Biogas Hawai'i

Planning and Design of a Biogas Reactor for the Treatment of Organic Waste from Coffee and Fruit Production

Environmental Engineering - Master Thesis

Overview

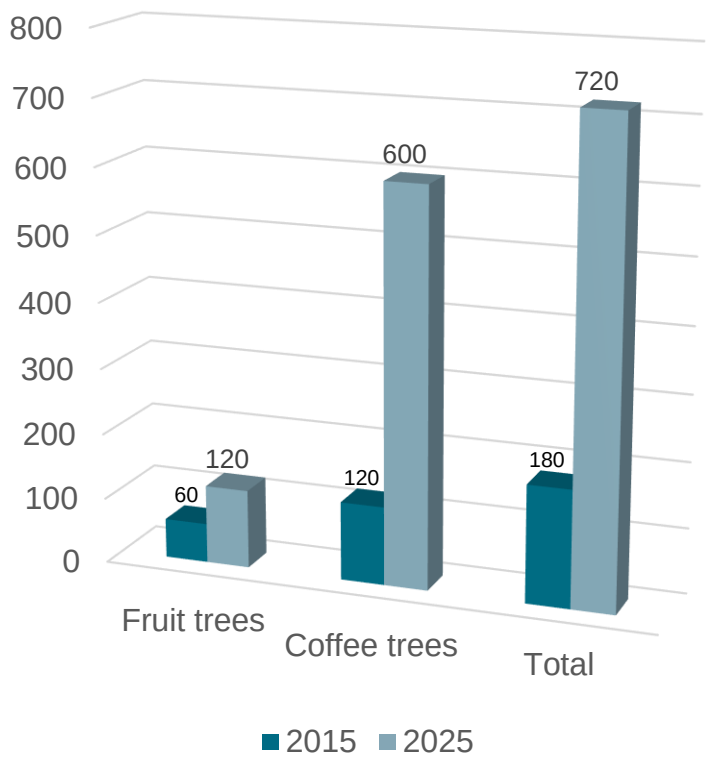
- The Farm
- Anaerobic Digestion
- Conclusion
- Follow-up
- Outlook

