Life Cycle Analysis in Engineering and applicability for a sustainable future

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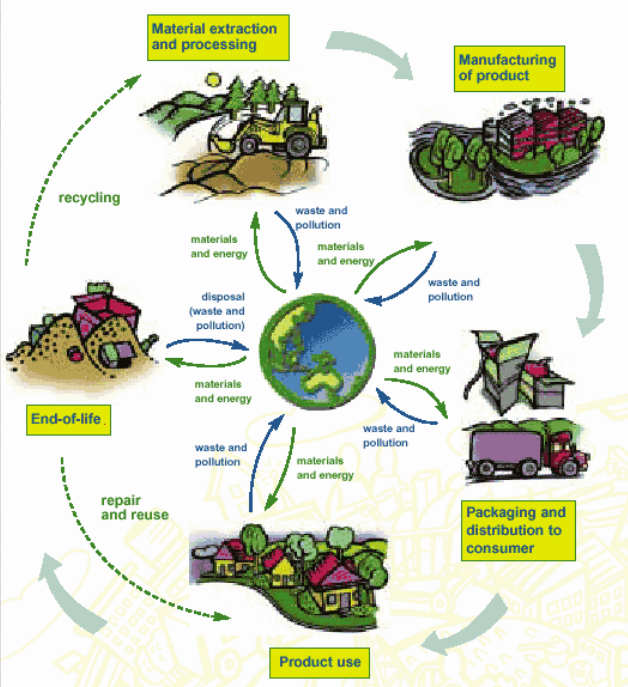
Overview

- What is Life Cycle Assessment?
- Case studies:
  - LCA in the last frontier: Casey Station
  - LCA of Kerbside Recycling in Victoria
  - Systematic review of greenhouse gas emissions for different fresh food categories
- Concluding remarks

What is **L**ife **C**ycle **A**ssessment?



Some example indicators

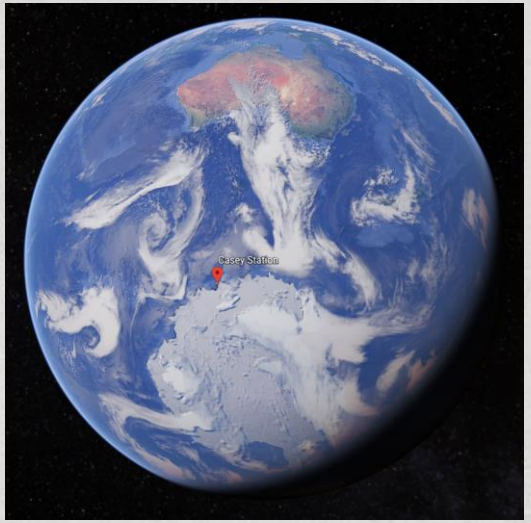
Impact category	Typical units
Climate change potential	kg CO_2-eq
Embodied energy	MJ
Acidification potential	kg SO_2-eq
Eutrophication potential	kg PO_4^{-3}-eq
Ecological footprint	Ha.a
Water use	kL
Carcinogens	DALY

"Compilation and evaluation of the inputs and outputs and the potential environmental impacts of a product system throughout its life cycle"

ISO 14040:2006

LCA in the last frontier: Casey Station

- Assoc. Prof. Karli Verghese, Dr. Enda Crossin, Dr. Simon Lockrey
- Using life cycle assessment to development environmental reduction strategies for Casey station



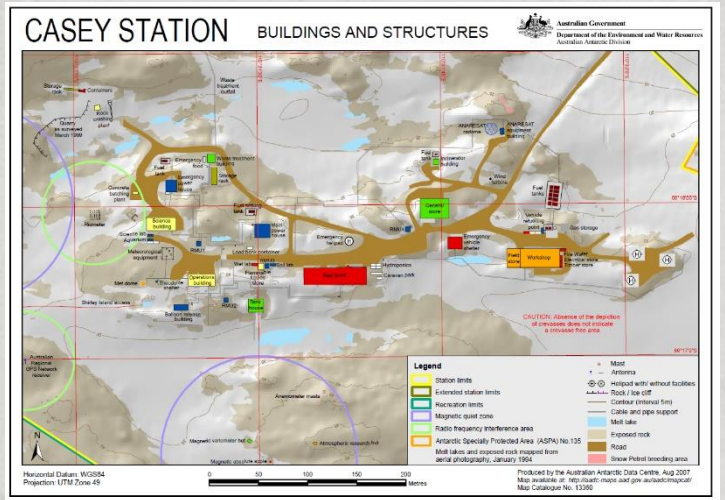
Goal and scope

Quantify impacts of operating Casey → Investigate drivers of impact → Understand relationships → Alternative scenarios → Develop environmental reduction strategy

