

# Regeneration of the Performance of Glass Fibre Recycled From End-of-life Composites or Glass Fibre Waste

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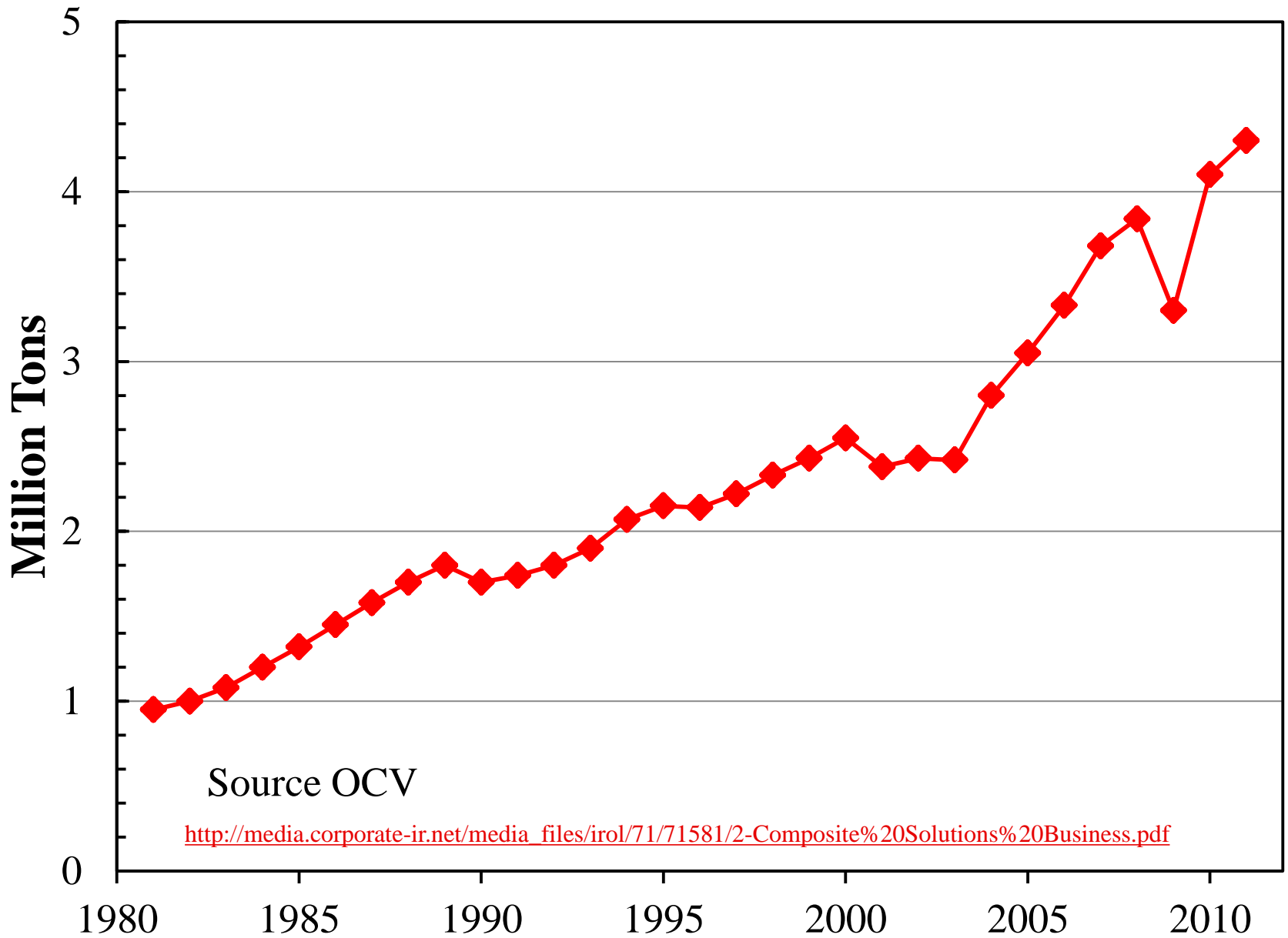
**EPSRC**

Engineering and Physical Sciences  
Research Council

 **AMRL**  
Advanced Materials Research Laboratory

- Introduction
- ACG Recycling Projects Overview
  - TARF-LCV
  - ReCoVeR
- Some Initial Results
- Conclusions

