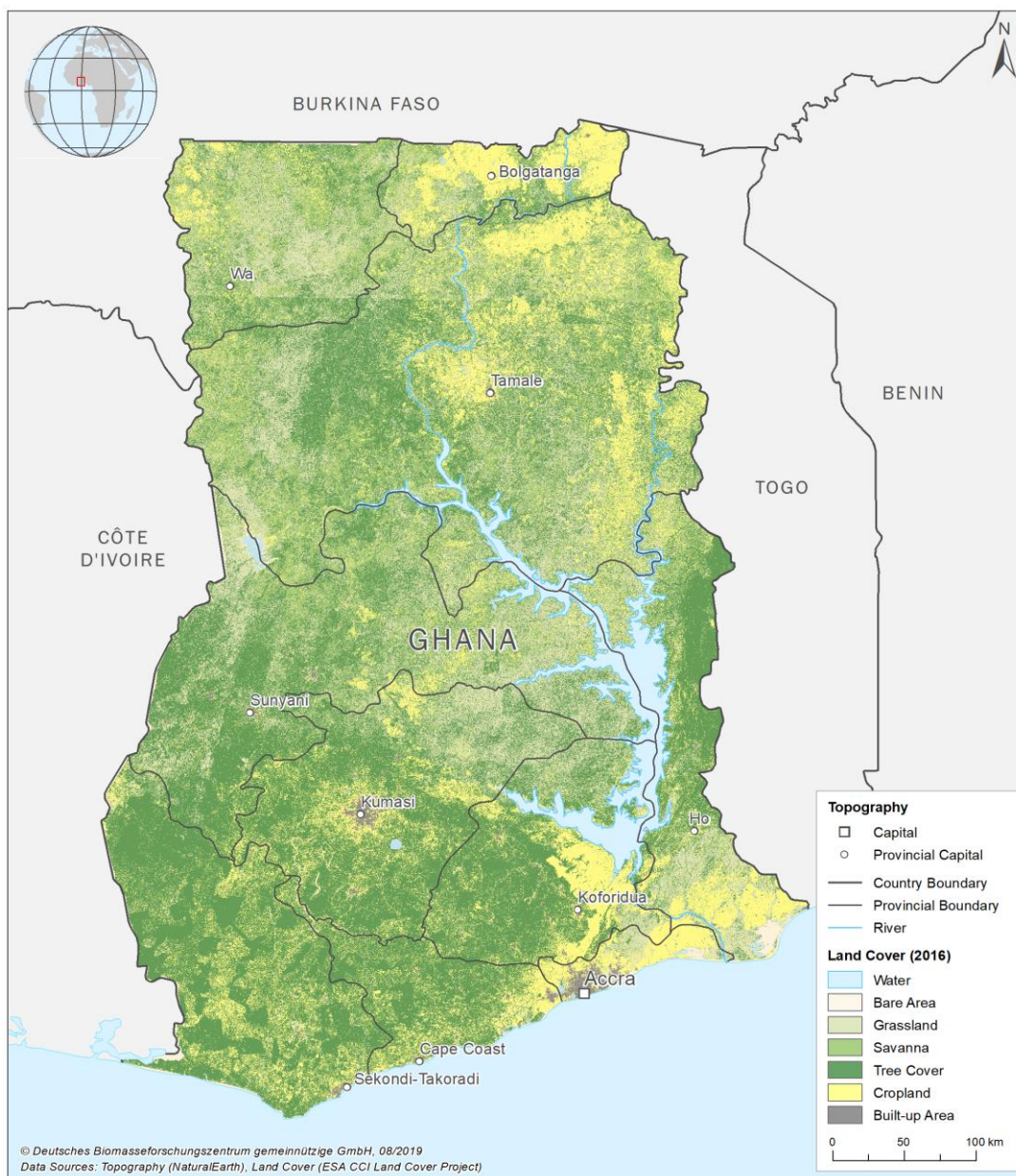


# SCREENING: BIOMETHANE FROM RESIDUES

Status: 08/2019

# GHANA



## CONTENT

|     |   |            |
|-----|---|------------|
| 1.  | What is the current land cover of the country?  | Cover page |
| 2.  | How have selected key information on population, economy, land use and energy developed in recent years?  | Page 1     |
| 3.  | What is the theoretical biomethane potential of all investigated residues in total? How much gas cylinders could be filled? How much charcoal could be replaced?    | Page 1     |
| 4.  | What are the most relevant residues (including residues of agricultural main products, animal manure and food waste) in terms of quantity and biomethane potential? | 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 cover?                  | Page 3     |
| 7.  | Which related residues can be identified for the TOP 10 agricultural main products and which potentials result?   | 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 trend in the production of the most important crop and where are the preference regions for mobilizing the related residues?                            | Page 5     |
| 11. | What are next steps for further research and resource mobilisation?   | Page 5     |
| 12. | Which biogas technologies were considered and what are the characteristics of these technologies?   | Page 6     |
| 13. | Which feedstock mixtures were considered and how high is the theoretical biomethan potential in this options?   | Page 7     |
| 14. | How could biogas systems in Ghana look like?  | Page 8-9   |
| 15. | Which gas utilisations were considered and what are the characteristics of these options?   | Page 10    |

## REMARK

The document "Screening: Biomethane from residues" is a very first and quick option to get an overview of available information on biomass resources in the selected country/region. Results are based on statistics, literature or surveys and calculations made by DBFZ/Germany. The document contains all conversion factors to reproduce and to customize the calculations.