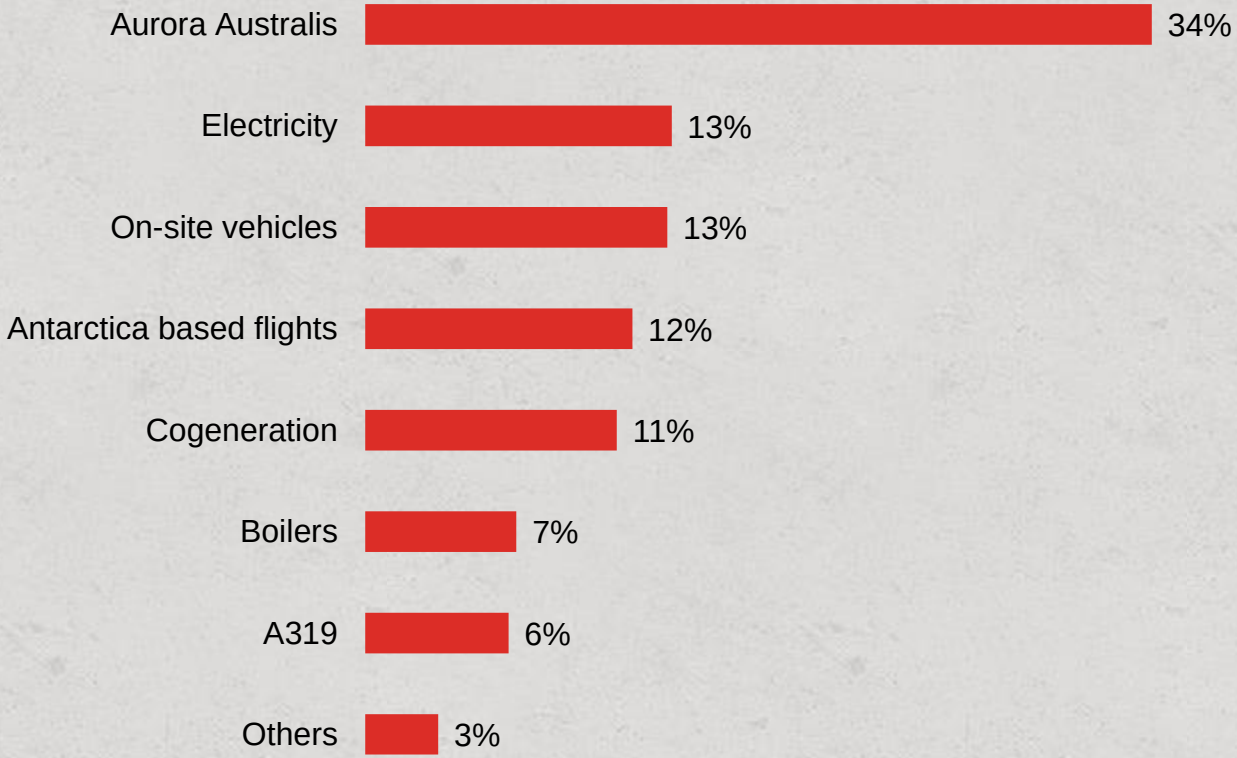




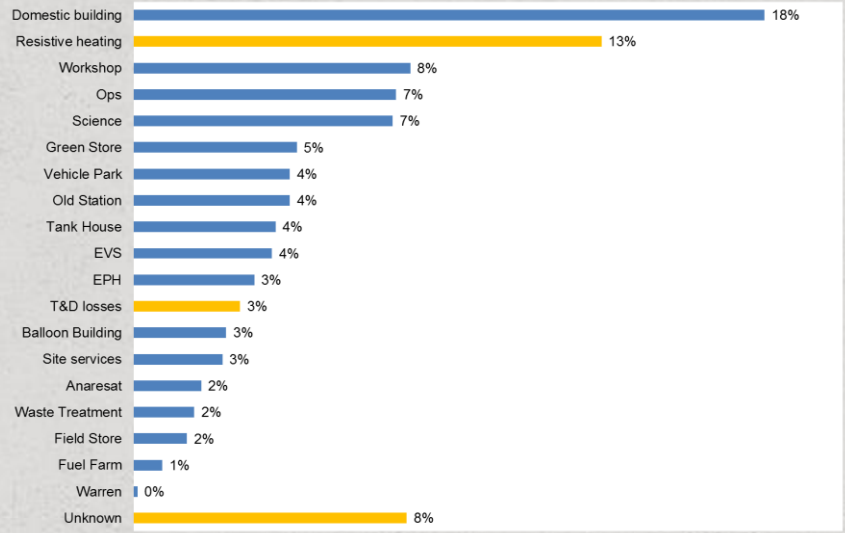


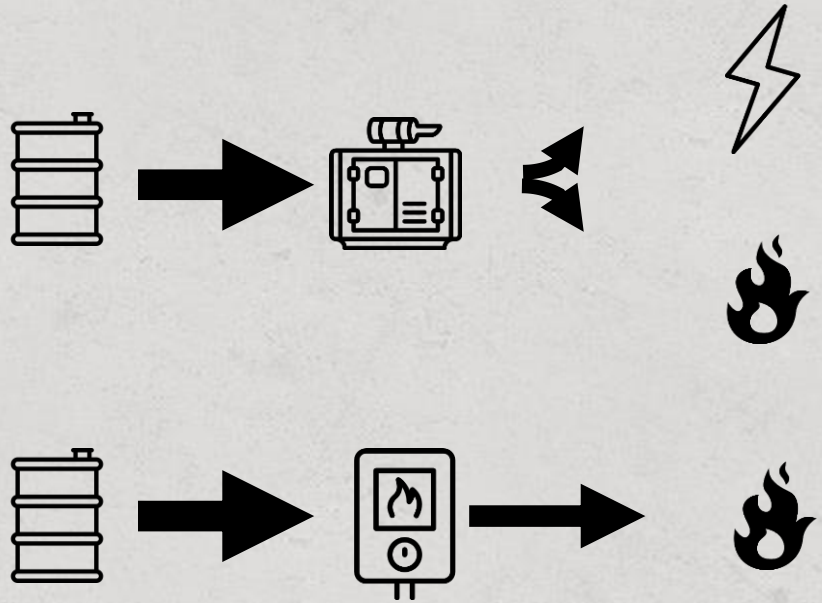


Drivers of climate change

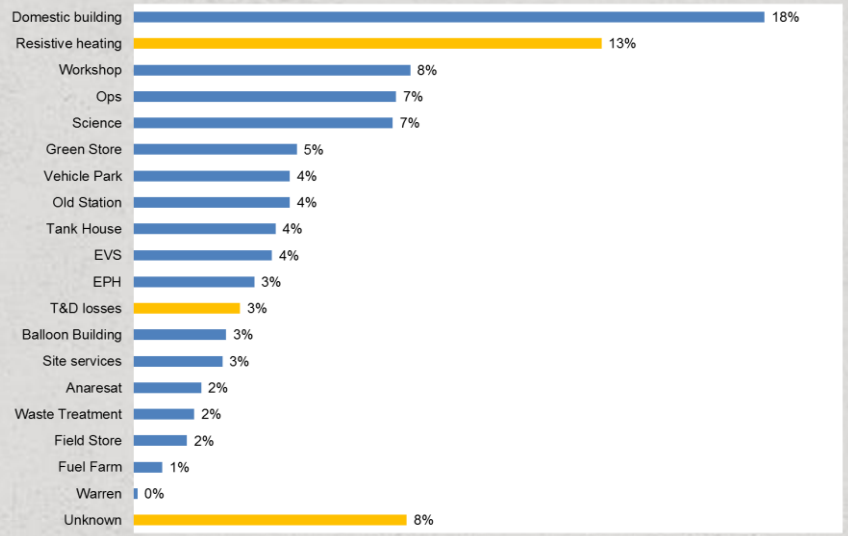


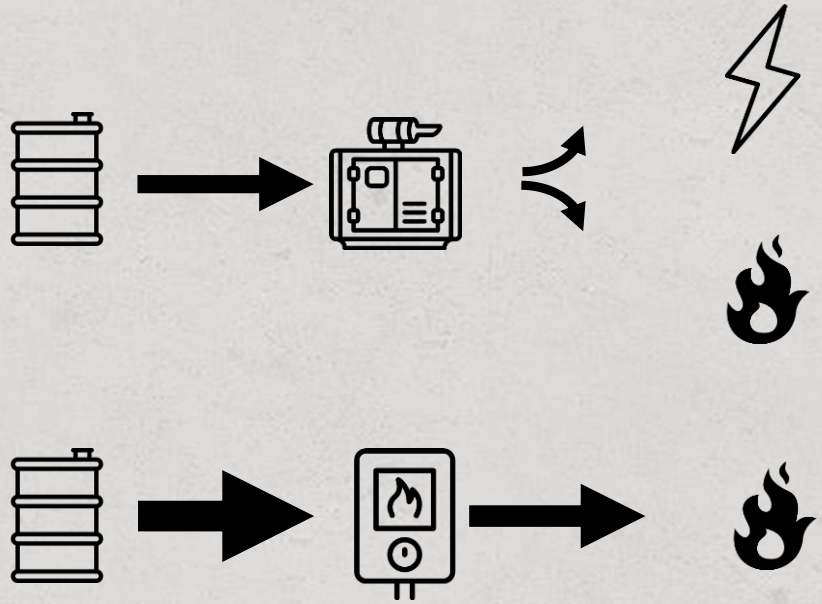
Electricity generation and use





Electricity generation and use





