RECYCLING & GREEN PROJECT IDEAS IN POLYMER FIELD

ANOMITRA CHAKRAVARTY
KPS CONSULTANTS & IMPEX PVT. LTD.

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MAIN THEME OF THE PROJECTS

REDUCE – Materials, Resources & Wastage

REUSE - Process waste

RECYCLE - Up cycle

RECOVER - Polymers from used products

Projects Discussed

1) TPE / TPV from waste EPDM and PP
2) Recycling of waste PET Bottles into value added products
3) Waste PET Bottles to Re-generated Polyester Staple Fiber
4) Recycling of waste Tetrapak into Wood Plastic Composite
5) Wood Powder – PVC Foamed Celuka Board
6) EVA Hollow Polymer Coil Mattress & Cushion material
7) Synthetic (Stone) Paper
8) 3 Layer Co-extruded Rigid PVC Roofing Sheet & Tile
9) EVA Encapsulation Film used in solar photovoltaic panels
10) Fly Ash + Recycled PP composite
11) Expanded Polyethylene (PE Foam)
12) Bamboo Fiber Composites

TPE / TPV FROM RECYCLED EPDM WASTE AND PP

> 45 % of automotive rubber waste (excluding tyres) is EPDM – weather strips, glass run channels, hose, vibration insulators, miscellaneous items.

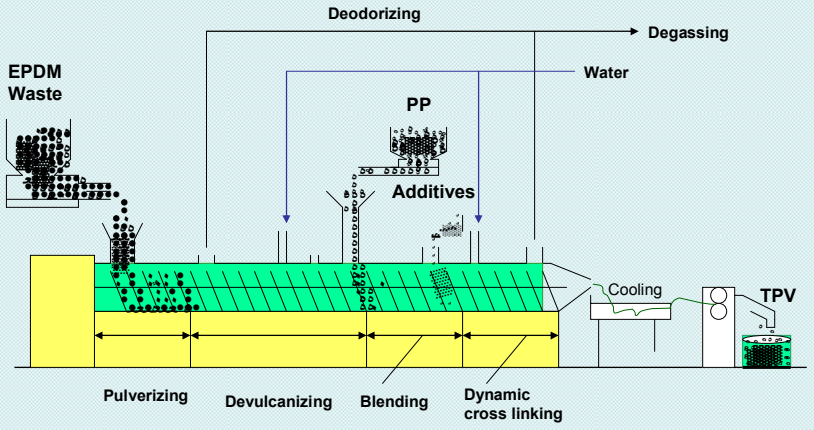
> Thermoplastic Vulcanizate (TPV) - blend of EPDM and Polypropylene combining flexibility of vulcanized rubber and processing ease of thermoplastics. Provides outstanding resistance to ozone, heat, weathering and various chemicals. Production scrap is recycled - reduces costs and waste.

> Thermoplastic Elastomer (TPE) – physical blend of thermoplastic & elastomer advantages of rubbery & plastic properties in single material.

> End Applications – Automotive, Appliances, Grips, Sports, Toys, Medical, Electronics etc.

Manufacturing process

- > **Grinding to 5 mm particle size, free of metal & fiber**
- > **Continuous process – extrusion**
- > **Four Extruder zones : Zone 1 - Pulverizing of EPDM by shearing action, Zone 2 - De vulcanization (selective breaking of cross-linking points) Zone 3 - Blending of reclaimed EPDM with PP (60- 80 & 20- 40 % by wt.) Zone 4 – Dynamic cross-linking of EPDM**
- > **Deodourization – high pressure water injected into the barrel in the de-vulcanization zone, odourous components removed by degassing**
- > **Dynamic cross-linking systems used - activated phenol formaldehyde resins or resol – resins (demerits – hygroscopic & staining), Peroxide & Co-agent(demerit - PP degradation), Grafted Silanes Sulphur, Activator (ZnO), Accelerators (TMTD, MBTS)**
- > **Additives – Stabilizers, Anti-oxidant etc.**
- > **Cooling & Pelletization**



Continuous recycling process for the production of TPV from EPDM waste

RECYCLING OF WASTE PET BOTTLES INTO VALUE ADDED PRODUCTS

Waste PET Bottles

Washed PET Flakes

RECYCLED PET GRANULES

CLEAR SHEET FOR THERMOFORMED PACKAGING

BLENDING WITH VIRGIN PET

NON FOOD CONTAINERS

STRAPPING TAPE

ENGINEERING PLASTICS

VARIOUS USES OF RECYCLED PET

1) Produce **CLEAR SHEET** for thermoformed packaging material e.g. health care, cosmetics, ready meal & snacks, dairy & bakery products, confectionary, consumer electronics, fruits etc. The sheet industry has the ability to extrude multi-layer sheet and this enables them to sandwich an R-PET layer between two outer layers of virgin PET particularly for food contact applications.

