Deutsches Biomasseforschungszentrum
gemeinnützige GmbH

DBFZ

Machbarkeitsstudie Biogas in Togo/Ghana (Phase 1)

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Abschlusspräsentation

Objectives

Objectives

- 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)

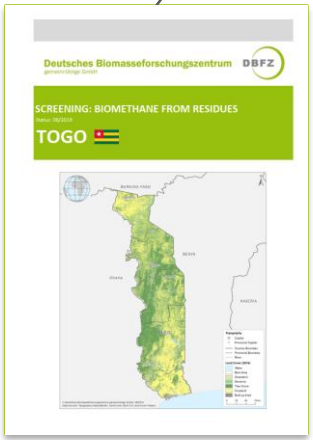
Land Cover

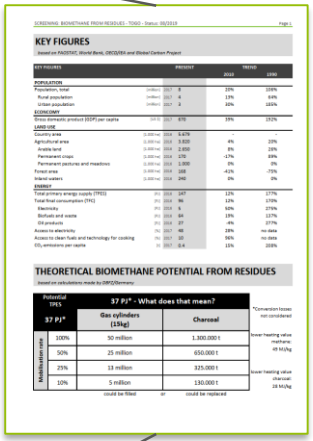
Key information on population, economy, land use and energy

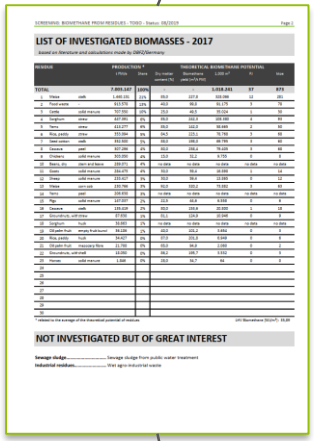
Investigated biomasses

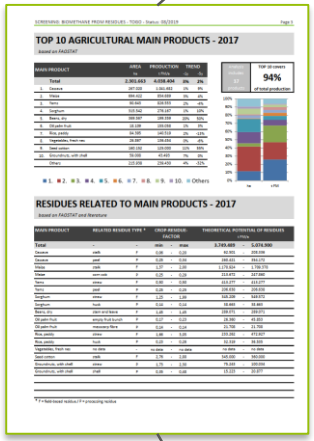
Crops

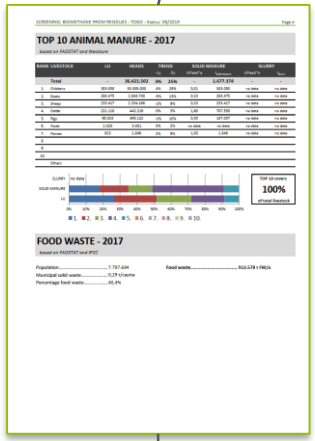
Livestock











Possible contribution to the renewable energy system

Not investigated biomasses

Agricultural residues

Food waste

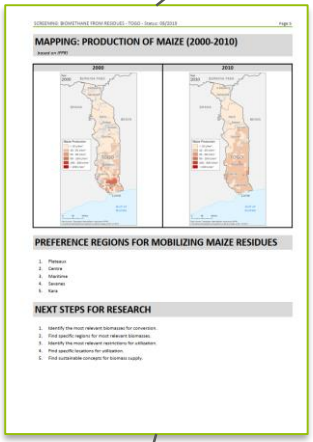
Output

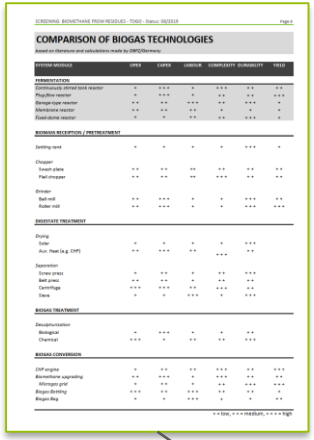
Country Profile (13 pages), example Togo (pages 7-12)

