Feedstock Composition and Biogas Yield: a Review

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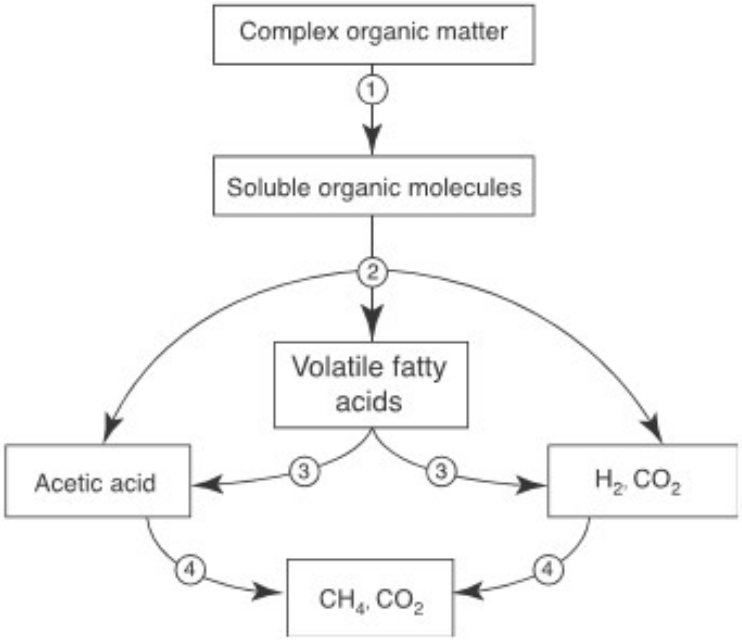
Anaerobic digestion (AD) process

Organic matter → CH_4 + CO_2 + water + minerals + microbial biomass + organic residue



- Decomposition of complex organic molecules
- Four steps, involving different groups of micro-organisms
- Each group has specific preferences, condition requirements
- Result is a delicate compromise

Source: Zupančič and Grilc (2012).

Global availability of biomass residues

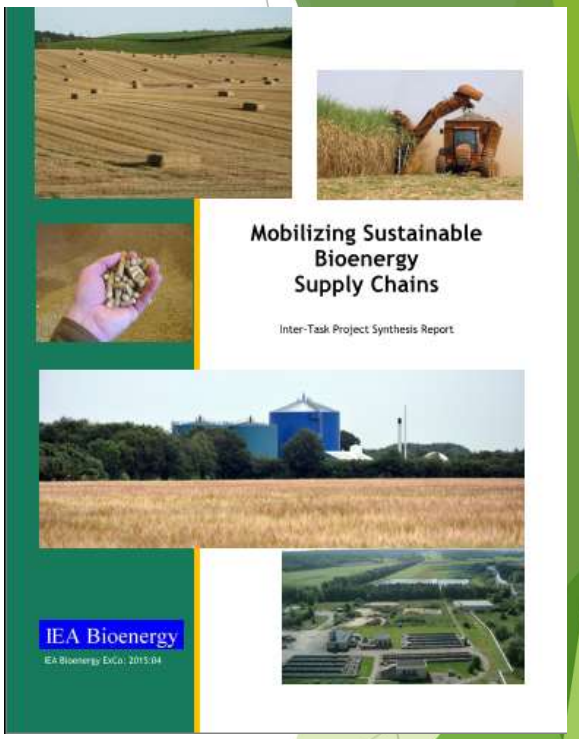
Availability of biomass residues EU and global (million tonnes per year)

Biomass type	Europe current	2020	Global current	2020
MSW biodegradable	591	460	2,694	3,253
C&I	460	359	1,941	2,390
Animal manure	969	853	10,320	12,016
Straw	405	870	4,963	5,240
POME			60	127
EFB			81	172
Bagasse			1,205	1,748
Husks			583	645
Bark, branches, leaves	554	1,377	532	1,376
Black and brown liquor	459	1,392	498	1,714

Source: E4Tech (2014)

Mobilising residues

- Not all biomass is easy accessible
  - 14 billion tonnes of collectable manure
  - 2.4 billion tonne of crop residues
- Total availabile biomass has a gross energy value of 49-62 Exajoules
- In 2050, 90 Exajoules will be available at low costs (2-3$/GJ)



Source: Smith et al. (2015) Mobilisation of sustainable bioenergy supply chains. IEA Bioenergy, Paris

