Industry Perspective

Consumer Goods – Animal Protein and Agribusiness | October 2022

Towards net zero: Harnessing waste to cut costs and emissions

UOB

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Content

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03 Executive Summary

04 Acknowledgements

05 Livestock sector
- Waste management: Born out of necessity
- New intensive farms are increasingly the norm
- Limited bio-fertiliser use now is a long-term opportunity

09 Palm oil sector
- Tackling emissions in the supply chain
- Significant opportunity to digest palm oil mill waste

11 Biogas: A carbon transition
- Three key drivers
- Livestock has sizable methane emission
- How much livestock methane can be captured?
- Harnessing palm oil mill's waste: upside and downside

15 Case studies
- The biodigester knowhow continues to evolve
- Examples of projects in Southeast Asia
- Why some anaerobic digester projects fail

22 Policies on renewable energy

27 Developing waste-to-energy
- Making sense of biogas projects with carbon credits
- Financing appetite in waste-to-energy projects

Executive summary

October 2022

Despite increasing pressure to tackle waste pollution and global warming, farm sustainability agenda is commonly viewed as a burden. In this report we explore cost-cutting opportunities to reduce greenhouse gas (GHG) emissions by monetising farm waste. While feedstock for methane capture can come from a variety of organic sources (such as industrial or commercial food waste or municipal solid waste); we believe two sectors in particular, livestock and palm oil, have the immediate potential and scale in Indonesia, Malaysia, Thailand and Vietnam.

To date, limited number of intensive livestock farms in this region have turned their wastes into energy. In countries where energy cost is subsidised, this subject presents itself as a challenge. Yet, where cost of conventional energy sources is higher, biogas provides intensive livestock farms – particularly swine and dairy – an opportunity to cut cost.

Similarly, palm oil mill effluent (POME) – a key source of methane emissions in the palm oil production – offers a commercial opportunity to generate electricity to reduce cost and/or be sold. To date, only a fraction (7-12 per cent) of palm oil mills in both Indonesia and Malaysia have biogas recovery projects or biogas power generators.

While burning biogas to generate electricity still contributes to carbon dioxide (CO_2) emissions, it remains a net-reduction; as methane is a significantly more potent GHG than CO_2. Electricity generated from burning biogas will likewise replace fossil fuel-generated electricity (thereby resulting in avoidance of CO_2 emissions from not burning the fossil fuels).

We believe the circular economy model is a viable solution, rather than a cost centre. Together with advances in technology, biogas projects can help address sustainability targets, given an increasing focus on food self-sufficiency and higher energy and fertiliser costs. Financing of the development and operation of such biogas projects may qualify for Green Loans under UOB’s Smart City Sustainable Financing Framework and Green Circular Economy Framework. The deployment of such biodigester technology will also help to reduce a corporate’s GHG emission, allowing them to explore sustainability linked loans as part of their overall debt capital mix.

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Livestock sector

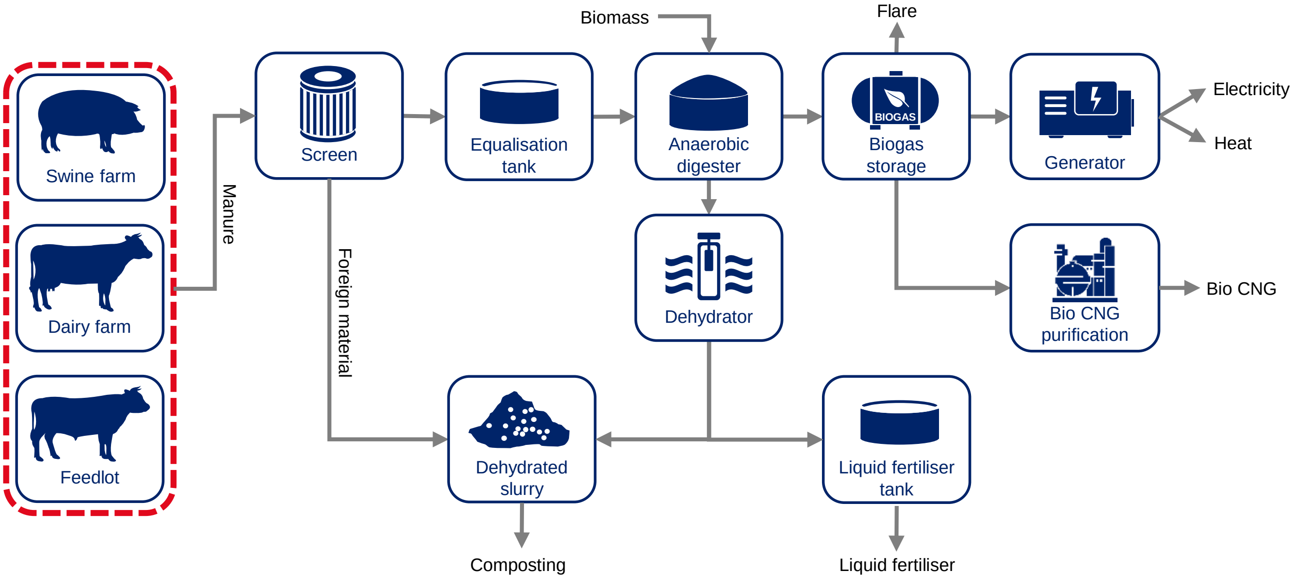
Born out of necessity

A major source of waste pollution in intensive livestock production is manure. In Southeast Asia, livestock manure is often employed as fertiliser on land to grow crop on small-scale farms. But this practice creates microbial contamination to the soil caused by untreated manure. Intensive livestock farm is increasingly the norm given space limitation in Asia, thus face the growing challenge of manure disposal. In tackling this issue, open-pit lagoons – where manure is collected and left to dry – are employed. This practice is harmful to the environment, as potent GHG – mainly methane – is released into the atmosphere. Methane is over 80 times more potent (over a 20-year horizon) as a heat-trapping gas compared to CO_2 – according to Sixth Assessment Report issued by Intergovernmental Panel on Climate Change (IPCC).

While open-pit lagoons are the easiest way to dispose the manure; pressure on its environmental impact is also increasing. In addressing this issue, lagoons in intensive farms today are covered to capture the biogas, which is commonly flared, rather than captured to generate heat or electricity. Biogas is mixture of methane (45 to 75 per cent content by volume), CO_2 (25 to 45 per cent) and other gases that can be used to generate power. Biogas can also be upgraded into biomethane, in a process that removes CO_2 and other impurities.

Anaerobic Digesters (AD) interest and adoption over time has been shaped by energy supply disruptions, as well as environmental protection and feed-in-tariffs policies. Technological improvements have since enhanced its efficiency in livestock farms and is employed today primarily to generate electricity (see Figure 1).

Figure 1: Upcycling of methane captured from livestock manure management

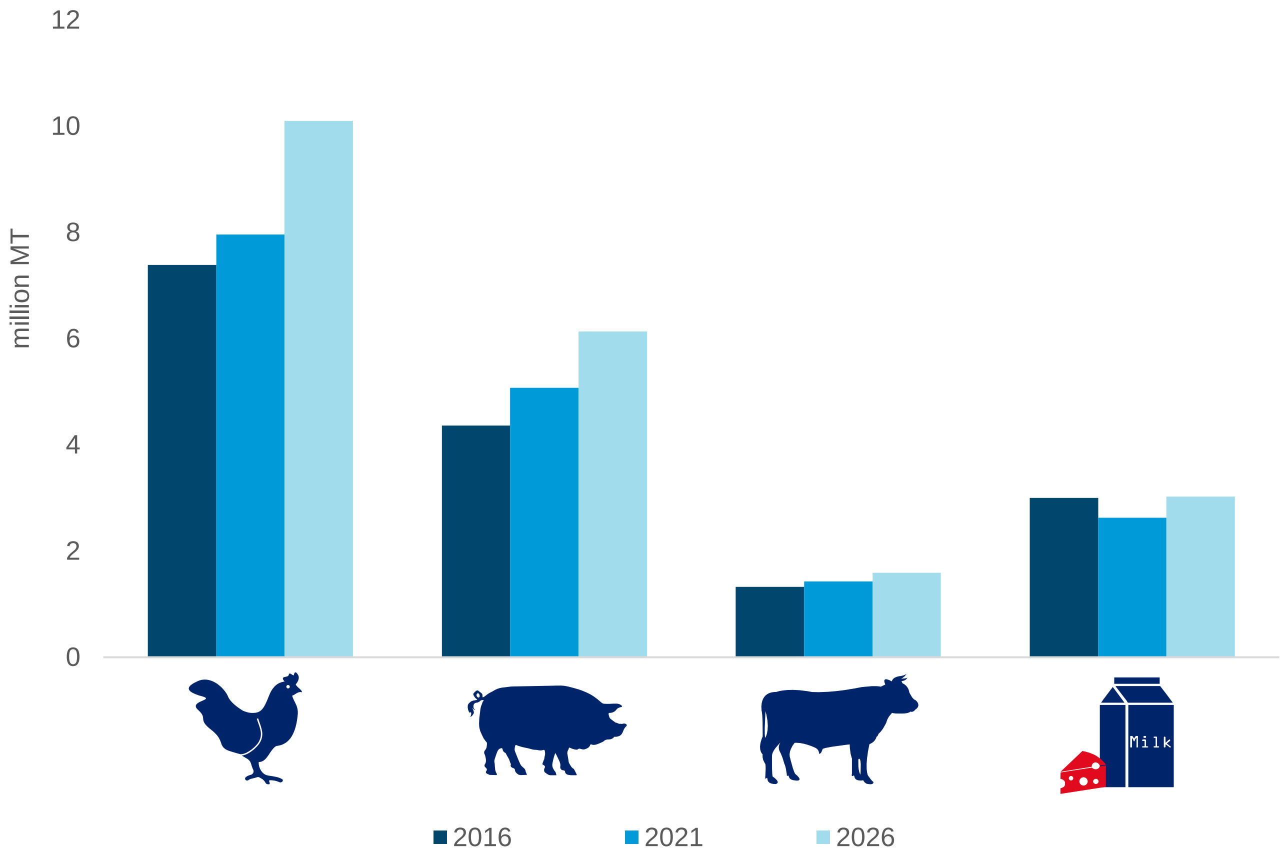


Source: Anaerobic digestion of swine manure: Sung-Hwan farm-scale biogas plant in Korea