# Global Glass Fibre Demand



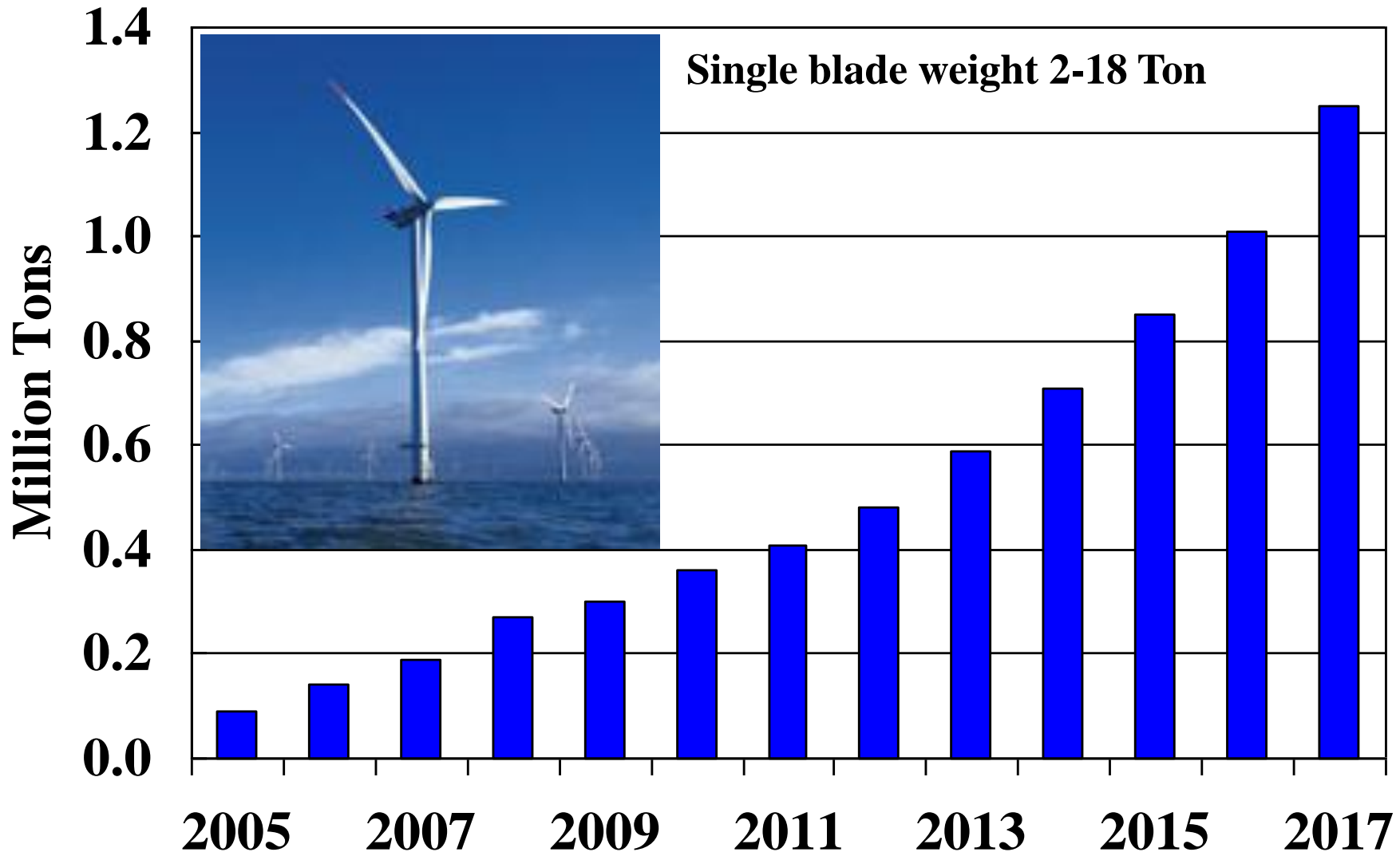
# Composites in Automotive

BMW photo as shown in Modern Plastics Magazine

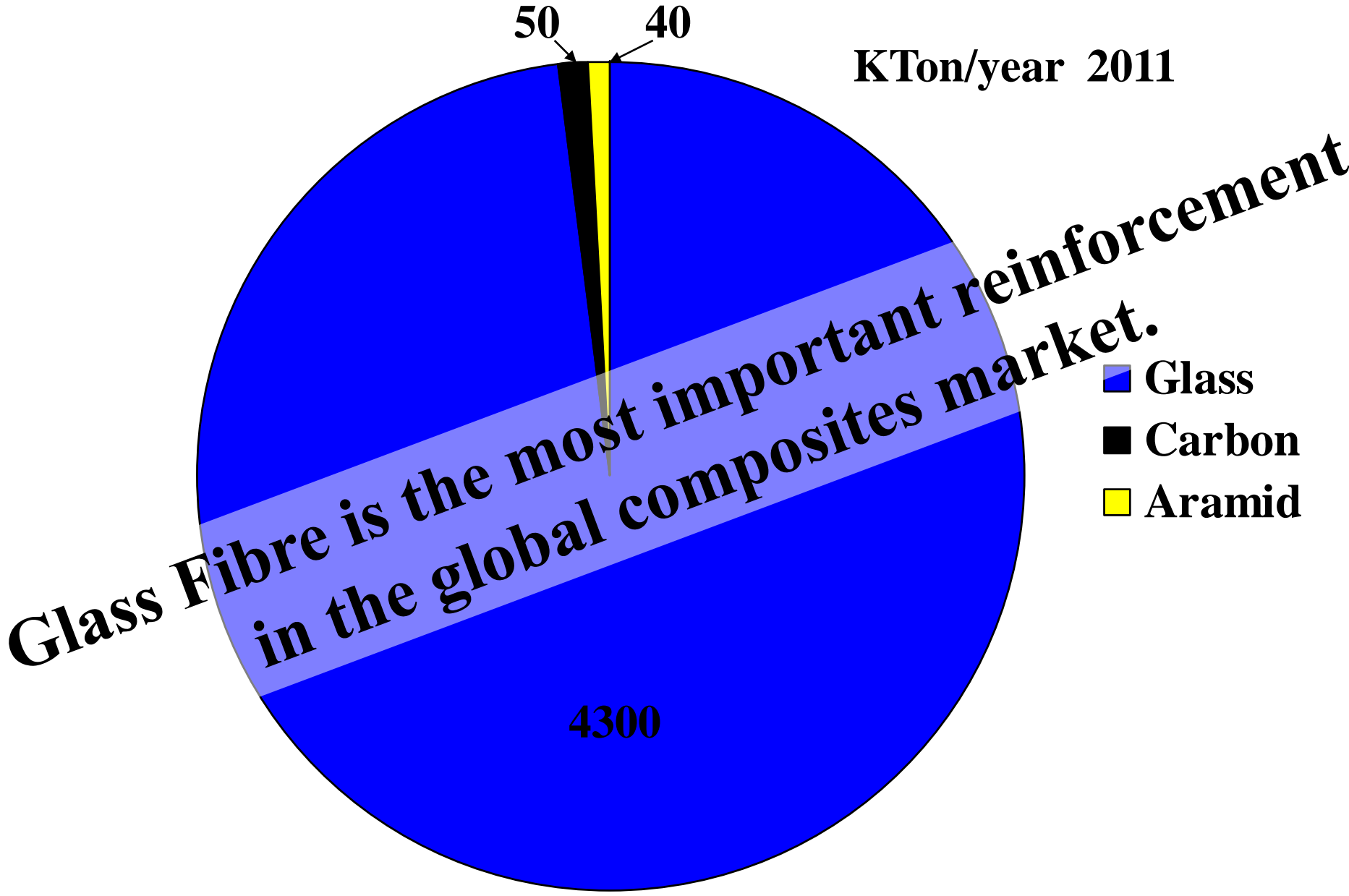


# Composite Wind Turbine Blades

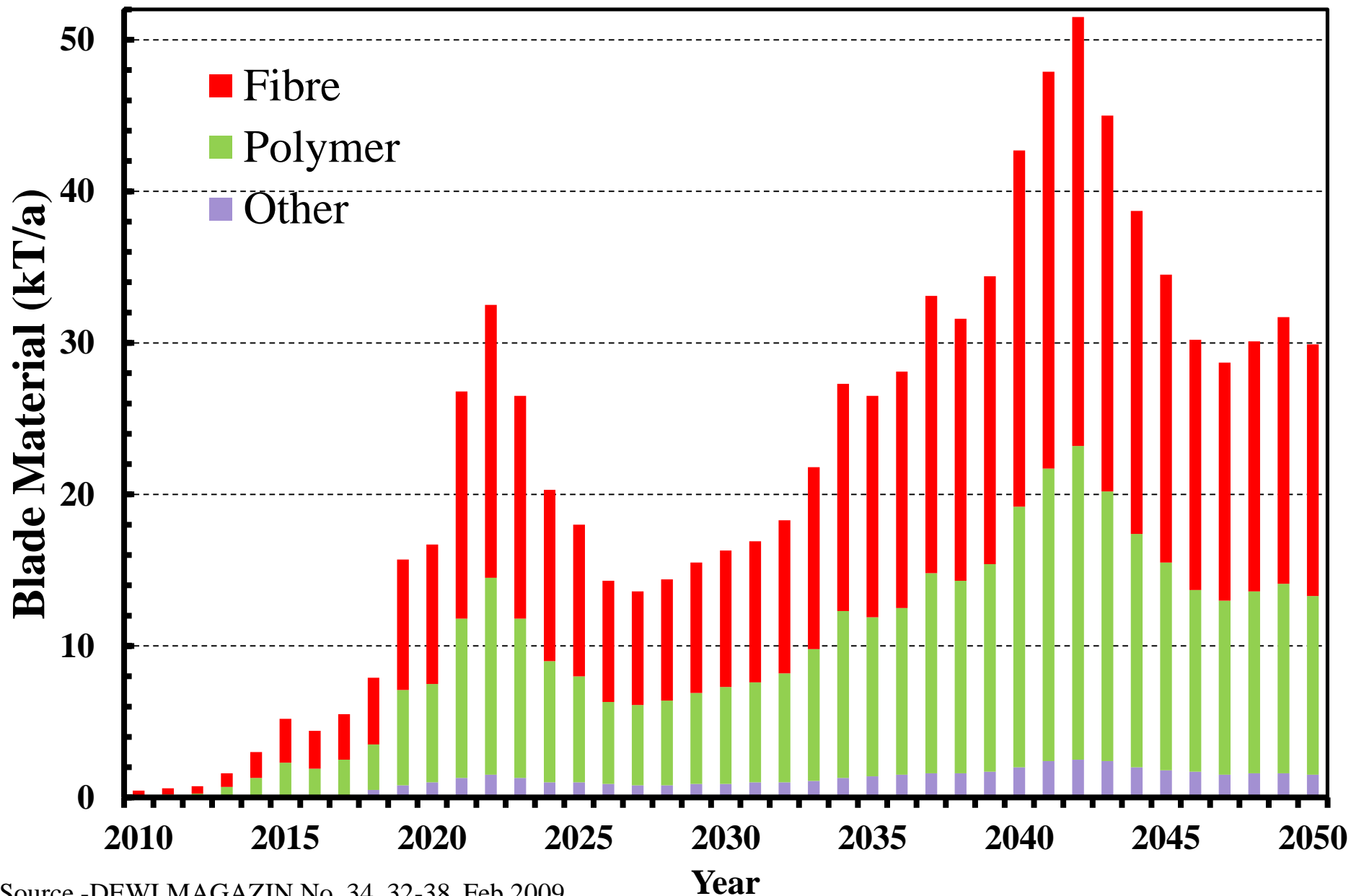
Forecasted Global Composite Rotor Blade Shipments, 2008-2017



