China-Ghana South-South Cooperation on Renewable Energy Technology Transfer (RETT)

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COLLABORATIVE RESEARCH ON RENEWABLE ENERGY TECHNOLOGY TRANSFFER – INDUSTRIAL BIOGAS

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PROMISING SECTORS FOR INDUSTRIAL BIOGAS DEVELOPMENT

Animal farms	• Piggeries, poultry farms, cattle farms, etc.;
Edible oil extraction and processing	• Oil-palm, coconut, shea-nut, and groundnut
Crop processing	• Rice, cashew, cocoa, shea-nut, etc.
Fruits and vegetables processing companies	• Pineapples, oranges, mango, and pawpaw; etc.

Notable industrial biogas systems

Company: Safi Sana
Daily biogas: 2000 m^3/d; Source, M. Mensah, KNUST

Company: Guinness Ghana Limited
Digester: UASB, 800 m^3 ; Source, CREK

Company: HPW Fresh & Dry Limited
Digester: Two CSTR, 450 m^3 each; Source, CREK

Company: GOPDC
Digester: two covered lagoons, 1000 m^3 each
Feedstock: POME; Gas: 18,000 m^3/d; Source, EC

Objectives of the study

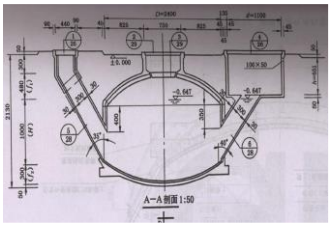
Main objective:

To identify promising industrial sites for demonstration of biodigesters, with know-how and technical support from China.

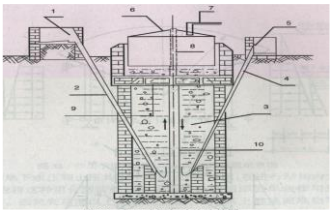
Specific objectives

- Compile technologies widely used in China
- Develop criteria for technology transfer from China to Ghana
- Carry out prefeasibility studies on potential sites