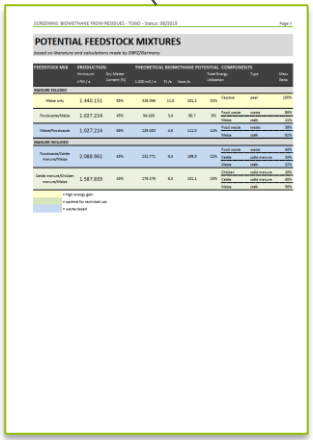
Top crop:
area of cultivation

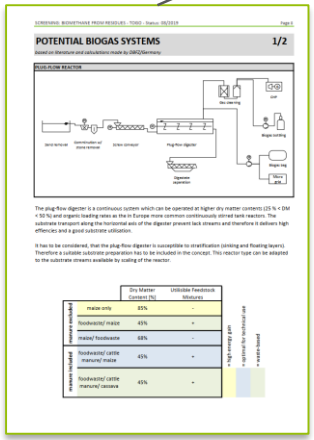
Potential feedstock
mixtures

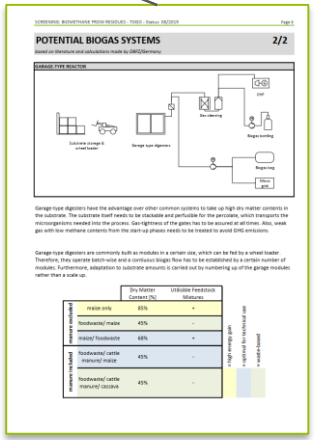
Potential biogas systems

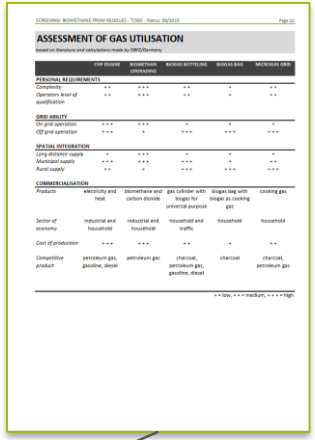












Regional hot-spots

Regional specific
biogas technologies

Options for gas
utilisation

Key information about Togo & Ghana

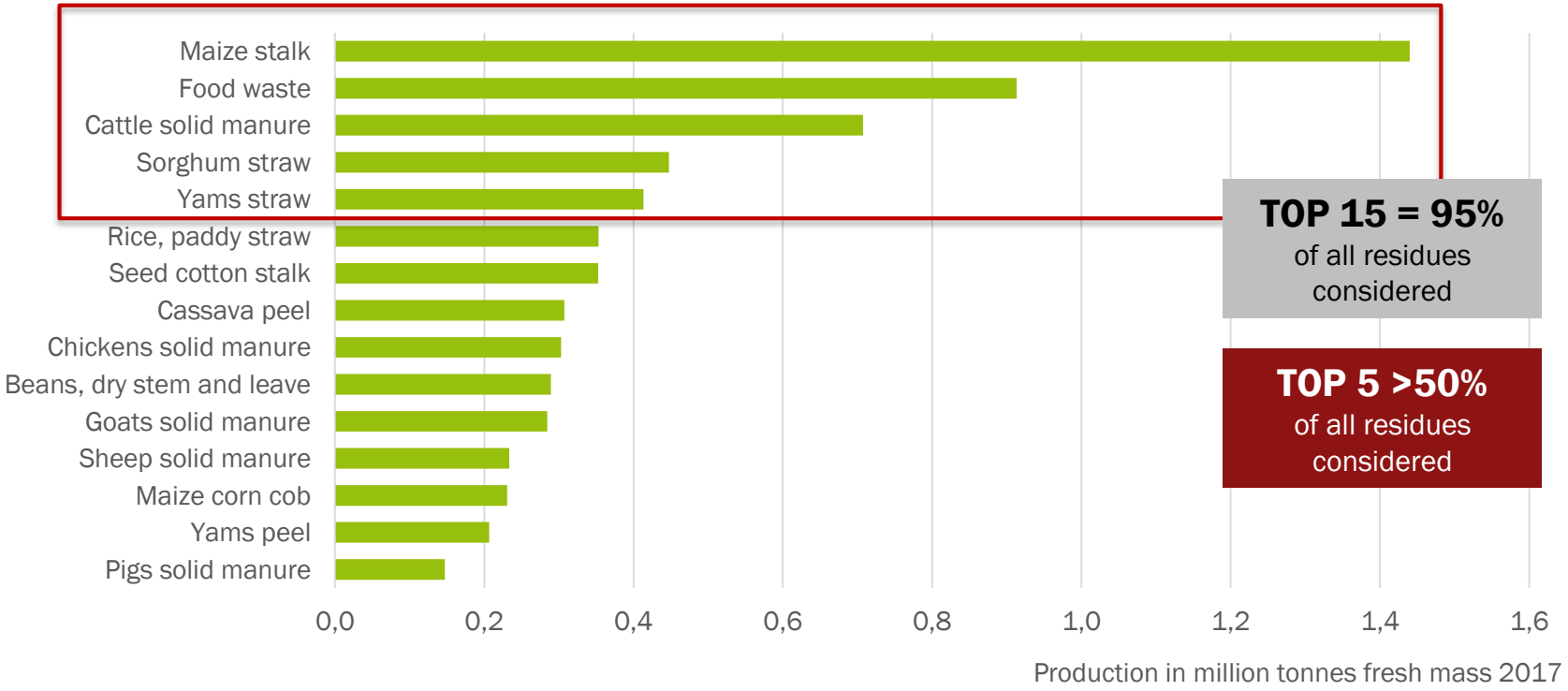
General Information

Ghana		Togo
29 m	**Population**	8 m
2,200 US $	**GDP per capita**	670 US $
84 %	**Access to electricity**	36 %
29 %	**Access to clean cooking fuels**	10 %
0.5 t	**CO2-emission per capita**	0.4 t

Results: Resource Screening Togo

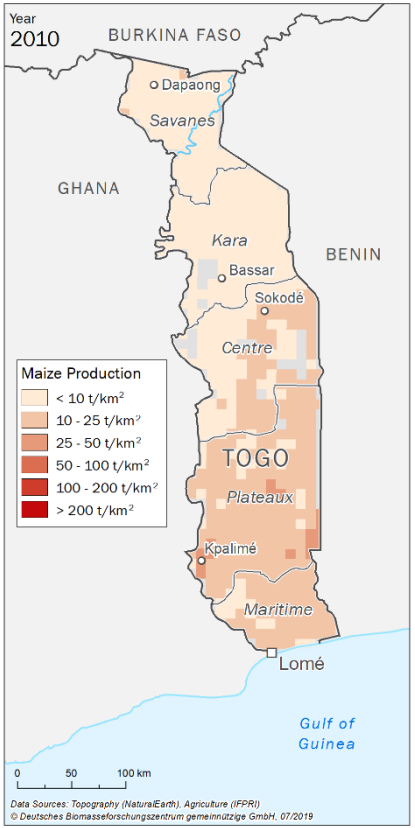
Resource Screening Togo

Top 15 Residues (2017)



