RIT

Biochar as a sustainable alternative of Carbon Black for opacity in Agricultural Mulch Films

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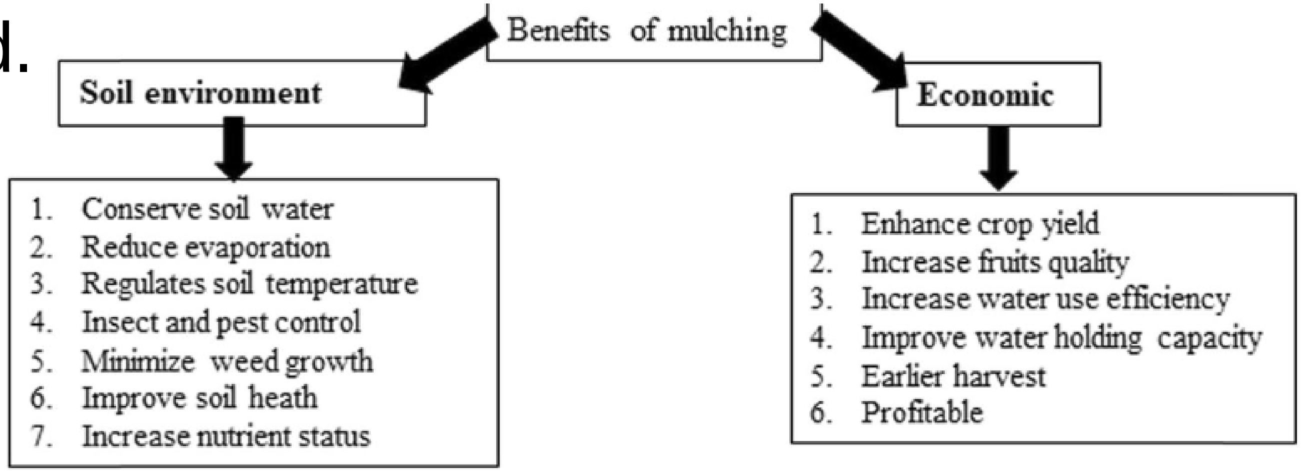
Agricultural Mulch Films (AMFs)

- Increase yield (Iqbal et al., 2020)
- Less water use (Iqbal et al., 2020) (Espi et al., 2008)
- Less pesticides and herbicides (Iqbal et al., 2020) (Espi et al., 2008)
- Avoids erosion (Iqbal et al., 2020) (Espi et al., 2008)
- >2 million t/year (Inglis et al., 2015)
- Most of it is polyethylene (PE) based.



Benefits of mulching (adapted from Iqbal et al., 2020)

Biodegradable Mulch Films (BMFs)

PBAT
PLA
PHA

- Biodegrades in the soil saving the labor of collection.
- Same agronomic performance
- Do not behave in the same way with traditional additives and fillers. (Hernandez-Charpak et al., 2022)
- Can **biochar** fulfill the roles of processing additive and **opacity filler**?

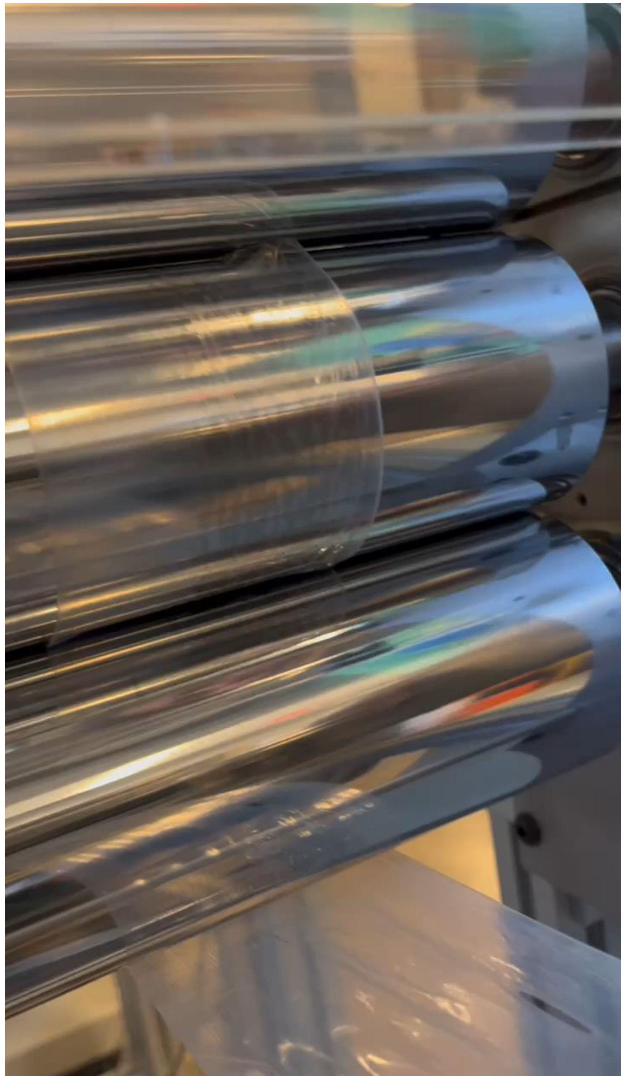
Carbon black

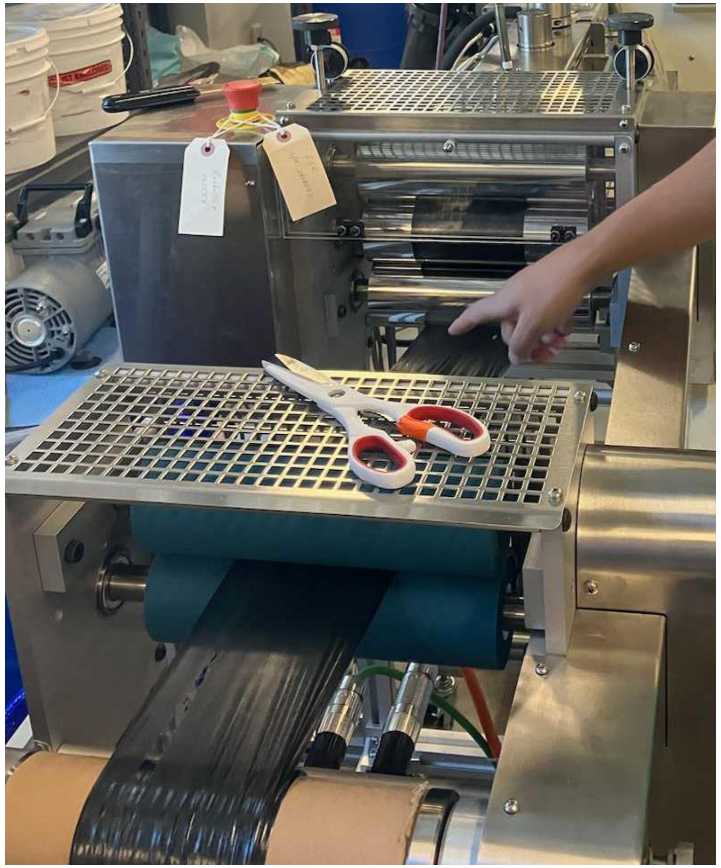
- Fossil fueled based
- Used only for opacity, up to 4 wt.%
- Interest in literature to displace it (Bélanger et al., 2023; Meisel et al., 2022)

Opacity

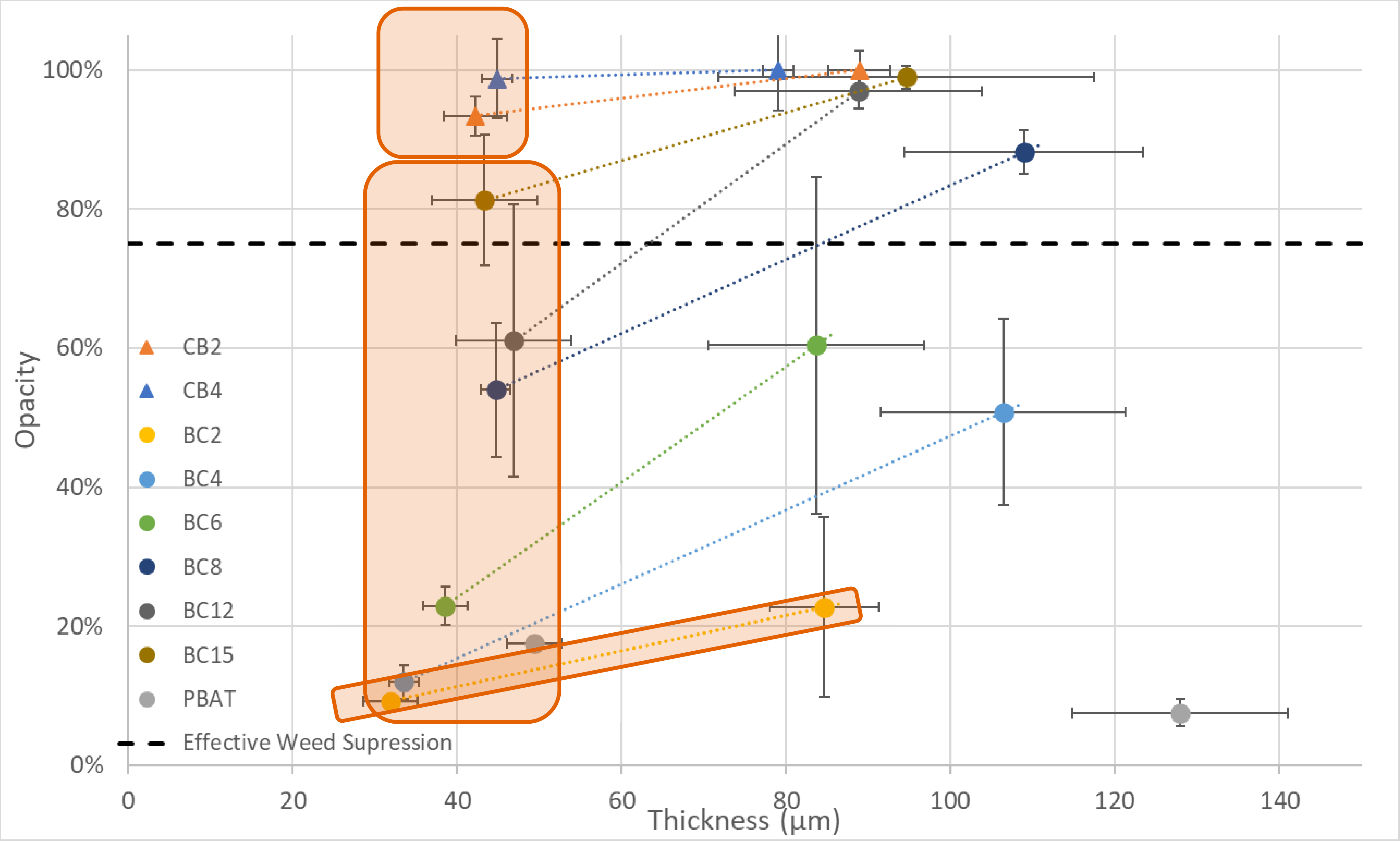
- Depending on film thickness and filler concentration (Zhao et al., 2022)

