



Petrochemicals and Recycling – Chemical Engineering for a Sustainable Planet

IChE Northern Region Chapter

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Outline



- Sustainability
- Overconsumption
- Petrochemicals
- Carbon Atoms
- Community Wastes as Resources
- Open Challenges
- Global Developments
- Scalable Technologies in India: Case Studies

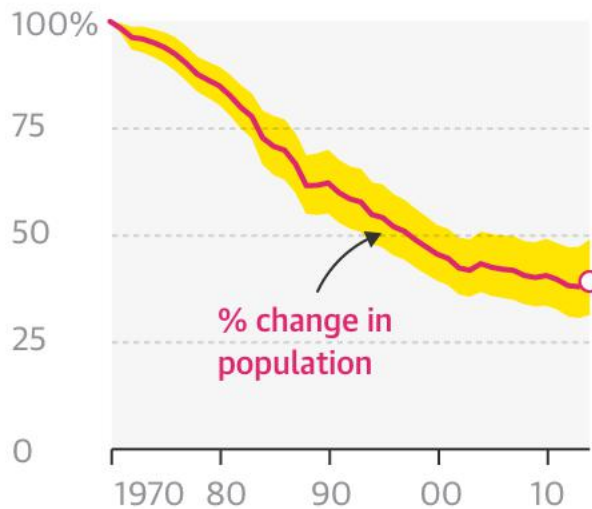


SUSTAINABILITY



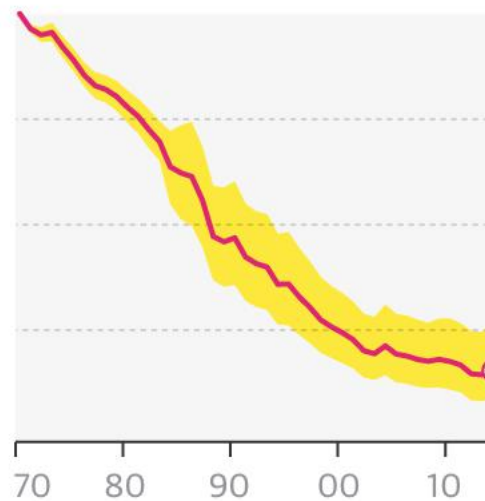
Meeting the needs of the present without compromising the ability of future generations to meet their needs

Worldwide, 60% of vertebrate animals have been wiped out since 1970



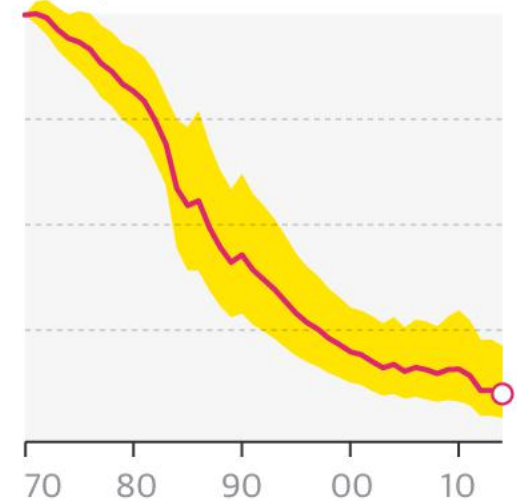
Freshwater habitats are the worst hit, with populations having collapsed by 83%