New intensive farms are increasingly the norm

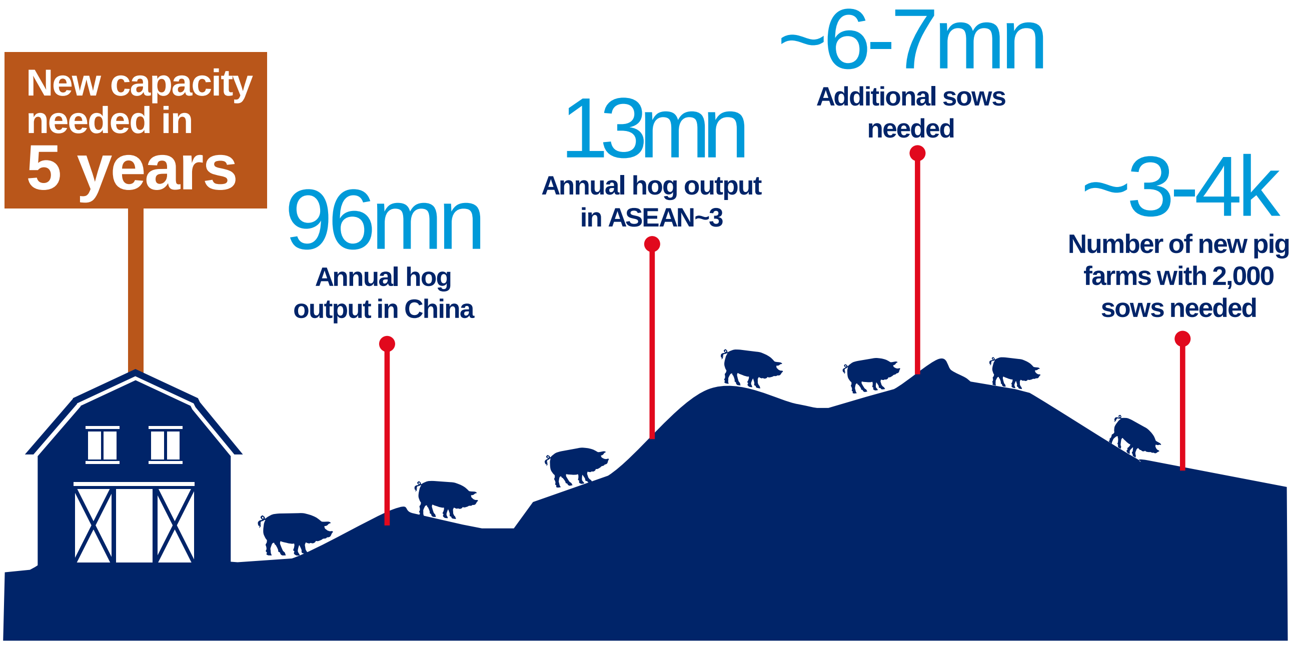
In meeting demand from Asia's growing income and population, animal protein production will continue to grow with less available land and resources. Driven by biosecurity and cost considerations, new livestock farm capacities in Asia will increasingly need to be industrialised. This compounds the challenge of manure disposal. The intensive model requires meaningful waste management, which is a critical initial farm design consideration to comply with existing regulatory guidelines in pollution control. Government regulations to manage livestock farm waste are also expected to tighten in areas closer to population centres; and this will have repercussions for future farm expansions.

Figure 2: Demand for chicken, pork, beef, and dairy in ASEAN-4*



Source: OECD FAO, USDA, UOB estimates
*ASEAN-4 = Indonesia, Malaysia, Thailand, Vietnam

Figure 3: Swine farms needed in China and ASEAN-3* by 2026F



Source: UOB estimates
*ASEAN-3 = Malaysia, Thailand, Vietnam

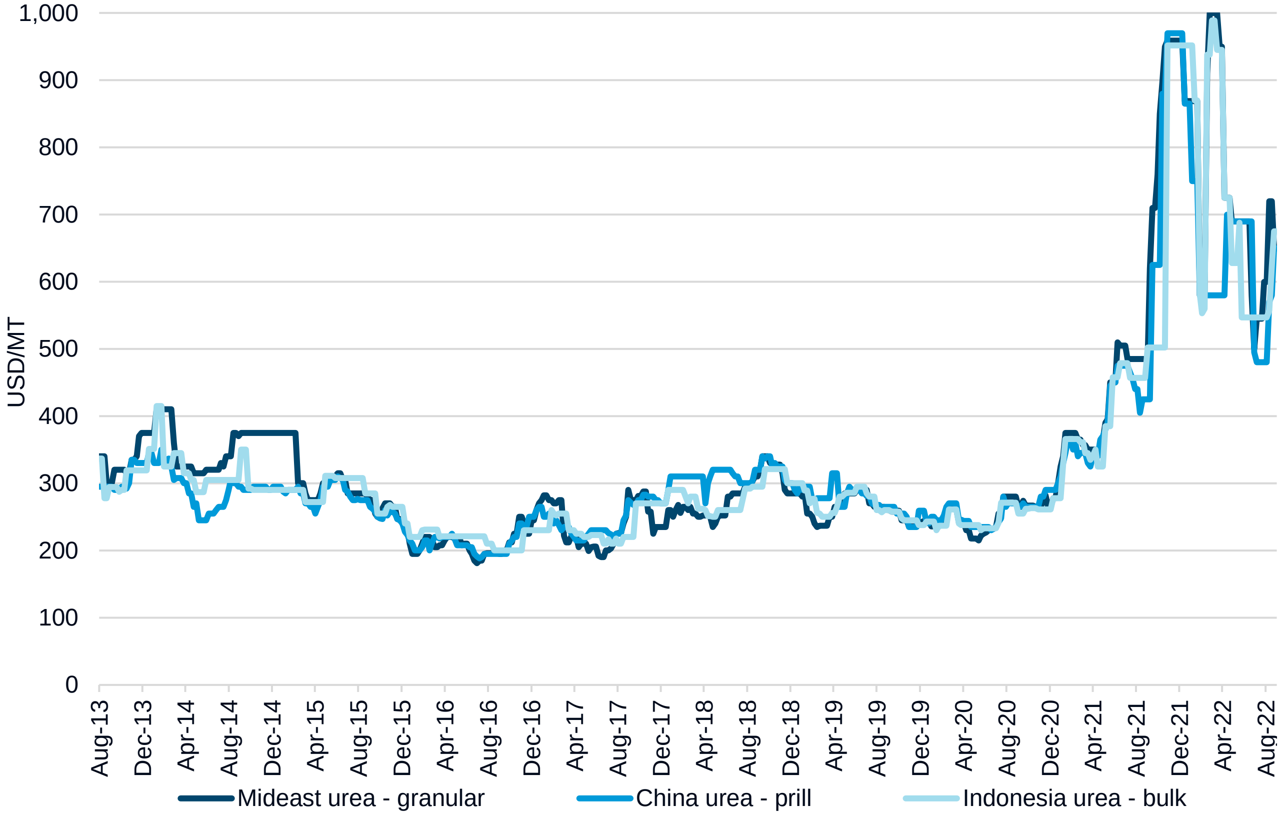
Excluding capacity upgrades of existing farms, between 2021 and 2026F we estimate 3,000-4,000 new 2,000-sow farms and 1,500-1,700 new 60,000 bird broiler farms would need to be added to meet demand within Southeast Asia (Indonesia, Malaysia, Thailand and Vietnam) alone. The amount of manure waste generated from these farms would require careful consideration to avoid degradation to surrounding soil and rivers.

Limited bio-fertiliser use now is a long-term opportunity

Use of inorganic fertiliser (Phosphate, Nitrogen, and Potash) currently remains the default for large croplands to achieve predictable results. Yet, usage is increasingly restrained due to significant increase in cost in the past year, driven by global supply constraints and more expensive feedstock.

For example, in early 2021, a deep freeze in US state of Texas impacted urea production capacity, causing global nitrogen supply disruptions. This was followed by sanctions on Belarus potash exports since August 2021, which created global supply limitations, given its 24 per cent share in the global export market in 2020 (based on TradeMap data). China's Phosphate

Figure 4: Inorganic urea prices



Source: Bloomberg

export restrictions since October 2021 (to conserve energy and to maintain domestic supply and prices) also contributed to higher international fertiliser prices, which has also had ripple effects on other products such as glyphosate. Finally, the Russia-Ukraine conflict further restricted urea feedstock due to sanctions, given Russia's 51 per cent share on global ammonium nitrate (feedstock for urea) exports in 2021.

In livestock AD, both liquid and solid bio-slurry (or bio-sludge) discharged after biogas capture can be employed as low carbon-footprint fertiliser. However, collection, further processing (e.g. pelletising) and logistics of bio-slurry as fertiliser raw material will incur additional costs. Hence, these costs need to be imputed in any offtake agreements.

Over the long term, further processing to enhance the Phosphate, Nitrogen, and Potash content of bio-slurry could offer an opportunity to further upgrade bio-fertiliser into a desirable substitute to inorganic fertiliser.

