GLOBAL DEVELOPMENTS IN TPO/TPE

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Robert Eller Associates is a 20 year-old global plastics consulting company

- Assist companies in the development of strategy and in the strategic decision making process by analyzing technical, marketing and economic implications
- Focus on Elastomers, ETP’s, PP Compounds/TPO, Automotive, and Compounding
- Eleventh year active in China

- Multi-client studies
- Single client studies
- Technical advising
- Mergers and acquisitions
Key Macro Issues Impacting TPO/TPEs

• Emerging middle class will drive consumer goods consumption in emerging economies (strong growth in automotive, electronics (communications), consumer durables and disposables and soft touch

• NA/Europe low economic growth will continue

• China GDP at 7.5%: higher productivity technologies will /are starting to be utilized, high labor intensity businesses move to lower labor cost economies or locations
  – Growth in Central China, SE Asia and India

• Quality will continue to be critical parameter and will continue to improve as emerging economies moves up the quality scale
  – Quality performance tiering still a key factor in emerging economies
  – Emotive marketing will continue to increase (appeal to the five senses, beyond touch)

• Light weighting will increase in value in automotive

• Aging population (NA/Europe) will drive health segments

• Resin suppliers will continue to look for opportunities to move downstream to bring increased value to their businesses

• "Green“ initiatives are taking hold
  – Migration/extractables have been lifted to high emotional issue with general public (BPA, PVC plasticizers, GE modified foods)
  – Bio-polymers (bio-sustainable and bio-degradable) will increase in significance
  – Recycle and design for end life will continue to increase

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2014
Global GDP Snapshot

Brave New World
More than four years after from the start of the U.S. recovery, the pace of growth has slowed globally. Average GDP growth over the previous four years, adjusted for inflation*

DATA SOURCE: IMF

U.S.: 4.2% in 2Q14
Thermoplastic Elastomer Industry Structure and Dynamics

• **Region:** shifted to global 4-5 years ago, key China role, re-shoring effects

• **Concentration:** bipolar, 10-12 large suppliers, many small compounders

• **Independent compounder:** plays significant role in TPEs/ resin companies dominate TPO globally with regional local independent compounder strength

• **Entry barriers:** easy to enter, IP not critical (formulation driven)

• **Entry paths:** multiple (captive resin suppliers, distributors, compounders, back integrated fabricators)

• **Target markets:** auto dominates, broad range of non-auto markets

• **Growth dynamics:**
  - EPDM, PVC substitution, automotive systems cost/weight save
  - Strong intra-TPE competition, cascade to lower cost TPEs
  - Broadening property envelope
  - Bio-TPEs entering
  - Applications development shifted to tier 1s, end users
  - Growth: tied to unit volume growth (e.g. auto) and substitution

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2014
Feedstock Developments

• Elastomer expansions
  POE capacity expansions
  • Singapore (ExxonMobil)
  • Thailand (Dow)
  • Middle East (XOM/SABIC, Sadara)

EPDM capacity expansion
  • Asia (market demand)
    – Koreans (SK, Kumho)
    – China (Lanxess, Sinopec, Celestica)
  • Middle East and North America (low cost gas)
    – Sumitomo, Dow, SABIC
  • Europe
    – Versalis

SBC expansions
  • SEBS
    – China (TSRC, Sinopec, Oretel)
    – Taiwan (Kraton, LCY)
  • SBS
    – China (LCY, Jusage, Dynasol)

• Excess capacity?
  Function of quality/performance tiering

• Role of gas economics

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2014
Feedstock Advantages

*Ethylene Cash Cost Curve 2012*

- **USD/Metric Ton**
- **Ethylene Capacity in Million Metric Tons**

**Source:** Dow Chemical, 2012
Ethylene Alpha Olefins (POEs AND POPs)

• Key characteristics
  - Low modulus
  - Low HDT
  - Poor compression set
  - Good impact modifier

• Low cost: 0.80-1.00 $/lb (1.80-2.2 $/kg)

• Global volume: ~ 800kT

• Chemistry:
  - Metallocene catalyst
  - Ethylene or Propylene copolymers
  - Co-monomers (octene, hexene, butene)

• Major suppliers(a):
  - Dow (Engage, Versify, Amplify, Infuse, Intune)
  - ExxonMobil(Exact, Vistamaxx)
  - Mitsui (Tafmer)
  - LG (Lucene)
  - SK/SABIC (Nexlene)
  - Borealis (former Dex)

• Markets/applications:
  - Impact modification (e.g. TPO is largest app)
  - Footwear
  - Packaging
  - Adhesives
  - Healthcare and personal hygiene
  - Nylon modification
  - Toys/Consumer goods
  - Blown film additive

• Growth potential:
  - High (> 6%/yr globally)
  - New plants in Singapore (ExxonMobil), Thailand (Dow/SCG group), KSA. Korea

• Intermaterials competition:
  - SBC compounds (SBCs have better oil absorption, compression set, heat distortion temperature)
  - EPDM (e.g. in TPOs)
  - Reactor TPOs, PVC

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2014
Extending the SBC Property Range

• **Specialty vs. Commodity**

• **The challenges:**
  - Steep melt viscosity decline with temperature (+ for high filler applications, high flow applications) limits processing / properties)
  - High compression set, especially at elevated temperatures

• **Higher levels of branching / improved high melt strength (HMS) grades which improve:**
  - Blow moldability
  - Foamability
  - Film extrusion/calendaring (for PVC film substitution)
  - Profile/tubing extrusion
  - Thermoformability

• **Improved compression set properties:**
  - Multiple rubber systems (some crosslinked)
  - Competition with o-TPV rubber substitution (e.g. body/glazing seals)

• **Lower molecular weight resin grades**
  - Easier processing

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2014
EPDM

• Significant capacity expansion
  – Asian Capacity: China (Lanxess, SK, Sinopec/Mitsui, Celestica), Korea (Kumho) and KSA (Al-Jubail (SABIC/ExxonMobil), Ras Rabigh (Sumitomo/Aramco))

• New process technology
  – Metallocene II from Dow
    • High Mooney, high diene without rate penalty
  – ACE from Lanxess

