Conversion of Wet Waste to Fuel and Value-Added Products using Hydrothermal Carbonization

Life cycle analysis

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UK-India Education and Research Initiative

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Agenda

Time (BST)	Session
09:00-09:15	Welcome
09:15-09:45	**Session 1: An introduction to life cycle analysis**
09:45-10:00	Session 1 Q+A
10:00-10:30	**Session 2: Life cycle analysis procedure**
10:30-10:45	Session 2 Q+A
10:45-11:00	Break
11:00-11:30	**Session 3: Life cycle analysis & hydrothermal carbonisation**
11:30-11:45	Session 3 Q+A
11:45-12:00	General Discussion and Close

Session I-
An introduction to life cycle analysis

This session will cover:

- What is an LCA? And why is this relevant to HTC?
- A brief history of LCA
- Applications of LCA
- Platforms and software for performing LCAs

Session 2-
LCA procedure

This session will cover:

- Components of LCAs
- Goal and Scope definition
- Inventory analysis
- Impact assessment
- Interpretation
- Options for further analysis and modelling of results
  - Parameter exploration
  - Sensitivity analysis
  - Uncertainty analysis
  - Statistical modelling

Session 3-
Life cycle analysis & hydrothermal carbonisation of wet waste

This session will cover:

- Options concerning treatment of wet waste
- Options for HTC of wet waste
- Components of HTC LCAs
- Review of existing HTC LCAs
- HTC LCA: Future work

Session I-
An introduction to life cycle analysis

What is an LCA? (1)

- The LCA is a method to study the following, in relation to the research object (process or product):
  - All inputs
  - All outputs

- It concerns the research object over the entire life cycle

- It aims to obtain the impact of the research object.

What is an LCA? (2)

- LCAs focus on the following:
  - Primarily GHGs
  - Other environmental impacts (such as ecotoxicity, land use etc)
  - Social impacts (i.e. job creation and health)
  - Economic impacts LCC (i.e. cost and savings over life cycle)

- It aims to obtain the environmental, social and/or economic impact of the research object.

Why is LCA relevant to HTC?

- Understand environmental, social and economic impacts of HTC

- Compare performance of the following:
  - HTC compared to competing technologies
  - Different feedstock types
  - Different HTC process conditions
  - Different product applications
  - Adoption of HTC in different regions, or specific sites

A brief history of LCA (1)

1960s
- Conceptualised in in response to concern over environmental degradation and resource limitations

1970s
- First applications in energy and waste management

1980s
- Numerous LCAs conducted, but lack of standardised methodology:
  -ISO 14040 and ISO 14044 developed
  -1st version of Ecoinvent LCI database released
  -UNEP promoted and supported LCA practical application of LCA

1990s
- Some standardisation developed:
  -Emergence of ISO
  -LCA code of practice Guidelines for Life-Cycle Assessment A “Code of Practice” by The Society of Environmental Toxicology and Chemistry

2000s
- Development of standardised methodology, life cycle inventory and promotion of LCA use

2010s
- Development of up to date handbook and guidelines:
  -ILCD handbook developed
  -LCA code of practice Guidelines for Life-Cycle Assessment

Applications of LCA

Product and process comparison

- GHG reduction
- Ecotoxicology reduction
- Cost reduction
- Social benefit

Product/process optimisation

- Identification of problem area
- Identification of alternatives/solutions

Awareness raising

- Identify problem area
- Quantify issues

Policy and strategy development

- Data to inform government policy on sustainable development
- Data to inform company policies on sustainable development
- Data to inform NGOs on areas to focus on

Platforms and software for performing LCAs (1)

Main LCA software

- GaBi
  - https://gabi.sphera.com/uk-ireland/index/
- Simapro
  - https://www.simapro.co.uk/simapro?gclid=CjwKCAjwndCKBhAkEiwAgSDKQfoCtyHyNwG2TPuC0dSsLrC4Zbi1SPVj29hQc_3oUTmhjDv8CWH6OxoCtpwQAvD_BwE
- One click LCA
  - https://www.oneclicklca.com/
- Open LCA (free)
  - https://www.openlca.org/