**Because of insufficient data the results have to be interpreted with the awareness of uncertainties! The compilation makes no claim to completeness!**

## KEY FIGURES

based on FAOSTAT, World Bank, OECD/IEA and Global Carbon Project, FAO and WLPGA

| KEY FIGURES                                      | PRESENT    |             | TREND |         |
|--|------------|-------------|-------|---------|
|  |            |             | 2010  | 1990    |
| <b>POPULATION</b>                                |            |             |       |         |
| Population, total                                | [million]  | 2017 29     | 18%   | 97%     |
| Rural population                                 | [million]  | 2017 13     | 5%    | 35%     |
| Urban population                                 | [million]  | 2017 16     | 26%   | 191%    |
| <b>ECONOMY</b>                                   |            |             |       |         |
| Gross domestic product (GDP) per capita          | [US \$]    | 2017 2.200  | 83%   | 902%    |
| <b>LAND USE</b>                                  |            |             |       |         |
| Country area                                     | [1.000 ha] | 2016 23.854 | -     | -       |
| Agricultural area                                | [1.000 ha] | 2016 15.700 | 1%    | 25%     |
| Arable land                                      | [1.000 ha] | 2016 4.700  | 2%    | 74%     |
| Permanent crops                                  | [1.000 ha] | 2016 2.700  | 0%    | 80%     |
| Permanent pastures and meadows                   | [1.000 ha] | 2016 8.300  | 0%    | -1%     |
| Forest area                                      | [1.000 ha] | 2016 9.365  | 2%    | 9%      |
| Inland waters                                    | [1.000 ha] | 2016 1.100  | 0%    | 0%      |
| <b>ENERGY</b>                                    |            |             |       |         |
| Total primary energy supply (TPES)               | [PJ]       | 2016 392    | 24%   | 77%     |
| Total final consumption (TFC)                    | [PJ]       | 2016 286    | 27%   | 58%     |
| Electricity                                      | [PJ]       | 2016 36     | 47%   | 127%    |
| Biofuels and waste                               | [PJ]       | 2016 101    | 10%   | -20%    |
| Oil products                                     | [PJ]       | 2016 148    | 38%   | 289%    |
| Access to electricity                            | [%]        | 2017 84     | 39%   | no data |
| Access to clean fuels and technology for cooking | [%]        | 2017 29     | 147%  | no data |
| CO <sub>2</sub> -emissions per capita            | [t]        | 2017 0,5    | 73%   | 346%    |
| Total CO <sub>2</sub> -emissions                 | [Mt]       | 2017 17     | 73%   | 346%    |

## THEORETICAL BIOMETHANE POTENTIAL FROM RESIDUES

based on calculations made by DBFZ/Germany

| Potential Total Primary Energy Supply (TPES) |      | 163 PJ - What does that mean? |                   |                                       |  | Remarks  |
|--|------|-------------------------------|-------------------|---------------------------------------|--|--|
|  |      | Gas cylinders (15kg)          | Charcoal          | Avoided Deforestation                 | Avoided Emissions  |  |
| Mobilisation rate                            | 100% | 220 million                   | 5.800.000 t       | up to 150.000 ha                      | Potential emissions highly depend on energy conversion efficiencies as well as the selection of a specific technology. It can be assumed that emission reductions between 40 and 60 % can be achieved. | Avoided deforestations constitute theoretical examples of reduction potentials and do not automatically relate to actual deforestation rates in Ghana.<br><br>Conversion losses were not considered. A lower heating value of 49 MJ/kg was used for methane and 28 MJ/kg for charcoal. |
|  | 50%  | 110 million                   | 2.900.000 t       | up to 75.000 ha                       |  |  |
|  | 25%  | 55 million                    | 1.450.000 t       | up to 37.500 ha                       |  |  |
|  | 10%  | 22 million                    | 58.000 t          | up to 15.000 ha                       |  |  |
|  |      | could be filled               | could be replaced | when using biogas instead of charcoal |  |  |

