology. Education, especially at the local level, is very important in the effective implementation of AD, as a major challenge often faced when implementing AD in areas where the technology was previously unknown is the "yuck factor" of using fuel produced by waste and excrement.[13] Educating constituents on the safety and cleanliness of the AD process, as well as the potential benefits of using AD, can help encourage the technology's adoption and sustained use.

Case Study: Biogas Sector Partnership Nepal (BSP-N)
In the late 2000s, biogas sanitation systems that consumed kitchen food waste and human excrement were installed in three Nepalese prisons as part of a program supported by the International Committee of the Red Cross (ICRC). Once the detainees in the prisons overcame their initial hesitation about eating food cooked by fuel derived from human waste, they realized the financial benefits of spending less of their allowance on cooking fuel. Additionally, 59% of inmates reported less smoke in prison kitchens, and 49% described improved sanitation and hygiene at the prison.[14] This program brought AD to small municipal prison communities through a partnership with an NGO; doing so not only allowed the public administration of the prisons to utilize their resources in starting up the program, but allowed the prison - a community of many people which produces significant amounts of waste - to put their waste to good use. The partnership with the ICRC also helped the program be successful as it was able to help educate detainees on the benefits of biogas, leading to increased approval of the program.

Scenario 4: Small-Scale Private Initiatives

In this scenario, private companies lease digesters to small entities with limited capital, such as individual households or small community cooperatives. The terms of the lease are such that the company will be eventually paid back the value of the digester and the lessee is only required to make monthly payments without a down payment. This significantly reduces the capital cost barrier many households in the developing world face when trying to purchase a digester. This lease system has been successfully used by the pyrolysis company Farm to Flame Energy in recent years and would translate well to similar situations in the AD industry[12]. This system provides a much lower-cost way for small-scale consumers to access AD technology, while still providing a way for companies to generate revenue.

Policy Recommendations

The following policy recommendations are based on general findings from literature, expert interviews and conclusions drawn from scenario building.

1. Regulatory policies such as **mandatory waste disposal, emission and discharge regulations, and improved land use policies** can incentivize large producers of waste to find sustainable means of disposal, ultimately leading to a stable supply of raw materials for AD technologies. By targeting these policies towards entities that generate a significant amount of waste, governments can create an environment conducive to private-private partnerships and support the growth of large-scale private initiatives (scenario 2) and small-scale private initiatives (scenario 4). In short, regulatory policies not only address environmental concerns, but also have the potential to drive innovation by increasing private-private partnerships and supporting the development of AD technologies.
2. The use of **feed-in tariffs** could encourage investment in large-scale public initiatives (scenario 1) for AD technologies. These tariffs, which guarantee a fixed price for the electricity generated from renewable energy sources, can provide a stable and predictable source of revenue for investors in AD infrastructure development and regulation. By offering long-term contracts at competitive rates, feed-in tariffs can attract a diverse range of investors and incentivize the development of AD technologies on a large scale. Additionally, feed-in tariffs can help to offset the initial costs of investing in AD infrastructure, making it more financially viable for national government entities to invest in large-scale projects. Overall, the use of feed-in tariffs can be a powerful tool for encouraging investment in AD technologies and supporting the growth of large-scale public initiatives in this area.
3. **Tax exemptions and credits** can provide a financial incentive for companies and individuals to invest in and adopt AD technologies. In some cases, traditional waste management methods may be cheaper in the short term but can have

negative long-term environmental and economic consequences, such as greenhouse gas emissions and landfills that eventually need to be remediated. Tax exemptions can help to level the playing field for waste-to-energy technologies, particularly in comparison to traditional waste management methods. By providing tax exemptions for AD technologies, policymakers can encourage the adoption of more sustainable options.

4. **Clear regulatory policies and industry standards** are necessary for ensuring that all eligible wastes can be used to produce biogas. In some countries, regulations for biogas - which determine the monetary value of the gas - are based not on the final quality of the gas itself, but on the feed waste from which it was produced. This can lead to eligible wastes going unused. By focusing on the quality of the final product, rather than the type of feed used, this policy can create a more flexible and inclusive regulatory environment for AD (scenario 1).
5. Implementing social programs, such as **educational initiatives** for teaching citizens about the benefits and safety of AD, could encourage the use of AD technologies in small-scale public initiatives (scenario 3). These programs could be focused on providing information and resources to local communities and individuals interested in using their waste for AD. Education is a crucial factor in the successful implementation of AD, as it can help to overcome the "yuck factor" that can often be associated with using fuel produced from waste and excrement. By providing information on the safety and cleanliness of the AD process, as well as the potential benefits it can bring, these programs can help to encourage use of AD products especially on a small scale like in households and small communities.