• Bio based from Lanxess
  – Uses Braskem sugar-based ethylene

• Significant quality/performance tiering

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2014
<table>
<thead>
<tr>
<th>Shift Type</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acquisition by major TPE supplier</td>
<td>- Merquinsa acquisition by Lubrizol,</td>
</tr>
<tr>
<td></td>
<td>- CTS by Mitsubishi</td>
</tr>
<tr>
<td>TPE entry from other sectors</td>
<td>- Hexpol acquisitions (Elasto, Horst Mueller, Excel)</td>
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<tr>
<td></td>
<td>- Albis (TPV entry)</td>
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<td></td>
<td>- Ravago acquisitions (Enplast/Polyprime)</td>
</tr>
<tr>
<td>Increasing role of independent</td>
<td>- Teknor Apex acquisition of DSM’s Sarlink</td>
</tr>
<tr>
<td>compounder</td>
<td>- China: KingFa, Xinda, Pret and more</td>
</tr>
<tr>
<td></td>
<td>- Washington Penn in Europe</td>
</tr>
<tr>
<td>Resin suppliers moving/expanding</td>
<td>- LCY into TPV (Globalprene)</td>
</tr>
<tr>
<td>downstream</td>
<td>- Kraton</td>
</tr>
<tr>
<td>Entrance into TPVs</td>
<td>- Entrance of many new compounders: Koreans, Chinese</td>
</tr>
<tr>
<td>Money coming out of China</td>
<td>- Nantong Polymax (TPE compound supply)</td>
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<tr>
<td></td>
<td>- TSRC acquisition of Dexco</td>
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<tr>
<td></td>
<td>- KingFa investment in Hydro S&amp;S</td>
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<tr>
<td>Product line diversification</td>
<td>- Kraiburg: high temp TPV (Hipex®)</td>
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<tr>
<td></td>
<td>- Dow: Intune</td>
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<tr>
<td>Shifts to Asian production</td>
<td>- Hexpol</td>
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<td></td>
<td>- Wittenburg</td>
</tr>
<tr>
<td></td>
<td>- Elastron</td>
</tr>
<tr>
<td></td>
<td>- Albis</td>
</tr>
<tr>
<td></td>
<td>- Kraton</td>
</tr>
</tbody>
</table>

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2014
## Role of the Independent Compounder; Global PP Compounding Plants

(Selection of plants for select PP compounders capacity >100 kT annual capacity)

<table>
<thead>
<tr>
<th>MNC Resin Supplier Compounders</th>
<th>NAFTA</th>
<th>S Amer</th>
<th>EU</th>
<th>Asia</th>
<th>Notes</th>
</tr>
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<tbody>
<tr>
<td>LyondellBasell</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>JV</td>
</tr>
<tr>
<td>Advanced Composites (Prime/Mitsui)</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Mytex (Mitsubishi Chem)</td>
<td>2</td>
<td></td>
<td></td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Borealis/Borouge</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>JV (2)</td>
</tr>
<tr>
<td>SABIC</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sumitomo</td>
<td>1</td>
<td></td>
<td></td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>ExxonMobil</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GS Caltex</td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>JV (1)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Independent Compounders</th>
<th>NAFTA</th>
<th>S Amer</th>
<th>EU</th>
<th>Asia</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hyundai EP</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>Toll with LyondellBasell for US/Europe/Brazil</td>
</tr>
<tr>
<td>KingFa</td>
<td>5</td>
<td>1</td>
<td></td>
<td></td>
<td>Controlling interest of Hydro S&amp;S</td>
</tr>
<tr>
<td>Xinda</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pret</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rhetech</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Washington Penn</td>
<td>5</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Techno Compound</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zylog Plastalloys</td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>28 kT</td>
</tr>
<tr>
<td>Machino Polymers</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>40 kT</td>
</tr>
</tbody>
</table>

Zylog and Machino capacities are as listed on their websites

**SOURCE:** ROBERT ELLER ASSOCIATES LLC, 2014
Regional supply chain differences:
MNC resin supplier compounders vs independent compounders

Braskem: No compounding
Dominant role of resin suppliers
Korea: Strong resin supplier and independent compounders
Sinopec: JV, passive role
Reliance: No compounding
The Battle Ground: Strong independent Compounders attacking MNC resin Supply compounders by localization

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2014
Roles of the Independent Compounder vs MNC Integrated Resin Supplier Compounder

• Independent compounders:
  - competitive in technology
  - typically have lower costs/prices
  - spend less on application/technical support
  - not the source of new specs or applications: “chasing the MNC compounders’ truck”

• MNC resin supplier compounders:
  - provide more technical support (design, flow analysis, fabrication and molding assistance)
  - often rely on supply chain relationships (Japan, Korea)
  - use compounding as market entry into emerging economies (low IP risk/low capital risk)

• As OEMs pressure the supply chain for lower costs and localization, role of independent compounder is increasing

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2014
Thermoplastic Elastomer Product Development Product Life Cycle Positions

- TPO BUMPER FASCIA
- SBCs, TPU IN FOOTWEAR
- SOFT TOUCH IN SPORTS/LEISURE, APPLIANCE/TOOL
- SBC-TPEs IN HOUSEWARES
- TPVs IN AUTO BODY/GLAZING SEAL
- SEVERAL TPEs IN WIRE/CABLE
- SBC-TPEs IN FOOD/PHARMA PACKAGING
- TPU IN MEDICAL TUBING
- SBC-TPEs IN AUTO BODY/GLAZING SEALS
- SBCs IN MEDICAL FILM/TUBING
- s-TPVs UNDER-HOOD SEALS/GASKETS (AUTO)
- o-TPVs AUTO RADIATOR HOSE
- BIO-TPEs

MARKET INTRODUCTION | GROWTH | MATURITY | SATURATION (DECLINE)

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2014
## Product Life Cycle Characteristics