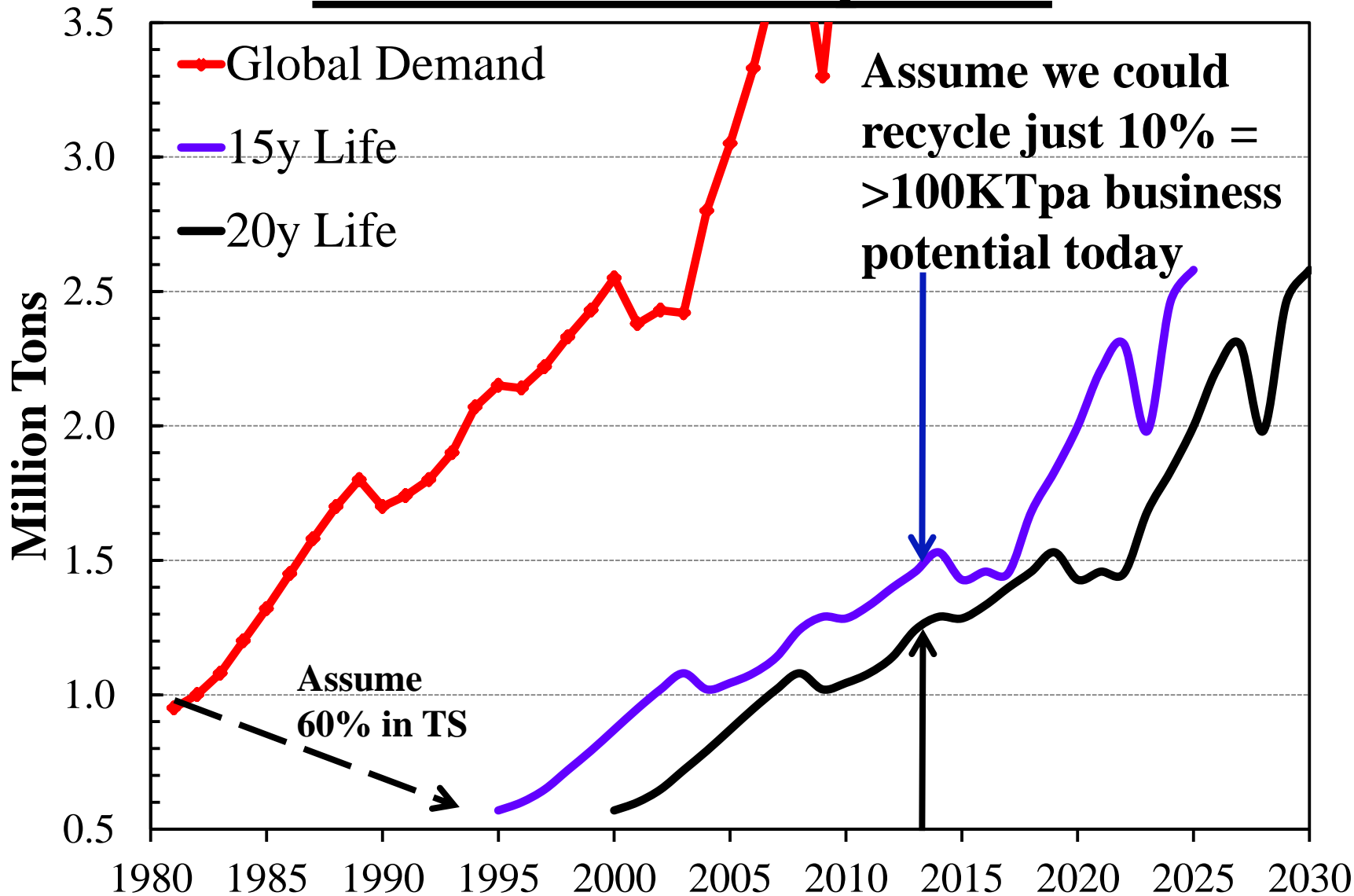
# Global Reinforcement Fibre Usage



# End-of-Life Blade Material in Germany

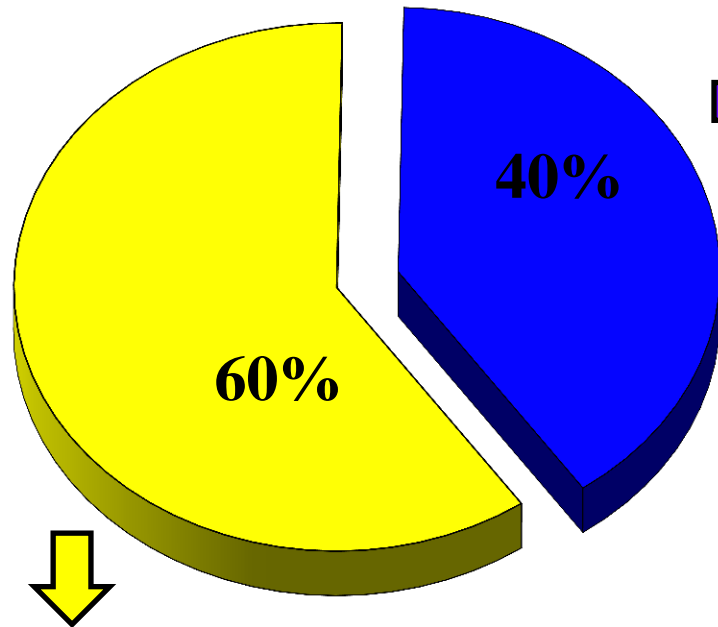


# Available End-of-Life Glass Fibre in Thermoset Composites



# Glass Fibres: End-of-Life Scenario

4.3 MegaTons Glass Fibre



*Mainly into chopped fibre  
thermoplastic composites.  
Intrinsically recyclable*

