Composite Technology for Work Boats - Can Composites Pay Their Way?

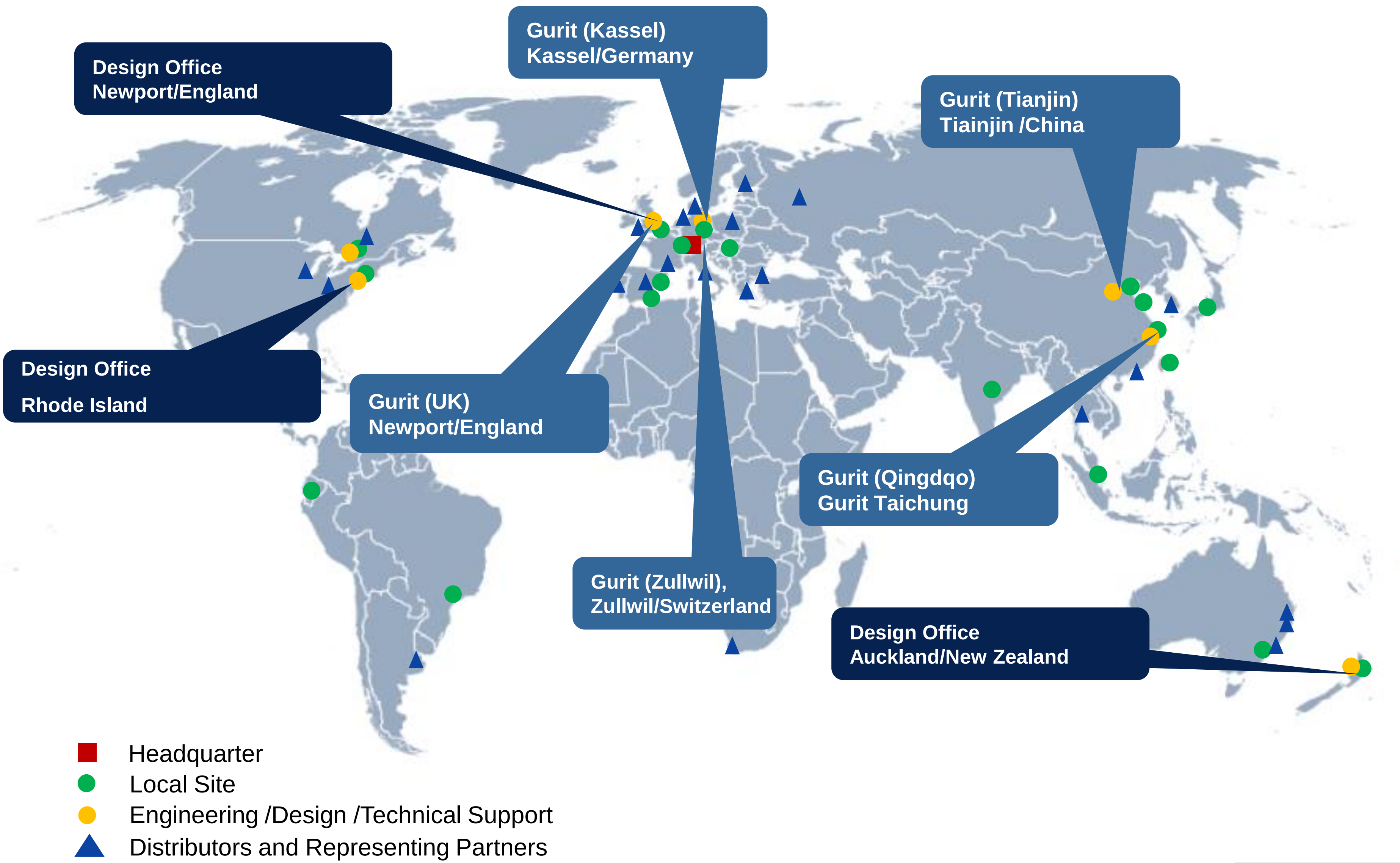
Wind Energy Tooling Transportation Marine

