“Innovation in Composite CNG Cylinders”

JEC ASIA 2009

Automotive & Mass Transport Forum

OWENS CORNING®

INNOVATIONS FOR LIVING™

OWENS CORNING® OCV™ Reinforcements

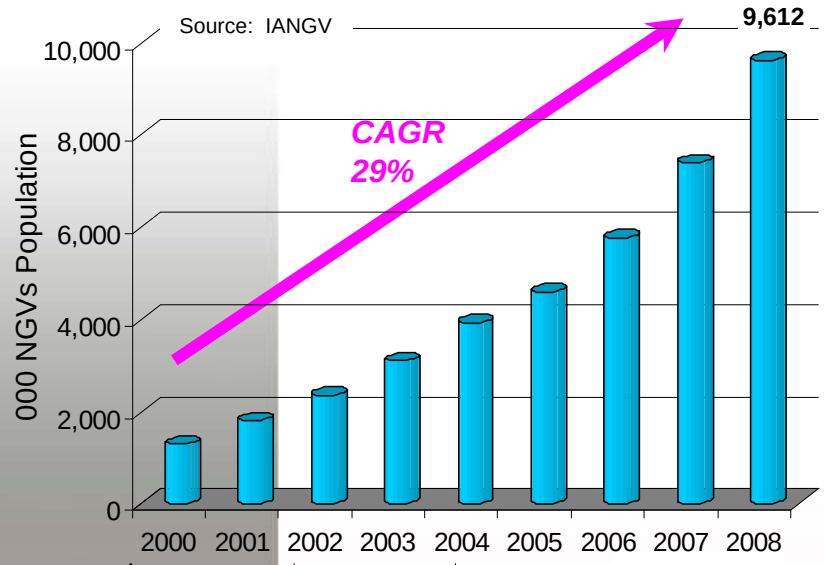
DELIVERING SOLUTIONS | TRANSFORMING MARKETS | ENHANCING LIVES

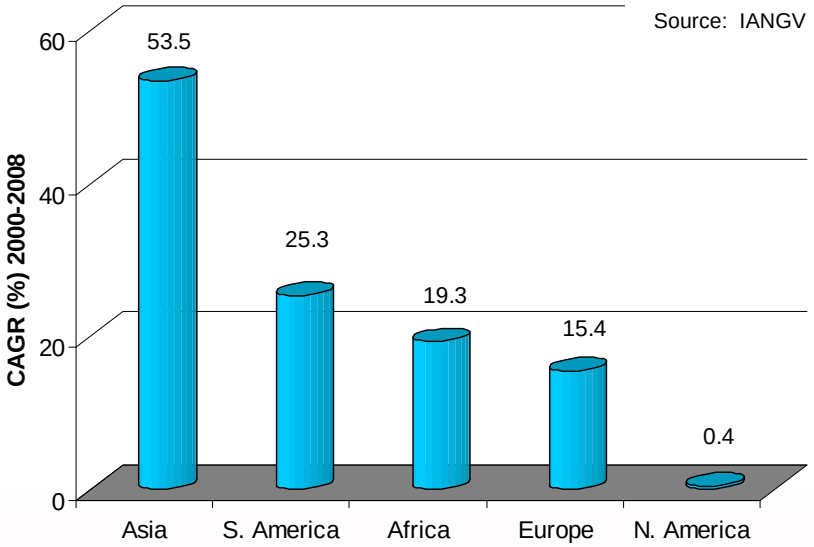
Owens Corning Company Highlights

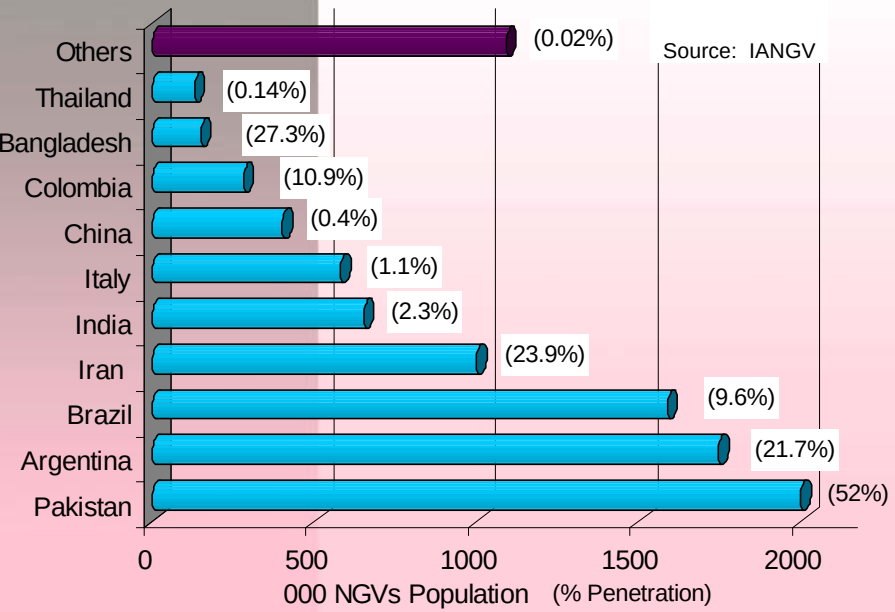
- **Building Materials and Composites**
- **Founded 1938**
- **$6 Billion sales in 2008**
- **16,500 employees in 30 countries**
- **Industry leader in all markets served**
  - Glass fiber insulation, roofing & asphalt and composite solutions
- **First company to trademark a color – Pink**
- **A Fortune 500 company for 55 consecutive years**
- **2008 Fortune magazine most admired companies**
- **OCV™ Reinforcements, OCV™ Technical Fabrics, OCV™ Non-Woven Technologies**

Agenda

NGV Market Status & Trends







- **2020 forecasts a NGV population of 50 mill at 15% CAGR**
- **Asia & S. America are leading the growth**
- **Developing countries are leading the growth**
  - **Cheaper fuel & lower pollution**
- **In Asia, India & China have low NGV population & low penetration offering greater scope for growth**

CNG Fuel – Key Drivers

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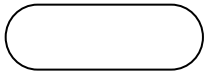
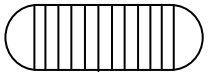