# LIST OF INVESTIGATED BIOMASSES - 2017

based on literature and calculations made by DBFZ/Germany

| RESIDUE                             | PRODUCTION *      |             | THEORETICAL BIOMETHANE POTENTIAL |   |                      |            |              |
|-------------------------------------|-------------------|-------------|----------------------------------|---|----------------------|------------|--------------|
|                                     | t FM/a            | Share       | Dry matter content [%]           | Biomethane yield [m <sup>3</sup> /t FM] | 1,000 m <sup>3</sup> | PJ         | ktoe         |
| <b>TOTAL</b>                        | <b>33.738.299</b> | <b>100%</b> | -                                | -                                       | <b>4.536.226</b>     | <b>163</b> | <b>3.889</b> |
| 1 Cassava peel                      | 5.448.875         | 16%         | 80,0                             | 258,4                                   | 1.407.989            | 51         | 1.207        |
| 2 Yams straw                        | 3.976.375         | 12%         | 85,0                             | 142,0                                   | 564.446              | 20         | 484          |
| 3 Food waste -                      | 3.378.148         | 10%         | 40,0                             | 99,8                                    | 337.139              | 12         | 289          |
| 4 Maize stalk                       | 3.311.025         | 10%         | 85,0                             | 227,8                                   | 754.251              | 27         | 647          |
| 5 Cattle solid manure               | 2.822.374         | 8%          | 25,0                             | 49,5                                    | 139.708              | 5          | 120          |
| 6 Cassava stalk                     | 2.401.199         | 7%          | 80,0                             | 153,6                                   | 368.824              | 13         | 316          |
| 7 Plantains trunk and leave         | 2.025.315         | 6%          | 12,5                             | 26,6                                    | 53.924               | 2          | 46           |
| 8 Yams peel                         | 1.988.188         | 6%          | no data                          | no data                                 | no data              | no data    | no data      |
| 9 Rice, paddy straw                 | 1.699.050         | 5%          | 84,5                             | 223,1                                   | 379.024              | 14         | 325          |
| 10 Plantains peel                   | 1.316.455         | 4%          | no data                          | no data                                 | no data              | no data    | no data      |
| 11 Cocoa, beans pod                 | 852.724           | 3%          | 85,0                             | 68,0                                    | 57.985               | 2          | 50           |
| 12 Chickens solid manure            | 744.780           | 2%          | 15,0                             | 32,2                                    | 23.974               | 1          | 21           |
| 13 Goats solid manure               | 640.000           | 2%          | 30,0                             | 59,4                                    | 38.016               | 1          | 33           |
| 14 Taro (cocoyam) straw             | 600.122           | 2%          | 85,0                             | 142,0                                   | 85.187               | 3          | 73           |
| 15 Maize corn cob                   | 530.550           | 2%          | 92,0                             | 320,2                                   | 169.861              | 6          | 146          |
| 16 Oil palm fruit empty fruit buncl | 493.953           | 1%          | 40,0                             | 101,2                                   | 49.988               | 2          | 43           |
| 17 Sheep solid manure               | 461.183           | 1%          | 30,0                             | 59,4                                    | 27.394               | 1          | 23           |
| 18 Oil palm fruit mesocarp fibre    | 345.767           | 1%          | 65,0                             | 94,9                                    | 32.813               | 1          | 28           |
| 19 Taro (cocoyam) peel              | 300.061           | 1%          | no data                          | no data                                 | no data              | no data    | no data      |
| 20 Pigs solid manure                | 222.450           | 1%          | 22,5                             | 44,6                                    | 9.921                | 0          | 9            |
| 21 Rice, paddy husk                 | 176.759           | 1%          | 87,0                             | 201,8                                   | 35.677               | 1          | 31           |
| 22 Horses solid manure              | 2.947             | 0%          | 28,0                             | 34,7                                    | 102                  | 0          | 0            |
| 23                                  |                   |             |                                  |   |                      |            |              |
| 24                                  |                   |             |                                  |   |                      |            |              |
| 25                                  |                   |             |                                  |   |                      |            |              |
| 26                                  |                   |             |                                  |   |                      |            |              |
| 27                                  |                   |             |                                  |   |                      |            |              |
| 28                                  |                   |             |                                  |   |                      |            |              |
| 29                                  |                   |             |                                  |   |                      |            |              |
| 30                                  |                   |             |                                  |   |                      |            |              |

\* related to the average of the theoretical potential of residues

LHV Biomethane [MJ/m<sup>3</sup>]: 35,89

## NOT INVESTIGATED BUT OF GREAT INTEREST

Sewage sludge..... Sewage sludge from public water treatment

Industrial residues..... Wet agro-industrial waste

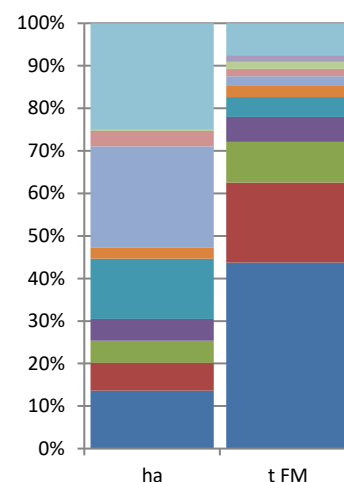
## TOP 10 AGRICULTURAL MAIN PRODUCTS - 2017

