Life Cycle Analysis of Plastic Waste

Dr Nawshad Haque | 23 May 2023
Team Leader (Techno-economic and Decarbonisation)

Ending Plastic Waste Mission Symposium

Sydney, Australia

Australia's National Science Agency

About the Presenter

- **Principal Scientist at CSIRO and leads multiple projects**
- **PhD in Chemical Engineering from University of Sydney in 2002**
- **Fellow of the Australasian Institute of Mining and Metallurgy, and Australian Institute of Energy**
- **Researching on LCA of energy systems (hydrogen) and a variety of metals, including steel, aluminium, copper, magnesium, ferroalloy, gold, nickel and rare earth and critical metals to identify opportunities for CO_2 emission reduction.**
- **Co-authors: Tu Xayachak (PhD Scholar), Biplob Pramanik (RMIT), Nargessadat Emami, Deborah Lau (CSIRO)**

Life Cycle Assessment and Techno-economic Evaluation Methodologies for End-of-Life Plastic Processing Technologies

Nawshad Haque[1], Tu Xayachak[2], Biplob Pramanik[3], Nargessadat Emami[4], Deborah Lau[5]

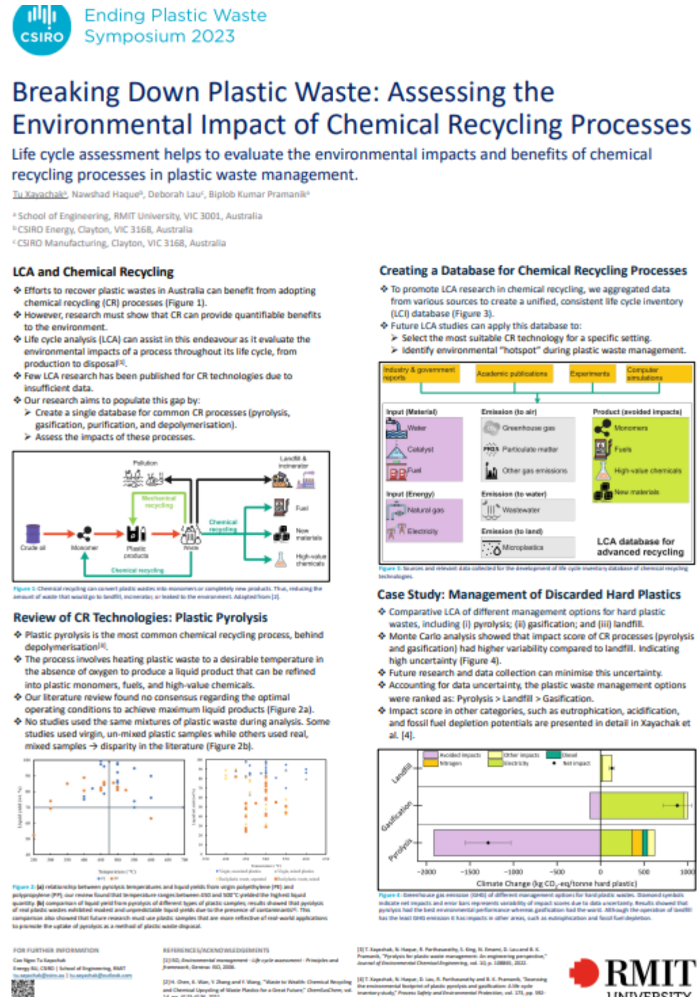
[1,2]CSIRO Energy, Clayton South, Melbourne, VIC 3169, Australia
[2,3]School of Engineering, RMIT University, VIC 3001, Australia
[4]CSIRO Environment, Black Mountain Science & Innovation Park, Acton, ACT 2601, Australia
[5]CSIRO Manufacturing, Private Bag 10, Clayton South, VIC 3169, Australia

Corresponding author: Nawshad.Haque@csiro.au

Abstract. Life cycle assessment (LCA) is now recognized as a method for measuring the environmental impacts o products, processes, and services. It provides a scientifically sound method of comparing products and processes o common grounds and to identify so called "hot spots" for reducing environmental impacts. A simplified set of indicato can be introduced as ECWW or energy, carbon-dioxide, water, and waste footprint of products to determine i environmental sustainability performance. There are several LCA software packages such as SimaPro, GaBi, ar OpenLCA, databases and international standards available. A review was published and a preliminary life cycle inventor (LCI) database has been developed for advanced recycling technologies, including pyrolysis and gasification. We hav used this LCI to model the impacts of pyrolysis and gasification for plastic recycling in Australia. The holistic impacts o Australia's plastic waste management system, if advanced recycling technologies are integrated into existing infrastructur will also be evaluated.

