PROGRESS ON IMPLEMENTING SUSTAINABLE PRACTICES IN COMPOSITES

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YOUR HOSTS

Casey Keulen, Ph.D, P.Eng.
Associate Professor of Teaching, University of British Columbia
Director of Knowledge in Practice Centre, Composites Knowledge Network

- Ph.D. and M.A.Sc. in Composite Materials Engineering
- Over 20 years experience in industry and academia working on polymer matrix composites in aerospace, automotive, marine, energy, recreation and others
- Experience working with over 150 companies from SME to major international corporations
- Expertise in liquid composite moulding and thermal management

YOUR HOSTS

Marcus Ivey, MSc, P.Eng.
Project Engineer
Exergy Solutions, Inc

- Materials Engineer with over 10 years industry experience in applied R&D, product development, and manufacturing
- Expertise in:
    - Metal matrix composite coatings
    - Wear resistant materials
    - Fiber reinforced polymer composites
    - Additive and advanced manufacturing
    - Materials characterization and testing

YOUR HOSTS

Christy Michalak, B.Sc.Eng.
Director of Manufacturing Development at NGen

- Leads national initiatives to accelerate technology adoption and support the growth of Canada's advanced manufacturing ecosystem
- Board member for CKN, where she contributes strategic insight and supports the advancement of our mission

NGen
Next Generation Manufacturing Canada

NGen is the industry-led, non-profit organization leading Canada's Global Innovation Cluster for Advanced Manufacturing. One of five national networks supported by Canada's ambitious Global Innovation Clusters Initiative.

SLIDE CONTRIBUTORS

- Thidas Loku
  - UBC Materials Engineering Undergraduate
- Atif Hussain, PhD
  - CKN Research Engineer

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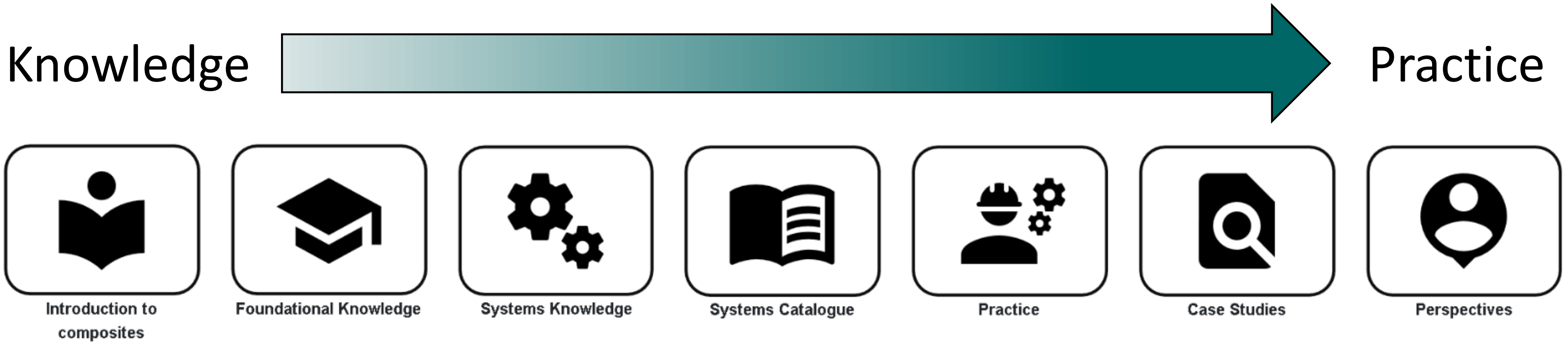
KNOWLEDGE IN PRACTICE CENTRE (KPC)

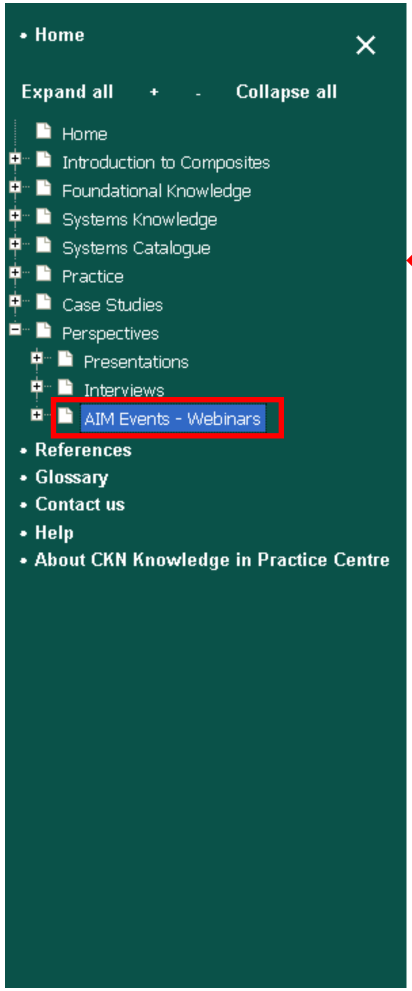
- A freely available online resource for composite materials engineering:

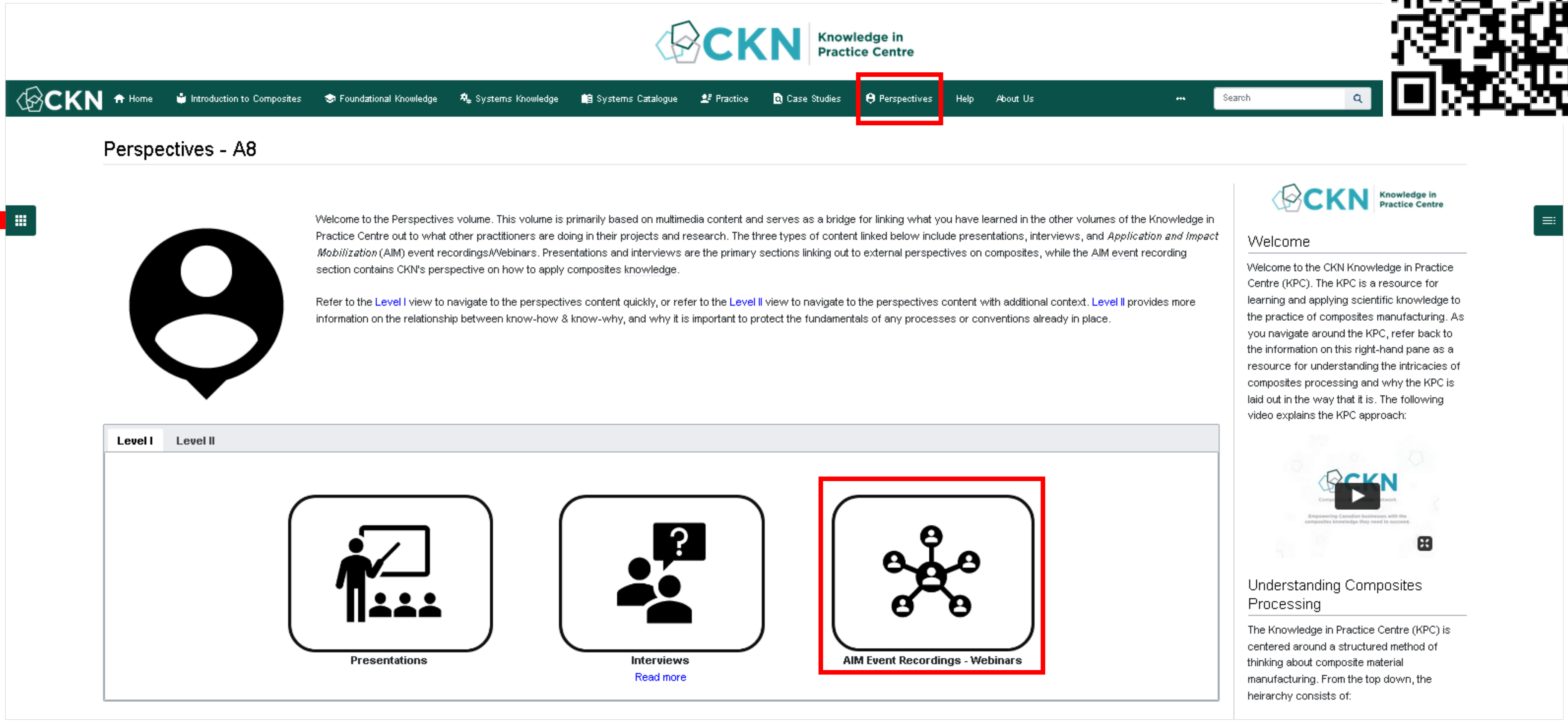
compositeskn.org/KPC

- 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/A414

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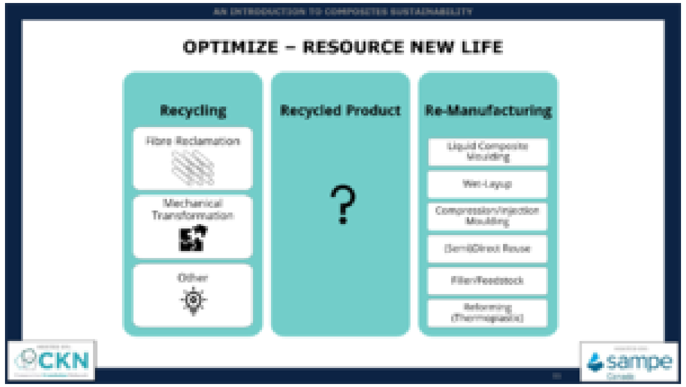
TODAY’S TOPIC:

PROGRESS ON IMPLEMENTING SUSTAINABLE PRACTICES IN COMPOSITES

PAST EVENTS ON SUSTAINABILTY

An Introduction to Composites Sustainability – A339

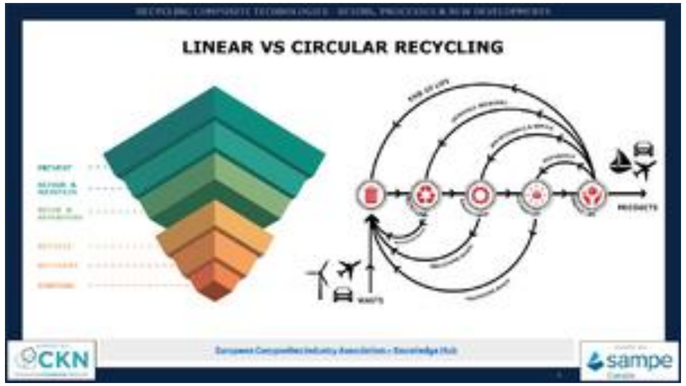
Presented by:
Dr. Adam W. Smith, CPI
Postdoctoral Researcher École de technologie supérieure, Montreal



https://compositeskn.org/KPC/A339

Recycling Composite Technologies - A380

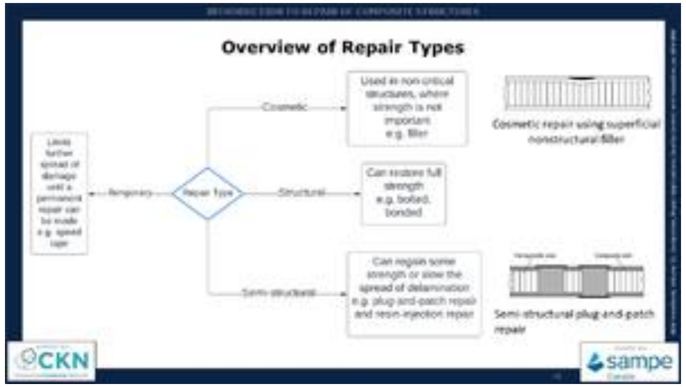
Presented by:
Nick Bigeau
CTO/Founder at
Resolve Composites



https://compositeskn.org/KPC/A380

Introduction to Repair of Composite Structures – A365

Presented by:
Dr. Casey Keulen
CKN



https://compositeskn.org/KPC/A365

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WHAT IS SUSTAINABILITY

"The global system, in which the needs of the present are met without compromising the ability of future generations to meet their own needs" – ISO

[1] https://www.unb.ca/initiatives/sustainability/about-us/index.html

IN PRACTICE

$4.5 trillion in economic value can be unlocked by 2030 through waste reduction

-The World Economic Forum 2025 [1]

[2]

Waste

Lost Material
Lost Energy
Lost Space

[3]

Efficiency

[4]

[5]

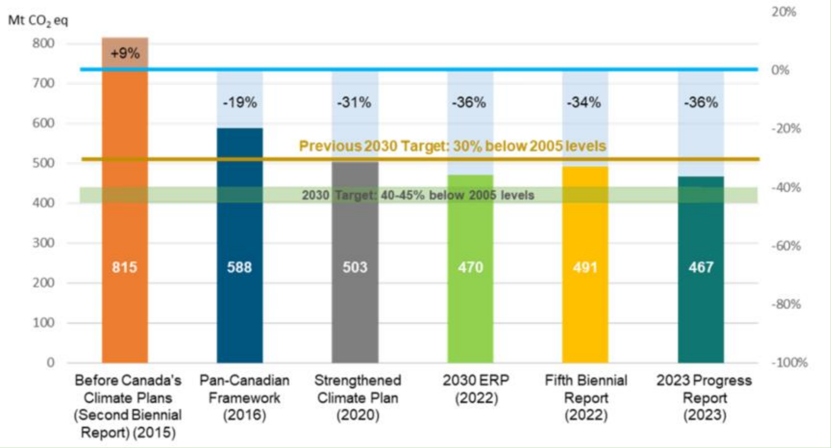
Resourceful
Compact
Pollution conscious

[1] https://www.weforum.org/stories/2022/06/what-is-the-circular-economy/
[2] https://en.wikipedia.org/wiki/Aircraft_graveyard. Top left image
[3] https://cen.acs.org/environment/recycling/companies-recycle-wind-turbine-blades/100/i27. Bottom left image
[4] https://www.compositesworld.com/news/anmet-installs-first-recycled-wind-turbine-blade-based-pedestrian-bridge. Top right image
[5] https://www.thisiscolossal.com/2021/11/wind-turbine-bike-shelters/. Bottom right
[6] https://assets.new.siemens.com/siemens/assets/api/uuid:f654c690-4311-467f-ac74-58b40688d36a/Circularity-Whitepaper-final.pdf

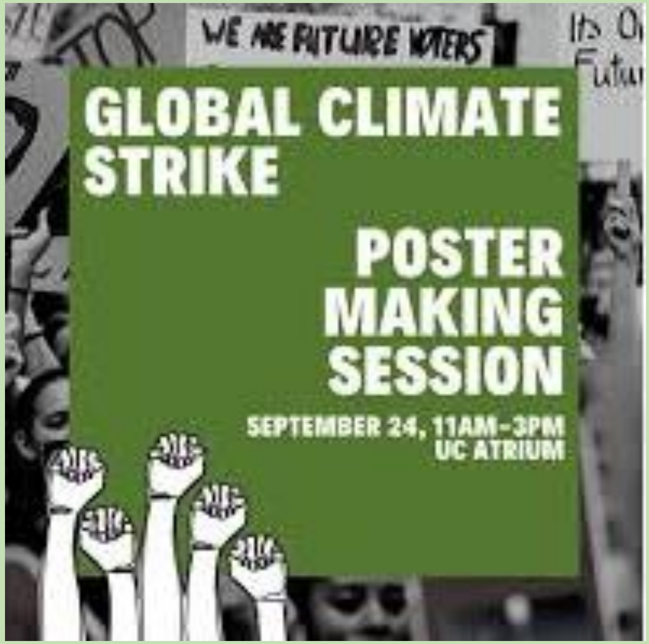
DRIVERS OF SUSTAINABILITY

[1]

