AUTOMOTIVE THERMOPLASTIC COMPOSITES . . .
INDUSTRY STRUCTURE AND NEW TECHNOLOGIES
RESPOND TO A GLOBAL RECESSION

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PREPARED FOR:
SPE AUTOMOTIVE COMPOSITES
CONFERENCE
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Robert Eller Associates LLC is a global plastics consulting company providing analysis in support of technical, marketing, and economic strategic management decision-making.

- Based in Akron, Ohio, with offices in Paris, Shanghai, New Zealand.
- Asia: Active in China, India, Middle East.
- Key Focus Areas: Thermoplastic Composites, TPEs, ETPs, Polyolefins, Automotive, Compounding, and Foams.
- Multiclient studies:
  - China TPE Market
  - North America/Europe TPE Market
- Single-client decision support analyses.
- Mergers and Acquisitions:
  - Complete management service for small acquisitions
  - Due diligence support
  - Technical advisors.
• Global Macroeconomic Situation/Automotive Impacts
• Fuel Price/Vehicle Sales/Electric Battery/Thermoplastic Composite (TPC) Relationships
• Automotive Supply Chain Responses
• TPCs in the Automotive Market
• Paths to the TPC Market
• TPC Materials/Fabrication Technology Responses and Applications
• Future Vision/Summary
THE FAMILIES OF AUTOMOTIVE THERMOPLASTIC COMPOSITES

AUTO TP COMPOSITES

MINERAL FILLED
  (a)
  PARTICLE
  MICRO(b)
  NANO

CARBON
  FIBERS
  NANO TUBES

GLASS REINFORCED
  SHORT GLASS (SGF)
  LONG GLASS (LGF)

BIOPOLYMERS AND NATURAL FIBER
  MAT (GMT)
  MATRIX
  FIBERS
  NATURAL
  SYNTHETIC

MAIN TARGET FOR THIS PRESENTATION

Notes:
(a) Talc, mica, basalt, etc.
(b) Micro-talcs opening new applications (e.g., exterior panels, hatchback on Ford Kuga)

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2009
MACROECONOMIC SITUATION/
AUTOMOTIVE IMPACTS
MACROECONOMIC IMPACTS ON GLOBAL AUTO MARKETS

• Global GDP slowdown – 2-year trough in West
• Slowed (but continued high) growth in Asia (esp. China)
• Auto overcapacity in West: Europe/U.S. have 53% of global auto capacity; 12% of global population
• Petrodollar export concerns:
  - substantial alternative energy investments (esp. battery/electric drive programs)
  - CAFE rise in U.S. (still lagging other major nations)
• Wage deflation/high unemployment
• Cash for Clunkers type programs stimulated US/Europe vehicle demand but will likely negatively impact 2010 sales
• U.S. credit lockdown (despite stimulus) \(\rightarrow\) erosion of consumer purchasing power
• OEM market share shift (especially in N. America)
• China stimulus package (higher % of GDP), more effective than Western stimulus packages
GLOBAL VEHICLE SALES OUTLOOK

Annual Growth
1990-2000 2.4%
2000-2005 3.6%
2005-2015 1.3%

VEHICLE SALES, MM UNITS

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2009

r/mydox/Auto Industry/Global Ind Volume TW 081209.xls

42% IN 15 EMERGING MARKETS; 58% IN EUROPE/U.S./JAPAN

2000: 57

2009: 9% DECLINE FOLLOWED BY RECOVERY IN 2010/2011

2015: 77?
U.S. AND EUROPE LIGHT VEHICLE SALES

SALES, MM UNITS

SOURCE: DEUTSCHE BANK, 2009

B/mydox/auto industry/NA and EUR sales.xls
GLOBAL REGION MARKET SHIFT IS UNDER WAY

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>2009 YTD SALES GROWTH/DECLINE</th>
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<tbody>
<tr>
<td>Europe*</td>
<td>-18%</td>
</tr>
<tr>
<td>N. America*</td>
<td>-26%</td>
</tr>
<tr>
<td>Japan*</td>
<td>-21%</td>
</tr>
<tr>
<td>Brazil</td>
<td>+ 5%</td>
</tr>
<tr>
<td>India</td>
<td>+ 5%</td>
</tr>
<tr>
<td>China</td>
<td>+42%</td>
</tr>
</tbody>
</table>

* = Mature markets represent 51% of global sales

Source: Robert Eller Associates LLC, 2009
W. EUROPEAN VEHICLE MARKET SHARE SHIFT

SALES SHARE, %

2005
2009 (EST)

FLEET MARKET SEGMENT

Sources: JD Power; Deutsche Bank; Robert Eller Assoc. LLC, 2009
U.S. FUEL ECONOMY OBJECTIVES: MINIMAL, BUT WITH SIGNIFICANT FLEET MIX & MATERIALS SELECTION IMPLICATIONS

AVERAGE FLEET FUEL ECONOMY BY GLOBAL REGION

SOURCE: PEW CENTER, 2008

HIGHER CAFE DRIVES COMPOSITES TECH.