The Model Farm

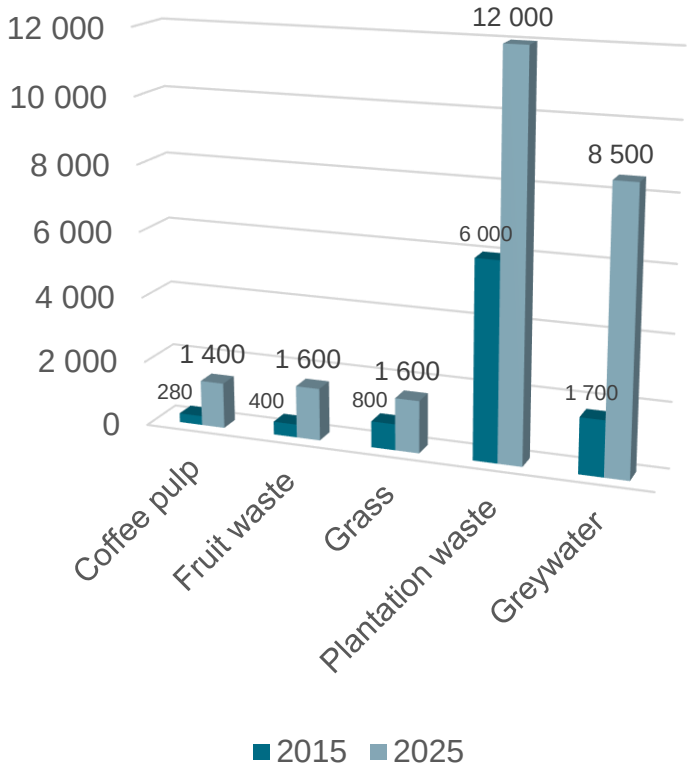
The Model Farm

The Model Farm

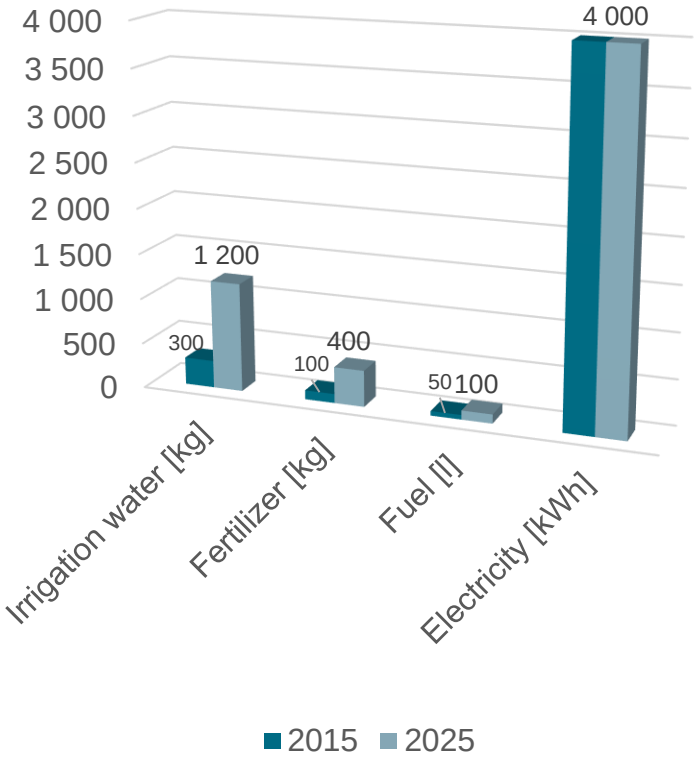
Trees



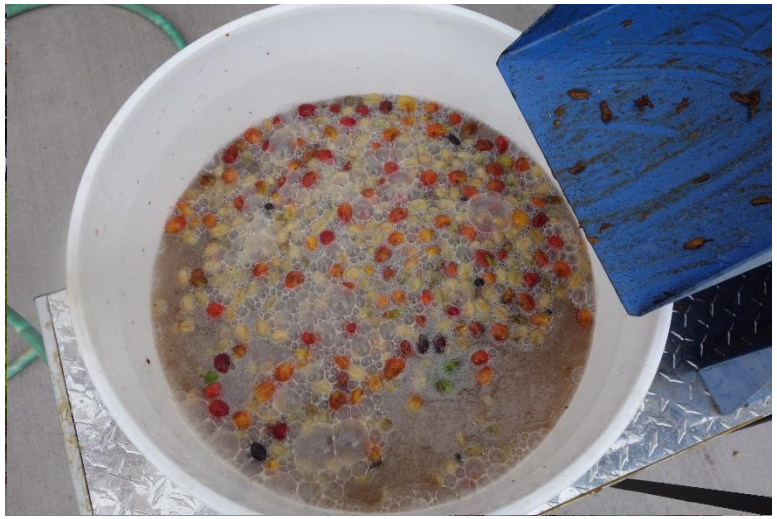
Organic waste [kg]



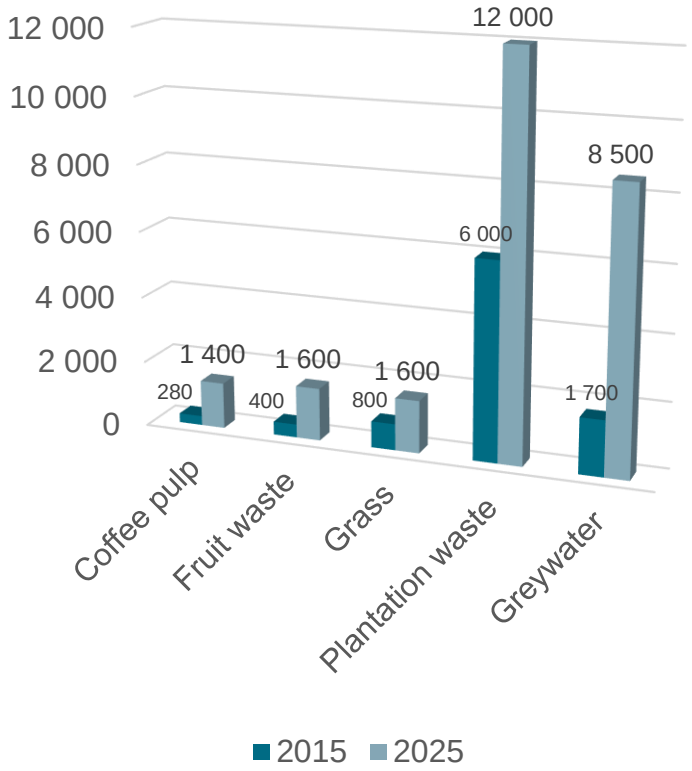
Resources



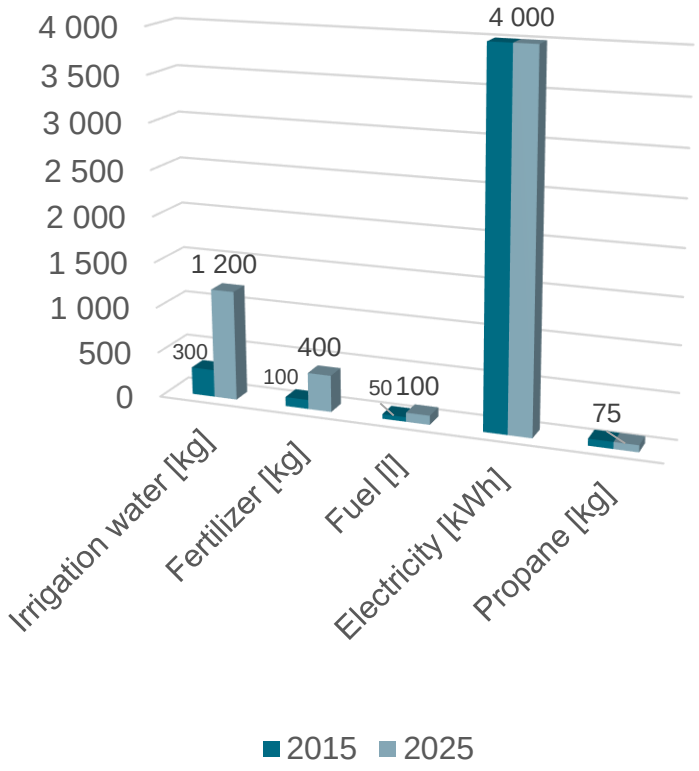
The Model Farm



Organic waste [kg]

