Pultrusion for Wind Blade Sparcaps

An Assessment of Business Cases and Challenges

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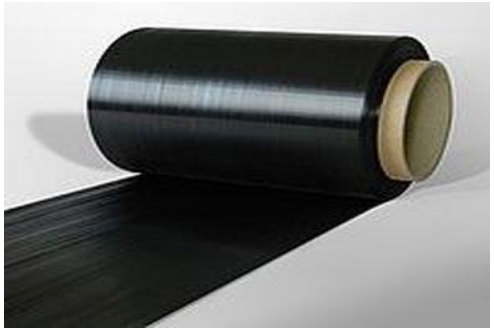
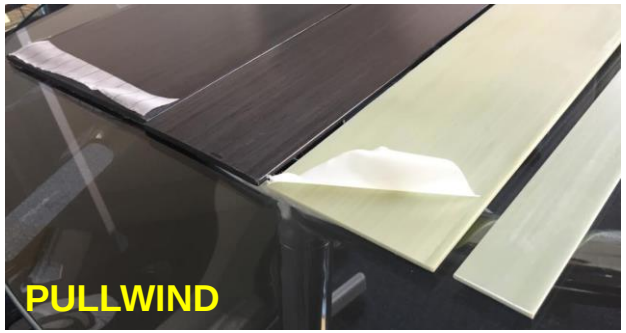
STRUCTeam Introduction

- 150+ completed projects
- One of the leading independent composite consultancy
- Cross-sector experience and great flexibility

Introduction

- Business cases for wind energy rotor blades design are heavily affected by cost of chosen manufacturing technology
  - Structural composites = prepreg and/or infusion – dominant technologies (established and developed in other markets).



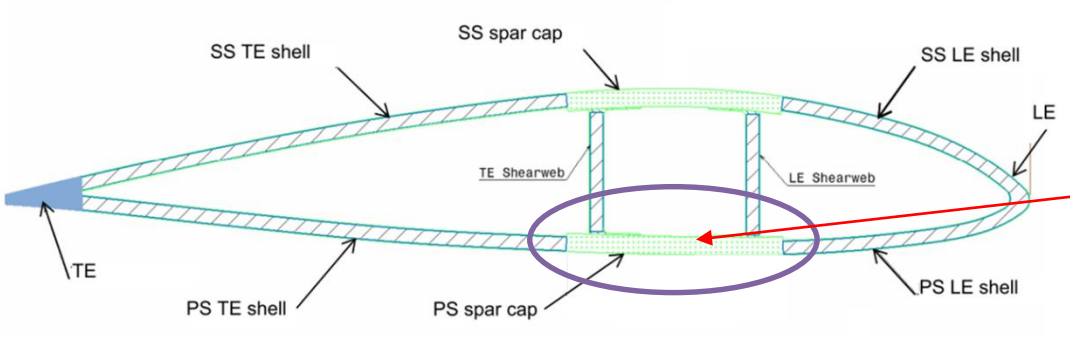


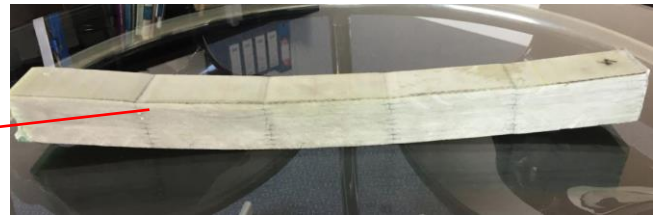
- OEMs continuously looking for cost effective and robust technologies.
  - So blade design and associated manufacturing processes must deliver an overall package for low cost, high quality and high production volumes, scalable anywhere in the world.

Why Pultrusion?

Industry Perspective

- Historically, Pultrusion introduced in wind energy in 2010
  - Only limited to carbon. No glass fibres-based pultrusion!
  - Driven by cost and product robustness requirements
  - Used in the spar cap region of the blade

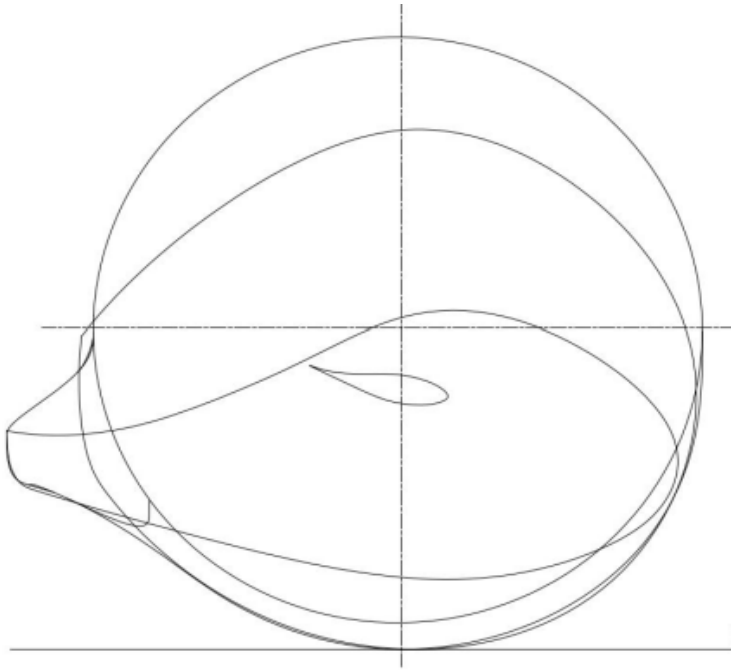




- OEMs are actively seeking their own pultrusion solutions. But without adequate supply chain positioning and relevant expertise, this is challenging.
  - Expertise required in Design, Materials technology and Manufacturing
  - Supply chain knowledge required for Equipment, Resin and Fibres

Why Pultrusion?