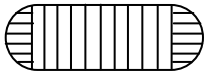
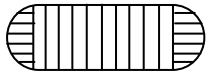
- **Rising Pollution & Environmental concerns**
  - **Natural gas is more environmentally friendly**
    - **Particle matter**
    - **Hydro Carbon**
    - **NOx**
    - **Carbon Monoxide (CO)**
- **Supply security**
  - **Crude Oil: 42 years consumption. Reserve in 61 countries (*)**
  - **Natural Gas: 58 years consumption. Reserve in 111 countries (*)**

    (*) Based on year 2007 proven reserves & consumption
- **Lower price & more energy efficient**
- **Proven Technology in Transportation**
  - **Large scale since 1960**

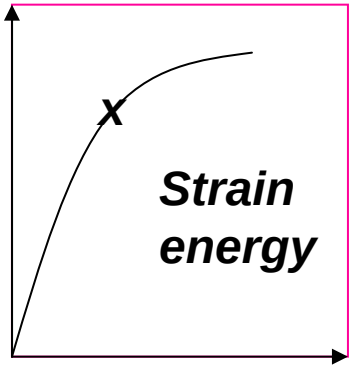
Classification of CNG Cylinders

	Type 1	Type 2	Type 3	Type 4
				
Market Share (%)	93%	4%	< 2%	< 2%
Structure	Metal	Metal Liner reinforced with resin Impregnated continuous filament (hoop Wrap)	Metal Liner reinforced with resin Impregnated continuous filament (fully Wrap)	Resin impregnated continuous filament with a non-metallic liner
Most commonly used	CrMo steel	CrMo steel with Glass Fiber	Aluminium with HP Glass &/or Carbon	HDPE liner with Carbon
Indicative cost - US$/litre	$3 to $5	$5 to $7	$9 to $14	$11 to $18
Indicative weight - Kg/litre	0.9~1.3	0.8~1.0	0.4~0.5	0.3~0.4

Sources: CompositeMarketReports.com
CompositeWorld.com

- **Evident weight reduction (up to 75%) in adopting Type 3 & 4 but comes at a cost…**