Palm oil sector

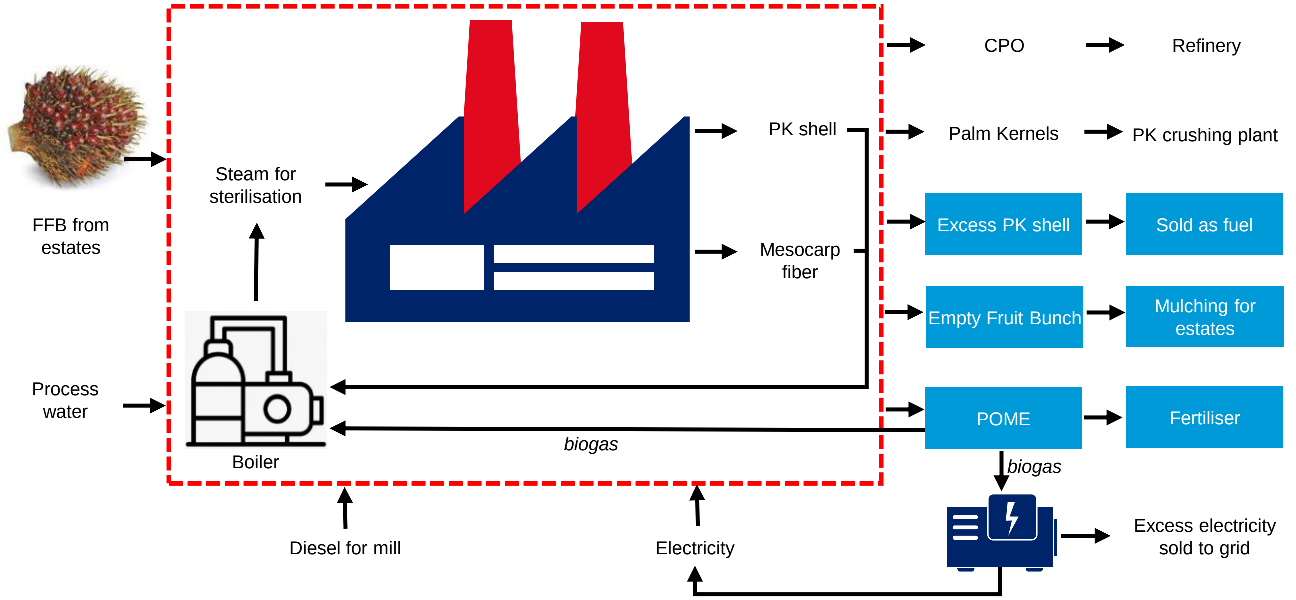
Tackling emissions in the supply chain

Oil palm plantations – primarily in Indonesia and Malaysia (given their combined c.85 per cent share of world palm oil production) – have received and continue to see pressure to be more sustainable in their operations. In addition to adhering to principles of No Deforestation, No Peat, No Exploitation (NDPE); plantations have an opportunity to capture methane – released from the effluent generated during the milling process – to curtail GHG emissions within their supply chain. Captured methane can be employed to generate electricity for own use and – where there is surplus power and infrastructure connectivity – be sold to the national grid.

Palm Oil Mill Effluent (POME) is a wastewater generated from palm oil milling activities, which requires treatment before discharging. For each metric ton (MT) of crude palm oil (CPO) production, approximately 2.5-3.0 MT of POME is generated. POME emits greenhouse gases into the atmosphere and, if discharged directly, pollutes the watercourses due to high acidity and chemical oxygen demand (COD) content, which deplete dissolved oxygen which aquatic life depends on.

According to a technical paper by Hosseini and Wahid entitled *"Pollutant in Palm Oil Production Process"*, the average green house gas (GHG) emissions produced from processing 1 MT of CPO is approximately 1,100 kg CO_2 equivalent. In our estimation, a palm oil mill with 60 MT/hour capacity operating 20 hours per day for 300 days per annum would be equal to 1.1 – 1.8 MW of electricity generation capacity.

Figure 5: Upcycling of methane captured from palm oil mill effluent (POME)



Source: "Pollutant in Palm Oil Production Process" by Hosseini and Wahid

Figure 6. POME electricity generation potential

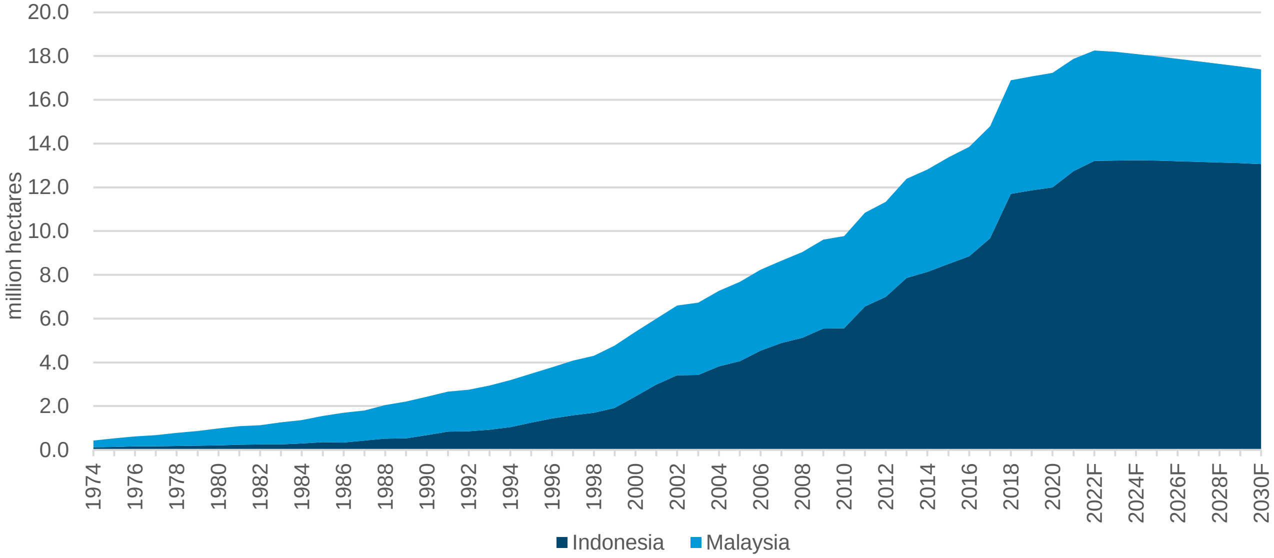
	Unit	Value	
		Min	Max
Mill capacity (MT per hour)	MT per hour	60	60
Operating hours	hours p.a.	6,000	6,000
FFB supply	MT	288,000	288,000
POME production	m^3/MT FFB	0.55	0.65
CH4 production potential	m^3 CH_4/MT FFB	7.29	11.69
Methane fraction in biogas	%	60%	60%
Methane conversion to electricity	kWh/m^3 CH_4	10.0	10.0
Gas engine efficiency	%	38%	38%
Potential gross electricity generated	kWh/year	7,978,176	12,793,536
Average generated capacity	MW	1.1	1.8
Chemical Oxygen Demand (COD) of fresh POME	mg/l	43,375	60,400
COD of treated POME	mg/l	5,500	9,000

Sources: "Pollutant in Palm Oil Production Process" by Hosseini and Wahid, USAID, Winrock International

Significant opportunity to digest palm oil mill waste

By 2026, we expect mature oil palm estates in Indonesia and Malaysia to reach 4.7 million hectares and 13.2 million hectares, respectively. As a rule-of-thumb, a 60 MT FFB/hour mill would be required to process FFB harvested daily from surrounding 10,000 ha of mature estate. Hence by 2026, Malaysia and Indonesia would need to operate 468 and 1,320 palm oil mills, respectively. Assuming all these mills were connected to the grid (mills in remote locations may require costly connection to existing grid), between 2.8 and 4.5 million MT p.a. of methane could potentially be captured. In our rough estimation, POME biogas (assuming all is captured) from all palm oil mills in both countries could therefore generate between 2.0 GW and 3.2 GW of potential combined power capacity.

Figure 7. Mature oil palm estates in Indonesia and Malaysia



Source: MPOB, Oil World, Indonesian Ministry of Agriculture, UOB estimates

Biogas: A carbon transition

"This undertaking may also qualify for carbon credits through Voluntary Carbon Markets (VCM), which can be sold to cover some of the cost in development and production of the biogas"

Three key drivers

The agriculture conversion into a more sustainable future remains a significant investment opportunity to upcycle a waste stream of an organic production process. Bio-digesters offer a growth opportunity in Asia; and this is being driven by three key factors:

1. **Demand** for renewable energy is expected to progressively increase not only as part of sustainability target, but also in consequence to rising cost. This reflects capacity constraints in conventional energy to meet rising demand over the long term

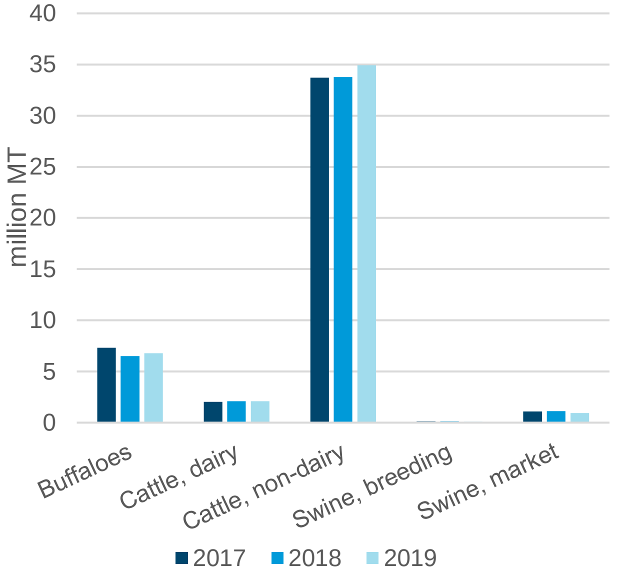
2. Biodigester **technology** coming to the market has progressively improved and are now less costly. European equipment has been at the forefront of this drive; although local/regional manufacture may provide cost-competitive alternatives

3. More stringent **regulatory** environment with regards to emissions and/or pollution is expected. While voluntary, energy-source targets declared by Southeast Asian governments will have implications on producers' cost and effort to manage and/or upcycle waste. In addition, the Paris agreement in December 2015 had paved the way for more robust guidelines in Voluntary Carbon Market.