Maize Production

Spatial distribution

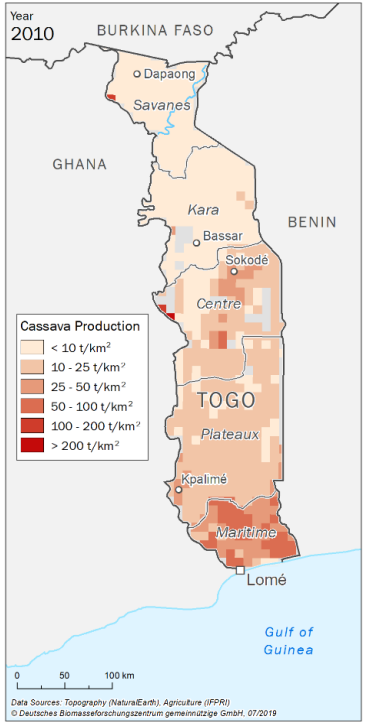


- Main concentration of maize production in southern regions *Maritime* and *Plateaux* as well as in eastern parts of *Centre.*
- Homogeneous distribution of production volumes in cultivation areas.
- Occasional intensification of production between 2000 and 2010.
- Decline in production in northern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

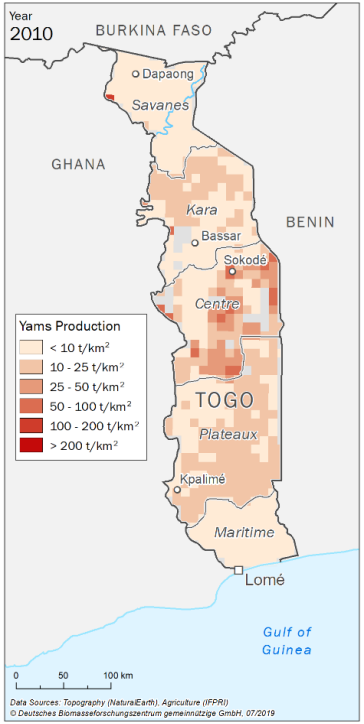
Agricultural residues

Variations between regions

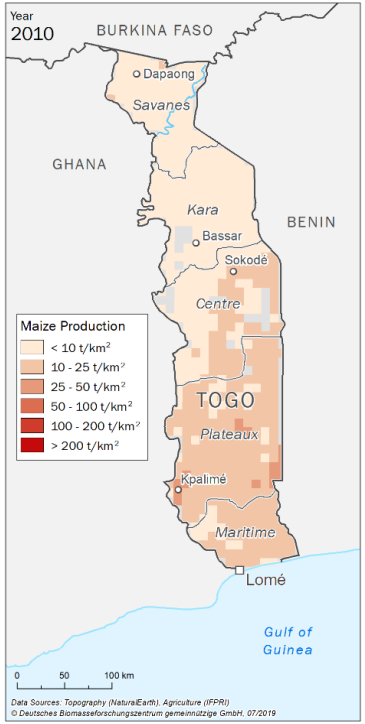
Cassava



Yams



Maize

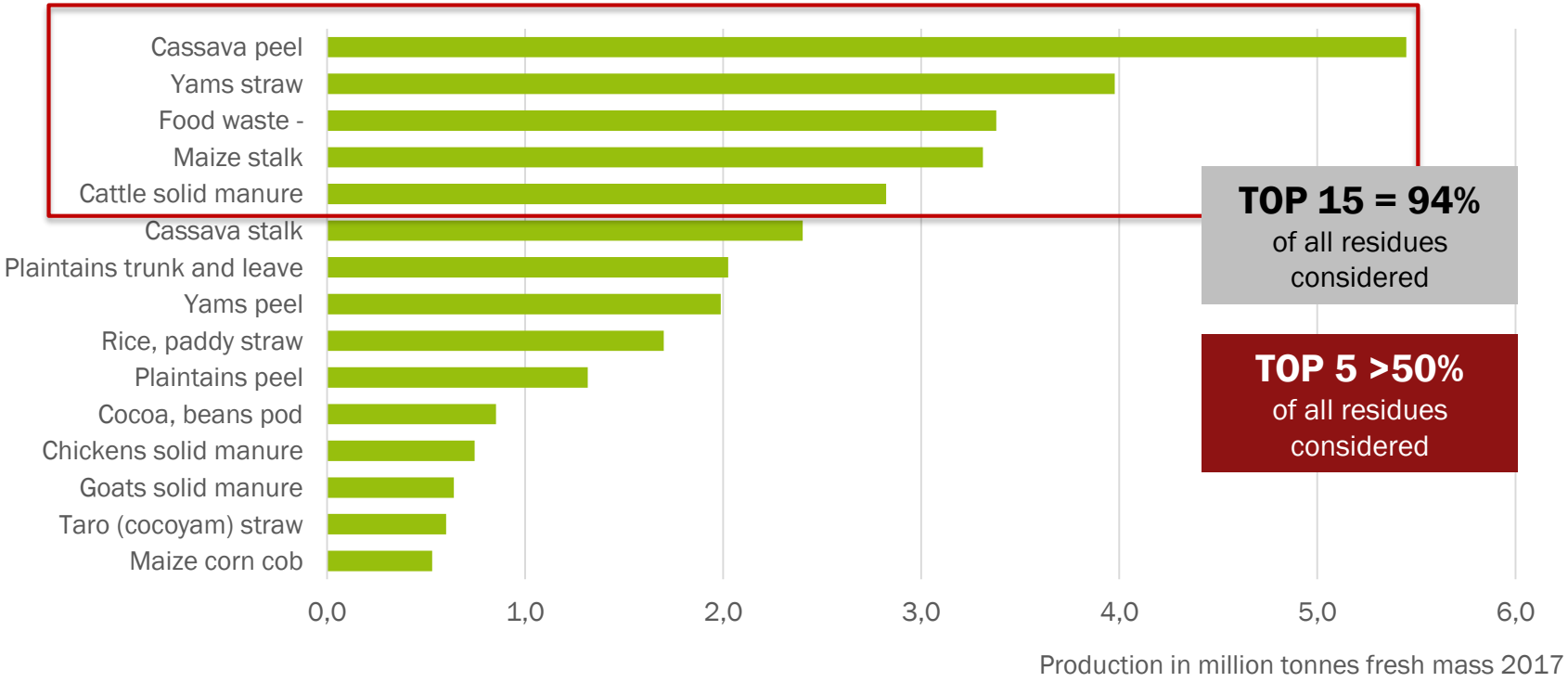


- **Cassava:** primary production in southern areas