based on FAOSTAT

| MAIN PRODUCT      | AREA<br>ha       | PRODUCTION<br>t FM/a | TREND     |            |
|-------------------|------------------|----------------------|-----------|------------|
|                   |                  |                      | -1y       | -5y        |
| <b>Total</b>      | <b>7.094.082</b> | <b>42.254.509</b>    | <b>4%</b> | <b>17%</b> |
| 1. Cassava        | 965.514          | 18.470.762           | 4%        | 27%        |
| 2. Yams           | 465.906          | 7.952.750            | 7%        | 20%        |
| 3. Plantains      | 368.505          | 4.050.630            | 2%        | 14%        |
| 4. Oil palm fruit | 364.595          | 2.469.763            | 1%        | 12%        |
| 5. Maize          | 1.000.000        | 1.965.000            | 14%       | 1%         |
| 6. Taro (cocoyam) | 183.960          | 1.200.244            | -8%       | -6%        |
| 7. Cocoa, beans   | 1.690.237        | 883.652              | 3%        | 0%         |
| 8. Rice, paddy    | 258.587          | 721.465              | 5%        | 50%        |
| 9. Oranges        | 17.604           | 702.861              | 2%        | 12%        |
| 10. Pineapples    | 10.734           | 677.112              | 2%        | 13%        |
| Others            | 1.768.440        | 3.160.270            | 2%        | -4%        |

■ 1. ■ 2. ■ 3. ■ 4. ■ 5. ■ 6. ■ 7. ■ 8. ■ 9. ■ 10. ■ Others

|  |   |
|--|---|
| Analysis includes<br><b>48</b><br>products | <b>TOP 10 covers</b><br><b>93%</b><br>of total production |
|--|---|



## RESIDUES RELATED TO MAIN PRODUCTS - 2017

based on FAOSTAT and literature

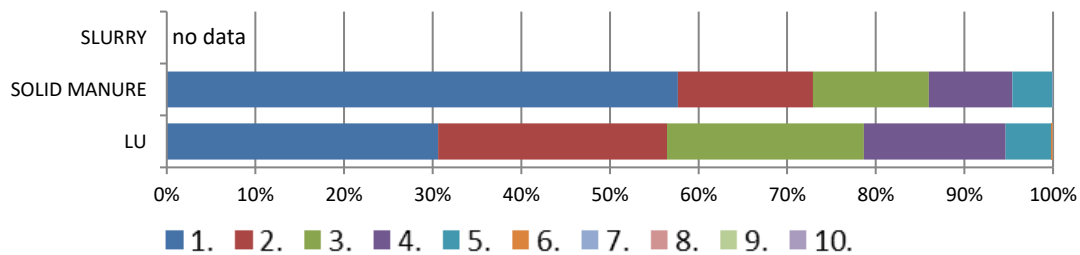
| MAIN PRODUCT   | RELATED RESIDUE TYPE * |   | CROP-RESIDUE-FACTOR |            | THEORETICAL POTENTIAL OF RESIDUES<br>t FM/a |                   |
|----------------|------------------------|---|---------------------|------------|---|-------------------|
|                |                        |   | min                 | max        |   |                   |
| <b>Total</b>   |                        |   | <b>min</b>          | <b>max</b> | <b>21.762.946</b>                           | <b>29.169.887</b> |
| Cassava        | stalk                  | F | 0,06                | 0,20       | 1.108.246                                   | 3.694.152         |
| Cassava        | peel                   | P | 0,25                | 0,34       | 4.617.691                                   | 6.280.059         |
| Yams           | straw                  | F | 0,50                | 0,50       | 3.976.375                                   | 3.976.375         |
| Yams           | peel                   | P | 0,25                | 0,25       | 1.988.188                                   | 1.988.188         |
| Plantains      | trunk and leave        | F | 0,50                | 0,50       | 2.025.315                                   | 2.025.315         |
| Plantains      | peel                   | P | 0,25                | 0,40       | 1.012.658                                   | 1.620.252         |
| Oil palm fruit | empty fruit bunch      | P | 0,17                | 0,23       | 419.860                                     | 568.045           |
| Oil palm fruit | mesocarp fibre         | P | 0,14                | 0,14       | 345.767                                     | 345.767           |
| Maize          | stalk                  | F | 1,37                | 2,00       | 2.692.050                                   | 3.930.000         |
| Maize          | corn cob               | P | 0,25                | 0,29       | 491.250                                     | 569.850           |
| Taro (cocoyam) | straw                  | F | 0,50                | 0,50       | 600.122                                     | 600.122           |
| Taro (cocoyam) | peel                   | P | 0,25                | 0,25       | 300.061                                     | 300.061           |
| Cocoa, beans   | pod                    | F | 0,93                | 1,00       | 821.796                                     | 883.652           |
| Rice, paddy    | straw                  | F | 1,66                | 3,05       | 1.197.632                                   | 2.200.468         |
| Rice, paddy    | husk                   | P | 0,23                | 0,26       | 165.937                                     | 187.581           |
| Oranges        | no data                | - | no data             | no data    | no data                                     | no data           |
| Pineapples     | no data                | - | no data             | no data    | no data                                     | no data           |