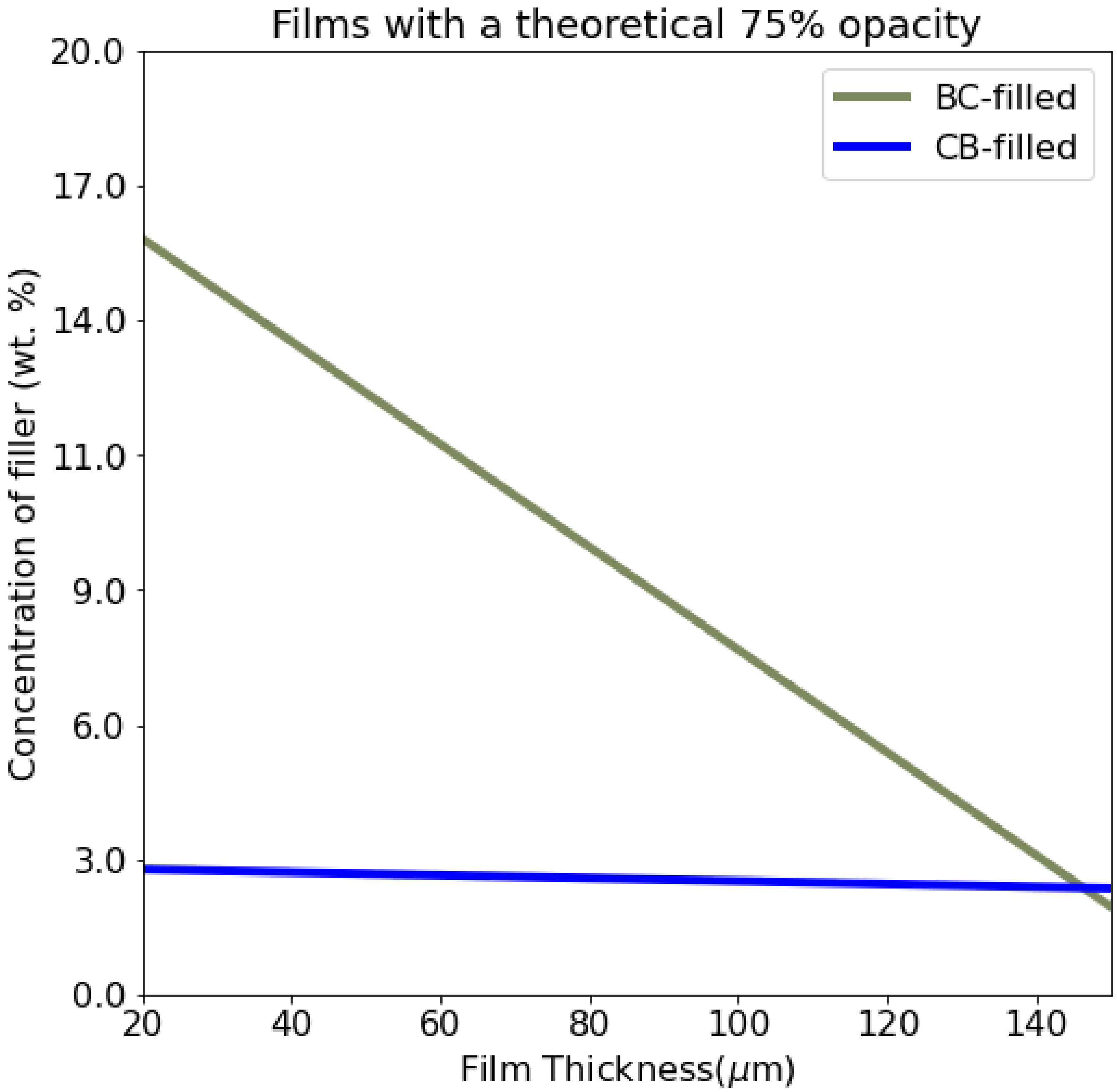
Opacity determination





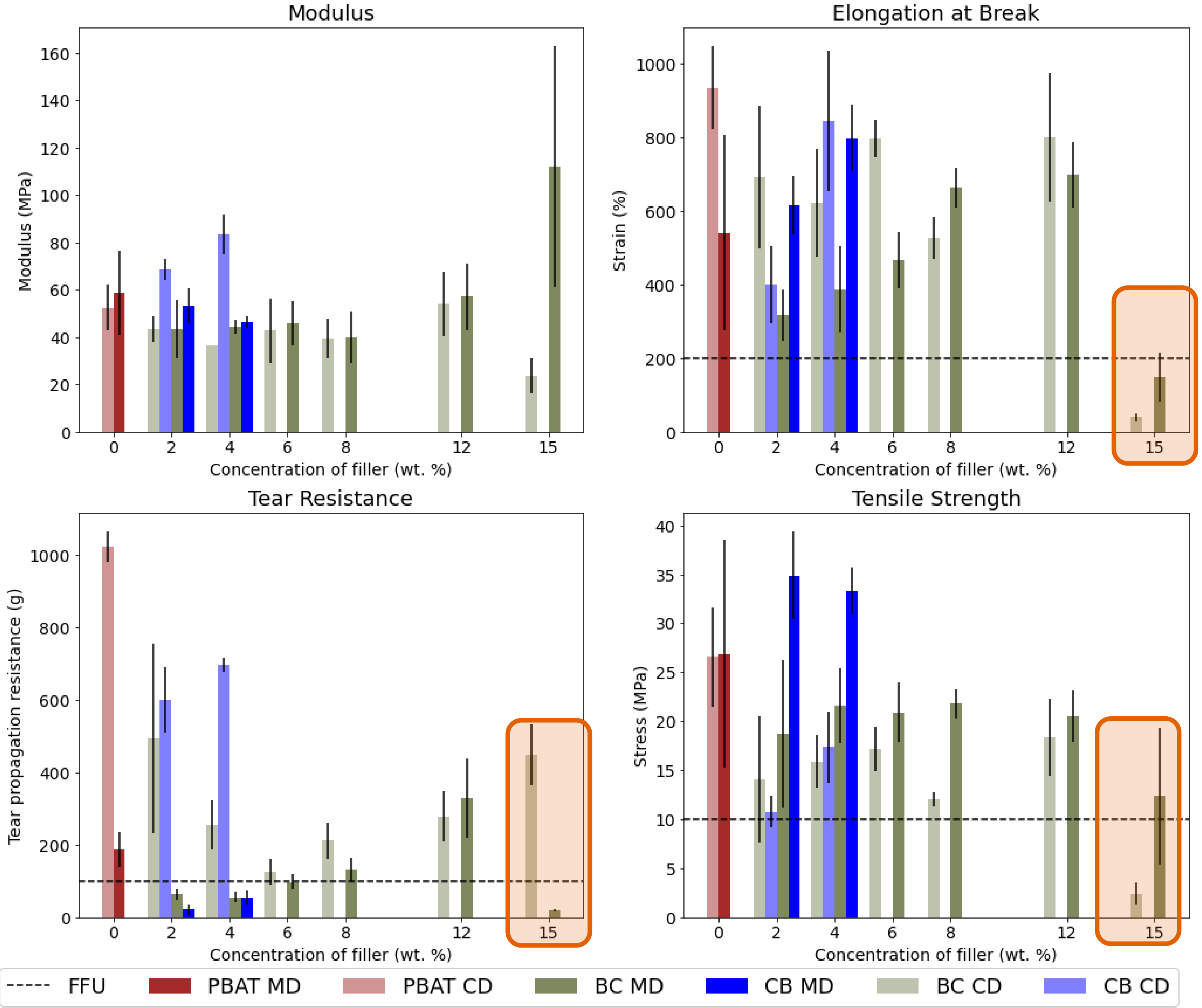
Carbon Black opaque films	Biochar opaque films
2 wt. % 4 wt. %	2 wt. % 4 wt. % 6 wt. % 8 wt. % 12 wt. % 15 wt. %
Under 50.4 µm	
DSC, TGA, Mechanical, Opacity	


100%
80%
60%
40%
20%
0%
Opacity
0
20
40
60
80
100
120
140
Thickness (µm)
CB2
CB4
BC2
BC4
BC6
BC8
BC12
BC15
PBAT
Effective Weed Supression


Films with a theoretical 75% opacity
BC-filled
CB-filled
Concentration of filler (wt. %)
20.0
17.0
14.0
11.0
9.0
6.0
3.0
0.0
20
40
60
80
100
120
140
Film Thickness(μm)