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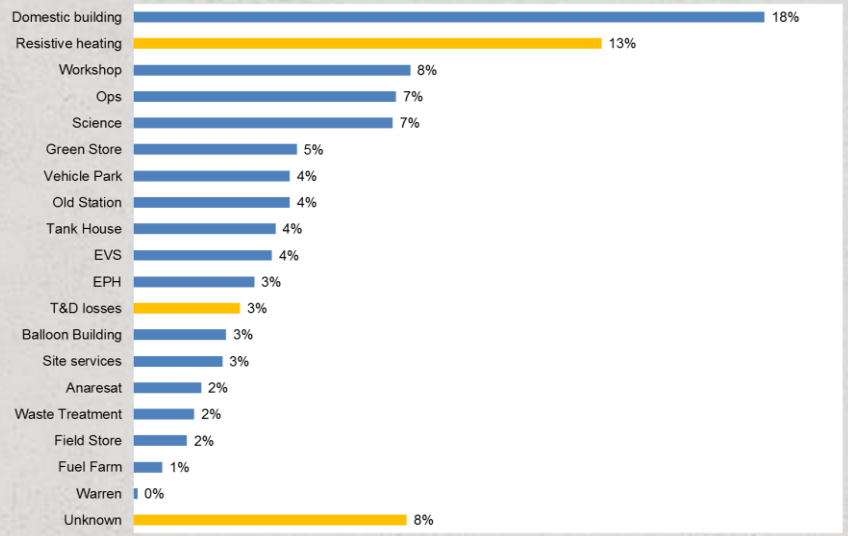
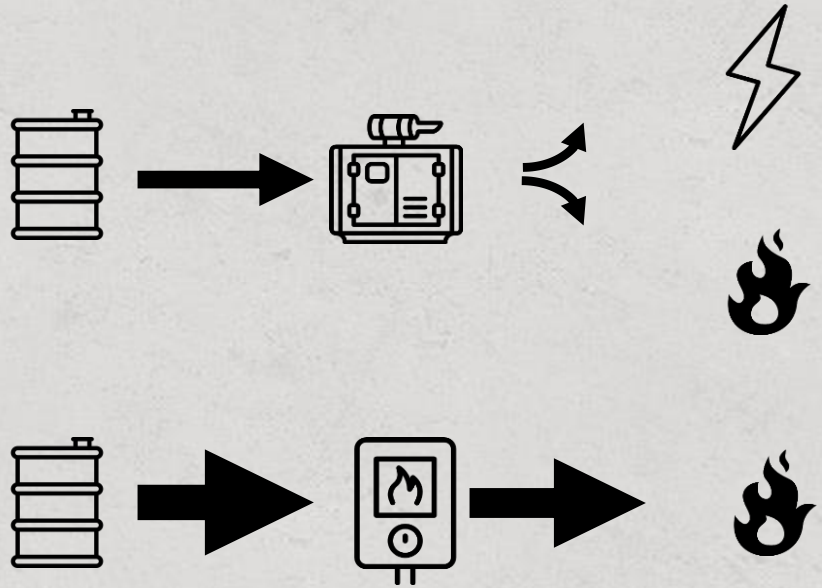
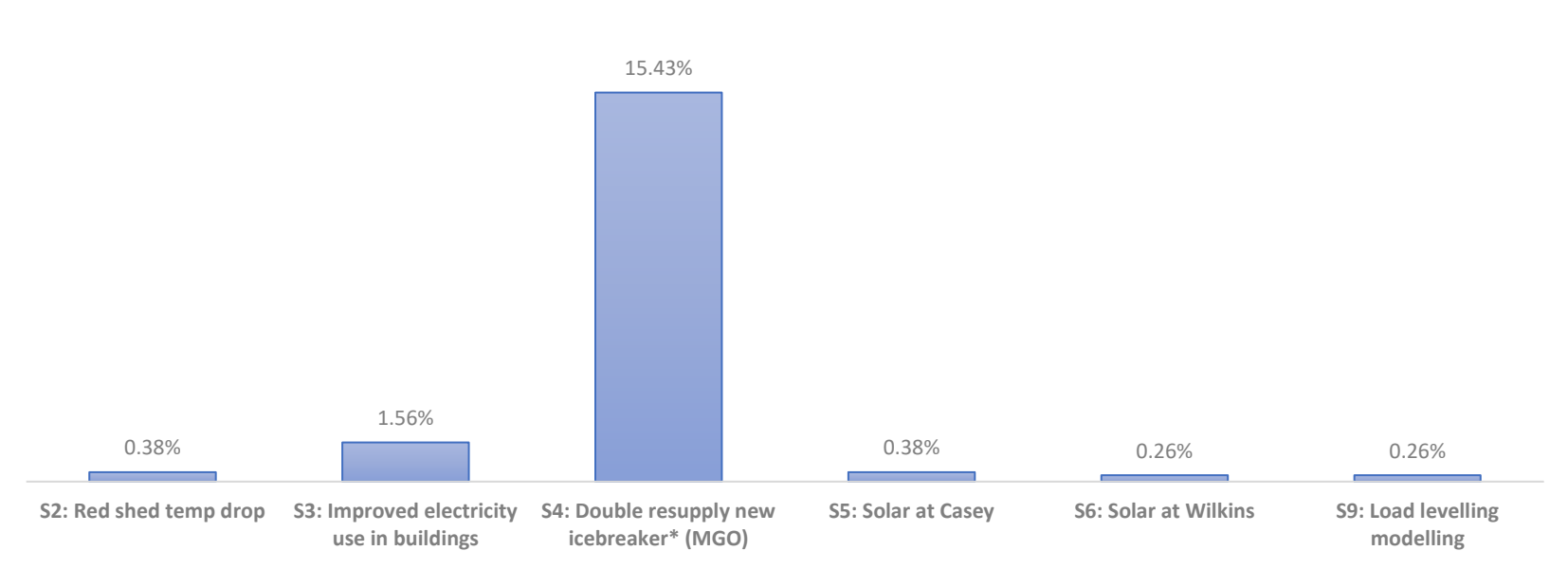




Reducing electricity demand increases fuel requirements for boilers

Scenario reductions



Outcomes for the AAD

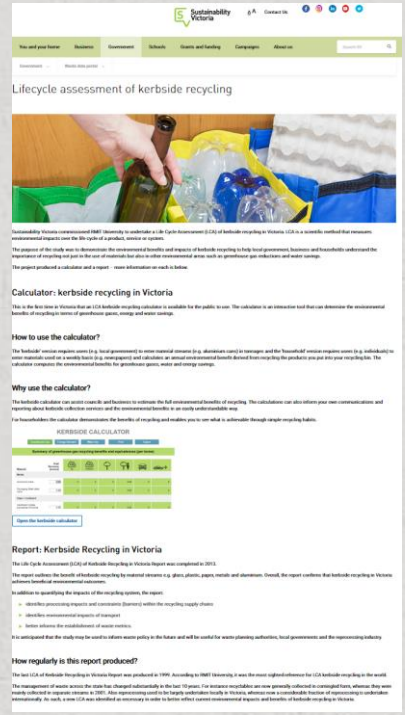
- Recognise need for systems & life cycle approach
- Informing modernisation and upgrade decisions
  - e.g. Which infrastructure investment will provide best environmental outcomes?

For those considering LCA

- Identify “sleeping giants”
- Data is critical
- Have an LCA champion
- Push and challenge the LCA experts
- Sometimes LCA isn’t the best tool, e.g. EIA may be better

LCA of Kerbside Recycling in Victoria (2015)