\* F = field-based residue / P = processing residue

# TOP 10 ANIMAL MANURE - 2017

based on FAOSTAT and literature

| RANK LIVESTOCK | LU      | HEADS             | TREND     |            | SOLID MANURE |                           | SLURRY   |                     |
|----------------|---------|-------------------|-----------|------------|--------------|---------------------------|----------|---------------------|
|                |         |                   | -1y       | -5y        | t/Head*a     | t <sub>solid manure</sub> | t/Head*a | t <sub>slurry</sub> |
| <b>Total</b>   | -       | <b>88.013.053</b> | <b>4%</b> | <b>27%</b> | -            | <b>4.893.735</b>          | -        | -                   |
| 1. Cattle      | 881.992 | 1.763.984         | 2%        | 14%        | 1,60         | 2.822.374                 | no data  | no data             |
| 2. Chickens    | 744.780 | 74.478.000        | 4%        | 29%        | 0,01         | 744.780                   | no data  | no data             |
| 3. Goats       | 640.000 | 6.400.000         | 1%        | 18%        | 0,10         | 640.000                   | no data  | no data             |
| 4. Sheep       | 461.183 | 4.611.831         | 2%        | 15%        | 0,10         | 461.183                   | no data  | no data             |
| 5. Pigs        | 148.300 | 741.500           | 2%        | 23%        | 0,30         | 222.450                   | no data  | no data             |
| 6. Asses       | 4.437   | 14.791            | 0%        | 3%         | no data      | no data                   | no data  | no data             |
| 7. Horses      | 1.474   | 2.947             | 0%        | 9%         | 1,00         | 2.947                     | no data  | no data             |
| 8.             |         |                   |           |            |              |                           |          |                     |
| 9.             |         |                   |           |            |              |                           |          |                     |
| 10.            |         |                   |           |            |              |                           |          |                     |
| Others         |         |                   |           |            |              |                           |          |                     |



TOP 10 covers  
**100%**  
of total livestock

# FOOD WASTE - 2017

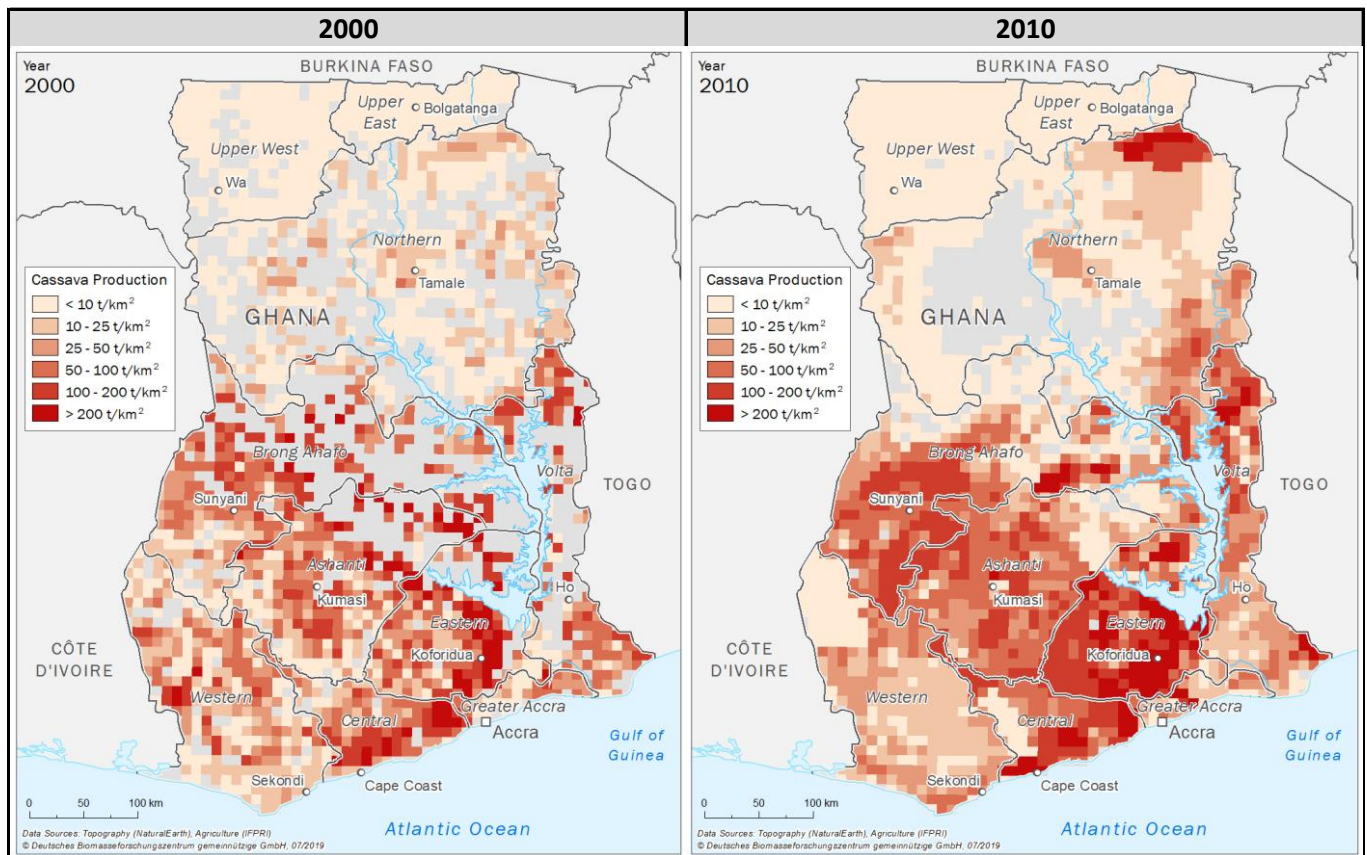
based on FAOSTAT and IPCC

Population..... 28.833.629  
Municipal solid waste..... 0,29 t/capita  
Percentage food waste..... 40,4%