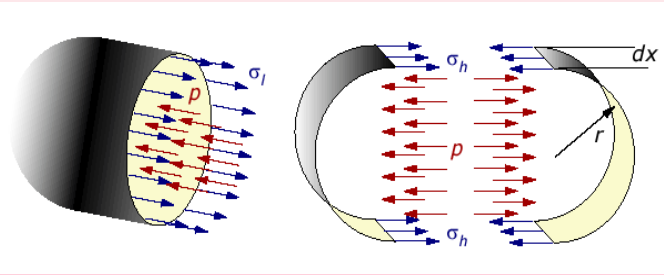
CNG Cylinder Needs



High specific strength, modulus, toughness

- **High operating pressure > 200bar**
  - Fuel density (n=PV/RT) > distance to re-fuel
- **Low weight could lower fuel consumption allow for payload increase**
- **Impact resistance**
- **Bullet resistant per testing protocol**
- **Long life (Static and Cyclic fatigue resistance)**
  - Determines design “Safety Factors”

Cylinder Type	Fibre Reinforcement	Minimum Burst Ratio	Minimum Stress Ratio
Type 1		2.25	N/A
Type 2	Glass	2.50	2.75
	Aramid	2.35	2.35
	Carbon	2.35	2.35
Type 3	Glass	3.50	3.65
	Aramid	3.00	3.10
	Carbon	2.35	2.35
Type 4	Glass	3.65	3.65
	Aramid	3.10	3.10
	Carbon	2.35	2.35



Extracted from ISO 11439 Standard

Why Composites?

- **Weight Reduction**
  - **Reduces fuel consumption**
  - **Reduces environmental footprint**
  - **Increases distance between refueling**
- **Corrosion resistance**
  - **Improves Safety**
  - **Increases Life**
  - **Reduces Maintenance**
- **Design flexibility**
  - **Improves Fuel System integration (Type 4 cylinder)**

High Performance Reinforcements Product Line

WindStrand® Reinforcements
FliteStrand® Reinforcements
ShieldStrand® Reinforcements
XStrand® Reinforcements

Available as Single End Roving or Fabric

Fiber glass filament

Roving

Fabric

Final Applications

Ref: Owens Corning

Innovation in Composite Cylinders

XStrand®
High-Performance Reinforcements

- **High Performance Reinforcements**
  - **XStrand® is one of the latest innovative solution from Owens Corning for the manufacturing of Industrial, Sports & Recreation items at affordable cost & sustainable availability.**
- **Practical Benefits of XStrand® Reinforcements**

  Compare to E-Glass:
  - **Up to 30% increased strength**
  - **Up to 17% increased modulus**
  - **Up to 30% lower coefficient of linear thermal expansion**
  - **Up to 10x better fatigue properties**
  - **Superior corrosion resistance**
  - **Higher temperature resistance**