**ReCoVeR and reuse  
as valuable  
chopped fibre ?**

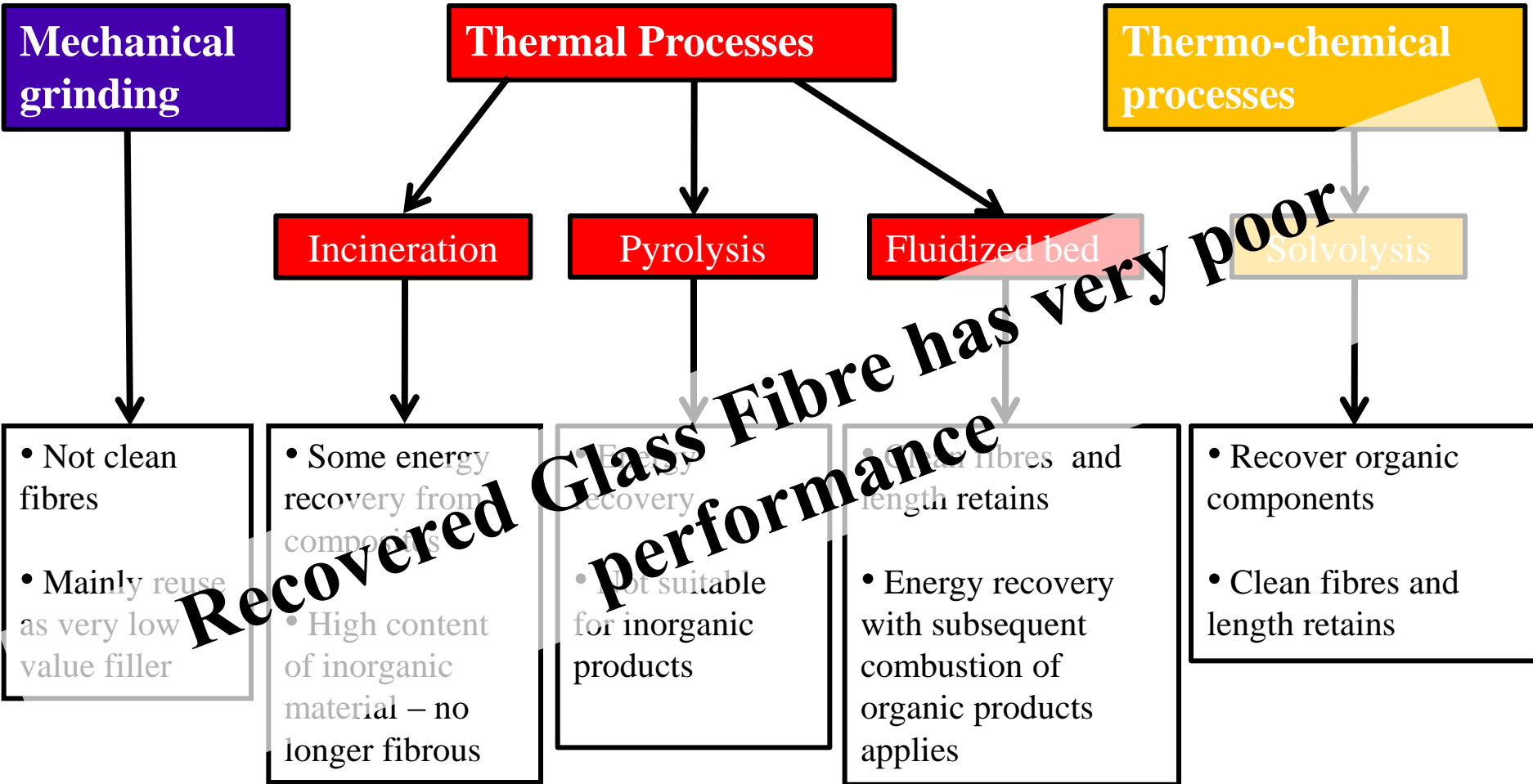
*Mainly into  
continuous fibre  
thermoset composites*

*Landfill no longer acceptable –  
but very difficult to recover  
continuous fibre*

*Challenging to recycle - so  
end-of-life = landfill ?*

(or +- zero value filler)

# GRP Recycling Techniques



**Recovered Glass Fibre has very poor performance**

- Not clean fibres
- Mainly reuse as very low value filler

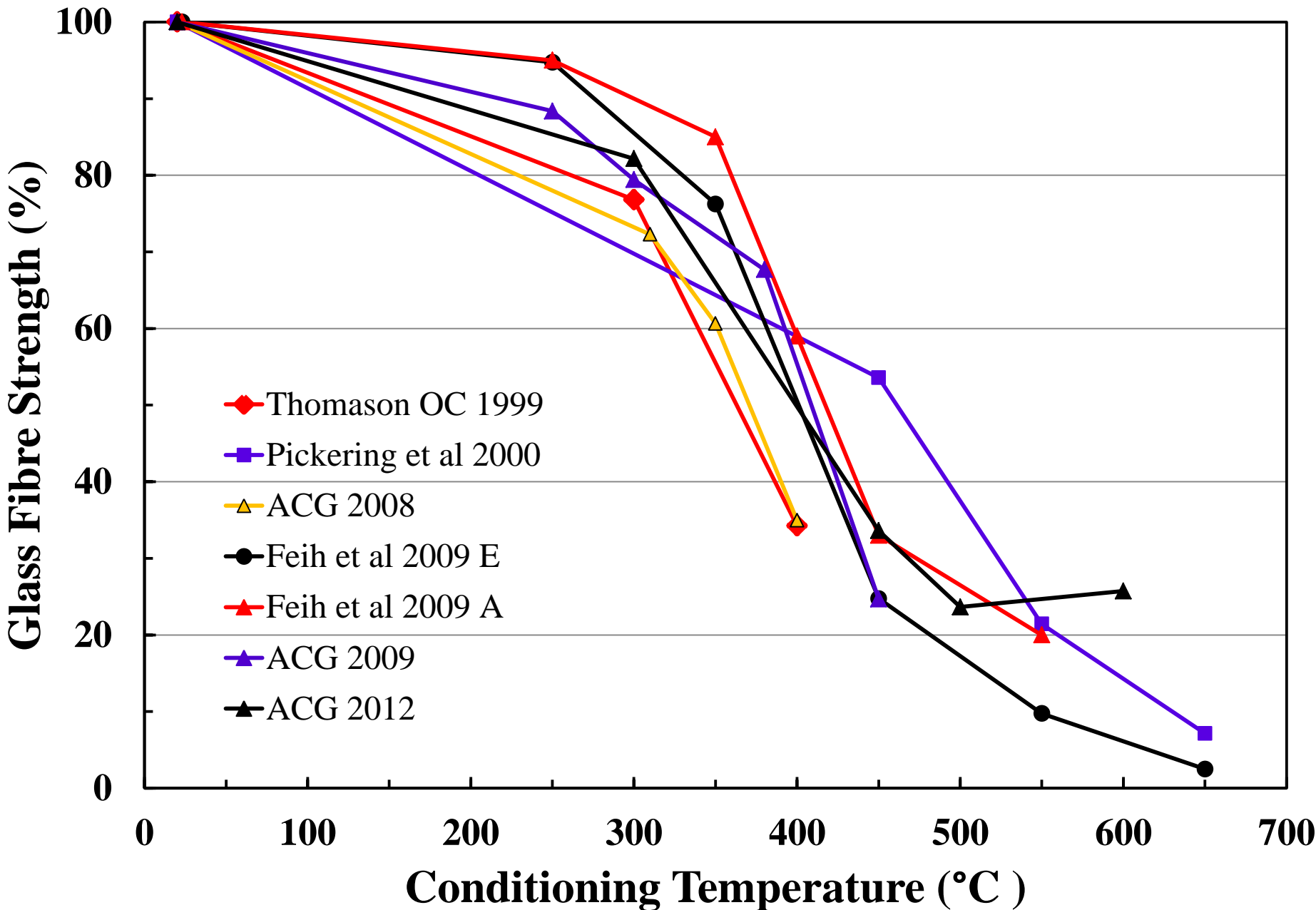
- Some energy recovery from components
- High content of inorganic material – no longer fibrous

