AN INTRODUCTION TO COMPOSITES SUSTAINABILITY

CO-HOSTED BY:

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Canada

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nasampe.org

YOUR HOSTS

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École de technologie supérieure, Montreal

- 2023 holder of the FRQNT B3X postdoctoral award
- Ph.D. & B.Eng. in Mechanical Engineering from McGill University
- 10 years of experience in composites manufacturing and sustainability

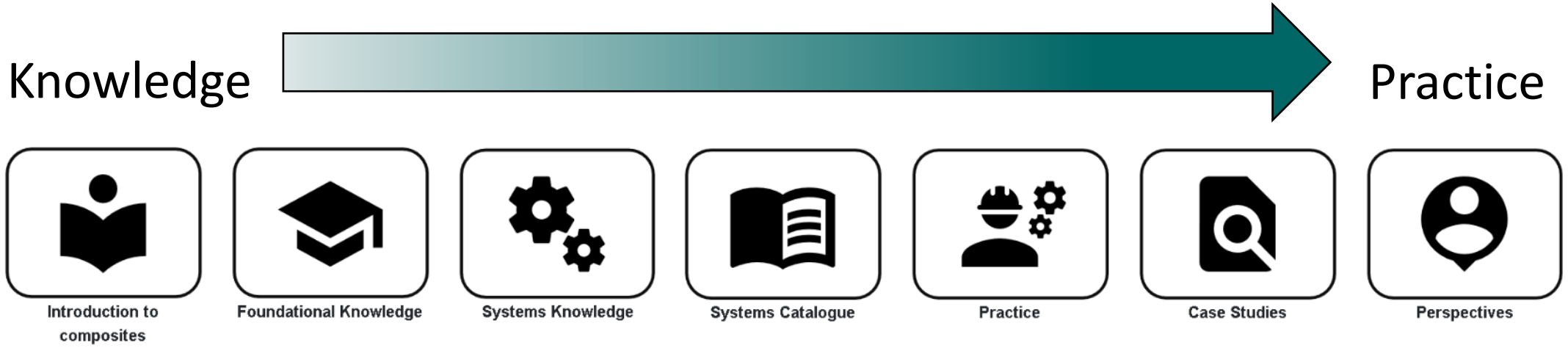
- Research website: www.smithcomposites.com

KNOWLEDGE IN PRACTICE CENTRE (KPC)

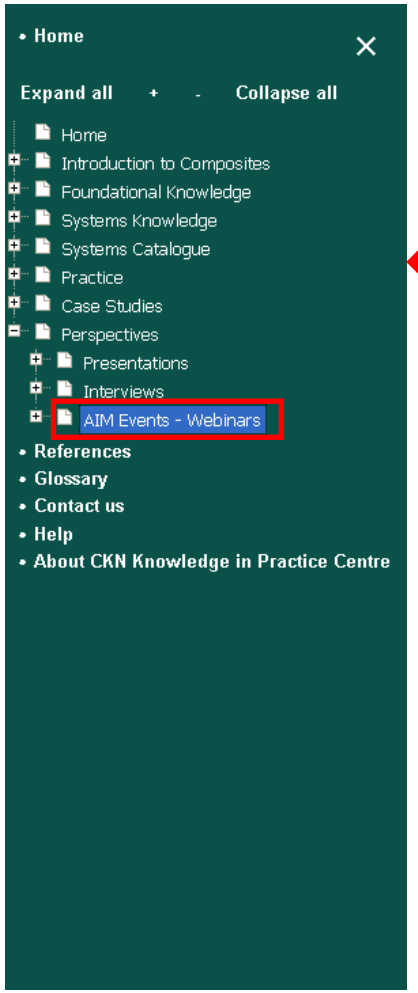
- A freely available online resource for composite materials engineering:

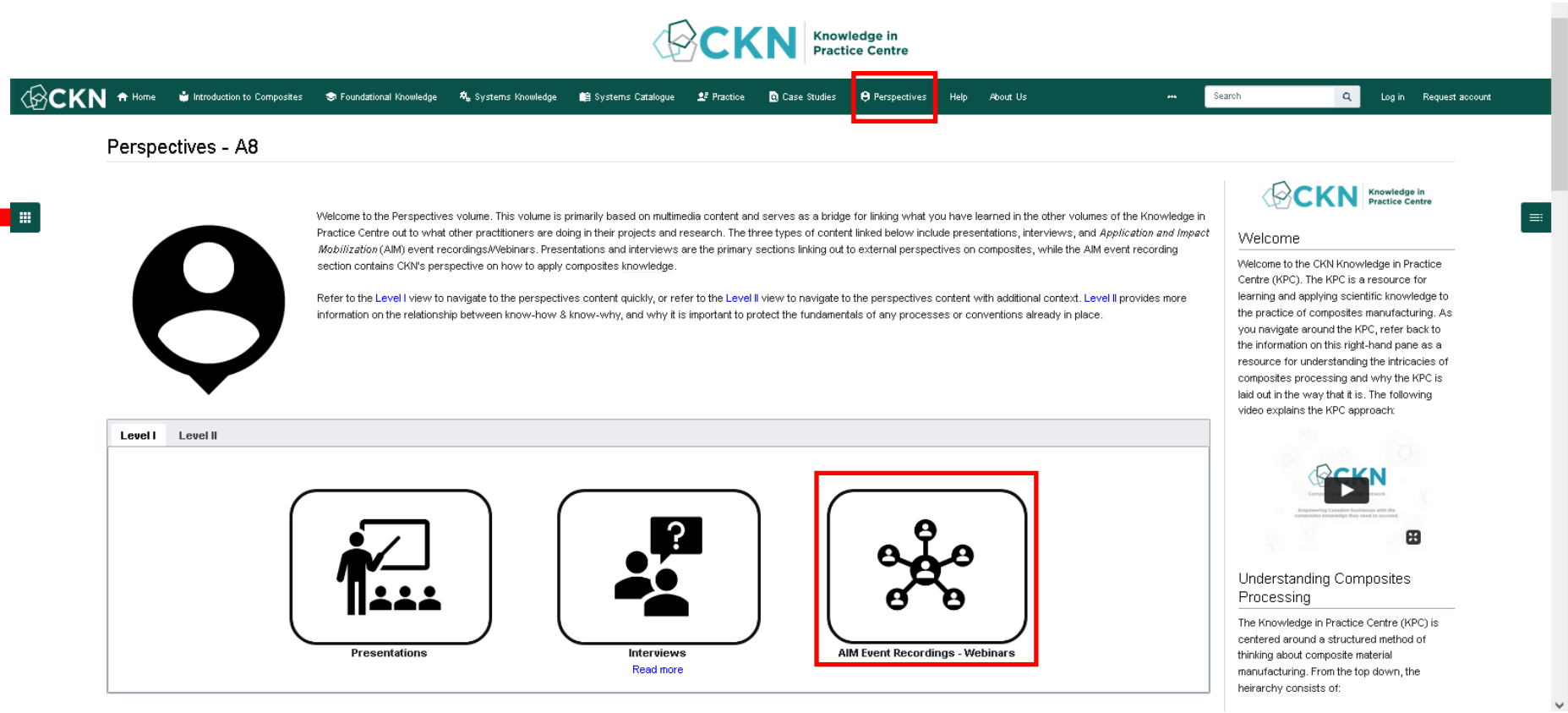
compositeskn.org/KPC

- Focus on practice, guided by foundational knowledge and a systems-based approach to thinking about composites manufacturing



PAST WEBINAR RECORDINGS AVAILABLE





Today's Webinar will be posted at:
https://compositeskn.org/KPC/A339

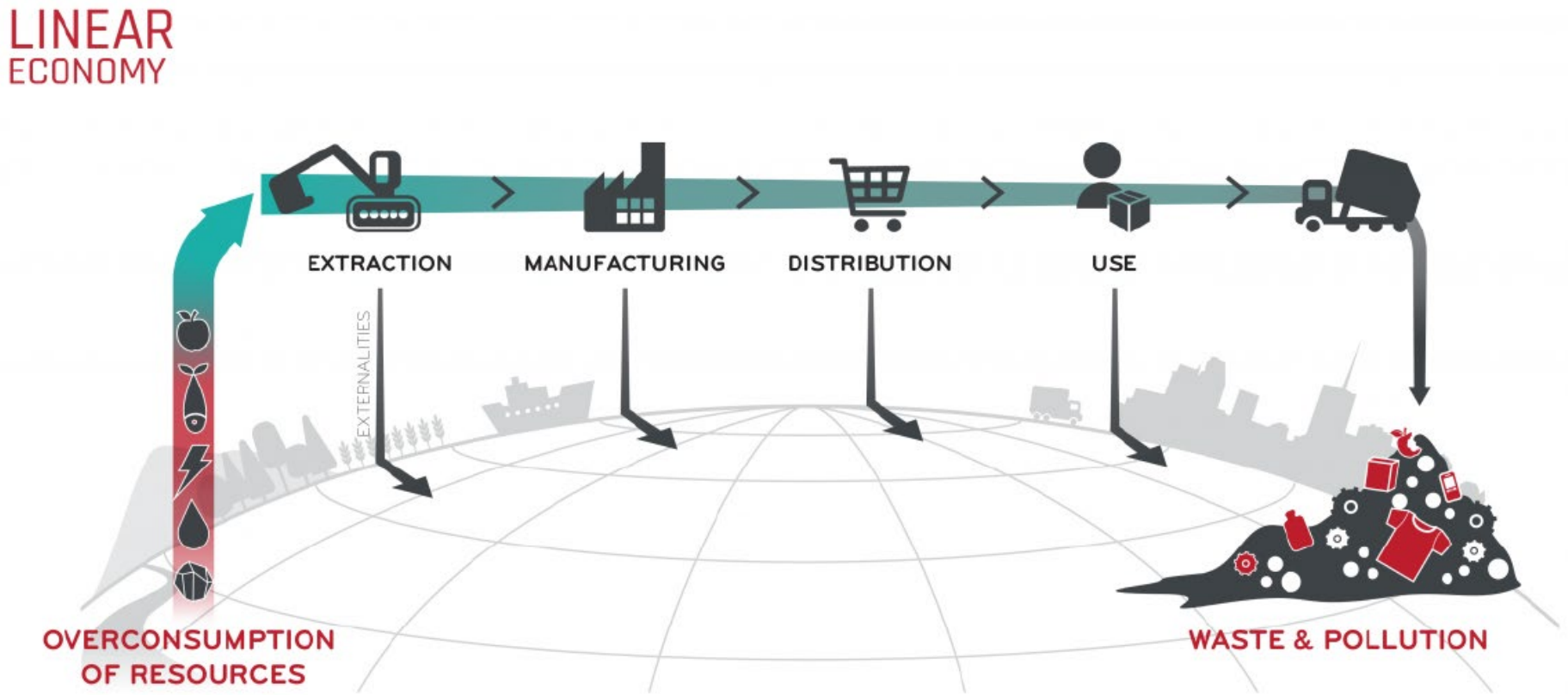
TODAY'S TOPIC:

An Introduction to Composites Sustainability

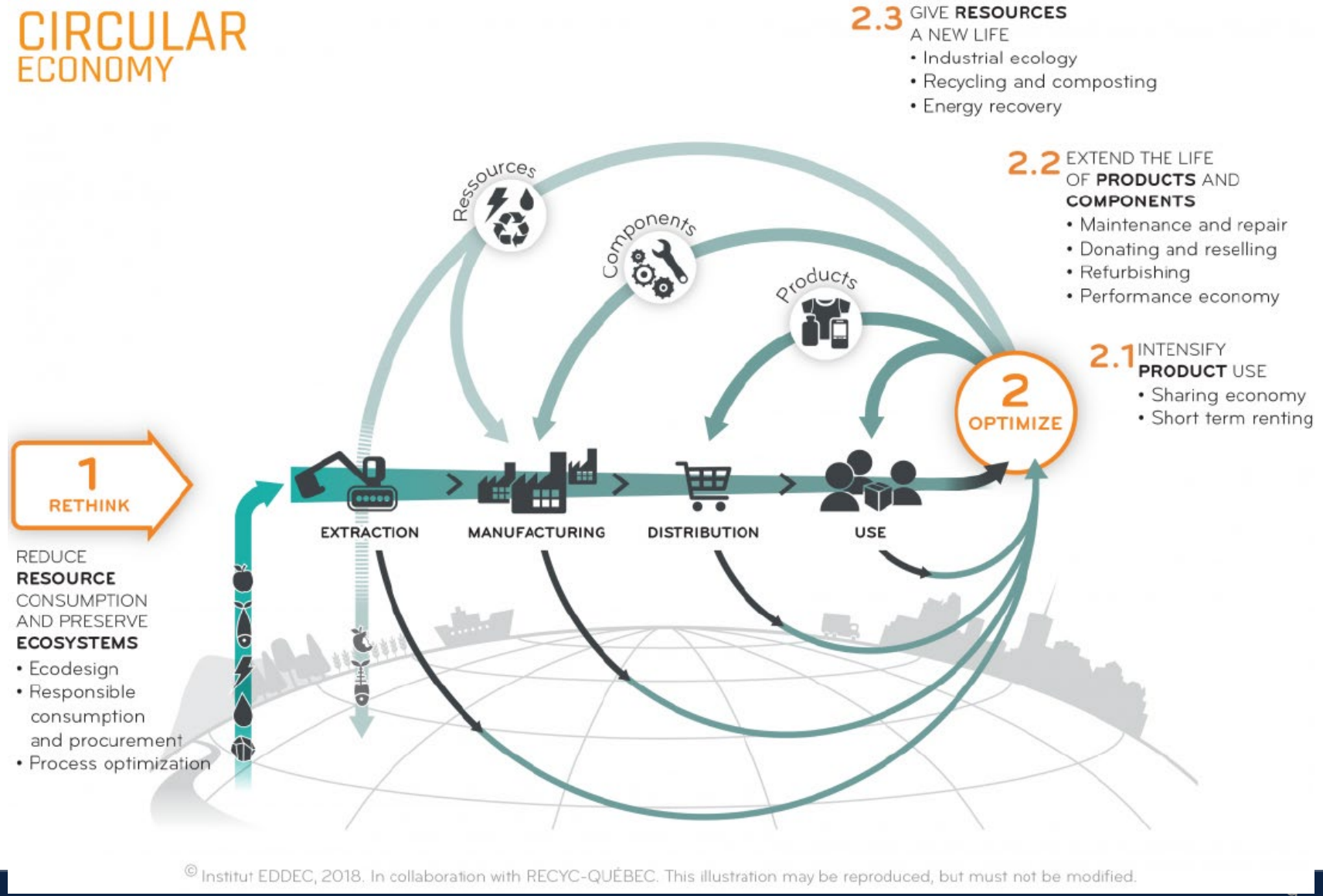
PERCEPTION vs. REALITY

PERCEPTION vs. REALITY

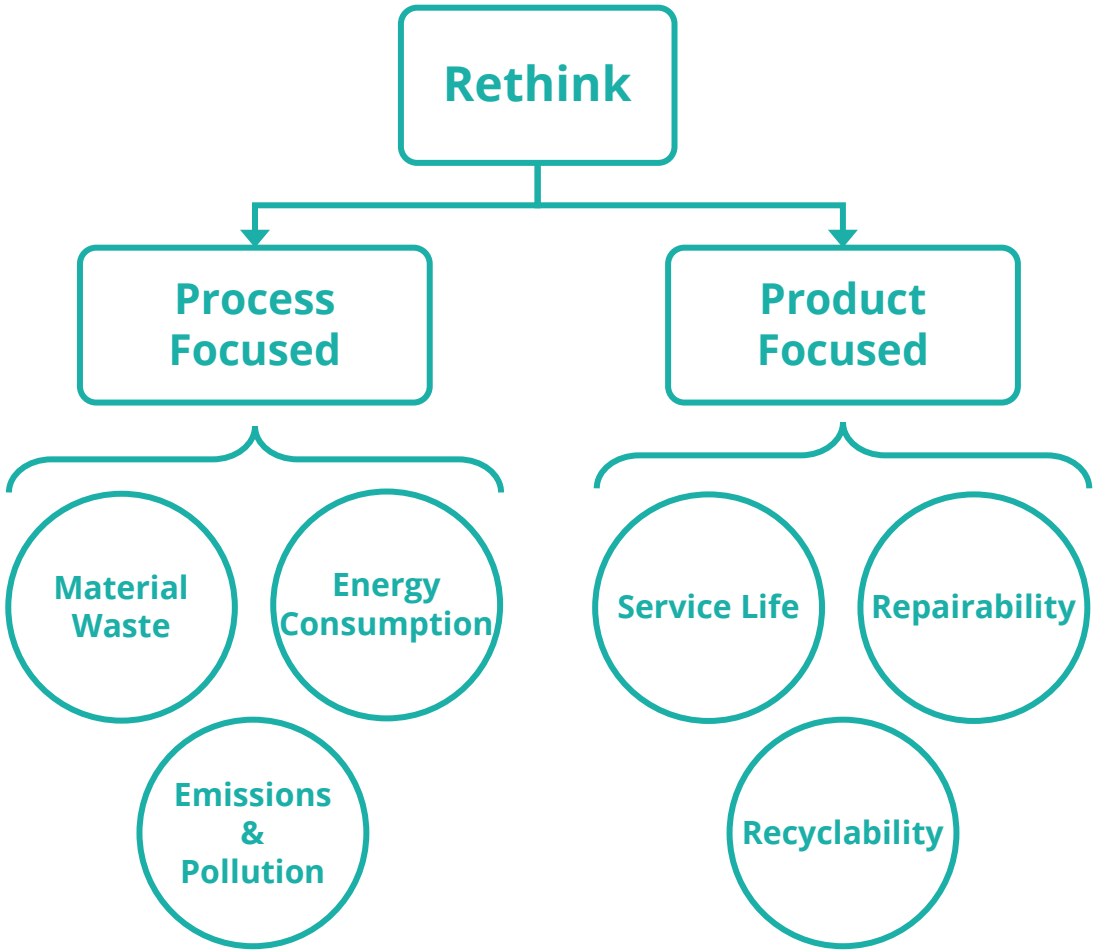
WHAT IS



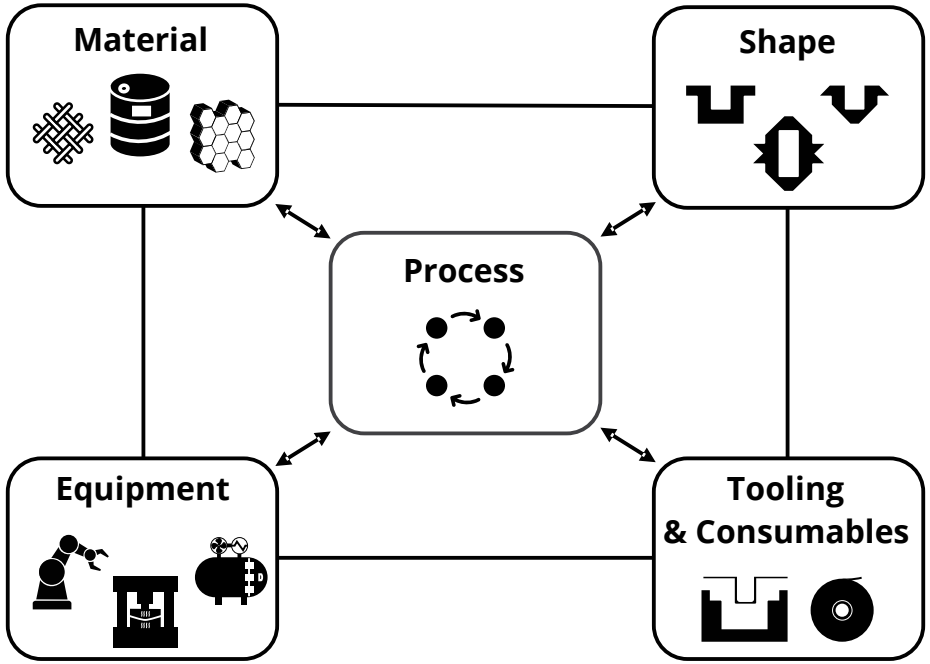
WHAT COULD BE



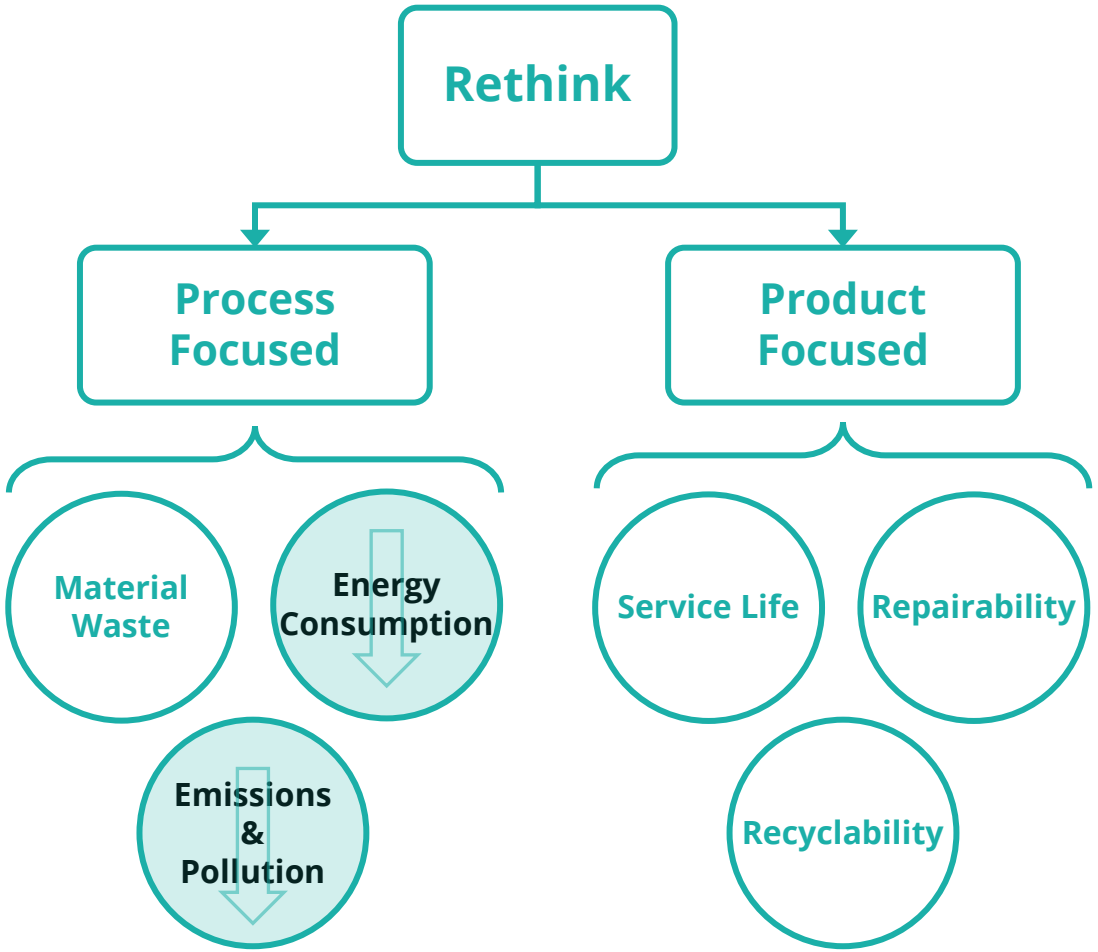
STEPS TOWARD CIRCULARITY - RETHINK



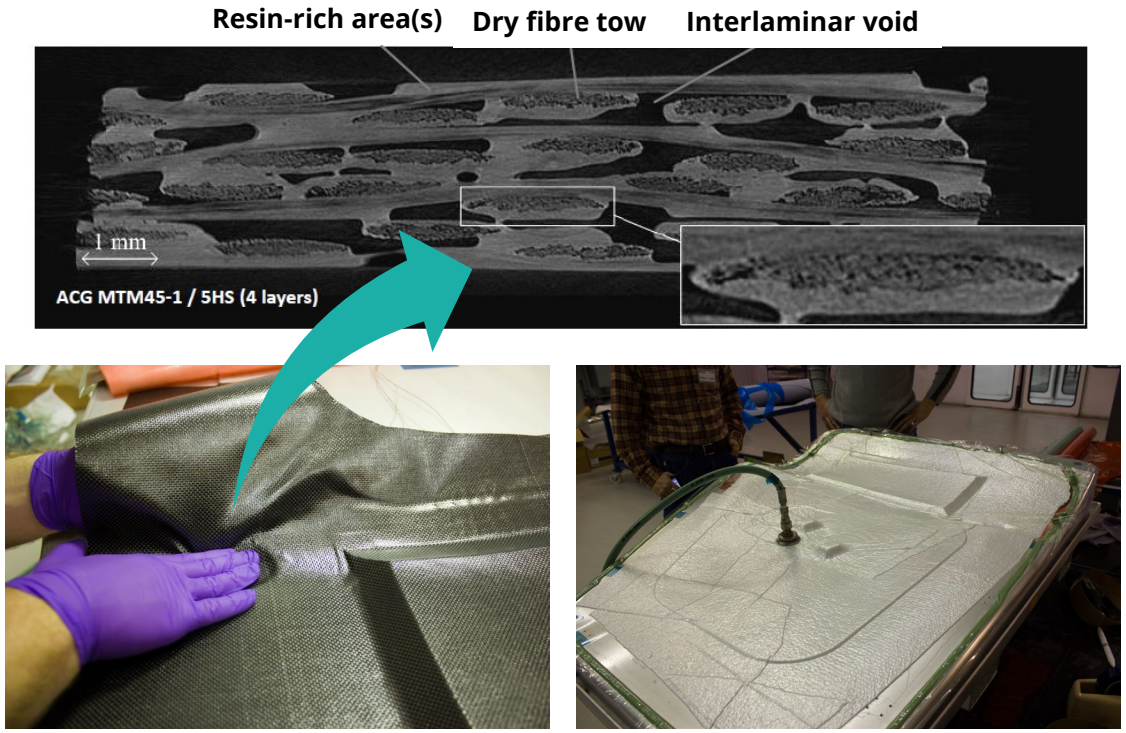
MSTE Manufacturing Process Flow



STEPS TOWARD CIRCULARITY - RETHINK

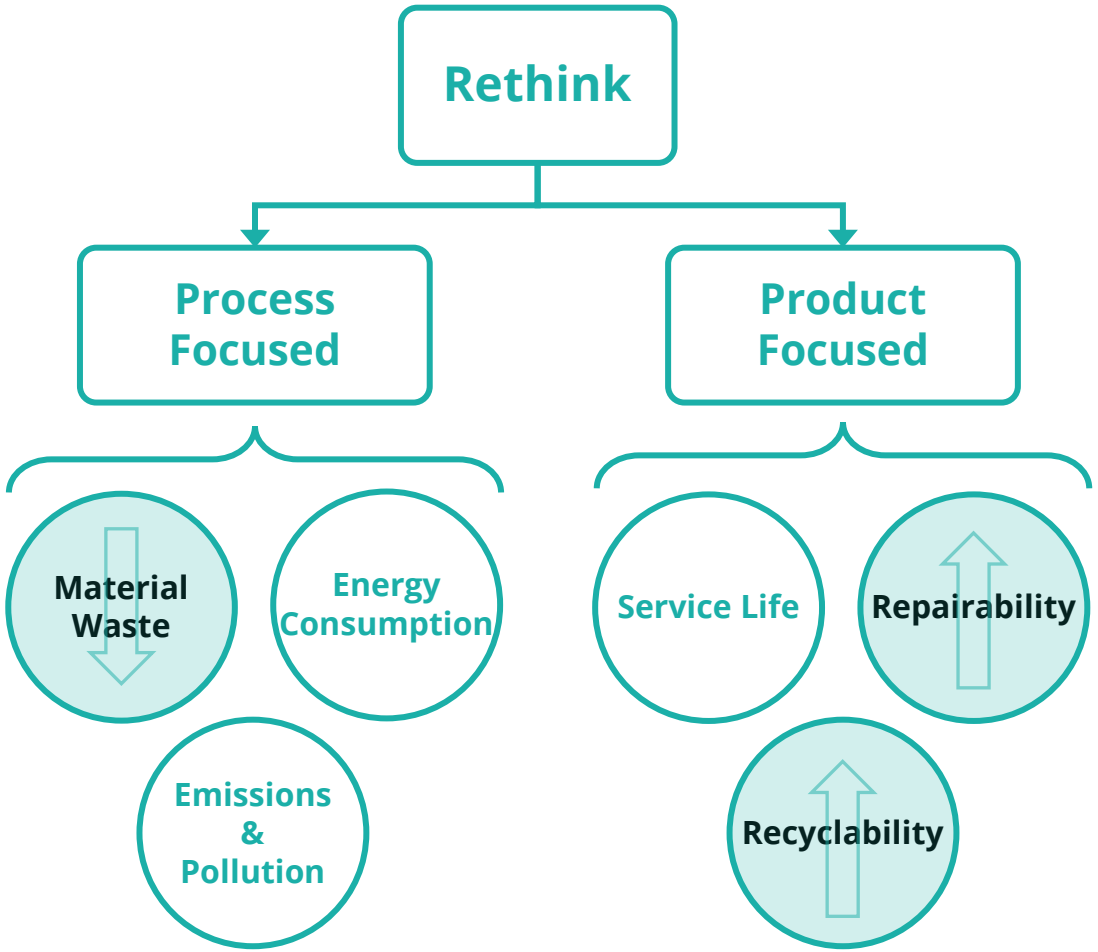