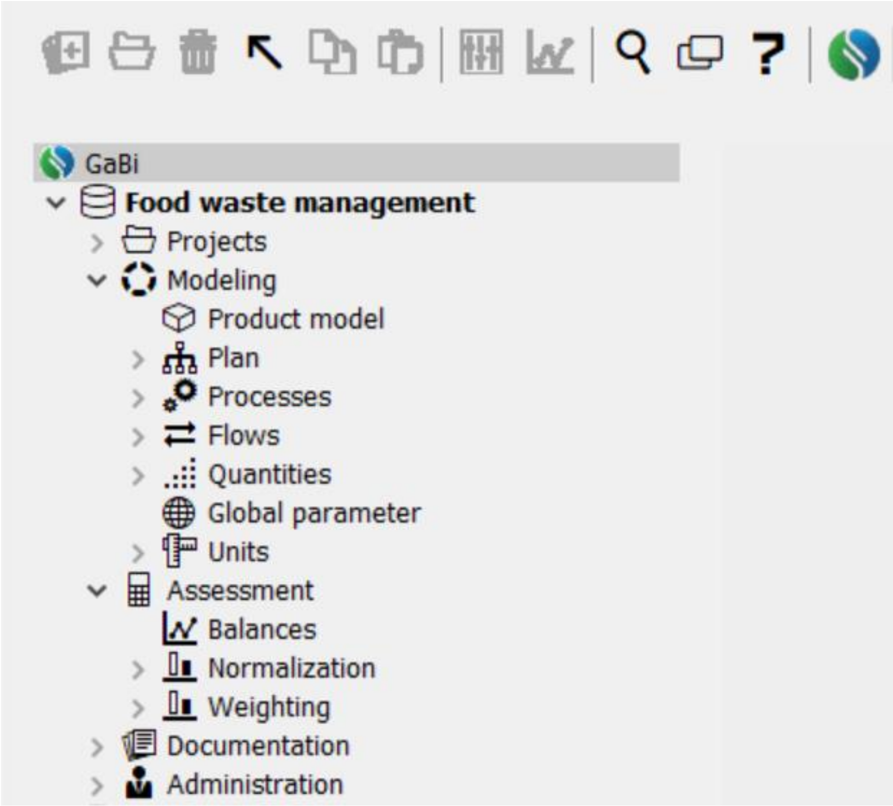
Waste management LCA

- WRATE
  - http://www.wrate.co.uk/

Platforms and software for performing LCAs (2)

GaBi

- Interface/platform to design LCAs
- Design system plans
- Input flows and processes
- Includes database
- Assess environmental, economic and social factors
- Explore parameters/tweak systems
- Export results, design reports etc



Databases for performing LCAs (2)

Software databases

- GaBi
  - https://gabi.sphera.com/uk-ireland/databases/
- SimaPro
  - https://www.simapro.co.uk/?gclid=CjwKCAjwndCKBhAkEiwAgSDKQcdVd3cLE0CIF3B1t_jjBHlQHutqL238bxCy_4TVrVepjrlrqfaHfBoCzUsQAvD_BwE

Specific databases

- Ecoinvent
  - https://ecoinvent.org/the-ecoinvent-database/

Other sources of data

- Literature
- Government databases
- Personal data and data from research groups

Question and answer session

- Thank you for listening
- Any Questions?

Session 2-

Life cycle analysis procedure

Components of an LCA? (1)

- LCA involves the following components:

1. Goal and Scope definition
2. Inventory analysis
3. Impact assessment
4. Interpretation
5. Further analysis and modelling of results

Goal and Scope definition (1): Goal

- The goal of the LCA specifies the following:
  - Intended application of results
    - i.e. demonstrating the GHG mitigation from HTC of food waste
  - The reason for generating the results
    - i.e. minimising GHG emissions in food waste treatment
  - The expected audience for the results
    - i.e. influencing food waste policy to promote HTC

Goal and Scope definition (2): Scope definition

- The scope definition of the LCA specifies the following:
  - The nature of the product under examination
    - Includes the functional unit
  - The level of detail in which the research object is being examined Includes:
    - the processes,
    - the methods, (extent processes are evaluated),
    - Assumptions and limitations,
    - Assessment of data quality
    - Critical review

Goal and Scope definition (3): Specific components (1)

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- The Functional unit (the precise specification of the function of the product)
  - I.e. kg CO_2eq/kg food waste treated
- The product system (the main activities)
  - I.e. Transport, heating, drying, end usage/product substitution, end disposal
- Scope (gate-gate, cradle-gate, cradle-cradle, cradle-grave)
  - I.e. gate-grave (from the point food waste to end disposal/product substitution)

Goal and scope definition (3): Specific components (2)

- The time and place
  - I.e 2021, India
- System boundaries (whether to include indirect emissions)
  - Construction of lorries used in transport not included
- Data sourcing (databases, peer-reviewed literature etc)
  - I.e only include data from peer reviewed articles

Inventory analysis (1)