- **Yams:** strong concentration of production in Centré
- **Maize:** main production in southern areas as well as eastern parts of Centré region

Results: Resource Screening Ghana

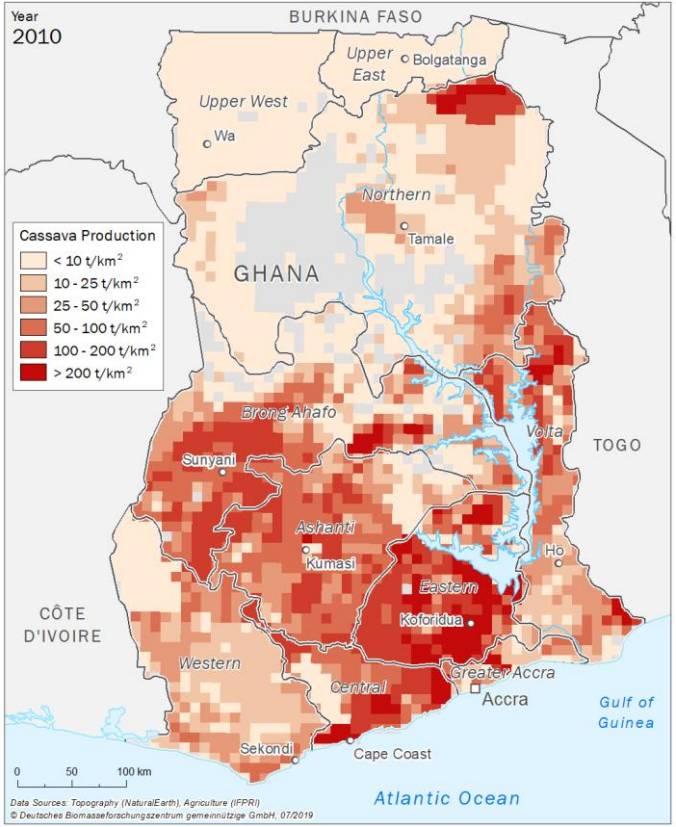
Resource Screening Ghana

Top 15 Residues (2017)



Cassava Production

Spatial distribution

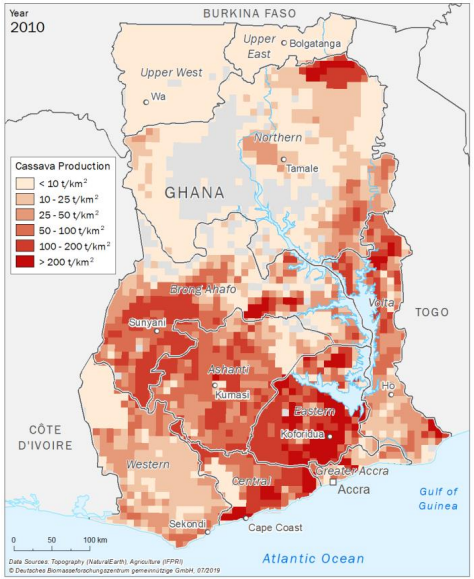


- The primary cassava production is concentrated in southern parts of Ghana, especially in *Eastern*, *Ashanti* and *Brong Ahafo* regions.
- Additional hot-spots can also be found in *Volta* and *Central* region as well as in north-eastern parts of *Northern* region.
- Significant intensification of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