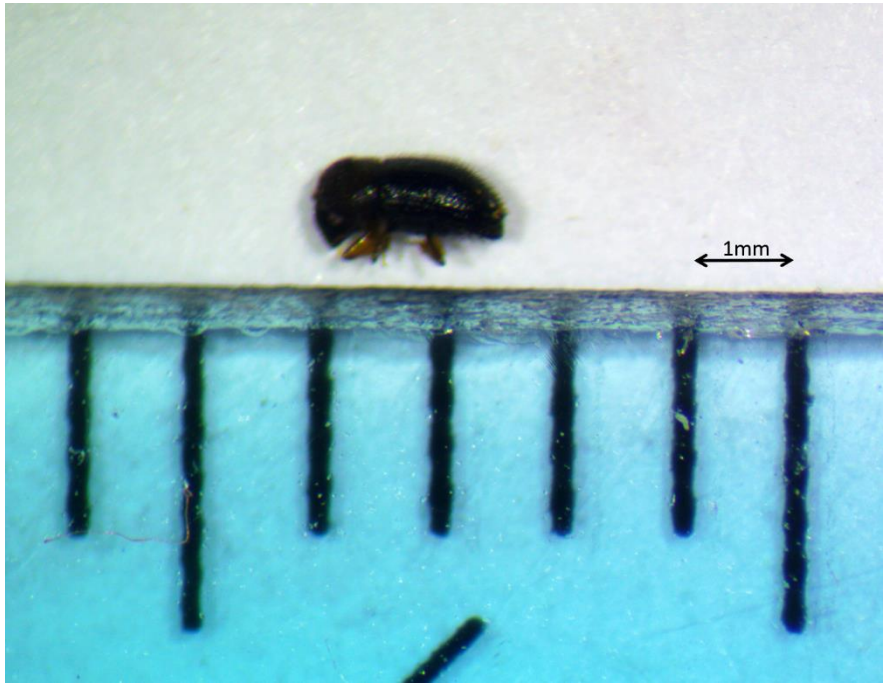


Resources

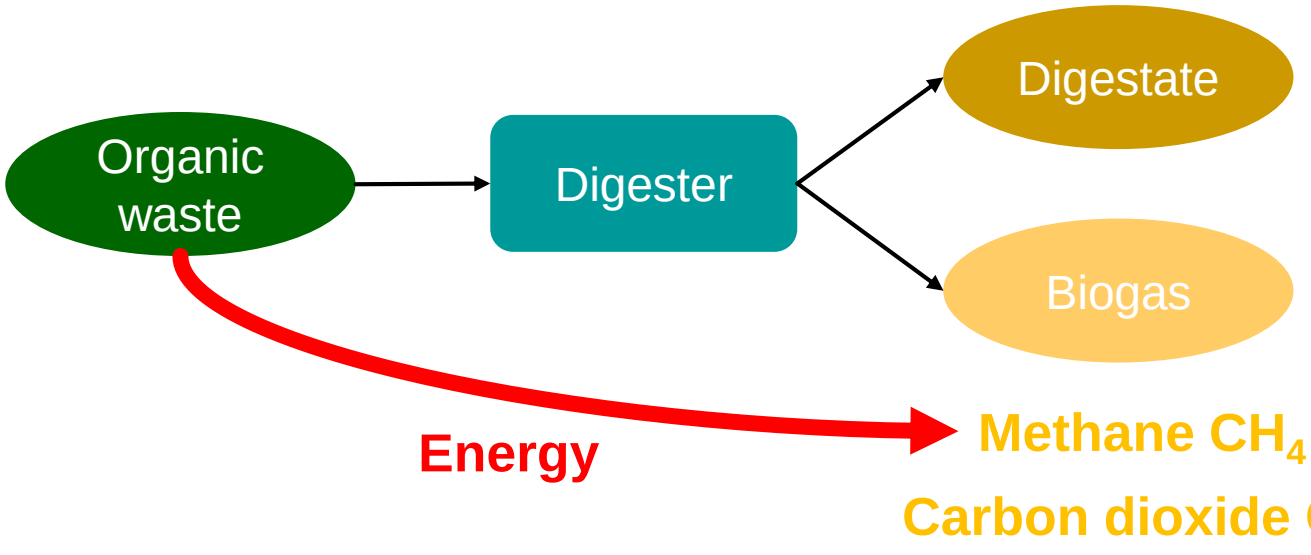


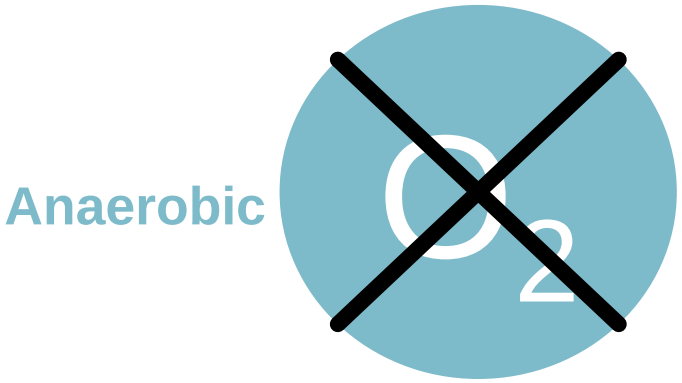
Potentials and Objectives of Organic Waste Treatment

- Closing of nutrient cycles
- Crop pest elimination – CBB
- Weed destruction
- Transport reduction
- Greywater treatment
- Prevention of odour development
- Affordability
- Usability of products/residues
- Applicability onto all organic waste fractions



Anaerobic Digestion





Feasibility Analysis

Climate	18°C – 29°C
Substrate	Available, suitable
Site	Accessible, developed, enough space, rocky
Anaerobic digester	OLR: 1.5kg VS/m^3/d, HRT: 42 d → **3.1 – 12.5 m^3**
Substrate Pre-processing	Storage for coffee processing waste, shredding
Biogas processing & storage	H_2O, H_2S, storage in bags and bottles
Digestate processing	Direct use as fertilizer
Costs	2’300 – 3’600 USD investment costs
Legal frame	Complex, no limitations, expert