**Food waste..... 3.378.148 t FM/a**

## MAPPING: PRODUCTION OF CASSAVA (2000-2010)

based on IFPRI



## PREFERENCE REGIONS FOR MOBILIZING CASSAVA RESIDUES

1. Eastern
2. Brong Ahafo
3. Ashanti
4. Central
5. Northern

## NEXT STEPS FOR RESEARCH

- ✓ Identify the most relevant biomasses for conversion.
- ✓ Find specific regions for most relevant biomasses.
3. Identify the most relevant restrictions for utilization.
4. Find specific locations for utilization.
5. Find sustainable concepts for biomass supply.

# COMPARISON OF BIOGAS TECHNOLOGIES

based on literature and calculations made by DBFZ/Germany

| 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>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                                    | +    | +     | +++    | +          | +++        |       |
| <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

# POTENTIAL FEEDSTOCK MIXTURES

based on literature and calculations made by DBFZ/Germany

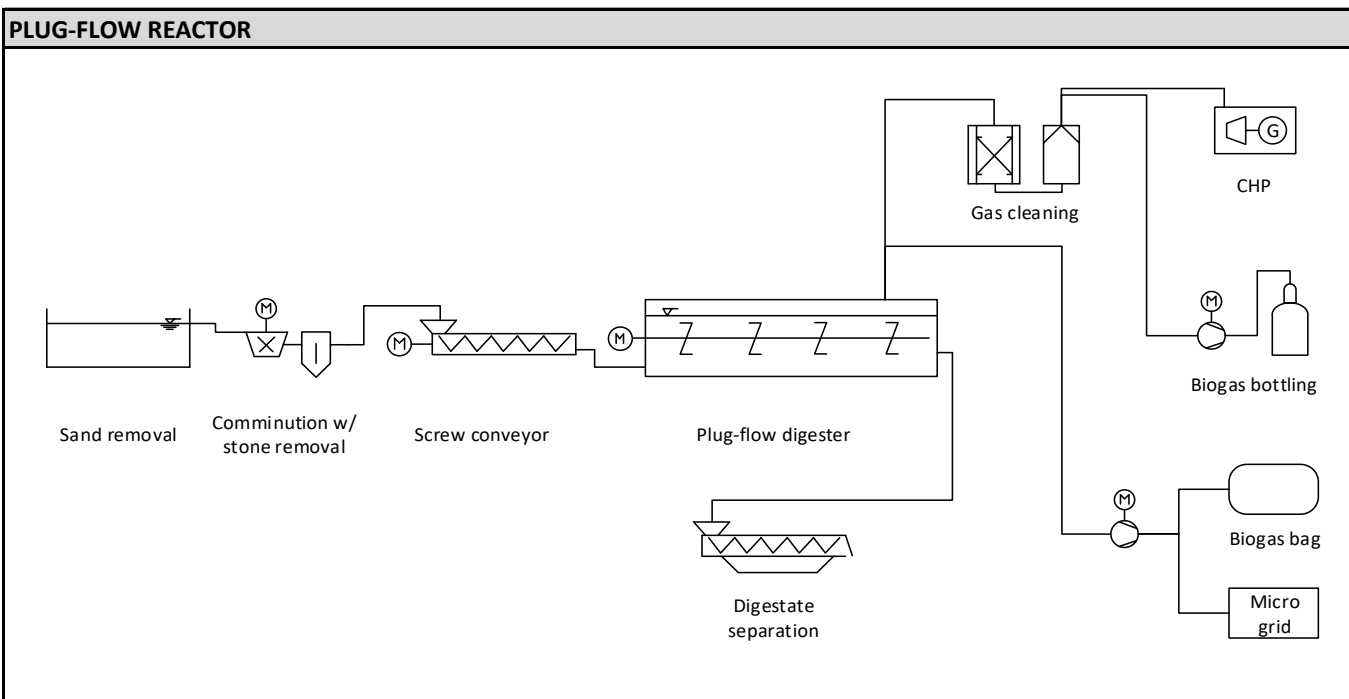
| FEEDSTOCK MIX                      | PRODUCTION         |                           | THEORETICAL BIOMETHANE POTENTIAL |       |          | COMPONENTS                  |                           |               |
|------------------------------------|--------------------|---------------------------|----------------------------------|-------|----------|-----------------------------|---------------------------|---------------|
|                                    | Amount<br>t FM / a | Dry Matter<br>Content [%] | 1.000 m3 / a                     | PJ /a | ktoe /a  | Total Energy<br>Utilisation | Type                      | Mass<br>Ratio |
| <b>MANURE EXCLUDED</b>             |                    |                           |                                  |       |          |                             |                           |               |
| Cassava only                       | 5.448.875          | 80%                       | 1.407.989                        | 51    | 1.206,95 | 31%                         | Cassava peel              | 100%          |
| Plantains/Cassava                  | 3.910.584          | 45%                       | 541.027                          | 19    | 463,78   | 12%                         | Plantains trunk and leave | 52%           |
|                                    |                    |                           |                                  |       |          |                             | Cassava peel              | 48%           |
| Foodwaste/Cassava                  | 3.860.966          | 45%                       | 461.899                          | 17    | 395,95   | 10%                         | Food waste waste          | 87%           |
|                                    |                    |                           |                                  |       |          |                             | Cassava peel              | 13%           |
| Foodwaste/Plantains/<br>Cassava    | 7.763.966          | 45%                       | 1.000.966                        | 36    | 858,05   | 22%                         | Food waste waste          | 44%           |
|                                    |                    |                           |                                  |       |          |                             | Plantains trunk and leave | 26%           |
|                                    |                    |                           |                                  |       |          |                             | Cassava peel              | 30%           |
| <b>MANURE INCLUDED</b>             |                    |                           |                                  |       |          |                             |                           |               |
| Cassava/Cattle manure              | 8.271.249          | 61%                       | 1.547.697                        | 56    | 1.326,71 | 34%                         | Cassava peel              | 66%           |
|                                    |                    |                           |                                  |       |          |                             | Cattle solid manure       | 34%           |
| Cassava/Cattle manure              | 4.433.453          | 45%                       | 556.010                          | 20    | 476,62   | 12%                         | Cassava peel              | 36%           |
|                                    |                    |                           |                                  |       |          |                             | Cattle solid manure       | 64%           |
| Foodwaste/Cattle<br>manure/Cassava | 8.292.715          | 45%                       | 1.017.469                        | 37    | 872,19   | 23%                         | Food waste waste          | 41%           |
|                                    |                    |                           |                                  |       |          |                             | Cattle solid manure       | 34%           |
|                                    |                    |                           |                                  |       |          |                             | Cassava peel              | 25%           |