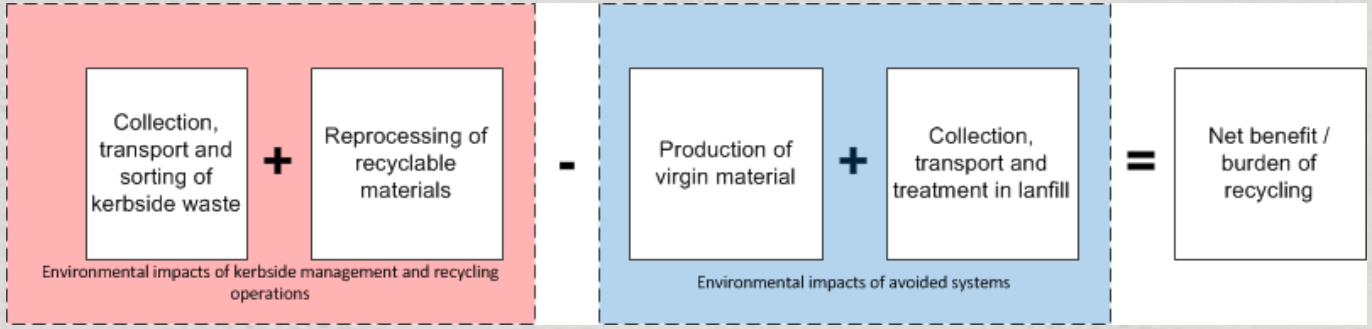
Andrew Carre, Dr. Enda Crossin, Dr. Stephen Clune



Sustainability Victoria

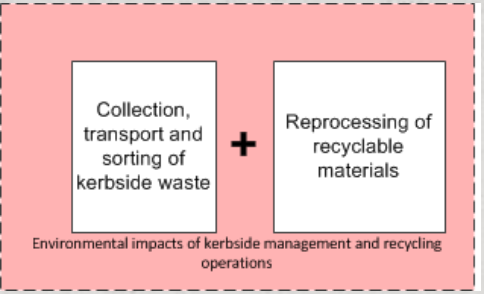
https://www.sustainability.vic.gov.au/Government/Victorian-Waste-data-portal/Lifecycle-assessment-of-kerbside-recyclables-in-Victoria

Environmental benefits or burdens of recycling in Victoria



- Based on previous LCA waste management studies
- Greenhouse gas emissions
- Smog
- Water pollutants
- Resource depletion
- Water use

How performance was assessed



Recycling System

Diagram shows primary mass flows only

Annual waste at kerbside

Glass packaging	72 kg
Steel cans	8 kg
Aluminium cans	3 kg
Paper - white	1 kg
Paper - mixed	110 kg
Paper - cardboard	45 kg
Plastic - PET	8 kg
Plastic – HDPE clear	4 kg
Plast - other	11 kg

Contamination	21 kg

Collection → ***Sorting***

Steel cans	4.7 kg
Aluminium cans	1.6 kg
Paper & cardboard - mixed	68.6 kg
Plastic – PET clear	4.3 kg
Plastic – HDPE natural	2.2 kg
Plastic - mixed	11 kg

Glass – cullet	61.2 kg
Glass – fines	10.8 kg
Steel cans	3.3 kg
Aluminium cans	1.4 kg
Paper & cardboard - mixed	87.4 kg
Plast – PET clear	3.7 kg
Plast – HDPE natural	1.8 kg

International Reprocessing

International shipping and road freight

- **Steel reprocessing, Malaysia**
- **Aluminium reprocessing, South Korea**
- **Paper reprocessing, China**
- **PET/HDPE reprocessing, China**
- **Mixed plastic reprocessing, China**

Local Reprocessing

Road freight

- **Glass reprocessing, Victoria**
- **Fines reprocessing, Victoria**
- **Steel Reprocessing, Victoria**
- **Aluminium reprocessing, New South Wales**
- **Paper Reprocessing, New South Wales**
- **PET/HDPE reprocessing, Victoria**

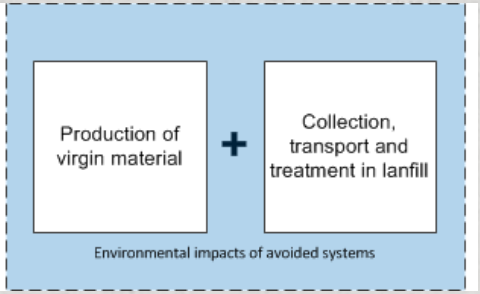
Material outputs

Steel ingot	4.4 kg
Aluminium ingot	1.5 kg
Packaging paper	57.8 kg
PET pellet	4.0 kg
HDPE pellet	1.8 kg
PP pellet	4.1 kg
HDPE pellet	2.5 kg
Other plastics	0.3 kg
Glass cullet	60.2 kg
Fine aggregate	10.6 kg
Steel ingot	3.1 kg
Aluminium ingot	1.4 kg
Packaging paper	73.6 kg
PET pellet	3.4 kg
HDPE pellet	1.5 kg

Disposal operations

Landfill operation and degradation of materials → ***Carbon storage***

How performance was assessed



Alternative System

Diagram shows primary mass flows only

Household waste generated

Glass packaging	72 kg
Steel cans	8 kg
Aluminium cans	3 kg
Paper - white	1 kg
Paper - mixed	110 kg
Paper - cardboard	45 kg
Plastic – PET	8 kg
Plastic – HDPE natural	4 kg
Plastic - other	11 kg
Garden waste	152 kg
Contam	21 kg