As a result of the collapse, Indian crocodiles are on the verge of extinction



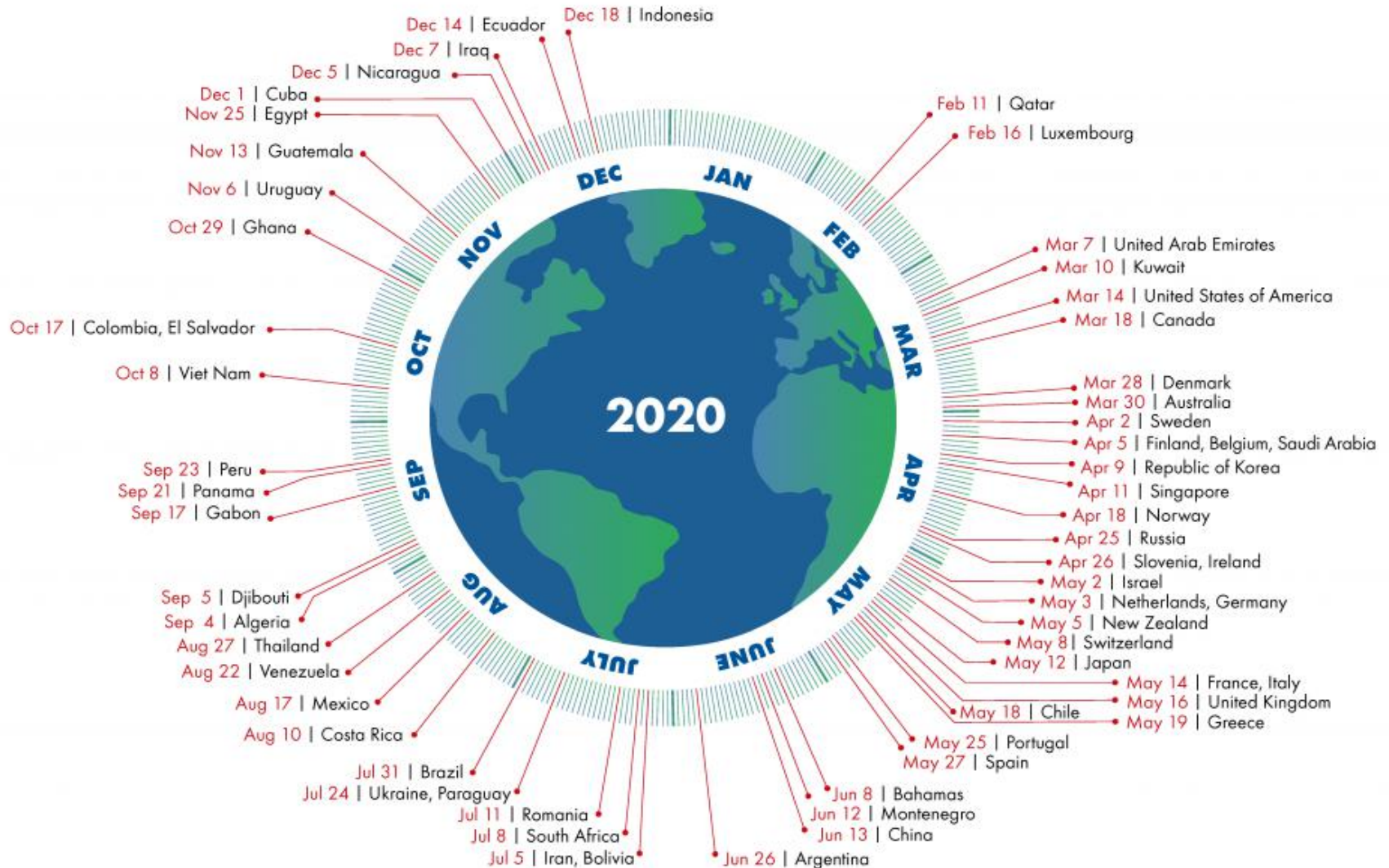
South and central America is the worst affected region globally

An 89% total drop - Giant otters and spider monkeys are among the species most affected



Country Overshoot Days 2020

When would Earth Overshoot Day land if the world's population lived like...

