Is a 100 m composite ship possible? what are the critical issues?

Dr Jasper Graham-Jones
Associate Professor Mechanical & Marine Engineering

Professor John Summerscales
and Badr Moutik
School of Engineering and Computing
University of Plymouth

UNIVERSITY OF PLYMOUTH

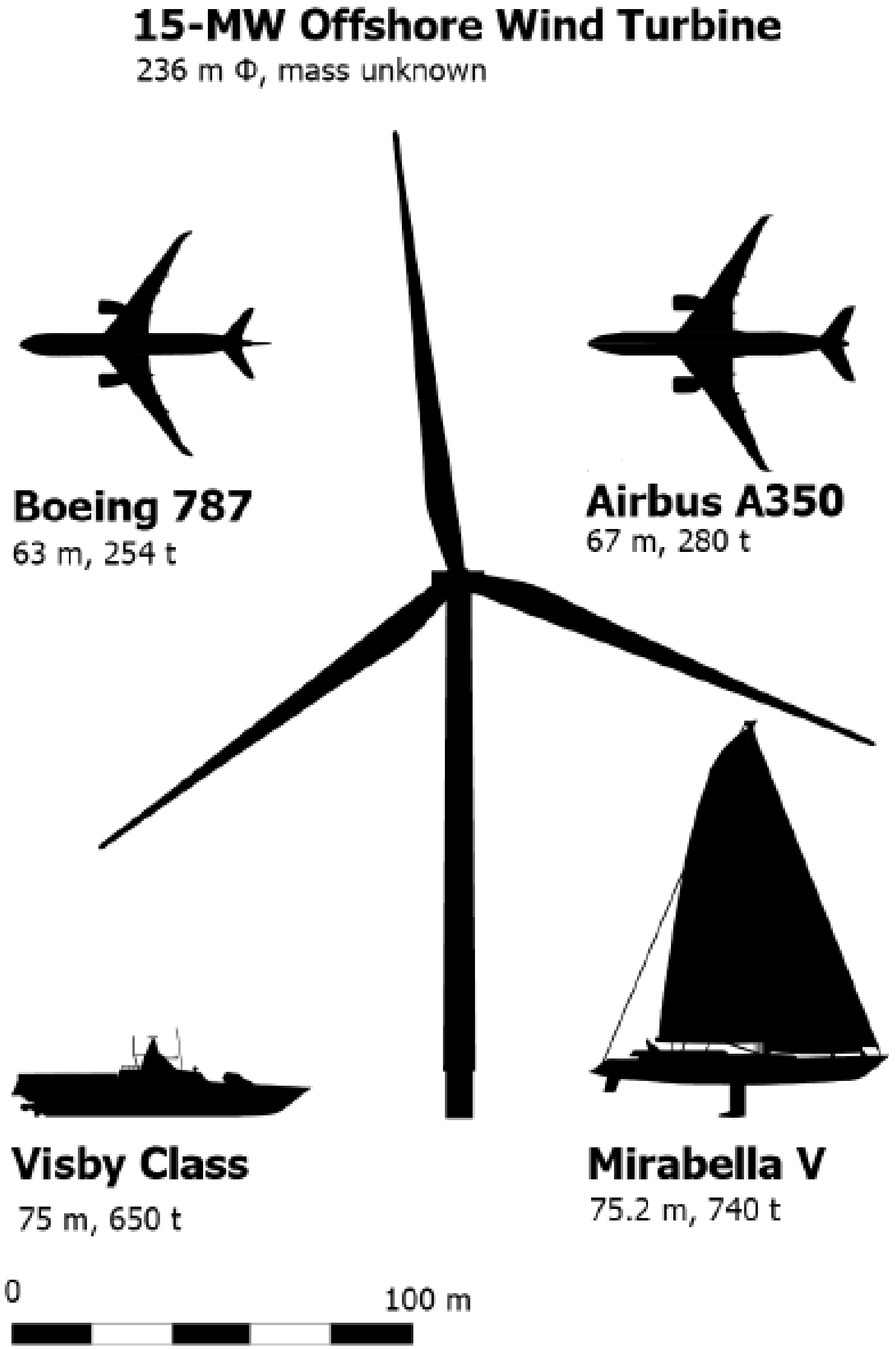
Fibre-reinforced polymer (FRP) matrix composites

- widely used in large marine structures
  - wind turbines where blade lengths are now over 110 m.
- materials of choice for small vessels
  - due to ease of manufacture, high hull girder stiffness, buckling resistance, corrosion resistance and underwater shock resistance.
    RNLI inshore composite lifeboats have increased service to over 60+ years
- Ships over 100 m are still built using traditional steel and/or aluminium so far not FRP.
- Composite ship lengths have increased over the past 50 years, but fundamental technical challenges remain for 100 m composite ships.
- Preliminary studies suggest a possible:
  - 30% saving in structural weight,
  - 7-21% reduction in total load displacement,
  - 15% cost saving.
- However, economic considerations, design codes, fire safety, manufacturing limits, and end of life scenarios need to be addressed before a 100 m ship is built.