U.S. CAFE LAG CONTINUES

SOURCE: PEW CENTER, 2008
FUEL PRICES: THERMOPLASTIC COMPOSITE EFFECTS

• There are fuel price tipping points $\Rightarrow$ shifts in vehicle preference
  
• 2008: $3.50-4.00/$gal. $\Rightarrow$ 100BN fewer miles driven in U.S.

• Price will rise and change auto and autoplastics paradigms:
  - rising demand/decreasing capacity
  - economic expansion (eventually)
  - global population jump by 1.0BN in next 12 years
  - “middle” class increase by 1.8BN (600MM in China)
  - U.S.: 750 cars/1,000 people
    China: 4 cars/1,000 people – If Chinese $\Rightarrow$ $\frac{1}{2}$
    ownership rate of the U.S., adds 400MM cars
  - easy-to-get oil has gotten harder to find
  - gas taxes in U.S. (remain constant at $0.18/$gal.?)

• Plug-in hybrids: emerging, bridge to a (composite intensive) electric car/alternative propulsion world

• Global Li-ion auto battery sales will jump from $12BN in 2010 to $35BN in 2015
AUTOMOTIVE SUPPLY CHAIN RESPONSES
U.S. AUTOPLASTIC SUPPLY CHAIN PRESSURES/RESPONSES

BANKRUPTCIES

OEM AGGRESSIVE SUPPLY CHAIN COST SAVE PRESSURES

SEVERE PRODUCTION DECLINE

SHIFT TO SMALLER VEHICLES

HYBRID ELECTRIC DRIVE SHIFT

TECHNOLOGY TRANSFER

U.S. TP COMPOSITES TECHNOLOGY LAG vs. EUROPE

TRANS-GLOBAL OEM PARTNERING

SHIFT TO EUROPEAN/ASIAN DESIGNS

OEM OWNERSHIP SHIFT (b)

RESIN SUPPLIER SHIFT TO LOW COST MONOMER REGIONS

REDUCED SERVICE FOR AUTO ACCOUNTS

IN-LINE (D-LFT) COMP’DG. BY TIER 1s(a)

TIER 2, 3 SUPPLIERS

ELIMINATION OF EXTRA STEPS

GLOBAL COMPETITION

GEOGRAPHIC OFFSHORE COMPOUNDERS ENTER

IMPORTED COMPETITORS/SUPPLIER REDUCTION

PRICE COMMODITIZATION

RESIN SUPPLIER SHIFT TO LOW COST MONOMER REGIONS

REDUCED SERVICE FOR AUTO ACCOUNTS

BANKRUPTCIES

SUPPLY CHAIN GLOBALIZATION

GLOBAL VEHICLE DESIGNS

VEHICLE DEMAND SLOWDOWN

SPECIFICATIONS

GLOBALIZATION PRESSURES

INCREASED EUROPEAN/JAPANESE INFLUENCE

ELIMINATE/REDUCE THE INEFFICIENCIES:

- MULTIPLE UNIT OPERATIONS
- EXCESSIVE LOGISTICS
- SCRAP GENERATION
- INEFFICIENT PROCESS TECHNOLOGIES
- SALES/MARKETING COSTS
- EXCESS LABOR COSTS

NOTES:
(a) STARTED FOR LGF-TPs
(b) e.g., MAGNA, BID FOR OPEL, FIAT/CHRYSLER, ETC.

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2009
THE AUTOMOTIVE MARKET
and
THERMOPLASTIC (TP) COMPOSITES
GLOBAL MACROECONOMIC EFFECTS ON AUTO TP COMPOSITES

DEMAND SLOWDOWN
BANKRUPTCIES
BANK CRISIS

GLOBAL MACROECONOMIC SITUATION

GDP DECLINE
CREDIT TIGHTENING
REDUCED PURCHASING POWER

GLOBAL MACROECONOMIC EFFECTS
ON AUTO TP COMPOSITES

SLOWED CAPITAL FOR NEW
TP COMPOSITE TECHNOLOGY?
INCREASED GLOBAL PLATFORMS

- SEVERE DROP IN EUROPE/U.S.
- SLOWED GROWTH IN EMERGING MARKETS (e.g., BRIC)

