

## **Machbarkeitsstudie Biogas in Togo/Ghana (Phase 1)**

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# Objectives

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- Overview-like quantification of relevant biogenic by-products from agriculture and food waste in Togo and Ghana.
- Screening of the spatial distribution of the three most important crops in Togo and Ghana.
- Identification and evaluation of country-specific biogas technology and gas utilisation options.
- Contextualizing the results for concrete application purposes.

# Agenda

# Agenda

**Biogenic residues**



Country specific **technology**



Country specific **gas conversion**



**Context**

# Output

# Output

## Overview



### WORKING DOCUMENTS

1. DBFZ Country Profile Togo (PDF)
2. DBFZ Country Profile Ghana (PDF)
3. Presentation (PPT)
4. Accompanying Document (PDF)

### DIGITAL

All documents in digital version

# Output

## Country Profile (13 pages), example Togo (pages 1-6)



Land Cover

Key information on population, economy, land use and energy

Investigated biomasses

Crops

Livestock

**SCREENING: BIOMETHANE FROM RESIDUES - TOGO - 2016 (RESIDUES)**

**CONTENT**

1. What is the current land use of the country? Page 1
2. How has selected key information on population, economy, land use and energy developed in recent years? Page 1
3. What is the theoretical biomass available as potential of all investigated residues in each of the main crop categories (i.e. those that are important to be targeted)? Page 2
4. What are the most relevant residues (including residual of agricultural main products, animal manure and food and feed waste) in terms of biomass availability per year? Page 2
5. Which residues have not been investigated, but are of great interest? Page 2
6. What are the most relevant agricultural main products in terms of quantity and how much of the total crop production of the country do they represent? Page 3
7. Which animal manure can be classified for the TOP 10 Agricultural main products and which potential yield? Page 3
8. What are the main livestock species and how much manure do they produce? Page 4
9. How much food waste is produced theoretically? Page 4
10. What is the need for the production of the most important crop and where are the production regions for producing the related biomass? Page 5
11. What are the main areas for further 'upstream' and 'downstream' investigations? Page 5
12. Which crop technologies were considered and what are the characteristics of these technologies? Page 5
13. Which livestock manure were considered and how high is the theoretical potential biomass in this sector? Page 6
14. Are there any food and feed wastings for cooking (EU) residues per year? Page 6
15. Which crop categories were considered and what are the characteristics of these residues? Page 10

**REMARK**

This document 'Screening: Biomethane from residues' is a very first and quick look-up overview of available information on biomass resources in the selected country/region. Results are based on available, historical or average and calculated values (DBFZ-database). The document content of information has to be updated and confirmed by calculations. Because our database data the results have to be interpreted with the same means of uncertainties: The calculation results are underestimations.

**SCREENING: BIOMETHANE FROM RESIDUES - TOGO - 2016 (RESIDUES)**

**KEY FIGURES**

Based on FAO/DFZ, Global Biomass, CROCIRES and Global Carbon Project

RESIDUES	THEORY	POTENTIAL	AVAILABILITY	RESIDUE	THEORY	POTENTIAL	AVAILABILITY
<b>AGRICULTURE</b>	1.000.000	2.000	200	100%	100%	100%	100%
Animal manure	1.000.000	2.000	200	100%	100%	100%	100%
Food and feed waste	1.000.000	2.000	200	100%	100%	100%	100%
<b>LIVESTOCK</b>	1.000.000	2.000	200	100%	100%	100%	100%
<b>THEORETICAL BIOMETHANE POTENTIAL FROM RESIDUES</b>	1.000.000	2.000	200	100%	100%	100%	100%

**THEORETICAL BIOMETHANE POTENTIAL FROM RESIDUES**

Indicated production range in GWh/annum

THEORY	37 PJ/ha* (15kg)	CHERRAL
100%	20 million	1.300.000 t
50%	10 million	650.000 t
25%	5 million	325.000 t
10%	2 million	130.000 t

\*Conversion factor: 1 GWh = 37 PJ

Possible contribution to the renewable energy system

**SCREENING: BIOMETHANE FROM RESIDUES - TOGO - 2016 (RESIDUES)**

**LIST OF INVESTIGATED BIOMASSES - 2017**

Based on FAO/DFZ, Global Biomass, CROCIRES and Global Carbon Project

RESIDUES	THEORY	POTENTIAL	AVAILABILITY	RESIDUE	THEORY	POTENTIAL	AVAILABILITY
Animal manure	1.000.000	2.000	200	100%	100%	100%	100%
Food and feed waste	1.000.000	2.000	200	100%	100%	100%	100%
Not investigated but of great interest	1.000.000	2.000	200	100%	100%	100%	100%

**NOT INVESTIGATED BUT OF GREAT INTEREST**

Energy yield: Energy yield from public waste treatment  
 Potential yield: Theoretical yield from agricultural waste

Not investigated biomasses

**SCREENING: BIOMETHANE FROM RESIDUES - TOGO - 2016 (RESIDUES)**

**TOP 10 AGRICULTURAL MAIN PRODUCTS - 2017**

Based on FAO/DFZ

AGRICULTURAL MAIN PRODUCTS	AREA	PRODUCTION	THEORY	POTENTIAL	AVAILABILITY
1. Cotton	240.000 ha	1.000.000 t	100%	100%	100%
2. Maize	1.000.000 ha	1.000.000 t	100%	100%	100%
3. Rice	1.000.000 ha	1.000.000 t	100%	100%	100%
4. Sorghum	1.000.000 ha	1.000.000 t	100%	100%	100%
5. Millet	1.000.000 ha	1.000.000 t	100%	100%	100%
6. Peanut	1.000.000 ha	1.000.000 t	100%	100%	100%
7. Cowpea	1.000.000 ha	1.000.000 t	100%	100%	100%
8. Soybean	1.000.000 ha	1.000.000 t	100%	100%	100%
9. Sesame	1.000.000 ha	1.000.000 t	100%	100%	100%
10. Sunflower	1.000.000 ha	1.000.000 t	100%	100%	100%

**RESIDUES RELATED TO MAIN PRODUCTS - 2017**

Based on FAO/DFZ and Biomass

MAIN PRODUCTS	RELATED RESIDUES THEORY	RELATED RESIDUES POTENTIAL	AVAILABILITY	THEORY	POTENTIAL	AVAILABILITY
Animal manure	1.000.000	2.000	200	100%	100%	100%
Food and feed waste	1.000.000	2.000	200	100%	100%	100%