Fibre-reinforced polymer (FRP) composites widely used in ships & marine structures:

Advantages –

- low densities ∴ lighter hulls
- excellent modulus- and strength-to-weight ratios
- corrosion resistance
- low maintenance requirements
- improved fuel consumption and/or increased cargo capacity.



Fibre-reinforced polymer (FRP) composites widely used in ships & marine structures

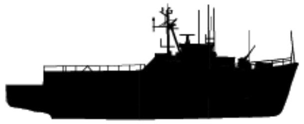
Limitations:

- high material, mould tool and labour costs
- complex design processes: unclear or poor guidance and legislation
- safety,
- end-of-life procedures.

Majesty 175 world's largest composite production superyacht built from carbon fibre and vinylester.

Table 1. Intermarine Mine-Counter Measures Vessels (MCMV) supplied to foreign navies.

Navy	Vessel Class	Vessels	Built/Delivere
Royal Malaysian Navy	Mahamiru	4	1985
Nigerian Navy	Ouhe	2	1987–1999
United States Navy	Osprey	12	1991–1998
Royal Australian Navy	Huon minehunter coastal (MHC)	6	1994–2003
Royal Thai Navy	Lat-Ya	2	1999



HMS Wilton
46.3 m, 450 t

Landsort Class
48 m, 360t

Visby Class
75 m, 650 t

Hunt Class
60 m, 752 t

Alexandrit Class
62 m, 890 t

composite sandwich

- thermal insulation lowers infrared signature and increases survivability in fire.
- non-magnetic, lower magnetic signature.
- very strong, low mass means a higher top speed, better manoeuvrability
- weighs roughly 50% less than equivalent strength steel.

Resin Infusion at Princess Yachts, Plymouth

Manufacturing Issues

- bagging processes consolidate laminate
  - higher fibre volume fractions
  - reduced resin-rich volumes & associated voids
  - better working environment than open mould methods
  - enclosed temperature-controlled facility
- 62 m long 10 m tall minesweeper hull infusion
- 21 t of resin, 45 t of fabric, 1.5 km spiral feed tube, 85 m × 35 m vacuum bag
- innovative materials and structures:
  - carbon fibre composite skinned sandwich construction, + aramid,
  - vinylester, epoxy resin, for increased mechanical performance
  - consequent improvements in economics and manufacturing processes.
- Composites are more competitive on a volume-for-volume basis due to their lower density and higher specific properties.

15 May 2014.

Princess Yacht 115 foot 35 m hull just released from mould

Fire Safety

- Piper Alpha - steel aluminium thermally conductive, heavy, expensive.
- loses approximately 50% of its load-bearing capability at 500°C
- intumescent materials swell when heated:
  - increased volume and decreased density.
  - key component of passive fire protection
- ProTek withstands a two-hour jet fire @ 0.3 kg/sec gas release.
- topside & subsea applications
- zero corrosion risk + maintenance-free for at least 30 years