<table>
<thead>
<tr>
<th></th>
<th>MARKET INTRO</th>
<th>GROWTH</th>
<th>MATURITY</th>
<th>SATURATION (DECLINE?)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sales vol.</strong></td>
<td>0→Low</td>
<td>Increasing</td>
<td>Steady</td>
<td>Steady or decline</td>
</tr>
<tr>
<td><strong>Dev. costs</strong></td>
<td>High</td>
<td>Reduced</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td><strong>Branding</strong></td>
<td>None</td>
<td>High</td>
<td>None (commodity)</td>
<td>None (commodity)</td>
</tr>
<tr>
<td><strong>Mkt. approach</strong></td>
<td>“Shaping”</td>
<td>Order seek</td>
<td>Order take</td>
<td>Exit</td>
</tr>
<tr>
<td><strong>Inter TPE competition</strong></td>
<td>Varies</td>
<td>Starts</td>
<td>Cascades to lowest cost TPE</td>
<td>Intense (supplier withdrawal)</td>
</tr>
<tr>
<td><strong>Incumbent</strong></td>
<td>Entrenched</td>
<td>Resistance</td>
<td>Replaced</td>
<td></td>
</tr>
<tr>
<td><strong>Supply Chain Systems</strong></td>
<td>None yet</td>
<td>Stimulates growth</td>
<td>Refined</td>
<td>Accepted or shift to new system</td>
</tr>
<tr>
<td><strong>Fabrication technology</strong></td>
<td>Standard</td>
<td>Adopt starts</td>
<td>Accepted</td>
<td>New challenger arrives</td>
</tr>
<tr>
<td><strong>Asia role</strong></td>
<td>None</td>
<td>Slight</td>
<td>Adopt</td>
<td>Wide use</td>
</tr>
<tr>
<td><strong>Global spec</strong></td>
<td>No</td>
<td>Starts</td>
<td>In place</td>
<td></td>
</tr>
<tr>
<td><strong>Example</strong></td>
<td>Radiator hose</td>
<td>Body/glazing seals</td>
<td>TPO fascia</td>
<td>- Pass. airbag door cover - SEBS→ TPO, EVA</td>
</tr>
</tbody>
</table>

**SOURCE:** ROBERT ELLER ASSOCIATES LLC, 2014
Maturing Businesses Becoming Commodities: Shift to Specialties

<table>
<thead>
<tr>
<th>CHARACTERISTIC</th>
<th>COMMODITY</th>
<th>SPECIALTY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of grades</td>
<td>- Many standard grades</td>
<td>- Few grades</td>
</tr>
<tr>
<td></td>
<td>- Compete for same business</td>
<td>- Highly targeted</td>
</tr>
<tr>
<td>Major TPE suppliers</td>
<td>Continue supply or exit</td>
<td>Enter compounding</td>
</tr>
<tr>
<td>Competitive basis</td>
<td>- Price</td>
<td>Performance (tailored)</td>
</tr>
<tr>
<td></td>
<td>- Trend toward global price</td>
<td></td>
</tr>
<tr>
<td>Property differentiation</td>
<td>None → minor</td>
<td>Highly differentiated</td>
</tr>
<tr>
<td>Sales/marketing approach</td>
<td>- Pursue existing markets</td>
<td>“Shape” new markets</td>
</tr>
<tr>
<td></td>
<td>- Take orders/Use distributors</td>
<td></td>
</tr>
<tr>
<td>Tech support, Applications dev.</td>
<td>Minimal</td>
<td>Substantial</td>
</tr>
<tr>
<td>Brand recognition</td>
<td>- Incumbent TPE suppliers (have it)</td>
<td>No: must be built</td>
</tr>
<tr>
<td></td>
<td>- New entrants without it (e.g. Sinopec, TSRC)</td>
<td></td>
</tr>
<tr>
<td>TPE examples</td>
<td>- Standard SEBSs, SBS, TPO</td>
<td>- New SEBS grades</td>
</tr>
<tr>
<td></td>
<td>- Some o-TPVs, TPO</td>
<td>- s-TPVs, Bio-TPEs</td>
</tr>
<tr>
<td></td>
<td>- Some COPEs</td>
<td>- Health care grades</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- New acrylic grades</td>
</tr>
</tbody>
</table>

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2014
## SBC Thermoplastic Elastomer Product Development Life Cycle

<table>
<thead>
<tr>
<th>Markets</th>
<th>Footwear</th>
<th>Soft Touch</th>
<th>Seals</th>
<th>HFFR</th>
<th>PVC Substitution</th>
<th>Bio-grades</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Building &amp; Construction</td>
<td>Medical</td>
<td>Consumer Driven</td>
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<tr>
<td></td>
<td>Automotive</td>
<td>(IV Sets)</td>
<td></td>
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<tr>
<td></td>
<td>Bottle cap liners</td>
<td>IV Bags</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Auto (slush skins)</td>
<td></td>
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<tr>
<td>Chemistries</td>
<td>SBS</td>
<td>HSBC/OBC</td>
<td>TPU</td>
<td></td>
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<tr>
<td></td>
<td>SBS SEBS/SBS</td>
<td>Specialty grades</td>
<td>SBC</td>
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<tr>
<td></td>
<td>SBC/POE SEBS</td>
<td>(x-linkable??)</td>
<td>COPE/TPEE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intermaterial</td>
<td>TPV</td>
<td>TPV</td>
<td>PTPA</td>
<td></td>
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<tr>
<td>Competition</td>
<td>EPDM</td>
<td>PVC</td>
<td>PVC</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Drivers</td>
<td>Low labor costs</td>
<td>Globalization</td>
<td>Domestic (government regs)</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>(shift from HK)</td>
<td>shift from NA/Europe</td>
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<tr>
<td></td>
<td>Costs</td>
<td>Costs</td>
<td></td>
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<tr>
<td></td>
<td>Exports</td>
<td>Exports</td>
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<tr>
<td></td>
<td>(RoHS/WEEE)</td>
<td>Domestic</td>
<td></td>
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<tr>
<td>Tech Reqmts</td>
<td>Low</td>
<td>Medium to High</td>
<td>Medium to High</td>
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<tr>
<td></td>
<td>Low to Medium</td>
<td>High</td>
<td>Medium to High</td>
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<td>Medium to High</td>
<td>Medium to High</td>
<td>Medium to High</td>
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</tr>
<tr>
<td>Who can do it?</td>
<td>Anyone</td>
<td>Nearly everyone</td>
<td>MNCs/ high competency</td>
<td></td>
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<td></td>
<td></td>
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<td>Chinese</td>
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<td>MNCs/ high competency</td>
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<td>Few to date</td>
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<td>Moderate to High</td>
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<td></td>
<td></td>
<td>Low</td>
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<tr>
<td>Life Cycle</td>
<td>Decline</td>
<td>Mature</td>
<td>Growth</td>
<td></td>
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<td></td>
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<td></td>
<td>Early growth</td>
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<td></td>
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<td>Introduction</td>
<td></td>
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<tr>
<td>Key Technologies</td>
<td>Injection</td>
<td>Injection</td>
<td>Profile Extrusion</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Foaming</td>
<td>Two shot</td>
<td>Profile extrusion</td>
<td></td>
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<td></td>
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<td>Slush molding</td>
<td></td>
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</tr>
<tr>
<td>Key Uncertainties</td>
<td>Properties vs EPDM</td>
<td>Meet codes for</td>
<td>PVC substitution</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PVC substitution driver</td>
<td>exports</td>
<td>driver</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Will consumers pay the</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>premium?</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