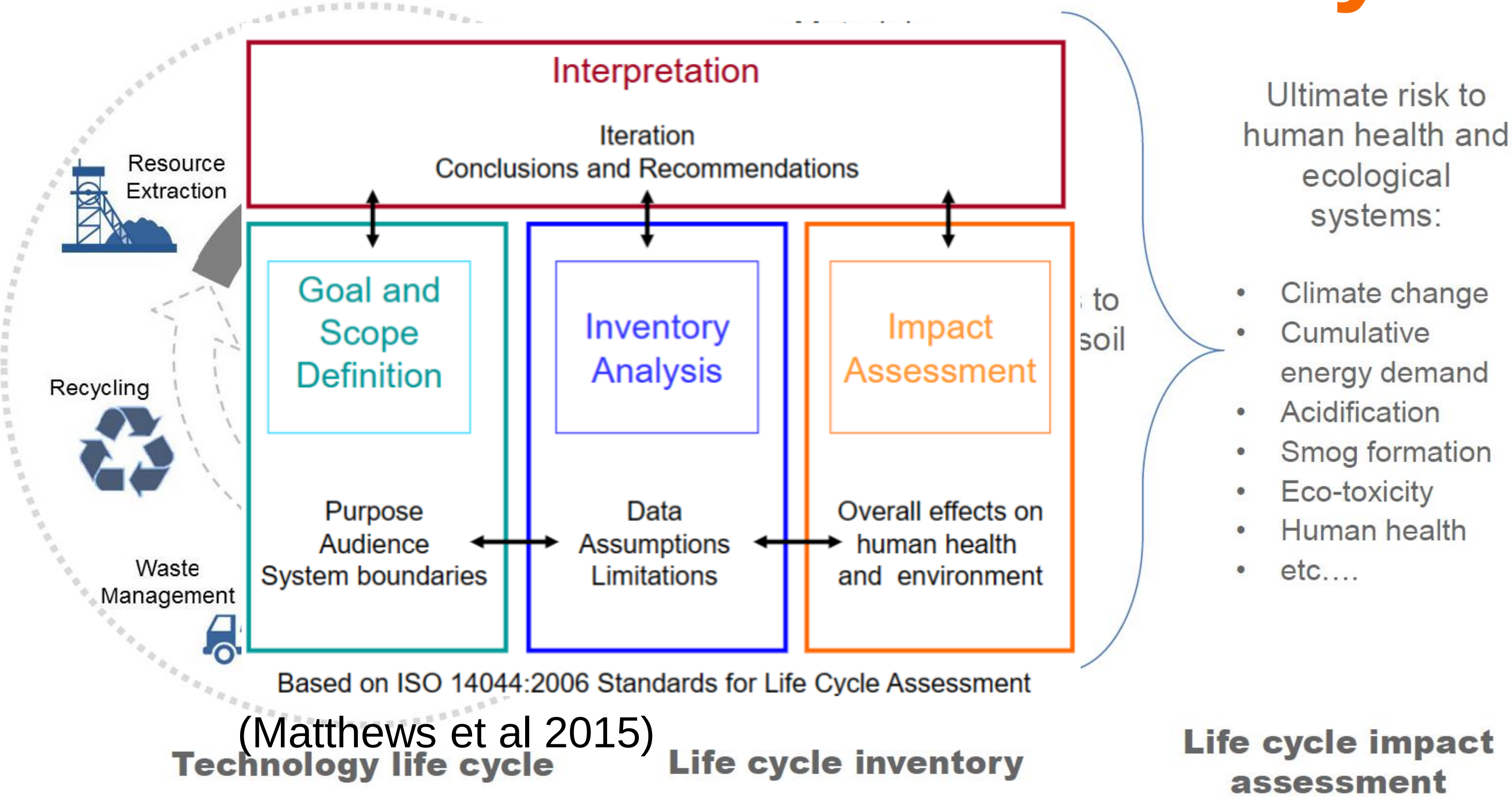
Experimentation

Fit for use (FFU) between 12 and 15 wt. % BC



Life Cycle Assessment (LCA)
Techno economical Analysis (TEA)

ISO 14040
ISO 14044



(Matthews et al 2015)

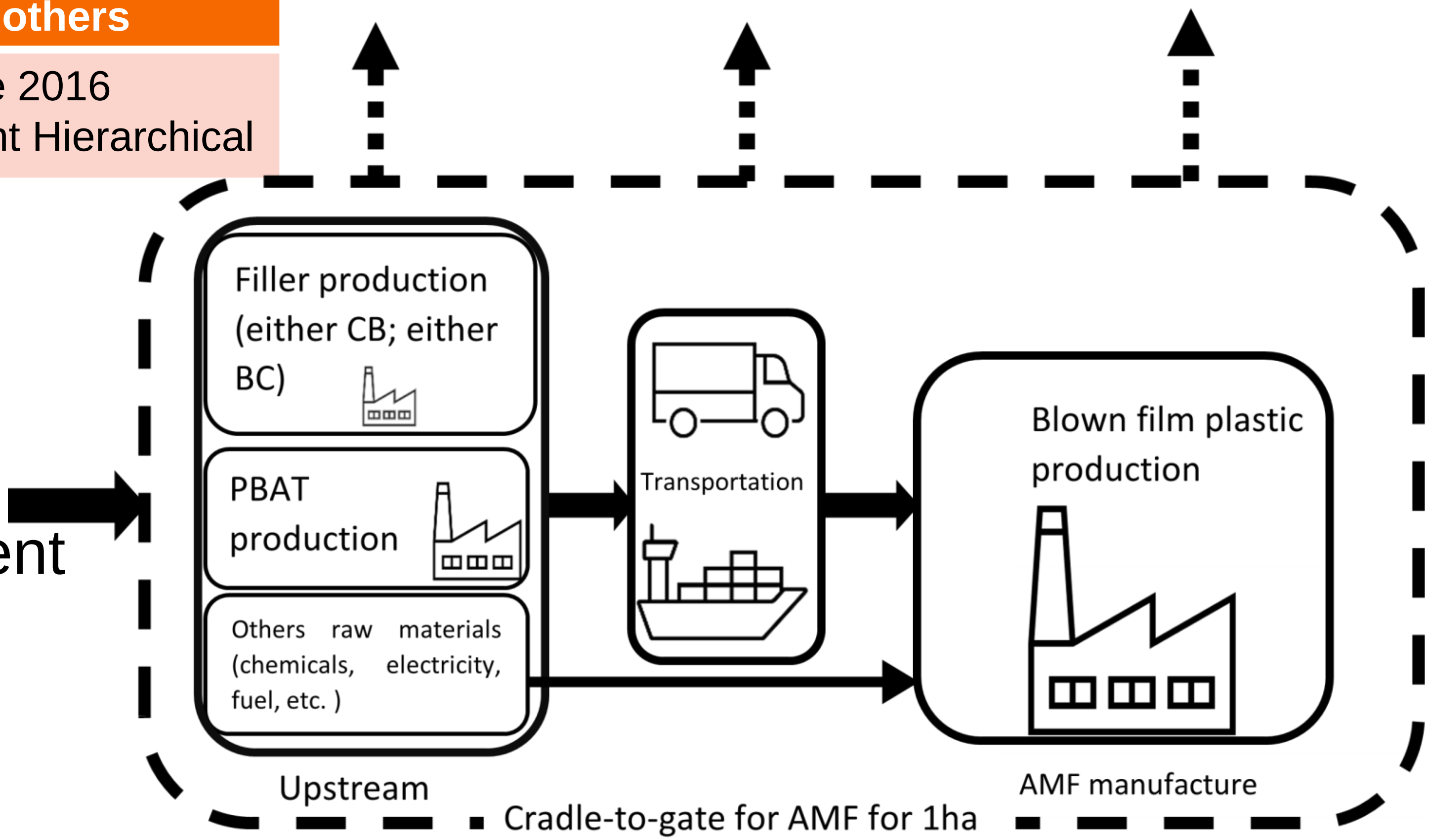
(Langhorst et al 2022)

- Goal and Scope
  - Boundaries
  - Functional Unit
  - Impact Assessment Methods
- Life Cycle Inventory (data)
- Life Cycle Impact Assessment
- Sensitivity Analysis

Category	Global Warming impact	All the others
LCI methods	IPCC v1 GWP 2021 (including uptake)	ReCiPe 2016 Midpoint Hierarchical

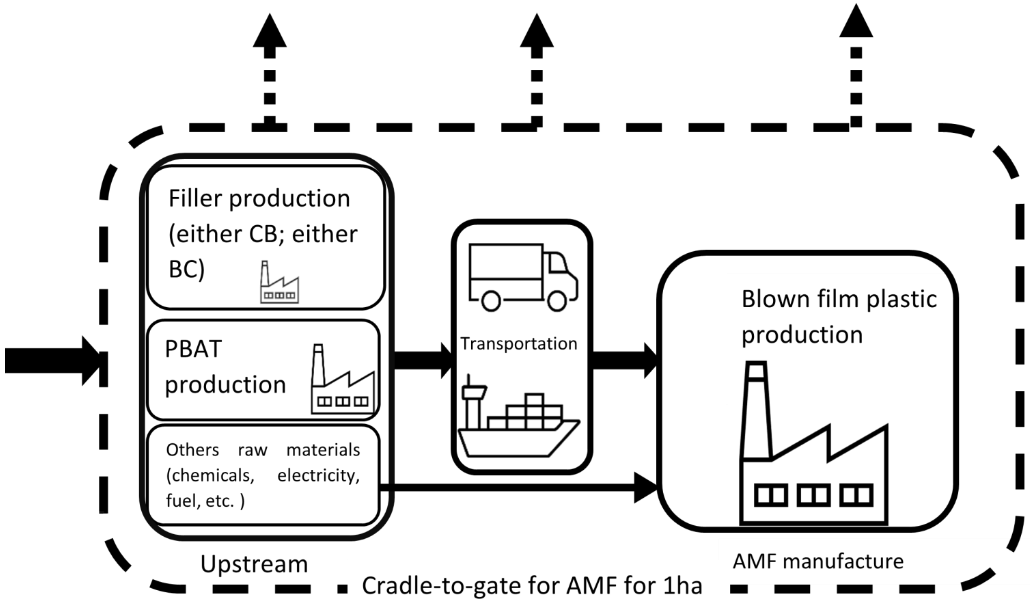
Cradle-to-gate

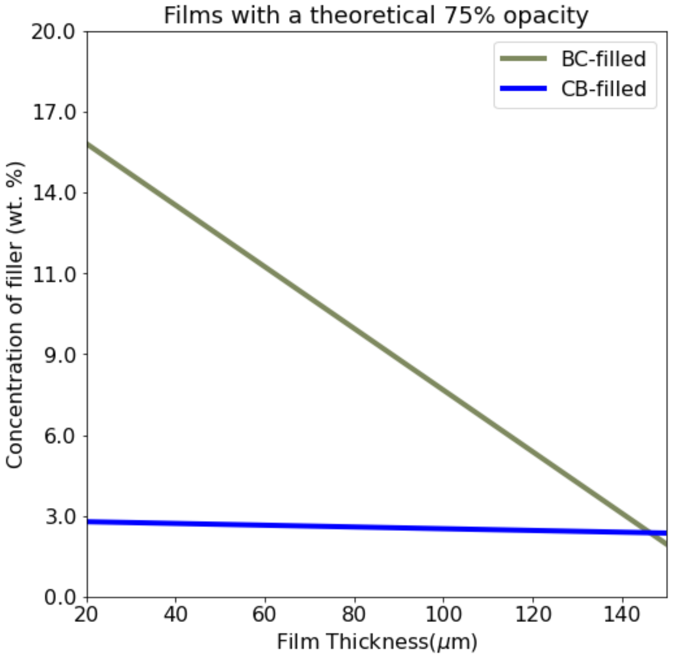
- ☑ Goal and Scope
- ☑ Life Cycle Inventory (data)
- ☑ Life Cycle Impact Assessment
- ☑ Sensitivity Analysis