Regulatory & Government Influence



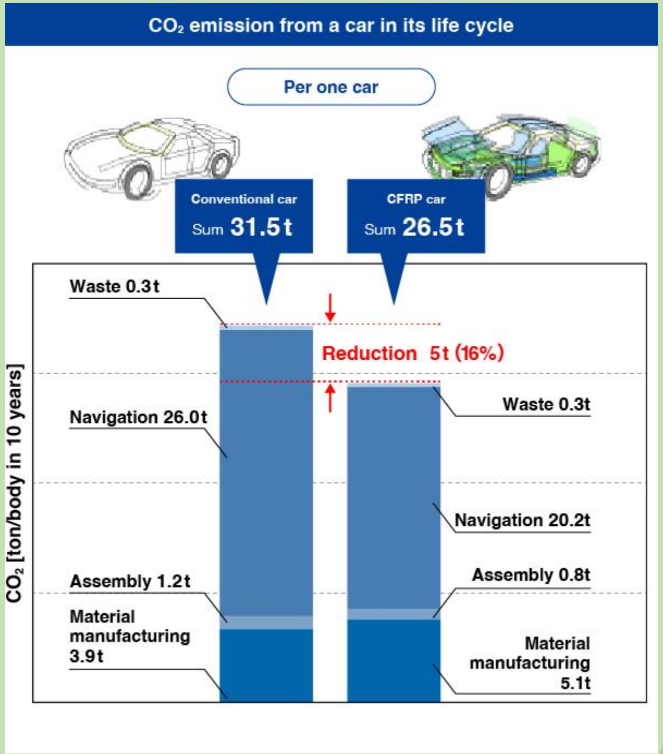
[2]



Market Demand

Economic Benefit

[3]



[1] https://publications.gc.ca/collections/collection_2022/eccc/En4-460-2022-eng.pdf
[2] https://carleton.ca/climatecommons/cu-events/poster-making-session-for-global-climate-strike/
[3] https://www.cf-composites.toray/aboutus/sustainability/lci.html

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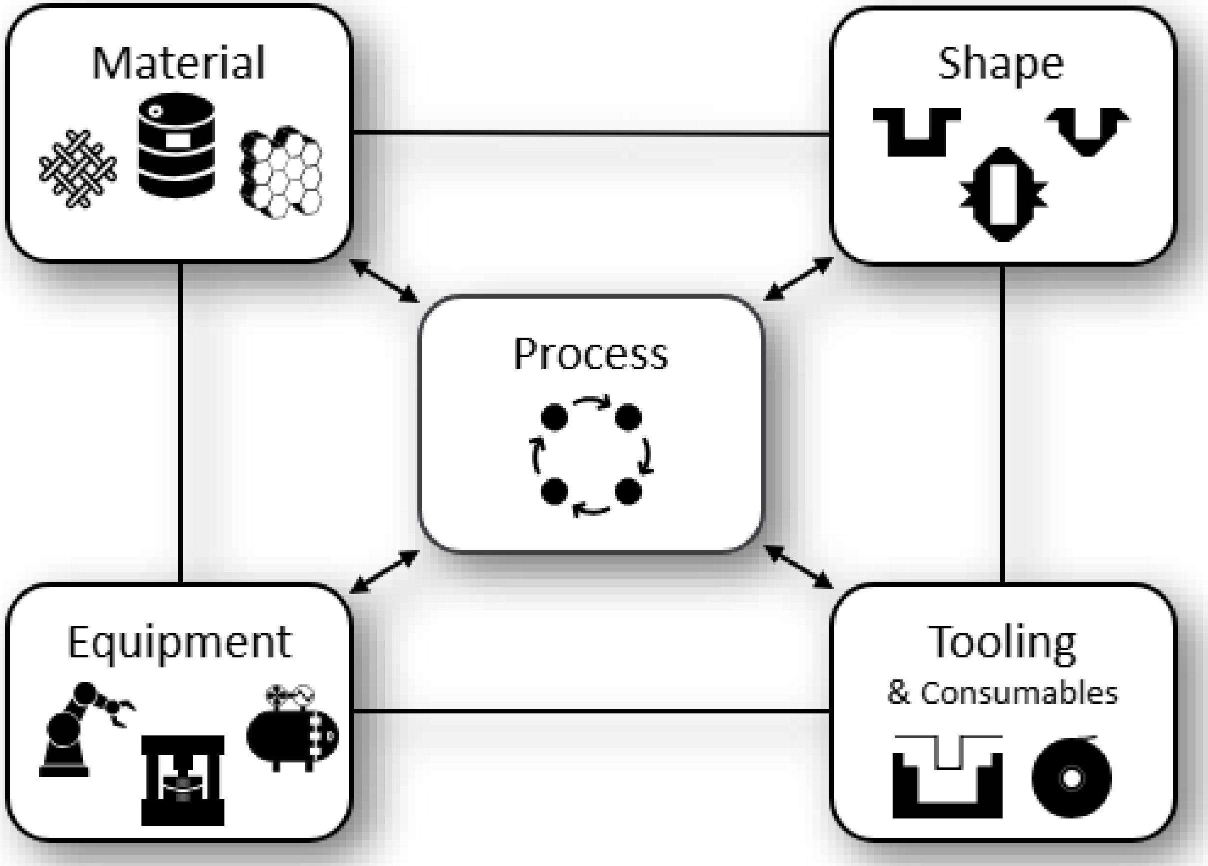
MSTEP AND DESIGN FOR SUSTAINABILITY



[1]

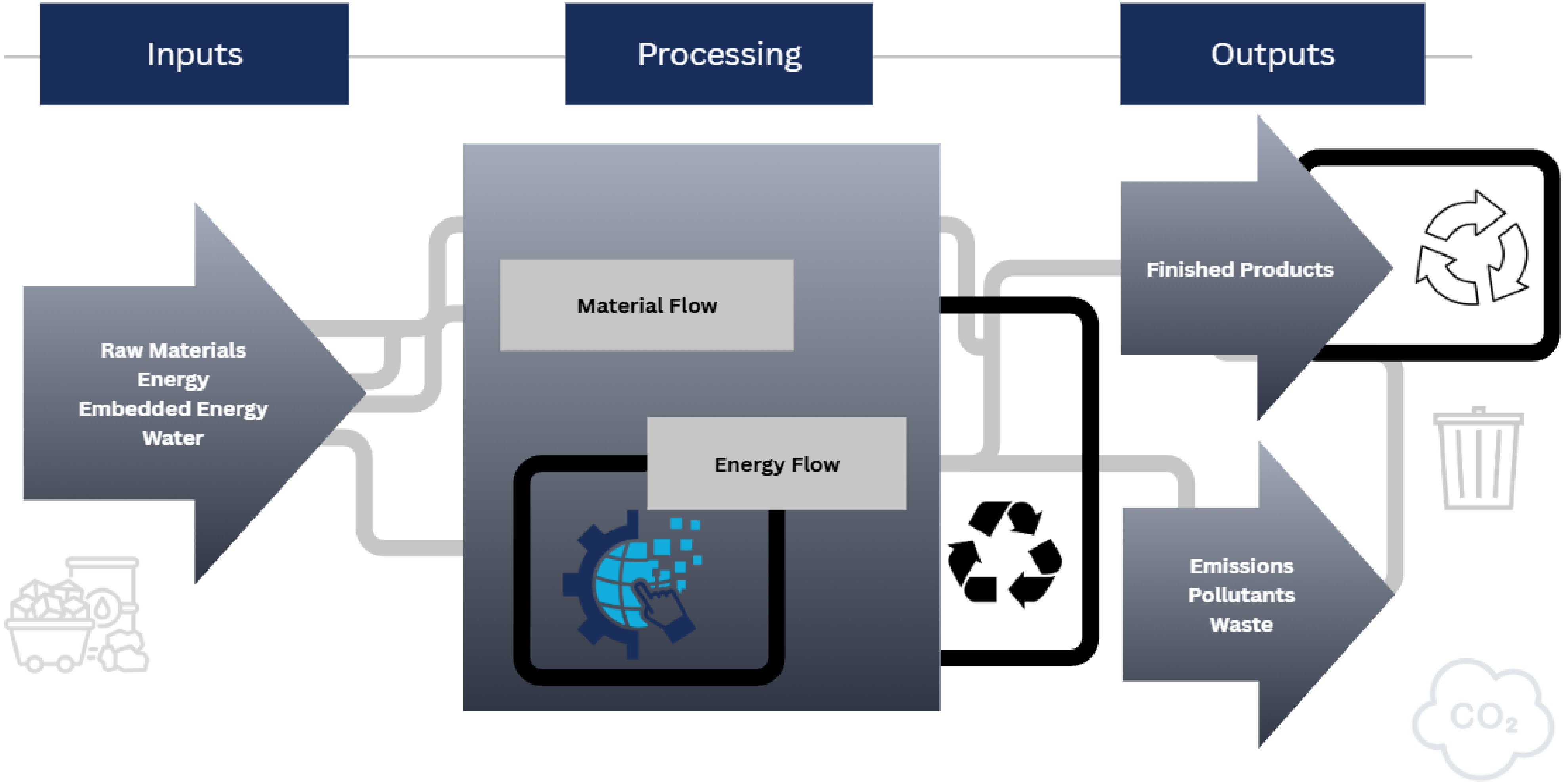
80% of a product's environmental impact is determined during the **design phase**