- Design consideration
  - Pultrusion offer benefits on FVF and therefore Specific Stiffness
- Designing with pultrusion is difficult
- Benefits are easily identifiable in the design
- Supply Chain is complex for very high volumes

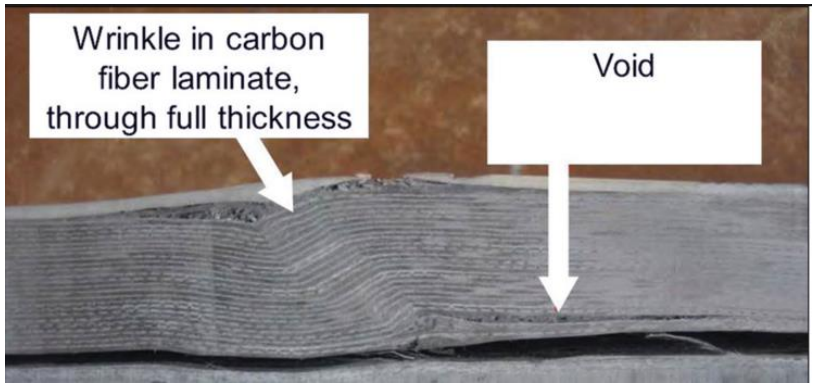


STL785C – STRUCTeam 80m Blade design deploying carbon sparcaps

Why Pultrusion?

Product Robustness

- Cost of Poor Quality
  - Sparcap is structurally critical!
  - Known fatigue failure in large blades due to sparcaps wrinkles
  - NCR/ factory **downtime costs** for wrinkle repairs **(12% capacity)**
  - Scrap rate for blades affected by wrinkles is 1-3%
  - Pultrusions = level of ‘guaranteed’ quality



Why Pultrusion?

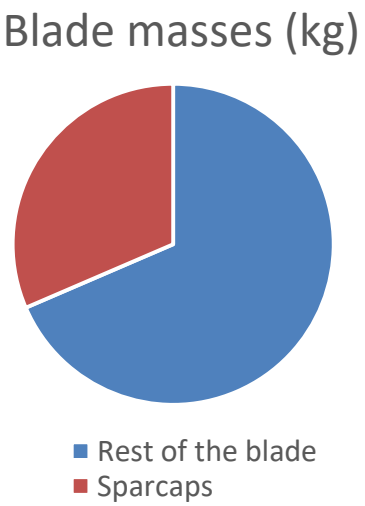
Cost Implications

- Pultruded solutions offer lower overall blade cost (vs. infusion)

- Material Cost
  - GRP and CFRP both show potential EUR/kg savings
  - Pultrusion use lower cost resin systems
  - Sparcaps are approx. 30% of total blade mass, so large potential material volume

- CAPEX
  - Pultusion tooling fairly basic
  - Lower workshop space costs

- OPEX
  - Suited to automated processes
  - Shorter blade manufacturing cycle times



OEMs' Unmet Needs

Current Spar Cap Technology

- 90% infusion-based/ 5% prepreg-based (Carbon)/ 5% pultrusion-based (Carbon)
- CF Pultruded spar cap pioneered and patented

OEMs need a solution

- Robust 'off-the shelf' pultrusion product
  - Specific properties, pricing, supply chain security, DNV-GL
- Tailored blade designs
  - Demonstrable performance gains
  - Certifiable designs

Unmet Needs

- **Epoxy solution for GF / CF pultrusion**
- **Enhanced fiber impregnation** and easy processing at pultrusion speed > 1 m/min
- **Solid supply chain** for pultruded part
- Technology **freedom to Practice**
- Ready to use **integrated solution**

PULLWIND AS A SOLUTION

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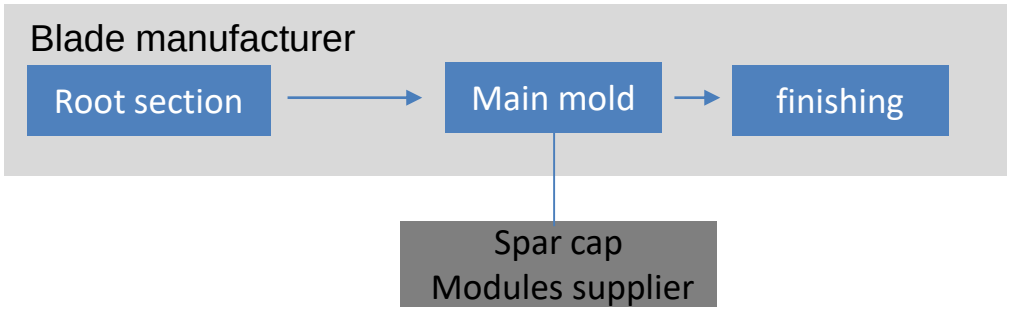
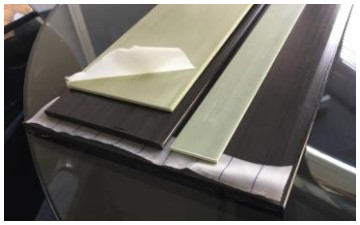
Blade Fabrication process

Today

Tomorrow





BENEFITS FOR BLADE MANUFACTURER

For a typical 80 m blade

- 5-15% Lower cost blade
- 15% CAPEX reduction
- 20% Man Hour reduction
- Lower defect rate