Livestock has sizeable methane emission

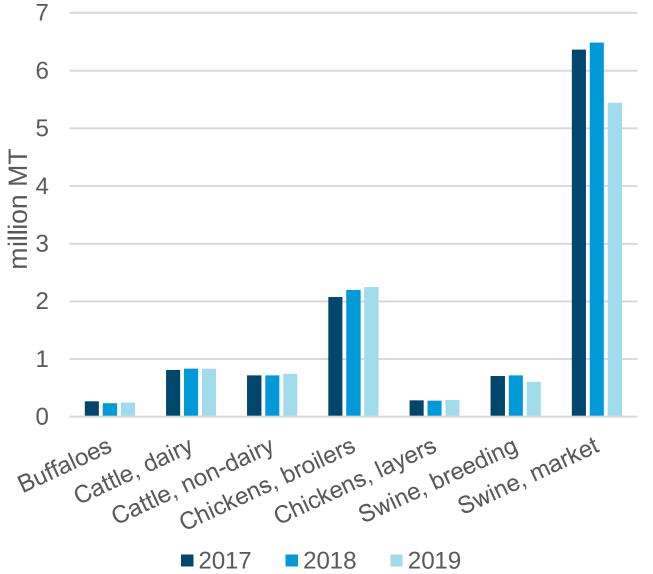
Tackling methane capture emission today has a greater urgency to limit rises in global temperature. In total, methane emissions from livestock farms in ASEAN-4 (Indonesia, Malaysia, Thailand, Vietnam) amounted to 55.3 million MT of CO_2 equivalent in 2019 – according to estimates made by the Food and Agriculture Organisation (FAO). Enteric fermentation (primarily from buffalo and cattle) contributed the lion's share (81 per cent) of methane emission in ASEAN, although there is limited opportunity in tackling this issue – apart from introducing methane-reducing feed ingredients – while other novel technologies are also being developed. Livestock emissions from manure management, on the other hand, can be better contained. In ASEAN-4, the majority of livestock emission from manure management comes from swine farms, followed by broiler and dairy and cattle farms (see Figure 9).

Figure 8: ASEAN-4* methane emissions from enteric fermentation in CO_2 equivalent



Source: FAO
**ASEAN-4: Indonesia, Malaysia, Thailand, Vietnam*

Figure 9: ASEAN-4* methane emissions from manure management in CO_2 equivalent



Source: FAO
**ASEAN-4: Indonesia, Malaysia, Thailand, Vietnam*

According to FAO, in 2019 key livestock sectors in ASEAN-4 emitted a total of 10.4 million metric tons of CO_2 equivalent of direct methane from manure management. Much of it comes from swine farms, despite significant losses from African Swine Fever (ASF) outbreaks in Vietnam. Broiler farms is the second largest contributor, followed by dairy farms. These emissions are dominated by smallholder farmers with limited capability to manage biogas emission from manure management.

There are also ongoing schemes provided by Non-Governmental Organisations (NGO) to mitigate methane emissions in smallholder farms. Given lack of coherent policies on agri-waste disposal within ASEAN-4, some form of partnerships with corporate off-takers through Corporate Social Responsibility (CSR) program and/or subsidy (to cover construction warranty issues and interest costs) would remain critical to support wide-scale GHG reduction in small livestock farms through mini or micro digesters (see interview box on page 16).

Large-scale intensive livestock farms on the other hand, have the potential to generate net positive cash flow given their scale and access to technology. We see this as an opportunity for wider and large-scale adoption of biogas production and conversion into power generation.

"By 2030, we expect large |farms (herds >1,000 heads) to account for over 70 per cent Vietnam's total swine farms from roughly half currently"

This undertaking could also qualify for carbon credits through Voluntary Carbon Market (VCM) in some countries. Carbon credits can be sold to cover some of the cost in development and production of the biogas. However, carbon pricing in VCM can be volatile.

How much livestock methane can be captured?

The need for strict biosecurity and cost containment in livestock farms is increasing, as attested by outbreaks of ASF and Avian Influenza. Over time, we anticipate more capacity in Southeast Asia to increasingly come from large intensive farms to meet rising demand for animal protein and dairy requirements, and to address food security. The manure coming out of these large-sized operations can generate energy that can be converted – through AD – into electricity and/or renewable natural gas sold into the market, subject to scale.

Vietnam's hog production is one example. By 2030, we expect hog volume from large farms (herds>1,000 heads) to account for over 70 per cent of Vietnam's total volume from roughly half currently. Based on manure output of 675 kg/market hog and biogas yield of 16 cubic meter/metric ton volatile solids with 60 per cent methane content, we estimate that these large fattening farms alone would emit over 55 thousand metric tons of direct methane by then – close to 13 per cent per cent of all methane emissions from ASEAN-4 manure management today. Hence a proactive industry would represent a significant mitigant for GHG emissions in the livestock sector.

Harnessing palm oil mill's waste: upside and downside

A palm oil mill's current practice to improve sustainability is typically to employ captured biogas as feedstock for the mill's boiler, where approximately 2.62 kWh of electricity can be generated from each cubic meter of POME. According to 2019 data presented by Sarwani et al. ("*Bio-Methane from Palm Oil Mill Effluent: Transportation Fuel Potential in Malaysia*"), there were 53 biogas recovery projects that registered with Clean Development Mechanism (CDM), out of 452 operating palm oil mills at the time.

Likewise, according to the Indonesian Ministry of energy and Mineral Resources, the country has 55 POME-based operating biogas power generators (as of September 2021) – out of 850 palm oil mills – with total capacity of 114 MW. This low share may have been attributable to:

1. Lack of information and/or interest
2. Low or subsidised cost of electricity
3. Lack of existing infrastructure to connect to the grid; when location is remote. In such a case, a methane capture project would be seen as a cost centre
4. Lack of regulatory incentive to undertake methane capture projects
5. Not scalable enough to consider as a competitive power producer, given the spread of palm oil mills over large area

Figure 10. Sample GHG emissions values in Indonesia

Plantation				Mill			
Emissions Source	**Unit**		**%**	**Emissions Source**	**Unit**		**%**
Chemical fertiliser	MT CO_2 eq p.a.	4,571	88%	Electricity	MT CO_2 eq p.a.	933	3%
Fossil fuel	MT CO_2 eq p.a.	537	10%	Inputs	MT CO_2 eq p.a.	48	0%
Electricity	MT CO_2 eq p.a.	98	2%	Wastewater	MT CO_2 eq p.a.	28,408	90%
Total	MT CO_2 eq p.a.	5,206		Transportation	MT CO_2 eq p.a.	2,158	7%
FFB production	MT p.a.	57,980		Total	MT CO_2 eq p.a.	31,547	
Total GHG emissions	kg CO_2 eq/MT FFB	90		CPO production	MT p.a.	55,702	
				Total GHG emissions	kg CO_2 eq/MT CPO	566	

Source: POME-to-Biogas Project Development in Indonesia, USAid and Winrock International

The low number of biogas plants nevertheless offer a significant opportunity for palm oil mill operators to reduce their emissions – when there is an economic return. A recent change in government policy towards renewable energy in Indonesia, for example, may allow for POME biogas plants to develop through a new incentive structure (see interview box on page 21).

Similar to livestock AD, bio-slurry solids discharged after biogas capture from POME can be used as fertiliser. The remaining liquid can be further enhanced by reducing its moisture content to produce concentrated liquid fertiliser. Bio-slurry solids combined with liquid fertiliser can also be mixed with empty fruit bunches (EFB), palm kernel expeller (PKE), boiler ash or palm fruit fibre as mulch in surrounding oil palm plantations.

Case studies of commercial biogas projects in Southeast Asia

"Without this scheme, manure from the small dairy farmers would have been discharged into nearby rivers"

The biodigester knowhow continues to evolve

The common format for anaerobic digester (AD) is a direct waste-to-electricity. Under this model, the farm would put the manure into an AD, run methane gas produced into a generator on site, and generate electricity for own use and to be sold (i.e. excess capacity) onto the grid. This model is feasible if the local electricity price is higher than the cost of electricity produced from the AD. Another approach is to purify, compress the biogas. This can be sold as cooking gas (Bio-CNG or Compressed Natural Gas, a substitute for Liquid Petroleum Gas or LPG) to surrounding businesses and households. However, additional cost for the purification process may make this product uncompetitively priced with commonly used LPG. Gas yield can be an issue in making this type of project financially feasible. One potential solution is to efficiently accumulate the feedstock, or to have multiple digesters in multiple farms and to transfer the biogas via pipeline to a centralised gas upgrade system.

Examples of projects in Southeast Asia

Methane capture allows intensive swine farms to manage manure and convert the methane to generate the farms' electricity requirement. While complex biodigester system may not be applicable for smaller scale contract farms of independent farms throughout Southeast Asia; it is generally an optional part of new large-scale farm design. For example, CP Foods is reported to have equipped all its swine farms in Thailand with biogas digesters to reduce power cost (in combination with solar panels).