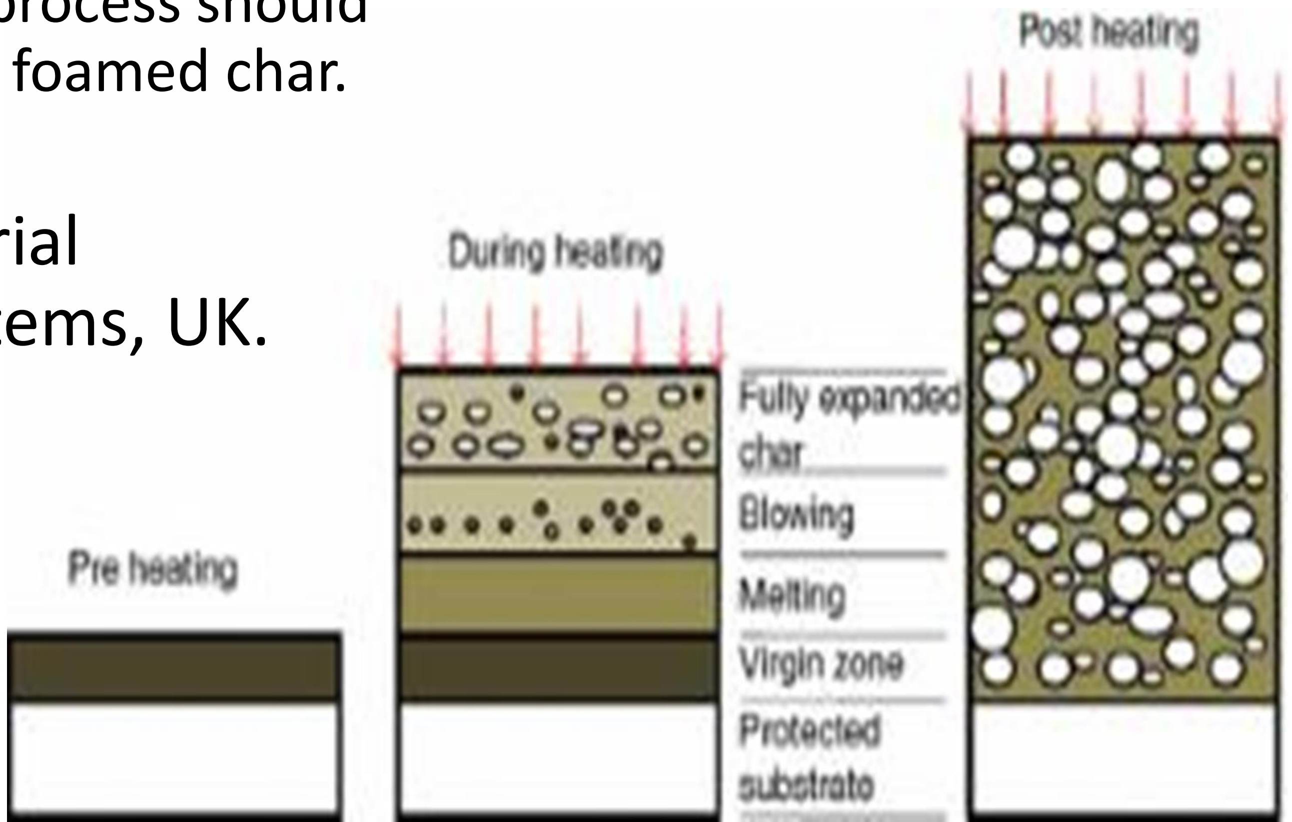
Fire (flame, smoke and toxicity/FST)   major design challenge for marine vessels

Fire performance of the FIBRESHIP composite laminates ranked by decreasing time to ignition (TIG)

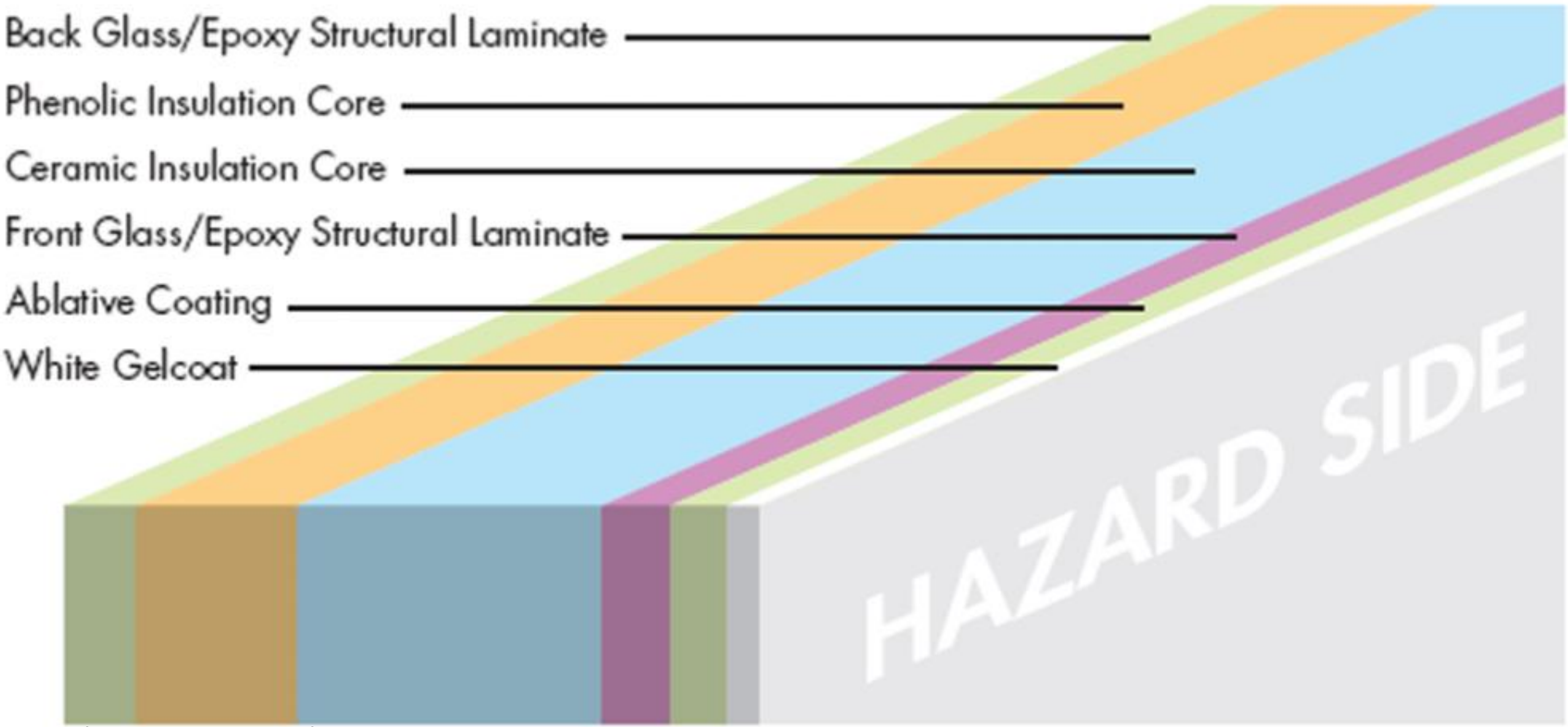
Polymer	System	Supplier	TIG (s)
phenolic resin	Cellobond™ J2027X	Hexion	101
vinyl ester	LEO system with(out) topcoat	Saertex	75 (50)
bio-based epoxy	Super Sap® CLR	Entropy	61
epoxy resin	Prime™ 27	Gurit	60
epoxy resin	SR1125 with(out) SGi 128 intumescent gelcoat	Sicomin	52 (53)
urethane acrylate	Crestapol® 1210	Scott Bader	44
methacrylic	Elium® thermoplastic	Arkema	23