Collection

Carbon storage

Landfill operation and degradation of materials

Disposal operations

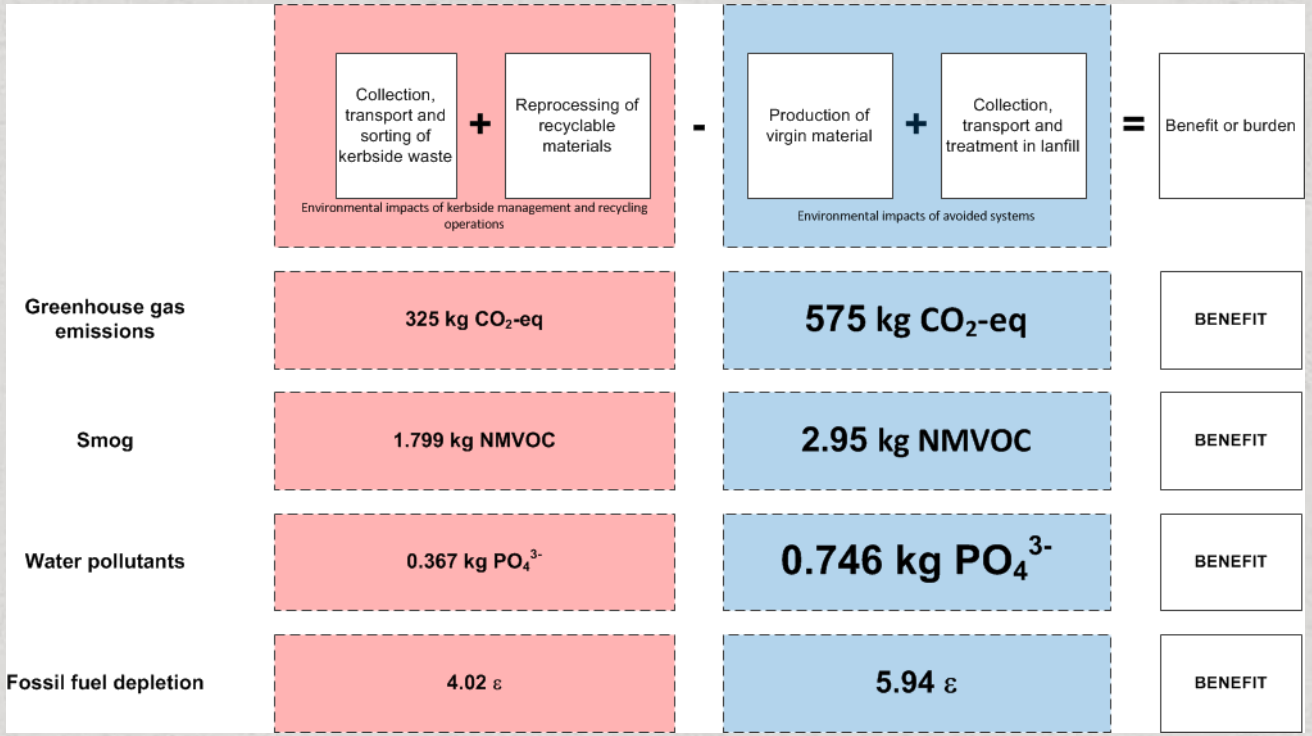
Production International

		Material outputs	
Paper Production, China		Paper, Kraft, China	57.8 kg
Paper Production, Australia		Paper, Kraft, Australia	73.6 kg
PET Production, Europe		PET pellet, generic	7.4 kg
HDPE Production, Europe		HDPE pellet, generic	5.8 kg
Other Plastics Production, Europe		PP pellet, generic	4.1 kg
		Other plastics, generic	0.3 kg
Steel Production, Australia	**International shipping**	Steel ingot, Malaysia	4.4 kg
Aluminum Production, Australia	**International shipping**	Aluminium ingot, South Korea	1.5 kg

Production Local

Steel Production, Australia	Steel ingot, Australia	3.1 kg
Aluminum Production, Australia	Aluminium ingot, Australia	1.4 kg
Glass Production, Australia	Glass cullet, Australia	60.2 kg
Aggregate Production, Australia	Fine aggregate, Australia	10.6 kg

Results (only some of them)



But….

- Most LCAs assume that the future is the same as the past
- Consequential LCA can help model future scenarios, based on market dynamics
- Critical for policy considerations

"..China's "Green Fence" policy could force additional infrastructure and processing costs upon local Material Recovery Facilities (MRFs), meaning that in the future, the generation of clear polyethylene terephthalate (PET), clear high density polyethylene (HDPE), mixed plastics and mixed paper and cardboard recyclate streams for export could become uneconomical."

For those considering LCA

- Stakeholder engagement critical
- Consequential LCAs are more uncertain, but can provide powerful insights

Systematic review of greenhouse gas emissions for different fresh food categories

Dr. Stephen Clune, Dr. Enda Crossin, Assoc. Prof. Karli Verghese
Journal of Cleaner Production, Volume 140, Part 2, 2017, pp. 766 - 783

Journal of Cleaner Production 140 (2017) 766–783

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Systematic review of greenhouse gas emissions for different fresh food categories

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ARTICLE INFO

Article history:
Received 7 July 2015
Received in revised form
23 February 2016
Accepted 19 April 2016
Available online 4 May 2016

Keywords:
Streamlined LCA
Food
Sustainable diets
Systematic review

ABSTRACT

This paper presents the results of a systematic literature review of greenhouse gas emissions for different food categories from life cycle assessment (LCA) studies, to enable streamline calculations that could inform dietary choice. The motivation for completing the paper was the inadequate synthesis of food greenhouse gas emissions available in the public domain. The paper reviewed 369 published studies that provided 1718 global warming potential (GWP) values for 168 varieties of fresh produce. A meta-analysis of the LCA studies was completed for the following categories: fresh vegetables (root vegetables, brassica, leaves and stems); fresh fruits (pepo, hesperidium, true berries, pomes, aggregates fruits and drupes); staples (grains, legumes, nuts, seeds and rice); dairy (almond/coconut milk, soy milk, dairy milk, butter and cheese); non-ruminant livestock (chicken, fish, pork); and ruminant livestock (lamb and beef). The meta-analysis indicates a clear greenhouse gas hierarchy emerging across the food categories, with grains, fruit and vegetables having the lowest impact and meat from ruminants having the highest impact. The meta-analysis presents the median, mean, standard deviation, upper and lower quartile, minimum and maximum results for each food category. The resultant data enables streamline calculations of the global warming potential of human diets, and is illustrated by a short case study of an Australian family's weekly shop. The database is provided in the Appendix as a resource for practitioners. The paper concludes with recommendations for future LCA studies to focus upon with respect to content and approach.