MSTEP supports thinking about:

- Cure cycle optimization
- Load optimization
- Material deposition and consolidation management
- Proactively defining service and maintenance requirements early in development

[1] https://assets.new.siemens.com/siemens/assets/api/uuid:f654c690-4311-467f-ac74-58b40688d36a/Circularity-Whitepaper-final.pdf

MANUFACTURING PROCESS



RESINS

Biobased polymers

- Derived from renewable biomass
- Some are biodegradable
- Should not compete with food resources

LEGO parts made from sugarcane-based PE [1]

Ineos Envirez (formerly Ashland): Polyester made partially From bio-based feedstock

CARBO4POWER recyclable wind turbine [2]

Melt and reformable vPCB [3]

Vitrimers – Dynamic bonding polymers

- Malleable with thermoset properties
- Formable, healable, weldable, chemically recyclable

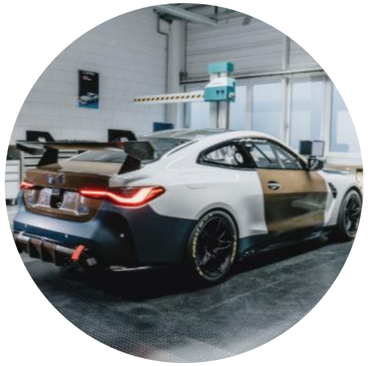
Reactive thermoplastic resins (RTPs)

- Does not produce a permanent crosslinks
- Processed like thermoset, performs like thermoplastic

Beneteau yacht mass produced with thermoplastic acrylic resin [4]

hfp
[2] https://www.freethink.com/energy/recyclable-wind-turbine-blade. Recyclable wind turbine blade from CARBO4POWER project
[3] https://vpcb.cs.washington.edu/
[4] https://www.beneteau.com/en-hk/oceanis-yacht/oceanis-yacht-60hfp

NATURAL FIBRES



Flax-based Bcomp in motorsport cars [1]

Hempcrete in University of Bradford's Business Center [2]

Jute Fibres [3]

3D printable house made from plant-based material [4]

Advantages	Disadvantages
• Low cost • Low density • Biodegradable • Reduced energy cost in manufacturing	• Hygroscopic • Poor interfacial adhesion with resins • Reduced long-term durability

Treatments/modifications

- Chemical and mechanical treatments for fibre-surface modification
- Hybridization (combining multiple types of fibres) – improves **fatigue resistance**, **impact tolerance**, **voids**

Basalt fibre [5]

[1] https://www.bmw-m.com/en/topics/magazine-article-pool/bcomp-bmw-m-motorsport-.html. BMW flax fibre panels
[2] https://buildingtalk.com/the-bright-building-a-shining-light-of-sustainability/
[3] https://jutegardens.com/blogs/news/what-is-jute
[4] https://www.3dwasp.com/en/3d-printed-house-tecla/.
[5] https://www.researchgate.net/figure/Basalt-fabric-Basalt-woven-yarn-http-basalttoday-2016-07-5691-iii-Basalt-Geo-mesh_fig2_333879449

LOW-WASTE MANUFACTURING

Conventional manufacturing processes, high waste or scrap from:

- Consumables
- Trimming/machining waste
- Manufacturing defects
- Resin/material contaminated waste

Low-waste manufacturing processes

- Automated fibre placement (AFP)
- 3D printing continuous fibres
- Reusable vacuum bags

Thousands of tonnes of consumables discarded from conventional manufacturing processes [1]

[1] https://www.plataine.com/blog/reduce-composite-material-waste/

CASE STUDY – NESTING AND KITTING – A404

Roll Length

Roll Width

Applied Dynamic Nesting
11.76 m of material
(Lowest Material Waste)

Photo Courtesy of JETCAM

Material Waste	Kitting Time
↓ Low	↑ High

Standard Progressive Nesting
12.21 m of material
(+3.8%)

Photo Courtesy of JETCAM

Material Waste	Kitting Time
Moderate	Moderate

Fully Progressive Nesting
12.45 m of material
(+5.7%)

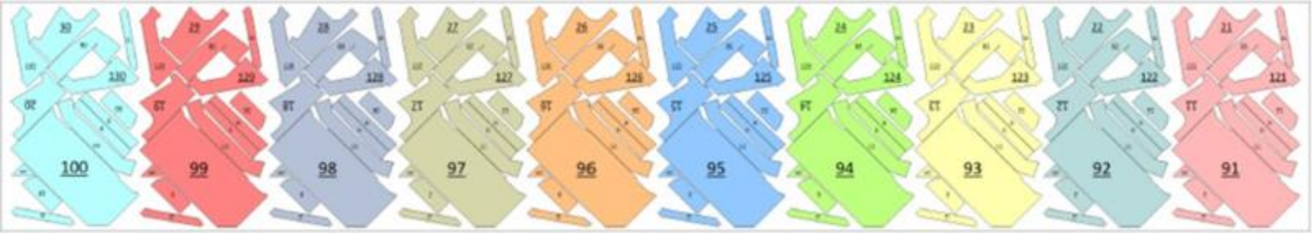
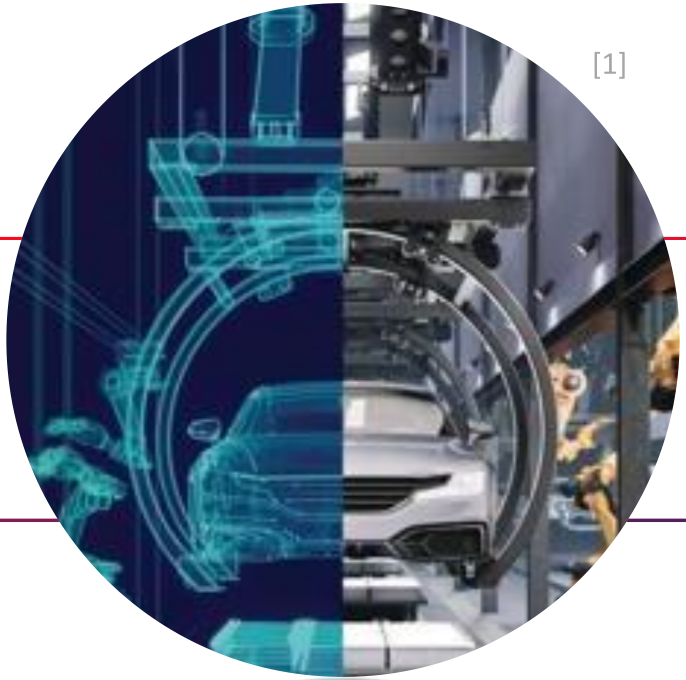


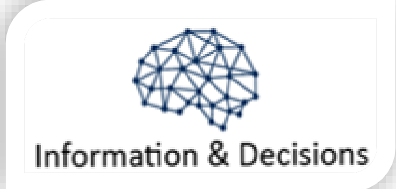
Photo Courtesy of JETCAM

Material Waste	Kitting Time
↑ High	↓ Low

DIGITIZATION AND SMART MANUFACTURING



[1]

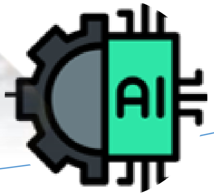


Faster data collection/organization
Real-time resource management
Optimizing process parameters

Predictive maintenance
Real-time simulation
Generation of synthetic data

Internet of Things (IoT)

Machine Learning (ML)



Artificial Intelligence (AI)

Digital Twin

[1] https://www.advancedmanufacturing.org/manufacturing-engineering/digital-twins-are-coming-of-age/article_6327b286-450b-11ef-8d28-67b829f8edd9.html

CASE STUDY – MIDDLE RIVER AEROSTRUCTURES SYSTEMS [1]

Challenges

- Processes over 3.5 million sqft. of raw material annually
- Expiration of material
- Missing inventory
- Sub-optimal usage of partial rolls

Paper Based → Smart Manufacturing

- Automated data logging (location, expiration date, length left, etc.)
- Job allocation
- Pick lists – ensures all material is used in its shelf life