*Source: Robert Eller Associates, LLC 2014*
PVC is a Major Substitution Opportunity

Advantages

• Price
• Incumbent in medical tubing and infusion bags, wire and cable, slush molded auto skins

Disadvantages

• High specific gravity
• Thermal stability
• Difficult to recycle
• Lower heat distortion
• Poor low temperature performance
• Plasticizer volatility
• Phthalate plasticizers (migration)
• Dioxin generation on combustion/incineration
• Halogenated (RoHS restrictions)

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2014
PVC Substitution Targets

• **Wire and Cable**
  – Halogen free/low smoke/low toxicity: EU driven

• **Medical**
  – Extractables, plasticizer free: emotive driven
  – Infusion bags and tubing

• **Automotive**
  – Skins and coated fabrics

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2014
Automotive: Key Market for Thermoplastic Elastomers

**THE AUTO MARKET**
- 40-50% of current TPE demand
- Key incumbents: EPDM, PVC, TPO
- Global footprint

- Role for lightweighting, systems cost-save
- Key target properties: low V.O.C., thin wall, low odor, oil/fuel resistance, heat resistance, sustainable
- Role for process technology, co-processing innovations

**SOURCE:** ROBERT ELLER ASSOCIATES LLC, 2012
Importance of Automotive varies between TPEs

<table>
<thead>
<tr>
<th>TPE TYPE</th>
<th>AUTO SHARE OF GLOBAL DEMAND</th>
<th>RECENT INCUMBENT</th>
<th>NOTE/ AUTO TARGETS</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPO</td>
<td>75%</td>
<td>None – TPO dominates</td>
<td>Bumper fascia, interior trim, skins Growth in non-auto markets</td>
</tr>
<tr>
<td>o-TPV</td>
<td>50%</td>
<td>NBR/PVC, ECO, CPE, EPDM</td>
<td>Boots/bellows, hose, short air ducts, Body/glazing seals</td>
</tr>
<tr>
<td>SEBS</td>
<td>15%</td>
<td>EPDM, o-TPV</td>
<td>Auto share growing via soft touch, skins, body/glazing seals, airbag doors</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(higher temp capability), wire/cable, soft touch trim panels</td>
</tr>
</tbody>
</table>

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2014
World Vehicle Sales by Region
Jan - Dec 2013

Source: WardsAuto.com

Largest, fastest growth auto market
### Regional Profit Trends In Auto Manufacturing

#### Profit: EUR billions

<table>
<thead>
<tr>
<th>Region</th>
<th>'07</th>
<th>'10</th>
<th>'12</th>
<th>Gain/Loss</th>
<th>Notes</th>
</tr>
</thead>
</table>
| BRIC/ROW     | 12  | 18  | 31  | 19        | - About half of 2012 profits are from China  
- India production will accelerate  
- Profit generation region going forward |
| NAFTA        | 9   | 16  | 23  | 14        | - Most profitable product mix  
- OEM cost structure improved  
- Auto interior polyolefin innovation leader  
- Attracting European and Asian supply chain |
| EU           | 15  | 3   | -1  | -16       | - Major overcapacity/slow recovery started  
- Production shift to E. Europe  
- ≈60% of plants operating at <75% capacity  
- Fierce competition depresses prices |
| Japan/S.Korea| 5   | -4  | 1   | -4        | - Has become export base  
- Microcars have 40% sales share in Japan |

1Profit captured by top 17 OEMs

DATA SOURCE: MCKINSEY

COMMENTS: ROBERT ELLER ASSOCIATES LLC, 2014
Auto Wages: Still Major Gap Between High and Low Paying Countries

Automobile industry average hourly compensation in 2012, including benefits

- Canada: $39.04
- Britain: $38.28
- France: $45.77
- Germany: $58.82
- Japan: $41.65
- United States: $45.34
- 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
China: High Growth Light Vehicle Market

DATA: Wards Auto

COMMENTS ROBERT ELLER ASSOCIATES LLC, 2014

34 MM by 2020
Why Asia Is Important To Western OEMs

WESTERN OEMs WITH LARGEST ASIA SALES

2013 SALES, $BN

VW
BMW
DAIMLER
GM
FORD

SOURCE: THE ECONOMIST, COMPANY REPORTS
Automotive Growth and Interior Polyolefin Increase

• Between 2014 and 2018 global production → 100 MM vehicles/yr

• ~ 70-80% of the growth will be in developing economies:
  • BRIC countries (Brazil, China, Russia, India), other Asia (e.g. Thailand)

• Mexico will continue to grow as an production/export hub

• Interior Tier 1/ Tier2 supplier regional investment will accelerate

GLOBAL LT VEHICLE PROD'N

16 MM vehicle production growth adds 645 kT of:
- polyolefin neat resin
- polyolefin compounds
- TPOs both reactor and compounded