1. Introduction

The consumption of food contributes to a significant proportion of a person's overall greenhouse gas impact (Dey et al., 2007), with agricultural production accounting for 19–29% of global anthropogenic greenhouse gas emissions (Vermeulen et al., 2012). Consumers are also displaying 'a moderately high level of concern' for the sustainability with respect to food production (Grunert et al., 2014, p. 187). Life cycle assessments (LCAs) of food ingredients and products provide the primary means to understand a food's environmental impact, discussed in this paper with specific respect to a food's Global Warming Potential (GWP).[1] While a substantial number of food LCA studies have been completed, comparing food impacts to enable decision making with confidence is difficult at present for four reasons.

First, it is often cited that LCA results should not be compared (Desjardins et al., 2012; Fesster et al., 2006; McAuliffe et al., 2016; Röös et al., 2013) due to variation in methodology choices, functional units, as well as temporal and regional differences.[2] Second, no single comprehensive review was identified that adequately covers the breadth of fresh foods available to consumers and

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[1] GWP values (represented as kg CO_2-eq/kg produce, was selected as an environmental indicator due to the global significance of climate change, and as a consistent metric reported in LCA studies. For example, Ibrouf and Fujita-Finas (2013) identified that 92% of Australian food LCA's reported Greenhouse gas emissions. The Life Cycle Impact Assessment guidance flagship project of UNEP/SETAC suggest that the sensitivity of LCA results should be explored to metrics other than GWP, such as fine particulate matter emissions, land and water use, and biodiversity loss (Frischknecht et al., 2016). Using one indicator in GWP only is a limitation of the paper, expanding to include additional indicators is an area for further research.

[2] These methodological differences are discussed later in the paper in Section 4.1.

http://dx.doi.org/10.1016/j.jclepro.2016.04.082
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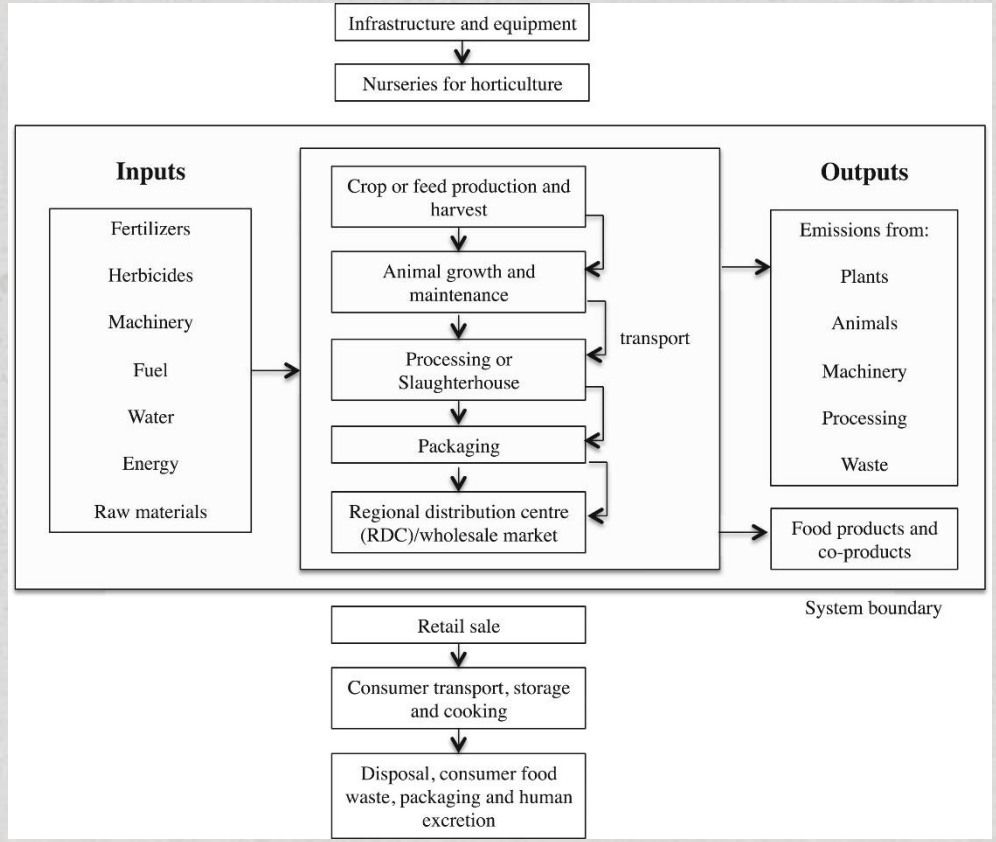
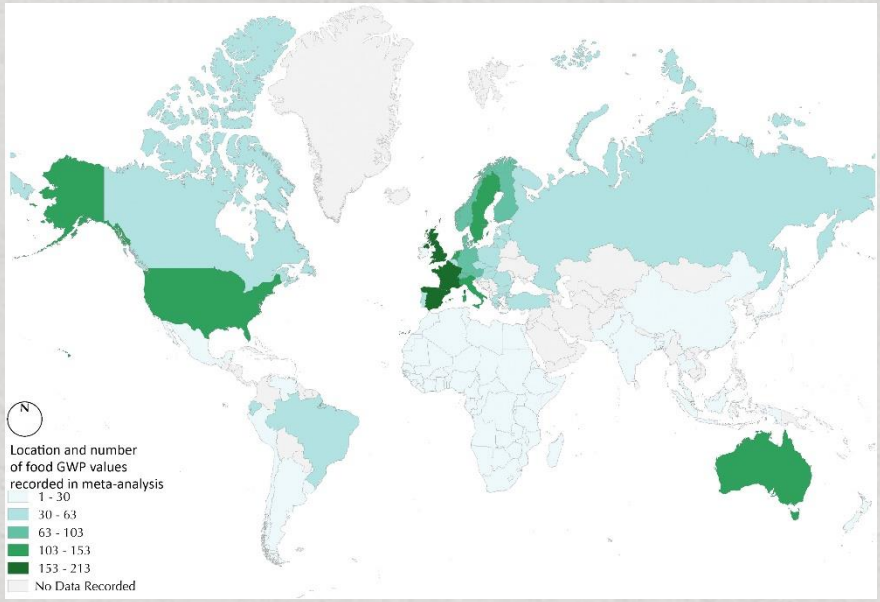
Systematic review of greenhouse gas emissions for different fresh food categories