Intumescent

- Epoxy-Based Intumescent Coating
  - marine industries and chemical manufacturing due to their hydrocarbon fire protection
- polymer melt should be viscoelastic
  - gases released during intumescence process should remain contained within it, forming a foamed char. glass fibre is holding char in location.
- ProTek intumescent isolation material produced by Solent Composite Systems, UK.



ProTek™ Structure



There are two insulating core

Solent Composite Systems. ProTek Passive Fire & Blast Restraint System.

[Online] [Cited: 20 February 2009.] www.solentcomposites.com/downloads/ProTek.pdf.

ProTek

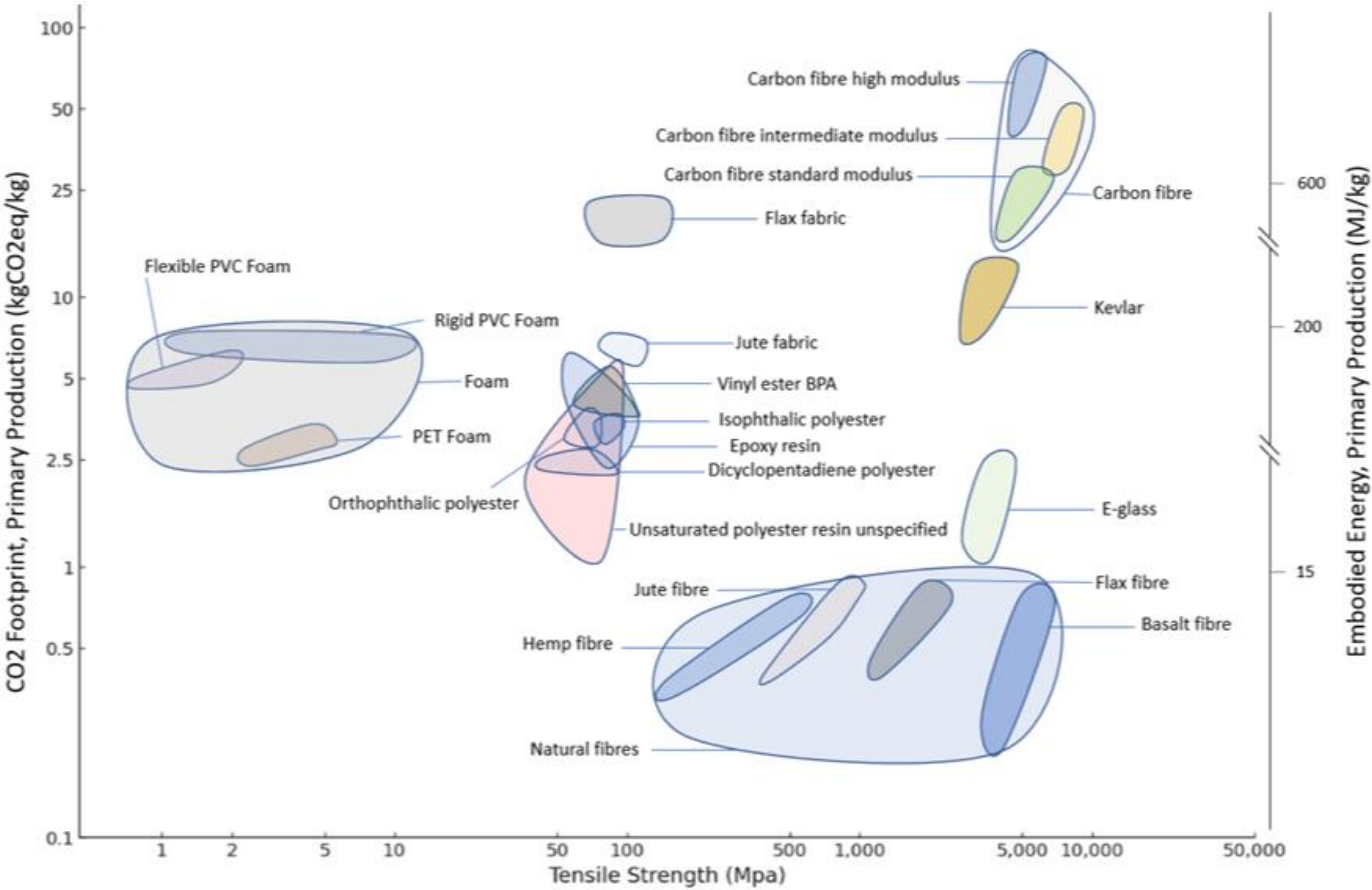
- Composite damage tolerance
  is the solution,
  e.g. intumescent and ablative
  composite panels (e.g. Protec)
  used offshore produce
  Fire Protection for up to 2.5 hours
  in a hydrocarbon jet fire
  with blast protection and
  thermal Insulation - 1200°C
  without additional thermal insulation