Optimized Cut Plans

- Recommends the most suitable material for each work order
- Combine several jobs into a single nest

Outcomes

5-10%
overall improvement in material usage efficiency

95%
of out time excursion defects eliminated

96%
first-time-right yield

7%
cost reductions for cutting and kitting operations

[1] https://www.plataine.com/wp-content/uploads/2023/02/Plataine-and-MRAS-ST-Engineering-Case-Study.pdf

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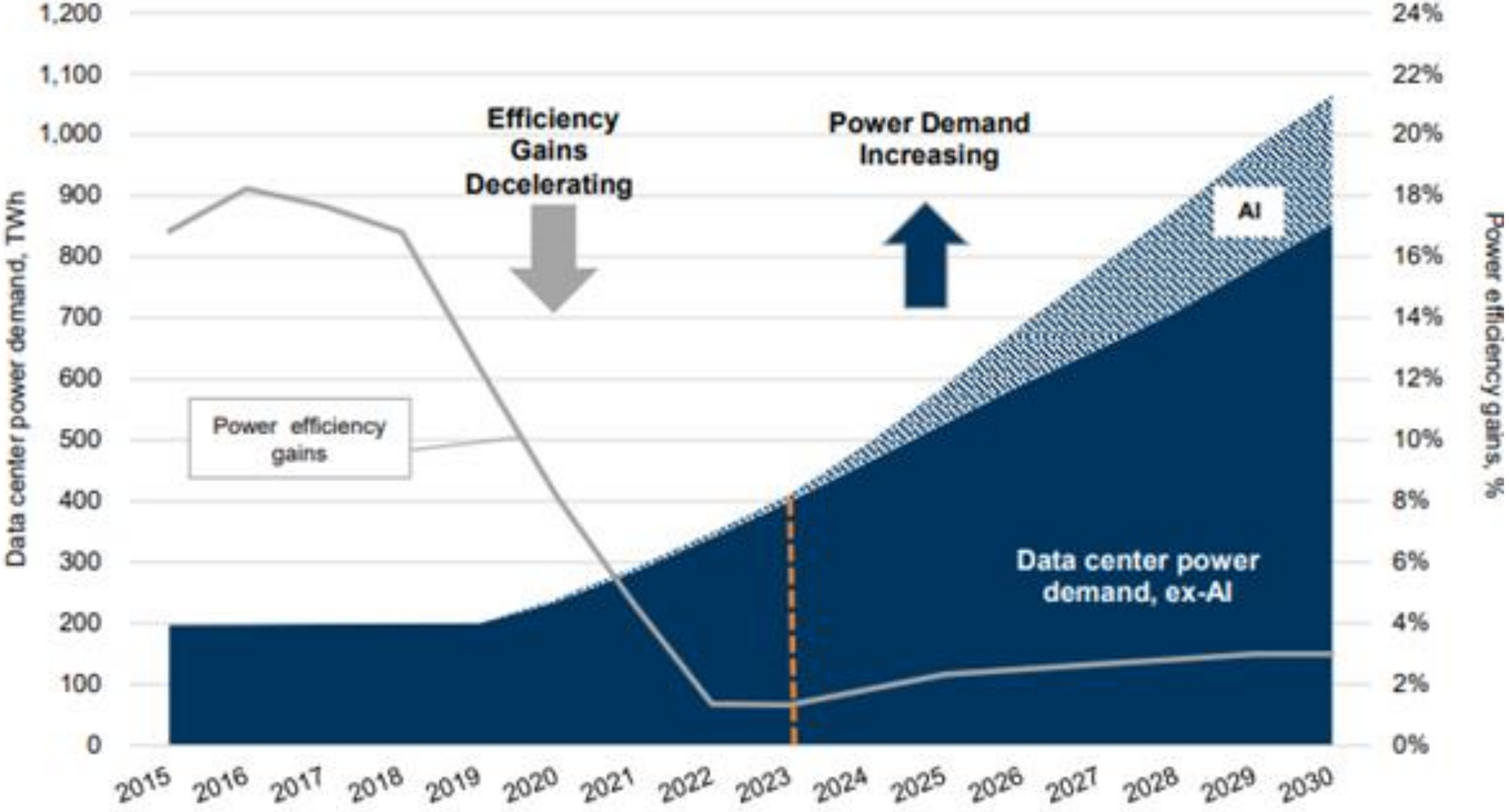
RISING DEMAND FOR DIGITIZATION

[1]



[1] https://www.velaw.com/insights/ais-power-consumption-could-put-the-grid-and-energy-regulators-to-the-test/

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LOW ENERGY MANUFACTURING - RESIN CURING

Conventional curing

High temperatures and pressures

High energy use

High heating/dwell times

UV/microwave radiation

- Hybrid thermo-UV curves

Low temperature/fast-curing resins

Out of autoclave (OoA)

- Benefits of autoclave with reduced energy consumption
- Mitigates faults transferred by human error

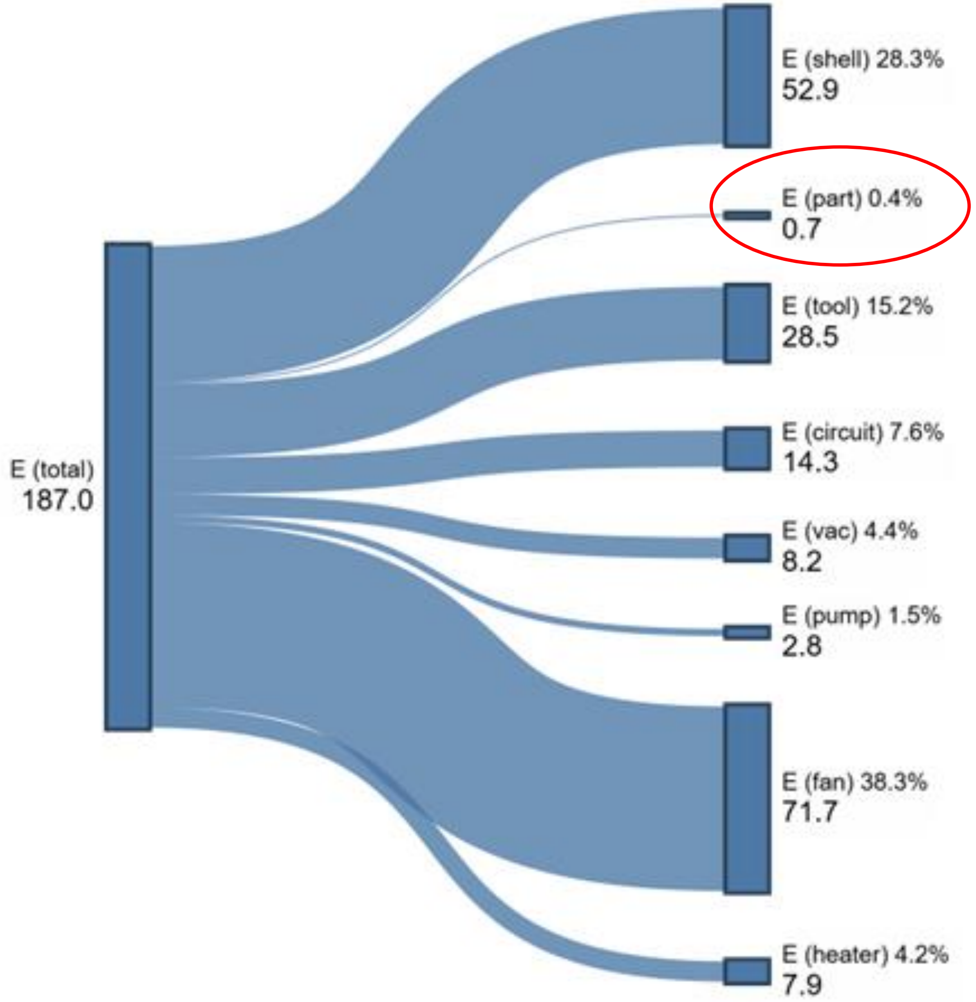
Extending out-life

- Ambient-storage prepreg
- UV cure would avoid the need for refrigeration

CASE STUDY – UBC AUTOCLAVE HEATING ENERGY USE

UBC Autoclave

[1]