Technical Concept / Assembly System

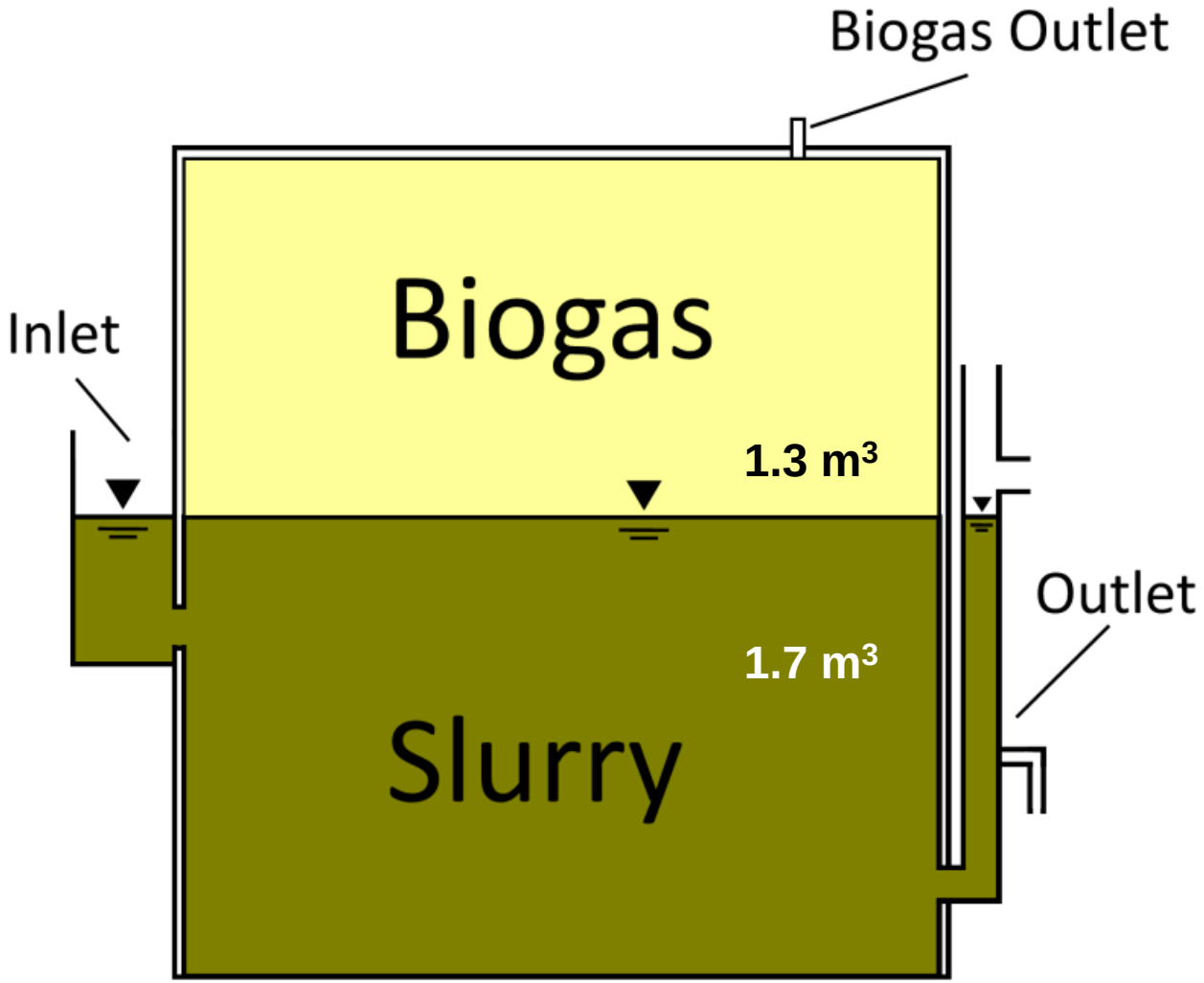
Parameter	Unit	
Active reactor volume	[m^3]	**1.7**
TS of feedstock	[%]	**7**
TS of organic waste	[%]	*40*
VS of organic waste	[%]	*90*
OLR	[$kgVS/m^3/d$]	**1.5**
HRT	[d]	**40**
Organic Waste input	[kg/d]	7.6
TS input	[kg/d]	2.8
VS input	[kg/d]	2.6
Water added	[l/d]	38
Total input	[l/d]	43
Processed organic waste fraction of present Scenario 3	[%]	65

Technical Concept / Assembly System

Assembly system		
Scenario 3 (50% Less Garden Waste)		
Biogas production	[Nm^3/d]	0.9
Biogas production	[kg/d]	1.1
Energy content	[kWh/d]	5.6
Electric energy content	[kWh/d]	1.7

Application	Biogas consumption rate [m^3/h]	Fraction of daily biogas production of assembly system [%]
Weed flaming	0.50	53
Refrigerator 100 l	0.05	5
Gas lamp	0.07	7
Electric generator per 746 W	0.42	45