Business case - STL Blade Portfolio

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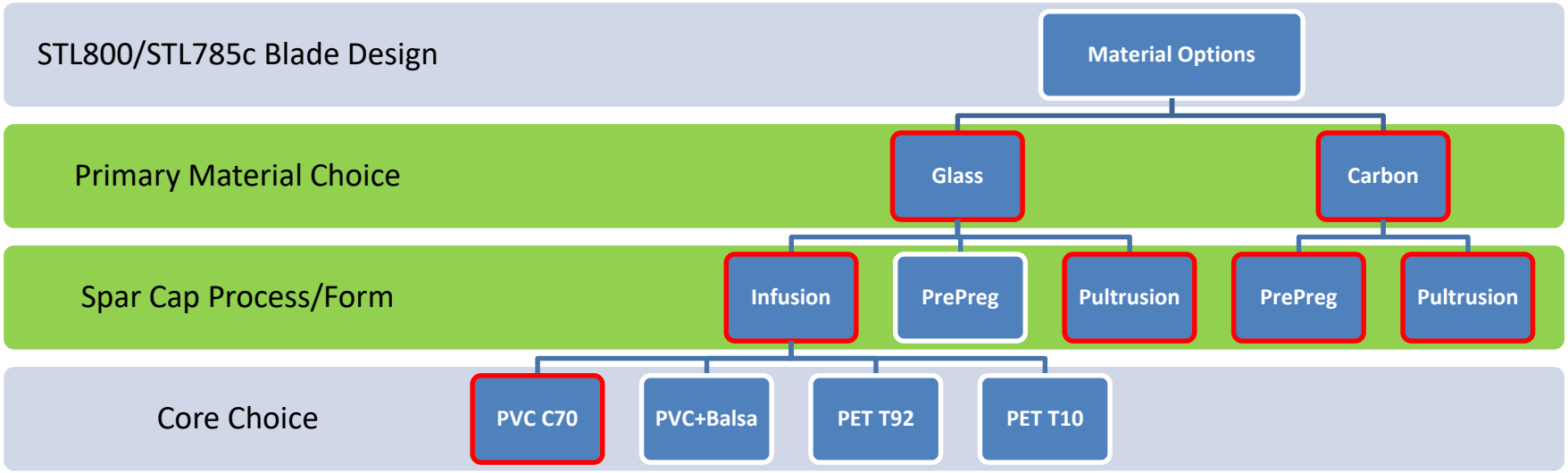
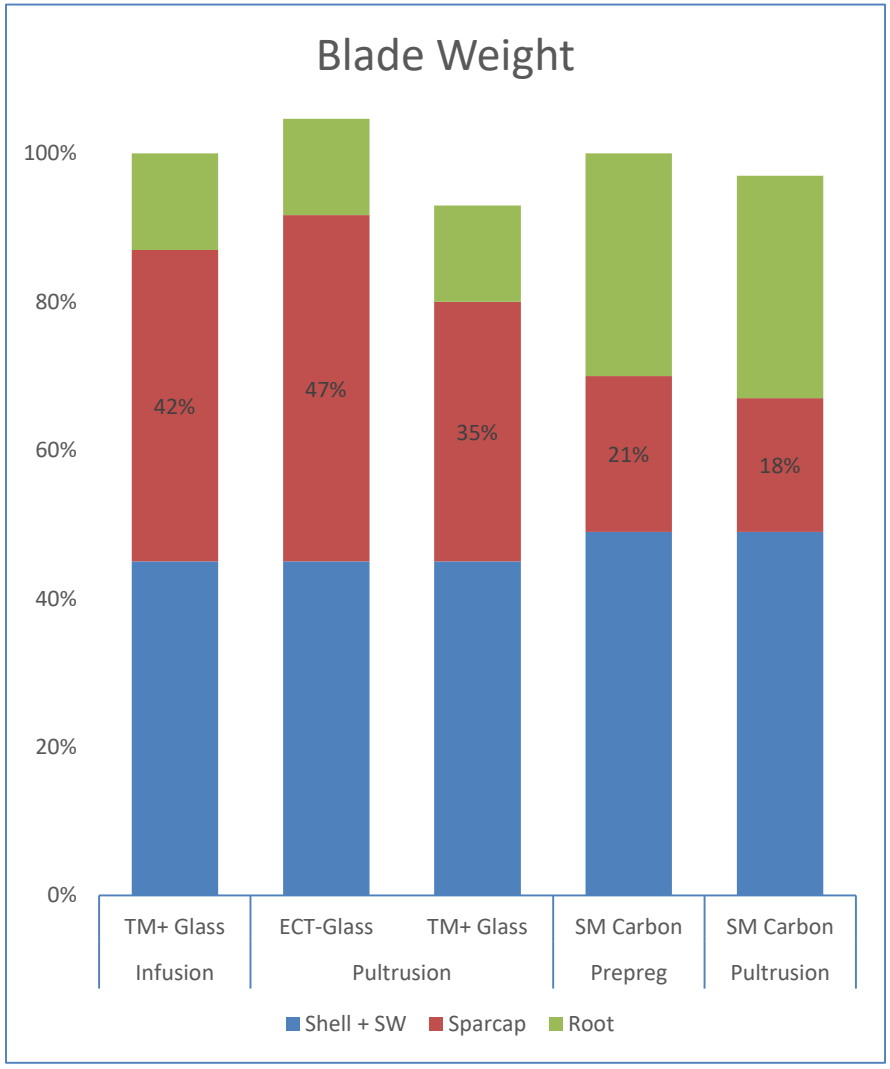
Blade Name	Unit	STL50	STL50c	STL565	STL635	STL635-2	STL690c	STL800	STL785c	STL820c
Blade Length	[m]	50.0	50.0	56.5	63.5	63.5	69.0	78.5	78.5	82.0
Rated Power	[MW]	2.0	2.0	2.0	3.3	3.3	3.0	6.0	6.0	5.0
Wind Class	[IEC]	IIIB	IIIB	S	S	IIIA	IIIA	IIA	IIA	IIIB
Average Wind Speed	[m/s]	7.5	7.5	7	9	7.5	7.5	8.5	8.5	7.5
PCD	[mm]	2110	2110	2110	2600	2600	3000	4100	4100	3600
Root Connection Solution		T-Bolt	T-Bolt	T-Bolt	T-Bolt	T-Bolt	T-Bolt	Insert	Insert	Insert
Root Connection		60xM36	60xM36	64xM36	74xM36	64xM39	82xM36	140xM36	140xM36	82xM36
								96xM42	96xM42	
Pre-bend	[m]	1	1.5	2	2	2	2	2	2	3
Max Chord Length	[m]	3.63	3.63	3.55	4.16	4.00	4.58	5.36	5.10	5.30
Process		Infusion	Infusion	Infusion	Infusion	Infusion	Prepreg	Infusion	Prepreg	Prepreg
Sparcap Material Material		Glass/ Epoxy	Carbon/ Epoxy	Glass/ Epoxy	Glass/ Epoxy	Glass/ Epoxy	Carbon/ Epoxy	Glass/ Epoxy	Carbon/ Epoxy	Carbon/ Epoxy
Core		PVC	PVC	PVC	PVC	PVC	PVC	PVC	PVC	PVC
Nominal Rotational Speed	[rpm]	15	15	12	12.5	12.5	11.1	12	12	11.34
Cut-in Wind Speed	[m/s]	3	3	3	3	3	3	3	3	3
Cut-out Wind Speed	[m/s]	25	25	25	25	25	25	25	25	25
Center of Gravity	[m]	14.8	12.2	15.9	20.11	22.77	16.35	27.35	23.27	23.65
Weight (excl. root connection)	[kg]	9100	7200	11030	21150	17100	18390	33600	23870	22560
1st Flapwise Freqruency	[Hz]	0.67	0.86	0.547	0.442	0.427	0.652	0.387	0.492	0.531
1st Edgewise Frequency	[Hz]	0.97	1.272	0.878	0.914	0.693	0.989	0.703	0.806	0.823