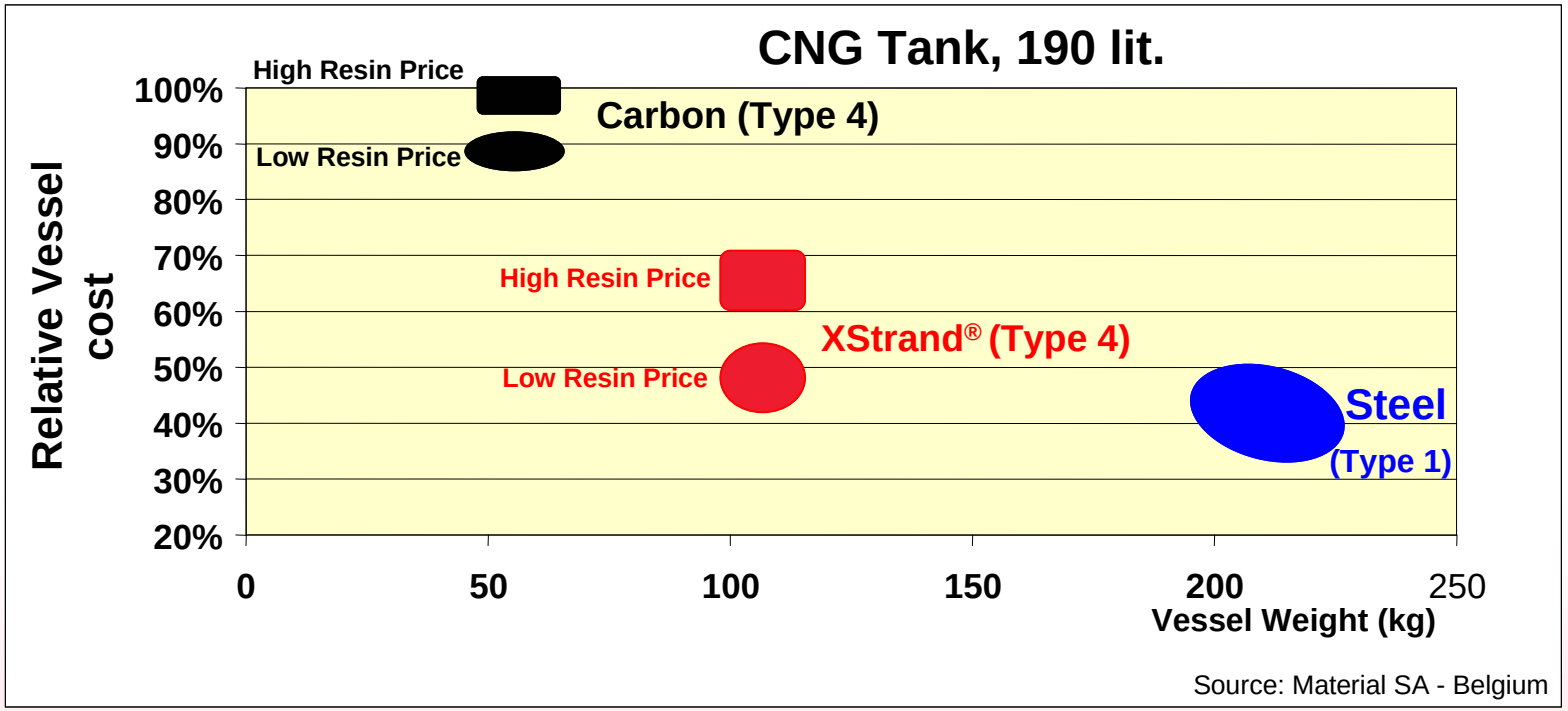
Reinforcements Properties Comparison

	E-Glass	OCV Advantex®	OCV XStrand®	AGY S2 Glass (*)	T700 Carbon Fiber (**)
Pristine Fiber Tensile Strength *(MPa)*	3,448	3,751	4,605	4,590-4,830	4,900
Impregnated Fiber Tensile Strength *(MPa)*	2,137	2,413	3,448	3,660-4,280	NA
Modulus *(GPa)*	72	81	87	86-90	230
Density *(g/cc)*	2.60	2.63	2.52	2.46-2.49	1.80
Specific Pristine Tensile Strength *(m)*	$1.35*10^5$	$1.46*10^5$	$1.86*10^5$	$1.88*10^5$–$2.00*10^5$	NA
Specific Tensile Modulus *(m)*	$2.82*10^6$	$3.14*10^6$	$3.52*10^6$	$3.52*10^6$–$3.73*10^6$	NA

