TPEs AND TPOs MEETING CURRENT AND FUTURE AUTOMOTIVE CHALLENGES

PRESENTED BY:

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TODAY’S OBJECTIVES

• The global automotive marketplace

• Current auto TPE and TPO example applications and challenges

• Developments in materials and fabrication technology

• Meeting the challenges/opportunities

• Future implications for suppliers and the automotive supply chain
- India pass car growth (2011-2020): 3 → 6-9 MM units
- India + China could represent growth potential ("11 – 20") of 20MM vehicles or 50kT at current SEBS and o-TPV compound utilization rates with no further penetration

### SEGMENT

<table>
<thead>
<tr>
<th>SEGMENT</th>
<th>SALES SHARE,%</th>
<th>GAIN/LOSS,%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2005</td>
<td>2014</td>
</tr>
<tr>
<td>Compact utilities</td>
<td>6.0</td>
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<tr>
<td>Compact sedans</td>
<td>10.6</td>
<td>14.2</td>
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<td>Mid-sized sedans</td>
<td>14.9</td>
<td>18.1</td>
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<tr>
<td>Wagons/Hatchback</td>
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<td>7.5</td>
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<tr>
<td>Mid-sized utilities</td>
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<td>12.4</td>
</tr>
<tr>
<td>Mid-sized PUTs</td>
<td>4.2</td>
<td>1.3</td>
</tr>
<tr>
<td>Full size PUTs</td>
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<td>11.6</td>
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<td>Vans/Minivans</td>
<td>8.7</td>
<td>5.3</td>
</tr>
<tr>
<td>Large sedans</td>
<td>8.2</td>
<td>4.1</td>
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<tr>
<td><strong>TOTAL SALES, MM UNITS</strong></td>
<td><strong>16.9</strong></td>
<td><strong>15.8</strong></td>
</tr>
</tbody>
</table>

**DATA SOURCE: AUTO PACIFIC**

**Source:** ROBERT ELLER ASSOCIATES LLC, 2014

**Smaller vehicles share gain:**
- smaller parts sizes
- increased pressure for soft interior features
- increased under-hood temperatures
REGIONAL GROWTH RATES ARE SHIFTING

PHOTO SOURCE: THE ECONOMIST
AUTO WAGES: STILL MAJOR GAP BETWEEN HIGH AND LOW PAYING COUNTRIES

Automobile industry average hourly compensation in 2012, including benefits

- **Canada** $39.04
- **United States** $45.34
- **Britain** $38.28
- **France** $45.77
- **Germany** $58.82
- **Japan** $41.65
- **Mexico** $7.80
- **Brazil** $18.78
- **Poland** $9.53
- **India** $2.10
- **China** $4.10
- **S. Korea** $25.74

...and lower-paying countries. Number of workers for the same cost as one U.S. worker.

Sources: Bureau of Labor Statistics: Center for Automotive Research
CHANGE IN U.S. JOBS SINCE DECEMBER, 2007

+ 12.2% EDUCATION, HEALTH CARE

+ 4.1% PROFESSIONAL, BUSINESS

- 0.8% TOTAL NON-FARM

- 2.4% GOVERNMENT

- 12.5% MANUFACTURING

SOURCE: BUREAU OF LABOR STATISTICS
Re-shoring drivers
- Increasing wages in low cost countries (15-18%/yr for last 3 years)
- Transportation costs
- Shorter/more controllable supply chain

Challenges
- Finding enough skilled workers in US
- Redesign/re-engineering required for higher cost environment
- Consumers willing to pay a bit more

Some examples
- Apple (mobile electronics)
- GE (water heaters, refrigerators)
- Ford (various auto parts)
- Whirlpool (washing machines)
- Foxconn/Hon Hai, Taiwan (electronic components for Apple, auto,)

TPE benefits
- More efficient manufacturing (2 shot, core back techniques)
- Reduced assembly costs
- Reduced labor content vs hand assembly
- Attracting Asian TPE suppliers
THE TPE FAMILIES INCLUDE TPOs

PTE FAMILIES

OLEFINIC (o-TPEs)

STYRENIC (SBCs)

SUPER-TPVs

OTHER

E-TPEs

SEBS (TPE-S)

VULCANIZED SBC TPVs (TPES-V)

SILICONE

ACRYLATES

OTHER

COPE

COPA

TPU

OTHERS

POEs ENTERING

OBC ENTERING

TPO

o-TPV

p-TPV (PARTIAL CROSSLINKED)

f-TPV (FULLY CROSSLINKED)