REFERENCES AND BIBLIOGRAPHY

1. Xayachak, T., Haque, N., Parthasarathy, R., King, S., Emami, N., Lau, D., Pramanik, B.P. (2022) Pyrolys plastic waste management: An engineering perspective. *Journal of Environmental Chemical Engine* 108865, DOI https://doi.org/10.1016/j.jece.2022.108865


Ending Plastic Waste Symposium 2023

Breaking Down Plastic Waste: Assessing the Environmental Impact of Chemical Recycling Processes

Life cycle assessment helps to evaluate the environmental impacts and benefits of chemical recycling processes in plastic waste management.

Tu Xayachak[a], Nawshad Haque[b], Deborah Lau[c], Biplob Kumar Pramanik[a]

[a] School of Engineering, RMIT University, VIC 3001, Australia
[b] CSIRO Energy, Clayton, VIC 3168, Australia
[c] CSIRO Manufacturing, Clayton, VIC 3168, Australia

LCA and Chemical Recycling

- Efforts to recover plastic wastes in Australia can benefit from adopting chemical recycling (CR) processes (Figure 1).
- However, research must show that CR can provide quantifiable benefits to the environment.
- Life cycle analysis (LCA) can assist in this endeavour as it evaluate the environmental impacts of a process throughout its life cycle, from production to disposal[1].
- Few LCA research has been published for CR technologies due to insufficient data.
- Our research aims to populate this gap by:
  - Create a single database for common CR processes (pyrolysis, gasification, purification, and depolymerisation).
  - Assess the impacts of these processes.

Review of CR Technologies: Plastic Pyrolysis

- Plastic pyrolysis is the most common chemical recycling process, behind depolymerisation[3].
- The process involves heating plastic waste to a desirable temperature in the absence of oxygen to produce a liquid product that can be refined into plastic monomers, fuels, and high-value chemicals.
- Our literature review found no consensus regarding the optimal operating conditions to achieve maximum liquid products (Figure 2a).
- No studies used the same mixtures of plastic waste during analysis. Some studies used virgin, un-mixed plastic samples while others used real, mixed samples → disparity in the literature (Figure 2b).

Creating a Database for Chemical Recycling Processes

- To promote LCA research in chemical recycling, we aggregated data from various sources to create a unified, consistent life cycle inventory (LCI) database (Figure 3).
- Future LCA studies can apply this database to:
  - Select the most suitable CR technology for a specific setting.
  - Identify environmental "hotspot" during plastic waste management.

Case Study: Management of Discarded Hard Plastics

- Comparative LCA of different management options for hard plastic wastes, including (i) pyrolysis; (ii) gasification; and (iii) landfill.
- Monte Carlo analysis showed that impact score of CR processes (pyrolysis and gasification) had higher variability compared to landfill. Indicating high uncertainty (Figure 4).
- Future research and data collection can minimise this uncertainty.
- Accounting for data uncertainty, the plastic waste management options were ranked as: Pyrolysis > Landfill > Gasification.
- Impact score in other categories, such as eutrophication, acidification, and fossil fuel depletion potentials are presented in detail in Xayachak et al. [4].