- Energy recovery
- Not suitable for inorganic products

- Energy recovery
- Energy recovery with subsequent combustion of organic products applies

- Recover organic components
- Clean fibres and length retains

# Strength after Thermo-Mechanical Treatment



# Key Research Questions

- **Mechanism(s) of strength loss during thermal recycling of glass fibre?**
  - **How to regenerate the fibre strength?**
  - **How to process recycled glass fibre?**
- 
- **How to improve temperature resistance of pristine glass fibre products?**

# ACG projects on GRP Recycling

## **Towards Affordable, Closed-Loop Recyclable Future Low Carbon Vehicles (TARF-LCV)**

- *8 University team (45 researchers) addressing the grand challenges facing the development of recyclable lightweight materials for future Low Carbon Vehicles*
- *£4.9M EPSRC funding, £550K to ACG*
- *ACG will focus on glass fibre science and composites technology (1Post-doc, 3 PhDs over 4 years)*

## **Regenerated Composite Value Reinforcement (ReCoVeR)**

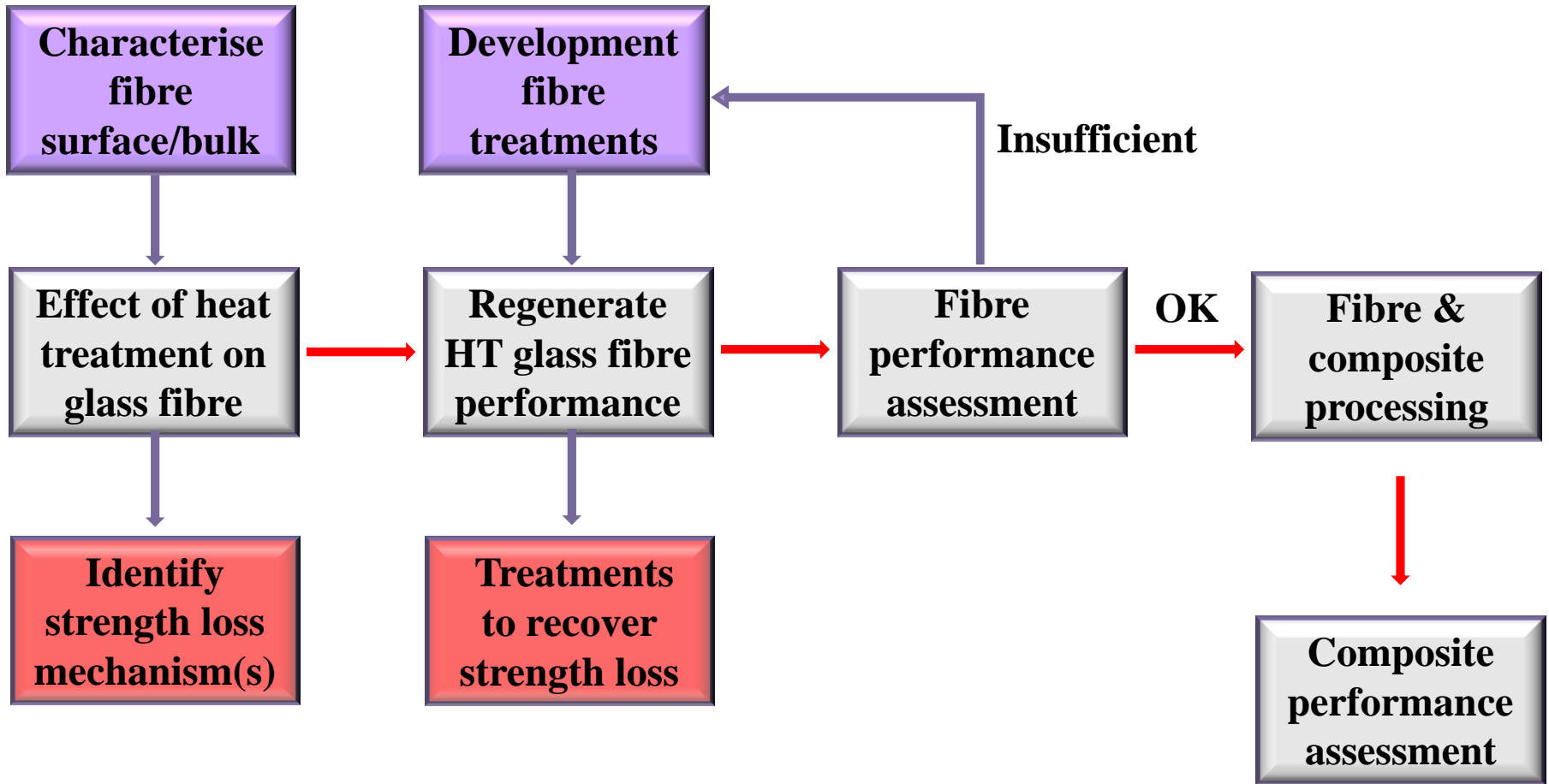
- *Cost effective regeneration of glass fibres recovered from recycled GRP composites (wind turbine blades)*
- *1Post-doc, 1+ PhD over 3 years*
- *£564K EPSRC funding.*
- *Support from Vestas, Owens Corning, DSM, SABIC*

# ACG GRP Recycling Projects Goals

**Enable the development of cost-effective “drop-in” glass fibre and composite products based on recycled glass fibres with regenerated mechanical performance**

- Generate a fundamental understanding of the degradation of glass fibre strength during thermo-mechanical conditioning (300-600°C)*
- Develop cost effective treatments (sizings) to regenerate the performance of thermo-mechanically treated glass fibres*
- Produce examples of glass fibre and composite products using regenerated glass fibres*
- Develop sizings that will enable high performance glass fibres to be recovered from thermally recycled GRP*

# Projects Overview



# Some Initial Results

## Materials

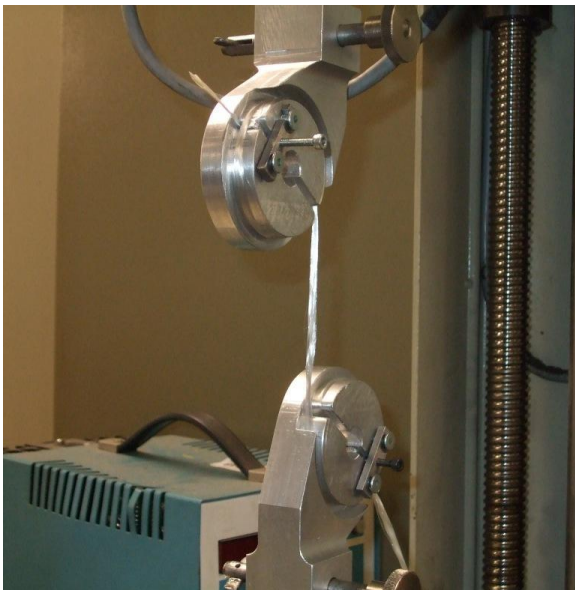
- **Boron Free E-glass (Advantex) OCV**
- **1200 Tex continuous, single end roving (pilot bushing)**
- **Nominal 17  $\mu\text{m}$  fibre diameter**
- **Sizing**
  - **US - Water sized = Unsized**
  - **APS - 1% wt.%  $\gamma$ -aminopropyltriethoxysilane sized**
- **Thermal Conditioning for 15 minutes in air**