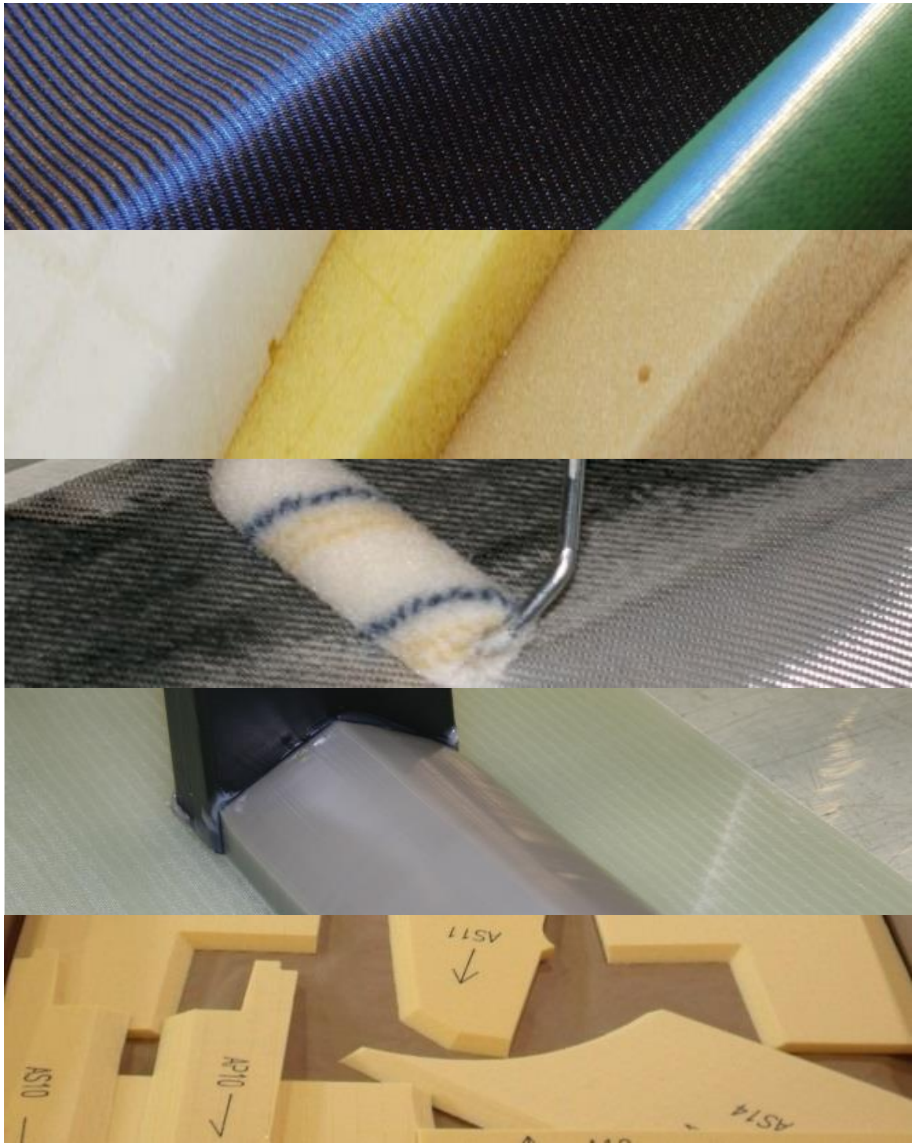
Composites Australia - April 2015

DANISH YACHTS

STIMSON YACHT DESIGN

Gurit
OUR GLOBAL FOOTPRINT





GURIT COMPOSITE MATERIALS

OUR OFFERING

- Pre-impregnated materials (prepregs)
- Full range of structural core materials including Corecell, PVC, PET, Balsa
- Formulated resins, adhesives and gel-coats
- Material cutting and kitting
- High Level Engineering Design and Technical support.

OUR FOCUS

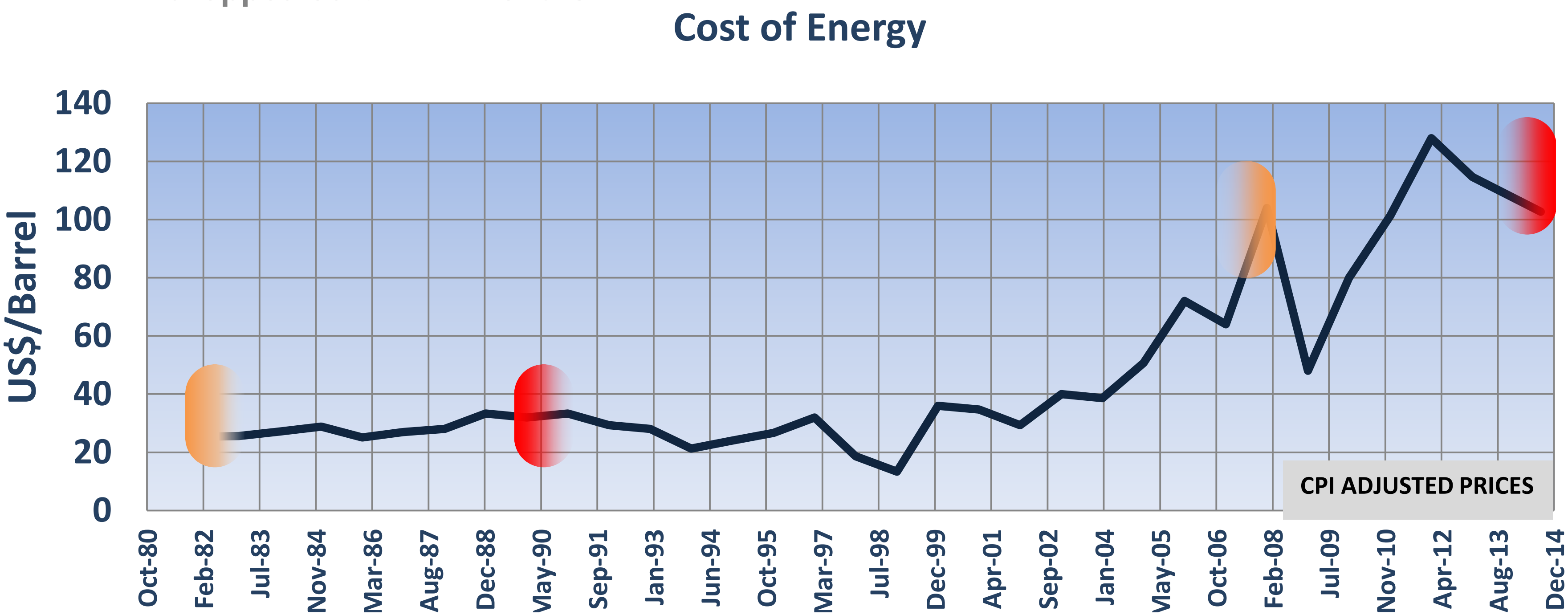
- Successfull adoption of advanced composite materials across a wide variety of sectors through design and innovation

Can Composites Pay their way?

- Rising fuel prices over the last 30 years has lead to increasing use of structural composites in transport, including aircraft and private cars. From initial adoption in components in the 80's to 90's to full structures in the 2000's

- In terms passenger miles per litre of fuel commuter ferries are one of the more energy intensive forms of public transport, so why do we have carbon cars and carbon planes but aluminium ferries?

- Are advanced composites still a realistic option given that fuel prices have now dropped 50% in 12 months?