2) Produce **CONTAINERS** for non-food contact applications such as bottles for Phenyl, Battery Water, Liquid Detergent, Cleaning Solution, Oils etc.

3) **STRAPPING TAPE** for bailing cotton & strapping boxes

4) Blending with virgin PET and other Engineering Plastics.

5) **Bottle Grade PET resin** through extrusion, thermal crystallization and Solid State Polycondensation (SSP). Increases IV and reduces Acetaldehydes & VOCs.

Manufacturing process

> Waste PET bottles shredded into flakes
> Labels & Caps separated
> Hot washing of PET flakes
> Drying of PET flakes
> Extrusion with vacuum degassing to remove moisture
> Filtration of solid contaminants
> Underwater strand pelletization
> Recycled PET Granules
> Very low fall in PET polymer Intrinsic Viscosity
> Low level of contaminants

WASTE PET BOTTLES TO REGENERATED POLYESTER STAPLE FIBER

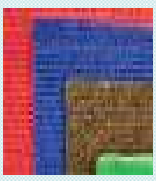
WASTE PET BOTTLES

REGENERATED POLYESTER STAPLE FIBER

USE OF PET BOTTLES IS GROWING @ 7 % YOY
INDIAN PET RESIN DEMAND > 650,000 MT IN 2012-13
PET SCRAP IN EXCESS OF 450,000 MT / Yr AVAILABLE
WORLD POLYESTER FIBER DEMAND GROWTH ~ 8.5 %

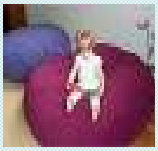
(a) Major use of R-PSF is in the **Needle-punched non-woven fabric** industry. Main application is in automotive segment (carpet, upholstery, trunk liner, roof insulation etc.), carpet segment (exhibition, floor, wall carpets & backing), filter segment and geo-textiles.
(b) **Fiber-fill and wadding** industry. End applications include stuffing for jackets, cushions, pillows, mattresses, toys, sleeping bags, quilts, fur fabrics etc.
(c) The other major use of R-PSF is in the **yarn spinning** industry. Spun yarn is used in textiles, bedspreads, pillow covers, sports wear, athletic shoes etc.









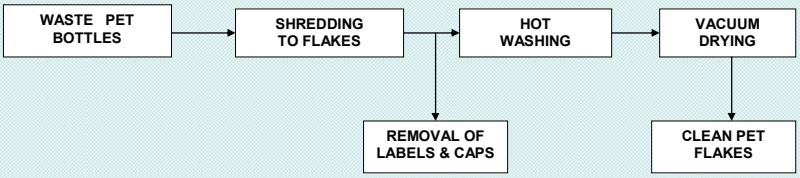


Clean PET Flakes

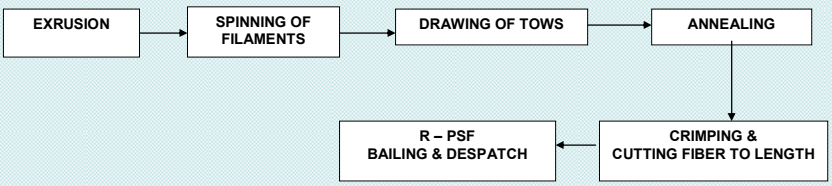
Re-generated Polyester Staple Fiber

Production Process Flow

1) Conversion of Waste PET Bottles to Clean PET Flakes



2) Conversion of PET Flakes to Polyester Staple Fiber



RECYCLING OF WASTE TETRAPAK INTO WOOD PLASTIC COMPOSITE

Tetrapak ® is well known packaging material for milk, juice, beverages. It is made up of Paper board (around 65 %), Low Density Polyethylene - LDPE (30 %) and Aluminium foil (5 %). The separation of paper, LDPE and aluminium fractions is not cost effective for recycling purpose.