# Fibre Testing

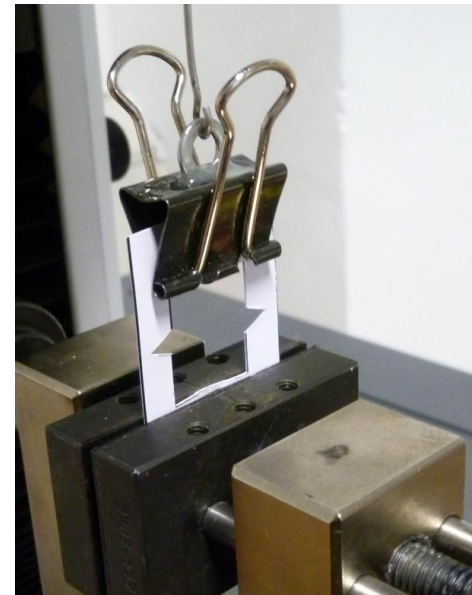
## Bundle Testing

- **ASTM 578 and ASTM 2256**
- **Gauge length: 250 mm**
- **Strain rate: 1.5 %/min**
- **10 tests per condition**
- **Only breaks > 3mm from grips recorded**

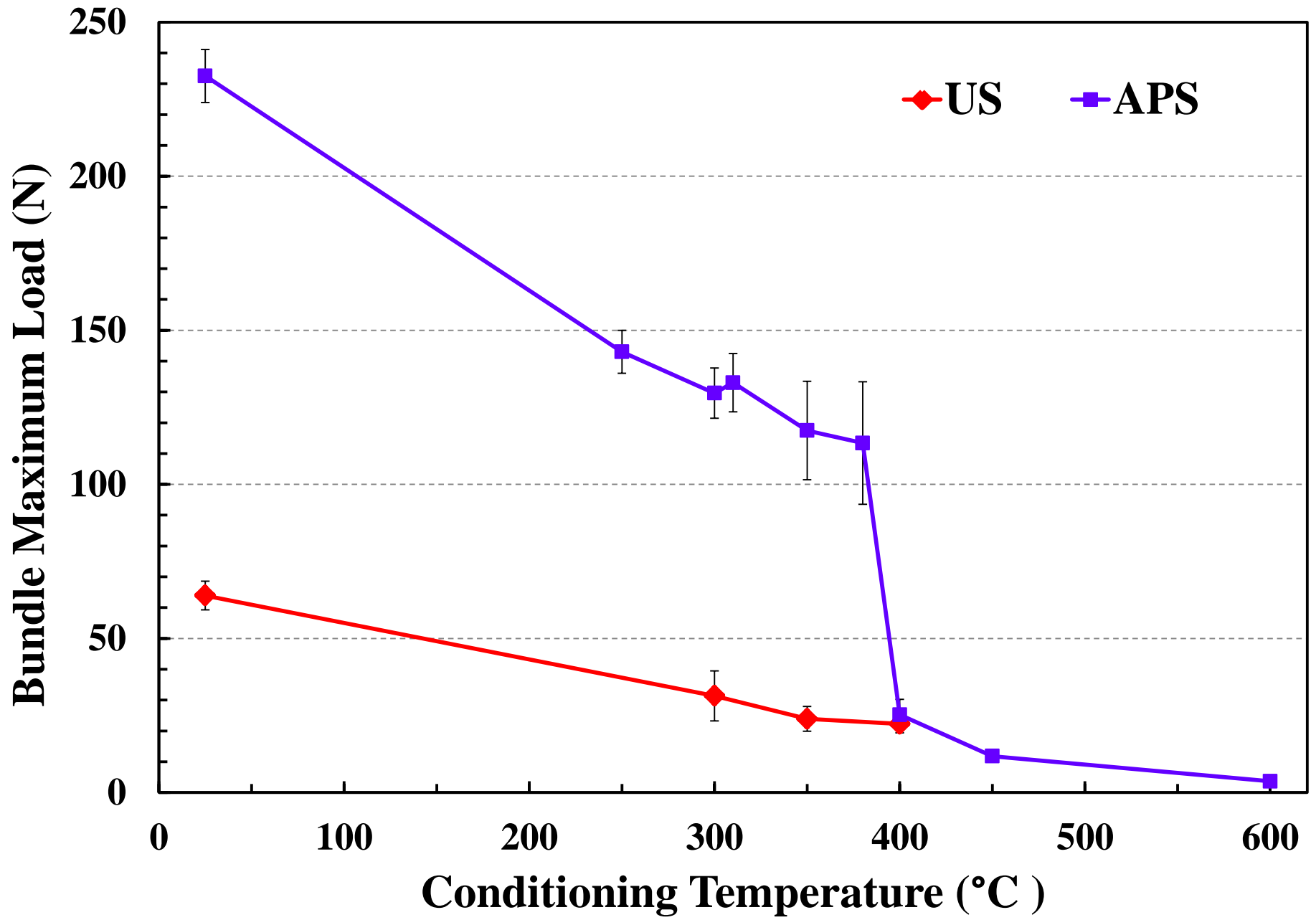


## Single Fibre Testing

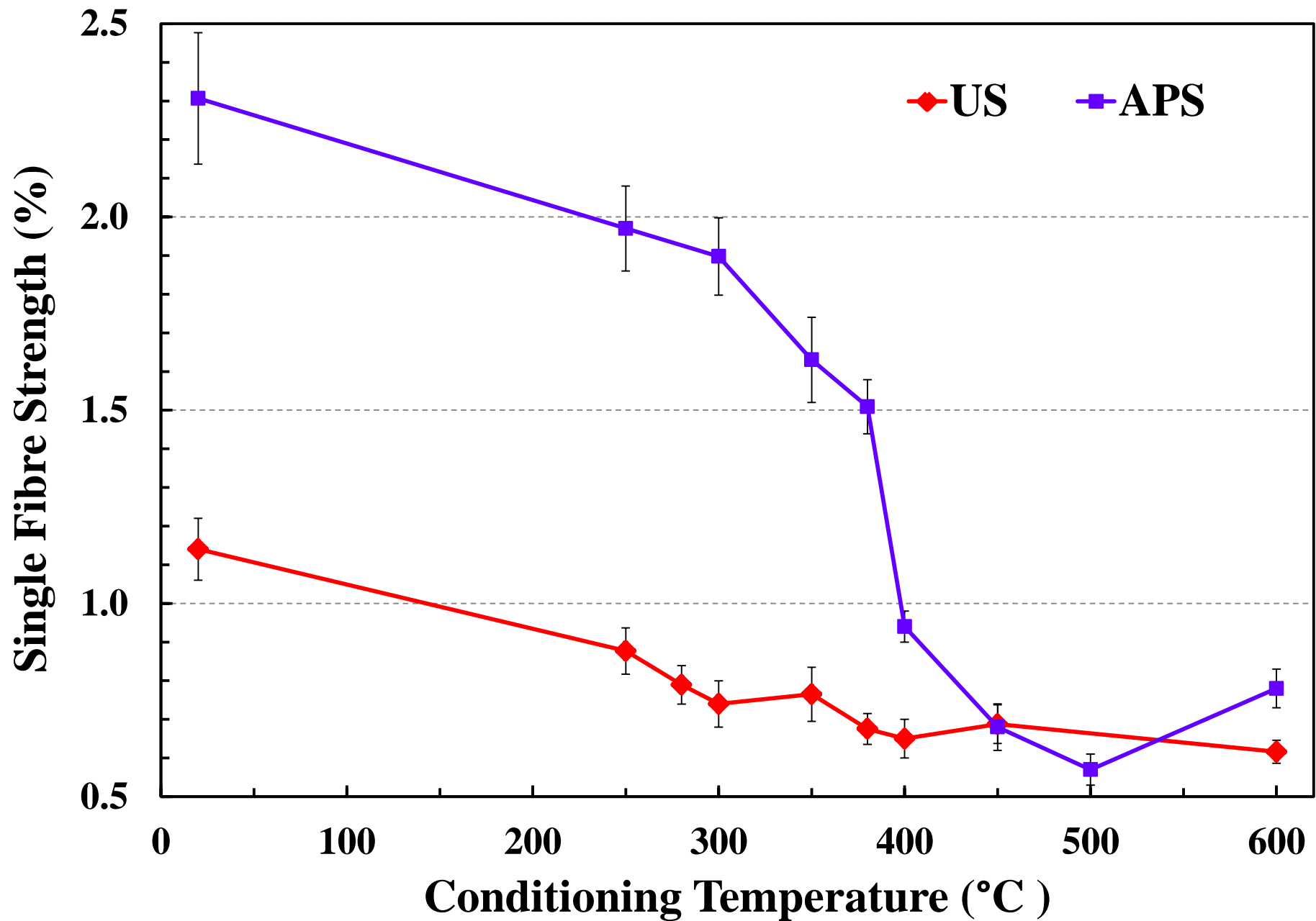
- **ASTM C1557-03**
- **Gauge length: 20 mm**
- **Strain rate: 1.5 %/min.**
- **70 – 100 fibres per condition**
- **Diameter average of 4 transverse measurements**