Technical Concept / Assembly System



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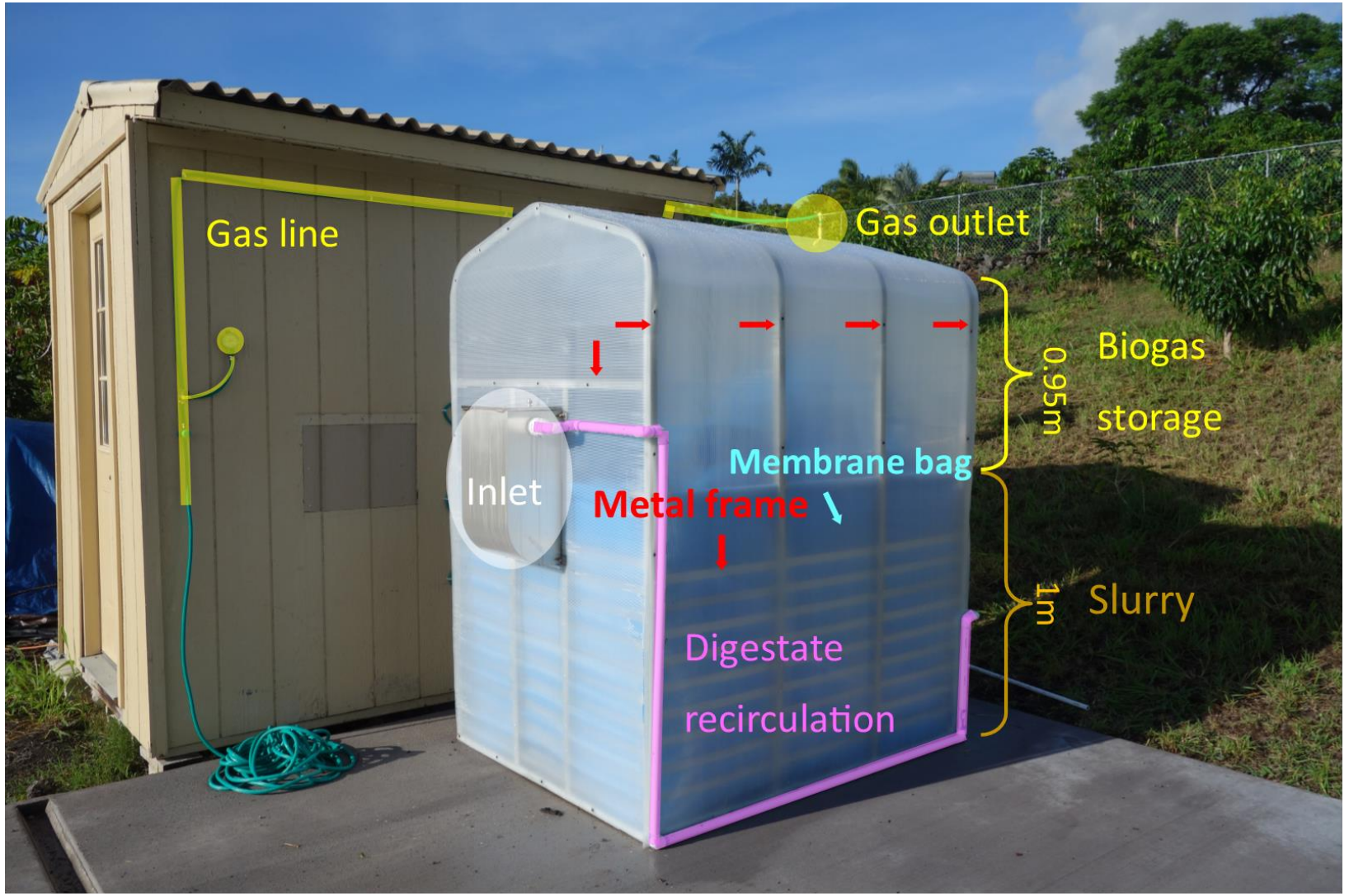