AUTOMOTIVE DEMAND

- PROFIT DECLINE
- DEEPER COST CUTS
- JOB CUTS
- TRIM CAPITAL EXPENDITURES
- REDUCE R/D
- SEEK OEM PARTNER/
GLOBAL SYNERGIES
- CONTINUED EMERGING MARKET
INVESTMENT
- RE-TOOL FOR SMALLER VEHICLES

AUTOMOTIVE OEMs

- IN-LINE COMPOUNDING
- AT-PRESS COMPOUNDING
- MULTI-SHOT PROCESSES
- CAPTIVE COM’DQ. BY TIER 1s
- PRESSURE ON INDEPENDENT
COMPONDERS
- SEEK NON-AUTO OPP’Y.

SUPPLY CHAIN

$18.5BN SUBSIDY REQUEST
(REC’D. $5BN)
(U.S.)

- INCREASED USE OF TP COMPOSITES
- PART WEIGHT REDUCTION PRESSURES
- PARTS CONSOLIDATION/MODULARIZATION
- INCREASED VALUE OF $/LB. SAVED
- ELECTRIC DRIVE/BATTERY INITIATIVES

FLEET COMPOSITION
SHIFT TO SMALLER CARS

FUEL ECONOMY AND ALTERNATE
ENERGY SUPPORT

VEHICLE COST
PRESSURES

GOVERNMENT
SUBSIDIES/
LOANS/ AID
PACKAGES

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2009
TP composite substitution driven by:

- Supply chain restructuring
- Weight save pressures (value weight savings [10% weight reduction yields 7% fuel economy improvement])
- System cost savings potential/parts consolidation
- Material cost savings for D-LFT vs. other LGF processes
- Green pressures and improved opportunities for natural fiber and carbon fiber TP composites
- Other plastic substitution (e.g., exteriors) stimulates TP composites (e.g., hatchback inner panel)
TP COMPOSITE TECHNOLOGY RESPONSES and OPPORTUNITIES
PATHS TO THE LGF-TP COMPOSITE MARKET

1. **COMPOUND:**
   - **COMPONDER** → LGF COMPOUND → INJECTION PRESS → MOLDED PART

   Componding facilitated early growth of LGF-TPs; does not require CAPEX

2. **D-LFT:**
   - **ROVING** → **IN-LINE COMPOUNDING EXTRUDER** → **COMPRESSION PRESS** → MOLDED PART
   - **RESIN** → **IN-LINE COMPOUNDING EXTRUDER** → **INJECTION PRESS** → MOLDED PART

   High growth potential; CAPEX required (favored by major Tier 1s); large parts, high volume required for competitive economics, good fiber length retention

3. **LGF CONCENTRATE:**
   - **CONCENTRATE** → INJECTION PRESS → MOLDED PART
   - **NEAT RESIN** → INJECTION PRESS → MOLDED PART

   Use existing equipment

4. **GMT OR LW-RT:**
   - **ROVING** → **EXTRUDER** → **BLANKS** → **PREHEAT** → **COMPRESSION PRESS** → MOLDED PART

   Early GMT being replaced by high quality; LW-RT competes with D-LFT in underbody shields

**SOURCE:** ROBERT ELLER ASSOCIATES LLC, 2009
# AUTO APPLICATIONS FOR TP COMPOSITES (a)

<table>
<thead>
<tr>
<th>APPLICATION</th>
<th>STATUS / NOTE</th>
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| Front end module/ carrier* (6-8) | - Major near-term D-LFT and LGF-PP pellet driver in N. American market  
- Established in Europe  |
| Door hardware module* (7-8)     | - Facilitates strong trend towards hardware consolidation  
- Brose is early leader |
| Instrument panel substrate* (7)       | - Started in Europe (Faurecia and JCI)  
- Both D-LFT injection and compression |
| Underbody shield* (8)               | - Will come from Europe with OEM transplants  
- LW-RT competes with D-LFT  
- Add-on acoustic layer being offered |
| Running board                  | - Started in N. America                                                                                                                      |
| Hatchback door*                | - 2012 Ford Escape (see Ford Kuga photo)  
- Combination with talc/PP exterior |
<p>| Overhead console/ Headliner structure | - Stimulated by changes in overhead design and construction                                                                                      |</p>
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<tr>
<td>Instrument panel structural ducts (15-18)</td>
<td>- Early Chrysler innovation (2007)(b)</td>
</tr>
<tr>
<td></td>
<td>- Requires vibration welding</td>
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<tr>
<td>Load floor</td>
<td>- Early GMT application</td>
</tr>
<tr>
<td>Spare tire well/storage module* (9-10)</td>
<td>- Competes with SMC, GMT; natural fiber candidate?</td>
</tr>
<tr>
<td>Seating*</td>
<td>- Competes with SGF-TPs</td>
</tr>
<tr>
<td>Engine covers*</td>
<td>- Starting in natural fiber composites in Europe</td>
</tr>
<tr>
<td>Battery carriers</td>
<td>- Stimulated by trend to electric drive vehicles?</td>
</tr>
</tbody>
</table>