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2014
Interior TPO/PP/TPE Compound Target Examples/Competition

PKG TRAY/TRUNK LINER
NFIB/PP

WINDOW ENCAP
SEBS, o-TPV

SEALS: o-TPV, SEBS

PILLAR TRIM: PP, TPO

ROOF LINER
DUCTS: FOAM

IP: SKINS (TPO, SEBS?, TPU)
FOAM SUBSTRATE

DUCTS: FOAM

DOOR SEALS
o-TPV, SEBS

PKG TRAY/TRUNK LINER
NFIB/PP

DOOR HARDWARE
MODULE, GF/PP

MEDALLION: FOAMS

DOOR TRIM PANEL
NFIB/PP

TPO SKINS
SEBS, TPO

ACOUSTIC BARRIER

SEAT TRIM (COATED FABRIC)

SEAT BACK

PHOTO SOURCE: ST. GOBAIN
TARGETS: ROBERT ELLER ASSOCIATES LLC., 2014
Factors Influencing Global Demand Outlook For Auto Interior PP Compounds And TPO

<table>
<thead>
<tr>
<th>Impact</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>+</td>
<td>Vehicle demand growth shift to Asia/emerging economies (e.g. China reaches 33 MM LV production in 2030). “Re-balancing” program could affect growth</td>
</tr>
<tr>
<td>+</td>
<td>Slow broadening of property envelope ➔ some new applications</td>
</tr>
<tr>
<td>-</td>
<td>Slowing LV production in Western economies (especially Europe)</td>
</tr>
<tr>
<td>-</td>
<td>Smaller vehicles’ share of global production will increase</td>
</tr>
<tr>
<td>-</td>
<td>Increased use of recyclate and bio-fillers</td>
</tr>
<tr>
<td>-</td>
<td>Bio-resins?</td>
</tr>
<tr>
<td>-</td>
<td>Lower specific gravity fillers and reinforcements challenging talc and glass</td>
</tr>
<tr>
<td>-</td>
<td>Increased polyolefin foam use</td>
</tr>
</tbody>
</table>

SOURCE: ROBERT ELLER ASSOCIATES LLC; GLOBAL POLYMER SOLUTIONS, 2014
Global Demand Outlook: Auto Interior PP Compounds and TPO

Demand for PP and TPO in interiors increases by 645kT (1.4 BN lbs) 2014 → 2018, driven by emerging market regions

<table>
<thead>
<tr>
<th>REGION</th>
<th>INTERIOR PP and TPO DEMAND (a)</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2014</td>
<td>2018</td>
<td>CAGR, % YR</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MM LBS</td>
<td>kT</td>
<td>MM LBS</td>
<td>kT</td>
</tr>
<tr>
<td>NA</td>
<td>2,380</td>
<td>1,082</td>
<td>2,000</td>
<td>909</td>
</tr>
<tr>
<td>ROW</td>
<td>6,600</td>
<td>3,000</td>
<td>8,400</td>
<td>3,818</td>
</tr>
<tr>
<td>TOTAL</td>
<td>8,980</td>
<td>4,082</td>
<td>10,640</td>
<td>4,727</td>
</tr>
</tbody>
</table>

(a) PP includes neat PP resin (usually copo) and PP compounds (including filler/reinf.)
TPO includes reactor TPO and compounded TPO

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2014
Slowing Polyolefin Demand\(^1\) Growth In NAFTA Auto Interiors

2015-2018:
- Slower polyolefin demand growth:
  - vehicle size reduction
  - lower wt reinforcements
  - recycled resin
  - foam/thin wall

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2014

\(^1\)Includes PP neat resin, PP compounds, TPO
### Polyolefin Interior Applications And Growth Drivers

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>IP substrate¹, TPO skin, Airbag door, glove box inner.</td>
<td>- Headliner substrate, - TPO: IP and door skin - Increased luxury req’ts</td>
<td>- Size reduction (smaller vehicles) - Bio-resins</td>
</tr>
<tr>
<td>Door trim</td>
<td>Foams: ducts, substrates</td>
<td>Thinwalling</td>
</tr>
<tr>
<td>Kick, seat trim (low copo)</td>
<td>Acoustic systems</td>
<td>Nat fib, fillers vs talc/ glass</td>
</tr>
<tr>
<td>Pillar trim (TPO for head impact &amp; air bag)</td>
<td>- Door hardware module, - Increased door panels</td>
<td>-Foaming, with reinforcement</td>
</tr>
<tr>
<td>Console(replaces ABS and PC/ABS)</td>
<td>- Increased TPO skin use (door trim, inst panels) - Increased all-PP constructs. - Door hardware module</td>
<td>- Compounding at the press Integrated processes</td>
</tr>
<tr>
<td>Seat back, package tray</td>
<td>Spare tire cover</td>
<td>Broaden filler/reinforcement</td>
</tr>
<tr>
<td></td>
<td>- POE use broadens TPO and PP compound performance - Increased reinforcement to further challenge ETPs</td>
<td></td>
</tr>
</tbody>
</table>

¹ Polyolefin IP substrates started in late 80s, initiated by Japanese compounders

*SOURCE: ROBERT ELLER ASSOCIATES LLC/ GLOBAL POLYMER SOLUTIONS, 2014*
# Gateway Technology Platforms In Auto TPO And PP Compounds

## Technology Platform

<table>
<thead>
<tr>
<th>Tech Platform</th>
<th>Example Gen 1 And 2 Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noise Absorbing Designs</td>
<td>Ducting and Air Management Systems</td>
</tr>
<tr>
<td>Lighter Weight Fillers</td>
<td>Substrates and Panels</td>
</tr>
<tr>
<td>Maleic Anhydride and Variants</td>
<td>Alloys/Blends, Fiber Reinforcements</td>
</tr>
<tr>
<td>Long Fiber Reinforcement</td>
<td>Structural Components</td>
</tr>
<tr>
<td></td>
<td>Long Carbon Fiber Reinforcement</td>
</tr>
<tr>
<td>Foaming Technologies</td>
<td>Light Weight, Soft Applications</td>
</tr>
<tr>
<td>Core-back Molding. Integrated Molding</td>
<td>Simplified Fabrication Of Multilayer Constructions(IP, Door Trim)</td>
</tr>
<tr>
<td>Processes</td>
<td></td>
</tr>
<tr>
<td>Cellulose Fiber Reinforcement</td>
<td>Door Hardware Module</td>
</tr>
</tbody>
</table>