Vacuum Bag Only Out-of-Autoclave Manufacturing

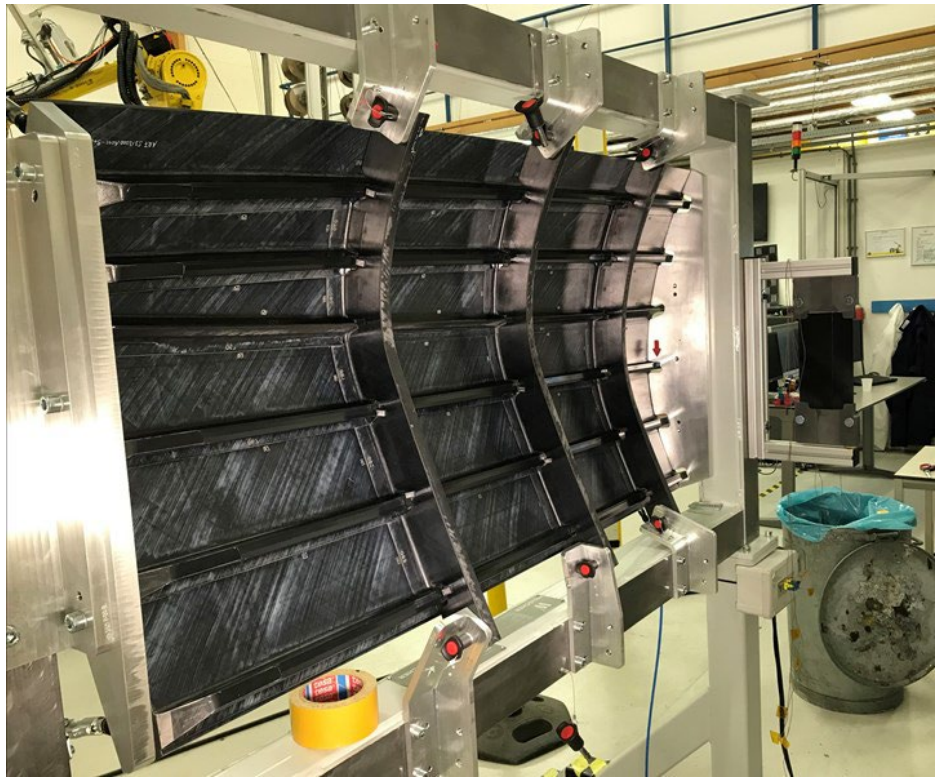


Micro-CT image courtesy of McGill MECH 544 Course Notes – 2015. Pascal Hubert

STEPS TOWARD CIRCULARITY - RETHINK

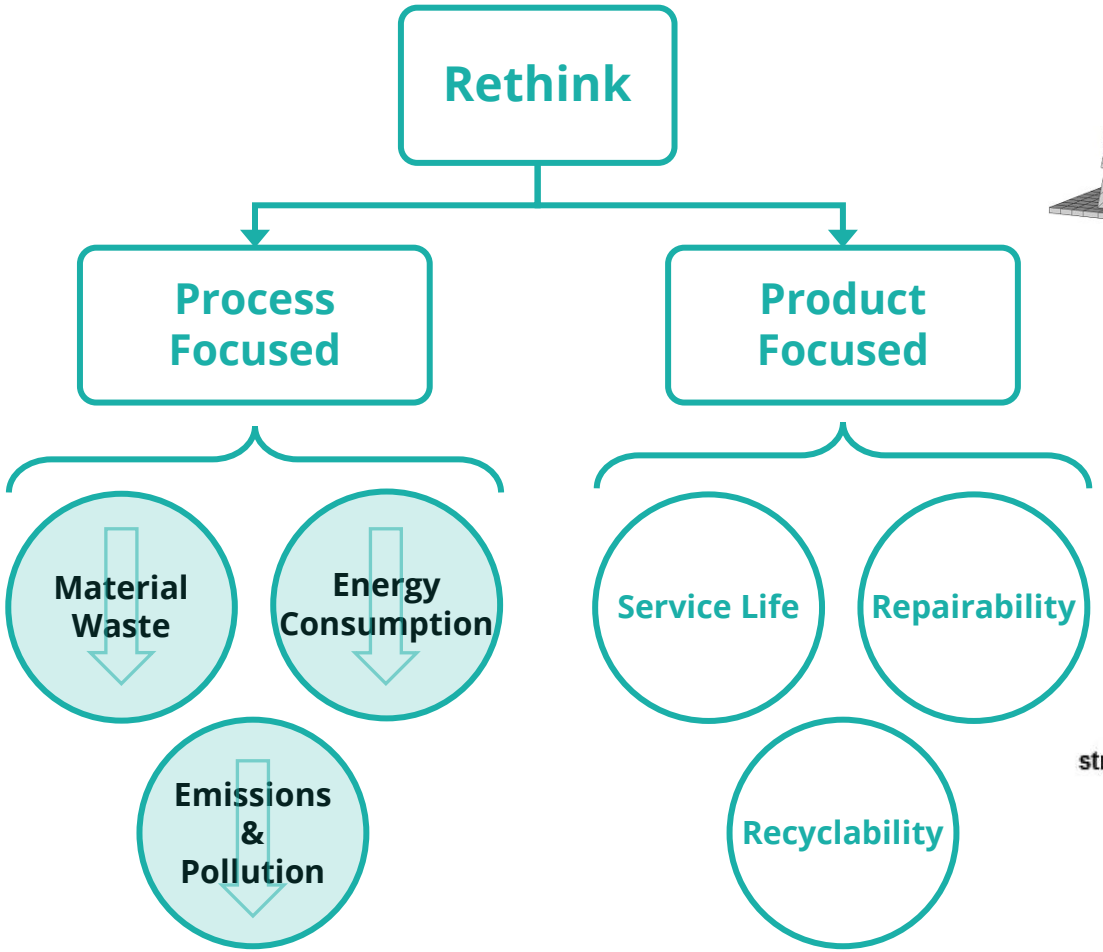


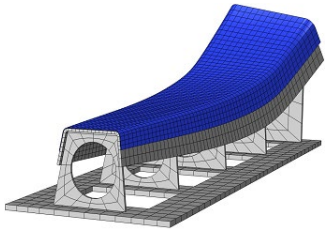
Thermoplastic Matrix Composites



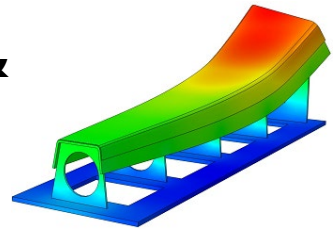
https://www.compositesworld.com/articles/compositeworlds-top-ten-articles-from-our-focus-on-design-column