Methane capture has also been introduced to thousands of small-scale dairy farmers in West Java, Indonesia. This project was undertaken with the help of NGOs such as Yayasan Rumah Energi (see interview below), who also arrange microfinancing scheme to build biodigester tanks through dairy cooperatives. Methane collected is utilised for cooking and for boiling water to improve hygiene in milking process (hence helping to reduce bacterial count, thereby improving raw milk selling price). Moreover, both liquid and solid bio-slurry (or biogas sludge) discharged after methane capture can be sold as fertiliser. Farmer repayment is arranged through deductions in milk deliveries to the cooperatives. Without this scheme, manure from the small dairy farmers would have been discharged into nearby rivers.

Case Study 1 Interview with Yayasan Rumah Energi

Please provide a description of Yayasan Rumah Energi and your key business

Yayasan Rumah Energi (YRE) is an Indonesian NGO established in November 2012 to assist grassroot communities in poverty alleviation, climate change adaptation and mitigation, and disaster risk reduction. YRE's goal is to provide its beneficiaries – the majority of whom are farmers, women and vulnerable communities – with a better quality of life and to improve resilience against the impacts of climate change. To achieve these goals, YRE focuses on four areas of sustainable development:

1. Renewable Energy
2. Food Security
3. Social Entrepreneurship
4. Water Access and Quality

These areas of development are delivered through policy advocacy; survey and data analytics; product R&D; enabling market ecosystems; and facilitating capacity development for grassroot communities.

Can you share an example of a live project where small farms install anaerobic digesters?

YRE's flagship program is the Indonesia Domestic Biogas Program (BIRU). BIRU has facilitated the installation of 27,909 biodigesters in 16 provinces across Indonesia (per 30 June 2022). BIRU has had a positive impact on more than 129,000 people, among which are 27,880 farmers. The program has trained 1,458 local masons and collaborated with 153 local partners including micro-finance institutions, SMEs, and educational institutions. The program incorporates a blended financing model where funds are sourced from local and national governments, corporate CSR, carbon credits, micro loans from MFIs, and user contributions.

What is the key motivation for a small farmers to install a micro-biodigester?

From our *Biogas User Survey* in 2021, there are several motivations for small farmers to install biodigester: (a) Savings (35 per cent), (b) Utilisation of manure (17.2 per cent), (c) Reduce LPG consumption (11.4 per cent), (d) Firewood substitution (5.3 per cent), (e) others (31.1 per cent).

What are the key risks and hurdles in this program, in terms of regulations, permits, financing?

There are several challenges facing this program:
(a) **Financing:** limited understanding of MFIs / Financial Institutions regarding the potential business of biogas technology,
(b) **Regulation:** insufficient agri-waste management policy. While several local governments do have waste management
policy in place, there is lack of enforcement and incentive for farmers.

What is the typical cost of building an AD for a small farm, the potential savings/ additional income for the farmer, are there subsidies involved and how long is the payback period?

There are several financial models in BIRU:
(a) Self-funded by the farmers (cash or loan),
(b) Full subsidy by government (APBD) or by corporation through CSR fund,
(c) Cost sharing with the government – either through CSR fund or self funded by farmers. Each biodigester built in BIRU program will get a subsidy (from carbon fund). From our 2020 data analytics, we analysed that each biodigester can be financed by loan with average monthly instalment of IDR 154,000 for 36 months.

>> Continue next page

<< Continued from page 16

Case Study 1: Interview with Yayasan Rumah Energi

How long is the construction process, who undertakes the construction; and who pays for it and its insurance?
Construction of biodigester takes 7 - 15 days (depending on the size of biodigester). YRE trains local construction partners to build biodigester with our standard. As part of the after-sales service, they also make inspection twice within 3 years. We monitor each biodigester under the BIRU Program. Since 2019, we have also repaired more than 600 units of broken biodigesters with the carbon fund.

What roles can corporate buyers and banks play in this program?
1. Provide low interest loan to the entire value chain of biodigesters (i.e. from biodigester installation to bioslurry offtake). This includes providing low interest rate to local cooperatives/ direct lending using fintech to biogas users and financing for the bioslurry offtaker and incorporate the carbon credits generated from bioslurry and biogas in the lending.

2. Link the biogas and bioslurry business to other portfolios such as livestock lending, lending to plantations/agriculture companies. If banks want green portfolio, banks can promote biogas and bioslurry as emission reduction initiatives for its customers.

3. Collaborate with local cooperatives. In some cases, local cooperatives do not require and/or are not allowed to accept third party financing as cooperatives have enough resources. What is required is the capacity building in assessing the risks, debt structuring, connection to wider off-takers, access to better technology and digitalisation. This is the background to why YRE is initiating a green cooperative program, where climate financing can be accessible down to the grassroot community. The green cooperative program is a collaborative program that merges financing from international climate funds, banks, cooperatives, fintech, carbon financing, etc. Thus, banks have a major role in this program.

Why some anaerobic digester projects fail

The concept behind AD is uncomplicated. The key ingredients are temperature, no oxygen, and mixing. However, the process before and after may get complicated, such as feeding the methanogens continuously and consistently. Often, problems also arise with the construction and permitting during the building process.

Each biodigester project would require customisation to accommodate local market economics (such as local gas and fertiliser prices) and to provide buffer in the projected financial returns (taking into account operating costs and debt repayments, if any) to cover the downside risks.

Amongst the key challenges in AD include:

1. The **variable methane content** of the manure itself. Different livestock produces different components in its manure, depending on given feed. This requires extra effort (including additional organic feedstock in some species) to ensure biogas systems run smoothly

2. **High investment/ operating cost** and **risk of under-performance**. Projects can fail when net financial incentives are absent (such as higher cost to produce electricity or clean fuel than the selling price, or when methane produced is less than expected)

3. AD requires continuous and consistent intake volume. **Improper operations** may break the system, destroy the bacteria inside. This includes excessive **antimicrobial** use in livestock farms, which may reduce gas yield

4. Lack of access to **long-term financing**. For small farms, this issue has so far been dealt with through subsidies to lower interest rates and to pay for construction warranty issues. But for large scale projects, commercial borrowing with collateral would be required

These challenges need to be resolved in the feasibility studies to ensure that ADs would remain economically viable even in a worst-case scenario. Hence, involvement of experienced contractors remains crucial in designing, building, and maintaining these systems, typically under a Build Operate Transfer (BOT) arrangement. There are cases whereby the system can also be developed under Build Own Operate Transfer (BOOT) or Build Own Operate (BOO) (see interview below). Digesters are operationally intensive assets and generally, there is limited experience in operating these types of assets. Failures can often be attributable to hiring the wrong operators.

In addition to having constant feedstock supply and its offtake arrangements (or agreements), common steps in digester projects that converts biogas into electricity would typically include: (1) sufficient grid infrastructure and power purchase agreement (PPA), (2) proven technology, (3) corporate legal entity, (4) site, building, environmental, electricity generation permits, (5) financial closure, (6) experienced, credit-worthy large-scale contractors, (7) grid connection and commissioning, and (8) performance monitoring.

Operating cost can be quite high; and this is generally because of decisions in the development process, resulting in unsuitable engineering solutions with high operating cost (AD is a very corrosive environment given the presence of Hydrogen Sulfide or H_2S in biogas).

Case Study 2 Interview with Sobono Group

Please provide a brief description of Sobono and your key business

Sobono Group (*ref: www.sobono.com.sg*) provides green energy solutions, with special focus on circularity and net zero outcomes. This includes various pathways for waste-to-resources conversion and valorisation; including agricultural biomass-to-energy, energy recovery from waste heat, and organic farm waste-to-energy through anaerobic digestion (AD) biogas production. We provide Build-Own-Operate (BOO) offerings including feedstock management, and upcycling of by-products of energy plants like digestate and ash.

Currently how do animal protein companies in Southeast Asia manage their farm waste?

Organic farm waste is handled with different approaches. Some companies set up inhouse treatment facilities, but with varying designs (not all meet zero methane discharge) with a few upcycle the manure to produce biogas by AD plant and harness valuable energy (power, steam or hot water). Direct disposal is challenging, with lack of qualified commercial disposal services or high disposal costs. Most abattoirs would dispose the raw animal by-products for pet or fish food production, with some just incinerated the non-edible products. Some animal farms also dispose the manure for composting (with carbon substrates) as bio-fertilisers.

What are the issues/challenges for an AD project owner to understand before pursuing such a project?

Often, there is lack of clear regulations to mandate the companies in treating or disposing their organic farm wastes in compliance with full aspects of ESG, so, few are motivated to introduce AD plants with the significant investment. The farms may not be of sufficient scales, or might lack the knowhow in operating AD plant safely and efficiently (e.g. on understanding the microbiological activities). Successful AD project can be achieved through good understanding of compliance requirements, available government supports, technology trade-off (on say deploying proven design like CSTR* AD), waste stream and characteristics (future farm expansion plan, bio-security management if external wastes are consolidated, addition of other substrates for co-digestion for reliable AD process, etc.). Alternative approach could be having a competence provider to implement the AD plant or to invest in the AD plant and selling alternative energy back to the farm.

What is the key difference between a gasification and an AD project?

Gasification is alike the reverse process of polymerisation, breaking down complicated organic matters into smaller empirical forms - H_2, CO_2, CO, CH_4 (some), NO_x, SO_x, etc. The gasification may work well for dryer waste material, and single substrate with less complex elemental components. Gasification's by-product or residues can be difficult to treat, as they may contains PAH, dioxin, and toxic substances; and good waste treatment system(s) for wastewater, sludge / ash, dirty air may be needed. On the other hand, the by-product of AD could be more valuable and less toxic (besides the concern on biosecurity) and the digestate is potentially useful for circularity economy for irrigation or production of biofertiliser.