Plastic Depolymerisation – CSIRO Project Team

- Michael Batten (Manufacturing) – Project Leader, products and processes
- Sarah King (Manufacturing) – Industrial Ecology
- Ashleigh Cousins (Energy) – Techno-Economics
- Nawshad Haque (Energy) – Techno-Economics
- Michael Somerville (Minerals) – Engineer, high temperature processing
- Tom Austin (Minerals) – Research Technician, high temperature processing

Evaluation of Plastic Waste Processing

Σ $ CO_2

Identify problematic polyolefin materials

Pyrolyse and analyse

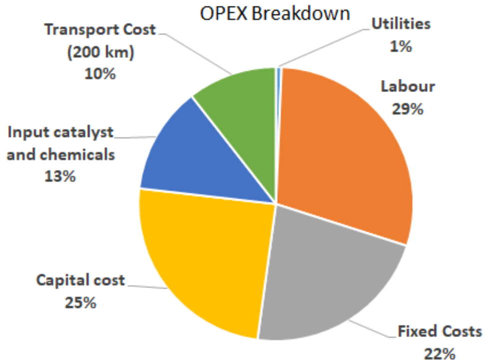
Techno-economic analysis and reporting

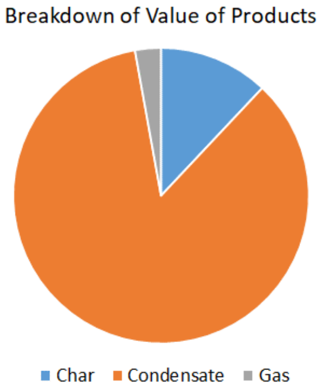
Evaluate and de-risk plastic-to-plastic processes in an Australia

Problematic waste streams – Ag plastic, oil containers, soft wrap
Modular-appropriate technology for regional communities

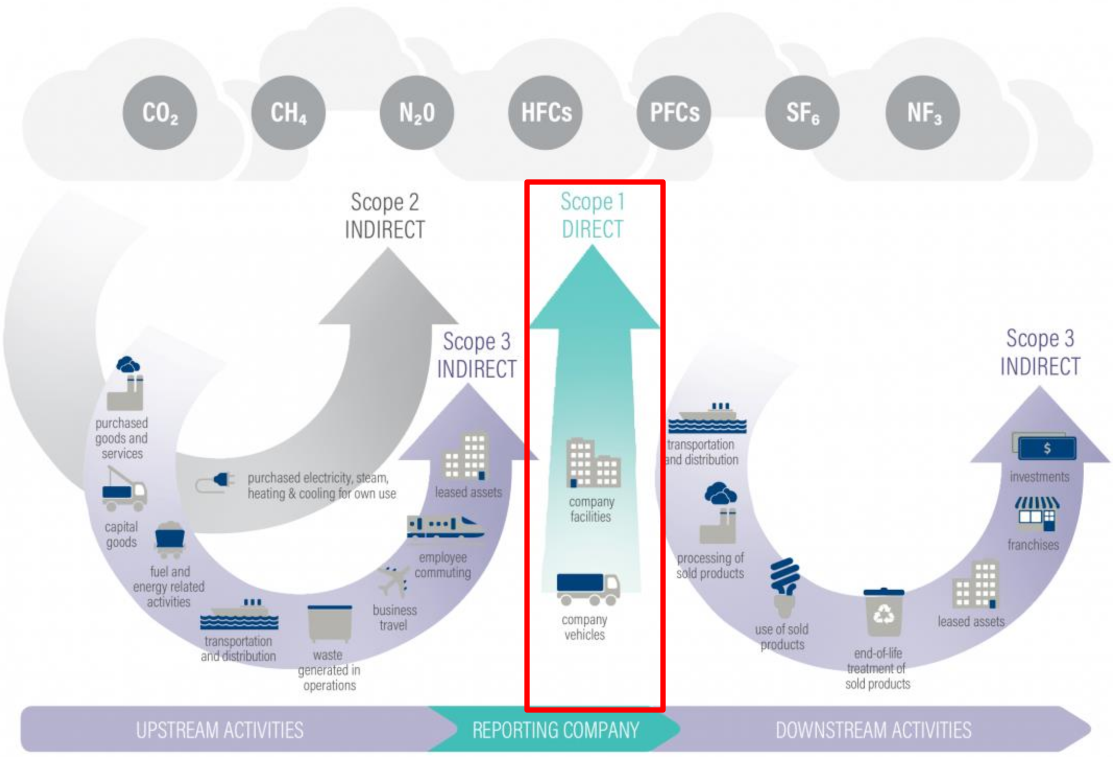
Assumptions:

5,000 tpa feed mixed plastic waste
Pyrolyse at 500 deg C

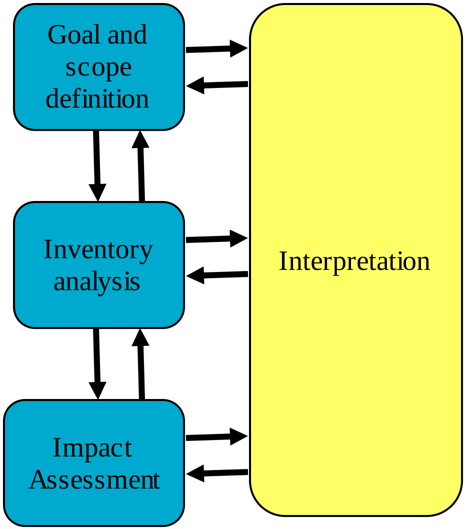




Remarks (one example case):
~$7-$10 M Capex
@High disposal cost >$350/t, Net present value is +


CO2
CH4
N20
HFCs
PFCs
SF6
NF3
Scope 2
INDIRECT
Scope 1
DIRECT
Scope 3
INDIRECT
Scope 3
INDIRECT
purchased goods and services
capital goods
fuel and energy related activities
transportation and distribution
waste generated in operations
business travel
employee commuting
leased assets
purchased electricity, steam, heating & cooling for own use
company facilities
company vehicles
transportation and distribution
processing of sold products
use of sold products
end-of-life treatment of sold products
leased assets
franchises
investments
UPSTREAM ACTIVITIES
REPORTING COMPANY
DOWNSTREAM ACTIVITIES

Stages of Life Cycle Assessment (ISO 14044)



- Why and for whom?
- Boundary demarcation, data collection
- Impact category selection, characterisation
- Assessment, interpretation, sensitivity analysis
- Update & improvement with new data

CSIRO has SimaPro, GaBi LCA software, in-house databases, experiences for various industrial process and products

Midpoint and Endpoint LCA Indicators

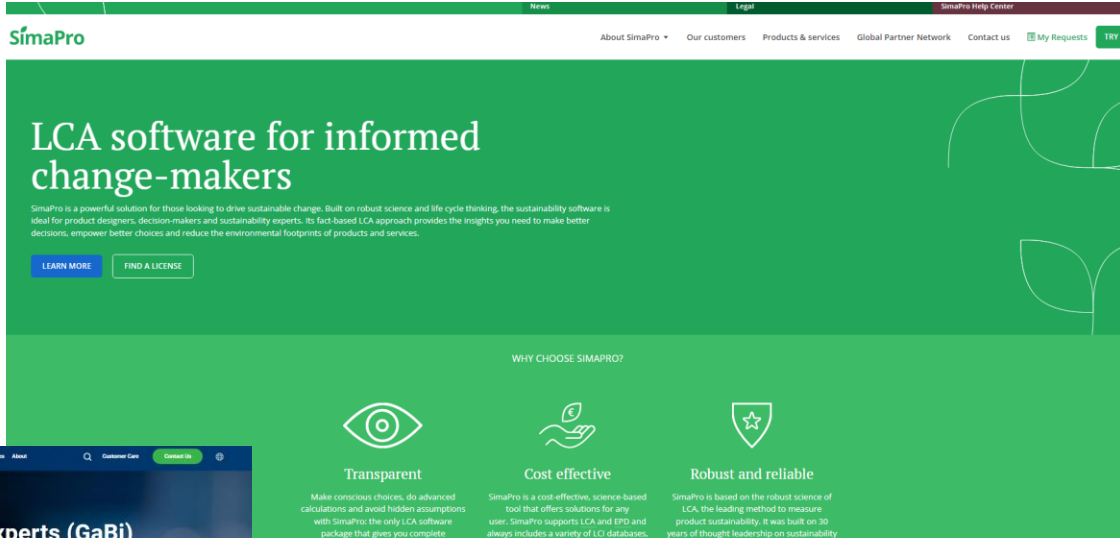
Indicators	Unit
Global Warming Potential (GWP)	kg CO_2-eq
Photochemical oxidation	kg C_2H_4-eq
Eutrophication	kg PO_4-eq
Carcinogens	kg chloro-ethylene eq
Toxicity	kg 1,4 Di-chloro-benzene eq
Land use	ha.year
Water Use	kL H_2O
Solid waste	kg
Fossil fuels	MJ surplus
Minerals	MJ Surplus