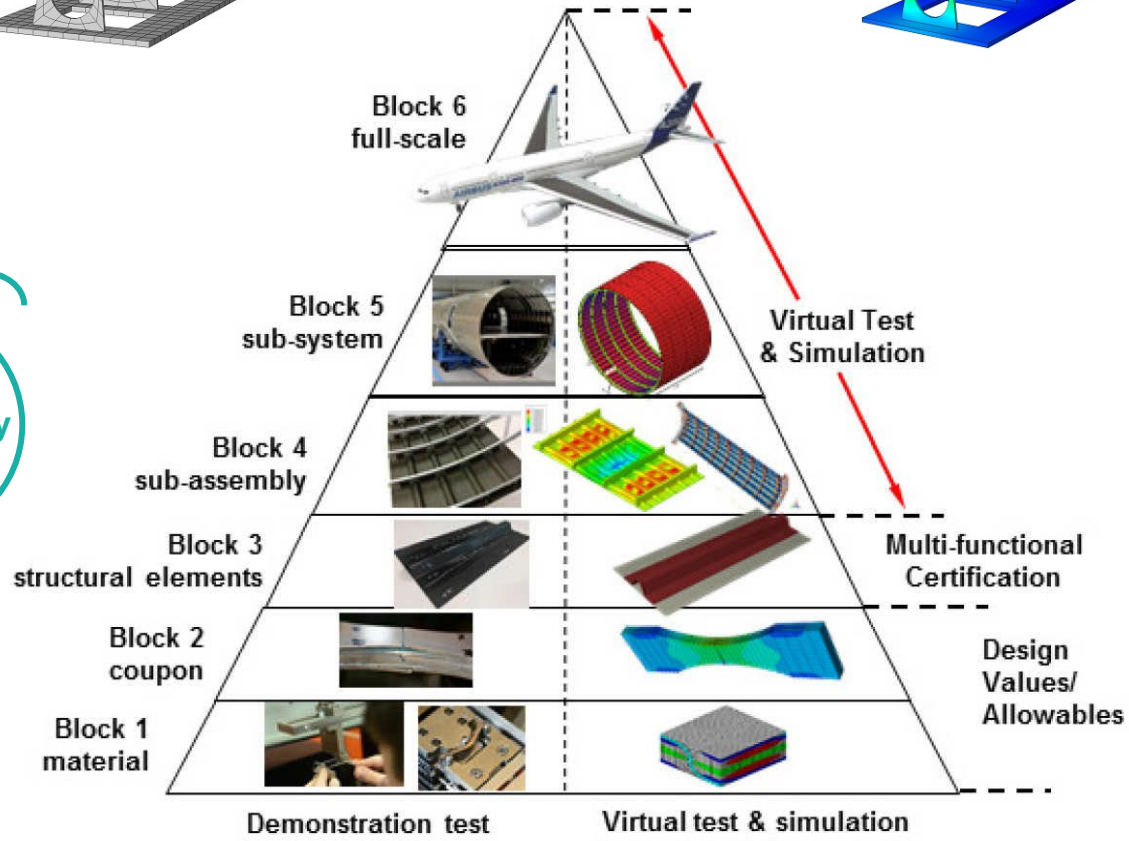
STEPS TOWARD CIRCULARITY - RETHINK





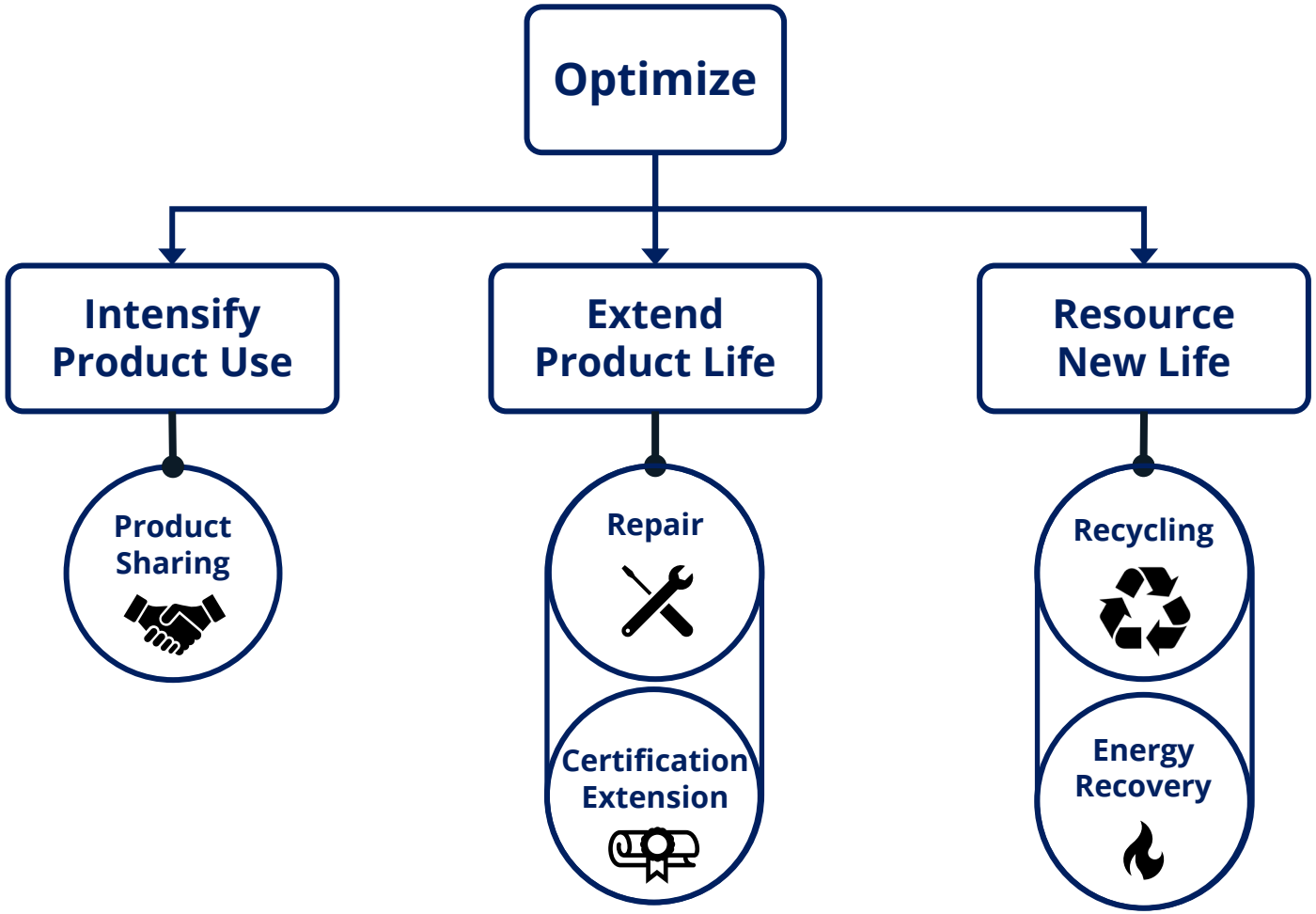
Process Simulation & Virtual Testing



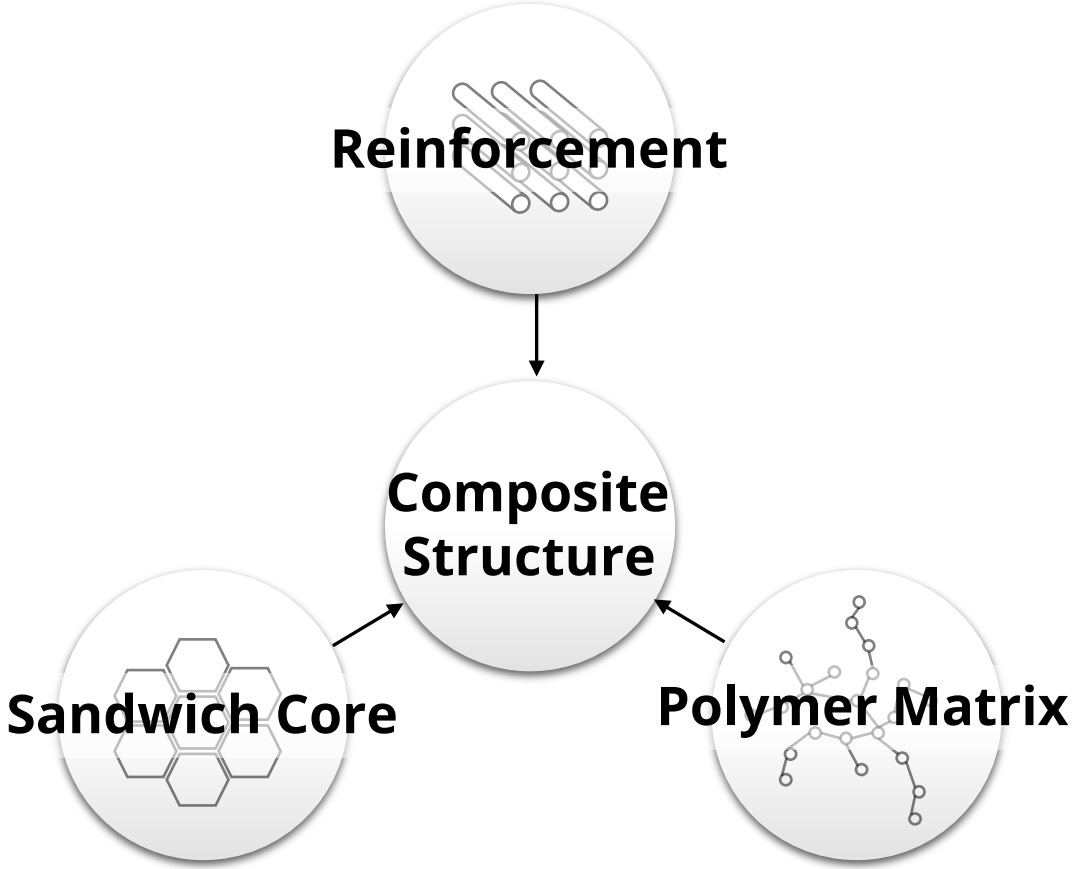


https://www.imperial.ac.uk/structural-integrity-health-monitoring/research/structural-integrity-and-failure-analysis/virtual-testing-/

STEPS TOWARD CIRCULARITY - OPTIMIZE



COMPOSITE WASTE TYPES



COMPOSITE WASTE TYPES

Pre-Manufacturing

- Prepreg Edge Trim
- Prepreg Rejects (Quality)
- Consolidated Plate Offcuts
- Resin Batch End
- Etc.

Manufacturing

- Textile Offcuts
- Part Trim/Rejects
- Expired Thermosets
- Core Offcuts
- Etc.

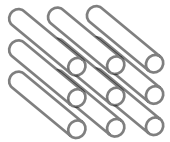
End-of-Life

- Wind Turbine Blades
- Decomissioned Aircraft
- Boats
- Composite Tooling
- Etc.

OPTIMIZE – RESOURCE NEW LIFE

Recycling

- Fibre Reclamation



- Mechanical Transformation

- Other

Re-Manufacturing

- Liquid Composite Moulding
- Wet-Layup
- Compression/Injection Moulding
- (Semi)Direct Reuse
- Filler/Feedstock
- Reforming (Thermoplastic)

OPTIMIZE – RESOURCE NEW LIFE

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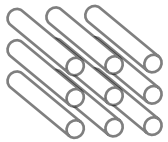

- Mechanical Transformation

- Other

Recycled Product

?