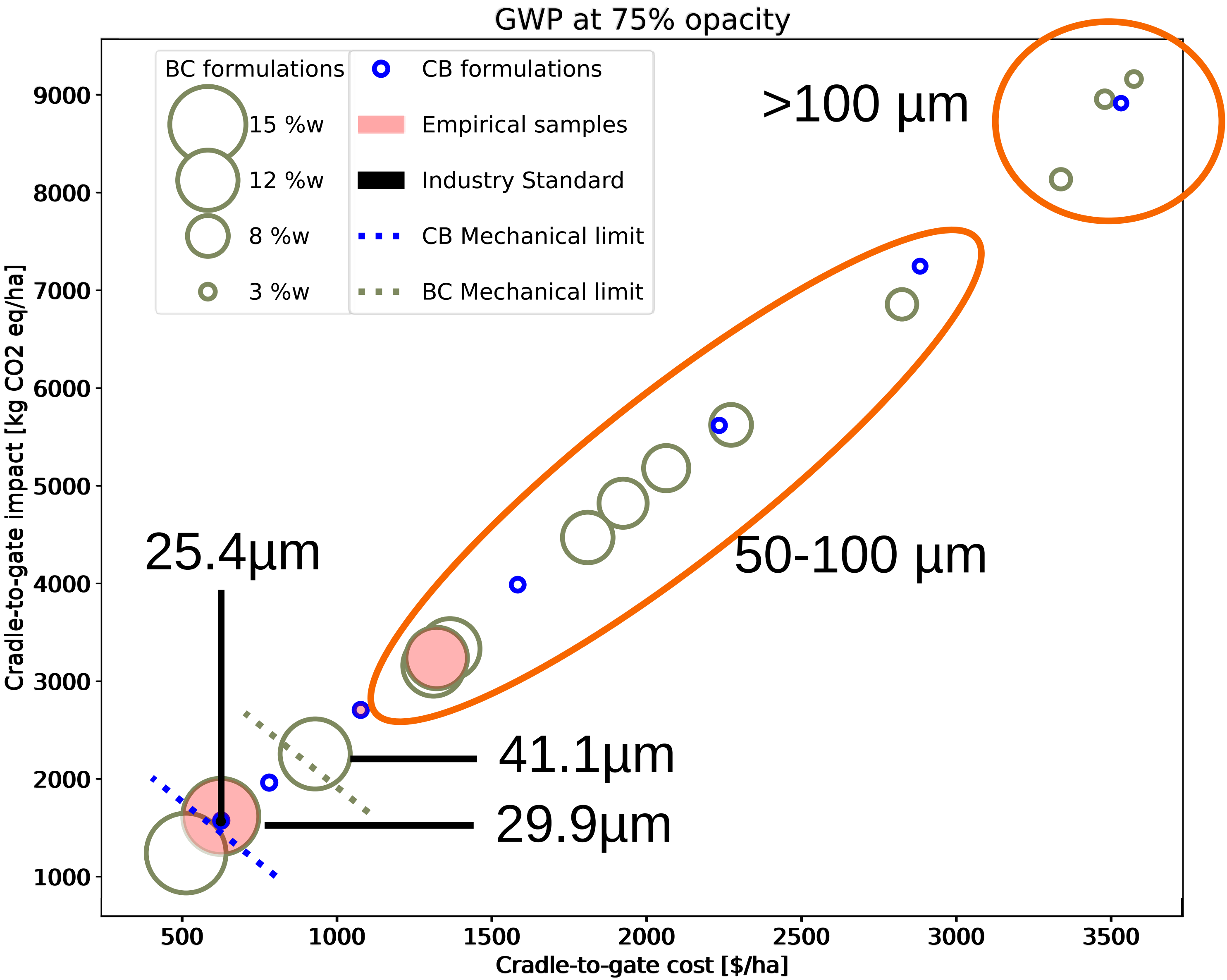


Source of data	Biochar production	Carbon Black production	PBAT production	Transport	Plastic extrusion
LCA	Sahoo et al. 2021 Bergman et al. 2022	Ecoinvent v3 as Meisel et al., 2022 and Haylock et al, 2018	Schrijvers et al. 2014	Ecoivent v3 as Choi et al, 2018	Choi et al, 2018
TEA	Sahoo et al. 2021 Bergman et al. 2022	Own purchase and Haylock et al, 2018	Own Purchase	Sahin et al, 2009	Haylock et al, 2018 Cimpan et al, 2016

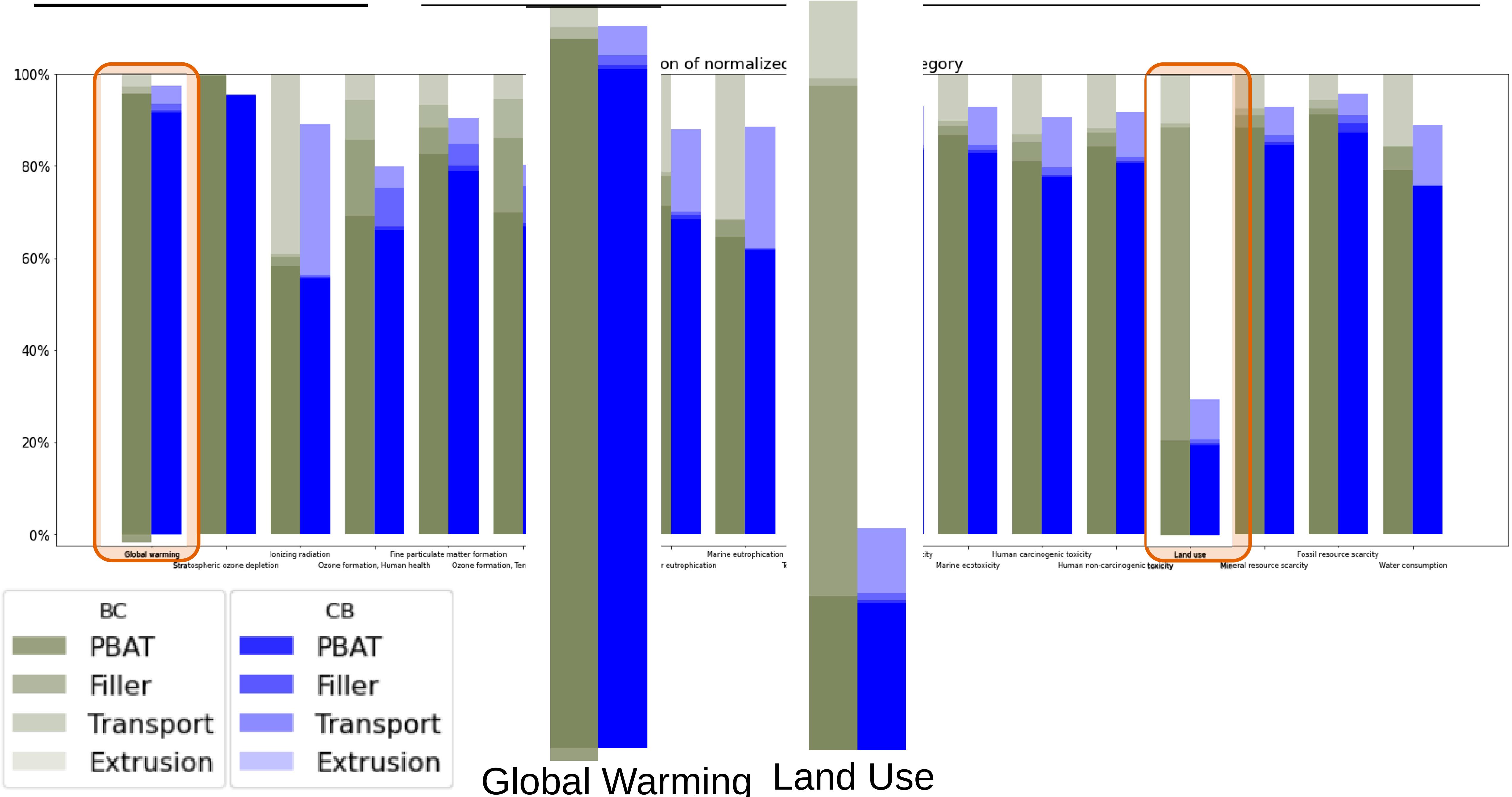
TEA and LCA


Filler production (either CB; either BC)
PBAT production
Others raw materials (chemicals, electricity, fuel, etc.)
Transportation
Blown film plastic production
Upstream
AMF manufacture
Cradle-to-gate for AMF for 1ha


Films with a theoretical 75% opacity
BC-filled
CB-filled
Concentration of filler (wt. %)
Film Thickness(μm)
20.0
17.0
14.0
11.0
9.0
6.0
3.0
0.0
20
40
60
80
100
120
140


GWP at 75% opacity
BC formulations
15 %w
12 %w
8 %w
3 %w
CB formulations
Empirical samples
Industry Standard
CB Mechanical limit
BC Mechanical limit
>100 µm
50-100 µm
25.4µm
41.1µm
29.9µm
Cradle-to-gate impact [kg CO2 eq/ha]
Cradle-to-gate cost [$/ha]
9000
8000
7000
6000
5000
4000
3000
2000
1000
500
1000
1500
2000
2500
3000
3500