*SOURCE: ROBERT ELLER ASSOCIATES LLC, 2014*
**Competition In Interior Soft Trim/Soft Touch**

**SOFT TRIM PROCESS MATERIALS OPTIONS**

**INJECTION**
- **CONV. INJECTION**
  - SOFT TOUCH PAINT
- **2-SHOT**
  - SEBS
  - TPV
  - TPU
- **OVERMOLD**
- **BACK INJECTION**
  - COATED FABRIC
  - FOILS
  - UNCOATED FABRICS

**SKIN PROCESSES**
- **SLUSH MOLD**
  - TPU
  - TPU BLENDS
  - PVC
  - TPO
- **VAC FORM FOILS**
  - THERMO-FORM
    - BACK INJECTION OR LOW PRESSURE MOLDING
    - TPO
    - PVC
    - TPU ALLOY SHEET
- **COATED FABRICS**
  - HAND WRAP OR VAC FORM
  - BACK INJECTION

**SOURCE:** ROBERT ELLER ASSOCIATES LLC, 2011
Multi-material Molding

• Cost save vs. incumbent skins methods
• TPVs and SBC-TPEs (TPE-S) competing
• Foaming will accelerate penetration
• Capital investment vs. labor costs (an issue in Asia)
• TPEs with high flow (large area/thin cross-section) required
• Craftsmanship improvement
• Recyclability
• Multi-color capabilities (2 color lower IP and door medallions are often desired by designers

Source: Robert Eller Associates LLC 2011
Door Trim

Example Multi-material (2-shot) Door Trim Panel
- Application: Door trim (dark areas)
- TPE Supplier: A. Schulman
- TPE Type: o-TPV
- OEM: Chrysler
- Vehicles: Caliber, Commander, Grand Caravan

TPE Benefits:
- Haptics → soft (luxury) touch
- Enhanced craftsmanship/multi-color capability
- Single step process/labor cost savings
- Cost save vs. multi-step approach
- Multi-material molding cycle time approaching single shot

TPE Skin Candidates: SEBS (TPE-S), o-TPV, TPU modified TPE (for use over PC/ABS)

Key TPE Challenge:
- Adequate flow (large area/thin cross-section (1-2 mm)
- Capital investment required
- Ability to incorporate foam
- Competition with textile inserts

Incumbents: Thermoformed/backfoam PVC or TPO sheet, PU spray (declining)

Photo Source: A. Schulman

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2014
Instrument Panel

Grain reproduction: key parameter

Logos

Hidden airbag doors

Craftsmanship

Photo Source: Robert Eller Associates LLC

Photo Source: Robert Eller Associates LLC

Photo Source: Robert Eller Associates LLC
2011 Chevrolet Cruze

Examples of Upgraded Interior on Small Car:

- Steering wheel mounted audio control
- Leather wrapped steering wheel (2LT and Eco models)
- 2-tone instrument panel
- Bluetooth® connectivity
- USB port
- Increased soft touch surfaces

Source: Robert Eller Associates LLC 2011
Instrument Panel of Today

2013 Nissan 370Z
Full skin
Substrate: PP comp’d
Deep projection
Integrated console
Integrated vents
Hidden airbag

Photo: Eller

2015 Mustang
Mixed surfaces
PVC slush skin
Integrated gauges
Retain retro design cues

Photo: Faurecia
2012 Ford Focus SE 5-Door:
Another example of small car luxury
IP Skin PVC Substitution Objectives

Environment
• Halogen free?
• Improve recyclability
• Reduce VOC/fog

Performance
• Satisfactory hidden passenger airbag deployment at -30ºC
• Grain reproduction
• Haptics
• Craftsmanship/fit & finish (shrinkage on heat aging effects)
• Mass reduction
• Long-term UV resistance (low Δ E)
• Heat aging resistance

Cost
• Reduce IP system costs
• Reduce skin costs
• Maintain current labor requirements???

Weight
• Reduce part/car weight

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2014
## Comparison Of Slush IP Skin Capabilities

<table>
<thead>
<tr>
<th>PROPERTY</th>
<th>SLUSH TYPE</th>
<th>SPRAY PU</th>
<th>NOTE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PVC</td>
<td>TPE</td>
<td>TPU</td>
</tr>
<tr>
<td>Raw material cost ($/lb.)</td>
<td>Lowest</td>
<td>Moderate</td>
<td>Highest</td>
</tr>
<tr>
<td>Typical skin weight (lbs.)</td>
<td>3 – 3.5</td>
<td>1.6</td>
<td>2 – 2.5</td>
</tr>
<tr>
<td>Low temp. airbag deployment (heat aging effect)</td>
<td>Some degradation after heat aging</td>
<td>No deployment performance</td>
<td>--</td>
</tr>
<tr>
<td>$\Delta E$ after UV exposure (2500 kJ, 89°C)</td>
<td>Highest</td>
<td>Very low ($&lt; 1$)</td>
<td>Very low ($&lt; 1$)</td>
</tr>
<tr>
<td>Shrinkage on heat aging</td>
<td>Moderate curling</td>
<td>Remains flat (no curling)</td>
<td>Minor curling</td>
</tr>
<tr>
<td>VOC</td>
<td>Medium</td>
<td>Lowest</td>
<td>High</td>
</tr>
<tr>
<td>Fog</td>
<td>Acceptable</td>
<td>Acceptable</td>
<td>High</td>
</tr>
<tr>
<td>Process window</td>
<td>Narrow</td>
<td>Wide</td>
<td>--</td>
</tr>
<tr>
<td>Scratch &amp; mar resistance</td>
<td>Good</td>
<td>Unknown</td>
<td>Very good</td>
</tr>
</tbody>
</table>

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2011
# PVC Substitution: Slush Molding