The manufacture of Wood Plastic Composite (WPC) presents a cost effective and technically feasible recycling solution that can produce value added product. WPC is a combination of cellulosic material (like wood fiber) and thermoplastic.

End products: Outdoor Decking & Flooring, Railing, Fencing, Wall Panel, Transportation Pallets (marine cargo, warehousing). Pallets made from WPC are waterproof, durable and do not require fumigation unlike wooden pallets.

Manufacturing process:

> Waste Tetra Pack packaging material shred & ground to powder
> Compounded with Virgin & Recycled HDPE, MAPE Compatibilizer, Anti-oxidant, UV Absorber, Lubricant, Colour MB, Biocide / Anti-microbial
> Single screw extruder – pellets
> Conical Twin Screw Extruder – profile extrusion
> Calibration & Cooling bath
> Cutting to length

WOOD POWDER - PVC FOAMED CELUKA BOARD

Wood Powder - PVC Foamed Celuka Board is a high performance and competitive substitute for high end Plyboard & Plywood in applications such as Kitchen / Bathroom Cabinets, Cupboards, Closets, Office Furniture, Work Stations, Partitions, Wall Paneling, Indoor Flooring, Construction Template / Formwork (Shuttering) etc.

Compounding: Main raw materials are PVC resin (virgin & recycled), wood powder and processing additives like Heat Stabilizer, Acrylic Processing Aid & Impact Modifier, Foaming agent (ADC + $NaHCO_3$), Foaming Regulator, Filler - $CaCO_3$ etc.

Manufacturing process involves dry mixing, extrusion, vacuum calibration, cooling and length / side cutting. Width of board manufactured is 1220 mm (4 feet) and thickness ranges from 5 mm to 30 mm. Density 0.55 to 0.75 g / cm^3

The project has reasonably high technology level, is environment friendly, no pollution, low power requirement and very low labour requirement.

LEED India Green Building Rating System

By incorporating this material - builders, architects, project managers can get LEED credit eligibility in a number of areas like Recycled Content, Low Emitting Materials, Regional Materials & Innovation in Design. With 26 points being required for general LEED certification, more than nine points can be cost effectively achieved through the use of WPCs.

Advantages of Wood – PVC Foamed Celuka Board over Ply board

> Completely Water Resistant
> Durability (long service life)
> Fire Retardant (self extinguishing) & Low Flammability
> High Dimensional Accuracy (extruded like plastics)
> Hard & Smooth Outer Surface
> Easy & Fast to Fabricate into end products (saves time & labour cost)
> Saves cost of laminates (no need of veneer, varnishing, painting etc.)
> Non - Toxic (no Formaldehyde release like plywood)
> High Impact Strength, Good Screw & Nail withdrawal strength
> Rot Proof & Termite Proof
> Good sound and thermal insulation
> Processed like plastics but behave like wood - can be sawed, screwed, nailed
> Efficient use of scrap resources hence environment friendly
> Density / Weight - similar to wood

EVA - Hollow Polymer Coil Mattress & Cushion Material

Hollow polymer coil mattress and cushion is an innovative material made from EVA (Ethylene Vinyl Acetate). The hollow polymer threads form an entangled three-dimensional network structure.

Features of Hollow Polymer Coil Mattress & Cushion

- Due to its entangled three-dimensional network structure the material provides excellent strength as well as flexibility.
- The material has excellent air permeability and heat dissipation - which makes the mattress & cushion breathable.
- The material can be easily washed with water to remove odour & dust.
- The material is mold, fungus, bacteria & mite proof. The material does not release any harmful chemicals and is EU - RoHS compliant.
- The material is much lighter (Bulk Density 0.06 – 0.08 g / cm^3) and more durable as compared to other mattress material.
- The material is environmentally friendly as it saves energy & water during production and can be 100 % recycled.
- No toxic fumes released in case of fire, no fire retardants used (unlike PU foam)

Basic manufacturing process – Extrusion

EVA Resin (14 to 20 % VA content)