Note:
(a) e.g., recently introduced melt processable polyurea-based TPEs

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2014

DYNAMIC VULCANIZATION IS A TECHNOLOGY PLATFORM FOR NEW s-TPVs

NON-TPO TPEs COMPETING IN THE AUTO TPE SECTOR
AUTOMOTIVE CHALLENGES/OPPORTUNITIES: TPEs

- Managing/benefiting from commoditization
- Systems cost reduction
- Weight saving/meeting shifting emissions and MPG requirements
- Luxury interiors: challenge and opportunity
- Simplified parts fabrication processes
- Adhesion: the path to new TPE applications
- Controlling acoustics
- Optimizing foaming benefits
- Globalization effects:
  - implementing global standards
  - supply chain for global platforms
  - regional supply chain shifts
AUTOMOTIVE CHALLENGES/OPPORTUNITIES: TPO and PP

• Serving automotive markets with commoditized products

• How to exploit benefits of polyolefins from shale gas and oil

• How to offer cost effective soft touch

• Scratch/mar resistance: still a challenge

• Thin walling for weight savings

• Density reduction with increased stiffness

• Role for cellulosic and carbon fiber reinforcement

• Enlarging the applications footprint from mature applications
### IMPORTANCE OF AUTOMOTIVE VARIES BETWEEN TPE TYPES

<table>
<thead>
<tr>
<th>TPE TYPE</th>
<th>AUTO DEMAND SHARE</th>
<th>RECENT INCUMBENT</th>
<th>AUTO TARGETS/CHALLENGES</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPO</td>
<td>80%</td>
<td>None – TPO dominates</td>
<td>Bumper fascia, interior trim, skins</td>
</tr>
<tr>
<td>o-TPV</td>
<td>50%</td>
<td>NBR/PVC, ECO, CPE, EPDM</td>
<td>Boots/bellows, hose, short air ducts</td>
</tr>
<tr>
<td>SEBS</td>
<td>15%</td>
<td>EPDM, o-TPV</td>
<td>Growth via soft touch, slush skins, seals</td>
</tr>
<tr>
<td>TPU</td>
<td>11%</td>
<td>EPDM, o-TPV</td>
<td>Grommets, sleeves, door sills, overmolded films, shift knobs, lamp seals, slush molding, wire/cable</td>
</tr>
<tr>
<td>COPE</td>
<td>10%</td>
<td>EPDM, o-TPV, fluorosilicones</td>
<td>Under-hood ducting, wire/cable, soft touch trim panels</td>
</tr>
<tr>
<td>super-TPVs</td>
<td>Small</td>
<td>High temp rubbers</td>
<td>High temp under hood applications</td>
</tr>
</tbody>
</table>

**SOURCE:** ROBERT ELLER ASSOCIATES LLC, 2014
BODY/GLAZING SEAL CHALLENGES: AUTO TPE BATTLEGROUND

• Dominant Incumbent:
  - EPDM

• TPE Challengers:
  - o-TPV, SEBS

• Dynamic vs. static requirements differ:
  - Acoustic/wind noise performance (requirements increasing)
  - Adhesion (to glass, polycarbonate) emerging
  - Parts integration opportunities
  - Surface friction properties
  - Meeting regional performance differences
  - Overcoming institutional resistance
  - The small car challenge

• Large potential auto TPE market
THERMOPLASTIC ELASTOMERS IN WINDOW ENCAPSULATION

• Application: Rear quarter window encapsulation seal

• TPE Candidates: PUR, o-TPV, SEBS (H-SBC), PVC, EPDM

• Key Properties: High flow (to reduce breakage)
  Glass adhesion
  UV/weather resistance
  Low compression set
  Squeak resistance
  Scratch resistance

• Notes: Example of intense inter-material competition
  - Example of static seal application
  - Two shot adds value
  - Colors?
  - Narrower profiles?
  - Systems cost save opportunities
  - Polycarbonate glazing could shift requirements

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2014
UNDER HOOD TEMPERATURE INCREASES ➔ HIGH HEAT TPEs

- **Application:** Air duct cuff
- **TPE type:** s-TPV (Zeotherm® TPV)
- **Key properties:** Heat resistance, Ease of processing, Polyamide adhesion

Note: Example of metal replacement (e.g. polyamide) pulling TPEs into under-hood applications

