Chemical Process and Energy Resources Institute
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AN ENVIRONMENTAL ASSESSMENT FOR ANAEROBIC DIGESTION OF BIOWASTE BASED ON LIFE CYCLE ANALYSIS PRINCIPLES

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Scope

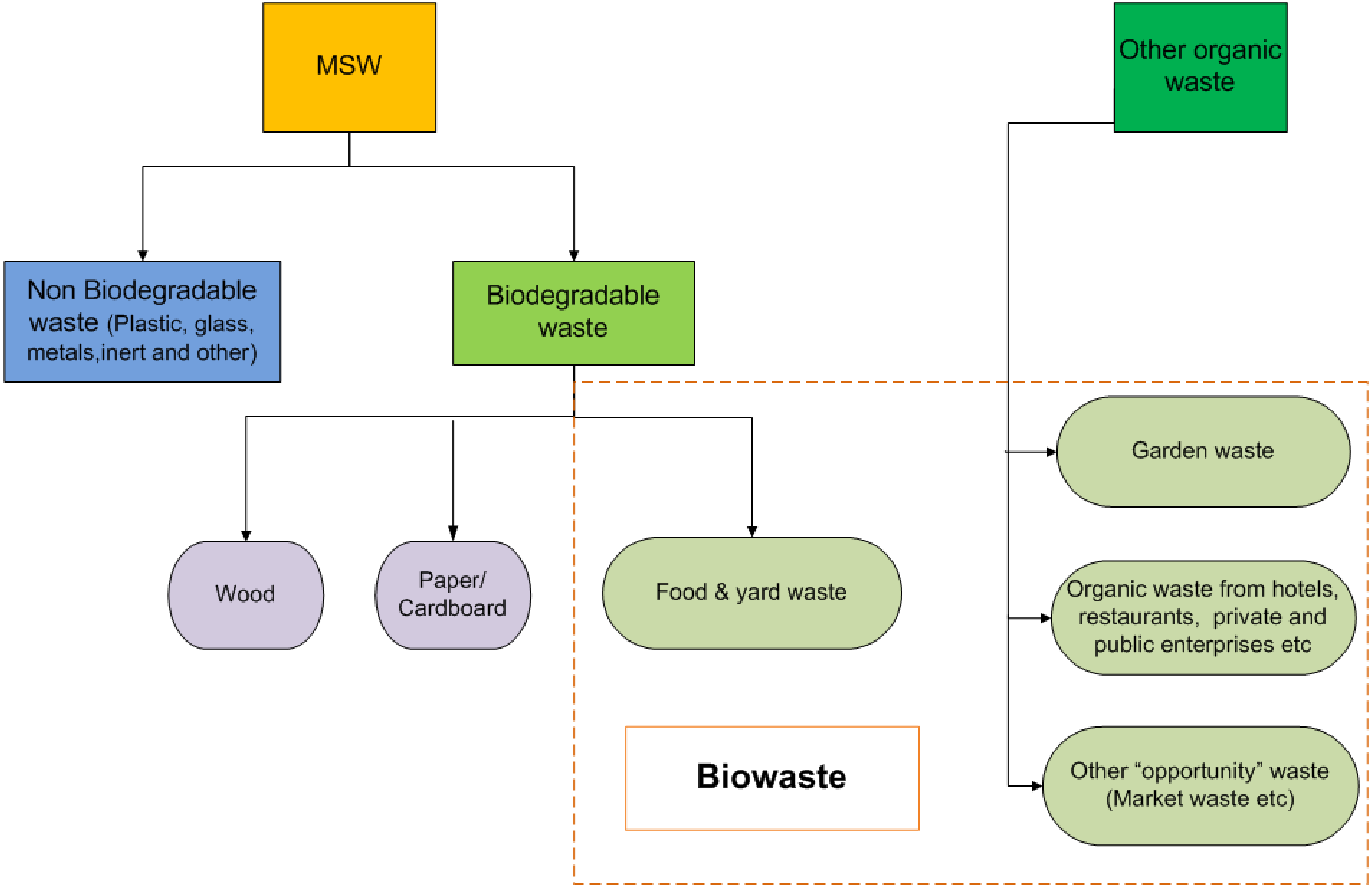
The total environmental impact of anaerobic digestion of biowaste, including:

- Digestion process
- Infrastructure of digestion unit
- Transportation of waste to digestion unit

and

comparison with the life cycle analysis of natural gas, which is substituted by produced biogas, under the same primary energy principles

Definition of biowaste



MSW

Other organic waste

Non Biodegradable waste (Plastic, glass, metals,inert and other)

Biodegradable waste

Garden waste

Wood

Paper/ Cardboard

Food & yard waste

Organic waste from hotels, restaurants, private and public enterprises etc

Biowaste

Other “opportunity” waste (Market waste etc)

Anaerobic digestion

- Anaerobic digestion involves a series of metabolic reactions such as hydrolysis, acidogenesis and methanogensis.

- Biogas is the main product of anaerobic digestion (48-65% methane, ca. 36-41% carbon dioxide, up to 17% nitrogen, <1% oxygen, 32-169 ppm hydrogen sulphide and traces of other gases.

- Biogas yield depends on: a) Composition of substrate, b) Microbial composition, c) Temperature, d) Moisture, e) bioreactor design

- Anaerobic digestion has come of age in the field of the treatment of the organic fraction derived from municipal solid waste, more so than any other alternative treatment technology developed in the last 20 years.

- In Europe, 244 installations dealing with the organic fraction of MSW have been constructed or are permitted and contracted to be construct (up to 2014)

- The cumulative capacity of all these anaerobic digestion plants amounts to 7,750,000 ton per year of organics going into the digestion phase.

Life Cycle Analysis for Anaerobic digestion

➢LCA data for anaerobic digestion are sensitive to the amount of methane which is produced for use as energy offset.

➢The magnitude of the benefit from energy offsets also depends on the energy fuel displaced

➢The calorific value and the biogenic fraction of fuel are the main parameters for the estimating of the credibility of the offsets

➢The purity of waste stream should be defined with respect to the purpose of the AD plants:

- Maximize the output of methane → mixed waste
- High quality of digestate → the purity of waste is very important

Examined Scenario (1)

Boundaries

The boundaries include mainly:

- The overall digestion process
- The infrastructure of digestion unit
- The transportation of waste to digestion unit

More specifically:

- Data represent the environmental exchanges due to biowaste pretreatment (inclusive the disposal of contaminants), biowaste digestion and post-composting of digested matter
- The use of presswater and digested matter as a fertilizer in agriculture are recorded
- Spreading of the fertilizer as well as transport from biowaste plant to farms are taken into account
- Gas purification and the use of the gas for co-generation are not included
- The internal consumptions of the plant are covered by a cogeneration unit utilization using the produced biogas

Examined Scenario (2)

Input data

Total solids/Dry substance (TS)	% wt	40%
Volatile solids (oTS)	% wt of TS	80%
Biogas yield	m3/kg oTS	0,544
Average CH4 content	%	60,0%
CH4 potential	m^3 CH4/kg oTS	0,327
CH4 potential (after 20 days)	% of TCH_4	97%
CH4 yield (after 20 days)	m^3 CH_4/kg oTS	0,317
Plant efficiency	%	80%
Expected yield of CH4	m^3 CH_4/kg oTS	0,253

Electrical Efficiency: 36%
Thermal Efficiency: 40%
Availability of the plant: 90%

Installed capacity: 1MWe

Carbon decomposition during digestion: 76%
Carbon decomposition during post composting: 24%
The total covered distances is 3km per day

Examined Scenario (3)

Functional unit-Method

Functional unit: 1 m^3 biogas

Method: the Greenhouse Gas Protocol Method

Greenhouse Protocol Method (1)

The total GHG emissions are calculated as the sum of GHG emissions, in CO2e, of all foreground processes and significant background processes within the system boundary.