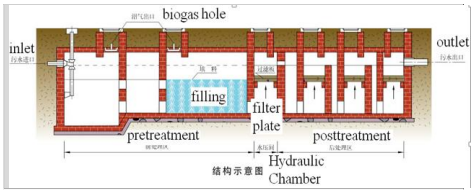
LOW END TECHNOLOGIES



Fixed dome digester

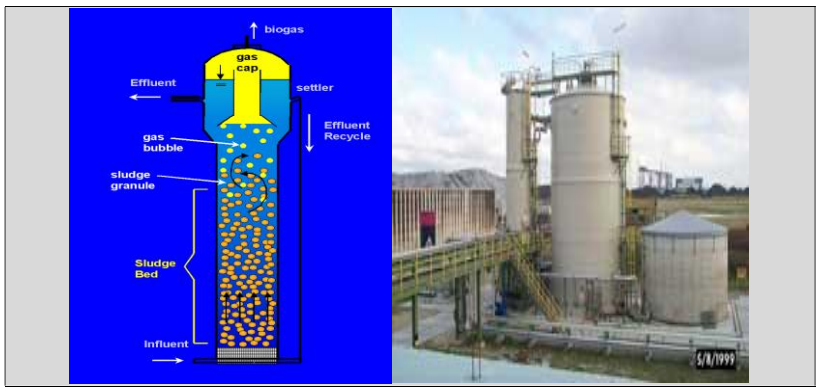


Floating drum

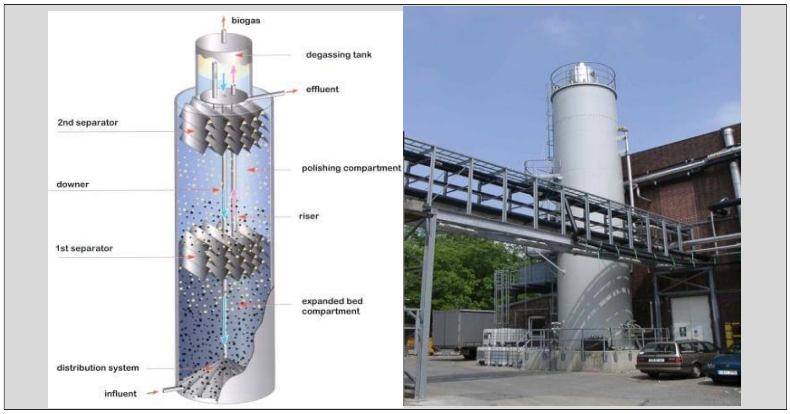


Septic tank digester

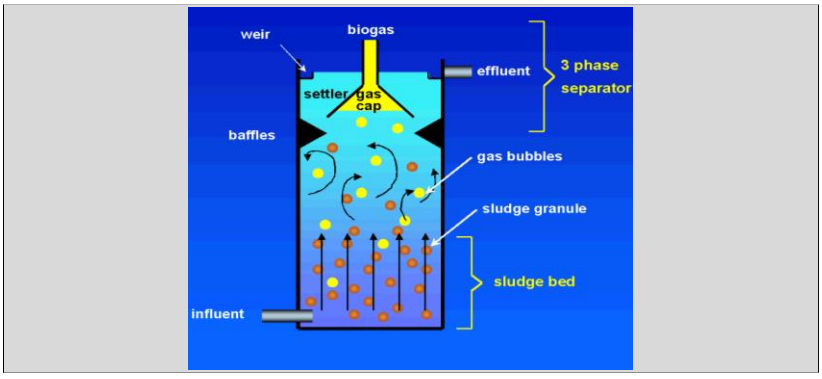
HIGH END TECHNOLOGIES



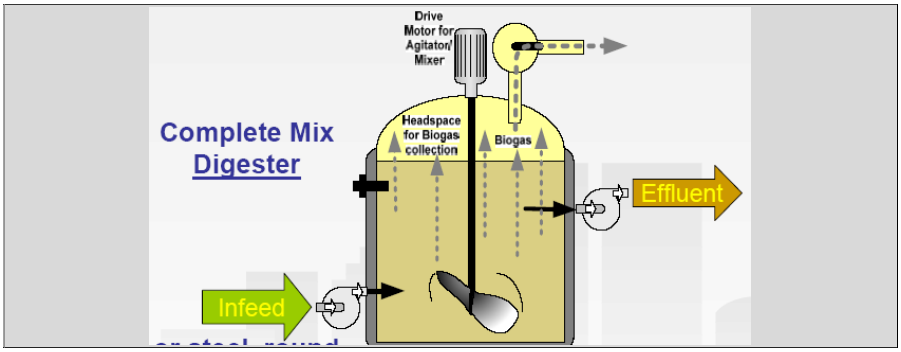
Expansion Granular Sludge Bed Reactor



Internal Circulation Anaerobic Reactor

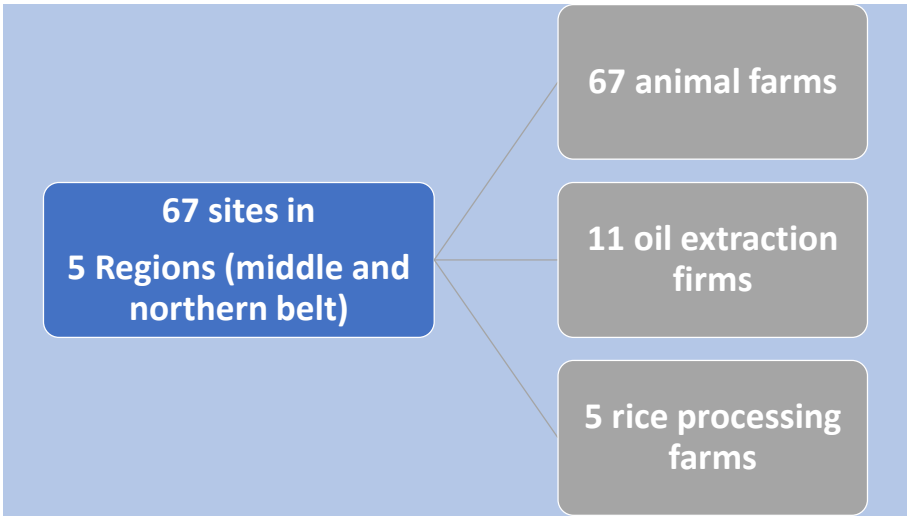


UASB



Complete mix digester

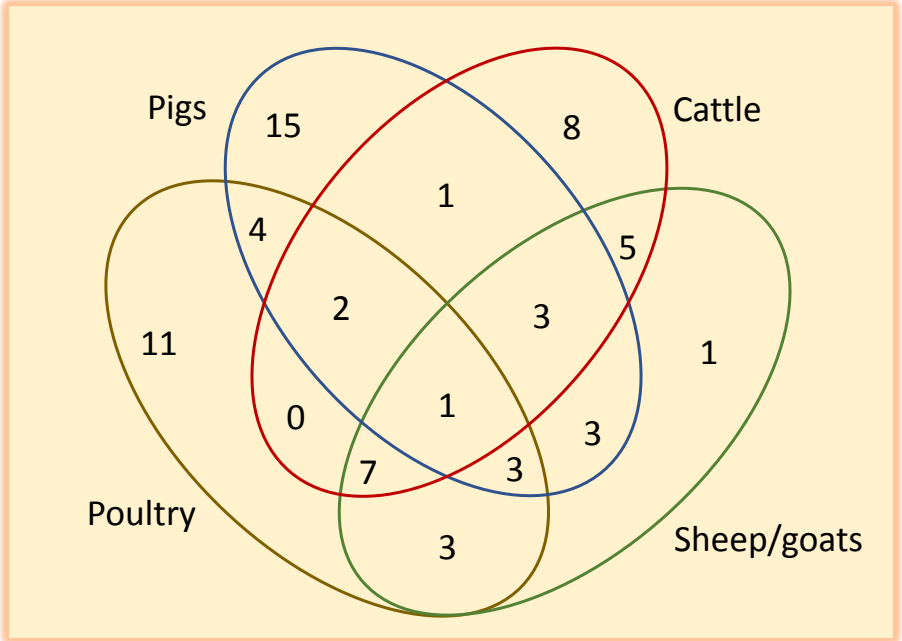
Overview of field work



Overview of field work

- Many farms are small with less than 100 livestock
- Northern and Upper Regions have few pig farms and in smaller scales, however, cattle and poultry farms are more visible.
- Rice processing is highly visible in the 3 Northern Regions
- Most palm oil extraction firms are small-scale

Breakdown of farms visited



Criteria for shortlisting of projects

- Geographical location
- Enthusiasm of owners
- Feedstock availability
- Need for energy and slurry utilisation
- Need for waste treatment
- Scale of the plant

Shortlisted projects

Animal husbandry	Oil processing
Shamo Piggery farm, Trede, AR	Juaben Oil Mill, Juaben, AR
Northern Empowerment Association, Bole, NR	Kwabena Asare Mill, Awiaso Adanse, AR

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Shamo piggery farms limited

Type/number of farm animals	Old site: Adult cattle 10, mature pigs 320, young pigs 480