- **Application:** Hot air duct (primarily turbo engines)
- **TPE type:** s-TPV (Zeotherm® TPV)
- **Key properties:** Heat resistance, Processing ease
- **Process:** Blow molding

Source: Zeon Chemicals

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2014
AUTOMOTIVE: KEY TARGET MARKET FOR NEW TPEs

**BUMPER FASCIA**
- TPO STILL DOMINATES, (SBC MODIFIER)

**UNDERHOOD** (INCLUDING SHORT DUCTS)
- s-TPV
- COPE

**IP SKINS**
- TPO RESURGING
- SEBS SLUSH, o-TPV
- COPE

**BODY/GLAZING SEALS**
- o-TPV
- HI MELT STRENGTH (HMS) SEBS

**WINDOW ENCAPSULATION**
- HIGH FLOW SEBS; o-TPV

**RADIATOR HOSE/BOOTS**
- o-TPV

**THE AUTO TPE MARKET**
- GLOBAL FOOTPRINT REQ'D, RECENT LUXURY DRIVE
- KEY DRIVERS: LOW VOC/ODOR, OIL FUEL RESISTANCE, HEAT RESISTANCE, SUSTAINABILITY (BIO), WEIGHT SAVE/LUXURY LOOK/HAPTIC, SMART SURFACES

**WIRE/CABLE**
- COPE
- o-TPV

**DOOR TRIM SKINS**
- TPO RESURGING
- HI FLOW SEBS, o-TPV
- COPE

**TRUNK LINER**
- TPO (DEEP DRAW FORMABLE)

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2013
ACOUSTICS: INCREASED OPPORTUNITY FOR TPEs/POLYOLEFINs

SOURCE: WALL STREET JOURNAL
ACOUSTIC TARGETS FOR TPEs/TPOs/PPs

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2014
ACOUSTIC TARGETS FOR POLYOLEFINS/TPEs/FOAMS

DASH MAT
SUPPLIER: CASCADE ENGINEERING

FLAT ABSORBER FOR GEAR DRIVE
NOTE: WHITE AREAS ARE MICRO-PERFORATED POLYOLEFIN FOAMS

FOAM SUPPLIER: SEKISUI ALVEO

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2014
AIR DUCTS: TARGET FOR POLYOLEFIN FOAMS

OVER 10 AIR DUCTS PER CAR

EXAMPLE AIR DUCT
MATERIAL: PP FOAM
PROCESS: TWIN SHEET FORMING
SUPPLIER: SEKISUI ALVEO

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2014
TPE/TPO CHALLENGE: GLOBALIZATION

The challenges, how to:
- Implement global specifications (starting)
- Have a uniform global supply and fabrication footprint
- Retain value associated with global standards
- Avoid commoditization and price challengers from local TPE suppliers

Background:
- Global platform usage is increasing
  - VWs MQB platform (5.5 MM global vehicles/yr) is leader
  - Platform volume for other OEMs (Toyota, Ford, Hyundai, GM is 2-3 MM vehicles/yr)
  - Typically on B/C segment vehicles (growth segments)
  - Global footprint (a “must have”)

- Greater product uniformity between regions for TPEs vs thermoset rubbers:
  - OEMs prefer uniform products /grades from -the -bag rather than in-house compounded rubbers

TPE supplier strategies:
- Meet global specs (not always easy)/local pressures
- Assure lot-to-lot uniformity. Build an unassailable reputation
- Follow OEM regional shifts
- Assure global footprint
The challenges:
- Save weight while adding value.
- Meet steeply increased emissions requirements

Background:
- A key target with new fuel economy regulations
- TPEs generally have a density advantage vs. incumbents
- Weight savings via parts consolidation are possible (especially where fastening devices can be eliminated)

TPE solutions:
- Target metal substitution
- Look for hard/soft combinations
- Foaming
- Thinwall where possible
- Solve the adhesion problems
- Seek multi-functionality (e.g. EMI shielding TPE gaskets)
The challenge:
- Reduce total parts cost (materials, fabrication, assembly)

Background:
- TPEs generally cost more than incumbent
- OEMs (finally!) working to examine total system costs (not $/kg)
- OEMs demand high performance, form and function, perceived quality
- Avoiding “cheap plastics” look

TPE solutions:
- Parts consolidation
- Redesign for ease of assembly
- Labor cost reduction
- Design for disassembly and recycling
The challenge (usually adhesion to rigid plastics):
- Improved adhesion is an application enabler/cost save
- Value add potential