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

# POTENTIAL BIOGAS SYSTEMS

1/2

based on literature and calculations made by DBFZ/Germany



The plug-flow digester is a continuous system which can be operated at higher dry matter contents (25 % < DM < 50 %) and organic loading rates as the in Europe more common continuously stirred tank reactors. The substrate transport along the horizontal axis of the digester prevent lack streams and therefore it delivers high efficiencies and a good substrate utilisation.

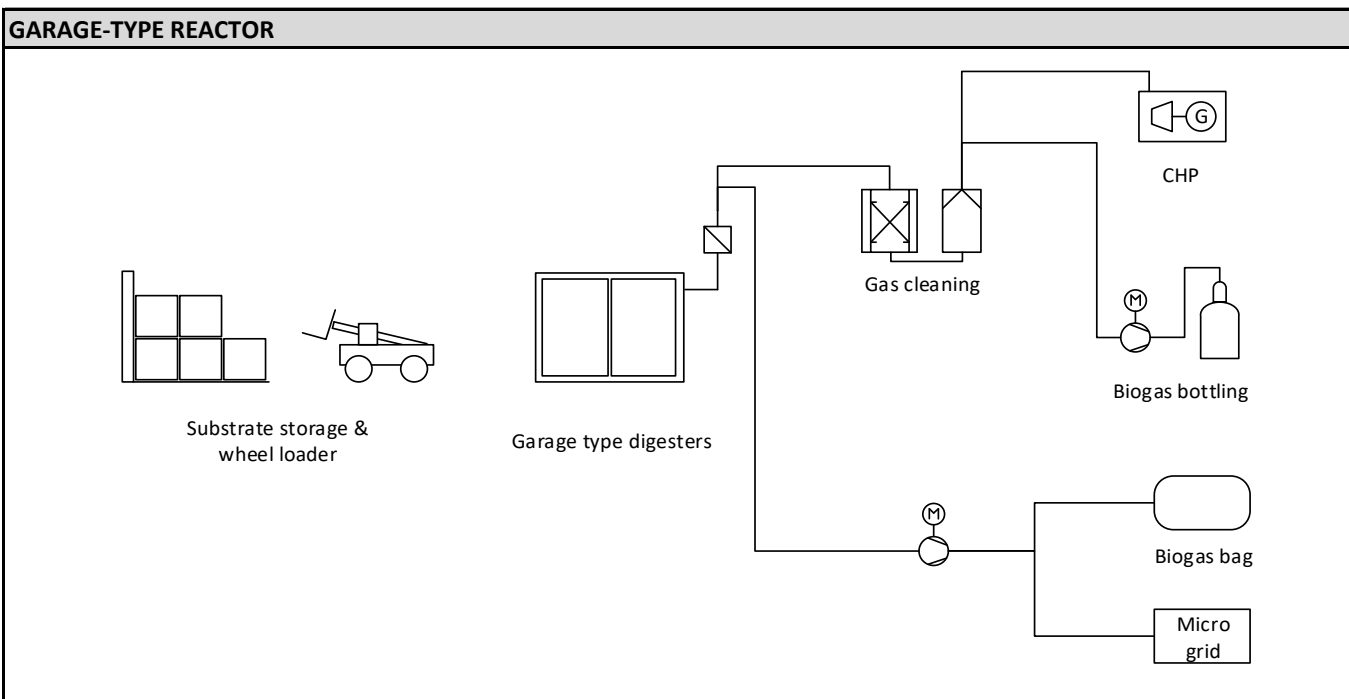
It has to be considered, that the plug-flow digester is susceptible to stratification (sinking and floating layers). Therefore a suitable substrate preparation has to be included in the concept. This reactor type can be adapted to the substrate streams available by scaling of the reactor.