Agricultural residues

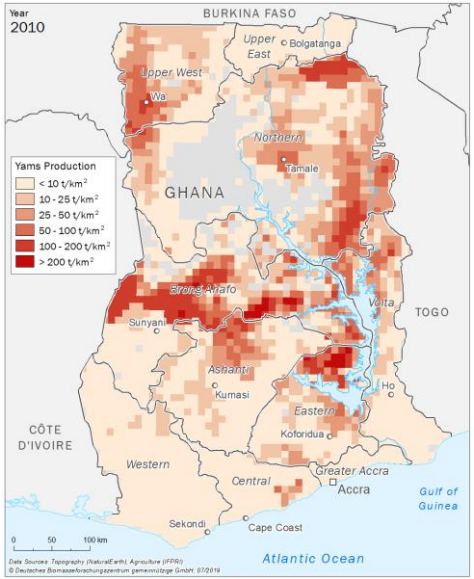
Variations between regions

Cassava



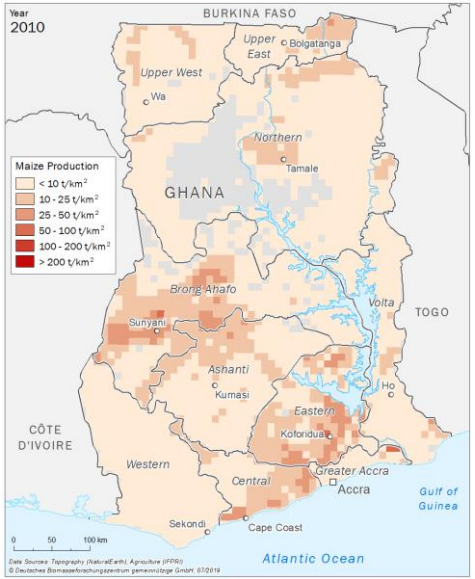
Primary production in southern regions

Yams



Primary production in central and northern regions

Maize



Scattered production hot-spot mostly in south

Results: Technology Screening

Technology

Deduction of technologies

1. **Definition of main components**
   - feedstock treatment
   - digestation
   - 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 componets
   - *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
FERMENTATION						
Continuously stirred tank reactor	+	+++	+	+++	++	++
Plug-flow reactor	+	+++	+	++	++	+++
Garage-type reactor	++	++	+++	++	+++	+
Membrane reactor	++	++	++	+	+	+
Fixed-dome reactor	+	+	++	++	+++	+
BIOGAS TREATMENT						
Desulphurisation						
Biological	+	+++	+	+	++	
Chemical	+++	+	++	++	+++	
BIOGAS CONVERSION						
CHP engine	+	++	++	+++	++	+++
Biomethane upgrading	++	+++	+	+++	++	++
Microgas grid	+	++	+	++	+++	+++
Biogas Bottling	+++	++	+++	++	++	+
Biogas Bag	+	+	+++	+	+	++

+ low ++ medium +++ high

- Qualitative evaluation of gas-conveying components

Technology (Ghana/Togo)

SYSTEM MODULE	OPEX	CAPEX	LABOUR	COMPLEXITY	DURABILITY	YIELD
BIOMASS RECEIPTION / PRETREATMENT						
Settling tank	+	+	+	+	+++	+
Chopper						
Swash plate	++	++	++	++	++	++
Flail chopper	++	++	++	+++	++	++
Grinder						
Ball mill	++	+++	+	+	+++	++
Roller mill	++	+++	+	+	+++	+++
DIGESTATE TREATMENT						
Drying						
Solar	+	+	+	+	+++	
Aux. Heat (e.g. CHP)	++	+++	++	+++	++	
Separation						
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 availiabillity
   - 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^3 / a	primary energy yield PJ /a	primary energy yield ktoe /a	energy potential use ratio	component		ratio	ammount t FM / a
manure excluded	cassava only	5.448.875	80%	1.407.989	51	1.207	31%	Cassava	peel	100%	5.448.875
	plaintains/cassava	3.910.584	45%	541.027	19	464	12%	Plaintains	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^3 / 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
   - ppatial integration
   - commercialisation
   - pompetitive product