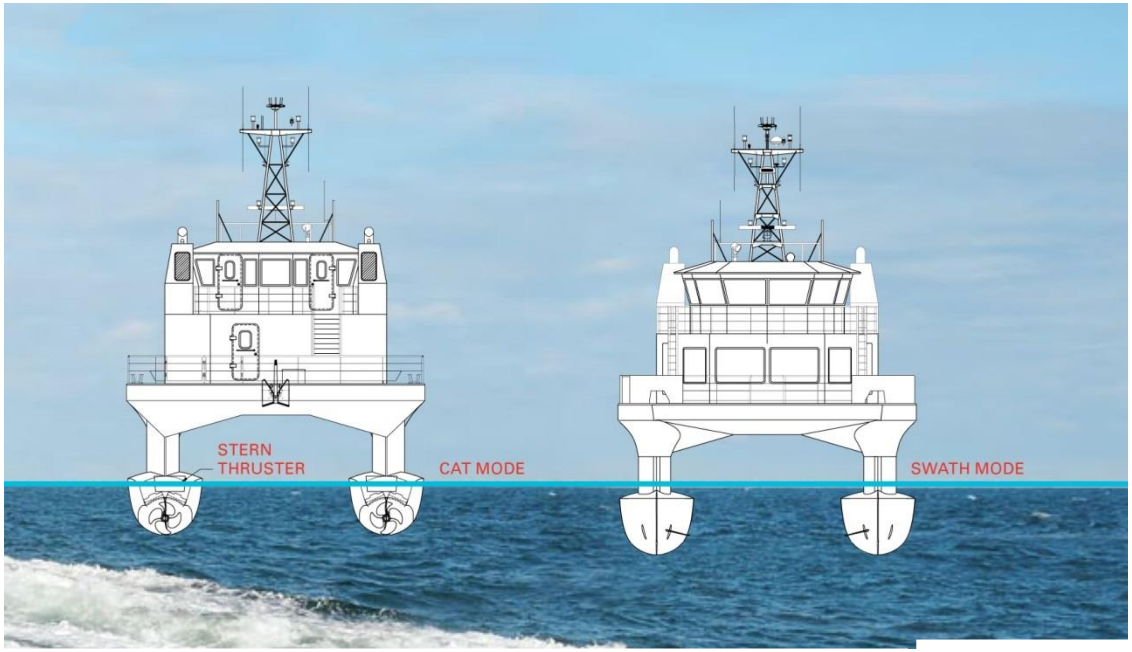
Danish Yachts - 24m Cat SWATH

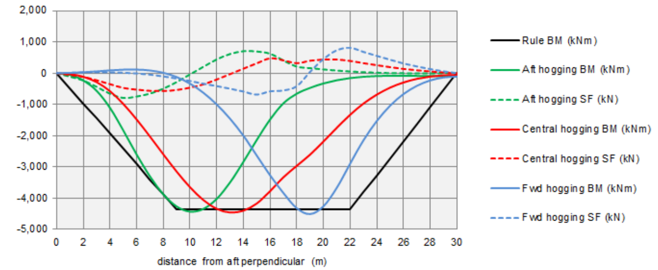
Danish Yachts – 24m Cat SWATH

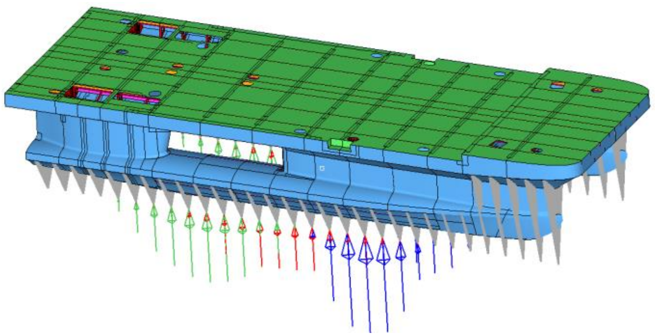
- Danish Yachts
  - Specialist in advanced composite construction and extensive use of carbon fibre for high performance and fuel efficient vessels.
  - Believers in cutting edge composite technology.
  - Long term engineering design and materials collaboration with Gurit.

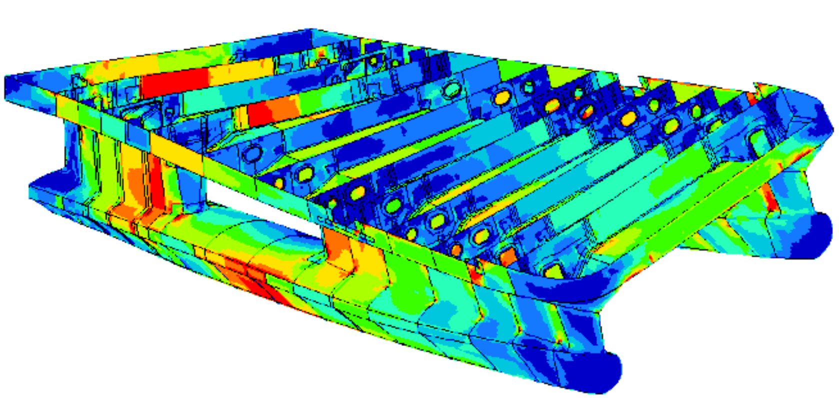
- 24m Cat SWATH Commerical Vessel
  - Commercial vessel for servicing offshore windfarms. World's first all carbon composite SWATH
  - Gurit engaged to re-engineer the composite structure of Boat 5 of this class, and reduced the structural weight by 15%.
  - Full carbon foam cored design using Corecell M-foam and Prime 20LV Epoxy resin supplied by Gurit.