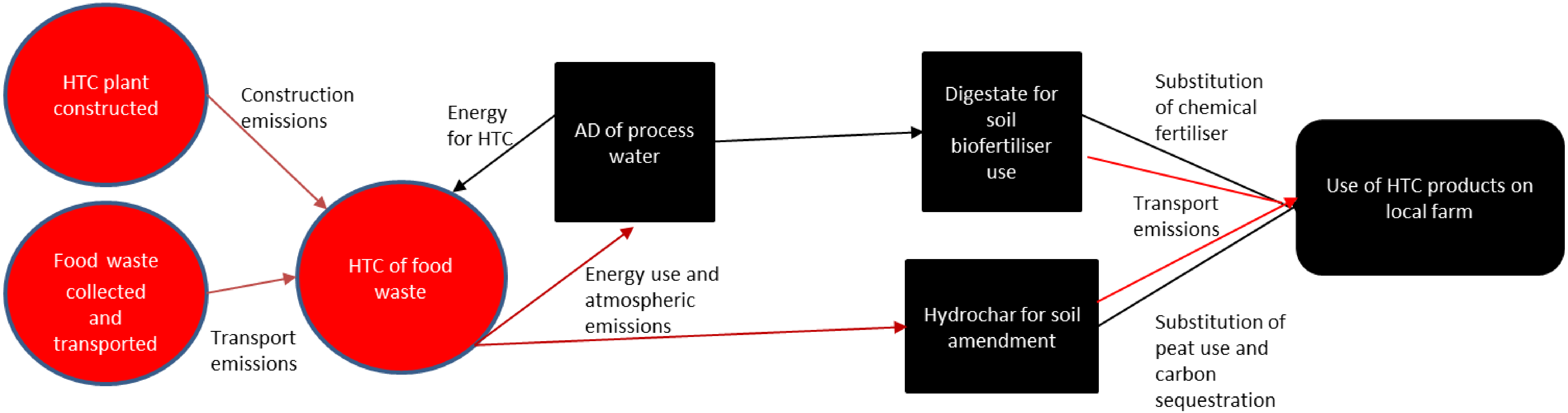
- Inventory analysis involves the compilation of quantified inputs and outputs for a system throughout its life cycle.

- This involves:

1. **Preparing for data collection** (i.e. deciding what data you require through defining a process chain)
2. **Collecting the data**
3. **Calculating the data** (making sure measurements are uniform)
4. **Allocating and partitioning** (considering system boundaries)

Inventory analysis (2): Preparing for data

- Decide what data you require through defining a process chain
  - I.e. for HTC of food waste



Inventory analysis (3): Collecting and calculating data

- Collecting data includes sourcing from:
  - Databases, literature, government data, experimental data

- Calculating data
  - Ensure that the data is derived from data gained from the same assumptions
  - Ensure the data is relevant for the scope of the LCA
  - If there are differences then calculate figures based on LCA scope
  - Compile data into the format required for the LCA (inputs/outputs)

Inventory analysis (4): Allocating and partitioning

Allocating

- Allocate an appropriate proportion of emissions for emission/mitigation factors that involve other systems
  - I.e. IIT may send 1TPD of food waste to a HTC site that processes 100TPD
    - IIT's food waste contributes to 1% of the total HTC construction emissions, energy usage etc
    - Can also use total energy production, hydrochar produced, or cost for collection for allocation

Partitioning

- Define split off points (what factors to include/exclude)
  - Typically if contribution of input= <1% then exclude
  - I.e. if <1% of total food waste collected by truck is from IIT over lifecycle, can construction and decommission emissions of truck in LCA for HTC of IIT food waste

Impact assessment

- Evaluating the significance of the potential impacts of the life cycle of the product, or process
  - I.e. The GHGs associated with IIT sending it's food waste for HTC

- The impact assessment involves:

1. **Classification** (grouping inputs and outputs with the same type of impacts i.e. global warming potential)
2. **Characterisation** (conversion of impacts into same unit measurement i.e. methane and nitrous oxide to CO_2eq
3. **Weighting** (optional) weigh different impact categories differently i.e. GWP> Land use

Interpretation

- Analysing the results in the context of the research question
  - I.e would sending IIT's food waste for HTC lead to GHG reductions
- Decide on most important results
- Use figures and tables to illustrate key findings
  - I.e key GHG generation areas for HTC of food waste
    - And key GHG mitigation areas
- Decide best format to present results
- Discuss limitations of results
  - I.e. error margins for data, or credibility of data

Further analysis and modelling of results (1)

Parameter exploration

- Can make alterations in LCA systems to assess impacts
  - I.e impact of using electric trucks for food waste transport
    - Or using renewable energy to power HTC reactor
    - Or landfilling digestate instead of use on farm
- Can help optimise systems such as food waste HTC
- Can help identify key risks if system has issues
- Conduct on LCA software

Further analysis and modelling of results (2)

Sensitivity analysis

- Assessment of the robustness of the LCA through measuring:
  - Impact of error margins of variables
    - highest and lowest likely values for all inputs and outputs