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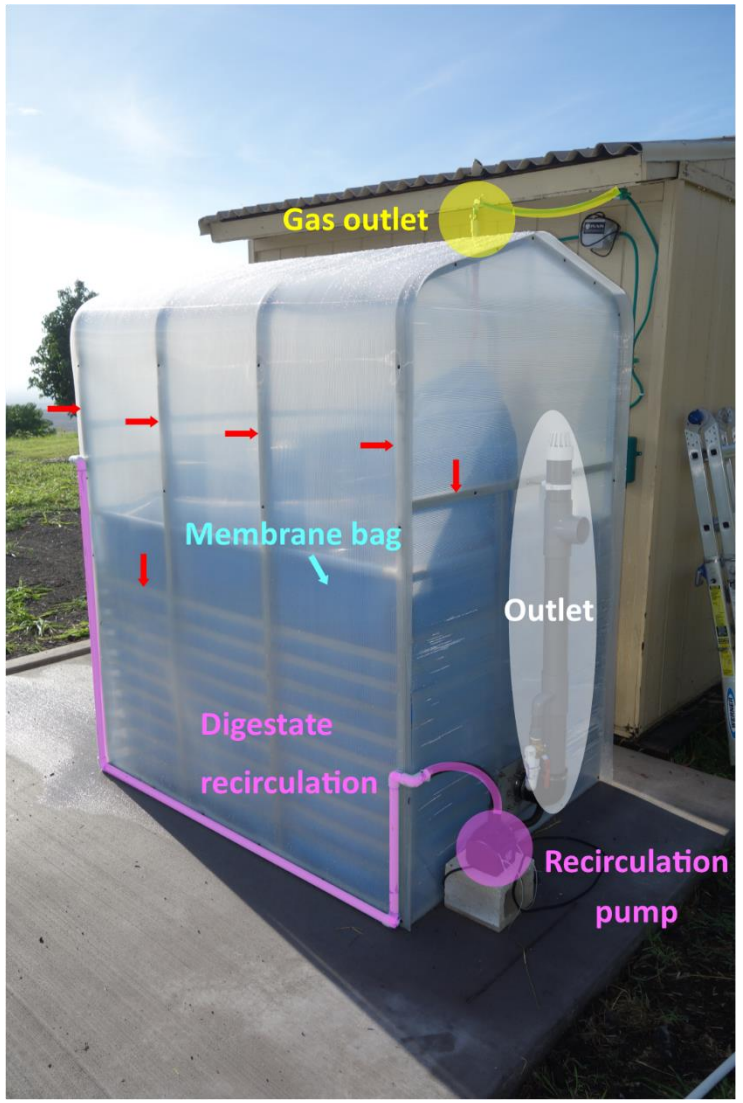
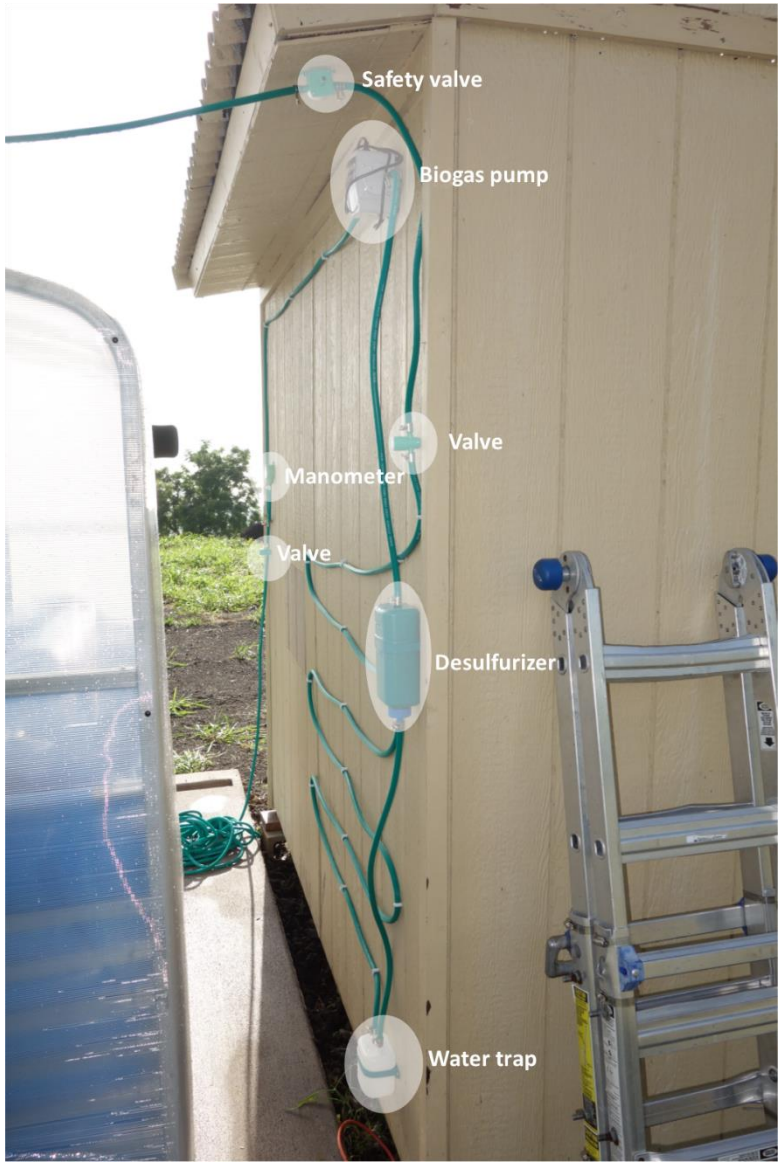
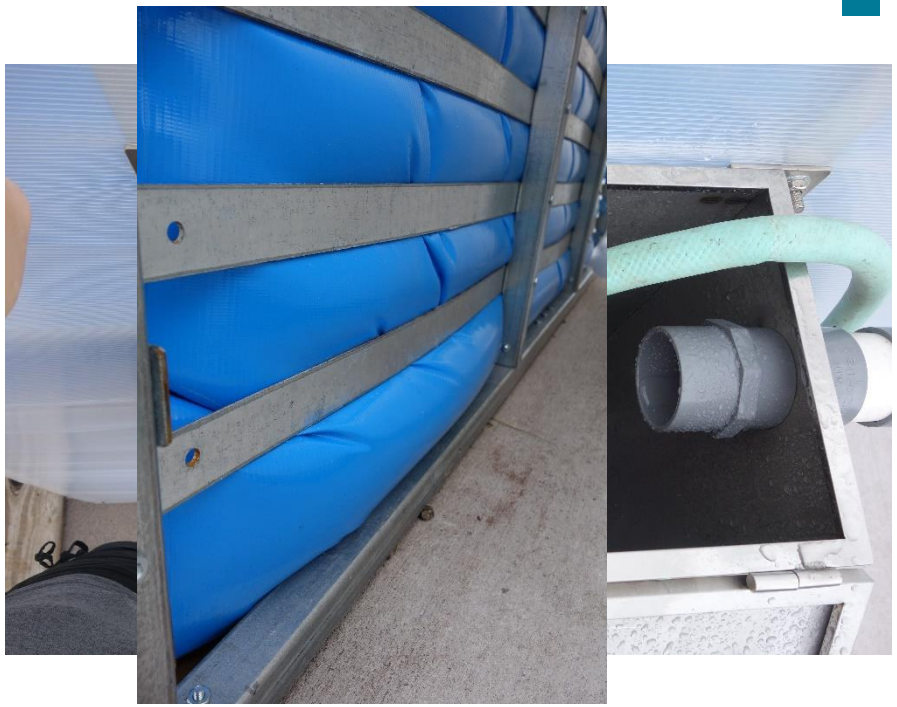


Technical Concept / Assembly System



Technical Concept / Assembly System

- 800 USD
- Administration ok
- Installation instruction ok except for gas applications
- Insufficient operation instructions
- Some improvements of digester design necessary
- Unrealistic operational parameters



	Target parameters	Producer Values	Producer Values
Substrate	Substrate Scenario 3	Food Waste	Vegetables
Active reactor volume [m3]	**1.7**	**1.7**	**1.7**
TS Feedstock [%]	**7**	12	9
OLR	**1.5**	2.9	4
HRT	**40**	34	19
Organic Waste [kg/d]	7.6	**25**	**65**

Costs and Benefits

Installation cost	[USD]
Assembly system	796.00
Assembly system shipping	865.00
Assembly system payment transfer	50.00
Biogas concrete slab	2'500.00
Small parts for construction	50.00
Sink for substrate pre-processing	197.00
Disposal system (Insinkerator)	217.00
Recirculation pump	100.00
Operation small parts	100.00
Total	**4'875.00**

Operation cost of electric applications.	[USD/a]
Disposal system	1.18
Recirculation pump	5.39
Biogas pump	1.05
Total	**7.62**

Operation cost	[USD/a]
Spare parts	50.00
Operation and maintenance work	2'737.50
Total	**2'787.50**