Conclusion

While AD is a relatively well-known technology that has been used for hundreds of years,[36] it is still underutilized worldwide. As successful adoption of AD would improve waste management, help mitigate climate change, and assist countries in the Global South with electrifying rural areas, it would be imprudent for the world to continue underutilizing this critically important technology in the coming decades. To improve the success rate of AD programs, governments should use policies such as feed-in tariffs, tax credits and exemptions, improved industry regulations and standards, infrastructure investment, and public education initiatives. The private sector can invest in partnerships with government entities as well as other private entities, assist with education initiatives, and offer leasing opportunities to increase digester affordability. With the public and private sectors working in parallel, anaerobic digestion could provide an incredible green window of opportunity for countries in the Global South.

References

1. World Bank Group. Solid waste management [Internet]. World Bank. World Bank Group; 2022 [cited 2022Dec13]. Available from: https://www.worldbank.org/en/topic/urbandevelopment/brief/solid-waste-management.
2. Vinti G, Vaccari M. Solid waste management in rural communities of developing countries: An overview of challenges and opportunities. Clean Technologies. 2022;4(4):1138–51.
3. Jouhara, H., Ahmad, D., van den Boogaert, I., Katsou, E., Simons, S., & Spencer, N. (2018). Pyrolysis of domestic based feedstock at temperatures up to 300 °C. Thermal Science and Engineering Progress, 5, 117–143. https://doi.org/10.1016/j.tsep.2017.11.007
4. Allsopp M, Costner P, Johnston P. INCINERATION AND HUMAN HEALTH. Exeter, United Kingdom: University of Exeter; 2010. Available from: https://www.ipcn.nsw.gov.au/resources/pac/media/files/pac/project-submissions/2018/04/eastern-creek-energy-from-waste-facility-ssd-6236/20180518t193048/incineration-and-human-health-greenpeace.pdf
5. United States Department of Agriculture. What is pyrolysis? [Internet]. USDA Agricultural Research Service. United States Department of Agriculture; 2021 [cited 2022Dec13]. Available from: https://www.ars.usda.gov/northeast-area/wyndmoor-pa/eastern-regional-research-center/docs/biomass-pyrolysis-research-1/what-is-pyrolysis/
6. Harirchi, S., Wainaina, S., Sar, T., Nojoumi, S. A., Parchami, M., Parchami, M., Varjani, S., Khanal, S. K., Wong, J., Awasthi, M. K., & Taherzadeh, M. J. (2022). Microbiological insights into anaerobic digestion for biogas, hydrogen or volatile fatty acids (VFAs): a review. Bioengineered, 13(3), 6521–6557. https://doi.org/10.1080/21655979.2022.2035986
7. United States Environmental Protection Agency. Environmental Benefits of Anaerobic Digestion (AD) [Internet]. EPA. Environmental Protection Agency; 2022 [cited 2022Dec13]. Available from: https://www.epa.gov/anaerobic-digestion/environmental-benefits-anaerobic-digestion-ad
8. Wilkie AC. Biogas uses [Internet]. Biogas: A renewable biofuel. University of Florida; 2019 [cited 2022Dec13]. Available from: https://biogas.ifas.ufl.edu/uses.asp
9. IEA. Outlook for biogas and biomethane: Prospects for organic growth, IEA, Paris. 2020. Available from https://www.iea.org/reports/outlook-for-biogas-and-biomethane-prospects-for-organic-growth/the-outlook-for-biogas-and-biomethane-to-2040
10. Kinney K. 2022
11. Weinberger M. 2022
12. Jyamfi K. 2022.
13. Kalina M, Ogwang JÒ, Tilley E. From potential to practice: rethinking Africa's biogas revolution. Humanit Soc Sci Commun [Internet]. 2022;9(1). Available from: http://dx.doi.org/10.1057/s41599-022-01396-x
14. Lohri C, Zurbrügg C, Giusti A, Mardini R, Vögeli Y. Decentralized Wastewater Treatment Solutions in Developing Countries Conference and Exhibition. Surabaya; Available from: http://www.susana.org/_resources/documents/default/2-1023-zurbrugg-iwa2805-dewats-surabaya-final.pdf
15. Gergel I. Waste to energy technologies overview [Internet]. Waste To Energy International. Waste To Energy International; 2021 [cited 2022Dec13]. Available from: https://wteinternational.com/news/waste-to-energy-technologies-overview/
16. De Dobbelaere A, De Keulenaere B, De Mey J, Lebuf V, Meers E, Ryckaert B, et al. Small-scale anaerobic digestion : case studies in Western Europe. Rumbeke, Belgium: Inagro; 2015.
17. Brady P, Borek, Theodore Thaddeus, III, Brown A, Mowry C. An economic analysis of mobile pyrolysis for northern New Mexico forests. Office of Scientific and Technical Information (OSTI); 2011
18. Diouf B, Miezan E. The biogas initiative in developing countries, from technical potential to failure: The case study of Senegal. Renew Sustain Energy Rev [Internet]. 2019;101:248–54. Available from: http://dx.doi.org/10.1016/j.rser.2018.11.011
19. Baky MAH, Hassan Khan MN, Kader MF, Chowdhury HA. Production of biogas by anaerobic digestion of food waste and process simulation. In: Volume 2: Economic, Environmental, and Policy Aspects of Alternate Energy; Fuels and Infrastructure, Biofuels and Energy Storage; High Performance Buildings; Solar Buildings, Including Solar Climate Control/Heating/Cooling;