Agricultural residues

**SCREENING: BIOMETHANE FROM RESIDUES - TOGO - 2016 (RESIDUES)**

**TOP 10 ANIMAL MANURE - 2017**

Based on FAO/DFZ and Biomass

ANIMAL MANURE	THEORY	POTENTIAL	AVAILABILITY	RESIDUE	THEORY	POTENTIAL	AVAILABILITY
1. Cattle	1.000.000	2.000	200	100%	100%	100%	100%
2. Pig	1.000.000	2.000	200	100%	100%	100%	
3. Sheep	1.000.000	2.000	200	100%	100%	100%	
4. Goat	1.000.000	2.000	200	100%	100%	100%	
5. Horse	1.000.000	2.000	200	100%	100%	100%	
6. Donkey	1.000.000	2.000	200	100%	100%	100%	
7. Mule	1.000.000	2.000	200	100%	100%	100%	
8. Buffalo	1.000.000	2.000	200	100%	100%	100%	
9. Camel	1.000.000	2.000	200	100%	100%	100%	
10. Rabbit	1.000.000	2.000	200	100%	100%	100%	

**FOOD WASTE - 2017**

Based on FAO/DFZ and Biomass

Population: 7.700.000  
 Municipal solid waste: 0,27 t/capita  
 Packaging: 0,08 t/capita

Food waste

# Output

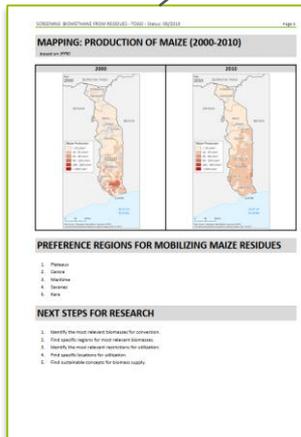
## Country Profile (13 pages), example Togo (pages 7-12)



Top crop:  
area of cultivation

Potential feedstock  
mixtures

Potential biogas systems

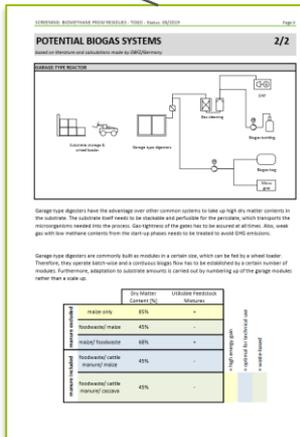
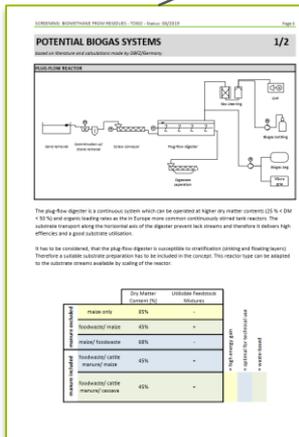


COMPARISON OF BIOGAS TECHNOLOGIES

Technology	CHP	CHP+H <sub>2</sub>	CHP+H <sub>2</sub> +H <sub>2</sub> O	CHP+H <sub>2</sub> +H <sub>2</sub> O+H <sub>2</sub>	CHP+H <sub>2</sub> +H <sub>2</sub> O+H <sub>2</sub> +H <sub>2</sub>
Substrate	++	++	++	++	++
Production cost	++	++	++	++	++
Energy efficiency	++	++	++	++	++
Flexibility	++	++	++	++	++
Scale	++	++	++	++	++

POTENTIAL FEEDSTOCK MIXTURES

Feedstock	CHP	CHP+H <sub>2</sub>	CHP+H <sub>2</sub> +H <sub>2</sub> O	CHP+H <sub>2</sub> +H <sub>2</sub> O+H <sub>2</sub>	CHP+H <sub>2</sub> +H <sub>2</sub> O+H <sub>2</sub> +H <sub>2</sub>
Maize	++	++	++	++	++
Wheat	++	++	++	++	++
Rice	++	++	++	++	++



ASSESSMENT OF GAS UTILISATION

Product	CHP	CHP+H <sub>2</sub>	CHP+H <sub>2</sub> +H <sub>2</sub> O	CHP+H <sub>2</sub> +H <sub>2</sub> O+H <sub>2</sub>	CHP+H <sub>2</sub> +H <sub>2</sub> O+H <sub>2</sub> +H <sub>2</sub>
Electricity	++	++	++	++	++
Heat	++	++	++	++	++
Hydrogen	++	++	++	++	++
Water	++	++	++	++	++