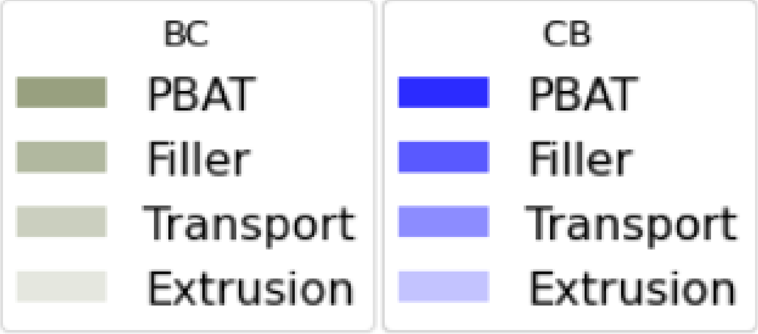
TEA and LCA

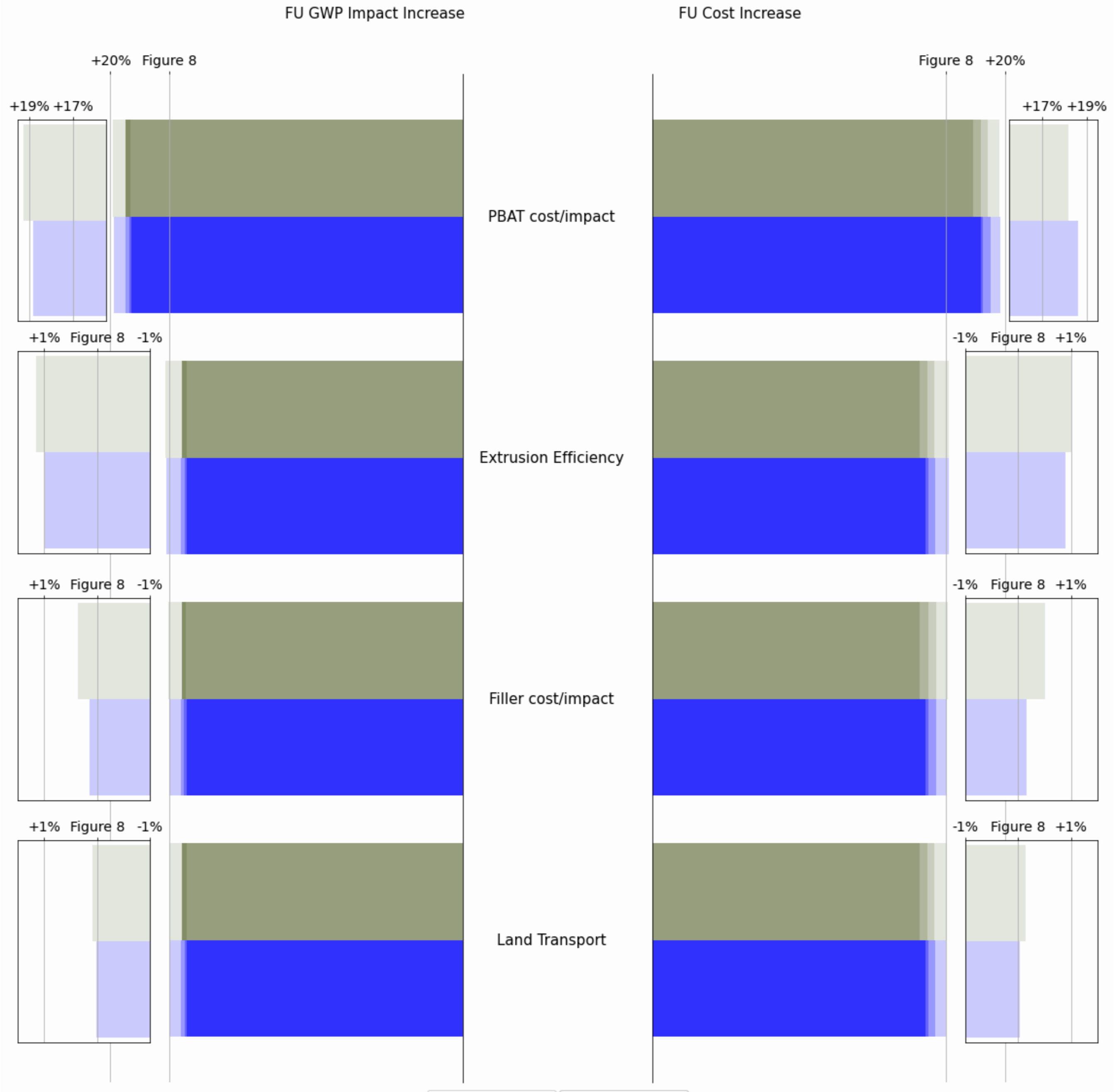

100%
80%
60%
40%
20%
0%
Global warming
Stratospheric ozone depletion
Ionizing radiation
Ozone formation, Human health
Fine particulate matter formation
Marine eutrophication
Marine ecotoxicity
Human carcinogenic toxicity
Human non-carcinogenic toxicity
Land use
Mineral resource scarcity
Fossil resource scarcity
Water consumption
BC
PBAT
Filler
Transport
Extrusion
CB
PBAT
Filler
Transport
Extrusion
Global Warming
Land Use

TEA and LCA

Our results are sensitive to the **PBAT** impact and cost

Filler (either BC or CB) has little effect on overall results





Conclusions

For mono-layer AMF **BC is not a sustainable alternative** of CB for opacity.

The cost and environmental impact are driven by the polymer used.

Assumptions of our work:

- Opacity variability is based on experimental data, produced with only **one** type of BC
- Same horticultural benefit from the two options

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Thank you!

Questions?

References!