# Fibre Bundle Test



# Single Fibre Tensile Test



# Results Thermal Conditioning on Fibre Strength

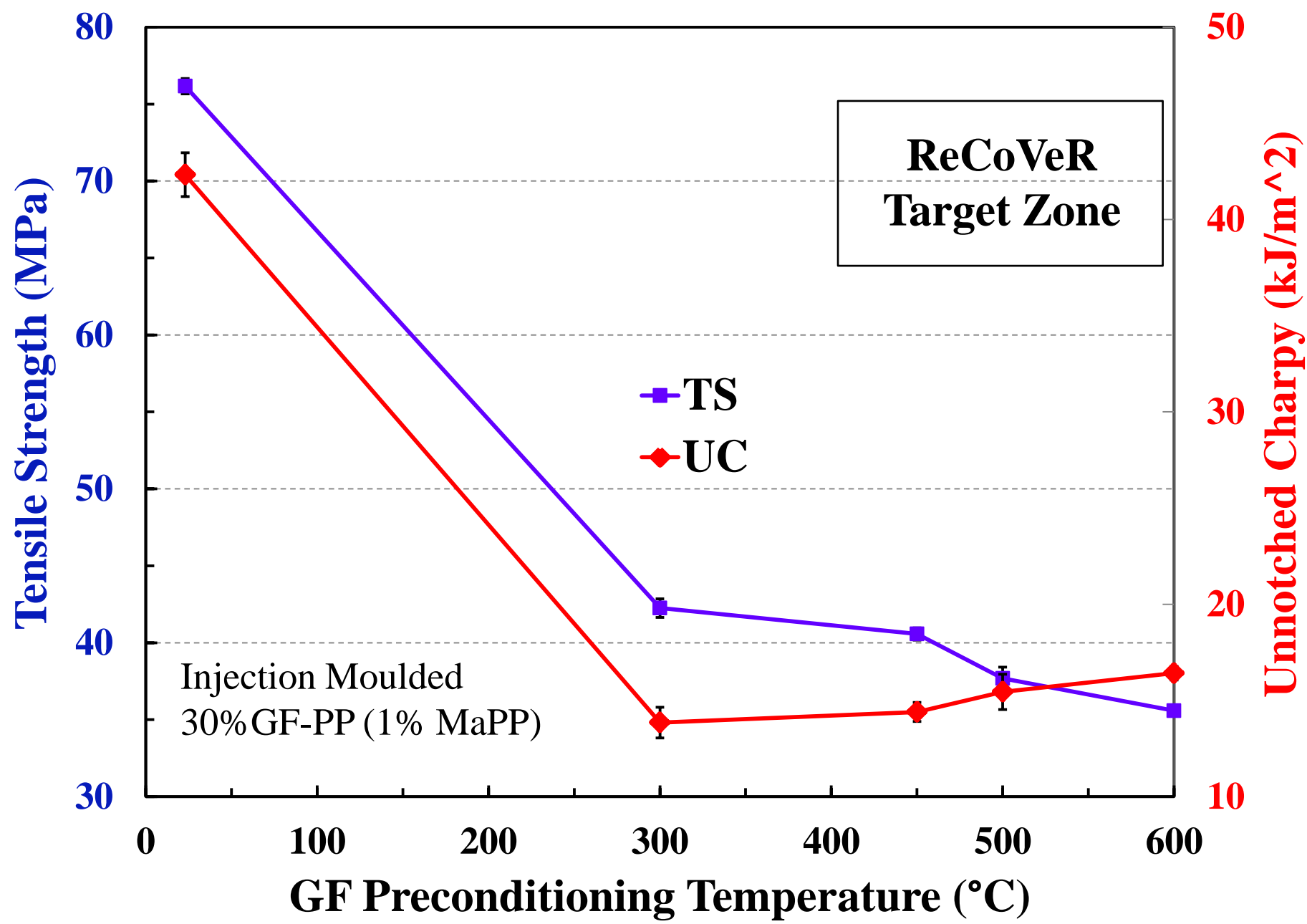
## APS Sized Fibres

- *Moderate strength loss in 23-300°C range*
- *Severe strength loss in 350-400°C*
- *No practical strength if conditioned above 450°C*