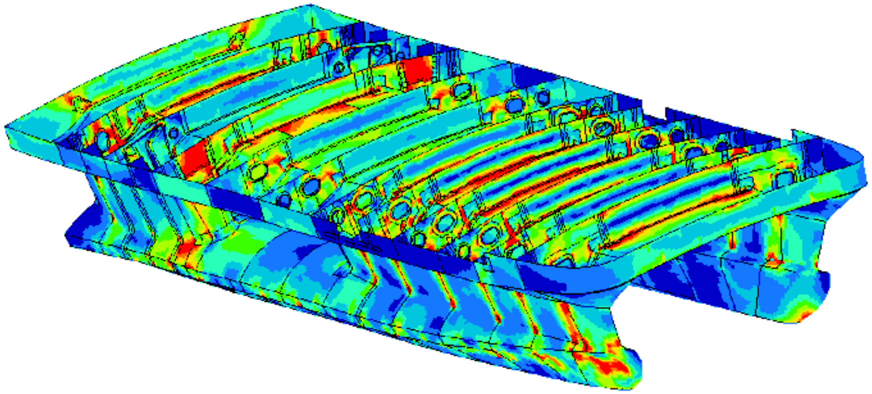
Danish Yachts – 24m Cat SWATH











Danish Yachts – 24m Cat SWATH

- SWATHs (**S**mall **W**aterplane **A**rea **T**win **H**ull) are used where excellent sea keeping is an operational requirement.
- Three modes of operation, conventional catamaran, SWATH and with crossdeck at water level. Achieved through water ballast in 45 seconds. Designed to provide comfort under way and a stable operating platform alongside wind turbines.
- Vessel is classed by Germanisher Lloyd.
- Hull configuration generates high loads on the connecting structure and struts.
- Narrow waterline plane drives the sea keeping performance of the vessel by reducing vertical acceleration in a wave encounter.   Requires tall narrow legs which makes for a challenging structure, as the hydrodymic requirement is paramount.
- Gurit provided structural engineering for the composite structure, which required indepth FEA of the global structure.

Danish Yachts – 24m Cat SWATH

Danish Yachts – 24m Cat SWATH

- „Flat Panel“ construction infused carbon and epoxy over Corecell M-Foam
- Female moulded hull for most hydrodynamically critical part, otherwise minimised mouds and jigs, use of infusion tables rather than custom tooling.
- Commercial work boat finish, with minimum filling fairing beyond what is needed to create a durable surface finish.
- Equivilent to a painted alloy finish initially, but better performance over time due to lack of corrosion issues, and no plate denting.
- Similar methods are used by a cluster of Northern European yards to create commercial work boats with a materials palettes most people consider only applicable for race boats.
  - Is it a regional specialisation and available capacity?
  - Is it due to European fuel costs and environment pressure or legislation?
  - Should this be a method we see more of outside of Europe?

20m, 22 knot, 150 Passenger Ferry

Gurit

- Gurit undertook a case study based around and E-glass foam cored ferry.
- Existing vessel used as a real life starting point to answer the question of „can composites pay their way“ for commercial vessels.
- Construction Method
  - Flat Panel.
  - Moulded lower hull, moulded top hat beams and mullions.
  - Infused epoxy using multiaxial non mat backed fabrics.
  - Aluminimum, Carbon and E-glass versions considered.

20m Passenger Ferry –Case Study

Gurit

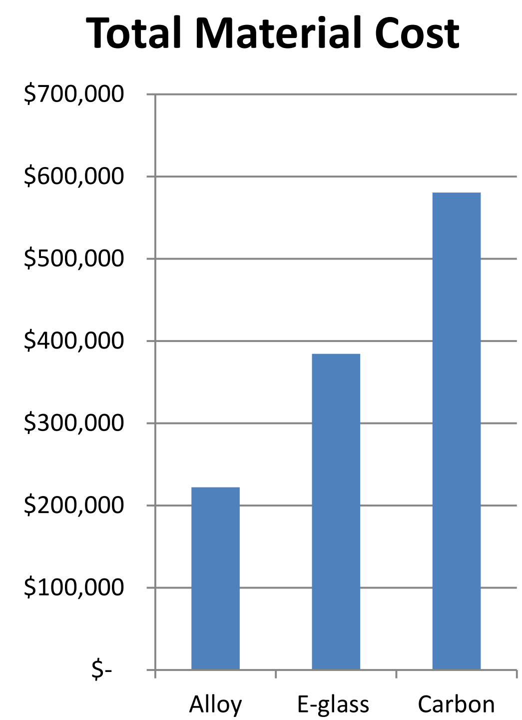
		Alloy	E-Glass	Carbon	
Structural Weight	subtotal	16820	12615	8410	kg
Insulation	Acoustic	1200	578	578	kg
	Fire	300	900	900	kg
	Thermal	300	0	0	kg
	subtotal	1800	1478	1478	kg
Propulsion Engines		2900	2900	2900	kg
Furniture and Systems		6607	6607	6607	kg
Light Ship Weight	subtotal	28127	23600	19395	kg
People		150	150	150	No.
Fuel		3500	3500	3500	l
	subtotal	15690	15690	15690	kg
Full Load	Total	43817	39290	35085	
	delta	0	-4527	-8732	kg

- Three structures considered, E-glass, Carbon and Alloy to equivilient design standards (DNV-HSLC).
- Insulated solution to fire protection.   Less thermal and accoustic insulation weight on the composite options.
- Same propulsion package for each version to minimise variables in weight and cost assumptions.
- Same fitout, passengers and fuel.