Re-Manufacturing

- Liquid Composite Moulding
- Wet-Layup
- Compression/Injection Moulding
- (Semi)Direct Reuse
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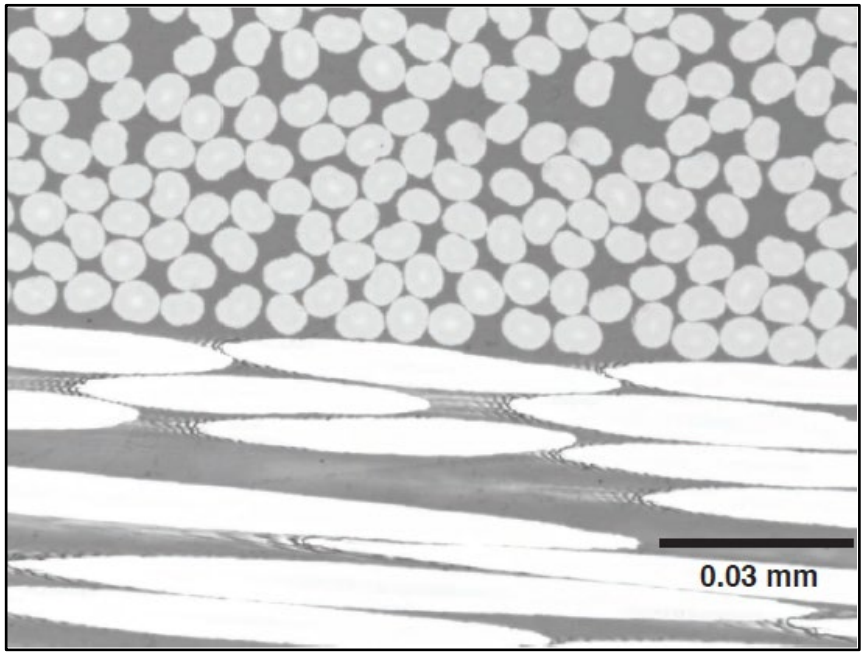
RECYCLING – FIBRE RECLAMATION

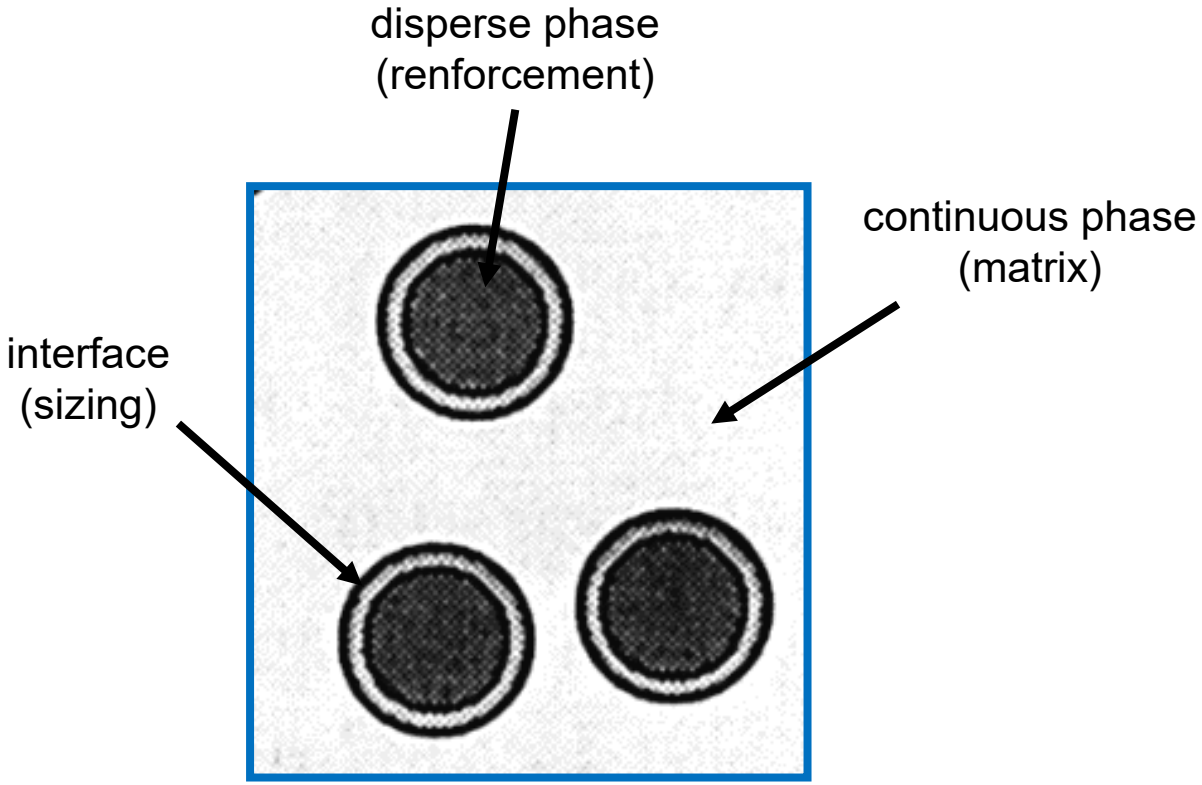
Objective

Separate reinforcing fibre from polymer matrix, while maintaining fibre length

Challenge

Separate the unseperable!

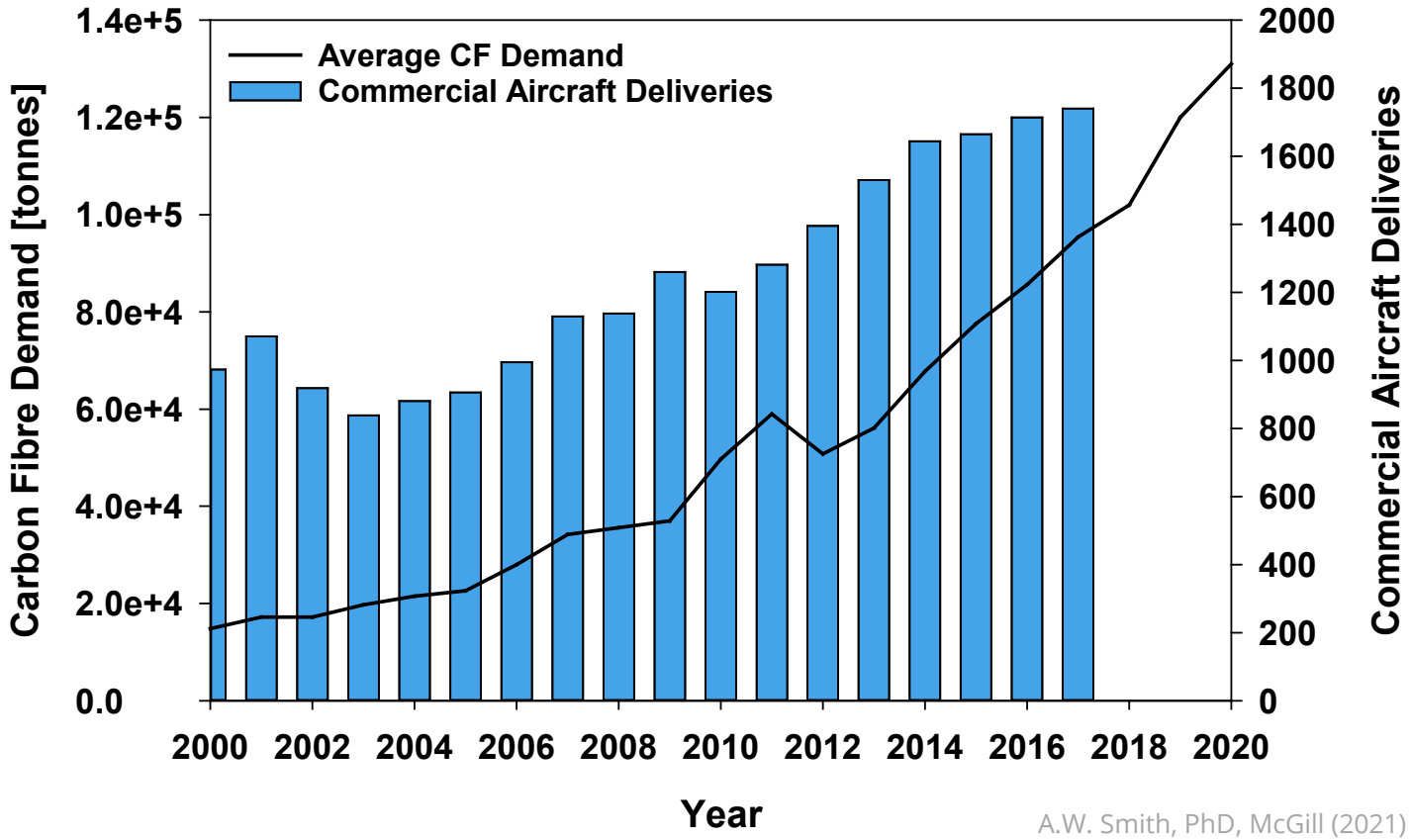




N. Krumenacker PhD, McGill (2018)
MEC786 Course Notes, ÉTS (2023)

RECYCLING – FIBRE RECLAMATION

- Carbon fibre (807 GJ/tonne) vs. Steel (13.63 GJ/tonne)
- 62,000 tonnes of carbon fibre present in composite waste estimated in 2020



A.W. Smith, PhD, McGill (2021)
Liddell et al. (2017), Jamison et al. (2015), Witik et al. (2013)

RECYCLING – FIBRE RECLAMATION

- 53,094 TJ – enough to power **50,000** Tesla Model 3s for **100 years** (EV Database).

https://evmagz.com/massive-shipment-of-tesla-model-y-and-model-3-evs-headed-for-north-america/

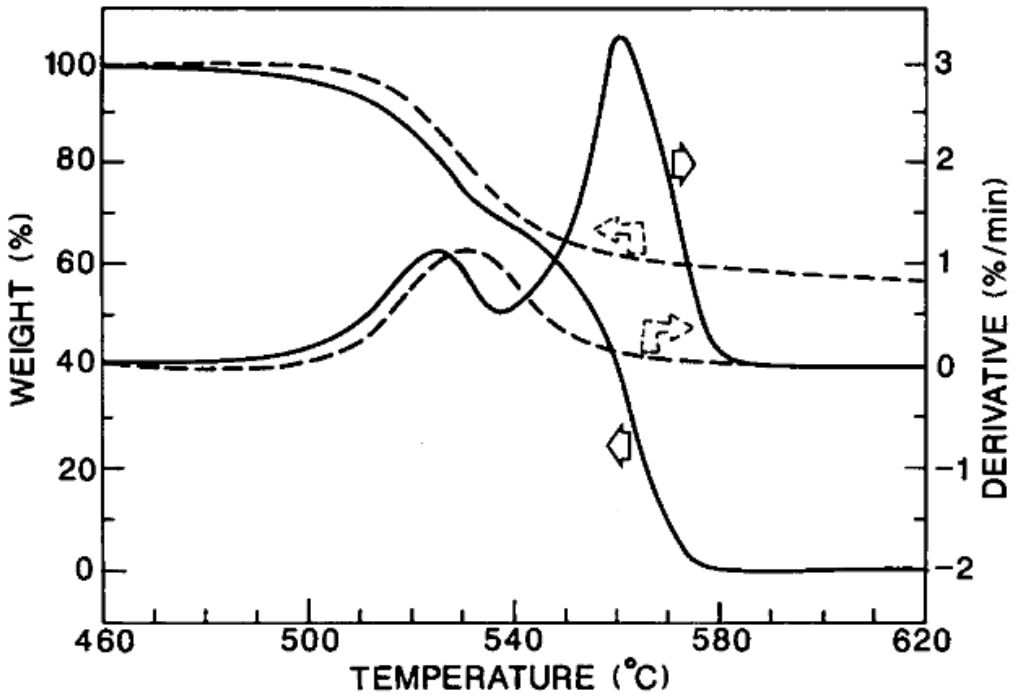
FIBRE RECLAMATION – PYROLYSIS

- Thermal decomposition of polymer matrix in the absence of oxygen (250 – 800 °C)
- Products include, solid, liquid and gaseous phases

https://www.youtube.com/watch?v=-ZQzfwdHf1I&ab_channel=VDIZentrumRessourceneffizienz

3:30 to 5:45

Fig. 1. Thermogravimetric curves for PEEK heated in air (—) and nitrogen (---) at 1°C/min.