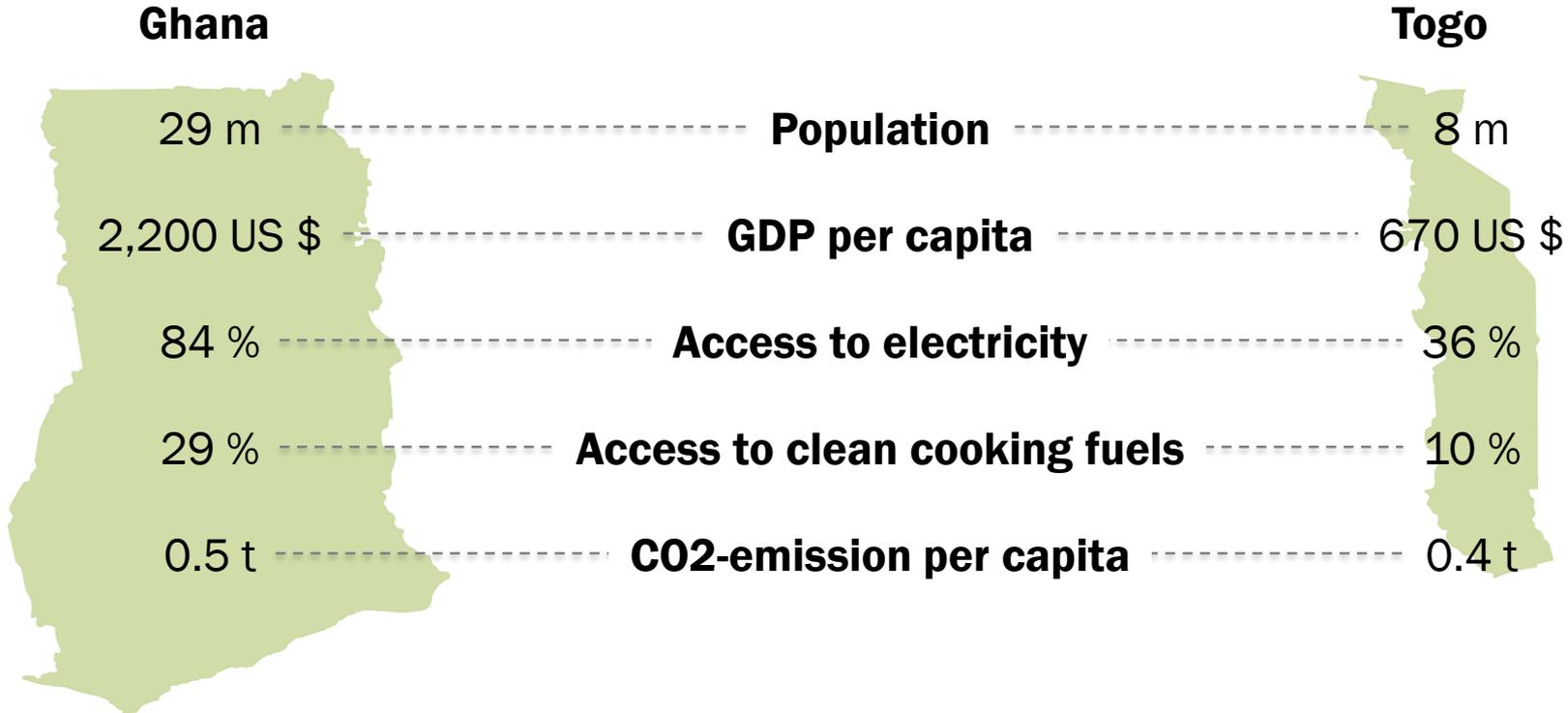
Regional hot-spots

Regional specific  
biogas technologies

Options for gas  
utilisation

# Key information about Togo & Ghana

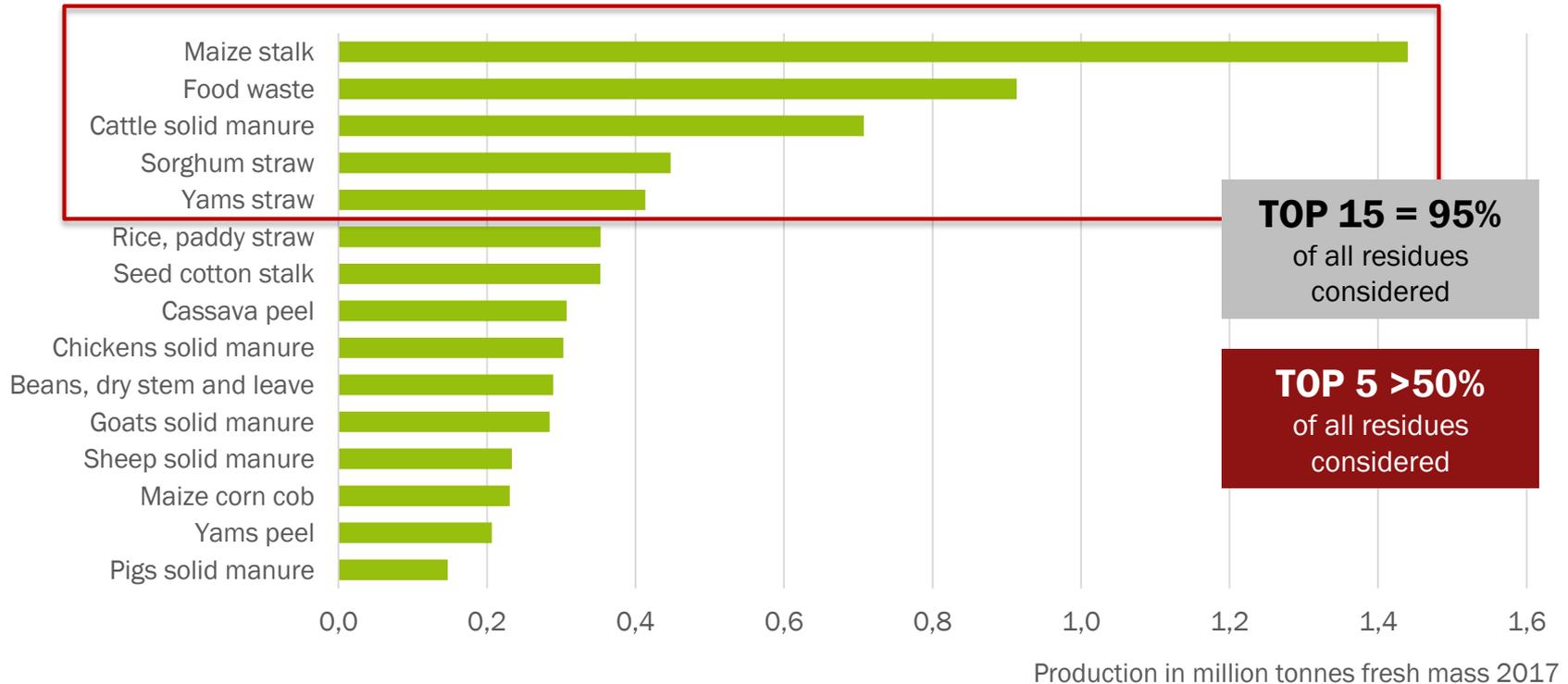
# General Information



## Results: Resource Screening Togo

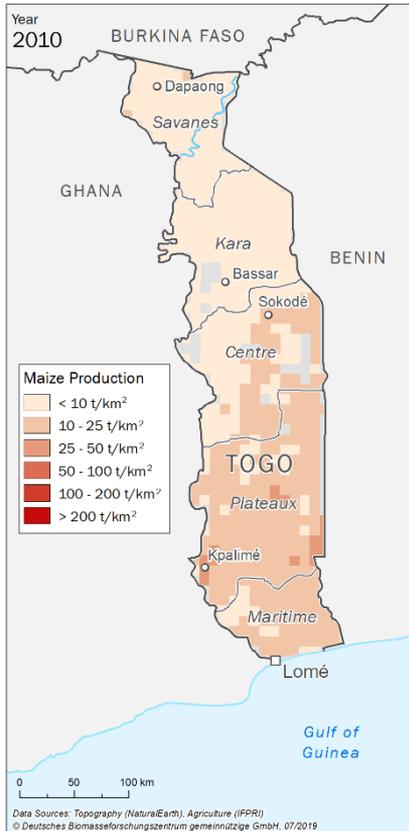
# Resource Screening Togo

## Top 15 Residues (2017)



# Maize Production

## Spatial distribution

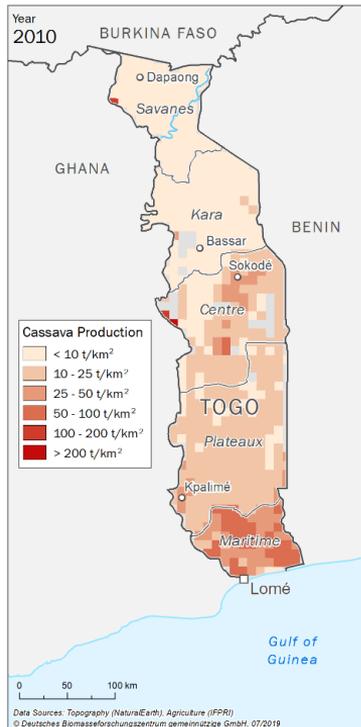


- Main concentration of maize production in southern regions *Maritime* and *Plateaux* as well as in eastern parts of *Centre*.
- Homogeneous distribution of production volumes in cultivation areas.
- Occasional intensification of production between 2000 and 2010.
- Decline in production in northern Maritime region.