RIT | Golisano Institute for Sustainability

RIT | College of Engineering Technology

FOUNDATION FOR FOOD & AGRICULTURE RESEARCH

NEW YORK STATE OF OPPORTUNITY. | Empire State Development

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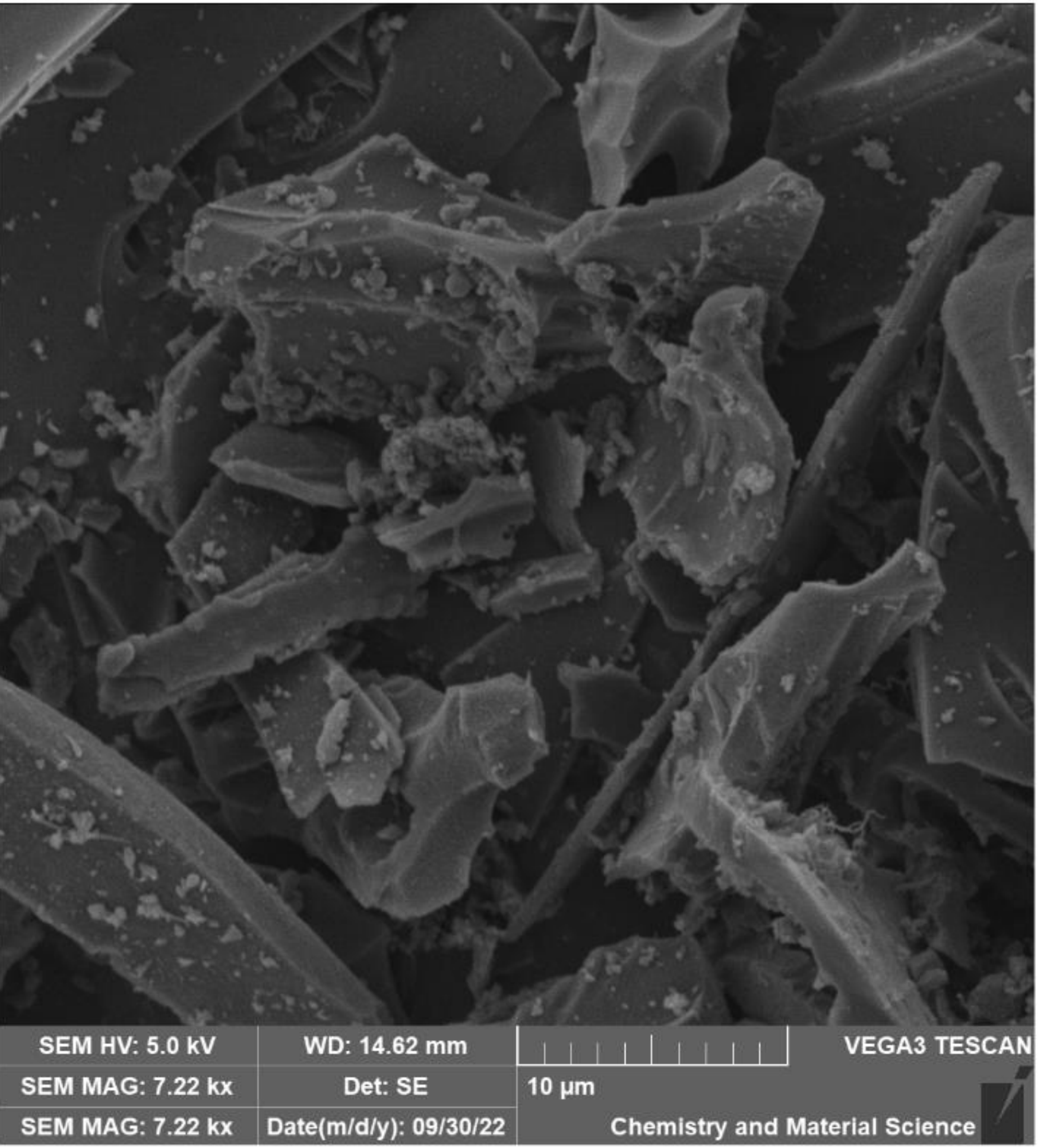
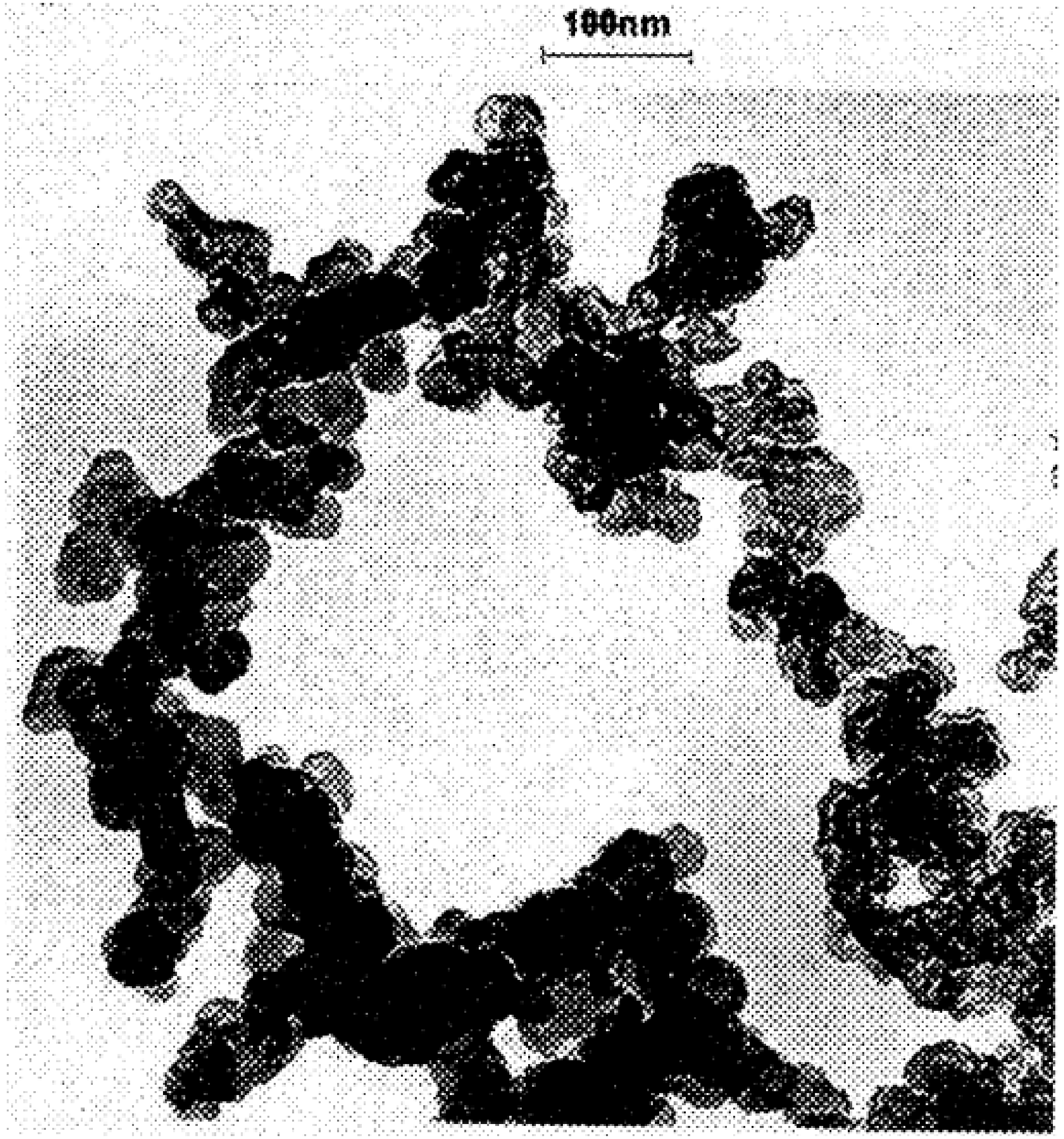
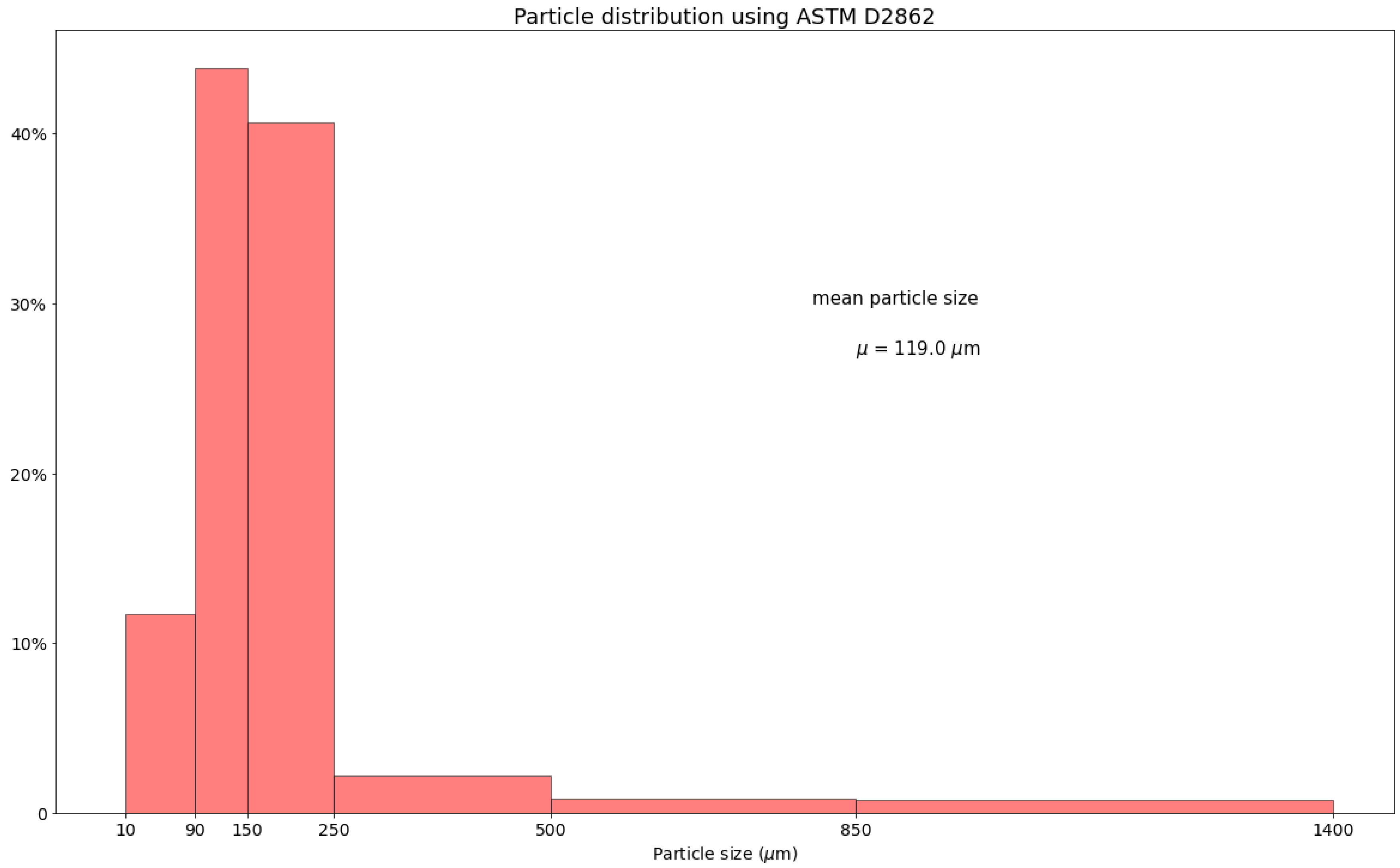
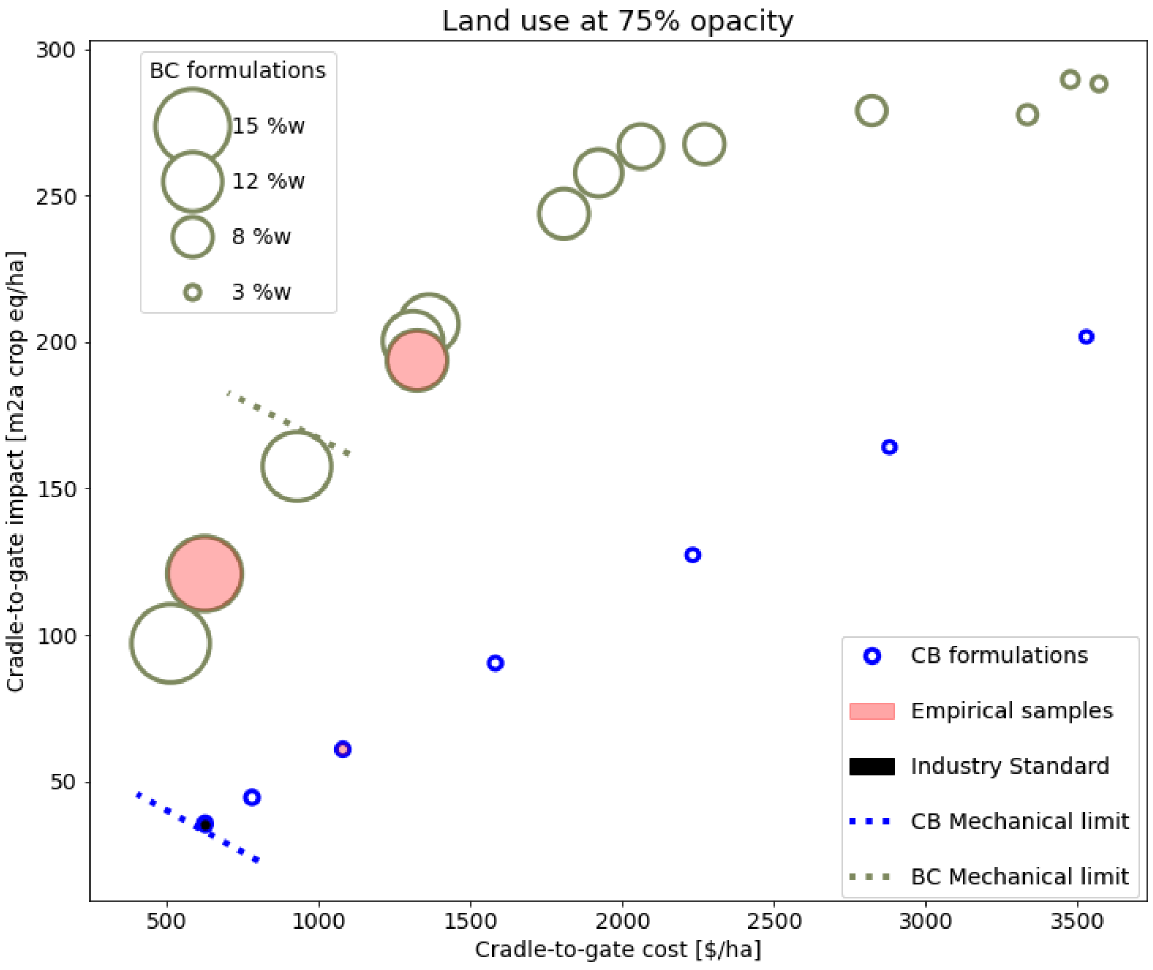

SEM HV: 5.0 kV
WD: 14.62 mm
VEGA3 TESCAN
SEM MAG: 7.22 kx
Det: SE
10 µm
SEM MAG: 7.22 kx
Date(m/d/y): 09/30/22
Chemistry and Material Science