Hollow Polymer Coil Mattress compared to other materials like Natural Latex Foam, PU Foam, Rubberized Coir Mattress, Metal Spring / Coil

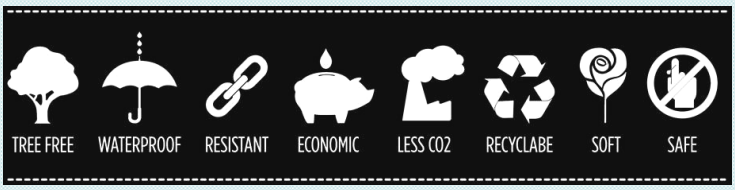
> Excellent performance (strength, flexibility, durability, breath ability, wash ability) to price ratio
> Much lower cost than Natural Latex Foam & Spring mattress.
> Flammability much lower than PU Foam, Rubberized Coir
> No toxic fumes released in case of fire
> No fire retardants used, no fillers (unlike PU Foam)
> No sagging over time (unlike Rubberized Coir)
> Can be 100 % recycled.

SYNTHETIC (STONE) PAPER

This innovative material is produced from $CaCO_3$ bonded with a thermoplastic resin like Polypropylene (PP) or High Density Polyethylene (HDPE) and processing additives. Proportion of micronized $CaCO_3$ can be as high as 75 %.

<u>Advantages of Synthetic / Stone Paper</u>

> **Naturally white & smooth surface**
> **Well suited for both printing & writing (lower ink consumption)**
> **Tear resistant**
> **Water & Grease resistant**
> **Acid Free & Anti Static**
> **No Grain Direction – strength in both directions**
> **Insect Resistant**



Features of Synthetic / Stone Paper

> Saving of natural resources and lower environmental impact
> No timber pulp is used in the production process thus saving forest resources (One ton of standard copy paper requires four tons of wood pulp)
> No water is used in the production process. (One ton of standard copy paper produces 60,000 liters of contaminated waste water)
> 50 % less power required to produce synthetic paper as compared to virgin paper and 30% less power required as compared to recycled paper.
> No chemicals like chlorine, acid, alkali or bleaching agent required,
> It is recyclable in both the plastic (preferred) and the paper recycling streams.
> It photo-biodegradable and will break down after 14 -18 months exposure to UV light.

Applications of Synthetic / Stone Paper

> Packaging > Shopping Bags > Labels & Tags > Banners & Large Format Signs
> Outdoor Applications > Books & Book Covers > Catalogues, Brochures, Manuals
> Wall paper > Greeting, Invitation & Business Cards > Boxes, Cartons & Envelopes
> Calendars, Flyers & Tickets

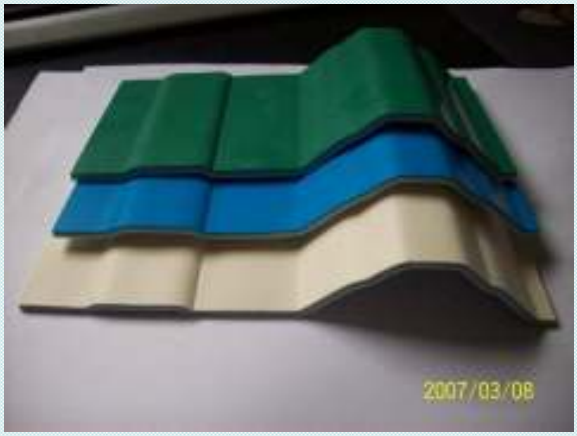
Manufacturing Process

Compounding -------- Mixing -------- Extrusion -------- Calandering -------- Stretching

Winding into rolls --------- Slitting (sides) --------- Coating -------- Cooling

> Thickness 80 to 400 microns

3 LAYER CO- EXTRUDED RIGID PVC ROOFING SHEET



Applications : Factory Building, Warehouse, Residential, Porch / Balcony, Car Parking Sheds, Portable Cabins, Markets, Resorts, Animal Shed etc.

Outer layer: U-PVC compound with very good weathering, UV light & corrosion resistance and very high light - fastness colour pigments (so that colour does not fade over time). Outer layer can be coated with ASA or PMMA resin.

Middle layer: Foamed U-PVC compound which provides rigidity and strength to the roofing sheet. Re-cycled PVC can be used. Also reinforcement with Glass / Carbon Fiber for higher rigidity & strength.