Impact category	Indicators	Unit
Human Health	Climate change	Disability adjusted life years (DALY)
	Ozone depletion	DALY
	Carcinogens	DALY
	Respiratory effects (organic/inorganic)	DALY
	Toxicity	DALY
	Ionising radiation	DALY
Ecosystem damage	Land use	Partially disappeared fraction* (m^2/y)
	Acidification/Eutrophication	PDF*m^2/y
	Ecotoxicity	PDF*m^2/y
Resource depletion	Minerals/fossil fuel	MJ surplus

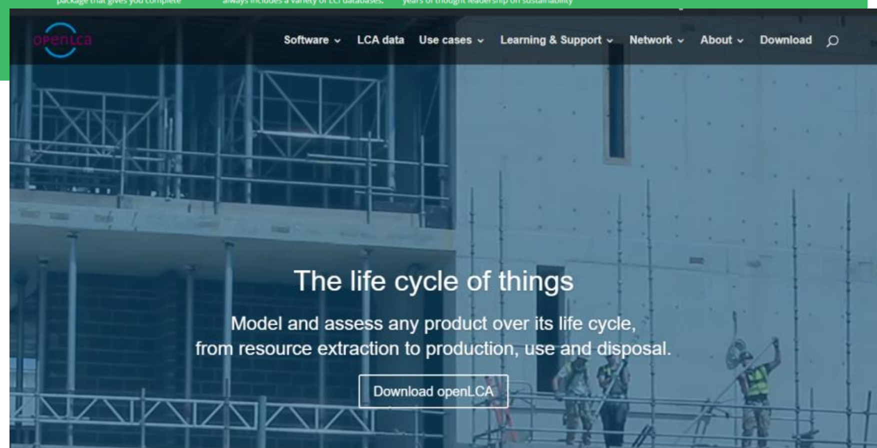
CSIRO **can report these indicators**

Sustainability Evolution

- Environmental Social Governance (ESG) is increasingly getting attention.
- Industries lack skill for environmental LCA, particularly for new conceptual technologies.
- We have developed capabilities, gained experiences and reputation.
- Flowsheeting, techno-economic and life cycle assessment are major tools and methodologies.
- Range of LCA software is used (e.g. SimaPro, GaBi)
- ASPEN Simulation Suite of Modules, SysCAD, METSIM, HSC Chemistry, HOMER, @Risk and others

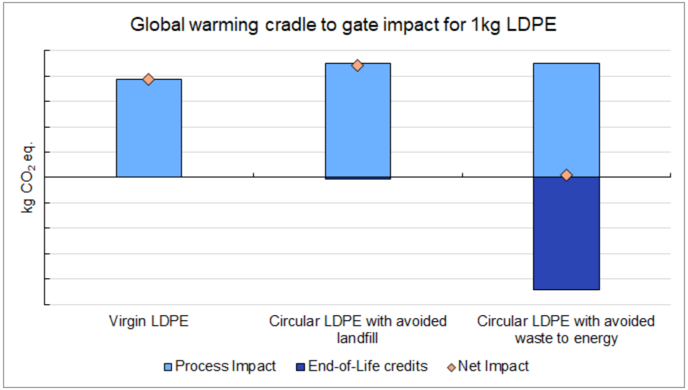

News
Legal
SimaPro Help Center
SimaPro
About SimaPro
Our customers
Products & services
Global Partner Network
Contact us
My Requests
TRY
LCA software for informed change-makers
SimaPro is a powerful solution for those looking to drive sustainable change. Built on robust science and life cycle thinking, the sustainability software is ideal for product designers, decision-makers and sustainability experts. Its fact-based LCA approach provides the insights you need to make better decisions, empower better choices and reduce the environmental footprints of products and services.
LEARN MORE
FIND A LICENSE
WHY CHOOSE SIMAPRO?
Transparent
Make conscious choices, do advanced calculations and avoid hidden assumptions with SimaPro: the only LCA software package that gives you complete
Cost effective
SimaPro is a cost-effective, science-based tool that offers solutions for any user. SimaPro supports LCA and EPD and always includes a variety of LCI databases.
Robust and reliable
SimaPro is based on the robust science of LCA, the leading method to measure product sustainability. It was built on 30 years of thought leadership on sustainability