Cooney and Wiles 1989

FIBRE RECLAMATION – PYROLYSIS

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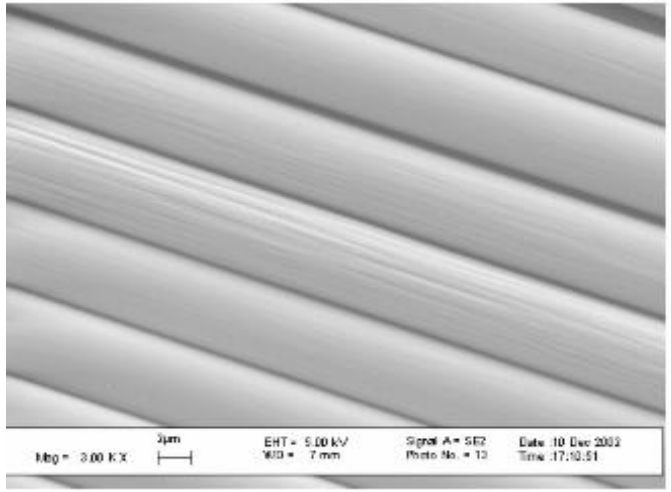
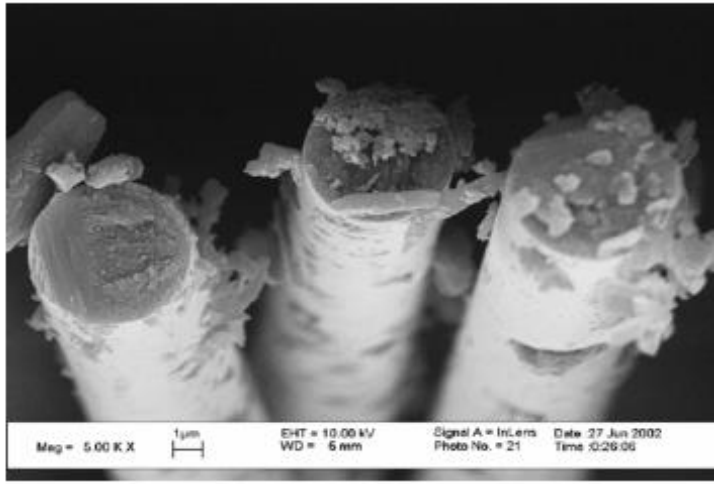
Clean fibre



Char residue from polymer decomposition

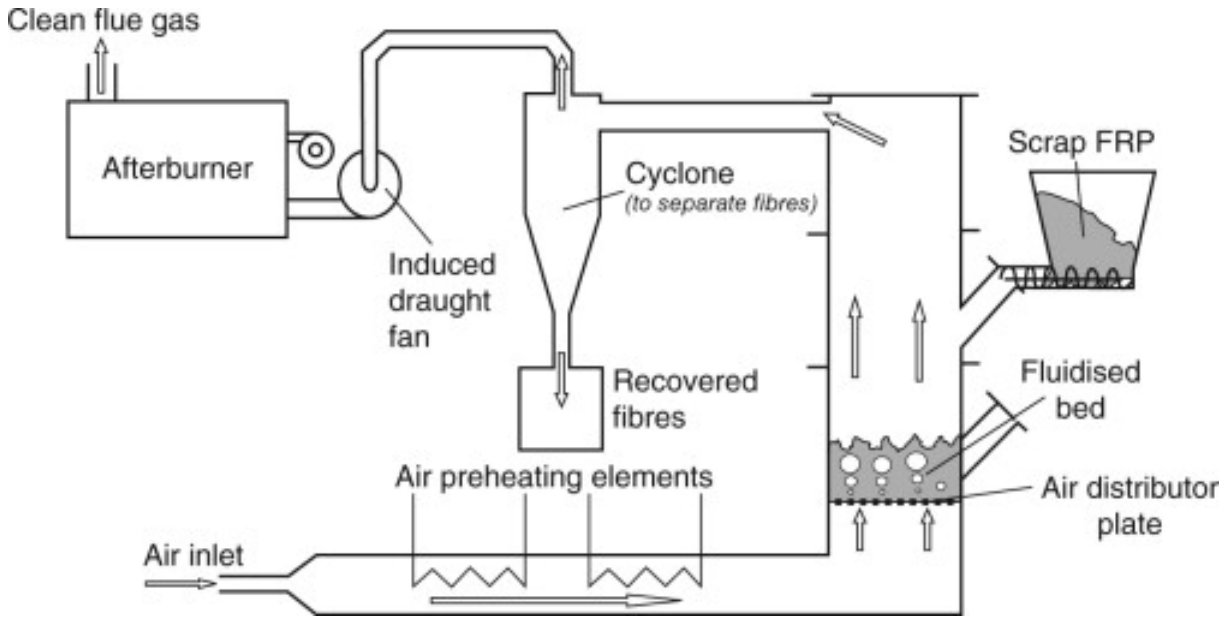


B. J. Jody, J. A. Pomykala Jr, E. J. Daniels, F. L. Paulauskas, and M. G. Abdallah, "A process to recover carbon fibers from polymer matrix composite scrap," in SAMPE, Long Beach, CA, USA, May 16 - 20 2004, pp. 41-53.
https://www.compositesworld.com/articles/composites-recycling-is-gaining-traction

FIBRE RECLAMATION – FLUIDISED BED

- Thermal-oxidative decomposition of polymer matrix (450 – 550 °C)
- Material sorting by elutriation and subsequent cyclone
- Developed at the University of Nottingham for continuous operation

Fig. 7. Fibre product recovered from SMC feed.



S.J. Pickering et al. A fluidised-bed process for the recovery of glass fibres from scrap thermoset composites. https://doi.org/10.1016/S0266-3538(99)00154-2.

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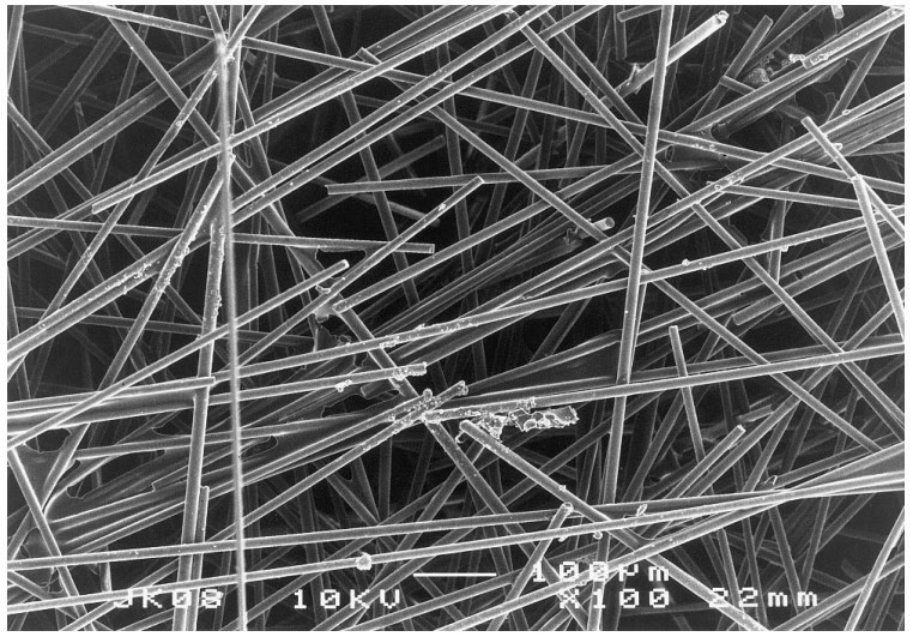


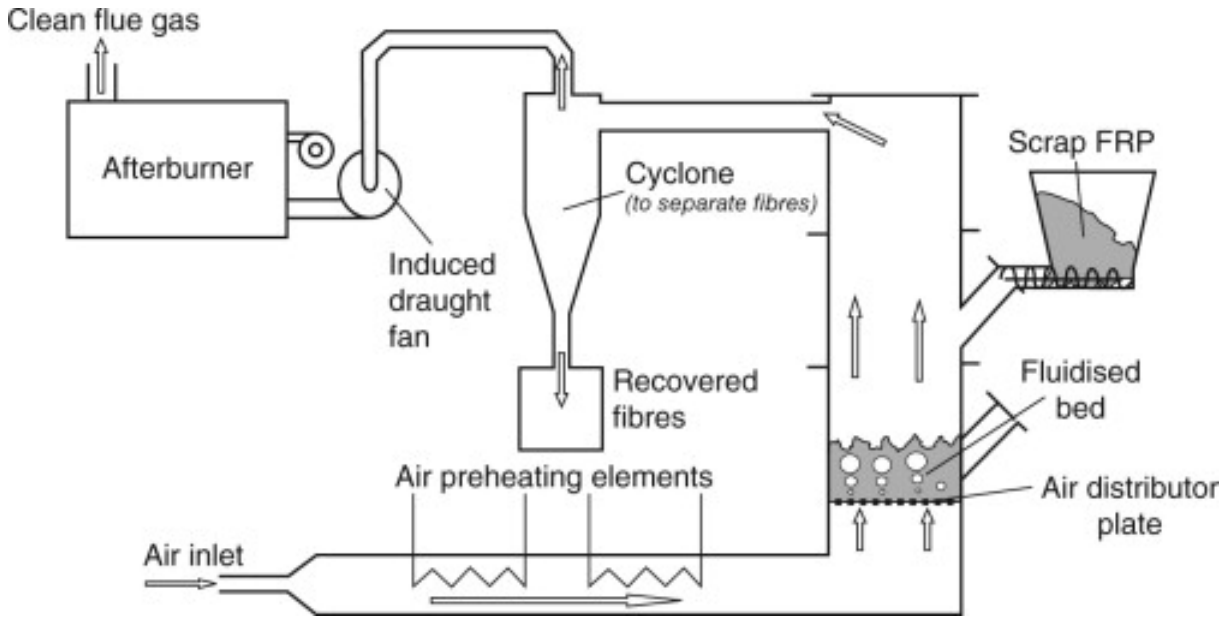


Fig. 13. SEM of veil containing reclaimed fibres.

S.J. Pickering et al. A fluidised-bed process for the recovery of glass fibres from scrap thermoset composites. https://doi.org/10.1016/S0266-3538(99)00154-2.

FIBRE RECLAMATION – SOLVOLYSIS

- Chemical decomposition of polymer matrix into low molecular weight components
- Solvents used include benzylalcohol, formic acid, acetone, water, etc.
- Reaction rate accelerated by agitation and temp-pressure manipulation

From: High performance recycled CFRP composites based on reused carbon fabrics through sustainable mild solvolysis route

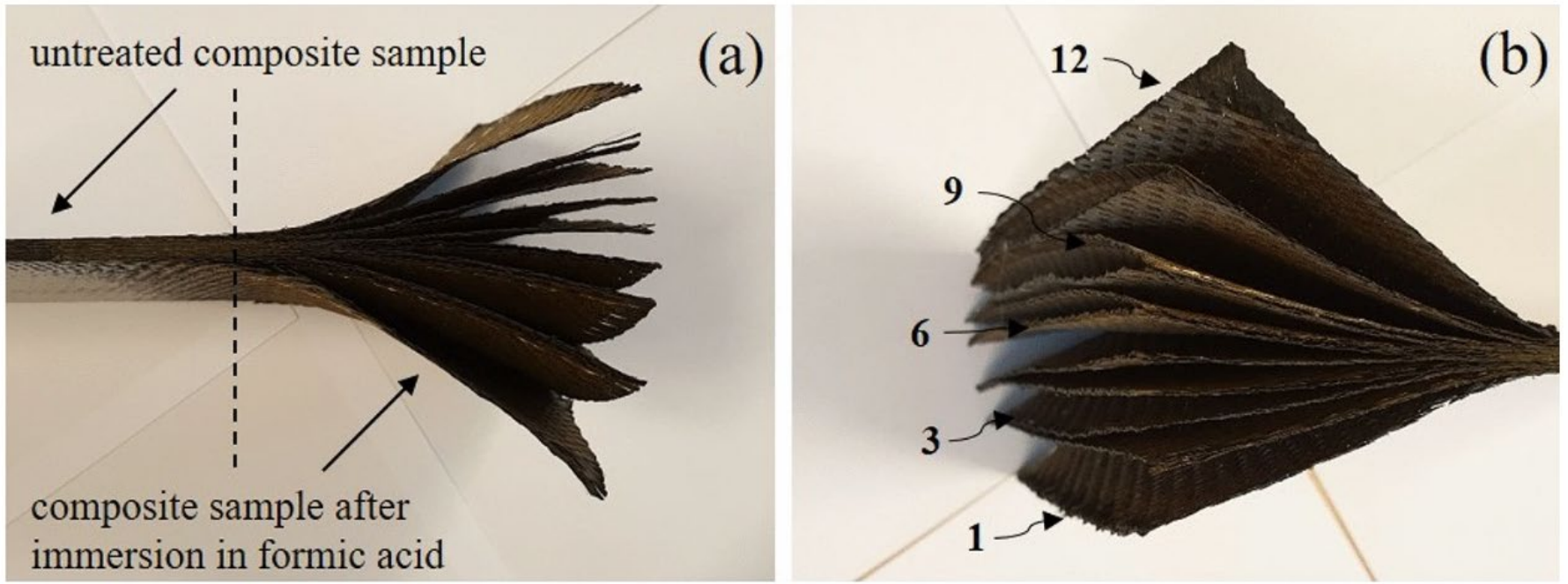
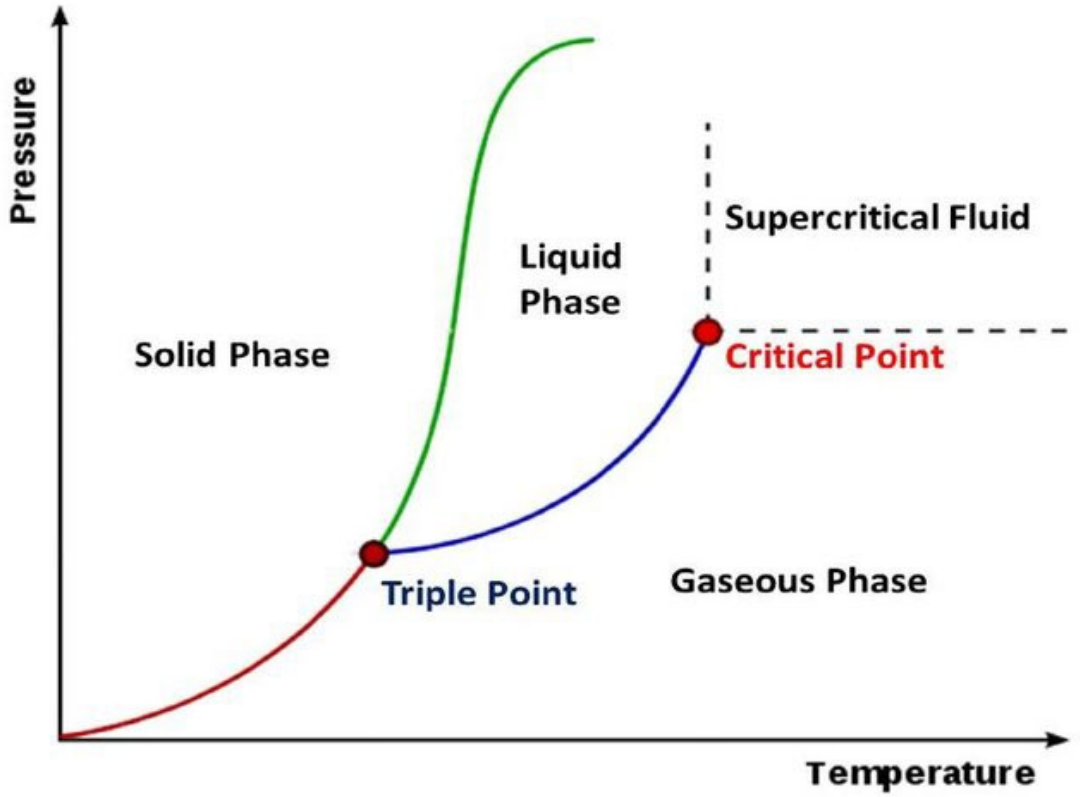