- 369 published LCA studies
- 1718 climate change values for fresh produce
- Years 2000–2015



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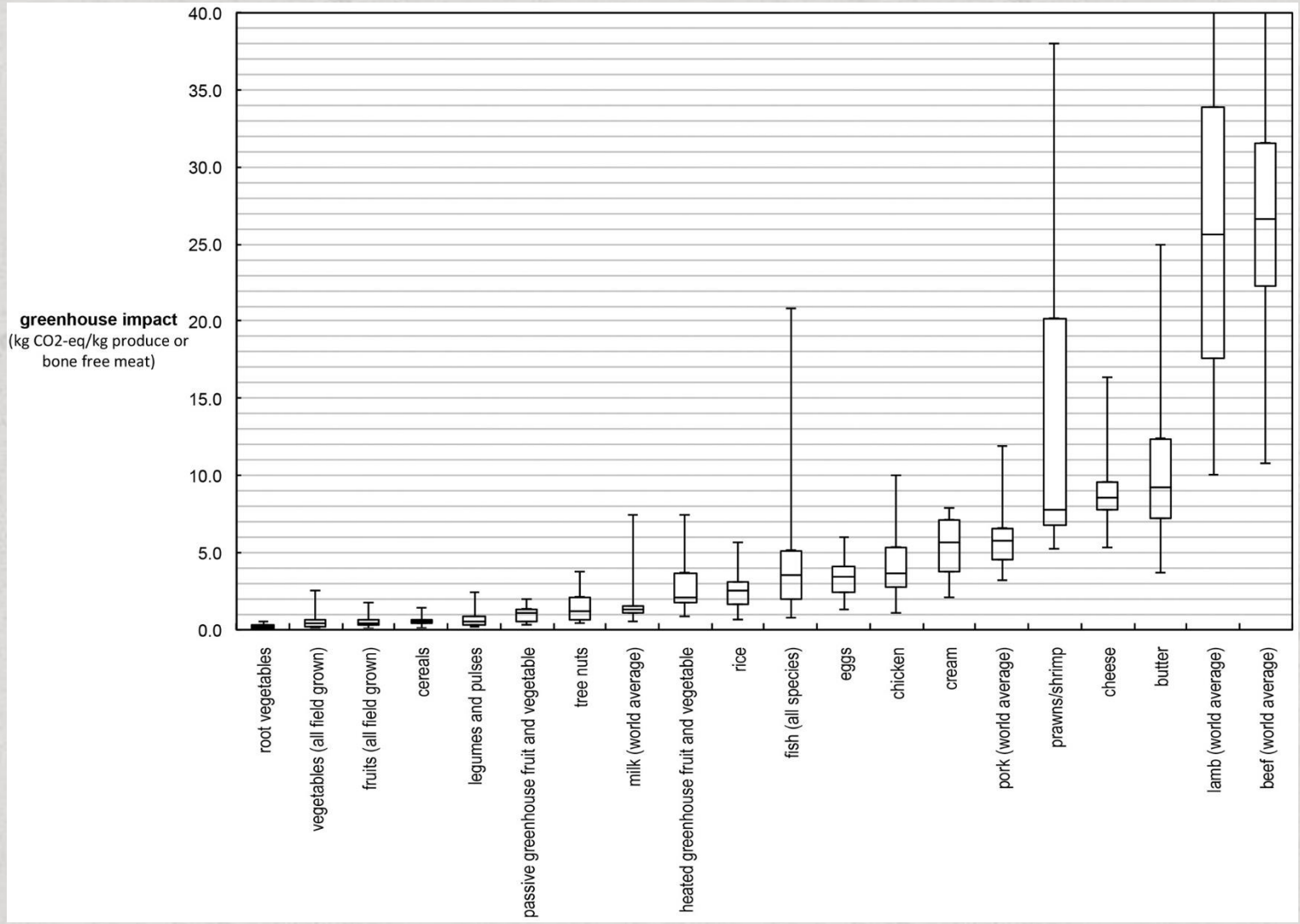

- Editors wanted to reject it
- Study now being used as a basis for research into low carbon diets
- Keep an eye out for an upcoming TV series on the ABC!

For those considering LCA

- Challenging beliefs can be difficult!
- A similar study has probably been done
- More meta-analysis are being completed
- Often rules of thumb which can guide decisions
- (but there are always exceptions to the rule)

Concluding remarks

- Spend time on the project scope, inc. what you are trying to answer
- How will you use the LCA with your environmental strategy
  - You might not get the answer you are expecting
- LCA champion to work with
  - Stakeholders
  - LCA practitioners (challenge them!)
- Systems thinking a critical outcome