Would you be able to share how much an AD would cost, cost of electricity produced/kWh?

An AD plant could cost between USD 2.5 to 4.0 million per MWe of electricity generation. For a

>> Continue next page

<< Continued from page 16

Case Study 2: Interview with Sobono Group

simple 5-year ROI covering O&M needs, the LCOE* could be between USD 0.10 to 0.12 per kWhe. Needs of other thermal resources like hot water or steam (produced from waste heat of electricity generation) could improve the ROI of the AD plant. Minimum threshold farm size would depend on displaced electricity rate, the off-taking of thermal, availability of suitable substrate for co-digestion, and value of back-end digestate nutrients.

How long is the construction process before an AD can be fully functional?

Total project timeline could be between 12 to 15 months, covering: Design and engineering, including testing for biogas potential (2 months); Civil structure, piling, excavation -- depend largely on how remote is the site, ease of mobilisation and local supports (4 to 6 months); Erection of CSTR** tanks and rest of plant (3 to 4 months); and Commissioning and testing including inoculation (3 months).

Can you share a successful project and what we can learn from it?

Sobono's customer, Biotech Farms Inc. (BFI) in Southern Philippines, had well demonstrated how organic waste from their pig and chicken egg layer farms could be upcycled through an CSTR* AD plant, generating electricity for the farms as well as dispatch to the local power grid. Beyond meeting the highest ESG standard, this circular economy undertakings of BFI *(ref: https://biotechfarms.com/sustainability-from-farm-to-plate-with-circular-economy/)* also contribute to co-digestion of other local organic waste, re-use of digestate for agriculture, grower-ship program for cultivation of energy crop, etc.

Image reproduced courtesy of Biotech Farms Inc.
** LCOE: Levelised Cost of Energy; ** CSTR: Continuous-Flow Stirred Tank Reactor*

Case Study 3 Interview with Austindo Nusantara Jaya

Please provide a description of ANJ Group and your key business

PT Austindo Nusantara Jaya Tbk. is a listed holding company based in Indonesia, engaging directly and through subsidiaries in the production and sale of crude palm oil (CPO), palm kernel (PK), palm kernel oil (PKO) and other sustainable food crops such as sago dan green soybean (edamame). We also embark on renewable energy from the agriculture waste, such as Biogas Power Plant.

What is the motivation for a company such as your group to build a POME biogas plant?

ANJ owns its first biogas power plant located at Belitung Island Plantation. It was built and run by PT Austindo Aufwind New Energy with the primary aim of reducing the plantation's GHG emissions by capturing methane released from POME and converting the biogas to generate electricity to be distributed to surrounding community through commercial agreement with PLN. Within our long term ESG ambitions and target, we aim to reduce GHG emission from operational activities by 30 per cent and to have net zero carbon – including carbon absorbtion and sequestration – by 2030.

What are the key regulatory considerations in operating a POME biogas plant?

POME biogas plant operation should be financially independent, able to comply with the environmental and operation license, and maintained in the ownership of the plantation company. A clear regulatory framework therefore should include:
(1) attractive feed-in tariff for electricity sales,
(2) clear regulation that there would be no transfer of ownership of the asset to PLN, and
(3) regulation to sell the biogas as fuel, as it is or in the form of processed biogas such as BioCNG.

What is the typical power generation capacity, cost of building a POME biogas plant from a 60-MT/hour mill and what is the cost of per kWh?

Depending on the supply base of palm fruit and liquid waste; a typical 60 MT/hour palm oil mill may provide up to 5-8 million Nm^3 of biogas, or up to 2MW electricity capacity equivalent. The electricity cost may vary depending on technology, equipment and location. The recent Presidential Decree implies biogas tariff between 7-11 cent USD/kWh, subject to year of operation, capacity, location factors. This tariff was based on research of average levelised cost of electricity from biogas in Indonesia.

How long is the construction process and what is the payback period for a POME biogas plant?

Construction would take 9 to 15 months, depending on selection of technology and equipment, logistical access to the site and equipment country of origin. Our tariff in Belitung was based on 2012 regulation, which would not provide a decent payback period. The new tariff in the recent Presidential Decree seems to provide reasonable payback; although we need to analyse them on per project basis.

What are the key lessons that you can share?

Selection of technology and equipment, financial viability of the project, either as electricity sales to PLN, own use or other utilisation, a capable and competent engineer on site to operate the facility, and local partner for service and maintenance.

Do you have plans to build more POME biogas?

Yes, we are embarking to build more POME biogas as part of ESG integration to our business strategy, particularly to reduce GHG emission and to be carbon neutral. We would like to see the effectiveness of the recent Presidential Decree's renewable energy tariff and government support toward the implementation of this regulation.

Policies on renewable energy

"Within ASEAN, Indonesia and Thailand seems to have higher targets in their shares of bioenergy in its renewable energy generation (8-11 per cent)"

The ASEAN scheme

Biogas is a small part of the drive towards renewable energy; and government incentives will remain essential in the feasibility of biogas projects. According to International Energy Agency (IEA), bioenergy accounts for around 10 per cent of world's primary energy in 2018; and is mainly coming from solid biomass, covering around 90 per cent of bioenergy supply. A further 7 per cent of global bioenergy supply (equivalent to 90 million metric tons of oil equivalent or MTOE) comes from liquid biofuels; and the remaining 3 per cent comes from biogas and biomethane (equivalent to 35 MTOE combined). Globally, Thailand ranked sixth in 2020 electricity generation from bioenergy at 30,692 GWh; while Indonesia ranked 10th at 12,382 kWh – based on data from the International Renewable Energy Agency (IRENA).

As ASEAN has set an ***aspirational*** target of achieving 23 per cent renewable share in primary energy supply ***and*** 35 per cent in installed power capacity by 2025; each of ASEAN-4 countries (Indonesia, Malaysia, Thailand and Vietnam) has various targets with respect to their shares of renewable sources in the energy mix. Within ASEAN, Indonesia and Thailand seems to have higher targets in their shares of bioenergy (i.e. consisting of **biomass**, **biofuels**, and **biogas**) in its renewable energy generation (8-11 per cent); while that of Malaysia and Vietnam have relatively lower targets (2-3 per cent); owing to different priorities in sources of renewable energy generation.

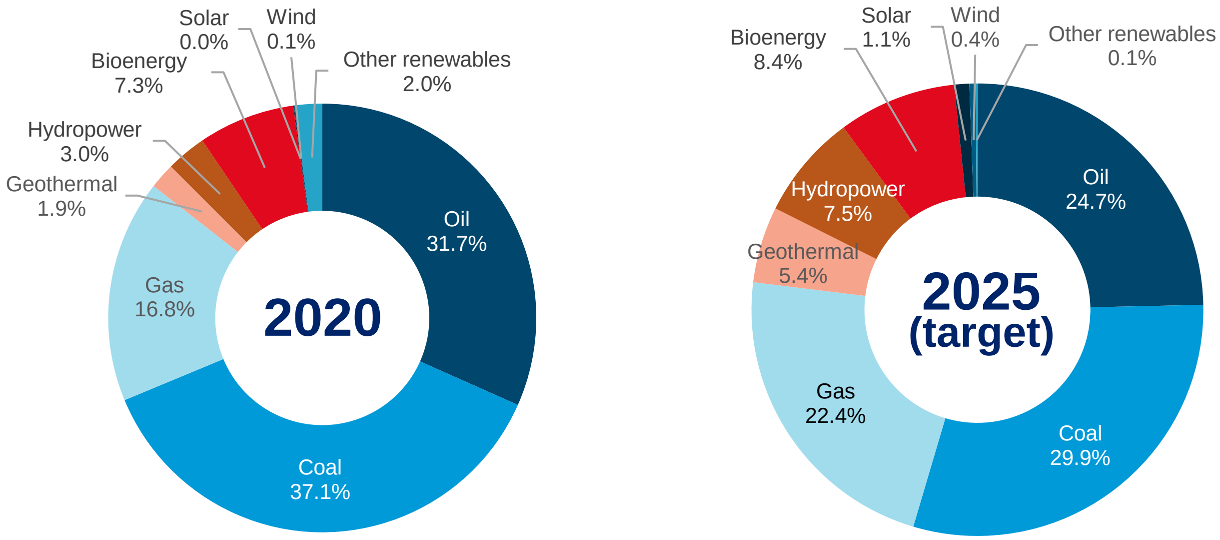
Indonesia

According to data from National Energy Council (DEN), share of bioenergy in Indonesia's primary energy supply mix in 2020 accounted for 7.3 per cent – of which biofuels (primarily B30 program) contributed about half. The other half comes from biomas; while biogas remained relatively small. But by 2025, the government – through Presidential Regulation No.22/ 2017 – aims to raise the bioenergy's share by more than double to 8.4 per cent (equivalent to 33.8 million metric tons of oil equivalent or MTOE); which is part of overall renewable energy share of 23 per cent.

To reach this goal, biogas is targeted to expand the fastest at 271 per cent to roughly 93 thousand TOE (metric tons of oil equivalent); while biodiesel and biomass contributions are targeted to grow 65 per cent and 25 per cent, respectively, from 2020 levels. An additional category, Coal Bed Methane (CBM), will also feature with contribution of 11.5 MTOE by 2025 from close to zero in 2020.