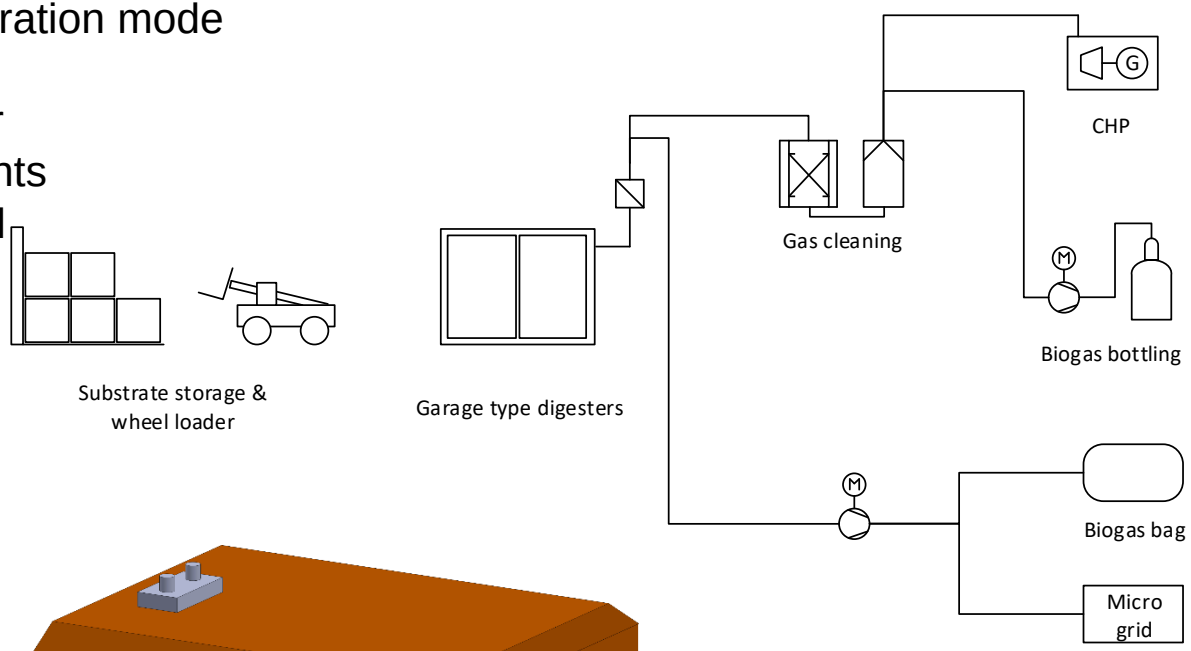
Country-specific technology

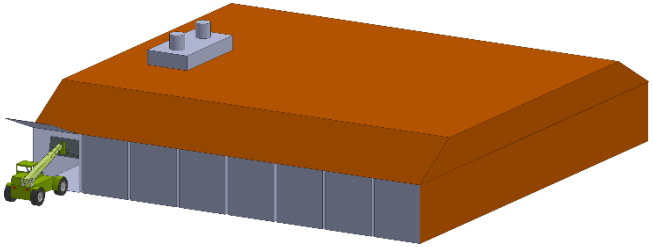
Box digester

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

		TM-Gehalt	Nutzbares Substrat
Ghana			
manure excluded	cassava only	80%	+
	plaintains/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%	-

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





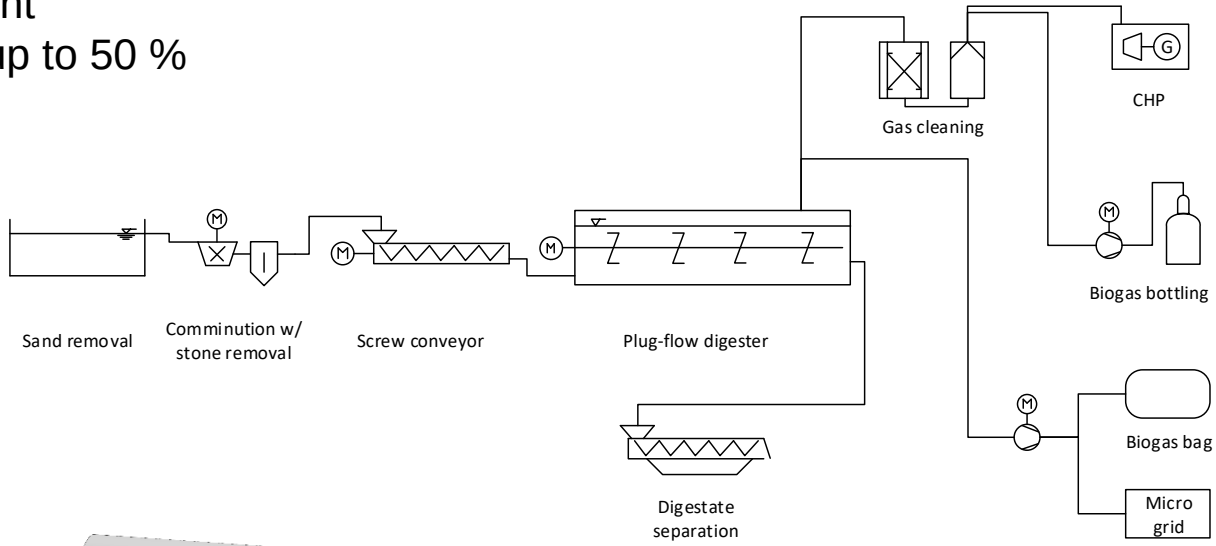
Country-specific technology

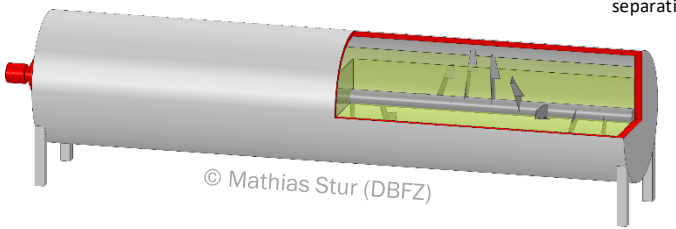
Plug-flow-digester

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

Ghana		TM-Gehalt	Nutzbares Substrat
manure excluded	cassava only	80%	+
	plaintains/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%	+

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





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
Personal requirements					
Complexity	++	+++	++	+	++
Operators level of qualification	++	+++	++	+	++
Grid ability					
On grid operation	+++	+++	+	+	+
Off grid operation	+++	+	+++	+++	+++
Spatial integration					
Long distance Supply	+	+++	+	+	+
Municipal supply	+++	+++	+++	+	++
Rual supply	++	+	+++	+++	+++
Commercialisation					
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 37 PJ*		37 PJ* - What does that mean?	
		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*		163 PJ* - What does that mean?	
		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

lower heating value charcoal: 28 MJ/kg

Summary & Next Steps

Summary

Results & next steps for research

Biogenic residues

↓ ?

Country specific **technology**

↓ ?

Country specific **gas conversion**

↓ ?