Materials Cost - Estimate

Gurit

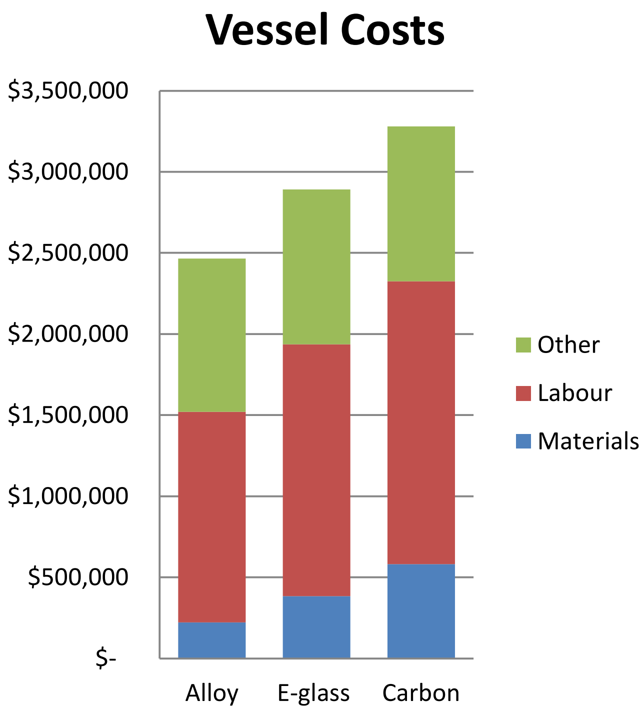
	Alloy	E-glass	Carbon	
Structural Weight	16820	12615	8410	
$ per kg including wastage	$ 13	$ 25	$ 61	$/kg
Materials Cost	$ 222,024	$ 315,375	$ 513,010	NZ$
Infusion Disposables		$ 27,700	$ 27,700	NZ$
Tooling Cost				
Lower hull moulds area		79	76	m2
beams and mullion mould area		9.4	9.4	m2
CNC Cut mould cost		$ 1,900	$ 1,900	NZ$/m2
Flat fabricated mould cost		$ 1,500	$ 1,500	NZ$/m2
Tooling Cost Total		$ 164,200	$ 158,500	NZ$
Amortised over how many vessels		4	4	NZ$/m2
Cost to be recovered per vessel		$ 41,050	$ 39,625	NZ$
Total Material Cost	$ 222,024	$ 384,125	$ 580,335	NZ$



- Materials costs for each version evaluated.
- Alloy a mixture of plate and extrusions.
- Tooling costs, and infusion disposables included in sum of composite material costs.
- Carbon hull mould slightly smaller due to less weight and so less expensive

Full Construction Costs - Estimate

Manufacturing Costs	Alloy	E-glass	Carbon	
Man Hour per 000kg structure	500	750	1,120	Man hours per tonne
Man Hour per 000kg of fit out	700	700	700	Man hours per tonne
Man-hours Structure	8,410	9,461	9,419	
Man hours per fit out	7,915	7,690	7,690	
	$ 65	$ 65	$ 65	/hour ex GST
Structure Labour Cost	$ 546,650	$ 614,981	$ 612,248	
Fit out Labour Cost	$ 514,469	$ 499,818	$ 499,818	NZ$
Insulation cost	$ 15,000	$ 25,000	$ 25,000	NZ$
Subtotal Variable Cost	$ 1,298,143	$ 1,551,624	$ 1,745,101	NZ$
Fixed Costs				
Engine	$ 250,000	$ 250,000	$ 250,000	NZ$
Furniture	$ 180,000	$ 180,000	$ 180,000	NZ$
Finishing and Lining	$ 200,000	$ 200,000	$ 200,000	NZ$
Electronics and Equipment	$ 300,000	$ 300,000	$ 300,000	NZ$
Total Vessel Cost	$ 2,228,143	$ 2,481,624	$ 2,675,101	NZ$
Shipyard's Profit	15%	15%	15%	
Total Vessel Sell Price	$ 2,562,364	$ 2,853,867	$ 3,076,366	NZ$
Price Difference		$ 291,503	$ 514,002	NZ$