Sustainable Cities and Communities, Including Transportation; Thermofluid Analysis of Energy Systems, Including Exergy and Thermoeconomics. American Society of Mechanical Engineers; 2014.
20. Haraguchi M, Siddiqi A, Narayanamurti V. Stochastic cost-benefit analysis of urban waste-to-energy systems. J Clean Prod [Internet]. 2019;224:751–65. Available from: http://dx.doi.org/10.1016/j.jclepro.2019.03.099
21. H. Lanier Hickman Jr Richard W. Eldredge. A Brief History of Solid Waste Management During the Last 50 Years [Internet]. MSW Management. 2016. Available from: https://www.mswmanagement.com/landfills/article/13023338/a-brief-history-of-solid-waste-management-in-the-us-during-the-last-50-years-part-1
22. International Renewable Energy Agency. Rise of renewables in cities: Energy solutions for the urban future. 2020. Available from https://www.irena.org/publications/2020/Oct/Rise-of-renewables-in-cities
23. Don D. Jones John C. Nye Alvin C. Dale. Methane Generation From Livestock Waste [Internet]. Energy Management in Agriculture; 1980. Available from: https://www.extension.purdue.edu/extmedia/ae/ae-105.html
24. Khalid H, Zhang H, Liu C, Li W, Abuzar MK, Amin FR, et al. PEST (political, environmental, social & technical) analysis of the development of the waste-to-energy anaerobic digestion industry in China as a representative for developing countries. Sustain Energy Fuels [Internet]. 2020;4(3):1048–62. Available from: http://dx.doi.org/10.1039/c9se00692c
25. Lemonde M. What is the Future of Small-Scale Anaerobic Digestion Plants? [Internet]. Biogas World. 2020. Available from: https://www.biogasworld.com/news/future-small-scale-anaerobic-digestion/
26. Mavridis S, Voudrias EA. Using biogas from municipal solid waste for energy production: Comparison between anaerobic digestion and sanitary landfilling. Energy Convers Manag [Internet]. 2021;247(114613):114613. Available from: http://dx.doi.org/10.1016/j.enconman.2021.114613
27. Rogoff MJ, Screve F. Introduction and Overview. In: Waste-To-energy. Elsevier; 2019. p. 1–12. Available from https://doi.org/10.1016/b978-0-12-816079-4.00001-3
28. Situmeang R, Mazancová J, Roubík H. Technological, economic, social and environmental barriers to adoption of small-scale biogas plants: Case of Indonesia. Energies [Internet]. 2022;15(14):5105. Available from: http://dx.doi.org/10.3390/en15145105
29. The Global Methane Initiative Agricultural Subcommittee. A Global Perspective of Anaerobic Digestion Policies. 2014. Available from https://www.globalmethane.org/documents/tools/a-global-perspective-of-ad-policies-incentives.pdf
30. United States Environmental Protection Agency. AgSTAR Data and Trends [Internet]. United States Environmental Protection Agency. 2014. Available from: https://www.epa.gov/agstar/agstar-data-and-trends
31. Serfass P. 2022
32. Lew D. 2022.
33. Pierre Doussoulin J, Salazar Molina C. A case study for economic viability of biogas production from municipal solid waste in the south of Chile. Biogas - Basics, Integrated Approaches, and Case Studies. 2022
34. Kirch K, Augenstein D, Batmale JP, Benemann J, Rutledge B, Salour D. Biomethane from Dairy Waste: A Sourcebook for the Production and Use of Renewable Natural Gas in California [Internet]. Suscon. Turlock, CA: Western United Dairymen; 2005 [cited 2022Dec13]. Available from: https://suscon.org/pdfs/cowpower/biomethaneSourcebook/Full_Report.pdf
35. HomeBiogas. Advantages and disadvantages of Biogas [Internet]. HomeBiogas. 2021 [cited 2022Dec13]. Available from: https://www.homebiogas.com/blog/advantages-and-disadvantages-of-biogas/
36. A short history of anaerobic digestion [Internet]. Penn State Extension. 2012 [cited 2022Dec19]. Available from: https://extension.psu.edu/a-short-history-of-anaerobic-digestion
37. Meegoda J, Li B, Patel K, Wang L. A review of the processes, parameters, and optimization of anaerobic digestion. International Journal of Environmental Research and Public Health. 2018;15(10):2224.