Notes:

Numbers in ( ) indicate typical weights per vehicle

* = technology transfer from Europe

(a) Includes both LFTs and GMTs
(b) First launched on ’97 MY Dakota and Cherokee

Sources: Dieffenbacher; Robert Eller Associates LLC
LFT-D-ILC COMPRESSION

Source: Dieffenbacher
IMC Injection Molding Compounder

Melt buffer

Shut-off nozzle

Re-direction valve

MX- or CX-clamp

Source: Krauss Maffei

Weighing, dosing & conveying systems

Start up valve with container

Twin screw extruder

Shot-Pot-Injection piston

b/mydox/papers/composites09 KraussMaffei.ppt
Plasticomp Pushtrusion™ Direct In-Line Compounding

Source: PlastiComp
LFT COMPOSITE OPPORTUNITY TARGETS

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2009

NOTES: * = HIGH PERFORMANCE MINERAL FILLED
(a) MAY CONTAIN ADDED ACOUSTIC ELEMENTS
(b) COMPETES WITH SGF-TP
(c) D-LFT AND LW-RT COMPETE FOR UNDERBODY SHIELD
FRONT END MODULES: PROVEN HIGH GROWTH TECH

- HOOD LATCH POINT
- CARRIER
- RADIATOR/HEAT EXCHANGERS
- FASCIA
- BUMPER BEAM
- ENERGY ABSORBER
- COOLING FANS

SGF-PP CHALLENGING SGF-PA
FRONT END CARRIERS: STRONG GROWTH DRIVER FOR D-LFT PROCESSES AND LGF-PP COMPOUND

VEHICLE: Audi A3  
MATERIAL: 30% LGF-PP  
PROCESS: D-LFT (injection)  
WEIGHT: 3 kg  
EQUIPMENT: Krauss Maffei  
PHOTO: Krauss Maffei

VEHICLE: Ford Fusion  
MATERIAL: 40% LGF-PP  
PROCESS: D-LFT (compression)  
EQUIPMENT: Dieffenbacher  
PHOTO: Dieffenbacher
UNDERBODY PANELS

• Established in Europe. Shifting to N. America. (German OEM shift accelerates N.A. penetration)
• Substitution driven by:
  - Component protection
  - Lithium-ion battery/electric drive share gain
  - Improved aerodynamics
  - Acoustics improvement (new target/value add zone)
• Many process/materials contenders:
  - GMT
  - LW-RT (lightweight GMT gaining share, approvals in place)
  - LGF-PP pellets
  - D-LFT processes/examples (Compression, Injection, Krauss Maffei, PlastiComp Pushtrusion™, others)
  - Aluminum, steel, thermoset composites
UNDERBODY PANELS

Vehicle: BMW 7-SERIES
Part: Underbody Shield
Material: 30% LGF-PP
Supplier: SABIC - Stamax 30YK430
Weight: 6.7 kg (total)
Drivers:
- Acoustics
- Aerodynamics
- Component protection
- Cost (vs. GMT)

Note:
Most European BMW passenger cars have LW-RT UB shields
EXAMPLE UNDERBODY SHIELD

Part: Typical underbody shield
Process: D-LFT compression
Equipment: Dieffenbacher
Material: 25-30% LGF-PP
Notes: - LW-RTP competes
       - Acoustic function being added (e.g., by Rieter, Carcoustics, others)
Photo: Dieffenbacher
Filled and fiber-reinforced TPs compete for substrate
LGF-PP pellets and D-LFT compete
Combo with 2-shot D-LFT molding saves unit operations
Integrated cross-car beam/structural duct potential
Example shown: Ford C-Max, Mazda 3, Volvo S40
Material supplier: Quadrant Plastic Composites AG
System supplier: Faurecia
Vehicle: Mercedes C-Class

Weight: 4.3 kg
Substitution drivers:
- Impact strength for crash resist.
- Ability to integrate shape features
- Corrosion resistance
Material: GMT-PP combination (random glass mat & fabric)
SPARE TIRE WELL: NATURAL FIBER TARGET

Vehicle: Mercedes A-Class

Material: Abaca fiber/PP

Substitution drivers:
- Good stiffness weight balance
- Green solution
- Energy saving (natural fiber vs. glass roving)
DOOR HARDWARE MODULES: GROWTH APPLICATION