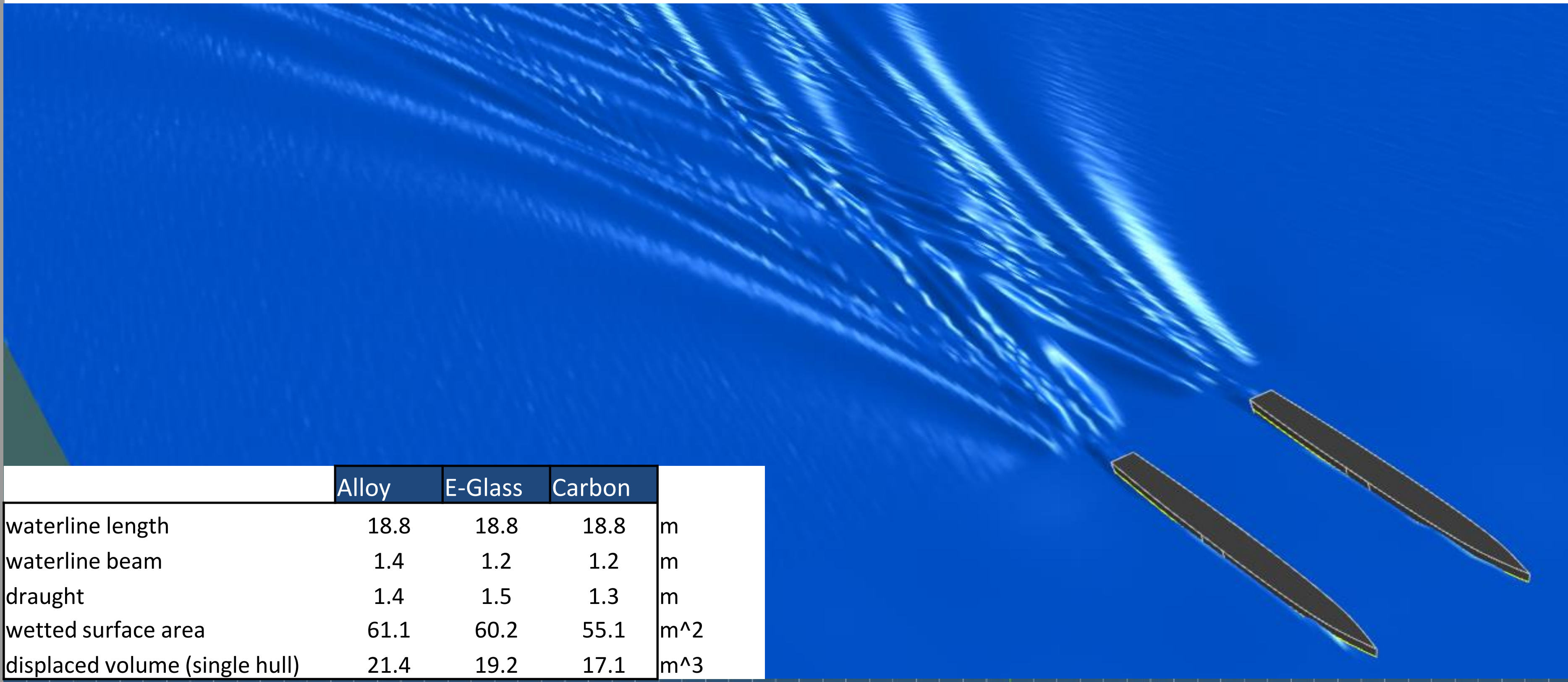


- Carbon Ferry 500k more expensive at purchase.
- E-glass Ferry 300k more expensive at purchase.

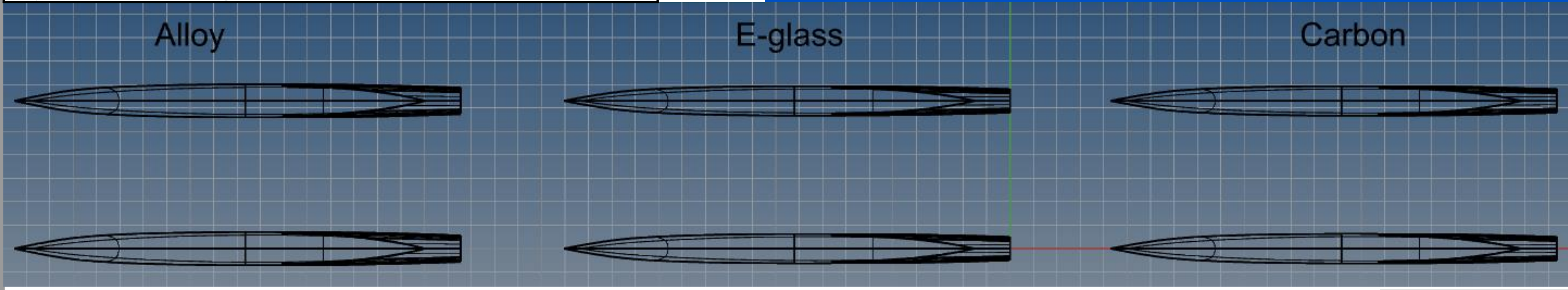
20m Passenger Ferry Resistance

- Three versions of the same basic hull shape as the original vessel
- Internal hull beam set to provide clearance for engine due to narrow displacement hull form. For composite this is to inside skin of foam sandwich, for the alloy design this is to the inside of the frame depth meaning a wider waterline beam
- Maximum hull draught limited to the same as the original E-glass version.
- Transom immersion kept as constant as possible between each version
- „Slender Body“ Hull resistance model used within HullSpeed software, hull resisitance work completed by Stimson Yacht Design.

20m Passenger Ferry Resistance



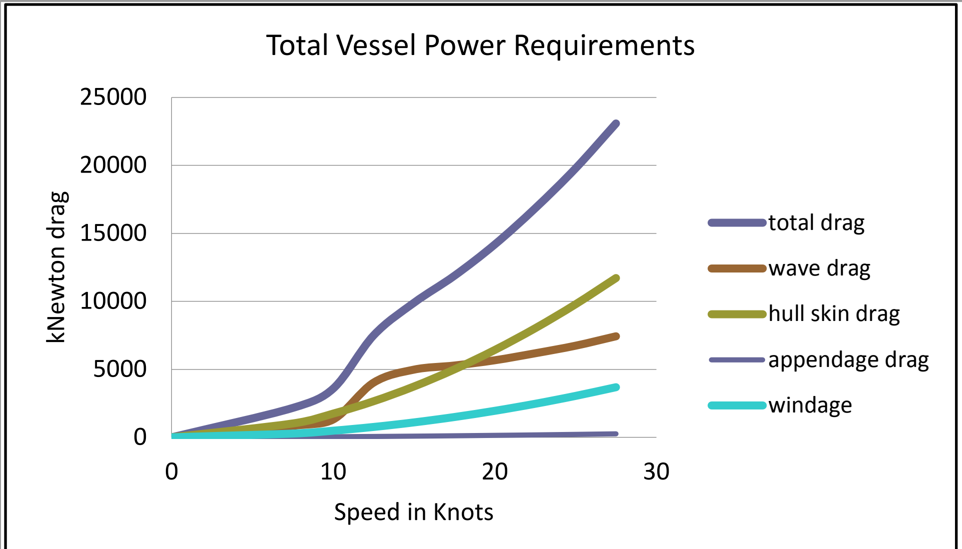
	Alloy	E-Glass	Carbon	
waterline length	18.8	18.8	18.8	m
waterline beam	1.4	1.2	1.2	m
draught	1.4	1.5	1.3	m
wetted surface area	61.1	60.2	55.1	m^2
displaced volume (single hull)	21.4	19.2	17.1	m^3