A common issue in the development of renewable energy in Indonesia cited by Asian Development Bank (ADB) remains the electricity subsidy, representing a handicap in the development of alternative energies. In 2017, PLN (State Electricity Company) also imposed BOT (Build-Operate-Transfer) policy and tariff setting based on nationwide average cost of electricity supply, which adversely affected the bankability of independent power producers. However, in 2020 Indonesia's Ministry of Energy and Mineral Resources issued a revision (Permen ESDM No. 4/2020) to previous BOT policy; and revised tariff setting is now based on local cost of electricity generation, rather than average national cost, with maximum contract for Independent Power Producers (IPP) of up to 30 years (subject to PLN's discretion). More recently, Presidential Regulation No. 112/2022 on *Accelerating Renewable Energy Development for Electricity Generation* also sets out maximum electricity purchase price from renewable sources (including biogas) based on capacity, year of operation, and locations.

Figure 11: Indonesia energy supply mix in 2020 and 2025 target



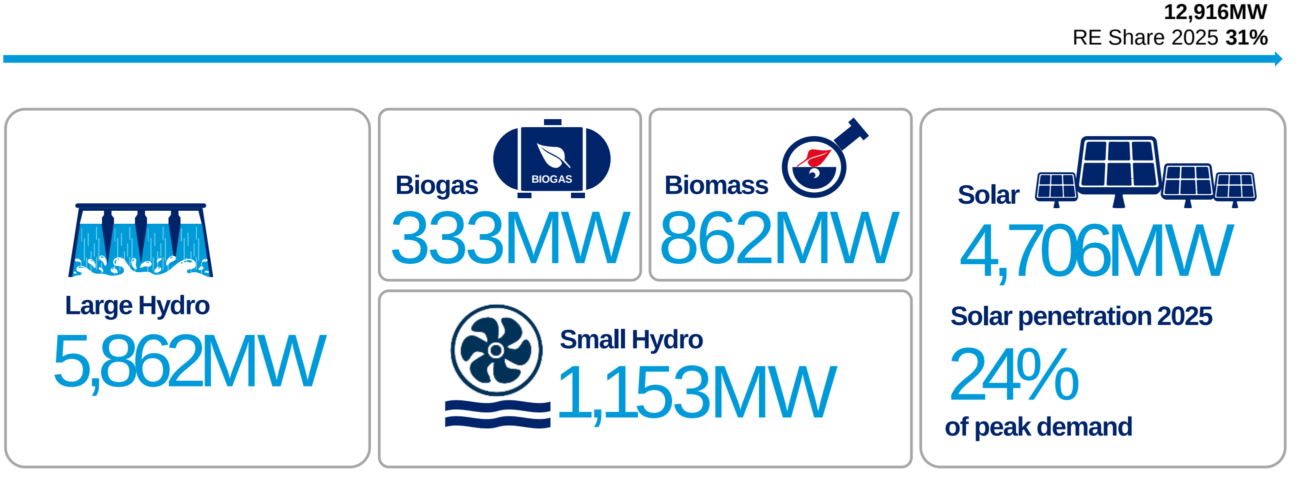
Sources: Presidential Regulation No.22/2017, Indonesia Energy Balance Sheet 2021

Malaysia

According to Malaysia Renewable Energy Roadmap 2021, a target of 333 MW capacity from biogas is to be achieved by 2025. This is part of its aim to achieve 31 per cent or 12.9 GW of renewable energy by 2025 (based on implementation of approved, committed and announced capacities under existing programs; including 1,174MW shortfall of the 31 per cent target). This biogas target only accounts for roughly 2.7 per cent of Malaysia's renewable energy target by 2025. Current average electricity tariff for businesses in Malaysia is comparable to that of Vietnam and Indonesia; but is relatively low compared to Singapore, Philippines and Thailand. Hence, the incentive to generate biogas capacity is lacking.

For the purpose of containing waste pollution and capturing GHG emissions from livestock farms, government incentives and/or additional cash flow stream from sale of bio-fertiliser would hence be needed. We believe carbon credits may offer some additional pathway as a solution (discussed in the next section).

Figure 12: Malaysia's target Renewable Energy mix in 2025

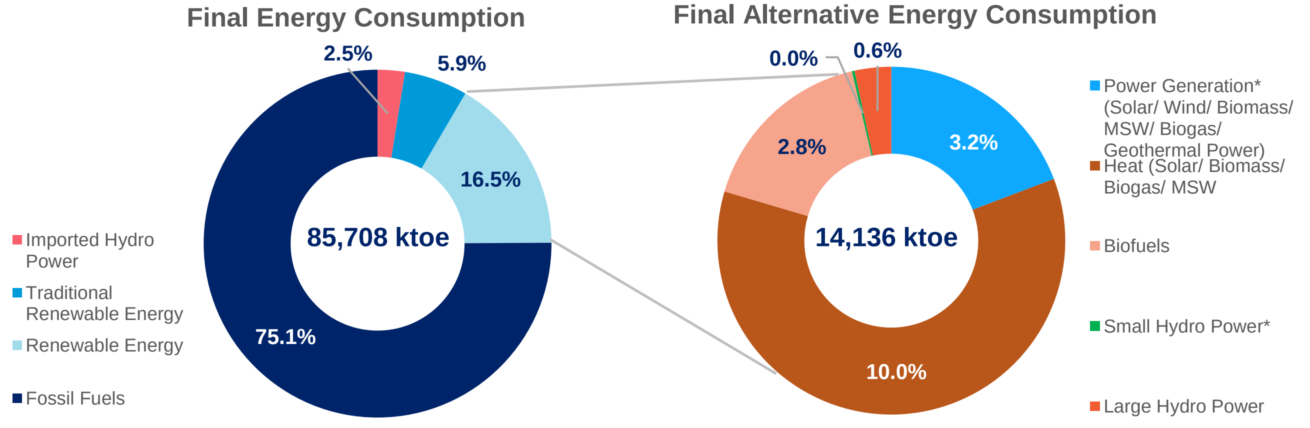


Source: www.seda.gov.my

Thailand

Based on Ministry of Energy's Power Development Plan 2018-2037, Thai energy mix in 2020 consists mostly of natural gas (57 per cent), lignite and imported coal (18 per cent) and the remainder renewable energy (including hydropower, imported hydropower and other renewable energy). By 2037, the share of renewable energy is targeted to expand to 36 per cent, including 6 per cent from energy efficiency. Within the renewable energy share itself, biogas is targeted to expand by 400 MW by 2037 from 530 MW (or 4.5 per cent of total installed renewable energy capacity) in 2019. This biogas target is expected to come from both industrial waste as well as livestock farms.

Figure 13: Thailand Renewable Energy Mix, 2019



Source: www.trade.gov

Figure 14: Thailand renewable energy capacity expansion target 2018-37 based on AEDP 2018

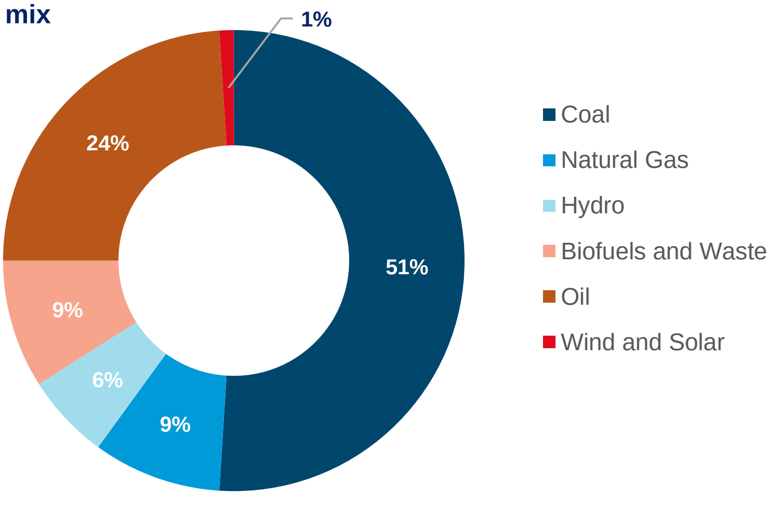
Renewable Energy	New capacity target (MW) by 2037
Biogas	1,183
Biomass	3,380
Small Hydropower	69
Solar	9,290
MSW (Municipal solid waste)	400
Wind	1,485
Industrial waste	44
Floating solar and hydropower	2,725
Community-based biomass power plants in 3 southern provinces	120
Total	**18,696**

Source: National Economic and Social Development Council 2020

Vietnam

Vietnam's primary energy supply mix in 2019 consists of 51 per cent in Coal, 24 per cent in Oil, 9 per cent in Natural Gas, 6 per cent in Hydropower, 9 per cent in Biofuels and waste, and 1 per cent in Wind and Solar. The government's eighth Power Development Plan (PDP8) was submitted for approval in May 2022; with projected base-load installed capacity of 146 GW by 2030 from 69 GW in 2020; where the share of biomass and other renewables (excluding wind, solar and hydropower) account for just 0.8 per cent. This share is expected to increase to around 2.2 per cent (or 3.2 GW) – based on 2021 draft – although final number will only be made official following the approval.

Figure 15: Vietnam 2019 energy mix



Source: IEA

Figure 16: Vietnam power generation sources

Power sources	2020	Draft PDP8	
		2025	2030
Coal-fired thermal power	20,431	29,523	37,323
Gas-to-power and oil/diesel-fired thermal power	9,030	14,055	28,871
Hydropower + pumped storage hydropower (include small-scale hydropower)	20,685	24,497	25,992
Wind power	630	11,320	18,010
Solar power	16,640	17,240	18,640
Biomass and other renewable power	570	2,050	3,150
Power import	1,272	3,508	5,677
Nuclear power			
Total capacity (MW)	**69,258**	**102,193**	**137,663**

Source: Baker McKenzie

Developing waste-to-energy

Making sense of biogas projects with carbon credits

There are two types of carbon markets: Compliance Carbon Markets (CCM) and Voluntary Carbon Markets (VCM). CCM is primarily structured as emissions trading schemes (ETS), where participants trade allowances-to-emit supplied by regulators. VCM, on the other hand, is a carbon offset exchanged in voluntary markets for credits (i.e. buyers voluntarily purchase emission reduction units per MT of CO_2 equivalent); and do not have legal or regulatory requirement. These carbon offsets must be verified and certified by independent certification bodies. According to Ernest & Young, as of 2021, total value of VCM reached over USD 1 billion – up from less than USD 0.5 billion in 2020. Aside from reducing energy cost and selling processed bio-slurry as fertiliser, an AD operator in industrialised livestock farm or palm oil mill can also generate revenue from sale of CO_2 emissions reduction under VCM.