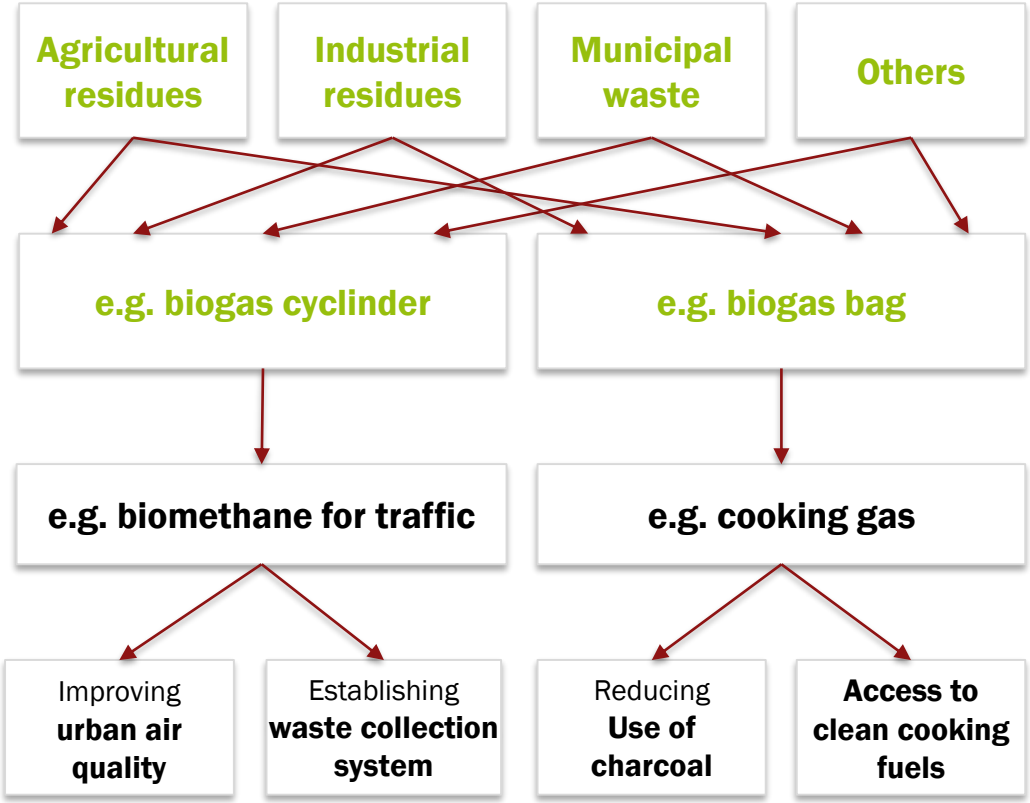
Context

- ✓ 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? Aceptance? Logistics? Demand?

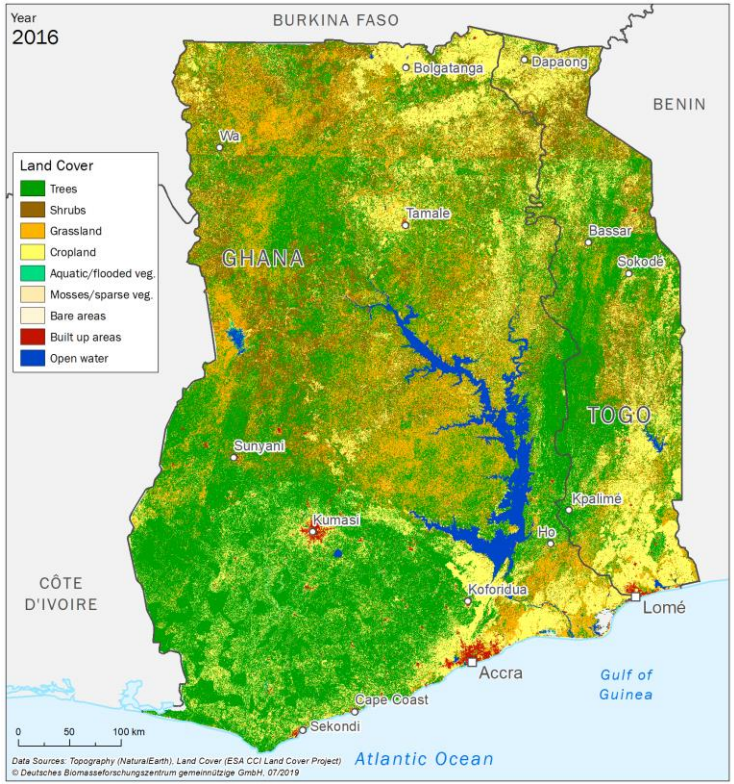
Next steps

- 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

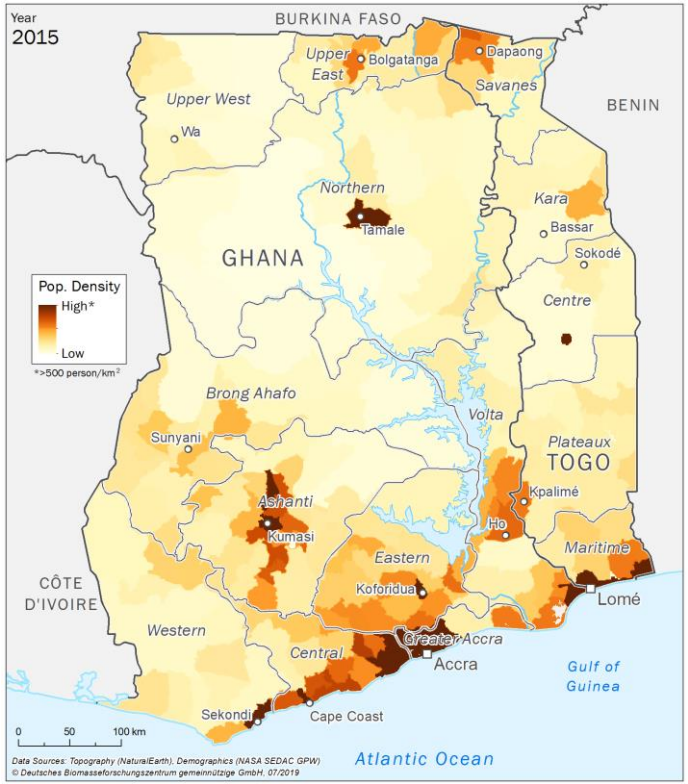
Land Cover (Togo & Ghana)