## Unsize Fibres

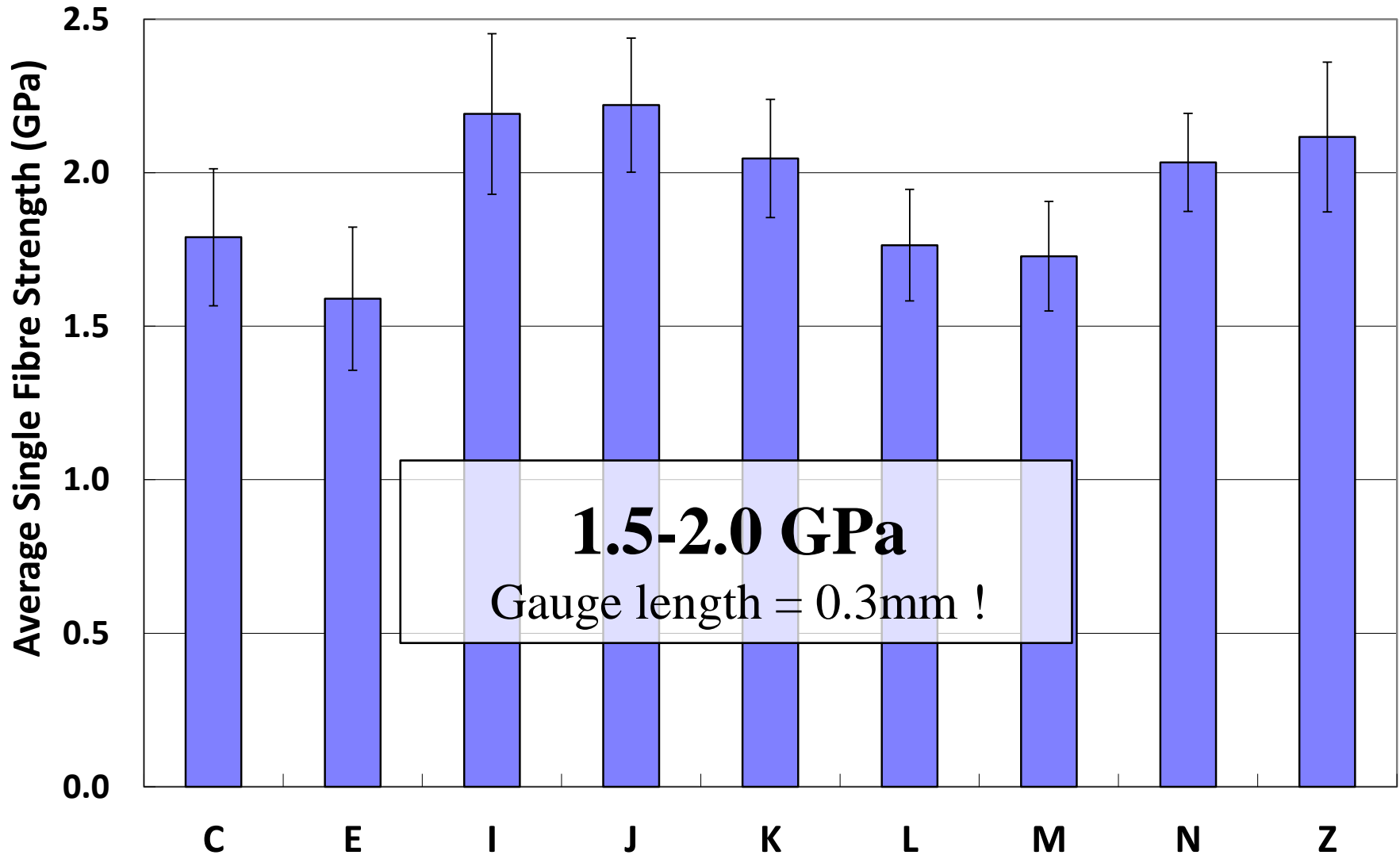
- *Low initial strength due to lack of surface protection*
- *Continually decreasing fibre strength with increasing conditioning temperature*

# GF Heat Treatment & Composite Performance



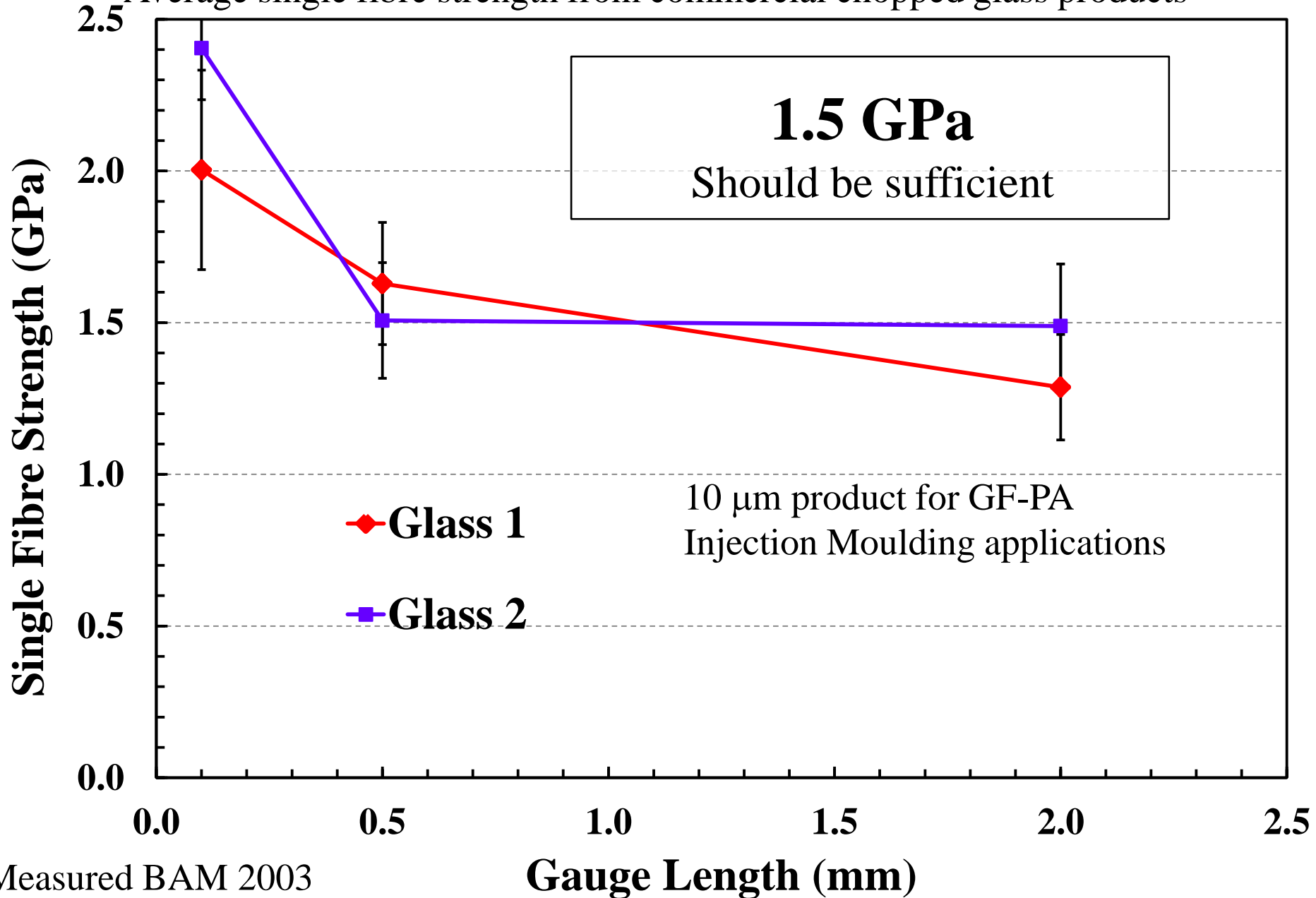
# Target Strength for ReCoVeRed Fibre ?

Average single fibre strength from commercial chopped glass products

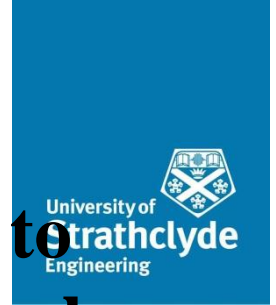


# Target Strength for ReCoVeRed Fibre ?

Average single fibre strength from commercial chopped glass products



# Conclusions



- **The development of a cost-effective technology to regenerate the properties of thermally recycled glass fibres would have major environmental benefits**
- **Sizing is essential to the retention of glass fibre strength**
- **Both sized and unsized glass fibres lose most of their strength after a short heat treatment above 400°C**
- **300-600°C conditioning of pristine chopped E-glass drastically reduces composite performance**
- **The ACG is developing treatments to ReCoVeR the strength of thermally recycled glass fibres**

# Announcement

**In August 2013 the Advanced Composites Group at the University of Strathclyde filed its first patent application in the area of**

## **Glass Fibre Recovery**

**covering cost effective, industrially applicable, treatments to regenerate the strength of thermally recycled glass fibres.**

# Glass Fibre Sizing Review

## Glass Fibre Sizings

*A Review of the Scientific Literature*



James L. Thomason

*“Never in the field of material science has so much of the success of so many applications depended on the knowledge of so few”*

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