FORD FIESTA

- LGF-PP
- Front Door Carrier plate wt. = 1042 grams
- Rear Door Carrier plate wt. = 670 grams
DOOR HARDWARE MODULE: GROWTH APPLICATION

VEHICLE: Chrysler Sebring convertible
MATERIAL: 40% LGF-PP
PROCESS: D-LFT (injection compression)
EQUIPMENT: Krauss Maffei
PHOTO: Krauss Maffei
HATCHBACK DOOR INNER: GROWTH APPLICATION

VEHICLE: Ford Kuga (2010)
APPLICATION: Roof spoiler and tailgate outer panel
GRADE: LyondellBasell Hifax TRC 280X
MOLDER: Plastal
REA NOTES:
- Inner panel is Stamax (SABIC)
- Potential for design transfer to the U.S. (2010)
PHOTO: Robert Eller Associates LLC

PART: Hatchback door inner panel
MATERIAL: 40% LGF-PP
STATUS: Prototype
PROCESS: D-LFT (injection)
EQUIPMENT: Krauss Maffei
COMPETITION: LGF-PP compound
PHOTO: Krauss Maffei
MERCEDES SMART FORTWO TAILGATE: PRECURSOR FOR LGF-PP IN BODY STRUCTURES?

- E-LF-PP gives high load bearing and impact absorbency
- Translation potential for rear seat backrest
- 20% Stiffness increase vs. earlier version
- LGF-PP move into body structures
- Early use of E-LF-PP (endless long fiber polypropylene)

Source: Weber Automotive; ESORO AG
EXAMPLE OF LGF-PP and E-LF-PP DIRECT PROCESS

Source: Robert Eller Associates LLC, 2009
DESIGN CONCEPT FOR E-LGF-PP BASED COMPACT CAR BODY STRUCTURE

Metallic front and rear elements

Double shell floor

Source: Weber Automotive; ESORO AG
BIOPOLYMER CANDIDATES FOR AUTOMOTIVE APPLICATIONS

BIOPOLYMERS

MATRIX

HC-BASED (E.G., PP)

-PLA
-POLYL-KANOATE
-SOY

FIBERS

NATURAL

VEGETABLE

ANIMAL (E.G., WOOL, HAIR)

SYNTHETIC

HC-BASED

BIO-BASED (BIOFIBERS)

VIRGIN

REGENERATED

PLA

POLYL-KANOATE

BAST FIBERS

-FLAX
-HEMP
-KENAF
-HENNEQUIN
-JUTE

LEAF

-SISAL
-CURANA
-BANANA
-BAMBOO

SEED

-COTTON
-KAPOTE

FRUIT

-COCONUT
-PINE
-OTHERS

WOOD

-OTHERS
-WOOD FIBER
-WOOD FLOUR

NOTE:  (a) USED IN BRAZIL, RECENT U.S. INTRODUCTION IN NYLON

SOURCE:  ROBERT ELLER ASSOCIATES LLC, 2009
FUTURE VISION/SUMMARY

- Like other auto plastics, TP composites (especially LF-RTPs) are affected by:
  - The global economic downturn
  - Market growth shift to Asia
  - Sharp global automotive production downturn
  - European/Asian OEM share gain in N. America
  - Share gain for smaller vehicles in the global fleet
  - Expected fuel price increase and slow penetration of hybrids and electric drive vehicles
The LF-RTPs have strong growth potential:

- Substitution on multiple (high weight) applications
- Growth in modular construction
- Renewed weight/cost save pressures
- Supply chain restructuring/direct fabrication savings
- Parts consolidation potential
- Front end modules/carriers, door hardware modules, and underbody shields will be near-term growth driver
- European/Asian share gain in N. America brings technology and designs to accommodate vehicle market shifts
FUTURE VISION/SUMMARY (Cont'd.)

• Intermaterial and inter-process competition:
  Multiple materials/processes are competing.
  D-LFT will make rapid share gains due to cost savings but could be restricted by capex requirements in a difficult investment environment.
  Natural fiber reinforcement will gain some share
  Carbon fiber TPCs will be pulled into the auto market

TP composites bring opportunities for adding value,
Parts consolidation/weight savings in most applications
Improved energy management/space savings
Adding acoustic functionality to underbody shield
Crosscar beam/structural duct integration in instrument panels

AUTOMOTIVE TP COMPOSITES: PART OF MANAGING IN A DOWNTURN
Thank You!

Robert Eller Associates LLC

CONSULTANTS TO THE PLASTICS AND RUBBER INDUSTRIES