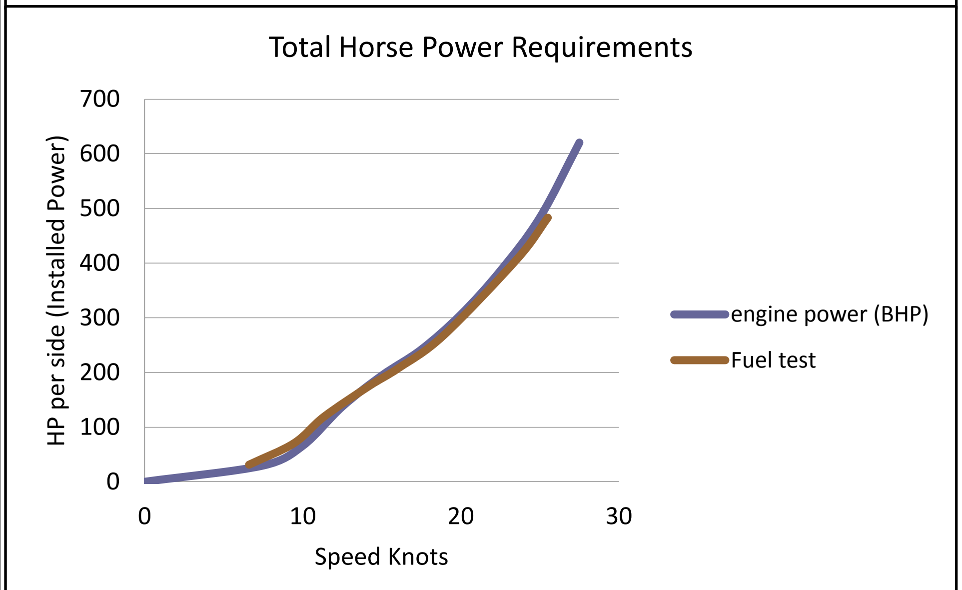


20m Passenger Ferry – HP and Fuel Burn

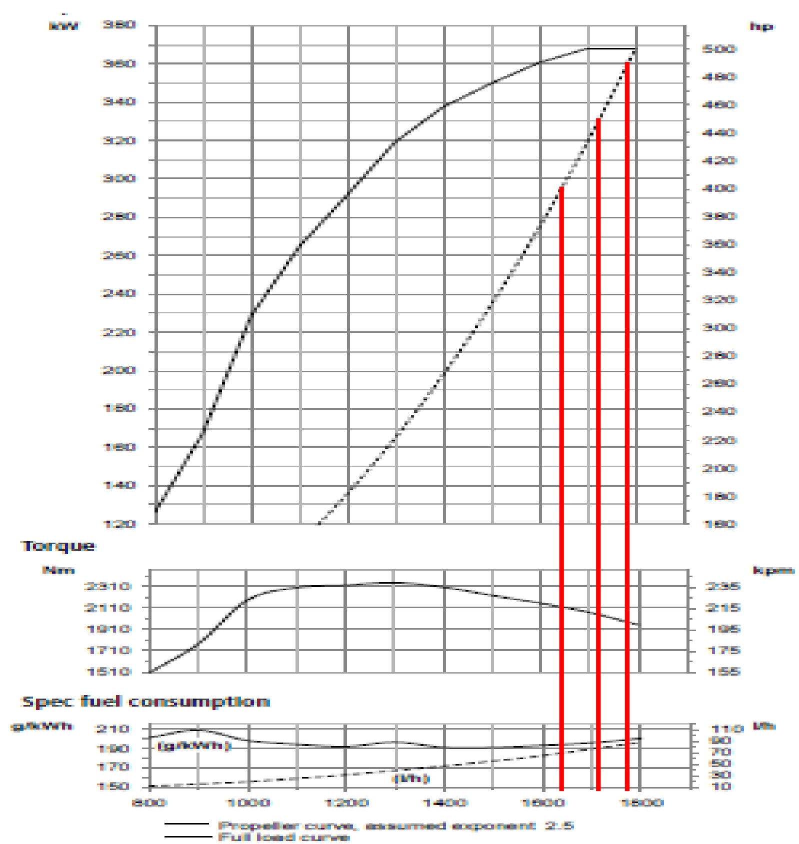
- Aerodynamic, appendage,and hull skin drag added to wave making to provide total drag
- Driveline and propellor efficiencess inputted to give installed engine requirements. Compared with on water measurements from parent vessel to ensure accuracy of the modelling method.
- Power plant for each version was the same to keep weight and cost constant between all three versions.
- Engine manufacturer‘s fuel curve used to derive specific fuel consumption at the three different maximum ratings. Hourly fuel consumption at 100% capacity and also 25% passenger load calculated.

20m Passenger Ferry – HP and Fuel Burn





	Alloy	E-Glass	Carbon	
HP/side FLD	487	450	408	HP
HP/side at 25%	400	365	326	HP
Fuel Consumption	161	145	129	L/h



20m Passenger Ferry - Utilisation

Depart	Arrive		Capacity	Miles
5:45	6:15	O	100	11
6:00	6:30	I	25	11
7:15	6:45	O	100	11
7:30	8:00	I	25	11
8:45	8:15	O	100	11
9:00	9:30	I	25	11
10:15	9:45	O	50	11
10:30	11:00	I	50	11
11:45	11:15	O	50	11
12:00	12:30	I	50	11
13:15	12:45	O	50	11
13:30	14:00	I	50	11
14:45	14:15	O	50	11
15:00	15:30	I	100	11
16:15	15:45	O	25	11
16:30	17:00	I	100	11
17:45	17:15	O	25	11
18:00	18:30	I	100	11
19:15	18:45	O	25	11
19:30	20:00	I	100	11
20:45	20:15	O	25	11
21:00	21:30	I	50	11
22:15	21:45	O	25	11
22:30	23:00	I	50	11
23:45	23:15	O	20	11

Totals	Nm	275
	Hours	12.5

- Utlisation based on an Auckland commutor route from city centre to Waiheke Island. 11 Nm each direction.
- 25 trips a day at 22knots, 275 Nm in 12.5hours of operation per day, 300 days a year.
- Full utilisation during the commutor runs with low numbers on return. % of capacity shown in table.
- Tourist numbers during the middle of the day
- Estimated daily fuel burn and annual fuel cost using the whole sale diesel price.
- Annual fuel savings for the lighter weight composite versions estimated