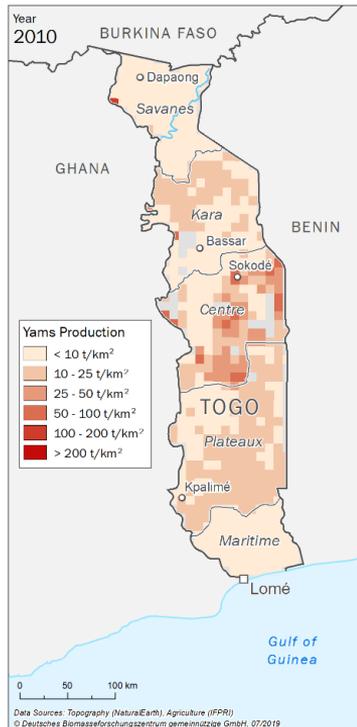
# Agricultural residues

## Variations between regions

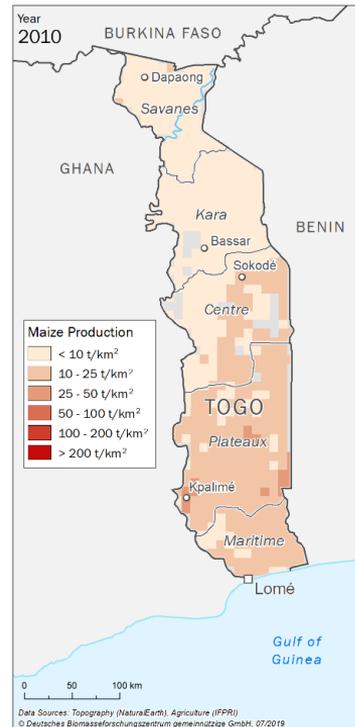
### Cassava



### Yams



### Maize

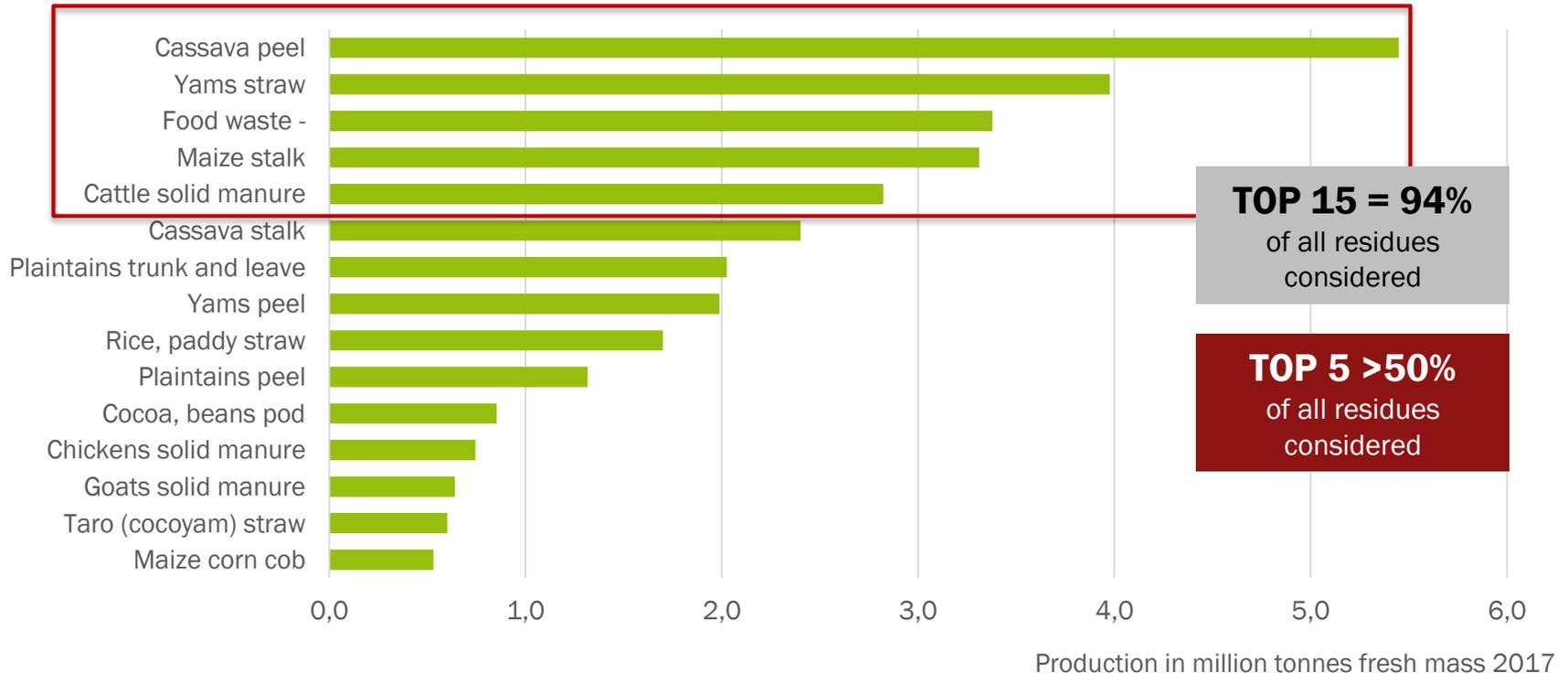


- **Cassava:** primary production in southern areas
- **Yams:** strong concentration of production in Centré
- **Maize:** main production in southern areas as well as eastern parts of Centré region