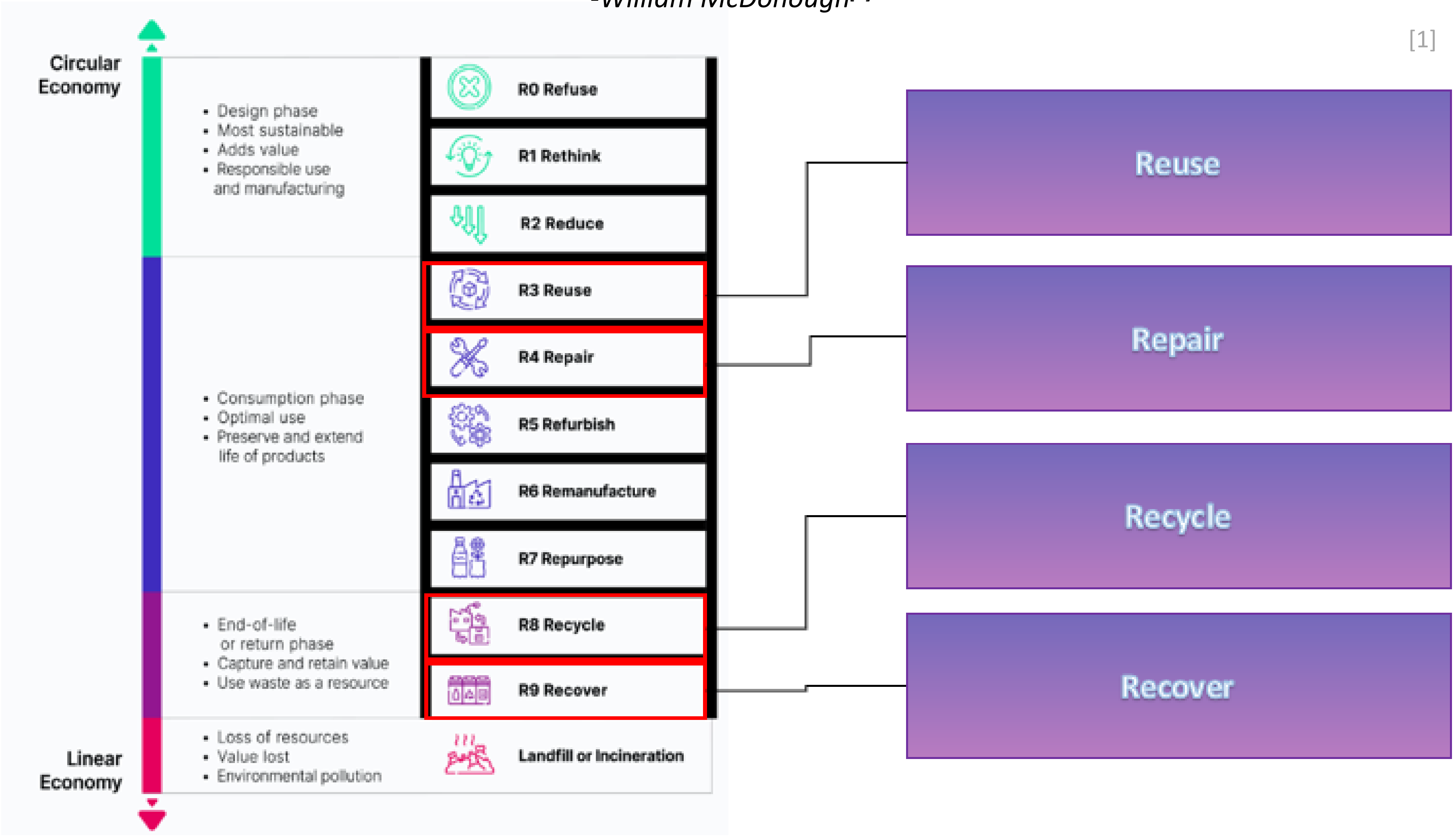


[1] Sun, Ethan. Unpublished

CIRCULAR ECONOMY FRAMEWORK

"Human beings don't have a pollution problem, they have a design problem"
-William McDonough[1]

[1]

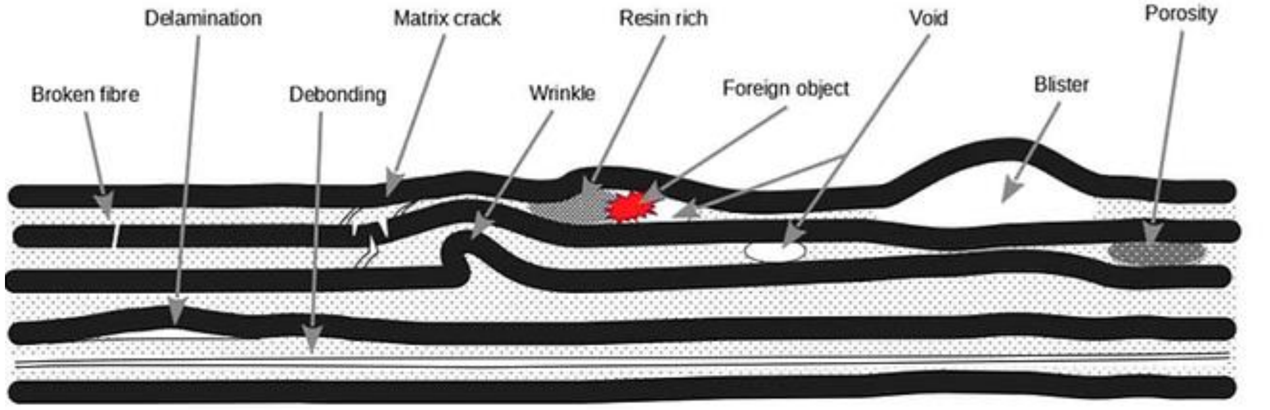


[1] McDonough, W., & Braungart, M. (2013). The upcycle: Beyond sustainability—Designing for abundance. North Point Press

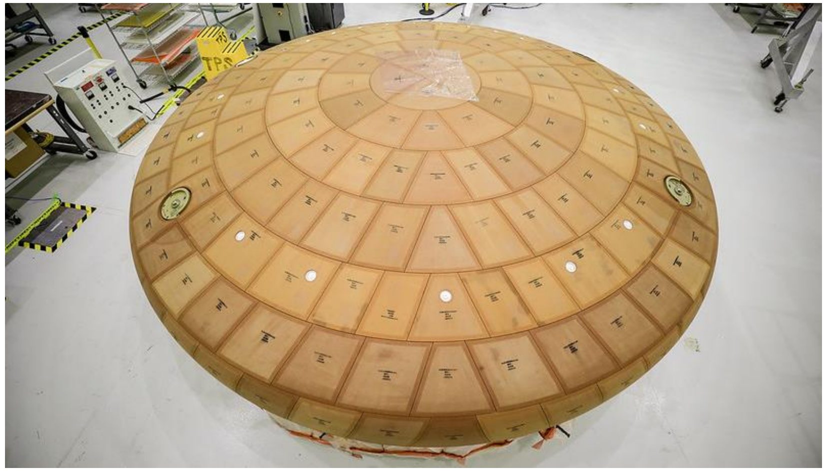
REUSE AND DURABILITY

Maintenance

- Reduction in renewal and replacement
- Predictive maintenance can be used to check for common defects



Common Defects in Composite Materials [1]



Heat Shield that Protects Spacecraft During Re-entry [2]

Factors influencing long-term wear

- Ambient conditions – temperature, humidity
- Exposure – chemical, radiation, weathering
- Loading – constant, cyclic, stress concentrations

[1] Bowkett, M., & Thanapalan, K. (2017). Comparative analysis of failure detection methods of composites materials' systems. Systems Science & Control Engineering, 5(1), 168–177. https://doi.org/10.1080/21642583.2017.1311240
[2] https://eaglepubs.erau.edu/introductiontoaerospaceflightvehicles/chapter/aerospace-materials/. Heat shield that protects spacecraft during re-entry