- Easy and quick to do on Excel or other platforms
  - Requires maximum and minimum values for inputs

Further analysis and modelling of results (3)

Uncertainty analysis

- Quantitative assessment of the error present in the data
- Assesses the robustness and reliability of the results
- Can assess the variables that are the most uncertain and have the greatest risk associated
- Takes longer than sensitivity analysis and can be conducted using Palisade @Risk software
  - Requires multiple values for inputs and outputs
  - Link: https://www.palisade.com/risk/default.asp

Further analysis and modelling of results (4)

Statistical modelling

- Reduce data and minimise variables if complex dataset
- Principle component analysis
  - Group variables that are intrinsically linked
  - Make the data more understandable
- Multiple linear regression
  - Asses the impact of multiple variables at once
- Relatively easy and can be conducted on SPSS or other statistical software

Question and answer session

- Thank you for listening,

- Any Questions?

Session 3-

Life cycle analysis & hydrothermal carbonisation

Life cycle analysis & hydrothermal carbonisation

- Specific options concerning treatment of wet waste
- Specific options for HTC of wet waste
- Specific components of HTC
- Review of existing HTC LCAs
- HTC LCA: Future work

Specific options concerning treatment of wet waste

Treatment options	Products	Pros	Cons
Energy generation		**Fossil fuels offset**	
Incineration	Energy & ash	Cheap, easy, energy generation	High air pollution, low efficiency
AD	Biomethane & digestate	Energy generation, nutrient recycling, low pollution	High tech, higher cost, potential operation and maintenance issues
HTC	Hydrochar & process water	High energy generation, low pollution	High tech, high cost
Pyrolysis	biochar	High energy generation, low pollution	High tech, high cost
Soil amendment		**Soil amendment products substituted**	
HTC	Hydrochar & process water	High retention of carbon and nutrients	High energy use and cost
Composting	Compost	Low energy use, low tech, low cost	High atmospheric/fugitive emissions
Disposal			
Landfilling, or dumping	N/A	Low tech, typically low cost	High GHGs and ecotxicity
Maceration	N/A	Low tech, typically low cost	High GHGs and water contamination

Specific options concerning HTC

Treatment options	Products	Processing of products	Pros	Cons
Energy generation			**Fossil fuels offset**	
	Hydrochar & process water	Combustion of hydrochar AD of process water	High energy generation, clean fuel, more established	Air pollution, no nutrient recycling, no carbon sequestration
Soil amendment			**Soil amendment products substituted**	
	Hydrochar & process water	Use of hydrochar as a peat substitute Use of process water as a biofertiliser, or for AD	High retention of carbon and nutrients. Substitutes peat (a high emission product)	Lack of studies on suitability as soil amendment product. Not an established product. Low, or no energy generation.
Adsorption			**Adsorption products substituted**	
	Hydrochar &process water	Use of hydrochar for bioremediation etc Use of process water for AD	High retention of carbon Reduces pollution	Lack of studies on suitability as an adsorption product. Not an established product. Low, or no energy produced

Specific components of HTC LCAs

Food waste qualities
- Quantity
- Composition (elemental content, moisture, ash, etc)

Transport
- Distance
- Vehicle type (i.e. diesel, biodiesel, electric etc)

HTC site
- Onsite or offsite
- Energy Source (non-renewable, or renewable)

HTC conditions
- Moisture loading
- Temperature
- Residence time

HTC products
- Hydrochar for energy, or peat substitution
- Process water for AD, or biofertiliser use

HTC product usage/disposal
- Use onsite
- Use on farm
- Disposal of digestate in landfill etc

Review of existing HTC LCAs

HTC options	Environmental performance	Studies
Energy production	Lower processing emissions than pyrolysis	Reiβmann et al. (2018)
	Higher energy gain than incineration and AD	Gupta et al. (2019); Lu et al. (2012)
Soil amendment	Lower processing emissions than composting	Lu et al. (2012)
	More soil amendment produced than composting	
	Considerable GHG mitigation using hydrochar as a peat substitute	
Other considerations	Improved performance using process waters for AD, or as an organic fertiliser	Berge et al. (2015); Li et al. (2013)
	Improved performance scaling up HTC plant size	Owsianiak et al. (2016)
Future considerations	Decarbonisation of grid energy	
	Development of carbon capture and storage	

HTC LCA: Future work

- Lack of research on:
  - Influence of food waste composition on HTC performance
  - Influence of region on HTC performance
  - Socio-economic performance of HTC
  - Future considerations for HTC
  - HTC and soil amendment
  - HTC and adsorption

Question and answer session

- Thank you for listening,
- Any Questions?