# Results: Resource Screening Ghana

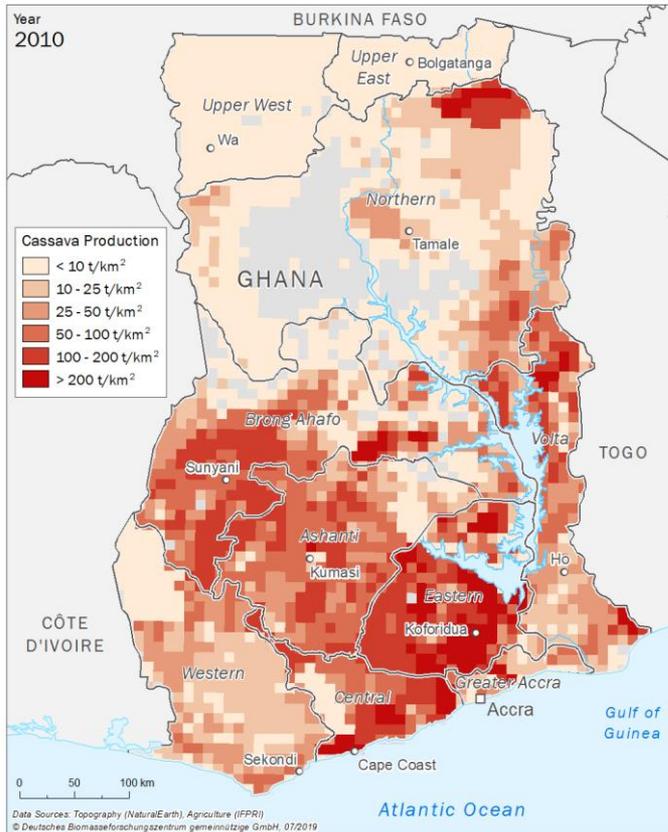
# Resource Screening Ghana

## Top 15 Residues (2017)



# Cassava Production

## Spatial distribution



- The primary cassava production is concentrated in southern parts of Ghana, especially in *Eastern, Ashanti* and *Brong Ahafo* regions.
- Additional hot-spots can also be found in *Volta* and *Central* region as well as in north-eastern parts of *Northern* region.
- Significant intensification of production between 2000 and 2010.



# Results: Technology Screening

## Deduction of technologies

### 1. Definition of main components

- feedstock treatment
- digestion
- gas conversion

### 2. Specification of evaluation criteria

- *OPEX*: Operating expenses
- *CAPEX*: Capital expenses
- *Labor*: expenditure of human labour
- *Complexity*: operational and technological complexity of the components
- *Durability*: durability and maintenance requirements
- *Yield*: Yield considering conversion efficiency

### 3. Qualitative evaluation (based on three differentiation levels)

# Technology (Ghana/Togo)



SYSTEM MODULE	OPEX	CAPEX	LABOUR	COMPLEXITY	DURABILITY	YIELD
<b>FERMENTATION</b>						
<i>Continuously stirred tank reactor</i>	+	+++	+	+++	++	++
<i>Plug-flow reactor</i>	+	+++	+	++	++	+++
<i>Garage-type reactor</i>	++	++	+++	++	+++	+
<i>Membrane reactor</i>	++	++	++	+	+	+
<i>Fixed-dome reactor</i>	+	+	++	++	+++	+
<b>BIOGAS TREATMENT</b>						
<i>Desulphurisation</i>						
Biological	+	+++	+	+	++	
Chemical	+++	+	++	++	+++	
<b>BIOGAS CONVERSION</b>						
<i>CHP engine</i>	+	++	++	+++	++	+++
<i>Biomethane upgrading</i>	++	+++	+	+++	++	++
<i>Microgas grid</i>	+	++	+	++	+++	+++
<i>Biogas Bottling</i>	+++	++	+++	++	++	+
<i>Biogas Bag</i>	+	+	+++	+	+	++
	+ low	++ medium	+++ high			

- Qualitative evaluation of gas-conveying components

# Technology (Ghana/Togo)



SYSTEM MODULE	OPEX	CAPEX	LABOUR	COMPLEXITY	DURABILITY	YIELD
<b>BIOMASS RECEPTION / PRETREATMENT</b>						
<i>Settling tank</i>	+	+	+	+	+++	+
<i>Chopper</i>						
Swash plate	++	++	++	++	++	++
Flail chopper	++	++	++	+++	++	++
<i>Grinder</i>						
Ball mill	++	+++	+	+	+++	++
Roller mill	++	+++	+	+	+++	+++
<b>DIGESTATE TREATMENT</b>						
<i>Drying</i>						
Solar	+	+	+	+	+++	
Aux. Heat (e.g. CHP)	++	+++	++	+++	++	
<i>Separation</i>						
Screw press	+	++	+	++	+++	
Belt press	++	++	+	++	++	
Centrifuge	+++	+++	++	+++	++	
Sieve	+	+	+++	+	+++	
	+ low	++ medium	+++ high			

- Qualitative evaluation of feedstock components (feedstock treatment)

# Feasible feedstock mixtures

## Deduction of mixtures

### 1. Two main Groups:

- manure excluded
- manure included

### 2. Three sub groups

- high energy gain feedstock
- optimal for technical utilisation
- waste-based (foodwaste)

### 3. Constraints

- real availability
- unaccounted demand for other utilization
- logistics

# Feasible feedstock mixtures

## Ghana



Ghana

FEEDSTOCK MIX											
	typ	ammount t FM / a	dry matter content	total biomethan yield 1.000 m <sup>3</sup> / a	primary energy yield		energy potential use ratio	component		ratio	ammount t FM / a
					PJ / a	ktoe / a					
manure excluded	cassava only	5.448.875	80%	1.407.989	51	1.207	31%	Cassava	peel	100%	5.448.875
	plantains/cassava	3.910.584	45%	541.027	19	464	12%	Plantains	trunk and leave	52%	2.025.315
								Cassava	peel	48%	1.885.269
	foodwaste/cassava	3.860.966	45%	461.899	17	396	10%	Food waste	waste	87%	3.378.148
Cassava								peel	13%	482.818	
foodwaste/plantains/cassava	7.763.966	45%	1.000.966	36	858	22%	Food waste	waste	44%	3.378.148	
							Plantains	trunk and leave	26%	2.025.315	
							Cassava	peel	30%	2.360.503	
manure included	cassava/cattle manure	8.271.249	61%	1.547.697	56	1.327	34%	Cassava	peel	66%	5.448.875
								Cattle	solid manure	34%	2.822.374
	cassava/cattle manure	4.433.453	45%	556.010	20	477	12%	Cassava	peel	36%	1.611.079
								Cattle	solid manure	64%	2.822.374
	foodwaste/cattle manure/cassava	8.292.715	45%	1.017.469	37	872	23%	Food waste	waste	41%	3.378.148
								Cattle	solid manure	34%	2.822.374
								Cassava	peel	25%	2.092.193

= high energy gain  
 = optimal for technical use  
 = waste-based

# Feasible feedstock mixtures

## Togo



Togo

FEEDSTOCK MIX											
	typ	ammount	dry matter content	total biomethan yield	primary energy yield		energy potential use ratio	component		ratio	ammount
		t FM / a		1.000 m <sup>3</sup> / a	PJ/a	ktoe /a				t FM / a	
manure excluded	maize only	1.440.151	85%	328.066	12	281	32%	Maize	stalk	100%	1.440.151
	foodwaste/Maize	1.027.214	45%	94.198	3	81	8%	Food waste	waste	89%	913.578
								Maize	stalk	11%	113.636
maize/foodwaste	1.027.214	68%	129.483	5	111	14%	Food waste	waste	39%	913.578	
							Maize	stalk	61%	1.440.151	
manure included	foodwaste/cattle manure/maize	2.088.961	45%	232.771	8	200	22%	Food waste	waste	44%	913.578
								Cattle	solid manure	34%	707.550
								Maize	stalk	22%	467.833
	cattle manure/chicken manure/maize	1.587.833	45%	176.276	6	151	16%	Chicken	solid manure	19%	303.050
								Cattle	solid manure	45%	707.550
							Maize	stalk	36%	577.233	