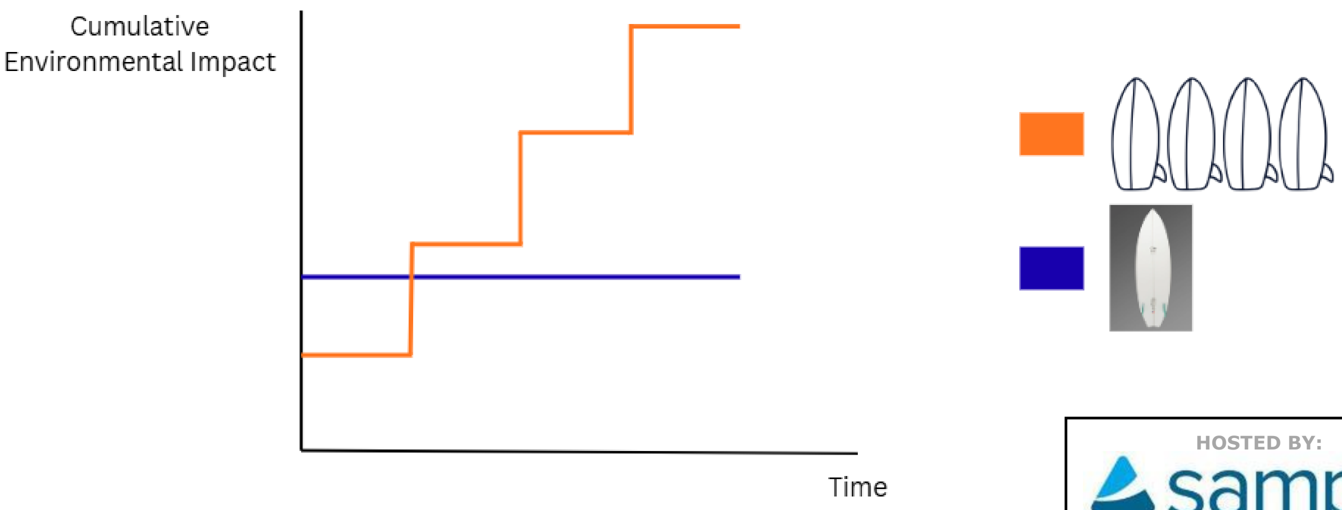
CASE STUDY – FCD SURFBOARDS

"Durability as Sustainability"

- Traditional balsa or bio-foam "lightweight" solutions suffered from durability issues
- Using extra glass fibre for strength significantly improved durability
    - Reduced the environmental impact of production of seasonal, disposable boards

FCD Surfboards [1]

Cost of Disposable Performance

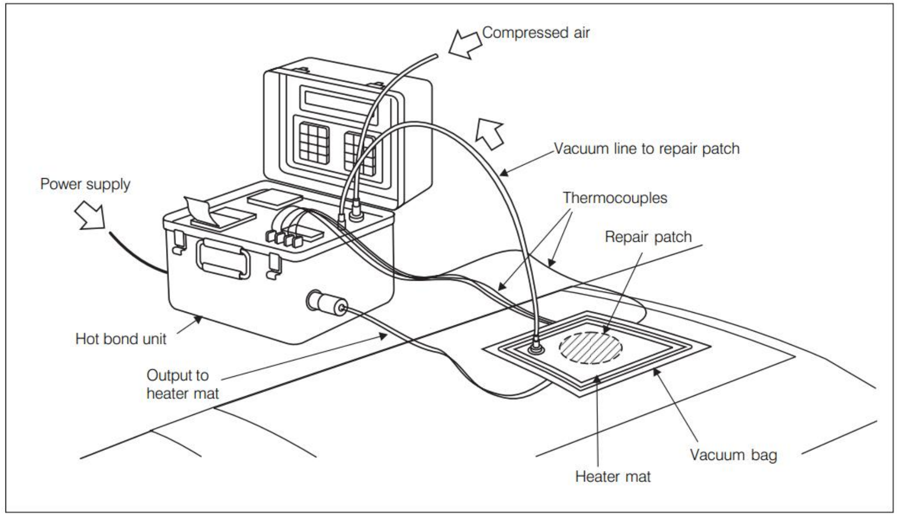


[1] https://www.fcdsurfboards.com/
[2] https://www.fcdsurfboards.com/materials

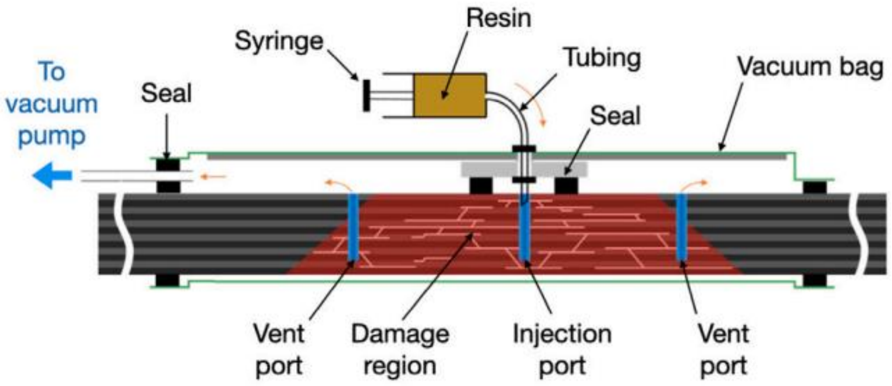
REPAIR

Design repairability into the product

- Repair strategies:
  - Patching
  - Resin injection
  - Self-healing technology
  - Retrofitting
- Enhanced by:
  - Choosing right fibre/resin system
  - Using protective treatments/additives
  - Design for maintenance – ie. Easy access points



Patching Repair [1]



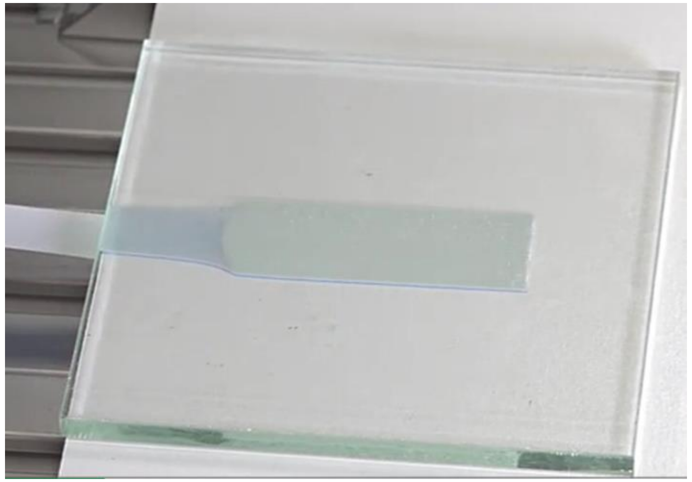
Resin Injection Repair [2]

[1] https://www.hexcel.com/wp-content/uploads/2026/01/Composite_Repair.pdf
[2]https://www.sciencedirect.com/science/article/pii/S1359835X23002841#:~:text=Resin%20injection%20repair%20(RIR)%20is,103%25%20by%20Thunga%20et%20al.

RECOVERY

- Disassembly
  - Large, complex structures are difficult due to joining/bonding
  - Machining burdens reduced by **designed disassembly**
- Designed disassembly
  - Modular structures
  - Reversible adhesives
  - Snap/interference fits
  - Removable fasteners

Nabrajoint Modular Turbine Blade [1]



Debond-on-Demand Adhesive (mechanical, thermal, or chemical actuation) [2]

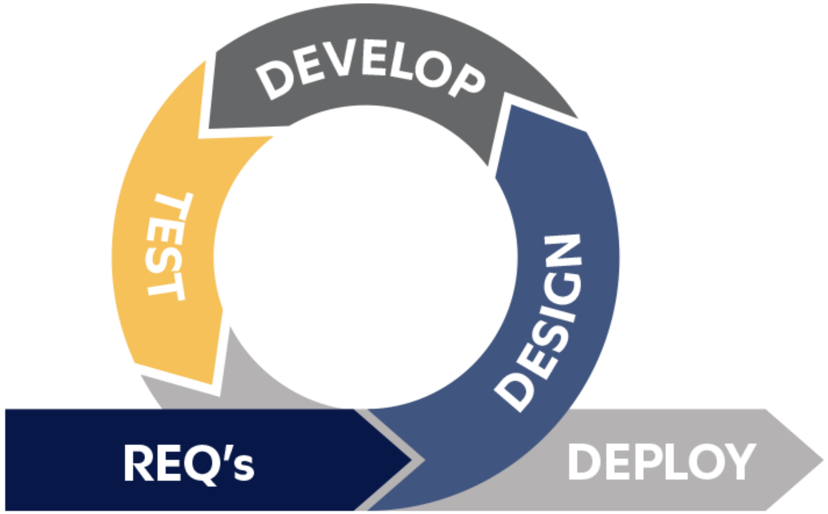
[1] https://www.youtube.com/watch?v=ZHM_-nr8QUQ
[2] https://lohmann-tapes.com/product-technologies/debonding-on-demand