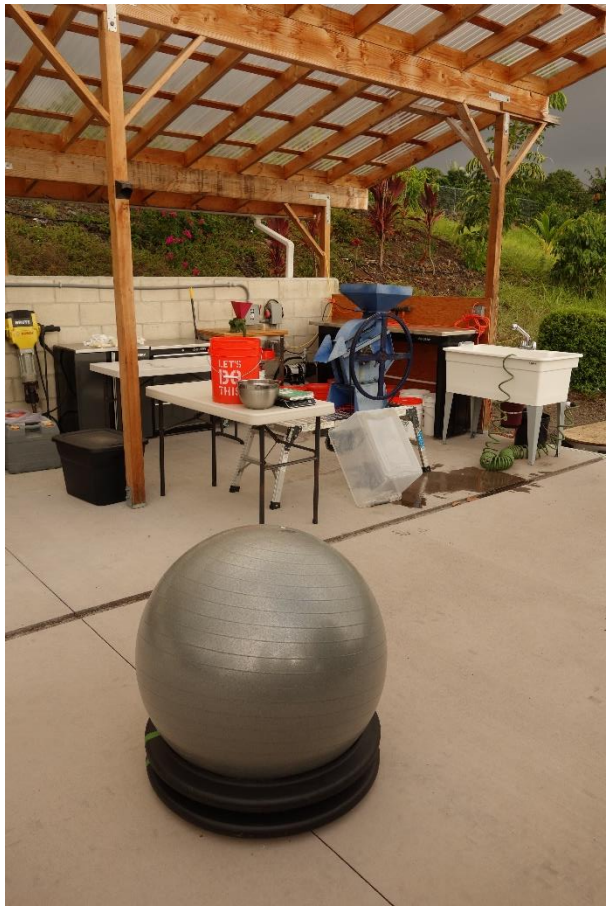
Benefits	[USD/a]
Additional fertilizer	n.v.
Treated coffee processing grey water	n.v.
Pest and weed destruction	n.v.
Substitution of flaming propane gas	300.00
Substitution of electricity	216.00
CBB mitigation	840.00
Reduced green waste transport distances	55.00
Total	**1'195.00**

Continuity

- Operator Manual
- Experts on Big Island and in Switzerland
- Follow-up projects on the model farm

Follow - up

- Stable operation
- Increase of feeding amount
- Structures optimized
- Gas used for cooking
- Gym ball as intermediate storage
- Trials for gas storage and use



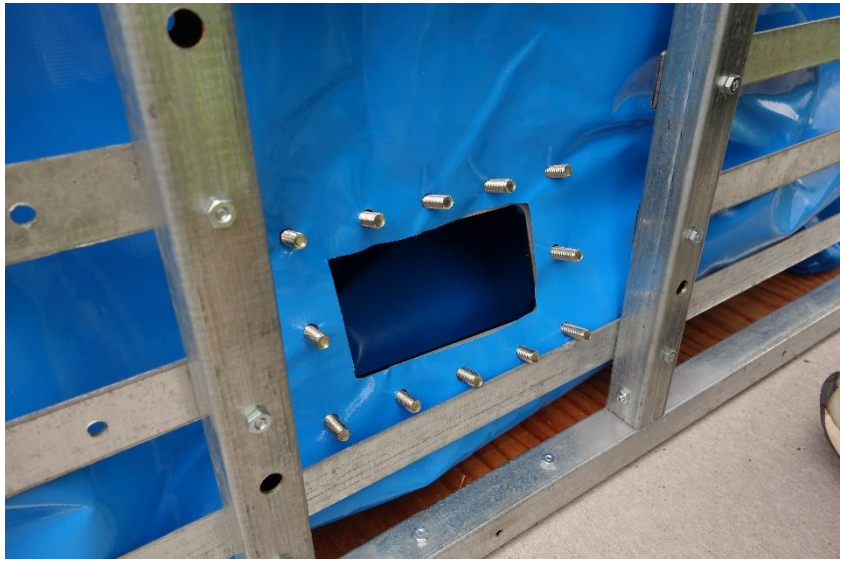
Conclusions & Outlook

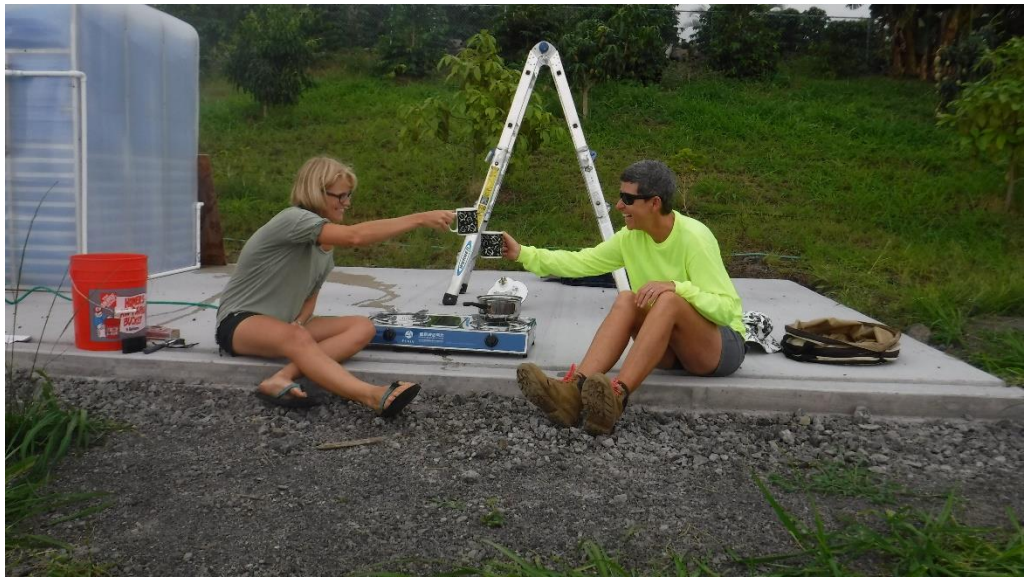
- Framework on Hawai'i island and on the model farm favours AD
- AD as a viable and valuable organic waste treatment technology
- Assembly systems are a good option