**Car Model:** Audi E8  
**Part:** Instrument Panel Skin Slush Molded  
**Raw Material Resin:** Kraton  
**Compound:** Laprene S formulated by SO.F.TER  
**Fabricator:** Peguform  
**Features:**  
- Halogen free, pthalate free  
- 30-40% lighter weight than PVC  
- Better low temperature performance than PVC  
- Better aging characteristics than PVC  
- Lower processing costs  
- Recyclable  
- Deep soft touch/haptics feel

*SOURCE: ROBERT ELLER ASSOCIATES LLC, 2014*
• PVC: the dominant incumbent strongly entrenched, cost effective
• SBC-TPEs: Phthalate-free, UV resistance, low temp properties
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

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

Photo: Kraiburg

Photo: Eller

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2014
### Under Hood Temperature Increases ➔ High Heat Thermoplastic Elastomers

<table>
<thead>
<tr>
<th>Application</th>
<th>Type</th>
<th>Key Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air duct cuff</td>
<td>s-TPV (Zeotherm)</td>
<td>Heat resistance, Ease of processing, Polyamide adhesion</td>
</tr>
<tr>
<td>Hot air duct (primarily turbo engines)</td>
<td>s-TPV (Zeotherm)</td>
<td>Heat resistance, Processing ease</td>
</tr>
</tbody>
</table>

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

**Source:** Zeon Chemicals

**Source:** Source: ROBERT ELLER ASSOCIATES LLC, 2014
Broadening the Thermoplastic Elastomer Application Base

• Application: High temp hose

• Target markets: Auto under hood, industrial hose

• TPE types: Several depending on heat resistance level (COPE, TPEE, s-TPV)

• Key properties: Temp resistance
Low stiffness

• Process: Water Injection molding technology (WIT)

• TPE enabling technology: Temp resist (s-TPVs)

• Note:
- Woven mesh inserted during molding process
- Mesh insertion developed at IKV

Source: Akro-Plastic GmbH

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2014
## Co-processing Drives Thermoplastic Elastomer Growth in Rigid/Flexible Systems

<table>
<thead>
<tr>
<th>TYPE</th>
<th>STRUCTURE</th>
<th>NOTE/EXAMPLE APPLICATION</th>
</tr>
</thead>
</table>
| Overmold, Film coex, 2-shot mold  | TPE Substrate (rigid segment) | - Soft touch phones  
- Some 2-tone applications  
- Vibration damping |
| Side by Side                      | TPE Rigid Segment           | - 2-tone  
- Door trim, console, IP  
- Bumper fascia |
| Edging                            |                             | - Body/glazing seals (profiles)  
- Cowl vent seals  
- Co-extrusion or 2-shot |
| Co-blow Mold                      | TPE (flexible) Rigid        | - Boots/bellows, hose  
- Ducting |
| Co-extrusion Blow Mold or Co-extrusion | o-TPV s-TPV or ETP inner | Under-hood:  
- Hose (e.g. fuel)  
- Duct |

Source: Robert Eller Associates LLC, 2012

r/mydox/Visio/Two Shot OM approaches 2012.vsd
Automotive Hose: Adding Value Via Coextrusion

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2014
Auto Acoustics Control Technologies: Role For TPEs

Automotive Acoustics Solutions

- Body/glazing seals* (a)
- Acoustic barrier and absorber Construction (b)*
- Sound deadening carpet (d)
- Acoustic glazing laminates
- Foams injected into body hollow sections (c)
- Improved engine mount isolation
- Parts re-design*

Gasketing to control BSR (d)*

Note: *= current or potential TPE/TPO/o-TPV opportunities
(a) High growth application for SBCs and o-TPVs
(b) Lightweight dash mats and heavy duty barriers (e.g. from Cascade Engineering)
  Includes polyolefin foams
(c) For example Betafoam™ from Dow based on PU foams
(d) For example from IAC/Stankiewicz
(e) Becoming common via feedback microphones (e.g. Honda Accord and Chevrolet Impala)
(f) BSR = Buzz, squeak, rattle

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2014
Medical

- Will this be the next major PVC substitution market?
- Target will be IV tubes and bags
  - Expect competition from transparent PP injection blow molded bottles in bags
  - China use per capita above global average
  - Volume potential is in excess of 300 kT/yr
- Has been limited substitution into applications (kidney, liver, some cancer applications)
- Regulatory driver has been lacking: will China lead?
- SBC compounds are prepared with compounds
- New COC elastomer from Topas targeted at medical
- Will the resin capabilities exist?
  - Supply shortage for higher performance/quality materials?
  - Sinopec role?
  - IV tubes take preference to bags (bottles)
- Big question: when?

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2014
PVC Substitution: Infusion Bags/Bottles

PHOTO: KRATON

**Application:** IV bag

**TPE type:** H-SBC (SEBS)

**Key properties:** Elasticity, Low temp, Clarity, PP compatibility, Melt strength

**Processing:** Co-Extrusion

PHOTO: KRAIBURG

**Application:** Infusion bottle closure

**TPE type:** H-SBC (SEBS)

**Key properties:** Re-sealing, Bond to polyolefins

**Processing:** 2 component injection

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2014
Wire and Cable

- > 300 kT PVC market with major substitution ongoing globally
- Europe driven: RoHS and WEEE requirements
- Major global OEMs have issued directives to eliminate PVC and halogen containing products on a global basis to eliminate potential risk of any of their branded manufactured electronic product containing halogen materials being disposed in landfills in Europe
- Low smoke requirements increasing
- Target applications are household cables and wires typically less than 200 Volts used for household power, electrical, electronic, computer, media and network applications
- SABIC IP was early compound supplier with Flexible Noryl
- Combustion toxicity

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2014
Flame Retardancy

- Flammability requirements: UL62 VW-1 and UL94 V-O
- Halogen free
  - Combustion toxicity
  - Environmental persistence
  - Chronic exposure
  - Bio accumulation
  - Non brominated technologies
    - Magnesium Hydroxide
    - Antimony Trioxide
    - Zinc Borate
    - Ammonium Polyphosphate
    - Melamine Polyphosphate
    - Melamine cyanurate
    - Metal phosphinates
- Low smoke