- 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 *Kumasis* 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

Demographic Distribution (Togo & Ghana)

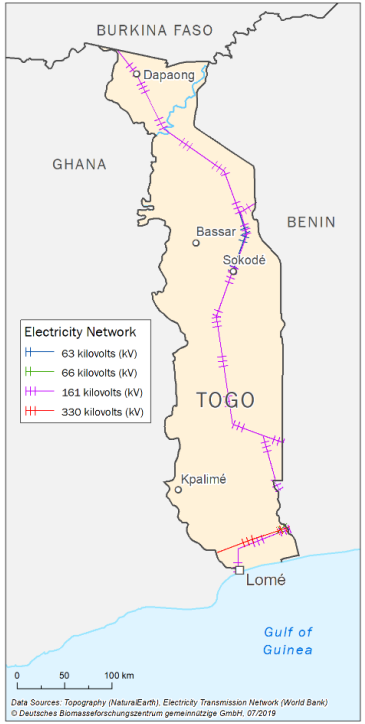


- High population density in southern regions, especially along coastal areas.
- Higher densities can be found also around administrative centres:
  - **Togo:** predominately around *Kpalimé* and *Dapaong.*
  - **Ghana:** *Kumasi, Koforidua, Ho, Tamale, Bolgatanga*.
- Most populous regions:
  - ***Togo:*** capital Lomé and surrounding region *Maritime* (2.6 million inhabitants) and *Plateaux* (1.4 million inhabitants).
  - ***Ghana:*** *Ashanti* (5.4 million inhabitants) and *Greater Accra* (4.6 million inhabitants).
- Population density has increased between 2000 and 2015 in areas with already high concentrations of population

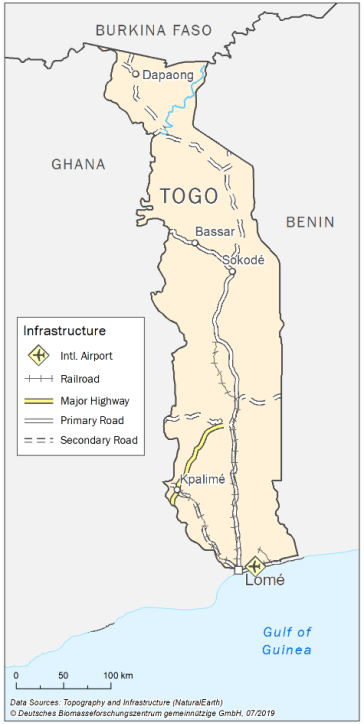
Basis for next steps

Infrastructure (Togo)

Electricity grid



Transport

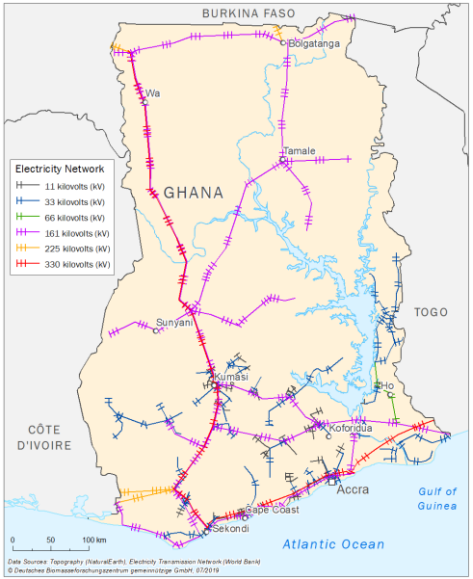


- **Electricity grid:** Main power transmission network in north-south direction: different capacities; main power line with highest capacity (300 kV) runs north of Lomé and crosses the country from east to west.
- **Transport:** Main transport network in north-south direction: linking populous coastal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

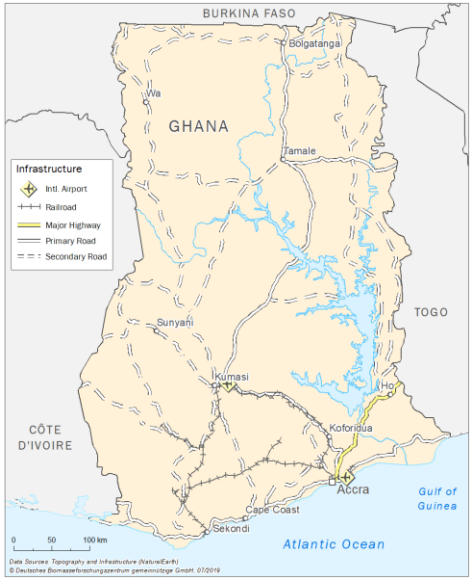
Basis for next steps

Infrastructure (Ghana)

Electrictiy 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

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Smart Bioenergy – Innovationen für eine nachhaltige Zukunft

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