Carbon credit sales are typically handled through a project developer (see interview with South Pole below) which will ensure that the project adheres to recognised carbon standards (i.e. Verified Carbon Standard or Verra and Gold Standard). Carbon credit projects have to complete a verification and assessment process before being listed on the registries and certified as carbon credits. These certified carbon credits may then be sold to a buyer who has committed to some level of greenhouse gas reduction. According to 2019 World Wildlife Fund (WWF) position and guidance on voluntary purchases of carbon credits, carbon credit quality is dependent on six criteria, as laid out below:

1 Real
All emissions reductions/ removals and project activities that generate them is proven to have genuinely taken place.

2 Measurable
All emissions reductions/ removals are quantifiable using recognised measurement tools, compared against a credible emissions baseline.

3 Permanent
Carbon credits represents permanent emissions reductions/removals. Internationally accepted-norm for permanence is 100 years.

4 Additional
Project-based emissions reductions/removals are additional to what would have occurred if the project had not been carried out.

5 Independently verified
All emissions reductions/ removals are verified with reasonable level of assurance by independent and qualified third-party.

6 Unique
No more than one carbon credit can be associated with a single emission reductions/ removals as one metric ton of carbondioxide equivalent. Carbon credits is stored and retired in an independent registry.

Source: Ernest & Young, WWF

"The financing of the development and operation of such biogas project may qualify for Green Loans under UOB's Smart City Sustainable Financing Framework and Green Circular Economy Framework"

The project developer subsequently monitors the performance over some agreed-upon contract period. The monitoring report is then independently assessed by an accredited validation and verification body (VVB) that audits the digester initially to verify the methane quantity.

Ownership of the carbon credits will depend on the agreement between the project developer and the project owner, which by default will be the biogas operator. Where project developer provide services such as project registration, certification, and intermediary roles, the compensation can take a revenue sharing model (the bulk going to the project owner). However, pricing will still depend on investor appetite, geographic limitations (e.g. Indonesia is yet to issue implementation rules on carbon credit trading, domestic or cross-border, following Presidential Regulation No.98/2021) as well as comparison with similar transactions. According to Ernest & Young (EY), in 2021, traded price for a metric ton of carbon credit from renewable energy and agriculture ranged between USD1.10 and USD1.36/MT.

Carbon credits can be employed for project owners' own carbon offsets, whenever carbon tax is mandated, as carbon credits are transferrable and have no expiry date, except when it is sold and retired.

Interview with South Pole

Please provide a brief description of South Pole and your key business

South Pole is climate solutions provider and carbon project developer. Since 2006, we have developed nearly 1,000 projects in over 50 countries to reduce over one gigaton of CO_2 emissions, and to provide social benefits to less privileged communities who are particularly vulnerable to climate change. Our projects range from sustainable agriculture/forest conservation to waste management, energy efficiency, and decentralised renewable energy. With global Climate Solutions platform, South Pole develops and implements comprehensive strategies that turn climate action into long-term business opportunities for companies, governments and organisations around the world.

How do you see opportunities in carbon credits from biogas projects in animal protein/palm oil?

One of the major initiatives resulting from COP26 is the Global Methane Pledge which has been signed by more than 100 countries. The pledge is to reduce methane emissions globally by 30 per cent by 2030 (from 2020 levels). The pledge indicates that methane avoidance is crucial for countries to reach their net zero emissions. Thus, more methane avoidance activities, such as biogas projects, should be accelerated and encouraged. The potential of biogas activities from palm oil and livestock farms in developing economies where agricultural activities remain dominant, such as the Southeast Asia region, is considerable. For example, in Indonesia alone, the technical potential of biogas from palm oil mills and the

**Source: Strategic Exploration of Economic Mitigation Potential through Renewables, ExploRE. BioDB. Basis data Potensi Bioenergi dari Limbah Agro Industri. Retrieved 27 September 2022 from https://gizexplore.shinyapps.io/biodb/*

>> Continue next page

<< Continued from page 28

Interview with South Pole

livestock industry is estimated to be 1,145 MW and 37 MW, respectively. Carbon credits could help accelerate development* of biogas projects and leverage this potential by mobilising financial support from private sectors to project owners. However, the palm oil industry is being scrutinised for its environmental impact. Market players are therefore carefully considering which palm oil products or companies are environmentally acceptable and aligned with sustainable practices. The demand for carbon credits follows the same approach; the reputational issues with palm oil can impact the price of biogas carbon projects.

What are the key considerations for an organisation looking to develop biogas projects, when it comes to carbon tax, carbon credit trading and its markets?

As corporates prepare for any form of carbon pricing such as carbon tax, they should revisit their near- and longer-term climate goals and any internal carbon pricing strategy. This usually involves the calculation of GHG footprints throughout their value chains, identification of mitigation opportunities and their associated costs of implementation, as well as emission sources that would be regulated under the carbon price. During this process, corporates/project owners need to be mindful when planning their GHG mitigation activities and understand whether the GHG mitigation activity is implemented under a carbon pricing scheme for the purpose of lowering their taxable emissions and tax liability, or for the purpose of developing carbon offset project(s) to generate carbon credits. This is because the same mitigation activity cannot be used for both purposes as that would double-count the emissions reductions. Whichever route they choose, corporates should design the most efficient roadmap possible to achieve their climate goals. This roadmap should also consider the local government regulations of GHG mitigation activities and the use and trade of carbon credits from these activities.

What would be the steps palm oil mills, for example, need to take to sell carbon credits?

For palm oil-related projects, the first and most important step is obtaining Principles & Criteria for Sustainable Palm Oil Production (RSPO) certification. The scrutiny leveled at the palm oil industry makes this crucial to demonstrating the project owner's commitment to applying sustainability practices throughout their value chain. The certification will be taken into account by credit buyers when selecting which GHG mitigation activities to support with carbon finance. The next step is ensuring that the implementation of the project activity is aligned with the applicable emission reduction methodology. It is also important to be aware of the carbon standard's requirements from the beginning in order to increase the likelihood of confirming eligibility and moving ahead with carbon credit registration in a timely manner. Once the project is registered, the monitoring system should also be properly and safely managed, in compliance with the carbon standard's requirement, so the project is able to generate verified carbon credits which it can then sell.

What role do you think a bank can contribute in carbon credit projects?

The support from banks is vital for GHG mitigation activities, helping to kickstart projects' implementation. Without financial support, project owners are not able to begin the implementation, encountering roadblocks at an early stage. Purchasing technology and equipment or starting construction: accessible funding from banks enables these activities to take place so that the project can begin operations, start reducing GHG emissions and from there start generating carbon credits. Once this is in process, the revenues from

>> Continue next page

<< Continued from page 29

Interview with South Pole

the carbon credits can help to sustain the project's operations in the long term. The initial financing from banks makes this all possible.

Where do you think VCM is headed as we move closer to renewable energy targets?
As we see the technological and financial barriers to developing renewable energy projects diminish, the financial support for such projects through carbon finance is becoming less critical compared to when the VCM first started. Therefore, the additionality of many renewable energy projects will be increasingly difficult to demonstrate as these markets get more competitive, especially in countries where the penetration of renewable energy in the national grid capacity is high. In these contexts, it is possible that such renewable energy projects will no longer be additional as they face low barriers to implementation and are increasingly common practice. However, while this may be the case for renewable energy sources such as wind and hydropower, not all renewable energy technologies face this trajectory in the VCM. Biogas projects may remain an exception as the GHG emission reductions that are generated from biogas stem not only from the emissions avoided from the electricity generation activity (when compared with the baseline scenario of fossil fuel-generated electricity), but also (and predominantly) from the methane avoidance activity. This makes such project types more complex and thus more attractive on the carbon market.

Financing appetite in waste-to-energy projects

As the animal protein and palm oil sectors continue to grow alongside Asia's rising income, the bankability of biogas/biomethane projects will depend to a large extent on government policies on existing energy subsidies, which may not be compatible with rising global energy prices and own net zero commitments by 2050/2060. Yet, improvements to date in AD technology (including methanogens), better predictability of biogas produced (when scalable), coupled with offtake contracts, will help to make these projects financially viable on a stand-alone basis.

In a context of project finance, AD projects would typically involve equity capital to get them off the ground; before they can generate contracted cash flow to qualify for debt refinancing. Commercial banks' terms and conditions may be punitive or cumbersome in an AD project's initial stages as a stand-alone project finance. A third-party independent engineer may also be needed to verify that what is proposed makes sense and will produce the power that it is designed for. For construction debt, a key element is to secure a credit-worthy off-taker; and in the case of waste-to-electricity projects, a power purchase agreement (PPA) would need to be in place.

As the financial industry accelerates their commitments towards green financing, new sustainable financing solutions may likewise be developed to address different needs. For example, the financing of the development and operation of such biogas project may qualify for Green Loans under UOB's Smart City Sustainable Financing Framework and Green Circular Economy Framework. The deployment of such biodigester technology will also help to reduce a corporate's GHG emission, allowing them to explore sustainability linked loans as part of their overall debt capital mix.

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