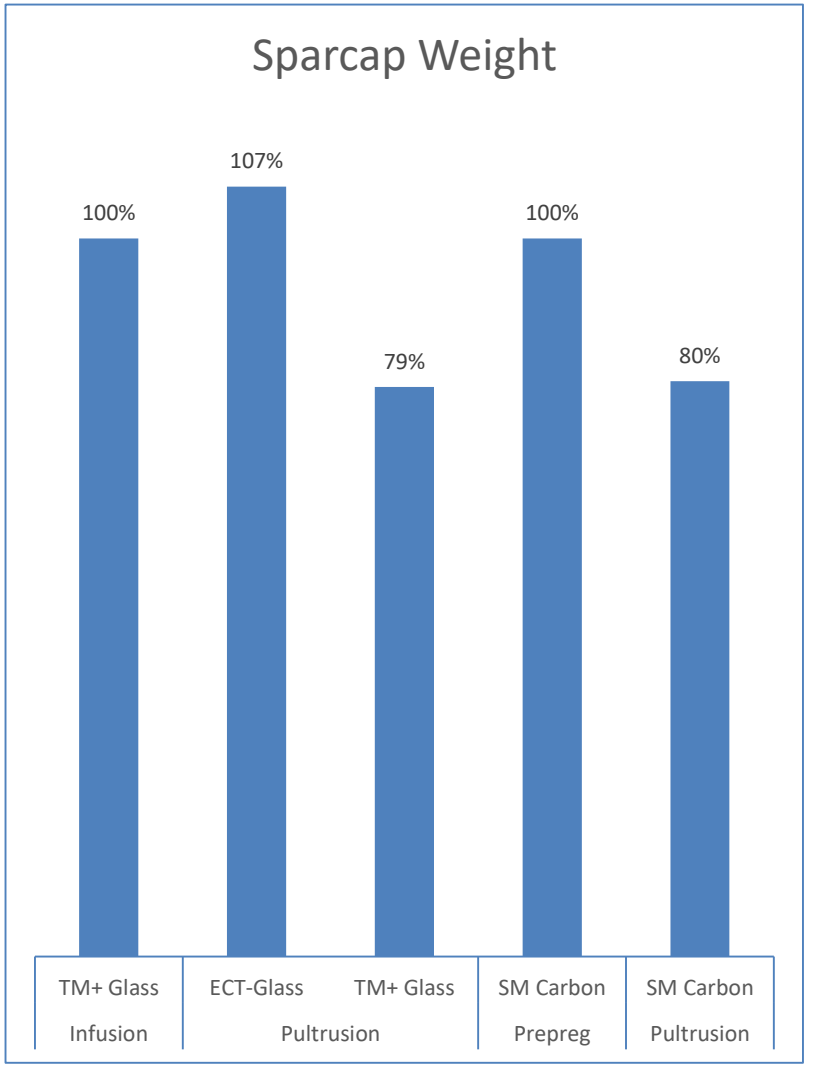
Blade Technology Options



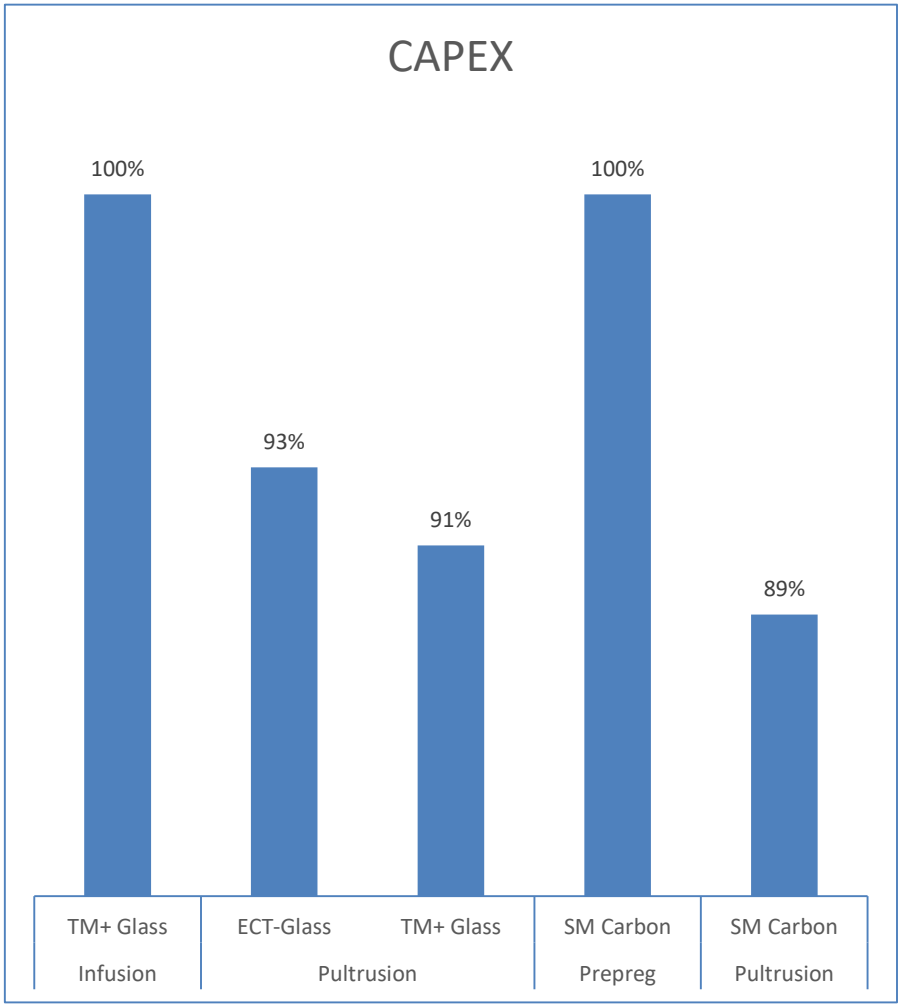
- STL Detailed Cost Model 80m Blade
  - Material Costs
  - Labour Costs
  - CAPEX (Tooling)
  - Cycle Time