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2014
Bio TPEs

- Driving forces:
  - Emotive from the consumer perspective
  - Sustainability from the manufacturer

- Applications
  - Driven by marketing to consumers/consumer oriented products (both disposable and durable goods)
  - Footwear

- Definitions
  - Renewable or Sustainable Compounds
    - Produced from renewable raw material sources that are sustainable from plants or animals
  - Bio-degradable
    - Compostable
    - International standards
      - Plastic biodegradation: EU13432/EN14995/ASTM D6400
      - Aerobic biodegradation: EN14046/ISO1485551
    - Can be either synthetic or bio-based

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2014
<table>
<thead>
<tr>
<th>Feedstock Source</th>
<th>Status and Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>Shenhua/Dow in China: Polyolefins plant under construction</td>
</tr>
<tr>
<td>Corn</td>
<td>PLA, polyols (COPE, TPU) Materials in production</td>
</tr>
<tr>
<td>Castor Bean</td>
<td>COPA (in production)</td>
</tr>
<tr>
<td>Biomass</td>
<td>Butadiene via butanediol Versalis (under development)</td>
</tr>
<tr>
<td>Waste CO</td>
<td>Butadiene Invista/Lanza Tech in development</td>
</tr>
<tr>
<td>Starch</td>
<td>Teknor Apex, Cereplast, Roquette (Gaialene) in production</td>
</tr>
<tr>
<td>Sugar</td>
<td>Braskem (in production for PE, PP planned) Dow Mitsui JV project delayed</td>
</tr>
<tr>
<td>Algae</td>
<td>Algenol (Dow) Solarzyme (Dow) Synthetic Genomics (ExxonMobil) All in R&amp;D/Pilot Plant stage</td>
</tr>
<tr>
<td>Yeasts</td>
<td>Amyris developed/ Kuraray polymerization/manufacturing Farnasene elastomers /being used in the tire market Isoprene under development Braskem/Michelin</td>
</tr>
</tbody>
</table>

Source: Robert Eller Associates LLC 2014
## Thermoplastic Elastomer Compounds Based on Renewable Raw Materials

<table>
<thead>
<tr>
<th>Elastomer Family</th>
<th>Renewable/Sustainable Source</th>
<th>Market Driver</th>
<th>Producers</th>
<th>Renewable Content (%)</th>
<th>Hardness Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>SBC</td>
<td>Starch (Gaialene)</td>
<td>Consumer products</td>
<td>Mitsubishi</td>
<td>20-50</td>
<td>22-85 (Shore A)</td>
</tr>
<tr>
<td>TPU</td>
<td>Polyols based on plants (corn and fats/oils)</td>
<td>Footwear</td>
<td>Lubrizol Bayer API GLS BASF/Oleon</td>
<td>20-70</td>
<td>70 (Shore A) to 55 (Shore D)</td>
</tr>
<tr>
<td>COPE (TPE-E)</td>
<td>Polyols based on plants (corn)</td>
<td></td>
<td>DSM DuPont GLS</td>
<td>20-60</td>
<td>35-55 (Shore D)</td>
</tr>
<tr>
<td>COPA</td>
<td>Castor Oil</td>
<td>Footwear</td>
<td>Arkema Evonik</td>
<td>25-94</td>
<td>35-72 (Shore D)</td>
</tr>
<tr>
<td>EPDM</td>
<td>Sugar (Braskem ethylene)</td>
<td></td>
<td>DSM</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**SOURCE:** ROBERT ELLER ASSOCIATES LLC, 2014
Plant-based Fillers/Fibers for Bio-Plastics/Elastomers

- Plant
  - Starch
  - Bromeliad
  - Bast fibers
  - Leaf
  - Seed
  - Fruits/Grains
  - Wood
    - Wood fiber
  - Wood fiber
    - Wood flour
  - Curana
  - Flax
  - Sisal
  - Cotton
  - Coconut
  - Hemp
  - Curana
  - Flax
  - Rice Hulls
    - Jute
    - Hennequin
    - Banana
    - Bamboo

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2014
**Biodegradable Thermoplastic Elastomers**

- **API (Italy): Apinat**
  - Based on TPU and aliphatic copolyester
  - Two series of biodegradable, one from
    - synthetic raw materials
    - renewable raw materials (polyols derived from plant (mainly corn))
  - Hardness from 55 Shore A to 78 Shore D

- **Green Dot Holdings (US): Terratek Flex GDH-B1**
  - Starch based compostable thermoplastic elastomer
  - Initial applications in cell phone cases, toys and furniture
  - Startup company, limited supply capabilities

**Source:** ROBERT ELLER ASSOCIATES LLC, 2014
Global TPE Summary

GLOBALIZATION/REGIONAL MARKET SECTOR SHIFTS
- CHINA (STRONG AUTO GROWTH)/INDIA (EMERGING)
- RE-BALANCING TOWARD CONSUMER MARKETS
- PATH-TO-MARKET DIFFERENCES
- QUALITY/PRICE TIER DIFFERENCES

ECONOMICS
- REGIONAL MFG COST DIFFERENCES
- REGIONAL SUPPLY CHAIN DIFFERENCES
- GDP/CAPITA DIFFERENCES
- INVESTMENT FROM ASIA/EUROPE

EXPANDING GLOBAL TPE OPPORTUNITIES

SUBSTITUTION EFFECTS
- CASCADE EFFECT → LOWER COST TPEs
- BIO-TPEs STARTING
- CHALLENGE TO RUBBER CONTINUES

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

NEW APPLICATION DRIVERS
- GROWTH VIA BOTH ORGANIC GROWTH AND SUBSTITUTION
- LUXURY (SOFT TOUCH/SILKY FEEL APPROACHES)
- RIDING ETP SUBSTITUTION’S COATTAILS
- RIGID/Flexible COMBINATIONS
- COMMODITIZATION VS SPECIALTIES

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2014
Thank You!

Robert Eller Associates LLC

CONSULTANTS TO THE PLASTICS AND RUBBER INDUSTRIES