A distinction is made between:

- GHG emissions from fossil sources (Fossil Emissions)
- Biogenic carbon emissions (Biogenic Emissions)
- Carbon storage (CO2 uptake)
- Emissions from land transformation

Stages:

☐ Characterization

☐ Weighting

Greenhouse Protocol Method (2)

Main Factors

Fossil CO2eq	Factor
Carbon dioxide	1
Carbon dioxide fossil	1
Carbon monoxide	1,57
Methane fossil	25

Biogenic CO2eq	Factor
Carbon dioxide biogenic	1
Carbon monoxide biogenic	1,57
Methane biogenic	25

CO2eq from land transformation and CO2 uptake	Factor
Carbon dioxide	1

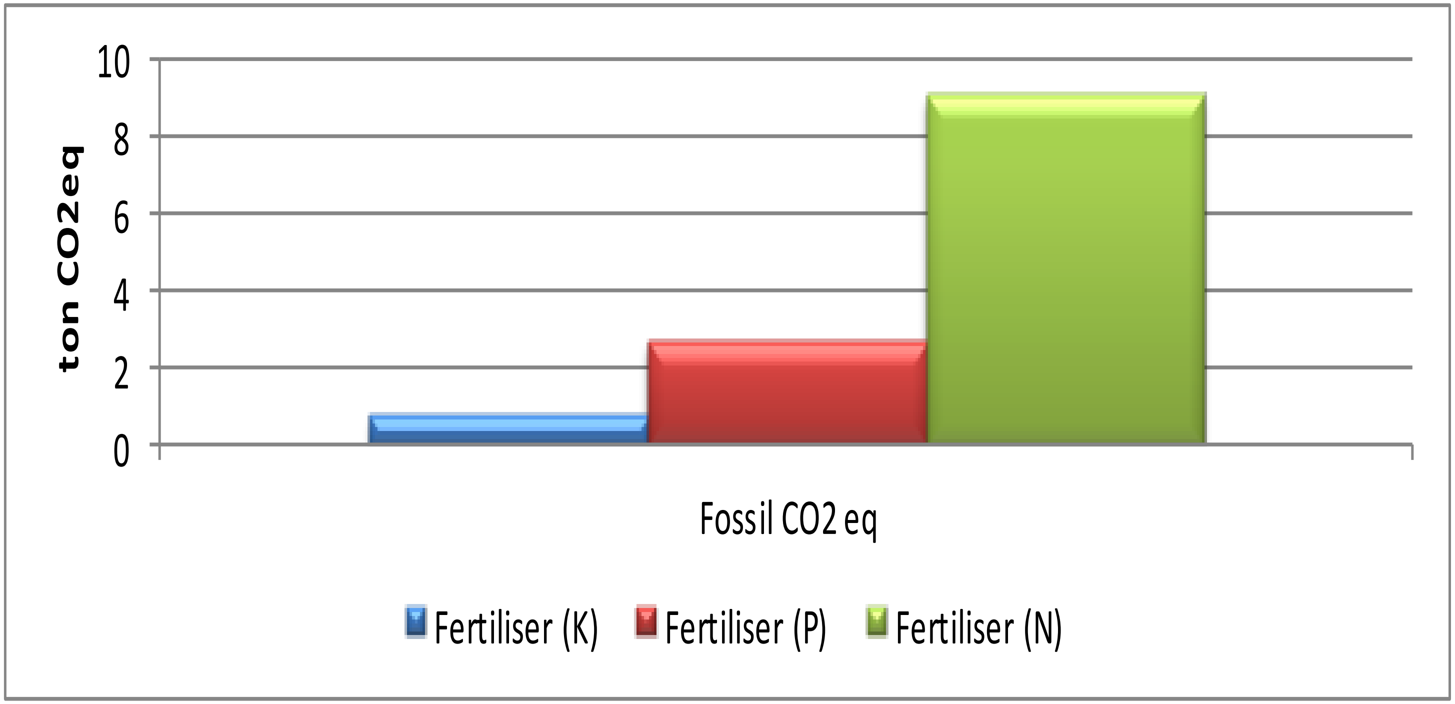
Similar impact to greenhouse effect for all types of emissions

Results (1)