Illustration of separated CF layers after partial immersion in formic acid.

FIBRE RECLAMATION – SOLVOLYSIS

- Environmental concerns
- Scaling challenges
- Supercritical water possible « green » alternative
  - 22.1 – 35 MPa
  - 400 – 650 °C



Eckert et al., (1996)
Morin et al. (2013). https://hal.science/hal-00695025

MECHANICAL TRANSFORMATION

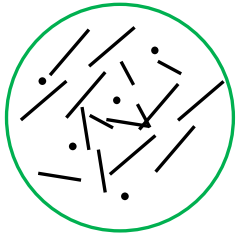
Objective

Reduce solid waste size via mechanical action to produce uniform recyclate(s)

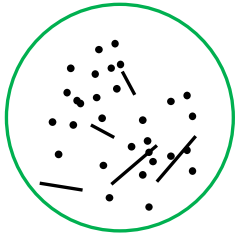
Challenges

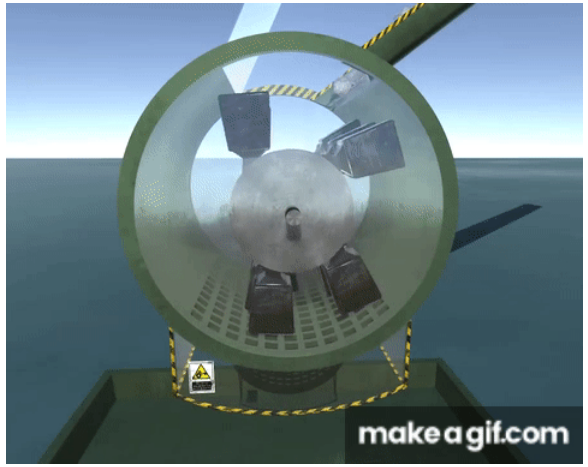
Health & safety, fibre damage , sorting & dismantling

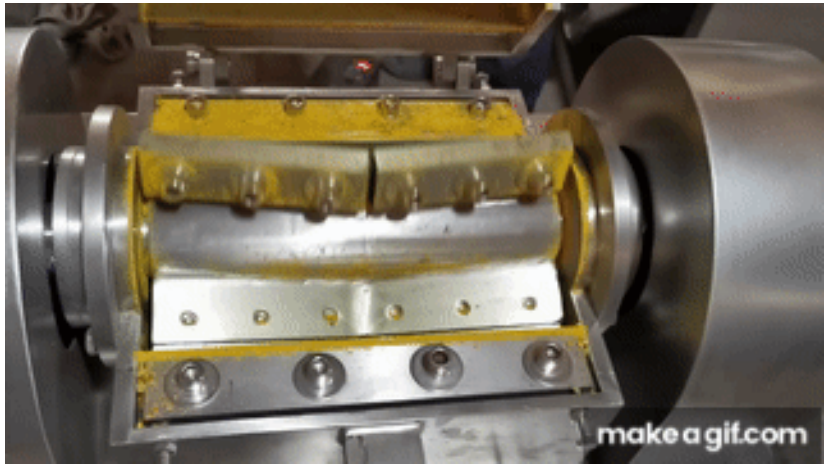
Fibre Rich



Resin Rich

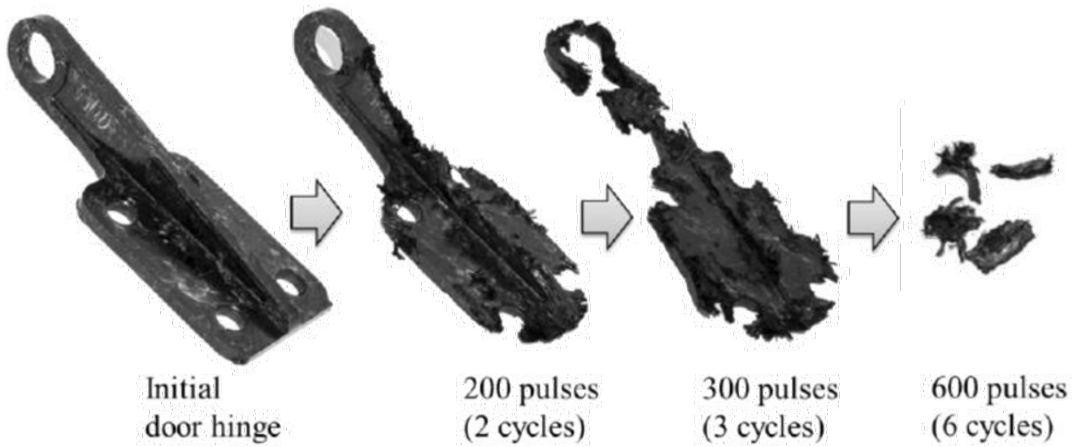


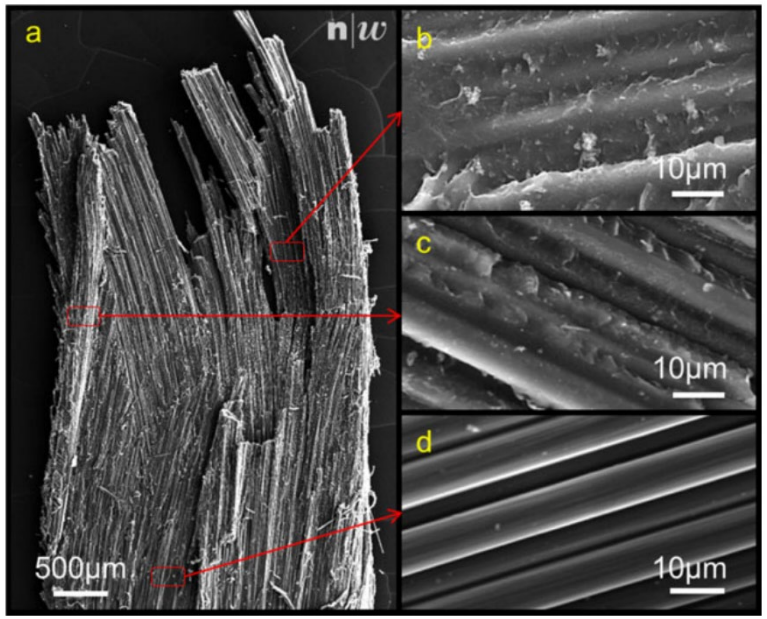




OTHER – ELECTRODYNAMIC FRAGMENTATION

- Rapid breakdown of the fibre-matrix interface due to high voltage micro pulses



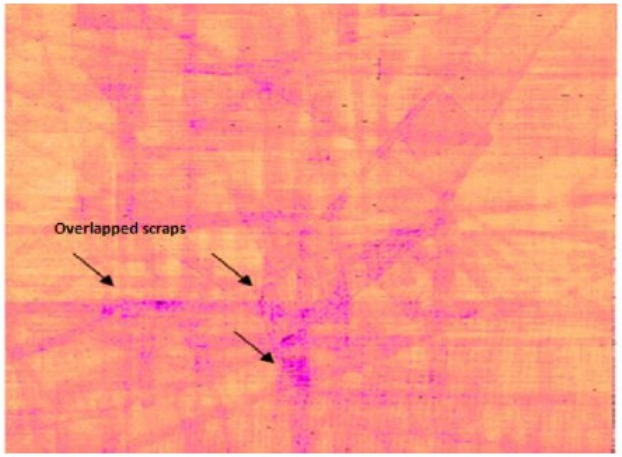


Cycle progression 50 – 200 kV (5 µs)

M. Roux et al. "Processing and Recycling of a Thermoplastic Composite Fibre/PEEK Aerospace Part," (2014)
N. Eguémann, "Etude du comportement mécanique de matériaux composites polymère PEEK/renfort fibre de carbone à architecture discontinue en plis," Université de Franche-Comté (2013)

OTHER – (RE)CERTIFICATION

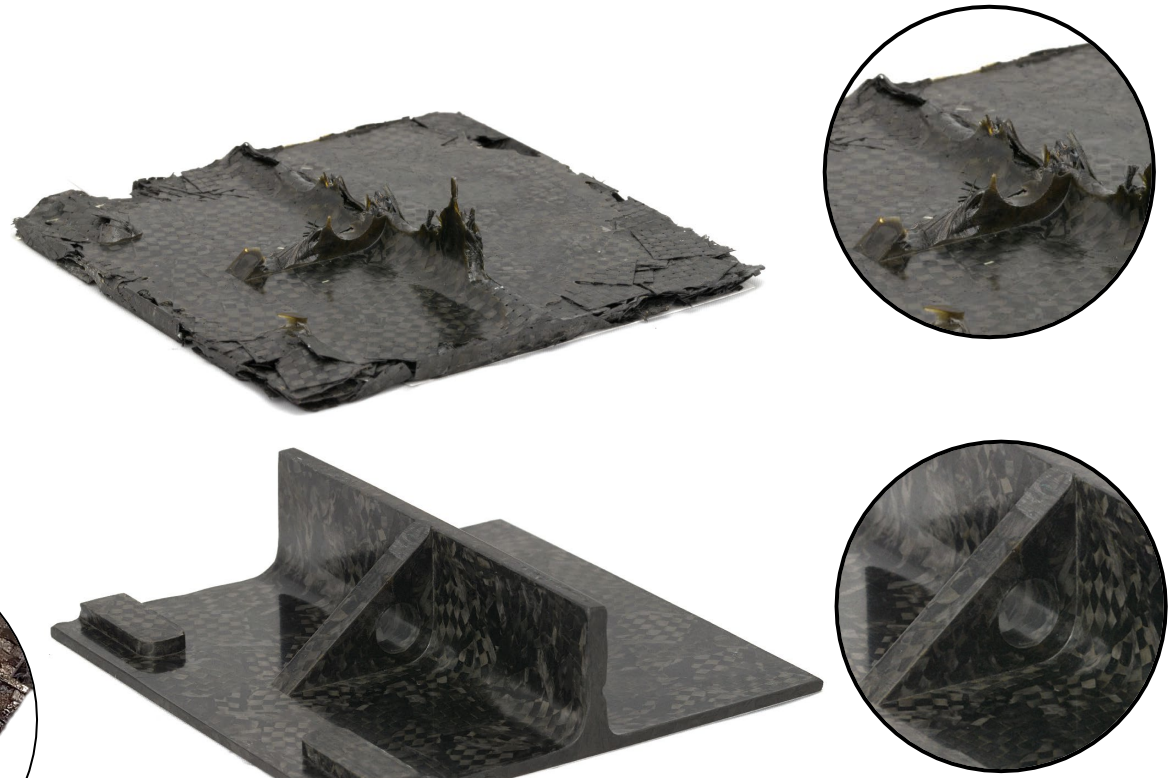
- Re-life procedure for expired thermoset prepreg rolls
- Prepreg patching and ultrasonic scanning