EASILY IMPLIMENTED TECHNIQUES

- Material monitoring & waste tracking
  - RFID or QR codes to track origin, shelf life, remaining material, etc.
- Design with sustainability in mind instead of an afterthought
- Consider total value created rather than ROI
  - Worker safety (Avoided insurance/lost time)
  - Brand image
  - Acquiring sustainability incentives/avoiding penalties
- Keeping value in the value chain
  - Scrap downcycling
  - Reducing consumable use (eg. Reusable vacuum bags)

Reusable Vacuum Bag

exergy



Engineering

Advisory

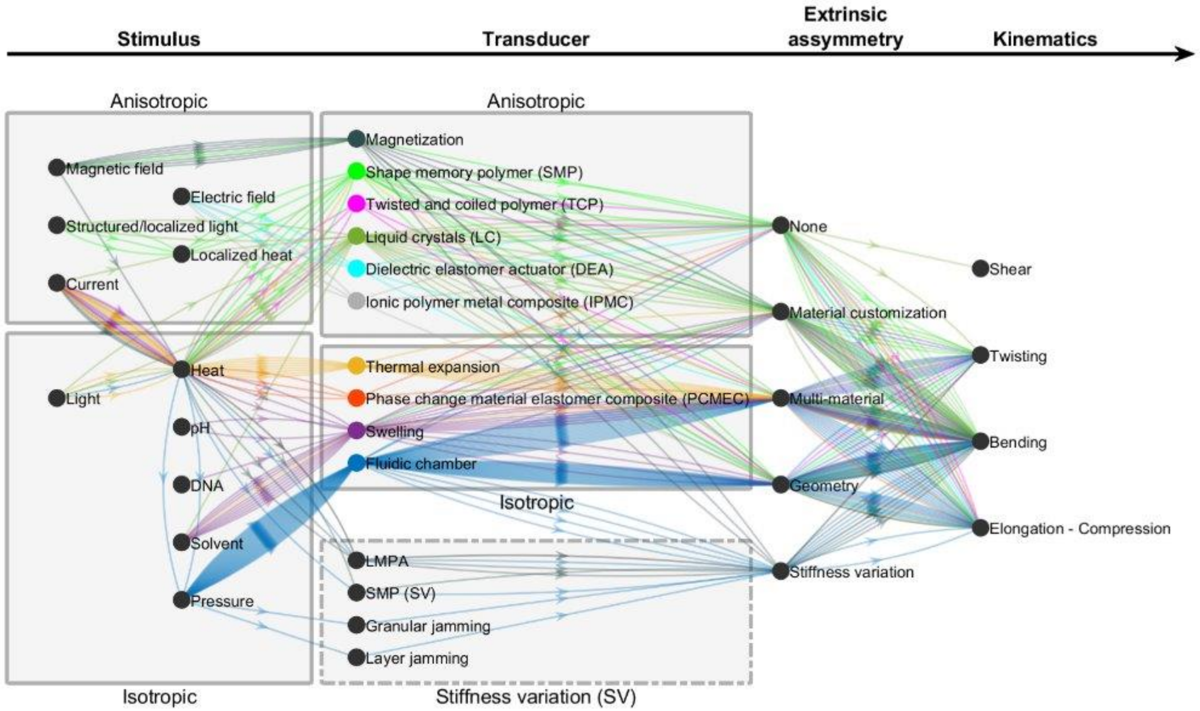
Advanced Manufacturing

- Based in Calgary, AB
- Technology solutions provider specializing in innovation
- Primarily working in energy market sectors – focus on sustainability and the energy transition
- Diverse, agile team of engineers and technologists
- In-house fabrication and advanced manufacturing to support technology development projects

exergy

THERMALLY RESPONSIVE MATERIALS FOR ENERGY GENERATION

- Developing a novel clean energy technology
- Relies on a thermally responsive material – harnessing geothermal energy to do work
- Literature review and feasibility assessment
- Why CRN?
  - Polymer and composites expertise
  - Conventional materials unable to meet our requirements
  - Access to state-of-the-art scientific literature



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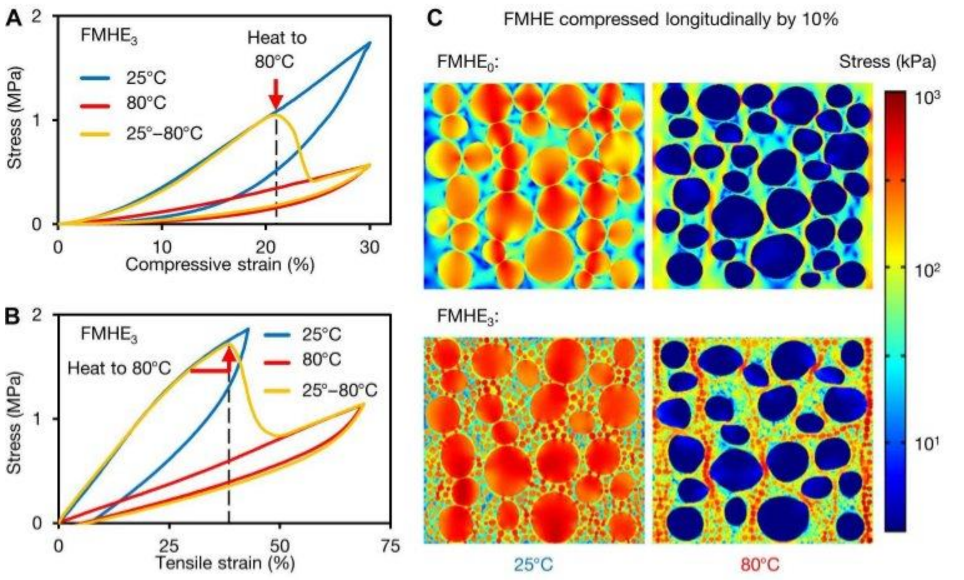
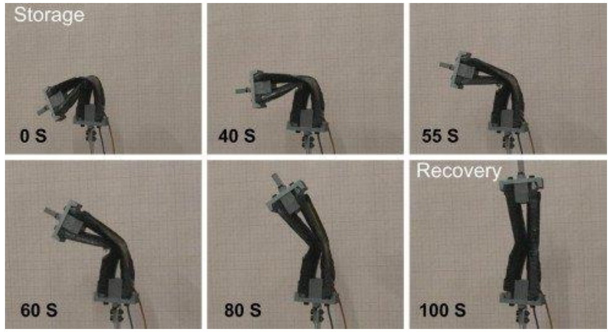
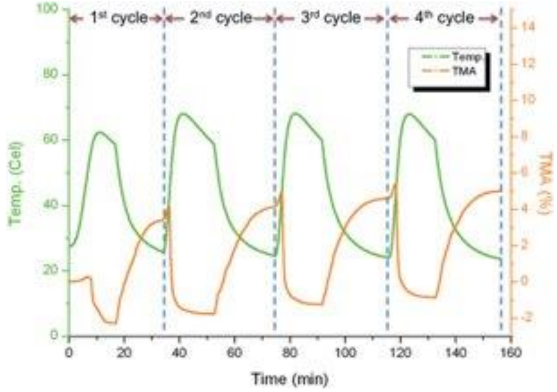
exergy

THERMALLY RESPONSIVE MATERIALS FOR ENERGY GENERATION

- 3-month scope
  - Broad literature search for candidate materials
  - Temperature range, work capacity, hysteresis, maximum strain, etc.
- Key Outcomes
  - Clarified fundamental polymer science challenges
  - Identified leading material candidates
- Exergy currently developing prototypes based on these material systems







Thank you for joining us!

Keep an eye out for upcoming AIM events:

A Path Towards Automation in a Prepreg Factory
Presented by Peter Richter, WRP Consulting
April 29, 2026
https://compositeskn.org/KPC/A415

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/A414

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