Daily/weekly/monthly quantity of wastewater)	Old site: 17,000 litres per day New site: 8,000 litres per day
Monthly cost of disposal of manure	Ghc 350 - 450 per month spent on sawdust and chemicals
Monthly electricity bill	~ Ghc 130
Average expenditure on fuel	Ghc 50.0 per day when grid power is unavailable
Main challenge	Waste disposal and nuisance caused to nearby communities

Northern Empowerment Association (NEA) Farm

Type/number of farm animals	Cattle 100, mature pigs 70, young pigs 20, poultry – 3500; ostriches are also raised.
Daily/weekly/monthly quantity of wastewater)	Poultry – 4 tractor trips/month Pigs – 4 barrows/day of hard manure. Cattle – 2 tractors for a month
Monthly cost of disposal of manure	N/A
Current use of manure/waste/slurry	For farming, excess disposed off
Main challenge	Waste disposal, electricity cost

Juaben Oil Mill

Activities	Oil palm fruit processing; palm oil processing
Daily quantity of wastewater	190 t/d
Expenditure on fuel (diesel)	45,000 Ghc/y
Electricity cost	Self-sufficient
Main challenge	Wastewater disposal
Conclusion	High potential for installation of biodigester

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Kwabena Asare Palm Oil Extraction

Activities	Palm oil extraction
Daily quantity of wastewater	8000 L/d
Expenditure on fuel (diesel)	45,000 Ghc/y
Electricity cost	Ghc 225/month
Daily fuel (diesel) cost	Ghc 30/day
Main challenge	Wastewater disposal, fuel cost
Conclusion	High potential for installation of biodigester