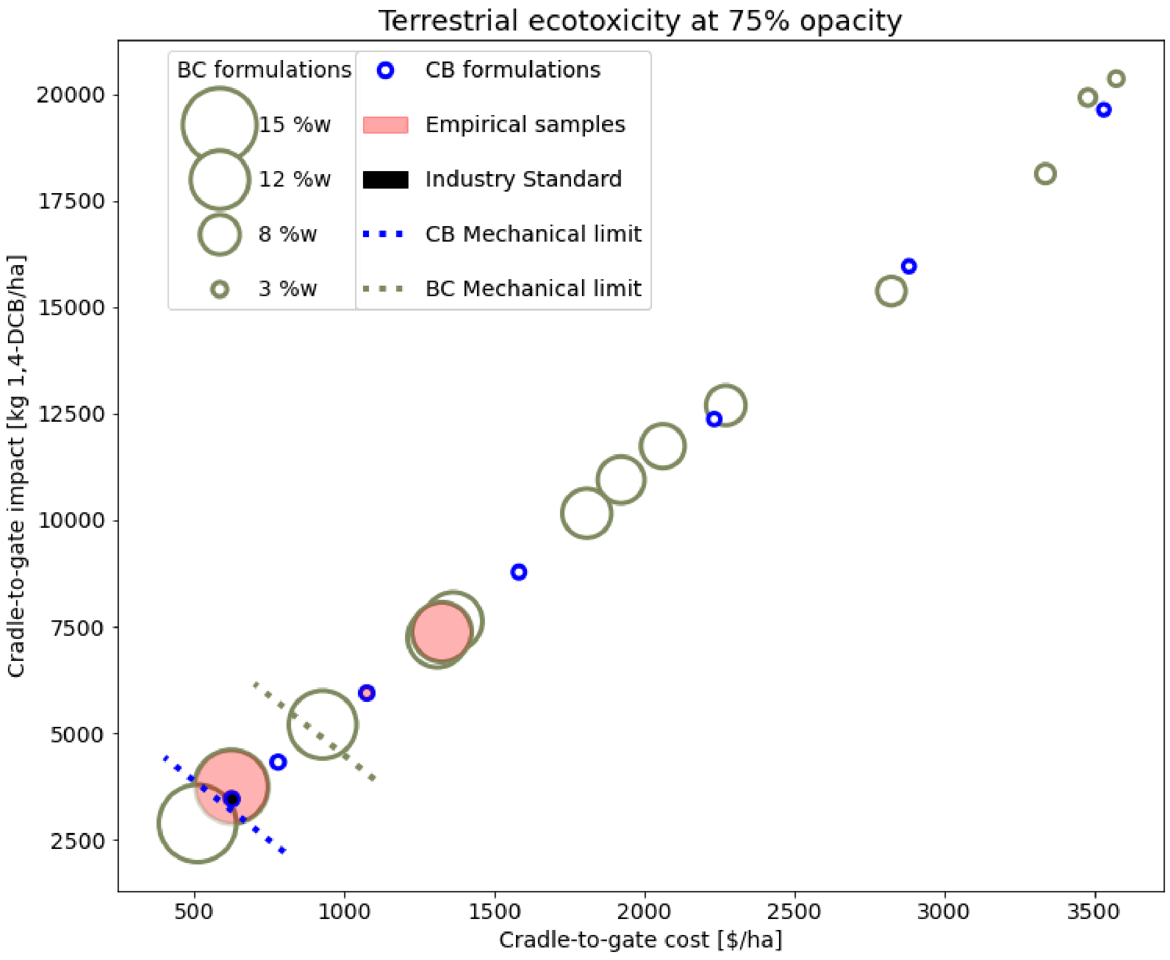

100nm

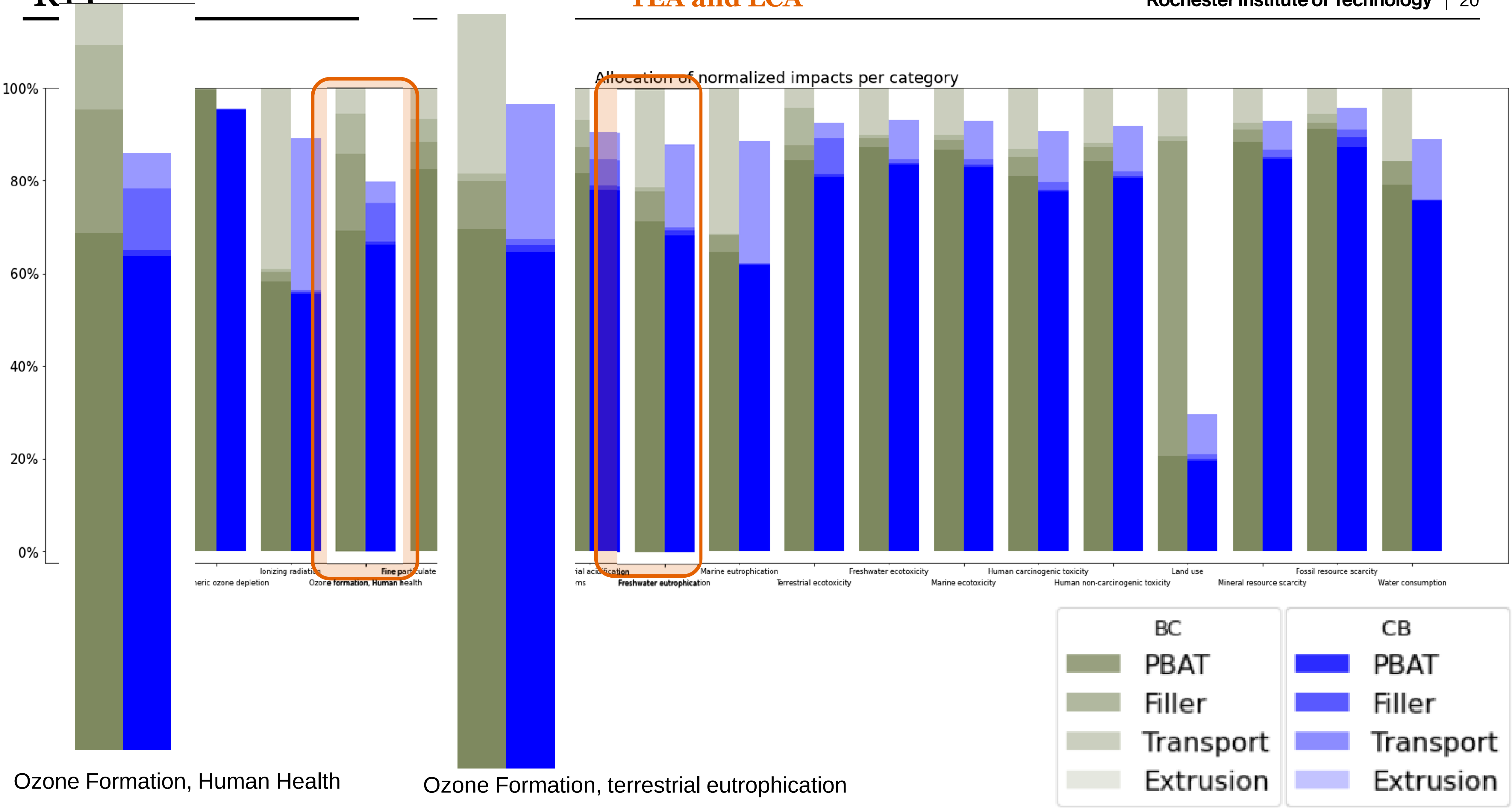
Maeno, 2006


Particle distribution using ASTM D2862
mean particle size
μ = 119.0 μm
40%
30%
20%
10%
0
10
90
150
250
500
850
1400
Particle size (μm)

Block	Category	Description	Value	Comment
BC (1 tonne)	Material Input from Technosphere	Bark chips, wet, measured as dry mass {RoW}	5932 kg	Feedstock needed (Bergman et al. 2022)
	Energy input from Technosphere	Diesel, burned in Agricultural machinery {GLO}	641.7 MJ	18L of diesel combusted at LHV*. (Bergman et al. 2022)
		Heat, central or small scale, natural gas {RoW}	0.31 MJ	From the burn of 8L of propane/NG**. (Bergman et al. 2022)
		Electricity, onsite boiler, hardwood	3336 kWh	From the burn of 834kg of woody biomass assuming at LHV• . (Bergman et al. 2022)
	Emissions	Carbon Dioxide, biogenic	9.49E3 kg	Supplemental information of (Sahoo et al. 2021)
		Carbon Monoxide, biogenic	3.46 kg	Supplemental information of (Sahoo et al. 2021)
		Methane, biogenic	0.753 kg	Supplemental information of (Sahoo et al. 2021)
		Nitrogen Oxides	9.73 kg	Supplemental information of (Sahoo et al. 2021)
		Particulates, <10 um	6.82 kg	Supplemental information of (Sahoo et al. 2021)
		Particulates, <2.5 um	0.055 kg	Supplemental information of (Sahoo et al. 2021)
		Particulates	5.19 kg	Supplemental information of (Sahoo et al. 2021)
		Propane	1.89 kg	Supplemental information of (Sahoo et al. 2021)
		Sulfur dioxide	0.157 kg	Supplemental information of (Sahoo et al. 2021)
PBAT (1 kg)	Material inputs from Technosphere	1,4-Butanediol	0.41 kg	Table 4 of (Schrijvers et al. 2014)
Copy block from PET granulate, supposing a 90% efficiency		Terephthalic acid	0.33	Table 4 of (Schrijvers et al. 2014)
		Adipic acid	0.37	Table 4 of (Schrijvers et al. 2014)