(*) Source AGY Pub. LIT2004-341

(*) Source TORAYCA.com /properties

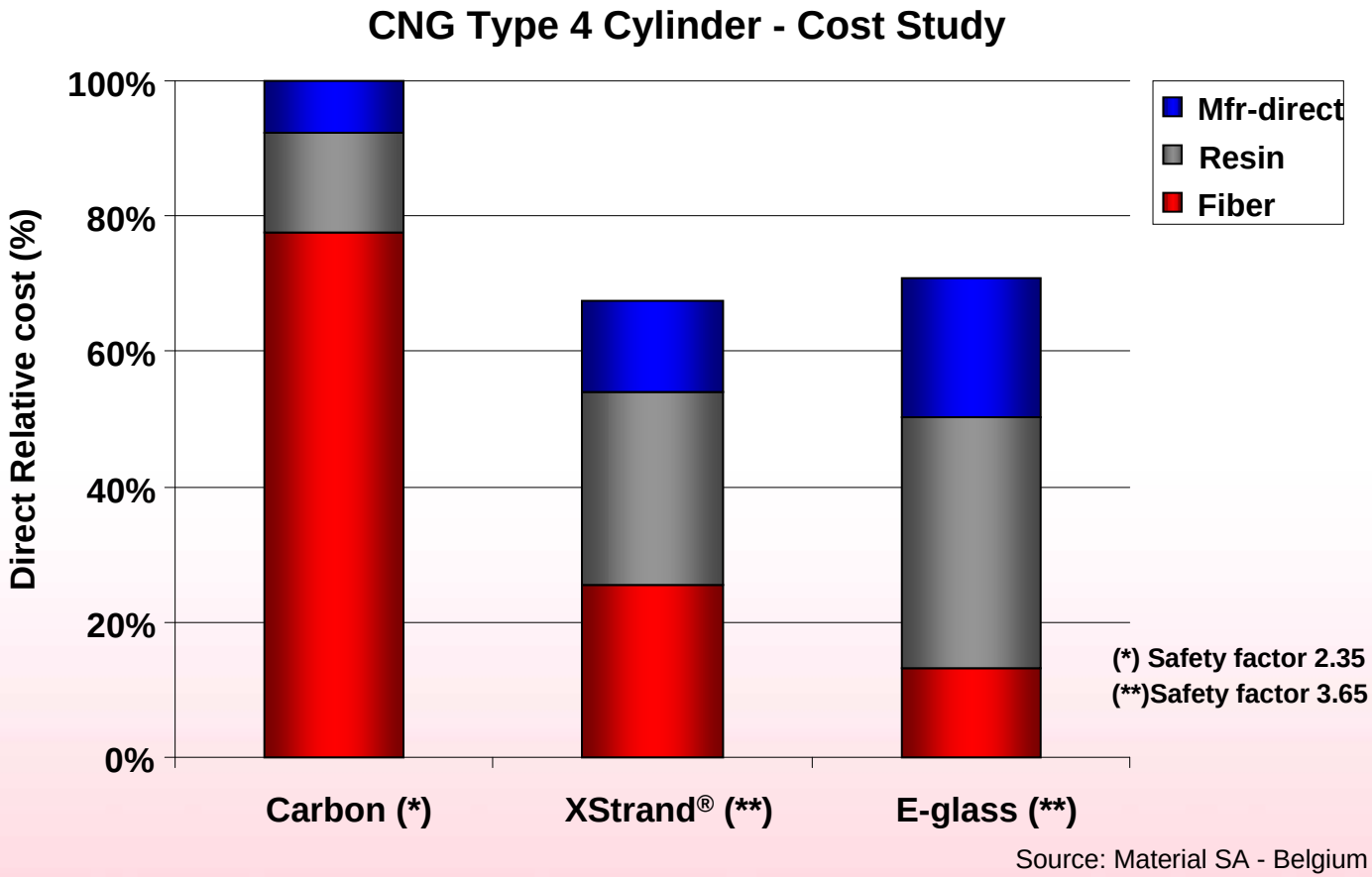
Value Proposition – Case Study -



Type 4 – 190 liter CNG Cylinder -Case Study- (Material SA- Belgium)

- **XStrand® reinforcement enables about 40% cost reduction versus Carbon/ Epoxy Type 4 solution (with obviously a weight penalty).**
- **XStrand® cylinder is half the weight of a typical steel tank.**

Cost Structure of Type 4 CNG Cylinder – Case Study



Source: Material SA - Belgium

- **Basis: 190L, 200bar CNG cylinder**
  - Direct Cost (fiber, resin, production)

OCV XStrand® makes High-Performance Affordable for CNG Composite Cylinder

- **Affordable Lightweight Performance**
  - High Strength, High Modulus glass fiber available in Large quantities
  - Allowing Comparable cost positioning to E-Glass reinforced CNG type 4 cylinder with weight Reduction
  - Substitution for S-Glass in CNG Type 3 & 4CNG cylinder– at a lower cost position
  - Replace or Combine with carbon fiber in CNG type 3 & 4 – where Cost is a critical factor to increase Market Penetration

- **Drivers for Substitution of Type 1 & 2 CNG Cylinder**
  - Shortage of seamless steel tubes
  - Increase concerns for Environmental impact
  - Better Integration to fit Car design
  - Experience consolidation in Composite tanks manufacturing
  - Evolution to Higher Pressure systems to reduce Payload

- **Opportunities**
  - Market Penetration through the gain of Technology leadership
  - Full recognition of CNG Fuel system from Car manufacturers (new car design integrating CNG fuel system)
  - Reduction of Safety factors for High-Performance Glass Fiber

Safer, Lighter, Stronger, Affordable

Market Drivers -

- **Improves Safety**
- **Reduces fuel consumption**
- **Reduces environmental footprint**
- **Reduces distance to refuel**
- **Available**
- **Affordable**

The success of NGV mass development will pass through the development of Affordable High-Performance Materials & Technology to bring storage tanks beyond actual limits.

Thank you

More information:

www.owenscorning.com/composites/

www.ocvreinforcements.com/hp/