Technical information

Parameter	JOM	KAPOP	SPF	NEA
Wastewater/effluent, m^3/d	193.0	6.0	16.6	10.0
Volume of digester, m^3	8492	264	731	439
Daily biogas production, m^3/d	3569	143	65	57
Net electricity generated, kWh/day	7500	300	140	120
Power, kW	416.4	25.0	11.4	10.1
Net heat, MJ/day	37478	1499	687	603

Digester type: Covered anaerobic lagoon
Retention time: 40 days, Mesophilic conditions

Technical information

Item	Details	Cost, USD			
		JOM	KAPOP	SPF	NEA
Fixed Capital Investment (FCI)					
Equip. and structural cost (ESC)		435679	30509	31979	24635
Installation cost	10% ESC	43568	3051	3198	2464
Housing and yard improve.	1-5% ESC	4357	1525	1599	1232
Engineering and supervision	15 % ESC	65352	4576	4797	3695
Contingency	10% ESC	43568	3051	3198	2464
Sub-total (FCI)		592524	42713	44771	34490
Working Capital (WC)					
Raw materials (inoculants,	2.5% FCI	14813	1068	1119	862
Maintenance	2.5% FCI	14813	1068	1119	862
Utilities	1% FCI	5925	427	448	345
Administrative costs	0.5% FCI	2963	214	224	172
Insurance	2% FCI	11850	854	895	690
Local taxes	1% FCI	5925	427	448	345
Research and lab analysis	1% FCI	5925	427	448	345
Community development	1% FCI	5925	427	448	345
Contingency	2% FCI	11850	854	895	690
Personnel cost	1.5% FCI	8888	641	672	517
Sub-total (WC)		88879	6407	6716	5174
Total Capital Investment		681402	49120	51487	39664

Benefit cost analysis

Parameter	Value
Construction period, months	6
Interest during construction, %	10
Plant life, years	15
Inflation rate	15%
Discount rate	10%
Equity, %	10%
Debt ratio, %	90%
Debt interest rate	25%
Debt term	6 years
Salvage value, USD	10% of FCI
Depreciation, straight line, 10 years	10% per y
Effective income tax rate	25%

Business models

Parameter	Unit	JOM	KAPOP	SPF	NEA
After-tax IRR - equity	%	229.3%	157.1%	17.1%	24.8%
After-tax IRR - assets	%	43.3%	36.3%	7.6%	11.7%
Simple payback	yr	1.9	2.3	9.6	7.2
Equity payback	yr	0.5	0.8	9.7	8.2
Net Present Value (NPV)	$	4,484,554	257,535	25,716	41,006
Annual life cycle savings	$/yr	589,601	33,859	3,381	5,391
Benefit-Cost (B-C) ratio		74.84	59.82	6.60	12.60

Greenhouse gas emission reduction

Type of Emission	JOM	KAPOP	SPF	NEA
Avoided Methane (tCO_2/yr)	38,690	1,550	705	618
Avoided Grid emissions ($t\ CO_2/yr$)	979	59	27	24
Avoided process heat emission (tCO_2/yr)	761	30	14	12
Avoided N_2O emissions (tCO_2/yr)	916	29	79	48
Total avoided emissions (tCO_2/yr)	41,346	1,668	824	701

Investment ideas

	A	B	C	D
Equity from farm/firm	10% TCI	10% TCI	33.3% TCI	33.3% TCI
Government subsidy	33.3% FCI	None	33.3% FCI	None
RE Fund (loan, interest 5%, debt term 10 y)	Diff.	Diff.	Diff.	Diff.

A, B – Investment by farm/firm
C, D – Investment by private entity

Other potential sources of concessionary:
Government controlled global-climate funds, funds available through CDM, NAMAs, etc.

Application of invest models - Shamo Piggery Farm

- For actual NPV values, multiply by a factor of 1000
- Payback (years), after tax IRR-assets (%), NPV (US$)

Conclusions

- Since the Ghanaian biogas industry lacks the skill to design and construct simple large-scale digesters such as covered lagoons as well as advanced plant such as CSTRs and UASBs, any technology transfer program should look at building local capacity to design and construct these plants using available local materials as much as possible.
- The covered lagoon is proposed for demonstration in selected pig farms and palm oil mills.
- The results show that the financial health for investing into biogas plants for the case studies, with sale of power, are favourable at the conditions considered even without upfront subsidy.
- Full-scale feasibility studies led by Chinese counterparts are required for the selection of the demonstration site.

Acknowledgements

Edem Bensah, CREK, Kumasi Technical University, Ghana