Non-lignocellulosic feedstocks

Residue	TS (%)	VS (% of TS)	Availability
Potato effluent	4	90	5.4 m3/tonne potato
Palm Oil Mill Effluent	3	86	0.7-0.9 m3/tonne FFB
Slaughtering waste	15	80	0.5 tonne/tonne meat
Vinasse	1	90	0.8-1.3 m3/tonne cane
Cattle slurry	11	82	7 tonne/hd/y
Food residues	20	92	55 kg/p/d
Chicken manure	40	75	73 kg/hd/y
Solid cattle manure	25	76	7 tonne/hd/y

Lignocellulosic feedstocks

Residue	TS (%)	VS (% of TS)	Availability (tonne/ha)
Silage maize	35	94	30
Wheat straw	98	93	5
Sugarcane bagasse	94	97	22
Coffee pulp	55	91	3
Forest residues	50	64	120
Empty Fruit Bunches	64	80	4
Banana pseudostems	5	4	77

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Determining biogas potential

- Goal: understand energetic value of a substrate
- What makes a good substrate? How do we compare?
- Metrics
  - BMP
  - VS
  - TS
  - FM
- Consider all metrics to get a full picture

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Method 1: BMP

- Relative measure of the strength of sample per g of VS (mL biogas/kg of VS / m^3 per tonne of VS)
- Added to digester (1:6 - VS:sludge), 30 days at 35^oC
- ‘Normalizes’ available VS
- Does not take account of
  - Ratio of VS to TS (FM)
  - Substance recalcitrance

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Biomethane potential - BMP

- Large variability between substrates
  - POME and potato mill effluents: high
  - Range 127 – 329 m^3 biogas/kg VS
- Large experimental variability
- Can be reported in terms of VS, TS, or FM
  - Difficult to compare
- Best choice: direct measurement of a specific substrate

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Metric 2: VS – Volatile Solids

- Oven dried, ignited at 550 °C
- Advantage: conveys available organic material
- However, no indication or biogas potential, does not indicate moisture content if reported as share of TS, rather than total %-age

VS – Volatile Solids

- **Low:** <300 m3 biogas/tonne VS
  - Lignocellulose, cattle and pig manures
- **Modest:** 300-500 m3 biogas / tonne VS
  - Chicken manure, MSW, banana stalks
- **High:** >500 m3 biogas/tonne oTS
  - POME, abattoir effluents, potato starch effluents
- Differences are likely due to nutrient limitation

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Metric 3: TS - Total Solids

- Oven-dried, represents for DWB
- Advantages: conveys moisture content
  - Consider difference between liquid and solid residues
  - Important operational consideration
- However, no indication of organic content or biogas potential

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TS - Total Solids

- **Liquids**: 1-15 %TS
  - POME, Vinasse, Aguamiel (Coffee)
- **Non-lignocellulosic solids**: 25-40 %TS
  - Manures, MSW
- **Lignocellulosic solids** (Wide range)
  - >90% Bagasse, Wheat straw, Corn Stover
  - 50%-90% Forestry, Palm Fibre, Coffee Pulp
- Recalcitrance can affect residence times
- Handling affects TS
  - Banana stalks: 5%
  - After sundrying for a month: 92%

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Metric 4: FM - Fresh Matter

- Oven-dried
- Advantages: conveys field conditions
- However, no indication of organic content or biogas potential, analysis required

FM - Fresh Matter

- **Metric for “as is” substrates**
- **Low**: < 50 m3 biogas per tonne FM
  - POME and coffee effluents, manure slurries, food residues
- **Modest**: 50 – 100 m3 biogas per tonne FM
  - Abattoir wastewater, municipal sewage sludge, coffee pulp
- **High**: 100 – 200 m3 biogas per tonne FM
  - Chicken manure, lignocellulosic feedstocks

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Some considerations:

- VS yields provide comparison between richness of substrates
- FM yields provide real world values, but need to account for availability to get the full picture
- Lignocellulosic feedstocks are recalcitrant, which increases residence times
  - Can be improved with pretreatment
- $\%CH_4$: indicates methane yield from biogas
  - Typically 60:40 for CH_4:CO_2
- C/N ratio: (indicates if codigestion is necessary)

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Conclusion

- High amount of feedstocks is available, especially in tropics
- Reporting of biogas potential depends on consistent data for comparison which are not readily available
- Framework presented here identifies key parameters and their conversions to provide maximum information for given feedstocks.

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Thank you for your attention

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