Global warming potential of inorganic fertilizers

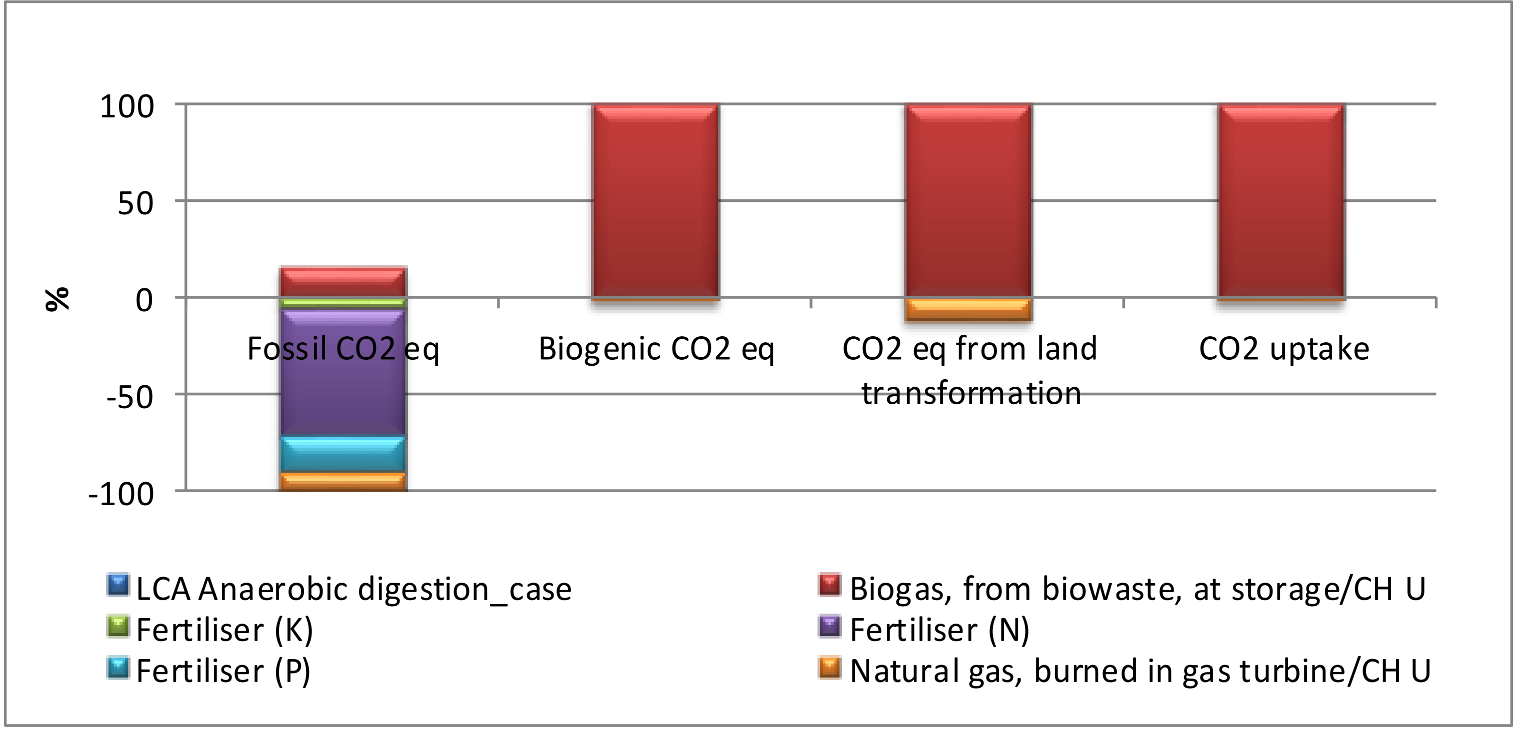
Natural gas is the main source for the energy demand of these processes

The formation of N-fertilizer has the highest impact to the greenhouse effect.



Results (2)