Inner layer: U-PVC compound with ultra white pigments for good lighting effect inside the warehouse / factory building.

Advantages : Durability (long service life), Excellent heat insulation
Excellent weathering / corrosion resistance (suited for coastal areas)
Excellent fire resistance, High impact strength, Acid & alkali resistant
Light weight – lower structural cost
Can be nailed, sawed or cut easily
Easy handling & installation (lower cost of installation & transportation)

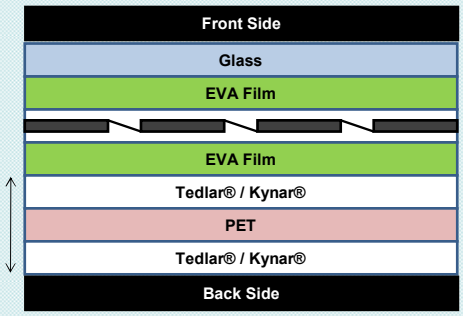
Synthetic Resin Roof Tile (ASA / PVC)

Two Layer Co - extruded Synthetic Roof Tile
Cover layer: Acrylonitrile Styrene Acrylate (ASA) or Polymethyl methacrylate (PMMA) resin Base : Foamed U-PVC compound

EVA ENCAPSULATUION FILM USED IN SOLAR PV PANEL

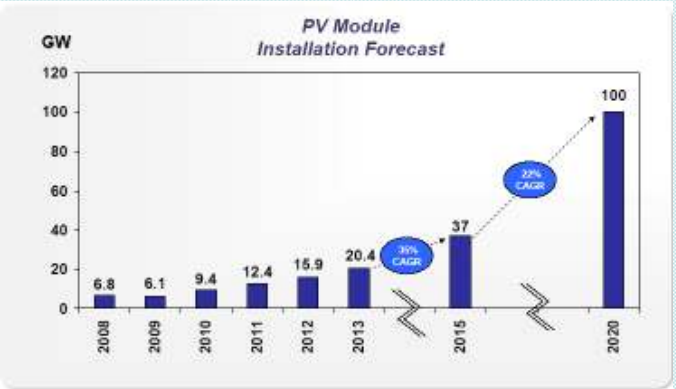
The field of solar photovoltaics for the generation of power is today one of the most upcoming and profitable business. Ethyl Vinyl Acetate (EVA) sheet is used for the encapsulation of Solar PV cells. Back Sheet consists of PET film laminated with Polyvinylidene Fluoride (PVDF) film on either side.

Basic structure of a PV panel



Requirements of PV Panel Encapsulation Film

- > High light transmission for front encapsulation film
- > Low modulus
- > Protect PV cell from corrosion
- > Good Adhesion to front glass and PV cell
- > Good Adhesion to back sheet and PV cell
- > Solar Grade EVA films have high VA content



PV Global Market Forecast, Source: Applied Materials

Some highlights of the Jawaharlal Nehru National Solar Mission

- > Make India a global leader in solar energy and the mission envisages an installed solar generation capacity of 5 GW by 2017, 25 GW by 2020, 100 GW by 2030 and of 200 GW by 2050.
- > The total expected investment required for the 30 year period will be around Rs. 85,000 Crores to Rs. 105,000 Crores.
- > Between 2017 and 2020 achieve tariff parity with conventional grid power

Basic Manufacturing Process – Extrusion (T Die) and 3 Roll Calandering

Film Width 1000 mm, Film Thickness 500 microns

Compounding – EVA Resin (28 to 33 % VA Content), Curing Agent (Peroxide) Co-agent (TAIC), Anti-oxidant, UV Absorber, Heat Stabilizer, Silane

In 2011 world consumption of EVA encapsulation film was 133 Million Sq. Meters

FLY ASH + RECYCLED POLYPROPYLENE COMPOSITE

+

> Fly Ash generated by Coal Fired Power Plants - Micronized
> Post consumer / post industrial PP – recycled into pellets
> Coupling Agent – Stearic Acid (easily available & economical)
> Stearic Acid 2% by wt. of Fly Ash in suitable solvent
> Drying at room temperature
> Fly Ash & Recycled PP in the ratio 1 : 1
> Melt mixing by single screw extruder to produce composite pellets or end pdts.