sphera
Customer Care
Contact Us
LCA for Experts (GaBi)
LCA for Experts Software built on the world's most robust LCA databases.
Achieve Your Sustainability Goals with Sphera's Best-In-Class Product Sustainability Software
With options for LCA professionals and non-LCA professionals alike, our solutions help users reach their company's LCA goals, regardless of their skill level.
Elevate Your Product Reporting
Communicate and collaborate with stakeholders and internal partners on environmental performance reports using customizable report templates. Automated reporting helps you interpret, use and share results and environmental insights across the value chain.


openLCA
Software
LCA data
Use cases
Learning & Support
Network
About
Download
The life cycle of things
Model and assess any product over its life cycle, from resource extraction to production, use and disposal.
Download openLCA

LCA work with industry & consulting

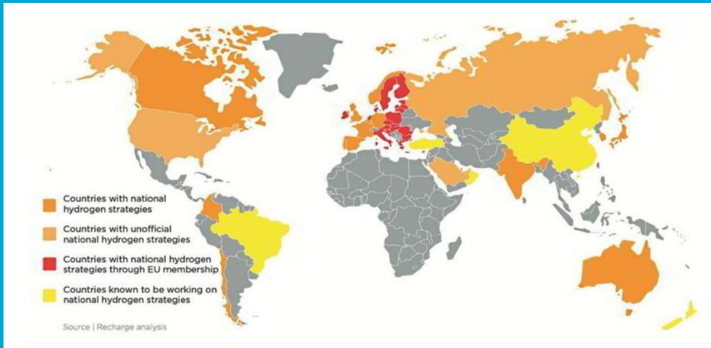
Advanced circular recycling of mixed plastic waste

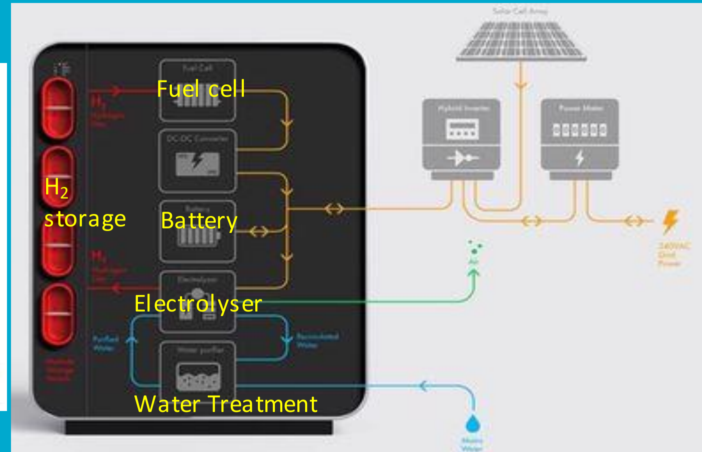


When the benefits/burdens from avoided W2E of MPW are considered in the model, the MPW system results in a 98% reduction in kg CO_2 eq when compared to LDPE from virgin ethane – more details will be released in future once our internal process is completed

What Questions?

- What are the main objectives of this work?
- Define boundary, agree on the scope of this work
- Which life cycle indicators are to be reported
- How much input data are available?
- Estimate time, resources & cost to undertake this work.
- Is an external peer review required?
- How detail report is required?
- Will it be released for use in public or internal business use?





Source: Lavo.com.au

Thank you

Energy
Dr Nawshad Haque
Principal Scientist

Team Leader (Technoeconomic for Decarbonisation)

+61 3 9545 8931 M 0434141506
Nawshad.Haque@csiro.au
Web: https://people.csiro.au/H/N/Nawshad-Haque
LinkedIn: https://www.linkedin.com/in/nawshad-