= high energy gain  
 = optimal for technical use  
 = waste-based

# Country-specific technology

## Deduction of concepts



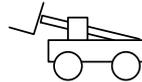
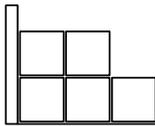
1. Identification of suitable digestion technologies
  - intersection of the requirements for digestion technology with feedstock properties
  - country and feedstock-specific evaluation
2. Evaluation of gas conversion
  - operators level of qualification
  - grid integration
  - spatial integration
  - commercialisation
  - competitive product

# Country-specific technology

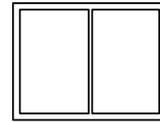
## Box digester

- Box digester in discontinuous operation mode
- Low complex technology
- High expenditure of human labour
- Suitable for high dry matter contents
- insensitive on extraneous material

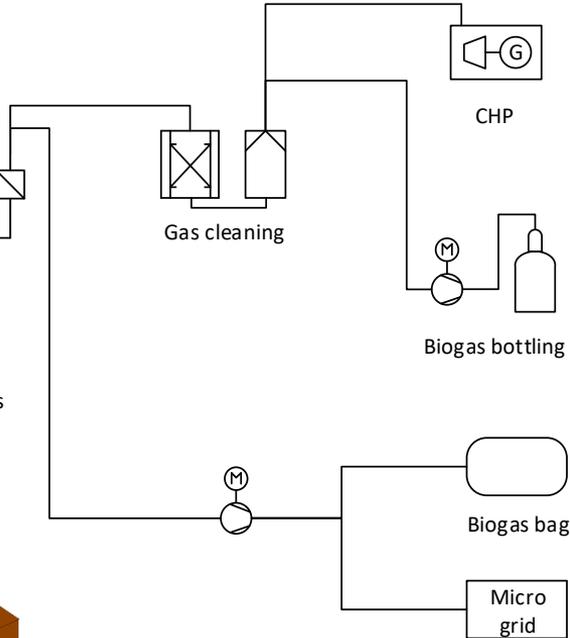
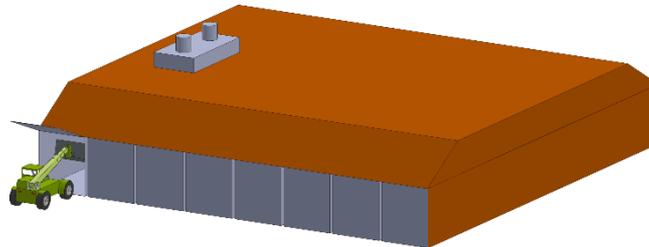
Ghana		TM-Gehalt	Nutzbares Substrat
manure excluded	cassava only	80%	+
	plantains/cassava	45%	-
	foodwaste/cassava	45%	-
	foodwaste/plantains/cassava	45%	-
manure included	cassava/cattle manure	61%	+
	cassava/cattle manure	45%	-
	foodwaste/cattle manure/cassava	45%	-
Togo			
manure excluded	maize only	85%	+
	foodwaste/Maize	45%	-
	maize/foodwaste	68%	+
manure included	foodwaste/cattle manure/maize	45%	-
	cattle manure/chicken manure/maize	45%	-



Substrate storage & wheel loader



Garage type digesters



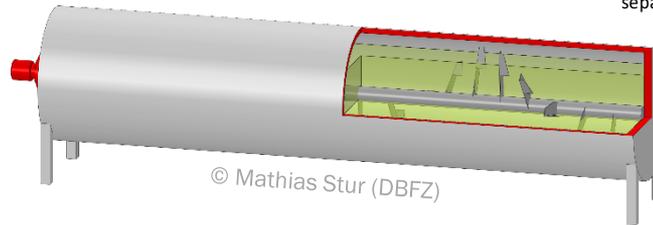
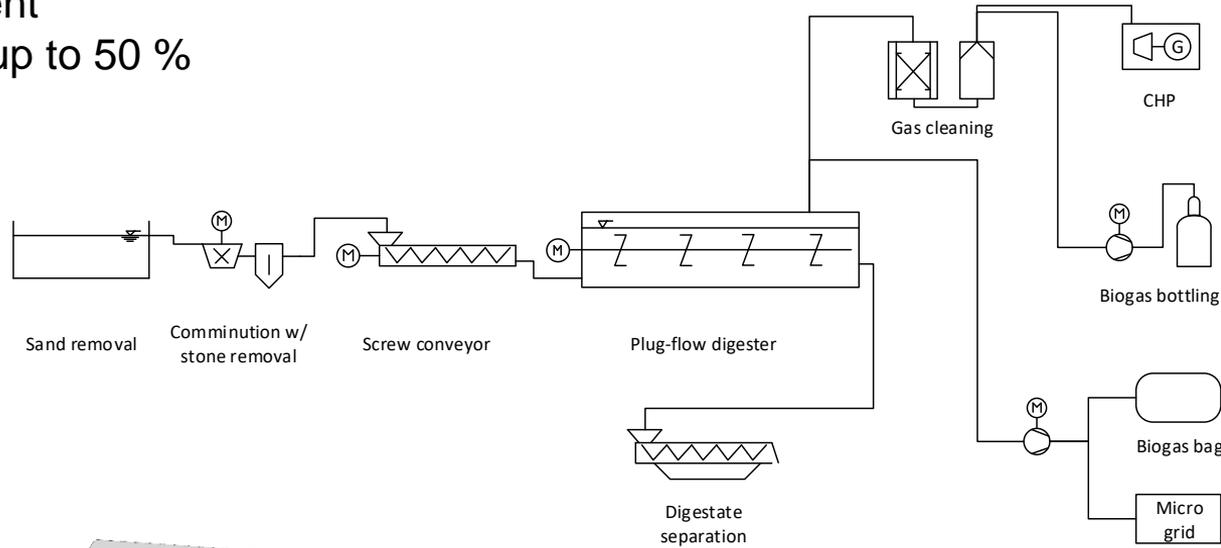
= high energy gain  
 = optimal for technical use  
 = waste-based

# Country-specific technology

## Plug-flow-digester

- Plug-flow-digester in continuous operation mode
- State of the art for waste treatment
- Suitable for dry matter contents up to 50 %
- Sensitive on extraneous material

		TM-Gehalt	Nutzbares Substrat
<b>Ghana</b>			
manure excluded	cassava only	80%	+
	plantains/cassava	45%	+
	foodwaste/cassava	45%	+
	foodwaste/plantains/cassava	45%	+
manure included	cassava/cattle manure	61%	-
	cassava/cattle manure	45%	+
	foodwaste/cattle manure/cassava	45%	+
<b>Togo</b>			
manure excluded	maize only	85%	-
	foodwaste/Maize	45%	+
	maize/foodwaste	68%	-
manure included	foodwaste/cattle manure/maize	45%	+
	cattle manure/chicken manure/maize	45%	+
= high energy gain = optimal for technical use = waste-based			