- Photo Protek fastened to a steel plate
  after being exposed to heat
  for one hour

End-of-life boats (and ships)

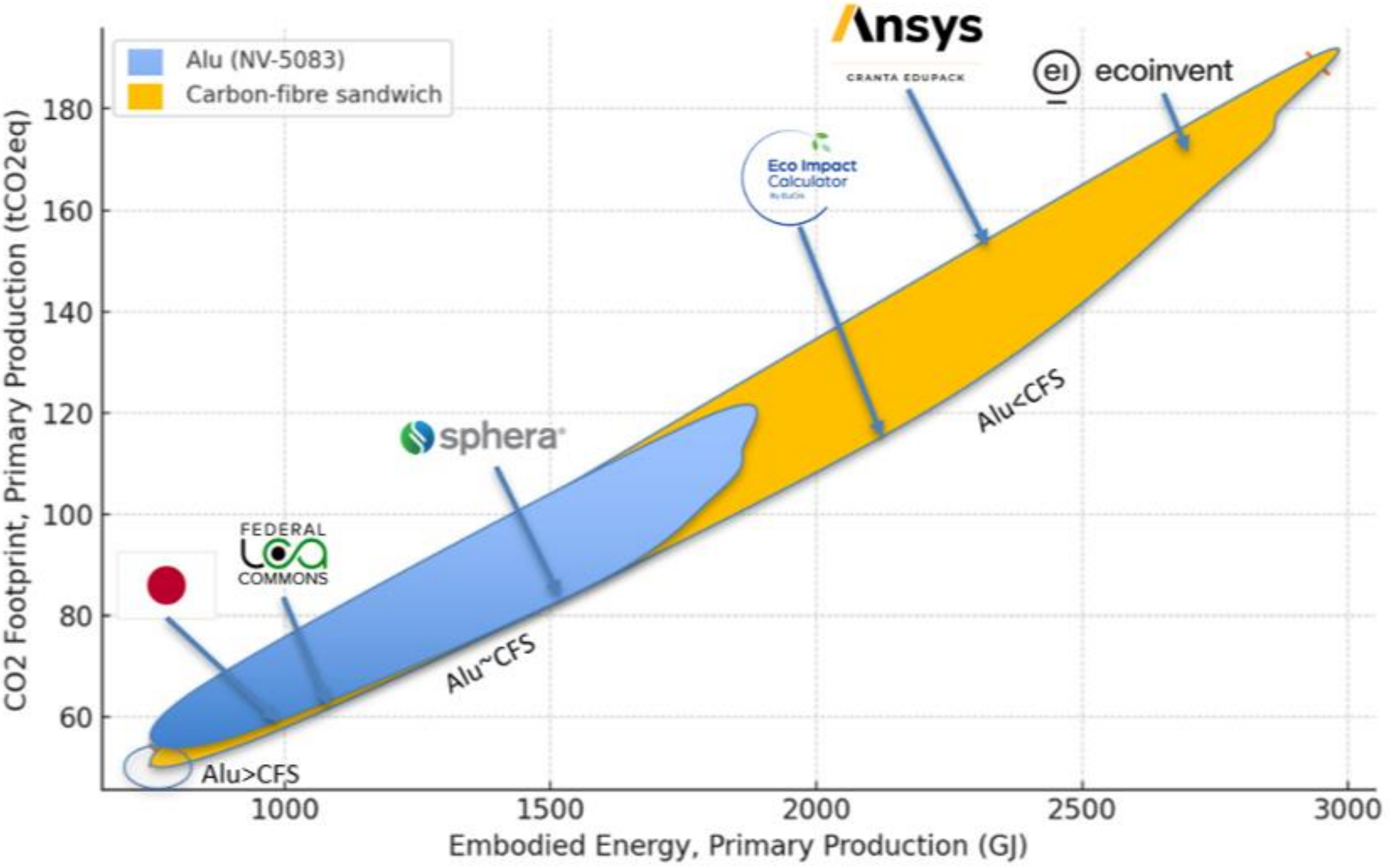
HMS Wilton
46 m 450 tons GRP
converted to the
Essex Yacht Club HQ