Background:
- Application in coatings, multi-materials, construction, blends, fillers, reinforcements, surface decorations
- Logos

TPE solutions:
- Sprayed surface adhesion promoters
- Additives and compounds
- Usually polar/non-polar combinations
  -- MA/resin combinations
  -- SMA
### Technology Platform

<table>
<thead>
<tr>
<th>Technology Platform</th>
<th>Example Gen 1 and 2 Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>ThermoPlastic Carbon Fiber Compounds</td>
<td>Structural and Semi-structural Components</td>
</tr>
<tr>
<td>Dynamic Vulcanization</td>
<td>New Families of Super- TPVs for Underhood Applications</td>
</tr>
<tr>
<td>Maleic Anhydride and Variants</td>
<td>Alloys/BLENDS, Improved Fiber Reinforcements</td>
</tr>
<tr>
<td>Long Fiber Reinforcement</td>
<td>Structural Components, Long Carbon Fiber Reinforcement</td>
</tr>
<tr>
<td>Foaming Technologies</td>
<td>Light Weight, Soft Applications</td>
</tr>
<tr>
<td>Core-Back Molding</td>
<td>Simplified Fabrication of Multilayer Constructions(IP, Door Trim)</td>
</tr>
<tr>
<td>Cellulose Fiber Reinforcement</td>
<td>Door Hardware Module</td>
</tr>
</tbody>
</table>

Source: Robert Eller Associates LLC, 2014
SHORT AIR DUCTS: MODERATE TEMPERATURE UNDERHOOD APPLICATION

• Application: Short clean air duct

• TPE Candidates: o-TPV, PVC/NBR

• Rubber competition: EPDM

• Key Properties:
  - Constant temp resistance to 135°C
  - Oil resistance
  - 75A hardness

• Fabrication process: Injection or blow mold

• Notes:
  - Recent example (not shown) is Hyundai short air duct based on Santoprene™ TPV
  - s-TPVs and COPE for higher temp ducts
  - Weight and cost save vs TS rubbers
  - Recyclability a benefit of TPE use

Photo source: ExxonMobil
TECH. PLATFORM : PP/FIBER REINFORCED DOOR HARDWARE MODULE

CANDIDATE MATERIALS : PP REINFORCED WITH LONG GLASS FIBERS OR 40% CELLULOSE FIBERS

SOURCE: BROSE
TECHNICAL TRENDS: SEBS COMPOUNDS

• Improved SEBS grades:
  - Slush moldable
  - Coated fabric grades
  - Able to compete with o-TPV in some applications

• Competition from improved PVC grades: to answer SEBS challenge

• Bio-elastomers

• Continued growth of multi-component technology:
  - Overmolding/2-shot and extension to foaming methods
  - Co-blow molding
  - Profiles

• Evolution of soft touch: silky feel

• Chinese commodity resin suppliers: catching up in quality and versatility, not there yet
OVERCAPACITY IN SOME ASIAN TPE SECTORS: EXAMPLE SEBS RESIN

SEBS RESIN CAPACITY IN CHINA/TAIWAN (2015)

ANNUAL CAPACITY, kt

<table>
<thead>
<tr>
<th>Company</th>
<th>Capacity</th>
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<tbody>
<tr>
<td>LCY</td>
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<tr>
<td>SINOPEC</td>
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<tr>
<td>TSRC</td>
<td>30</td>
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<tr>
<td>KRATON</td>
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</tr>
<tr>
<td>ORETEL</td>
<td>20</td>
</tr>
</tbody>
</table>

Specialty grade focus

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2014
PRICE PRESSURES ON TPEs - DOWNWARD

CURRENT PRICES

DOWNWARD PRICE PRESSURES

COMPETING MAT’LS.
- OBC
- POEs
- EPDM(d)

TECHNOLOGY
- PROLIFERATION

MACRO ECONOMICS
- SOFT GLOBAL ECONOMY
- EMERGING REGIONS SLOWING

REGIONAL SHIFTS
- SHIFTED BRIC MARKETS
  - SHIFT TO LOWER QUALITY/PRICE TIERs (b)
  - GENERALLY LOWER PRICED MARKETS
  - CHINA PRICING MODEL (c)