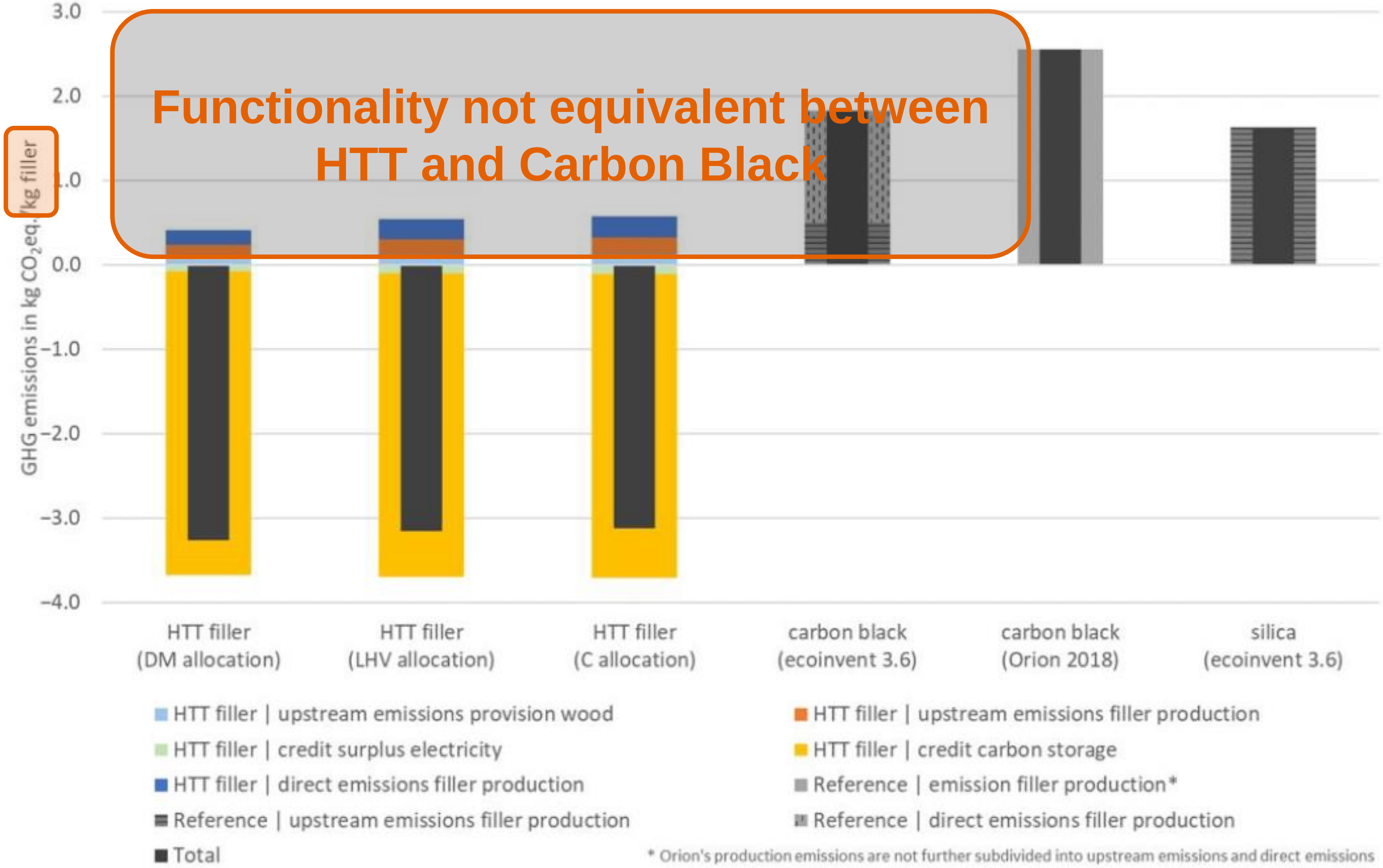

Land use at 75% opacity
BC formulations
15 %w
12 %w
8 %w
3 %w
CB formulations
Empirical samples
Industry Standard
CB Mechanical limit
BC Mechanical limit
Cradle-to-gate impact [m2a crop eq/ha]
Cradle-to-gate cost [$/ha]
300
250
200
150
100
50
500
1000
1500
2000
2500
3000
3500


Terrestrial ecotoxicity at 75% opacity
BC formulations
15 %w
12 %w
8 %w
3 %w
CB formulations
Empirical samples
Industry Standard
CB Mechanical limit
BC Mechanical limit
Cradle-to-gate impact [kg 1,4-DCB/ha]
Cradle-to-gate cost [$/ha]
20000
17500
15000
12500
10000
7500
5000
2500
500
1000
1500
2000
2500
3000
3500

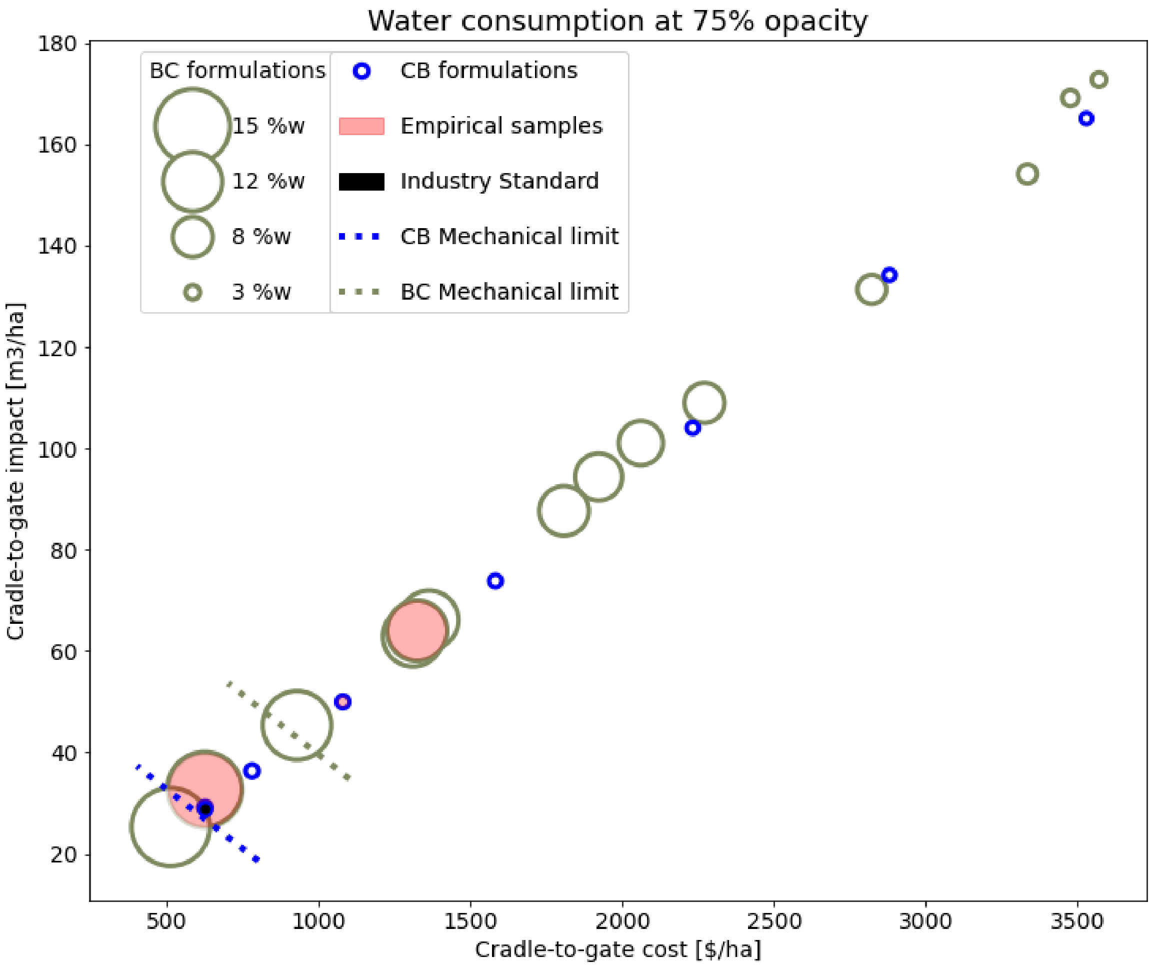


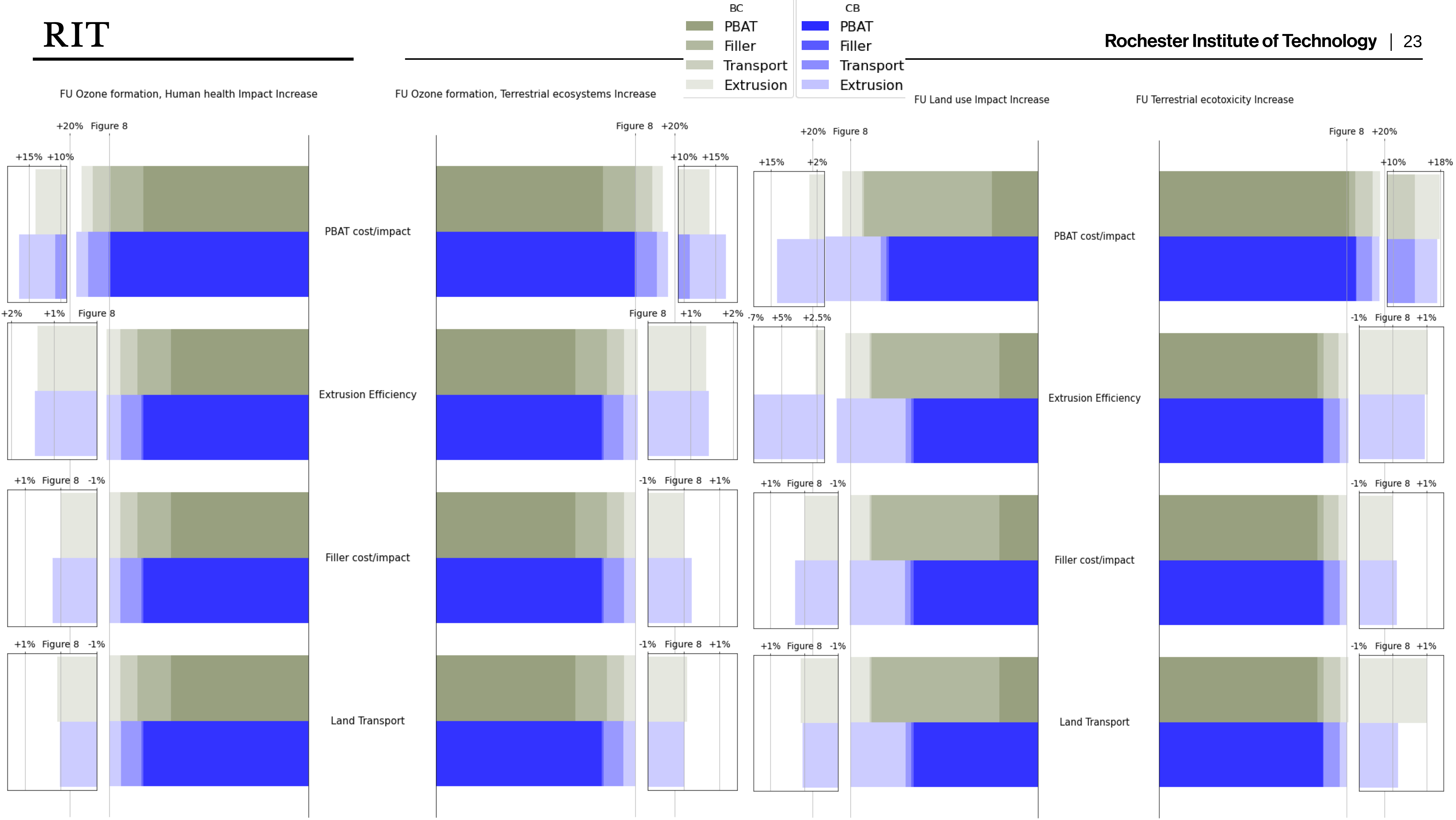
Ozone Formation, Human Health

Ozone Formation, terrestrial eutrophication



(Meisel et al., 2022)


Water consumption at 75% opacity
BC formulations
15 %w
12 %w
8 %w
3 %w
CB formulations
Empirical samples
Industry Standard
CB Mechanical limit
BC Mechanical limit
Cradle-to-gate impact [m3/ha]
Cradle-to-gate cost [$/ha]
180
160
140
120
100
80
60
40
20
500
1000
1500
2000
2500
3000
3500


BC
PBAT
Filler
Transport
Extrusion
CB
PBAT
Filler
Transport
Extrusion
FU Ozone formation, Human health Impact Increase
FU Ozone formation, Terrestrial ecosystems Increase
FU Land use Impact Increase
FU Terrestrial ecotoxicity Increase
PBAT cost/impact
Extrusion Efficiency
Filler cost/impact
Land Transport
Figure 8
+20%
+15%
+10%
+18%
+2%
+1%
-1%
-7%
+5%
+2.5%