Comparative
Life Cycle Inventory data

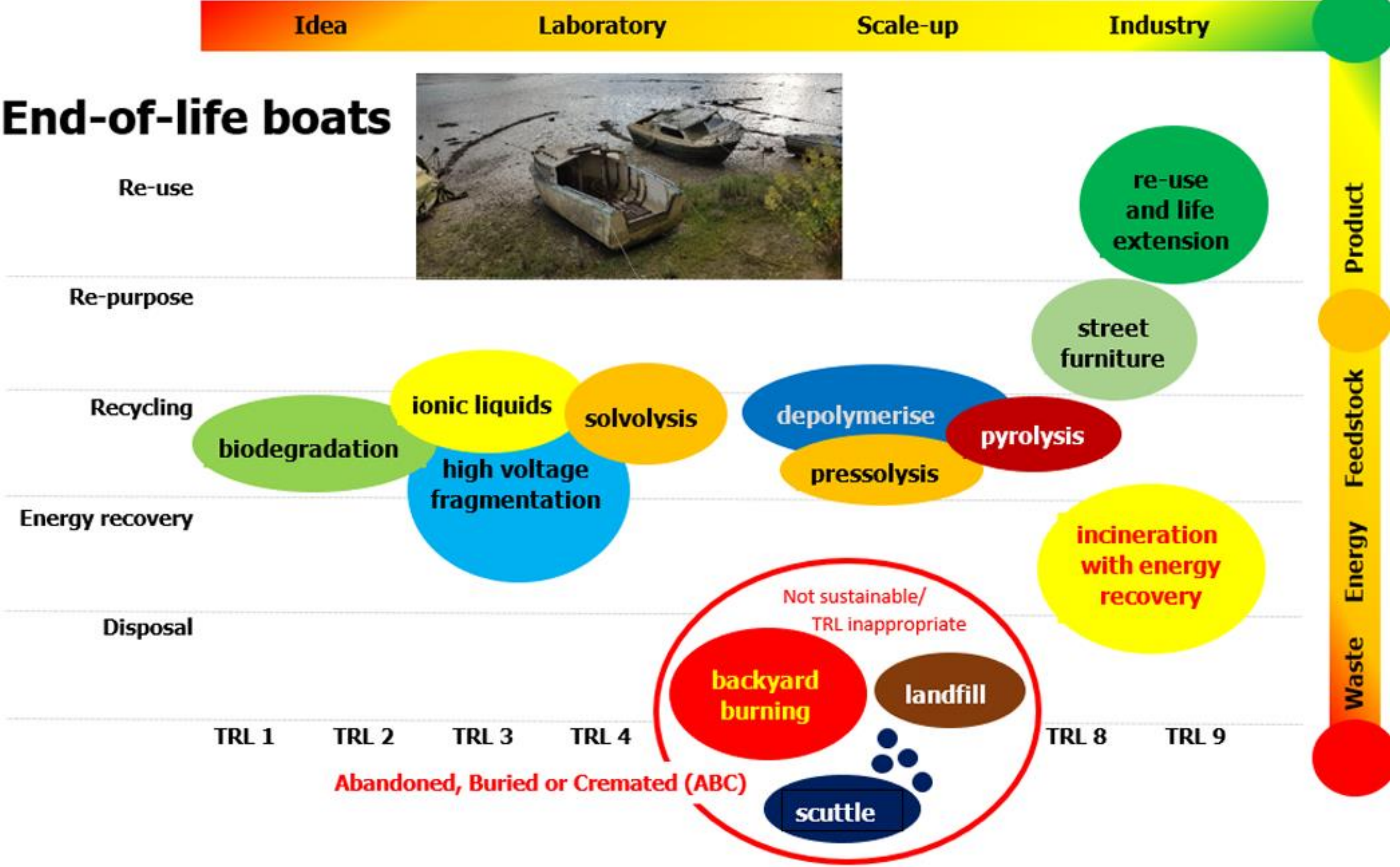


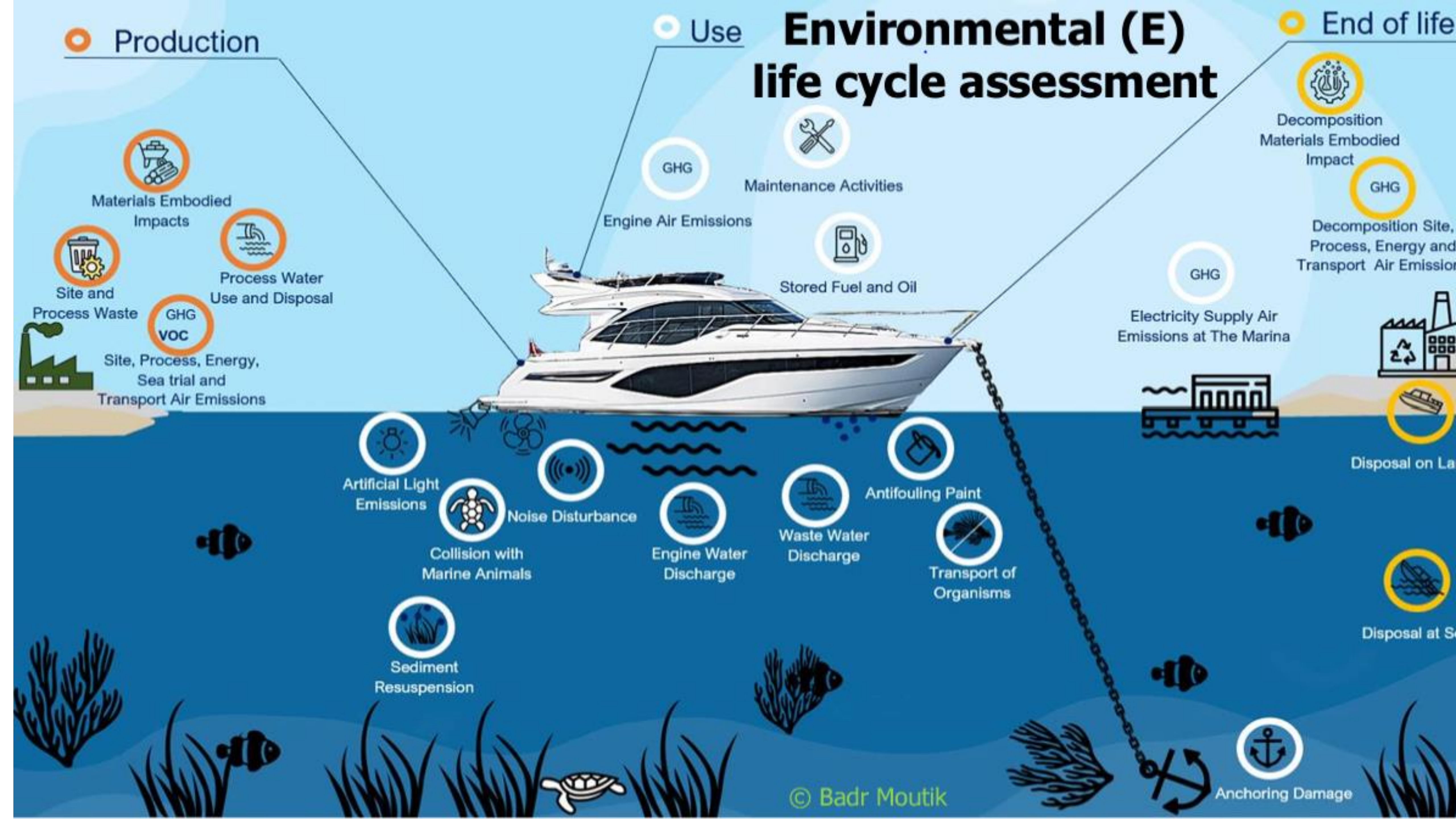
Updated composite materials Ashby graph

LCA comparison of CFRP vs auminium

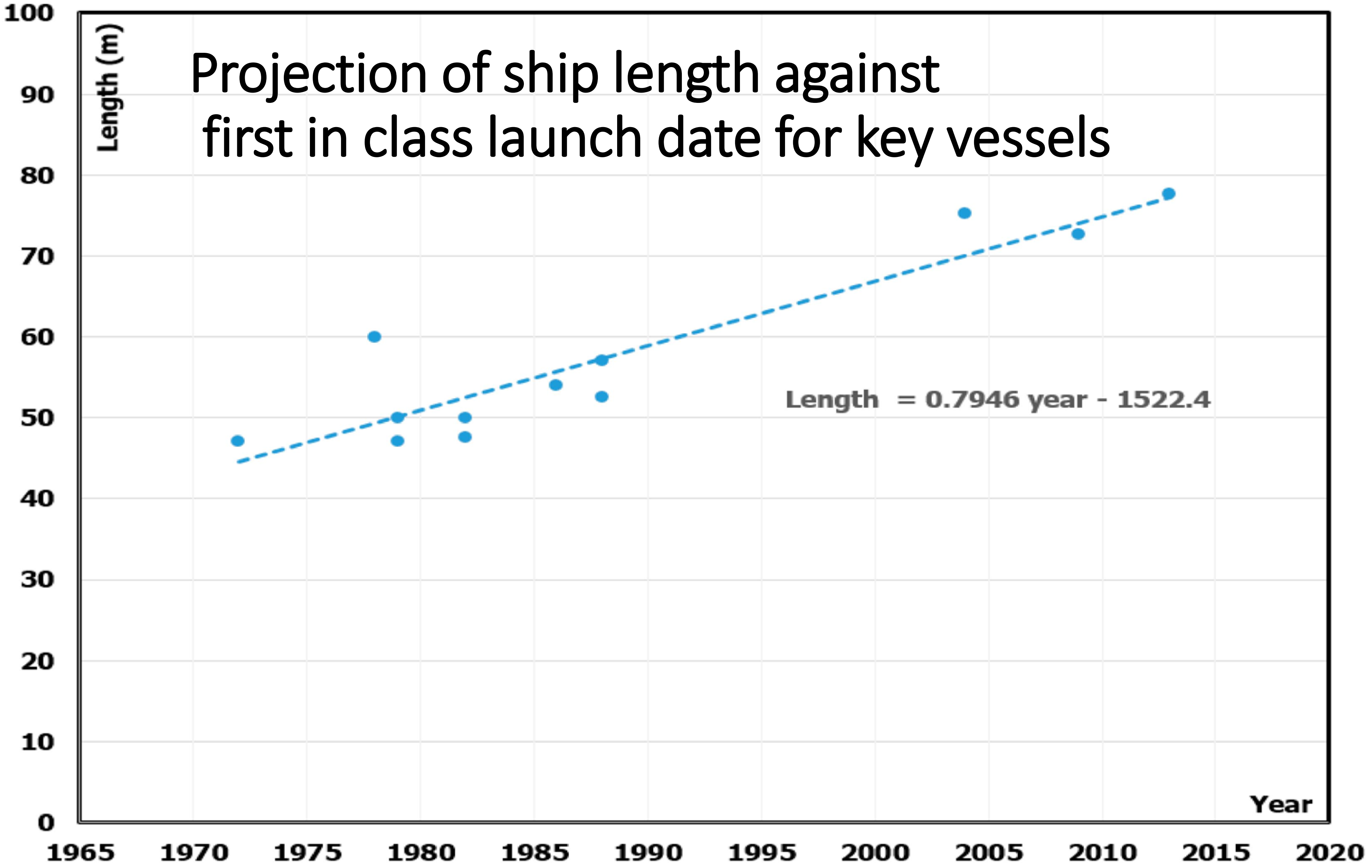


Comparative LCA of aluminium and CFRP composite: Marine craft hul
Database icons indicate various CF data


Idea
Laboratory
Scale-up
Industry
End-of-life boats
Re-use
Re-purpose
Recycling
Energy recovery
Disposal
re-use and life extension
street furniture
ionic liquids
solvolysis
biodegradation
high voltage fragmentation
depolymerise
pyrolysis
pressolysis
incineration with energy recovery
Not sustainable/ TRL inappropriate
backyard burning
landfill
scuttle
TRL 1
TRL 2
TRL 3
TRL 4
TRL 8
TRL 9
Abandoned, Buried or Cremated (ABC)