|                        |                                   | Dry Matter Content [%] | Utilisable Feedstock Mixtures |  |
|------------------------|-----------------------------------|------------------------|-------------------------------|--|
| <b>manure excluded</b> | cassava only                      | 80%                    | -                             |  |
|                        | plantains/ cassava                | 45%                    | +                             |  |
|                        | foodwaste/ cassava                | 45%                    | +                             |  |
|                        | foodwaste/ plantains/ cassava     | 45%                    | +                             |  |
| <b>manure included</b> | cassava/ cattle manure            | 61%                    | -                             |  |
|                        | cassava/cattle manure             | 45%                    | +                             |  |
|                        | foodwaste/ cattle manure/ cassava | 45%                    | +                             | high energy gain<br>optimal for technical use<br>waste-based |

# POTENTIAL BIOGAS SYSTEMS

2/2

based on literature and calculations made by DBFZ/Germany



Garage-type digesters have the advantage over other common systems to take up high dry matter contents in the substrate. The substrate itself needs to be stackable and perfusable for the percolate, which transports the microorganisms needed into the process. Gas-tightness of the gates has to be assured at all times. Also, weak gas with low methane contents from the start-up phases needs to be treated to avoid GHG emissions.

Garage-type digesters are commonly built as modules in a certain size, which can be fed by a wheel loader. Therefore, they operate batch-wise and a continuous biogas flow has to be established by a certain number of modules. Furthermore, adaptation to substrate amounts is carried out by numbering up of the garage modules rather than a scale up.

|                 |                                   | Dry Matter Content [%] | Utilisable Feedstock Mixtures |  |
|-----------------|-----------------------------------|------------------------|-------------------------------|--|
| 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%                    | -                             | high energy gain<br>optimal for technical use<br>waste-based |

# ASSESSMENT OF GAS UTILISATION

based on literature and calculations made by DBFZ/Germany

|   | CHP ENGINE                      | BIOMETHANE<br>UPGRADING       | BIOGAS BOTTLING                                | BIOGAS BAG                            | MICROGAS GRID           |
|---|---------------------------------|-------------------------------|--|---------------------------------------|-------------------------|
| <b>PERSONAL REQUIREMENTS</b>            |                                 |                               |  |                                       |                         |
| <i>Complexity</i>                       | ++                              | +++                           | ++   | +                                     | ++                      |
| <i>Operators level of qualification</i> | ++                              | +++                           | ++   | +                                     | ++                      |
| <b>GRID ABILITY</b>                     |                                 |                               |  |                                       |                         |
| <i>On grid operation</i>                | +++                             | +++                           | +  | +                                     | +                       |
| <i>Off grid operation</i>               | +++                             | +                             | +++  | +++                                   | +++                     |
| <b>SPATIAL INTEGRATION</b>              |                                 |                               |  |                                       |                         |
| <i>Long distance supply</i>             | +                               | +++                           | +  | +                                     | +                       |
| <i>Municipal supply</i>                 | +++                             | +++                           | +++  | +                                     | ++                      |
| <i>Rural supply</i>                     | ++                              | +                             | +++  | +++                                   | +++                     |
| <b>COMMERCIALISATION</b>                |                                 |                               |  |                                       |                         |
| <i>Products</i>                         | electricity and heat            | biomethane and carbon dioxide | gas cylinder with biogas for universal purpose | biogas bag with biogas as cooking gas | cooking gas             |
| <i>Sector of economy</i>                | industrial and household        | industrial and household      | household and traffic                          | household                             | household               |
| <i>Cost of production</i>               | +++                             | +++                           | ++   | +                                     | ++                      |
| <i>Competitive product</i>              | petroleum gas, gasoline, diesel | petroleum gas                 | charcoal, petroleum gas, gasoline, diesel      | charcoal                              | charcoal, petroleum gas |

+ = low, ++ = medium, +++ = high

## ABBREVIATIONS

|         |   |
|---------|---|
| FAOSTAT | Database of the Food and Agriculture Organization of the United Nations |
| FM      | Fresh matter  |
| IEA     | International Energy Agency   |
| IFPRI   | International Food Policy Research Institute                            |
| IPCC    | Intergovernmental Panel on Climate Change                               |
| ktoe    | Tonne of oil equivalent   |
| LHV     | Lower Heating Value   |
| LU      | Livestock unit  |
| MJ      | Megajoule   |
| Mt      | Megatonne   |
| OECD    | Organisation for Economic Co-operation and Development                  |
| PJ      | Petajoule   |

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