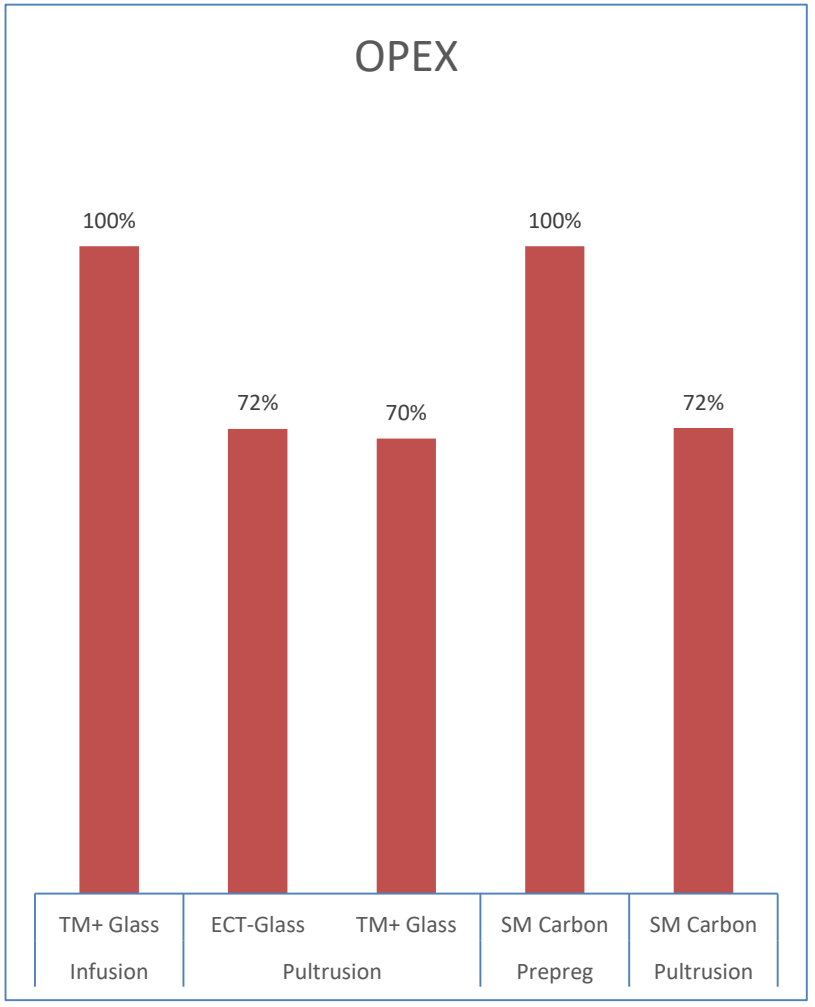
Blade Weight



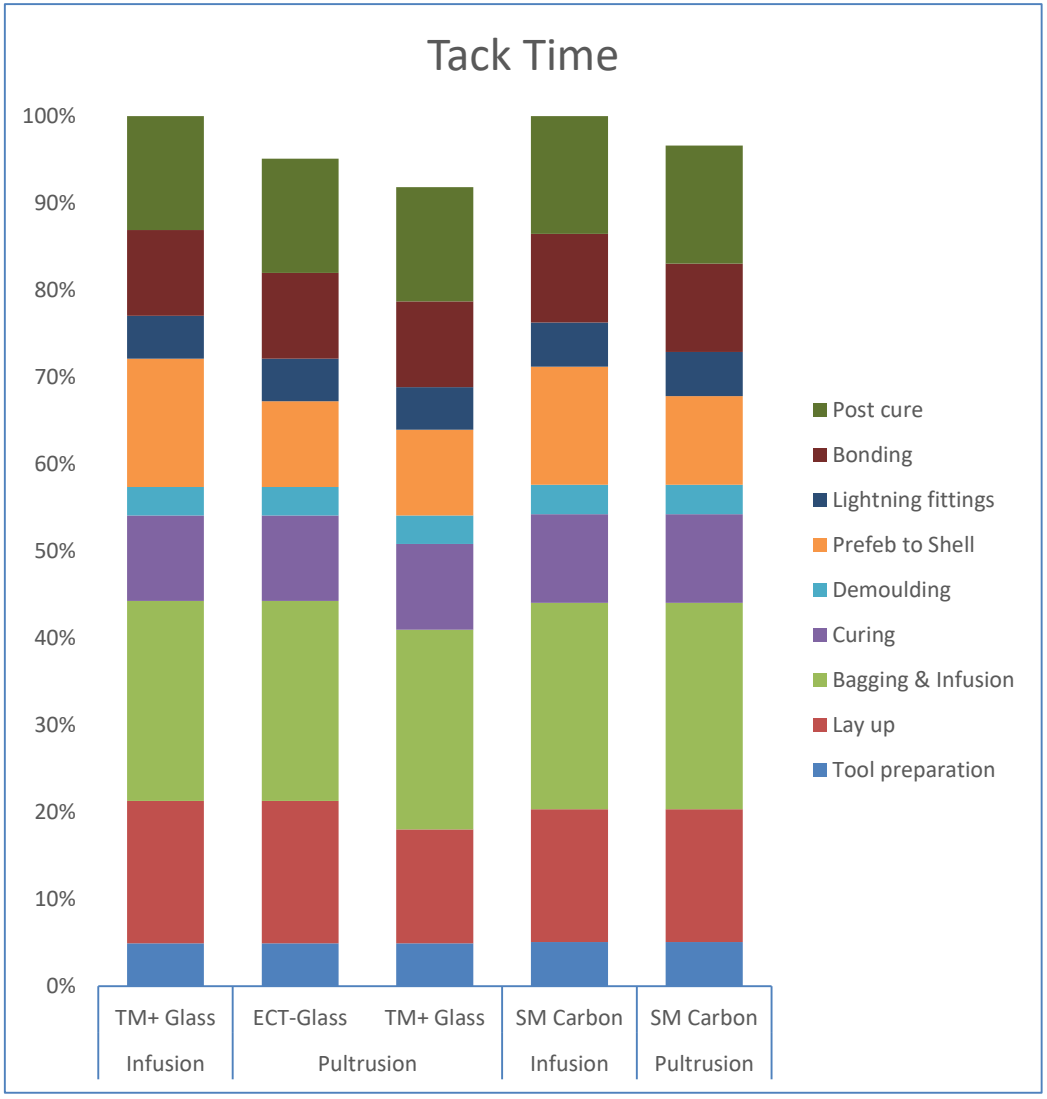


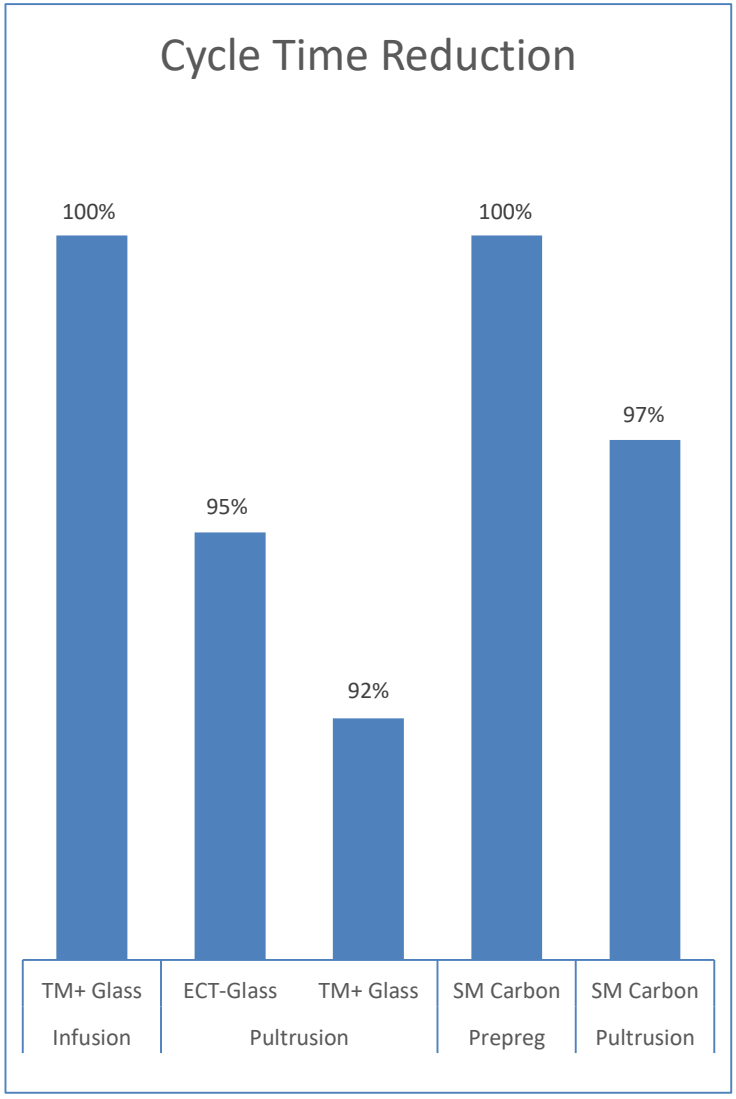
CAPEX & OPEX



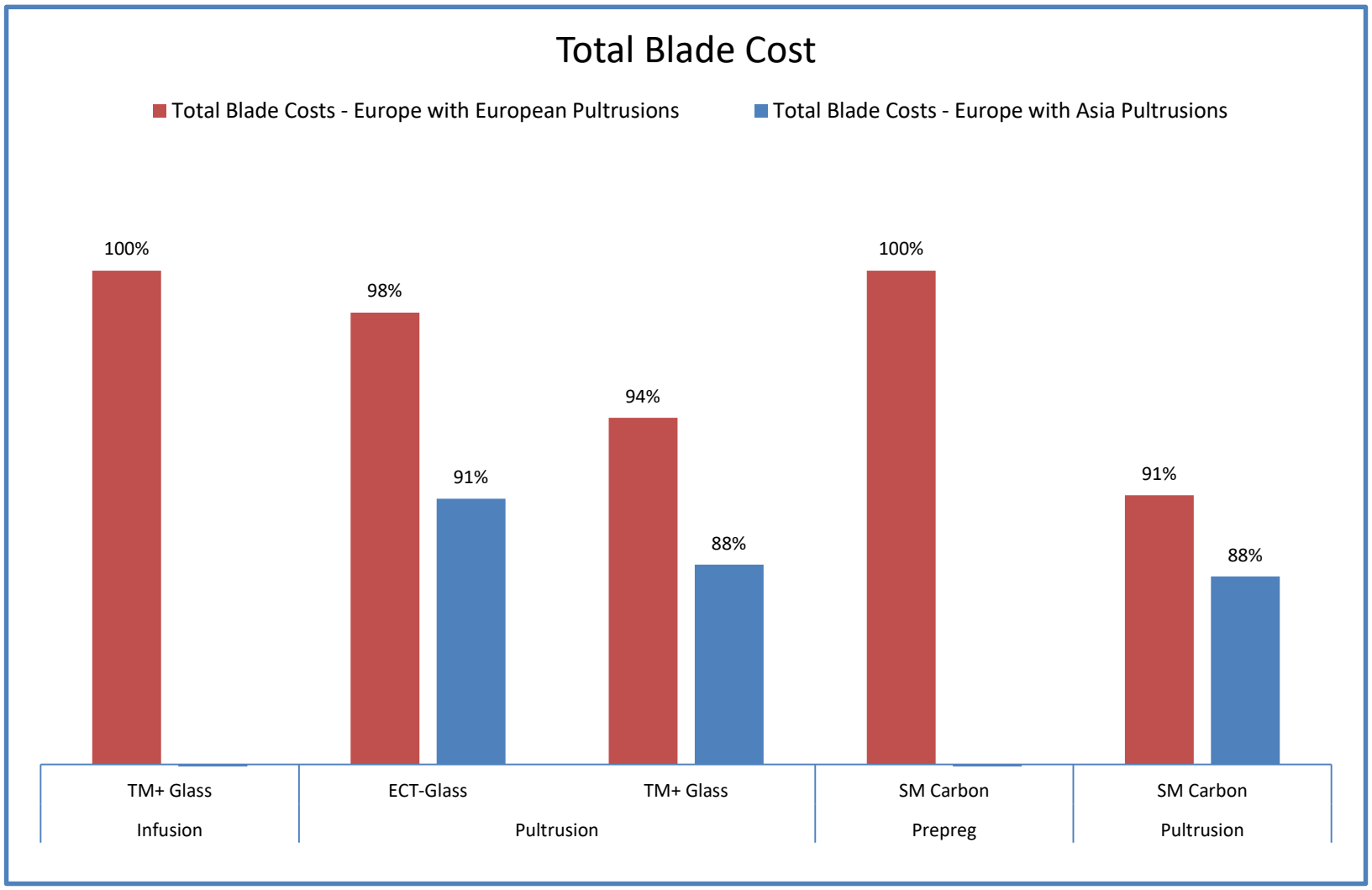


Cycle Time

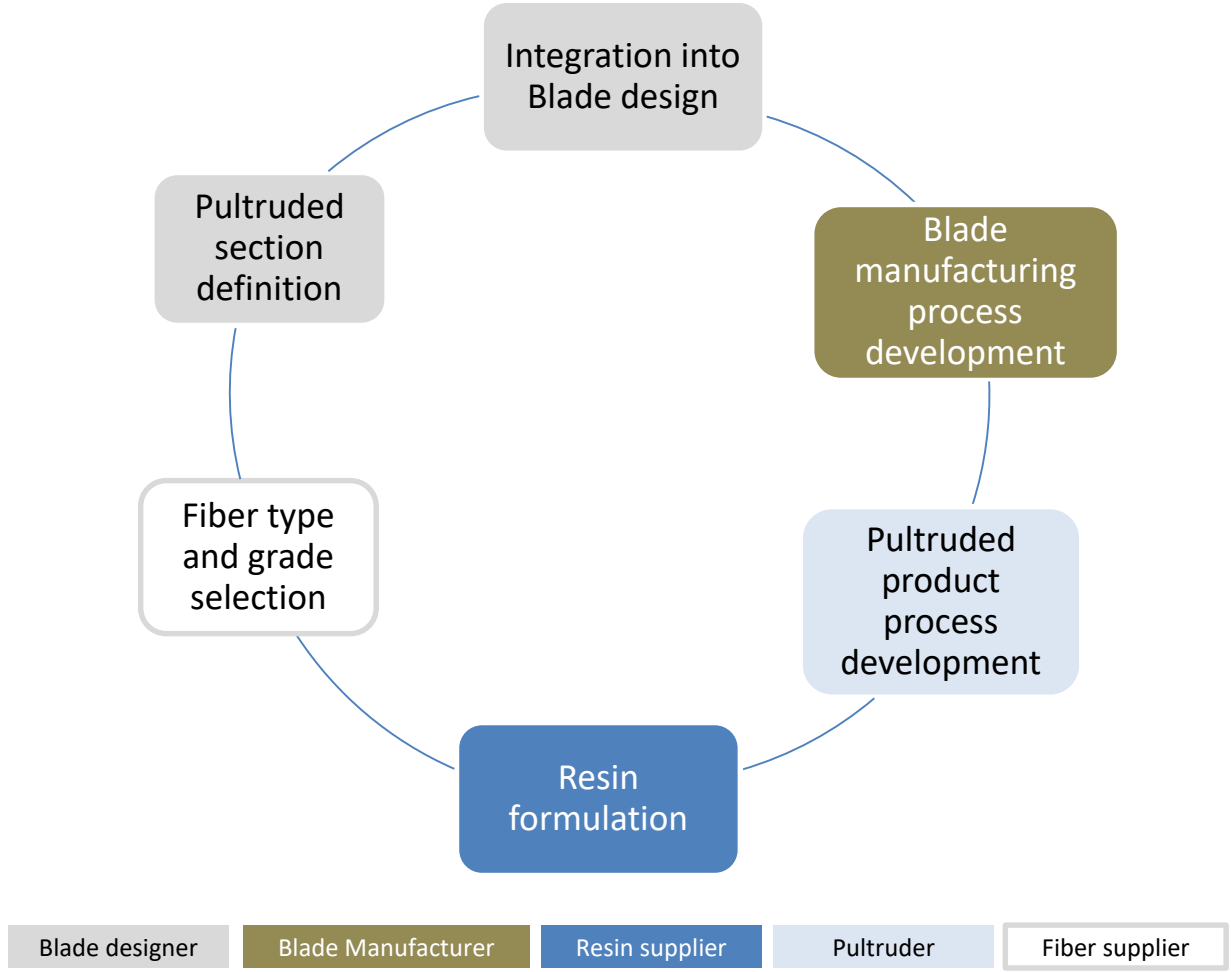




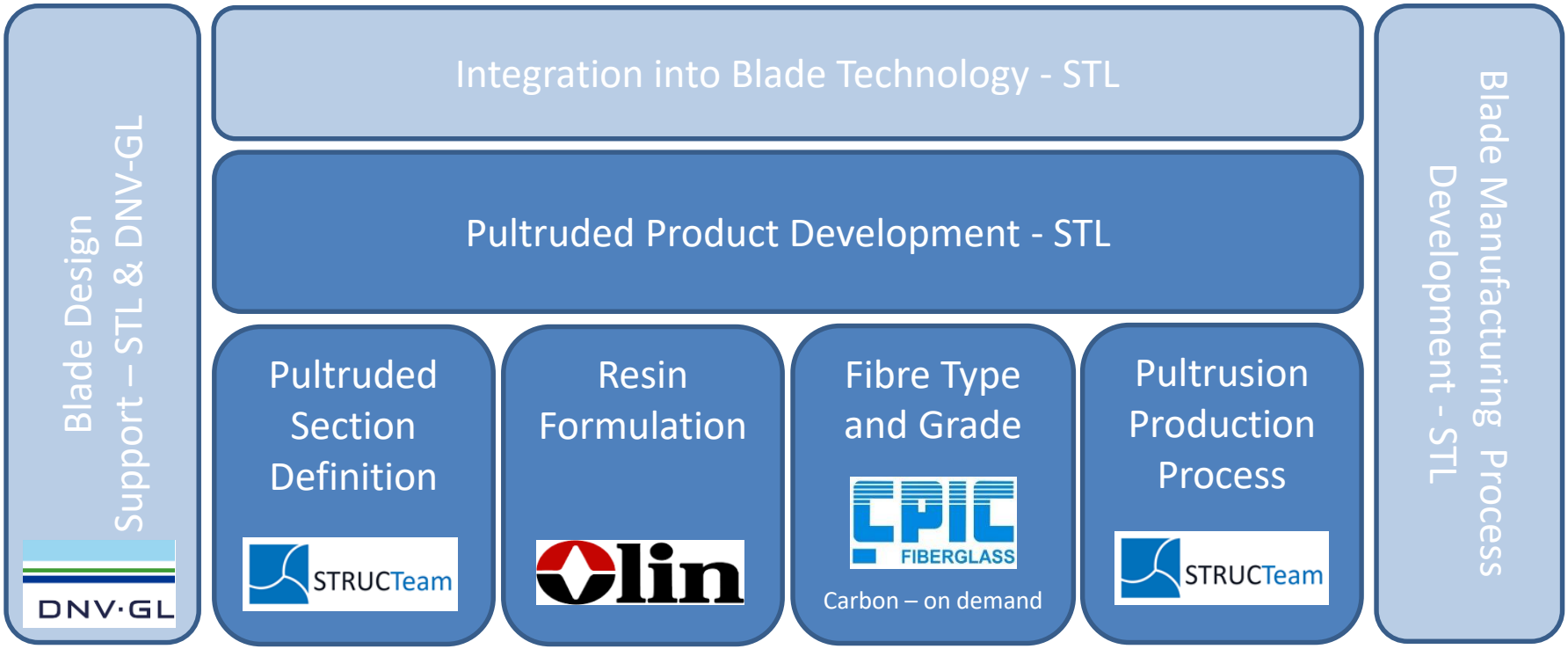
Blade Total Cost



OEM Challenges - adopt pultrusion



PULLWIND – Consortium Organisation



Conclusion

Pullwind Business case:

- Overall cost savings achievable for all Business Cases with pultruded sparcaps
  - Between 9% and 12% for 80m Blades
  - Most benefitial case is for a blade manufactured in Europe with pultrusions shipped from low labour cost country (i.e. China)
- Pultruded sparcap designs:
  - Allow for high reduction in OPEX (labour costs - 15 - 30%)
  - Allow for reduction in CAPEX
    - → 10% CAPEX reduction for 80m blade
    - → No need for prepreg cutting machine, consolidation table and cold storage
  - Allow for overall Blade weight reduction (up to 3 - 7%)

Pullwind as a Solution

- Established pultruded product – Fulfil DNV-GL requirement for blade
- STL have design and manufacturing support to help adopt pultrusion in retrofit existing blade and or new generation blade designs
- Flexibility of supply chain

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