Example1

Syndecrete is a precast lightweight composite containing fly ash and post-industrial recycled polypropylene fiber waste from carpet manufacturing. To date, Syndecrete has developed 13 standard colors and a library of over 500 custom colors and mix designs. Applications of this product include: countertops, table tops, tiles, fireplace surrounds, landscape elements, sinks, bathtubs etc.

Example2

PLASH by Chubu Electric – Japan
Improved impact strength

Expanded Polyethylene (PE Foam)

Expanded Polyethylene or PE Foam is mainly produced through extrusion technologies. The foams are created by first dissolving and mixing an inert gas in the molten PE, secondly expanding the gas into a lot of small bubbles or cells and finally cooling the expanded PE and thereby creating the final foam. The LDPE may also cross-linked to provide additional strength & properties

- Foam can be shaped into different semi-finished products such as tubes, profiles, sheets and blocks / produced in any colour
- Expansion results in a substantial reduction of density and hence weight. LDPE typically has a specific density of 920 kg / m³. On the other hand the average density of PE foam is 30 kg / m³ (15 kg / m³ to 90 kg / m³).
- Foam PE has a high heat and sound insulation capacity and excellent shock absorbing capability.
- Main users building, packaging, automotive & sports goods industry.
- Modern technology utilizes inert gases like CO_2, N_2, Butane, LPG etc. as physical blowing agents and a foaming amplifier used when low densities and high foam homogeneity is required

Applications of Expanded Polyethylene

Packaging of consumer electronic products like LED / LCD TV, Washing Machine, Air conditioner, Microwave Ovens, Laptops, Computer Monitors etc.
Packaging of Furniture
Packaging of Fruits (Nets)
Pipe insulation / Wall insulation in building construction
Sports equipment
Packaging of equipment / Export packaging

Bamboo Fiber Composite

Bamboo is a member of the grass family and is one of the fastest growing plants. Bamboo cultivation is free of pesticide and fertilizer and does not require a lot of water to grow. Bamboo fibers are blended into a thermoplastic matrix (like Polypropylene) to produce bamboo fiber reinforced plastic.

> Bamboo fiber is a renewable biological resource
> It is a low cost material improving economics of the end product
> It is strong yet light weight - improving strength of composite
> It is hydrophobic (repels water), rot proof, anti-bacterial, anti-allergic and fire resistant.
> It provides excellent resistance to compression and flexion.
> It is naturally bio-degradable

Bamboo fiber composite (BFC) is an ideal engineering material to replace plastic products with lower cost and better performance.
It is an environmentally positive material --- partly based on renewable biological product and helps in reducing the carbon footprint.

> Bamboo fiber loading can be as high as 50 % by weight of the polymer.
> Bamboo fiber reinforced plastics can be processed by injection moulding or extrusion
> End applications - Table ware (bowls, plates, trays, glass, cutlery etc.), Kitchenware, Containers, Household appliance housing, toothbrush stems, Flower pots, Toys, automotive interior trims, Furniture items (stools, chairs, table etc.), handles, combs, motorcycle seat, car seat etc.

Typical values comparing BFC with other materials

NO	Item	Density	Hardness	Tensile Strength	Flexural Strength	Flexural Modulus	IZOD Impact, Notched
		g/cm³	D	MPa	MPa	MPa	KJ / m2
1	30% Bamboo fiber reinforced composites	1.04	65	32	51	2410	11
2	40% Bamboo fiber reinforced composites	1.04	71	45	79	3895	6
3	50% Bamboo fiber reinforced composites	1.04	73	50	84	4620	4
4	Polypropylene	0.97	65	20 - 35	10 - 25	1000-2000	2 - 20
5	50% Hemp fiber reinforced composites PP	1.08	75	62	89	5430	5
6	30% glass fiber reinforced composites PP	1.13	95	75	100	4500	8
7	30% Calcium carbonate filled PP	1.13	--	28	48	2000	4

Source: Bamtac

THANK YOU

KPS Consultants & Impex Pvt. Ltd.
812 Devika Tower, 6 Nehru Place
New Delhi 110019, India.
www.kpsimpex.com , kpspltd@gmail.com