	Alloy	E-Glass	Carbon	
Total Daily Fuel Burn	1751	1572	1383	litres
Total Annual Fuel Burn	525410	471703	415009	litres
Annual Fuel Cost	$ 493,275	$ 442,852	$ 389,626	$NZ

Net Present Value After 20 years

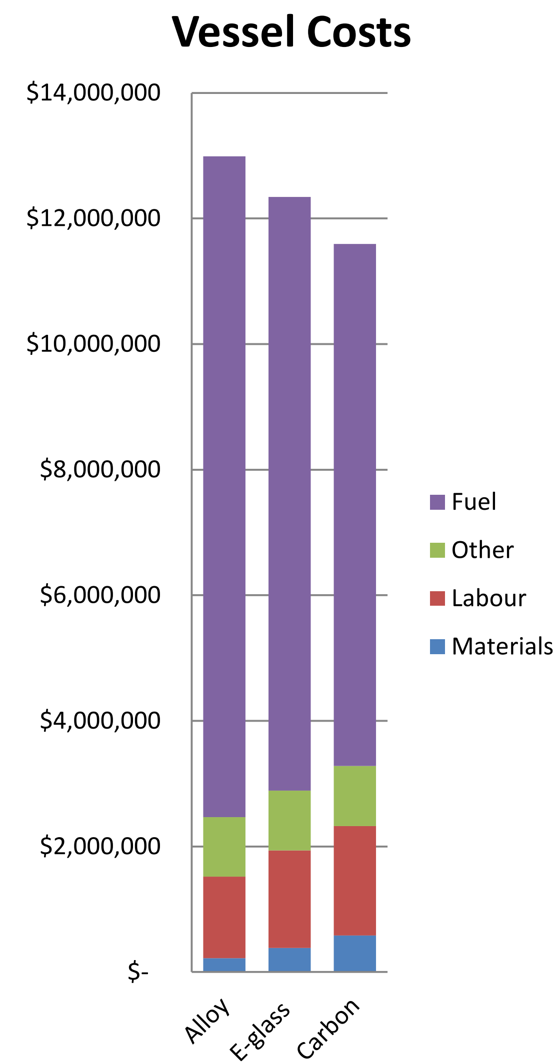
- Net Present Value analysis performed to evaluate each of the options, as both composite versions required additional up front captial investment with the promise of savings in the future
- 10% total discount rate on future earnings
  - 2% inflation rate for NZ Reserve Bank target
  - 3% cash investment rate (ex inflation)
  - 5% Risk assignment

- Only very small rise in fuel prices expected (above inflation) of 0.16% based on current market projections.
- 20 year life span of ferry modelled prior to major refit.
- Maintainence costs estimated by a remaining value of the basic structure at 20 years if no maintenance, and this cost spread over the vessels 20 year operation.   Alloy 75% retained value at 20 years.   Composite 95%.

Net Present Value After 20 years

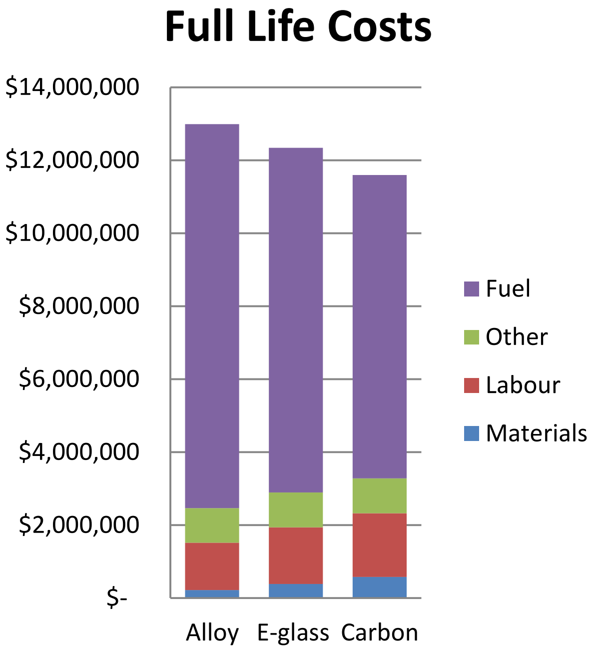
Assumptions		
Wholesale Diesel Price	93.88	cents/litre excluding GST
Diesel Prices out to 2035	0.16%	Above Inflation
Base Inflation	2%	Reserve Bank Long Term Target
Base Interest Rate (risk free)	3%	
Risk	5%	
Total Discount Rate	10%	

	Alloy	E-Glass	Carbon	
Structure Residual Value in 20 Years	75%	95%	95%	
Total Fuel Cost over 20 Years	$ 10,526,211	$ 9,450,213	$ 8,314,401	NZ$
Structure Depreciation over 20 years	$ 192,133	$ 46,135	$ 55,799	NZ$
Total Cost	$ 10,718,343	$ 9,496,347	$ 8,370,201	NZ$
Potential Saving over 20 Years		1,221,996	2,348,143	NZ$
Upfront Cost Differential		-$ 291,503	-$ 514,002	NZ$
Net Present Value		$ 250,900	$ 518,735	NZ$
Net Present Value just fuel saving		$ 187,339	$ 459,186	NZ$



Conclusions

- Both E-glass and Carbon have a payback period of around 5 years.
- Significantly higher purchase price results in an equally significant decrease in fuel consumption.
- Nett Present Values
  - E-glass $190,000 over 20 years
  - Carbon $460,000 over 20 years
- Foam cored composite construction in E-Glass or Carbon is cost effective for the end user when compared with alluminium.
- Carbon fibre structure offered the best return for the vessel owner.
- This is for a low speed ferry in displacement mode, not a high speed specialist vessel.
- Reduction in CO_2 emmissions over 20 years.
  - E-glass 2500 T
  - Carbon 5200 T



Thank you!

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