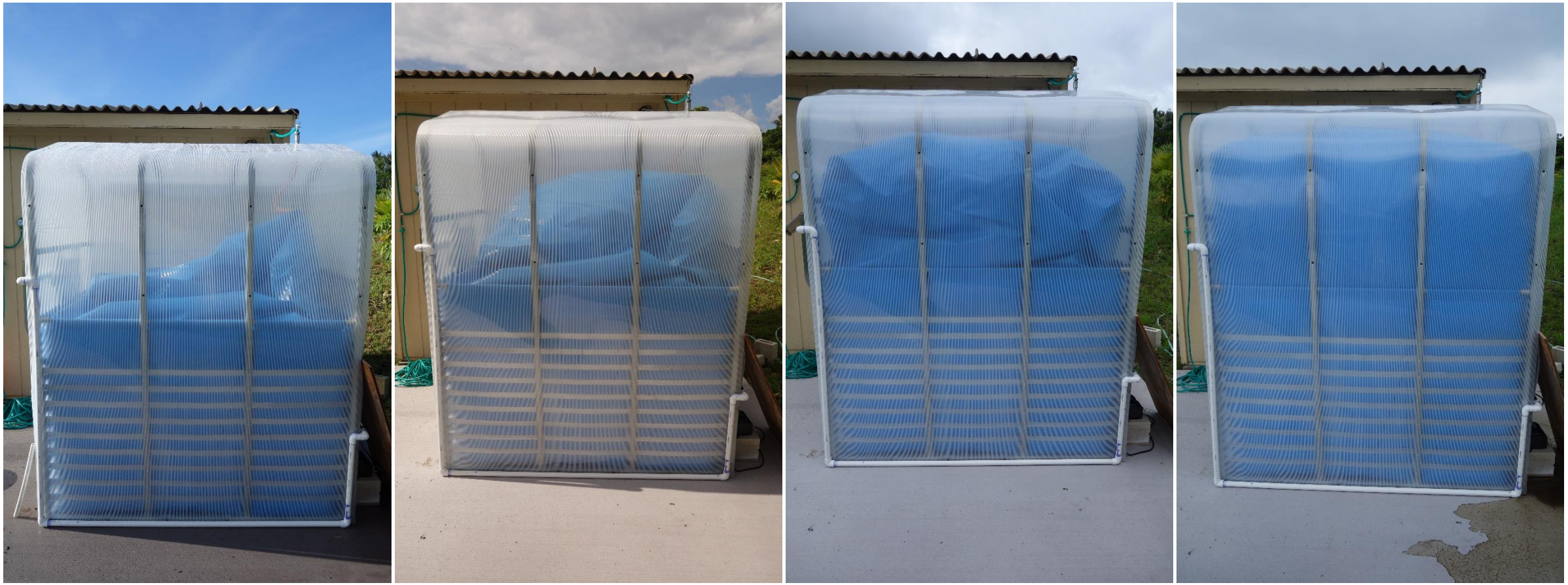
  → but there is room for improvements
- Basic data collected, overview on the farm and first implementations completed

  → consecutive work
- Follow-up projects
  - Monitoring
  - Reactor design
  - Biogas handling
  - …


LET'S
DO
THIS.







Feasibility Analysis

	Scenario 1 All Substrate	Scenario 2 Without Grass	Scenario 3 50% Less Plantation Waste
Present			
TS [kg/d]	10.3	9.7	5.2
VS [kg/d]	9.2	8.7	4.6
Water [m^3/d]	0.135	0.128	0.067
Total inflow [m^3/d]	0.147	0.138	0.074
Active reactor volume based on OLR [m^3]	**6.1**	**5.8**	**3.1**
Active reactor volume based on HRT [m^3]	5.9	5.5	3.0
Resulting HRT based on reactor volume defined by OLR [d]	42	42	42
Future			
TS [kg/d]	21.0	19.8	10.7
VS [kg/d]	18.8	17.7	9.6
Water [m^3/d]	0.275	0.261	0.139
Total inflow [m^3/d]	0.300	0.282	0.153
Active reactor volume based on OLR [m^3]	**12.5**	**11.8**	**6.4**
Active reactor volume based on HRT defined by OLR [m^3]	12.0	11.3	6.1
Resulting HRT based on reactor volume [d]	42	42	42

Feasibility Analysis

		Present			Future		
		Scenario 1	Scenario 2	Scenario 3	Scenario 1	Scenario 2	Scenario 3
		All Substrate	Without Grass	50% Less Plantation Waste	All Substrate	Without Grass	50% Less Plantation Waste
Biogas production	[Nm3/d]	5.4	5.0	2.7	11.0	10.2	5.4
Energy content	[kWh/d]	32.4	30.1	15.9	65.5	60.9	32.5
Electric energy content	[kWh/d]	9.7	9.0	4.8	19.7	18.3	9.8

Feasibility Analysis

Investment		Costs [USD]
Substrate/Digestate storage and handling	Buckets with lids, 10 pieces	45
Pre-treatment	Shredder/chipper (high TS)	950 - 1'300
	Shredder/"Insinkerator" (low TS)	200 - 370
Digester	Assembly system, 3 m^3, incl. basic gas treatment	750 - 1'500
Gas storage	Readily constructed, 1 m^3	50
Operation	Recirculation pump	100
Monitoring	Devices	200
Total investment costs	approximately	2'295 - 3'565

Operation		Costs [USD/a]
Energy	Electricity	negligible
	Fuel for transports	negligible
Maintenance	Spare parts, approx 5 % of invest.	100 - 200
Personnel	Operation and control, 230 h/a, 15 USD/h	3'750
Total operation costs	with personnel costs	3'850 - 3'950
	without personnel costs	100 - 200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Lifestyle in Comfort!
AD Systems