Product
Feedstock
Energy
Waste



Environmental (E)
life cycle assessment
Production
Use
End of life
Materials Embodied Impacts
Site and Process Waste
Process Water Use and Disposal
GHG
VOC
Site, Process, Energy, Sea trial and Transport Air Emissions
GHG
Engine Air Emissions
Maintenance Activities
Stored Fuel and Oil
GHG
Electricity Supply Air Emissions at The Marina
Decomposition Materials Embodied Impact
GHG
Decomposition Site, Process, Energy and Transport Air Emission
Disposal on La
Disposal at S
Artificial Light Emissions
Collision with Marine Animals
Noise Disturbance
Engine Water Discharge
Waste Water Discharge
Antifouling Paint
Transport of Organisms
Sediment Resuspension
Anchoring Damage
© Badr Moutik


Projection of ship length against first in class launch date for key vessels
Length (m)
Year
Length = 0.7946 year - 1522.4
100
90
80
70
60
50
40
30
20
10
0
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020

Conclusions

- FRP composites have the potential to:
  - revolutionize the marine industry
  - reduce weight and environmental impacts
  - offer improved range, non-magnetic and stealth properties, and
  - reduced maintenance requirements.
- further research and development are needed to overcome the challenges of manufacturing large composite structures and developing effective end-of-life technologies.

The 100m composite ship - technically feasible:

- economic case linked to life cycle thinking
- overcautious design pending naval architects/composites designers having increased confidence.