RAW MAT’LS COSTS
- SEBS OVERCAP’Y
- EPDM OVERCAP’Y

MARKETS
- MATURING COMMODITY MARKET SECTORS
- SLOWING BRICs GROWTH

INDUSTRY STRUCTURE
- NEW ENTRANTS (a)
- NEW REGIONAL COMPOUNDERS

(a) Asian suppliers entering Western markets
(b) e.g. Global, glocal, local, bottom end
(c) e.g. Cash flow vs. return on capital pricing model
(d) EPDM is in global overcapacity

ROBERT ELLER ASSOCIATES LLC, 2014
TECHNICAL TRENDS AFFECTING AUTOMOTIVE TPEs

• COPEs:
  - High temperature resistance
  - Adhesion
  - Haptics
  - Multi-shot

• TPOs:
  - High flow
  - Thin wall capabilities
  - Use in acoustic components
  - Role of POEs
  - Renewed skins growth

• o-TPVs:
  - High flow/glass adhesion grades for window encapsulation
  - Continued penetration into body seals and glass run channels
  - Improved attachment systems for body seals
GLOBAL AUTO TPE STRATEGY ANALYSIS WHEEL

REGIONAL AUTO PRODUCTION SHIFTS IMPLICATIONS
- ASIA, N. AMERICA, S. AMERICA
- EMERGING MARKET ADAPTATION
- INDUSTRY STRUCTURE DIFFERENCES
- QUALITY/PRICE TIER DIFFERENCES

GLOBALIZATION
- GLOBAL PLATFORM IMPLICATIONS
- REGIONAL SUPPLY CHAIN DIFFERENCES
- TIER 1 CONSOLIDATION

SUBSTITUTION
- CASCADE EFFECT → LOWER COST TPEs
- BIO-TPEs
- RUBBERS
- SUSTAINABILITY, BIO-TPEs ROLE

PROCESS INNOVATIONS
- FOAMING APPROACHES
- MULTI-SHOT MOLDING/CORE BACK
- SLUSH MOLDING
- TEXTILE COATING
- DYNAMIC MOLD HEATING

EXPANDING GLOBAL AUTO TPE WORLD

BROADER PROPERTY RANGE
- SOFT TOUCH
- IMPROVED ADHESION
- HIGHER TEMP CAPABILITY
- SURFACE QUALITY

NEW APPLICATIONS DRIVERS
- GROWTH VIA BOTH AUTO PROD’N AND SUBSTITUTION
- LUXURY (SOFT TOUCH APPROACHES)
- WEIGHT SAVE
- FABRICATION ASSEMBLY/ MATERIALS COSTS SAVE
- RIDING ETP SUBSTITUTION’S COATTAILS
- FOLLOWING ELECTRONICS GROWTH

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2014
PARADIGM HAS SHIFTED IN GLOBAL AUTOMOTIVE TPEs & TPOs

• Grade commoditization: bifurcation into commodity & specialty

• N. American shale gas/oil: shifts economic competitiveness in polyolefins

• Emerging auto markets: Highest global growth rates

• Auto TPE demand growth: via both unit volume growth and substitution

• Supply chain: broadening, new entrants

• Asian TPE competition: Intensifying, $ coming out of Asia(e.g. Kraton/LCY

• Emergence of global:
  - auto platforms
  - standards/performance requirements(starting with TPOs)

• New technical challenges:
  - High temperature
  - Luxury feel
  - Lightweighting/parts integration
SUMMARY

- **TPE challenges:** easily met via the inherent capability of TPEs, TPOs
- **Globalization:** will help TPE penetration into automotive
- **TPE property envelope:** expanding → access to new targets
  - Heat resistance
  - Soft touch
  - Foaming
  - bio-TPEs

- **Fabrication methods:** → oprocess cost save
  - Two shot
  - Twin sheet forming (especially foams)
  - Core-back methods
  - Co-processing (co-blow, coex)

- **Global platform trend:** offers global TPE opportunities

- **Regional auto TPE growth:**
  - Emerging markets (increased substitution to Western levels, organic growth)
  - Western, global TPE brands will benefit most in short term
  - European markets, slow recovery
• “Windows” to TPE and TPO automotive growth:
  - Volume reduction effect of vehicle downsizing
  - Adhesion
  - Foaming
  - Parts consolidation
  - High temperature resistance
  - High flow
  - Soft touch
  - Surface quality
THANKS FOR YOUR ATTENTION

Robert Eller Associates LLC
CONSULTANTS TO THE PLASTICS AND RUBBER INDUSTRIES