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# Country-specific technology

## Gas conversion options



Evaluation of gas conversion options (personal/grid/spatial/commercialisation)

	CHP engine	Biomethan upgrading	Biogas botteling	Biogas Bag	Microgas grid
<b>Personal requirements</b>					
Complexity	++	+++	++	+	++
Operators level of qualification	++	+++	++	+	++
<b>Grid ability</b>					
On grid operation	+++	+++	+	+	+
Off grid operation	+++	+	+++	+++	+++
<b>Spatial integration</b>					
Long distance Supply	+	+++	+	+	+
Municipal supply	+++	+++	+++	+	++
Rual supply	++	+	+++	+++	+++
<b>Commercialisation</b>					
Products	electricity and heat	biomethan and carbon dioxide	gas cylinder with biogas for universal purpose	biogas bag with biogas as cooking gas	cooking gas
Sector of economy	industrial and household	industrial and household	household and traffic	household	household
Cost of production	+++	+++	++	+	++
Competitive product	petroleum gas, gasoline, diesel	petroleum gas	charcoal, petroleum gas, gasoline, diesel	charcoal	charcoal, petroleum gas
	+	low	++	medium	+++
					high

# Contextualisation

# Contextualisation

## Togo



Potential TPES		<b>37 PJ* - What does that mean?</b>	
<b>37 PJ*</b>		Gas cylinders (15kg)	Charcoal
Mobilisation rate	100%	50 million	1.300.000 t
	50%	25 million	650.000 t
	25%	13 million	325.000 t
	10%	5 million	130.000 t

could be filled                      or                      could be replaced

\*Conversion losses not considered

lower heating value methane:  
49 MJ/kg

lower heating value charcoal:  
28 MJ/kg

# Contextualisation

## Ghana



Potential TPES		163 PJ* - What does that mean?	
163 PJ*		Gas cylinders (15kg)	Charcoal
Mobilisation rate	100%	220 million	5.800.000 t
	50%	110 million	2.900.000 t
	25%	55 million	1.450.000 t
	10%	22 million	58.000 t