Annex

Challenges: There are a variety of challenges associated with the implementation of anaerobic digestion plants in the developing world. Many of these challenges are summarized in the introduction of this brief, but additional challenges - and their potential mitigation methods - are noted in the table below. The greater overall challenge is the lack of investigation into these challenges.[13] Additional challenges, sourced from articles discussing the Indonesian[28] and Chilean context[33] as well as general concerns noted by the authors of this brief, are included. Many of the challenges here are broadly relevant to the global context and are thus included in the table.

Table 1: additional challenges to the implementation of AD plants and potential mitigation methods

Potential Challenge	**Mitigation Method**
Additional data investigating potential successful initiatives, especially ones that consider local input and agency of the technology, are needed	Conduct feasibility study and literature analysis in the area where digesters would be implemented
Small-scale waste-to-energy facilities tend to be less profitable than large-scale (urban)[17]	Without capital investment for a large-scale facility, small-scale facilities will need to start the program and be scaled up. Proper management of funds can allow for future growth.
The market price of biogas depends on demand; low demand could make the process unprofitable	Government policies that increase demand, such as a policy that requires a certain percentage of municipality energy to come from biogas or subsidizing homes that switch from nonrenewable fuel to biogas
Biogas is a lower-value fuel due to potentially corrosive impurities (such as H_2S)[34]	Market biogas as cooking fuel only, and invest in further refinement processes to remove impurities for transportation fuel usage
Production of biogas – and its quality - is temperature-dependent[35]	Begin implementing process in areas with stable climates, then invest in work on optimization for less stable areas
Social acceptance and broader buy-in may be difficult to garner, especially considering the “yuck factor” of using excrement and waste to make fuel[13]	Government policies that encourage biogas use through health education initiatives, subsidies, or other socially relevant methods
Lack of trained engineers and operators[18]	Public-private partnerships that match trained personnel to areas in need of assistance
Significant optimization process required[37]	Recruit international experts and engineers to assist with process optimization pro-bono
Post-digester refining may be necessary depending on digester output[26]	Post-optimization, produce cost-benefit analysis to determine if refined product can be sold for transportation use at a higher value.
Land logistics – the storage of the digester and product might be expensive, but must be safe	Clear land use and ownership policies
Projects may be abandoned if communities move or run out of feedstock	Use the mobile digester model, which allows for the digester to continue being used in another area if use lapses in one area
Users of small-scale/community-level digesters often cannot benefit from carbon credit schemes[10]	Public-private partnership carbon credit purchasing program
Agriculture is exclusively seasonal in many areas[18]	Implement digesters capable of digesting animal waste, human waste, and other food wastes
Major barrier of initial cost of technology[18]	Public-private partnerships can provide low-interest loans for the up-front costs of the units
Challenges from fossil fuel companies[31]	Public sector support for clean energy and clean energy requirement policies

Glossary

Term	Definition
AD	Anaerobic Digestion: The process of decomposing organic waste using microorganisms in the absence of oxygen
Biogas	A gaseous renewable energy source, composed mostly of methane and carbon dioxide, produced by microbes during anaerobic digestion processes
Feed-in tariffs	Policy involving long term commitments used to encourage renewable energy technologies
IEA	International Energy Agency
Pyrolysis	Process of the thermal decomposition of materials at elevated temperatures
WTE	Waste-to-Energy: technologies that convert waste products into energy
Sustainable Development Goals (SDGs)	The SDGs are a collection of 17 interlinked global goals designed to be a "shared blueprint for peace and prosperity for people and the planet, now and into the future"