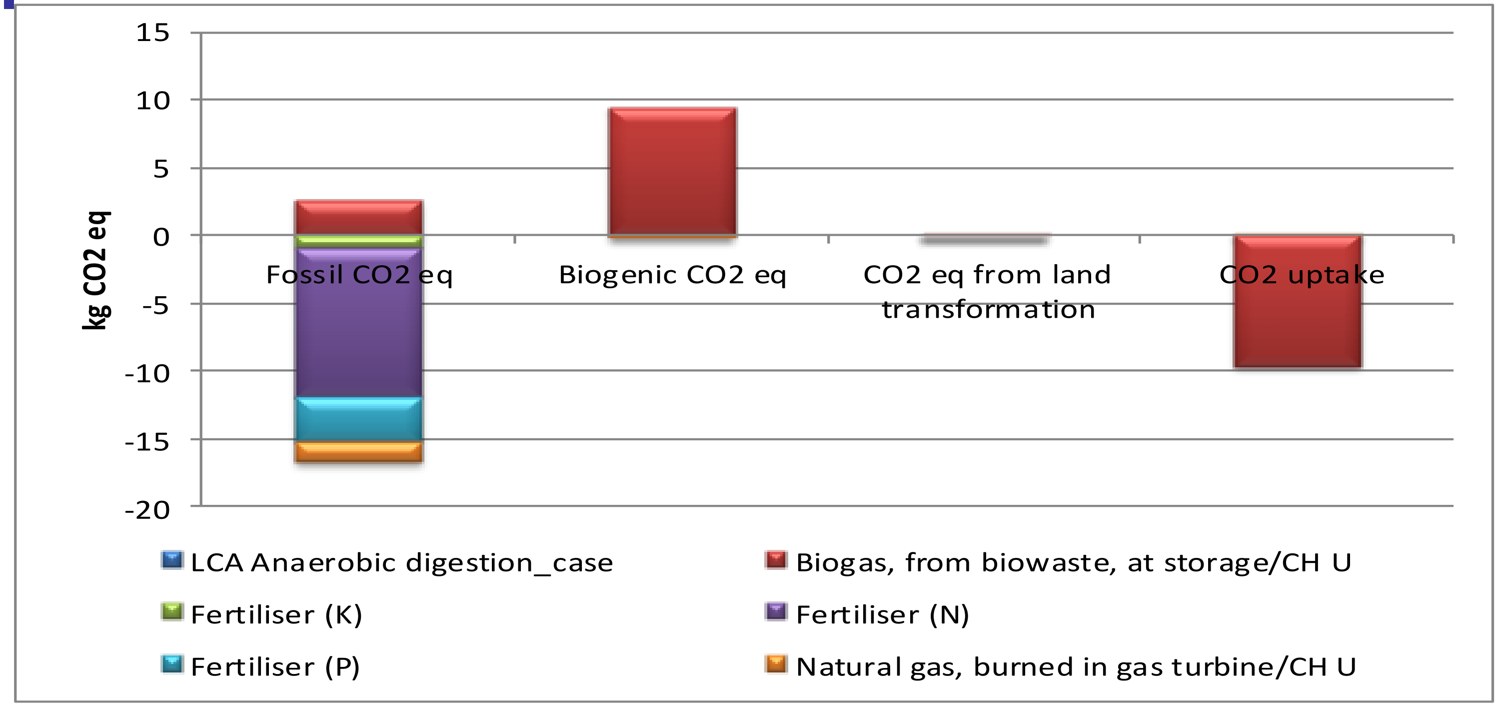
Characterization profile



The avoided emissions from the production of inorganic fertilizers and from the substitution of natural gas to produced biogas are introduced.

Results (3)

Weighting profile



- ➢The biogenic emissions for the LCA of natural gas are resulting from the energy mix
- ➢The substitution factor of inorganic fertilizer is estimated at 60%
- ➢The avoided emissions from the production of –N fertilizer have the highest value
- ➢The fossil emissions have lower value than the biogenic emissions in the biogas production

Results (4)

Summary

	Biogas from biowaste	**Fertilizer (K)**	**Fertilizer (N)**	**Fertilizer (P)**	**Natural Gas, burned in gas turbine**
Fossil CO2eq	2,62	-0,964	-10,9	-3,22	-1,52
Biogenic CO2eq	9,32	0	0	0	-0,0004
CO2eq from land transformation	2,29E-5	0	0	0	-2,73E-6
CO2 uptake	9,64	0	0	0	-0,000373

Conclusions

- The production of inorganic N-fertilizer has the highest impact to the global warming potential comparing with the other types of inorganic fertilizers.

- The emissions created from the plant manufacture contributed very little towards the whole life cycle environmental impacts.

- The comparison with the life cycle analysis of natural gas, which is substituted by produced biogas, shows the benefits of the specific method to greenhouse effect.

- Comparing with landfiling (usual applied waste treatment in Greece), the total environmental impact is reduced significantly.

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Biowaste
Paper
Metals and Plastics
Glass
Rest Waste
ISWM - TINOS

Life

Thank you for your attention