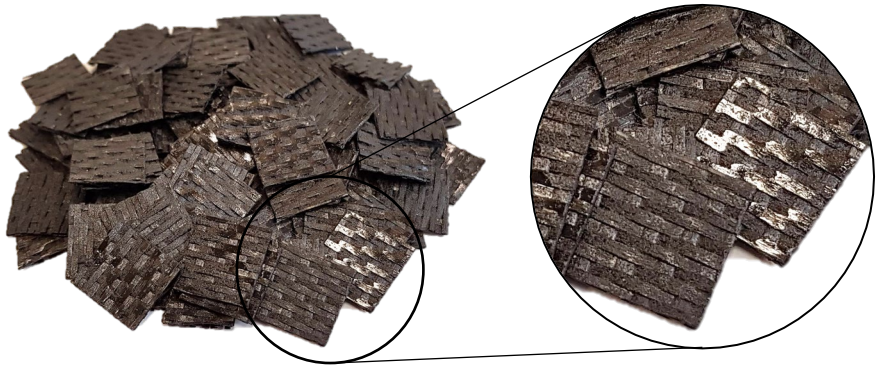


C. S. R. de Souza et al., 2019. doi: 10.1021/acssuschemeng.8b04852.
http://www.himawari-frp.com/products_step.shtml

OTHER – CHEMORHEOLOGY MANIPULATION

- Changing the curing and flow behaviour of prepreg offcuts
- Create a strand-based compression moulding compound

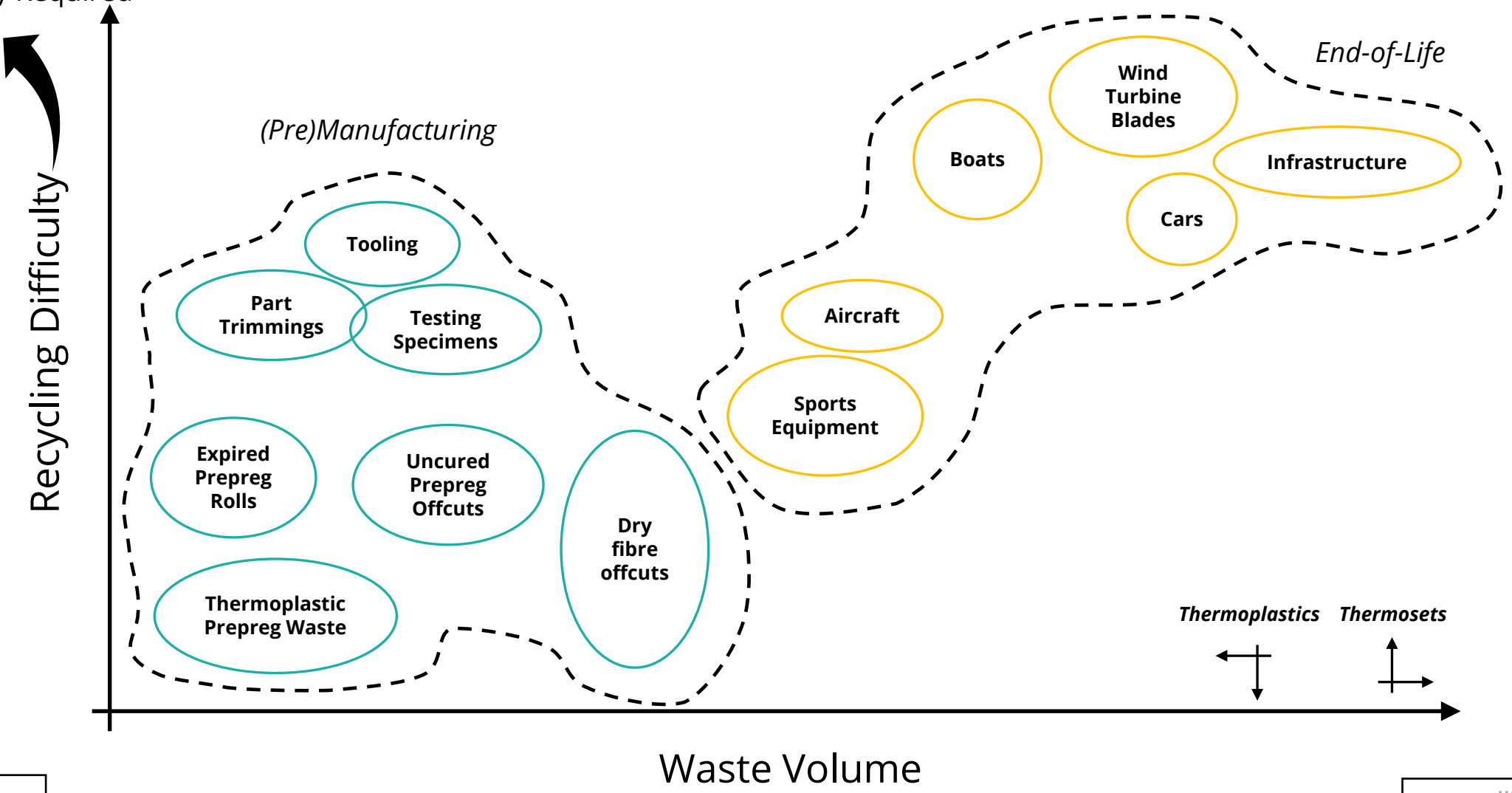




A.W. Smith, PhD, McGill (2021)

- Technical Difficulty
- Contamination
- Energy Required
- Cost

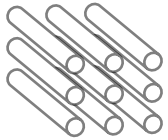
RECYLING-WASTE MAP



OPTIMIZE – RESOURCE NEW LIFE

Recycling

- Fibre Reclamation



- Mechanical Transformation

- Other

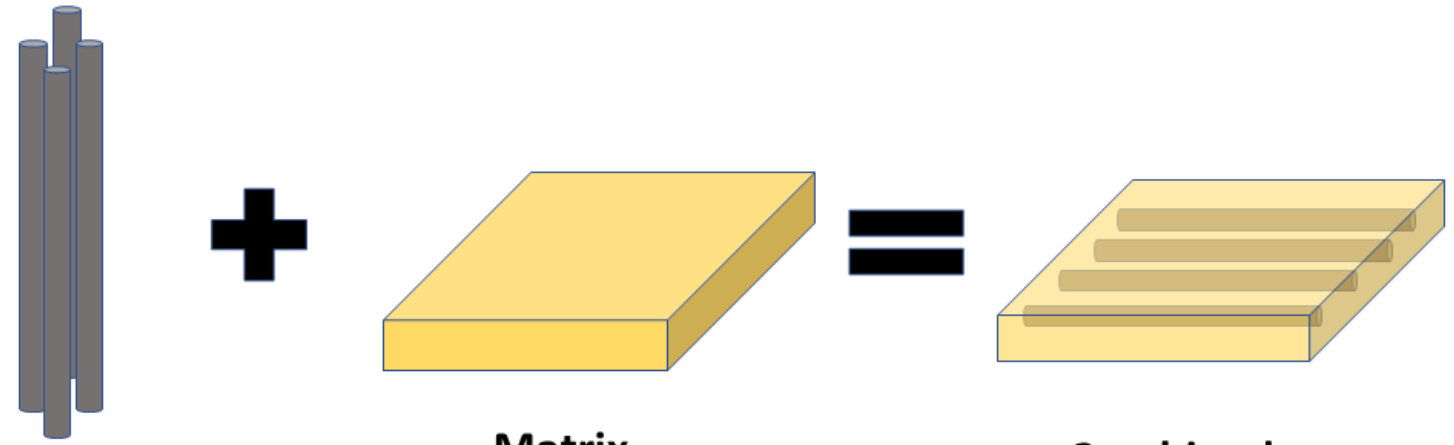
Recycled Product

?

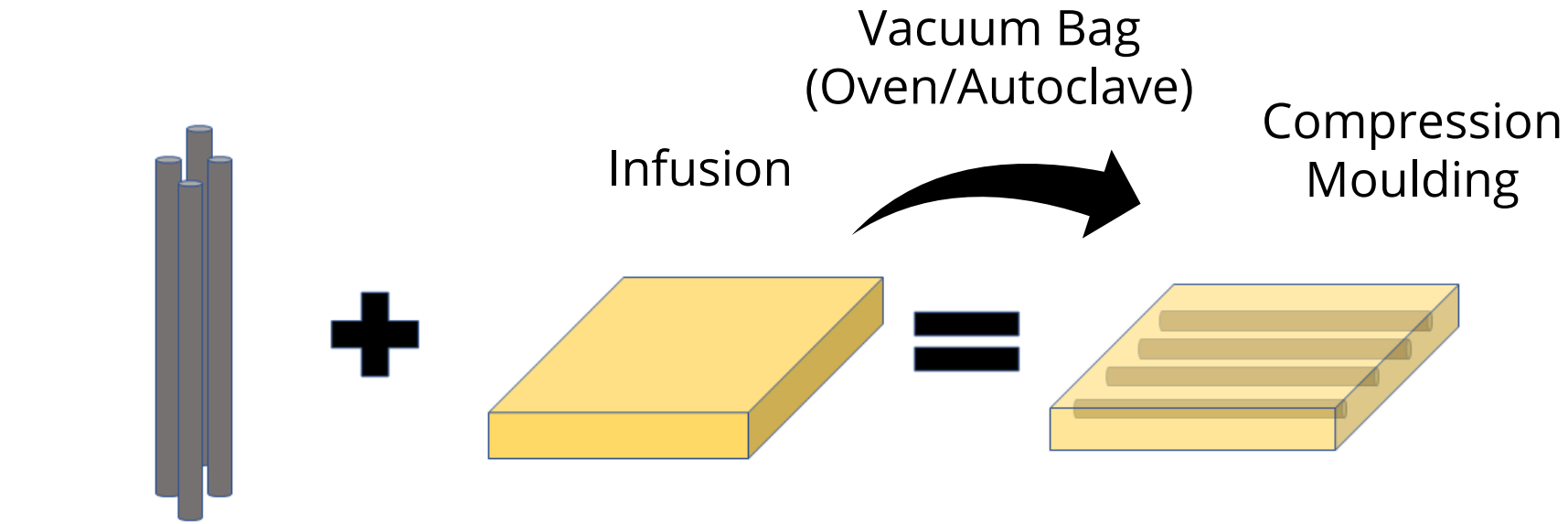
Re-Manufacturing

- Liquid Composite Moulding
- Wet-Layup
- Compression/Injection Moulding
- (Semi)Direct Reuse
- Filler/Feedstock
- Reforming (Thermoplastic)

RE-MANUFACTURING – FIBRE RECLAMATION



RE-MANUFACTURING – FIBRE RECLAMATION



RE-MANUFACTURING – MECHANICAL TRANSFORMATION

REFORMING (THERMOPLASTICS)

LEARNING OUTCOMES

- ✓Expanded view of sustainability and the impact of early decision making « RETHINK »
- ✓Different waste types and characteristics
- ✓Summary knowledge of composites recycling and re-manufacturing techniques
- ✓Appreciation for the complexity of sustainability – one size does not fit all

ADDITIONAL REFERENCES

- Slide 6
  - https://www.coriolis-composites.com/fiber-placement-machines/coriolis-c1/
  - https://www.motortrend.com/news/eurp-1103-mclaren-30-years-carbon-john-watson/
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Thank you for joining us!

Keep an eye out for upcoming AIM events:

Introduction to Tooling for Composite Materials Processing
Hosted by Dr. Casey Keulen
September 27, 2023
https://compositeskn.org/KPC/A340

And don't forget to visit the KPC for more information:

https://compositeskn.org/KPC

Today's Webinar will be posted at:
https://compositeskn.org/KPC/A339