could be filled or could be replaced

\*Conversion losses not considered

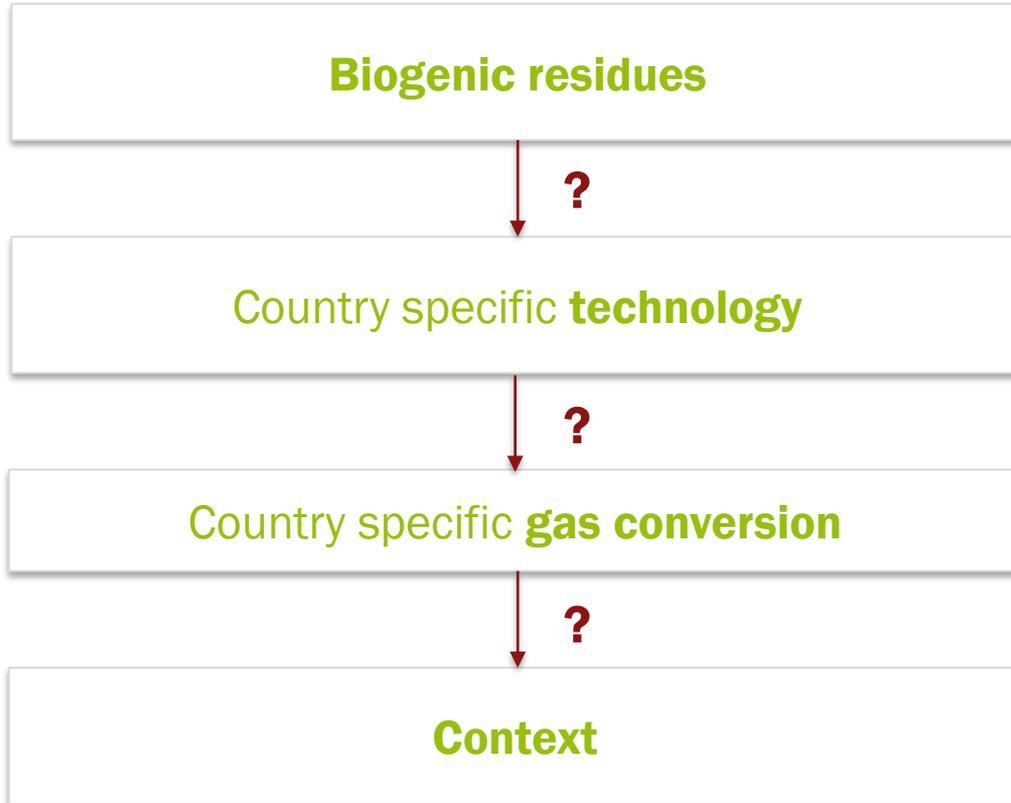
lower heating value methane:  
49 MJ/kg

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28 MJ/kg

## Summary & Next Steps

# Summary

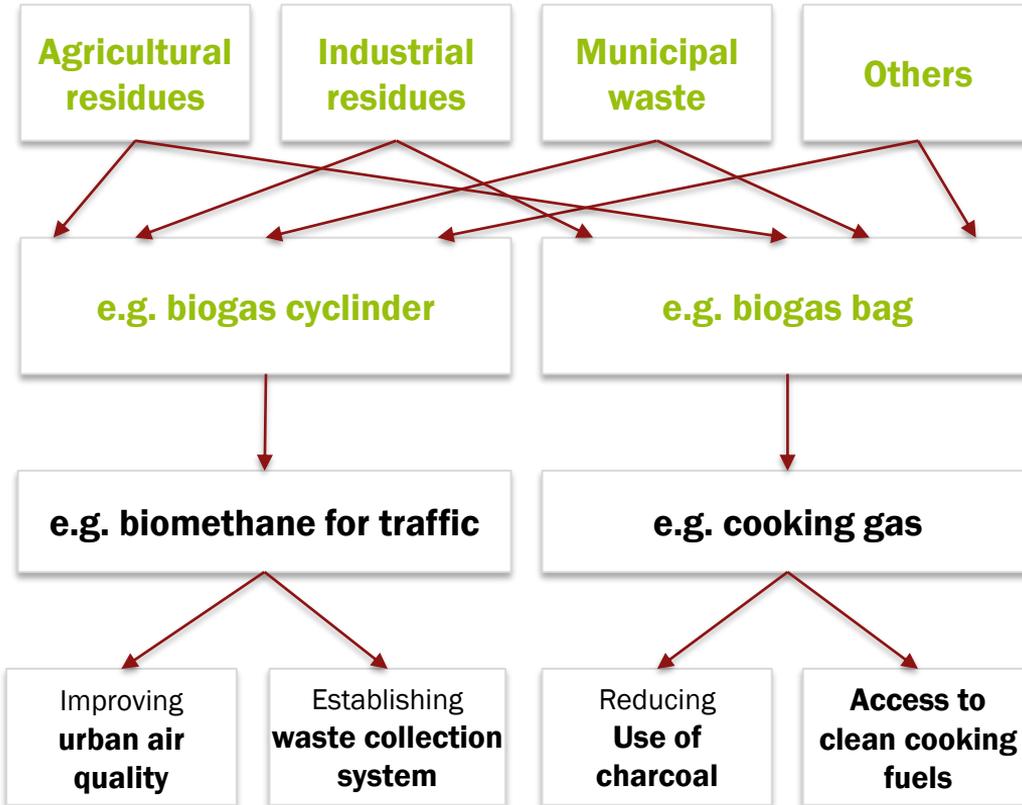
## Results & next steps for research



- ✓ Relevant resources
  - ✓ Spatial distribution of the three most relevant biomasses
  - ✓ Country specific technologies
  - ✓ Gas conversion options
  - ✓ Contextualizing results for concrete application purpose
- **Developing sustainable biogas concepts**

# Results & next steps for research

## Examples



**Mobilisation? Collection? Logistics?  
Costs?**

**Electricity grid? Production cost?  
Skilled staff?**

**Price? Acceptance? Logistics?  
Demand?**

## Next steps

- Identifying regional restrictions on biomass use for digestion.
- Identifying an efficient gas conversion option (gas cylinder, cooking gas, electricity, etc.) for biogas/biomethane.
- Identifying regions/sites with promising framework conditions for the construction of biogas plants.
- Development of concepts for sustainable biomass supply and utilization of fermentation residues.

**→ Implementation requires involvement of local partners and stakeholders!**

# Basis for next steps

## Land Cover (Togo & Ghana)



- Land cover is predominately characterized by tree and shrub covers
- Decline in forest area since 1990:
  - **Ghana:** 9%
  - **Togo:** 75%
- Large agricultural areas:
  - **Ghana:** in south-eastern coastal regions, around the city of *Kumasi* and in north-eastern border areas with *Togo* and *Burkina Faso*.
  - **Togo:** in southern regions as well as along northern border areas with *Ghana* and *Burkina Faso*.

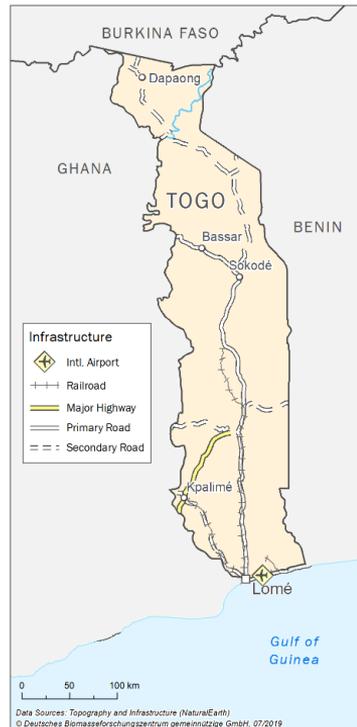
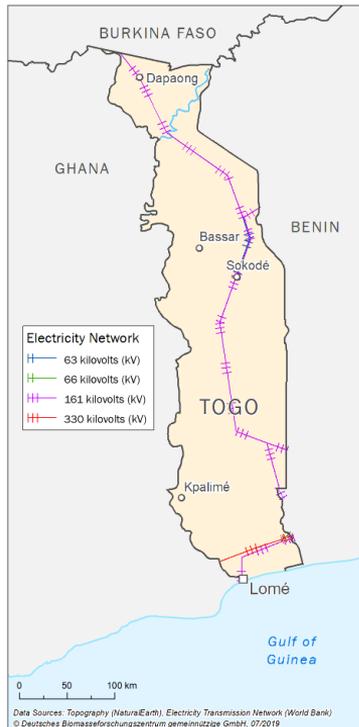


# Basis for next steps

## Infrastructure (Togo)

### Electricity grid

### Transport

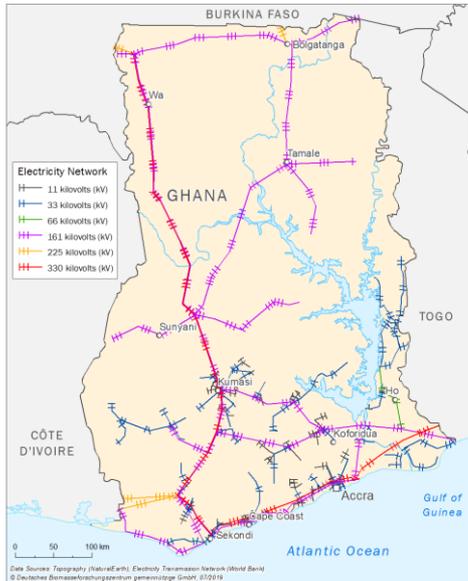


- **Electricity grid:** Main power transmission network in north-south direction: different capacities; main power line with highest capacity (300 kV) runs north of Lomé and crosses the country from east to west.
- **Transport:** Main transport network in north-south direction: linking populous coastal regions with the north-western border regions; Main expressway between Kpalimé and Accra; Disused rail network connects Lomé with Kpalimé and Sotouboua

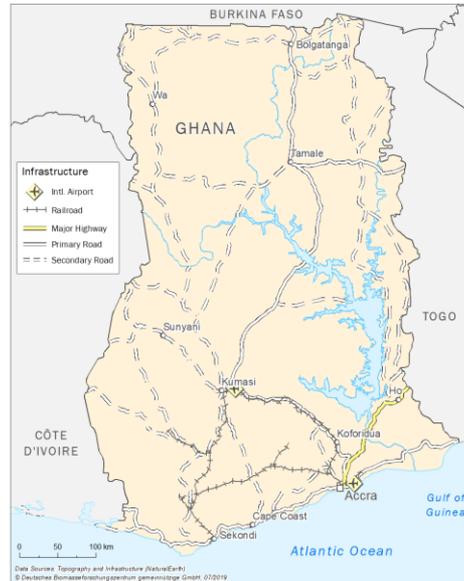
# Basis for next steps

## Infrastructure (Ghana)

### Electricity grid



### Transport



- **Electricity grid:** wide network with various voltage capacities connect all administrative centres and densely populated areas
- **Transport:** main highways connect the most densely populated parts of the country, denser road network in southern parts of the country, ongoing projects to improve and expand the rail network



## Smart Bioenergy – Innovationen für eine nachhaltige Zukunft

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