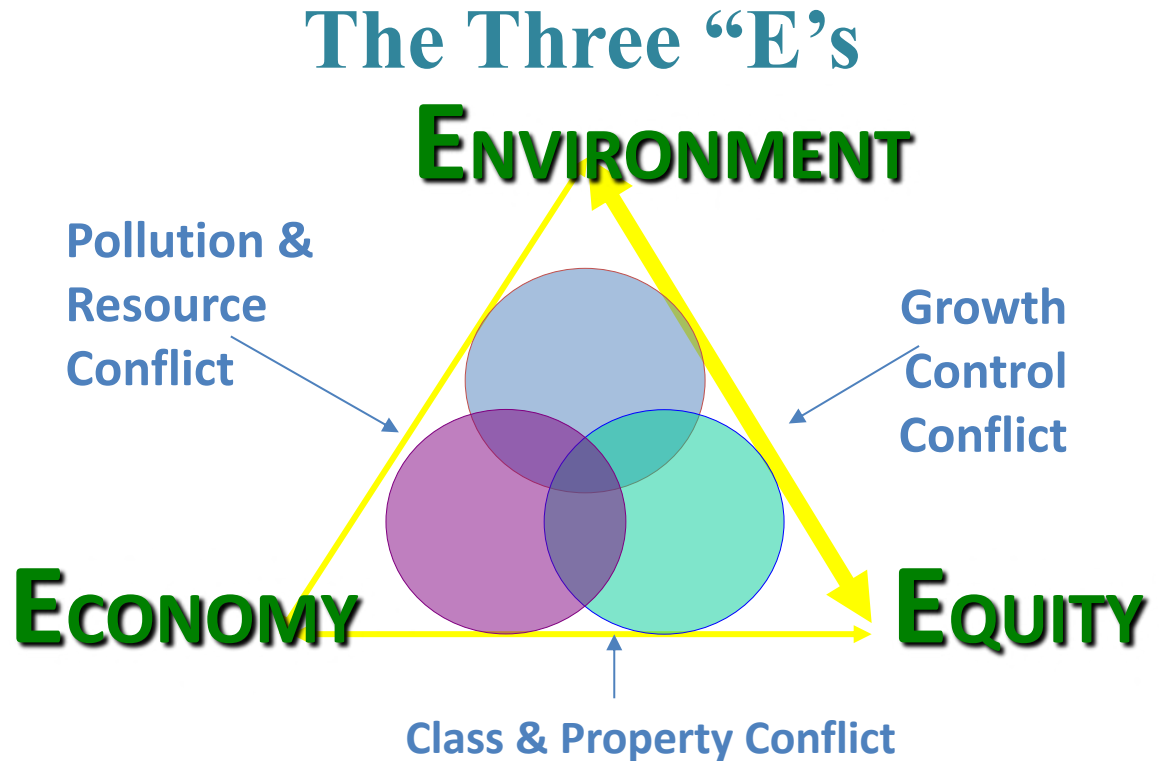




Human Well-Being



- Ecological Life Support Systems
 - Air, water, soils, climate system, nutrient cycles, biotic communities
- Economic Support Systems
 - Markets, income, wealth, employment, trade
- Social Support Systems
 - Equity, education, health care, law & governance, culture, liberty





India – Bulk Carbon Imports Fuels (2018-19)



Commodity	Import, MMT/yr	% C	Imported C, MMT/yr
Crude Oil	220	85%	190
Coal	200	75%	150
Natural Gas	15	77%	11.6

Demand Side Response

- Reduce energy requirement (enhance efficiency)
- Reduce carbon requirement (non-carbon energy e.g. solar, wind, geothermal)

Supply Side Response

Find about 350 MMT of domestic carbon (on current basis) to replace our fuel carbon imports

Need “carbon” security solutions within our control



India – Bulk Imports Petrochemicals (2017-18)



Category	Production '000 MT	Capacity utilization %	Imports '000 MT	Imports CAGR %
Synthetic Fibre/Yarn	3625	83%	260	10.9%
Polymers	9276	92%	4751	9.6%
Synthetic Rubber	308	72%	608	4.5%
Detergent Intermediates	743	108%	206	14.7%
Performance Plastics	17	61%	583	17.2%

*~ 6.4 MMT Petrochemicals, meaning ~ 5 MMT of
carbon atoms also enter India via Petrochemicals imports*

Source: Chemicals and Petrochemicals Imports data, Ministry of Chemicals and Fertilizers, Govt of India (2018)



Domestic Carbon Sources (estimates)



- India – Second most populous nation ~18% of World population
- Limited availability of landfill space; high cost of urban land
- Carbon atoms discarded by each of us adds up!

Carbon Source	Scope, MMT/yr	% C, approx	Potential C, MT/yr
Agri-residue (surplus)	120	40%	48
Forest residue	150	42%	63
Sewage / dairy / animal husbandry / distillery	400	45%	180
MSW	60	25%	15
Used Cooking Oil	5	85%	4
Industrial/Urban C-emissions	500+	28-75	>150

> 460 MMT of carbon excluding massive coal reserves

All the carbon we need is available within our borders

But Repurposing Carbon needs Water, Energy, Catalysts, Equipment, Labour



Petrochemicals



Searching for Domestic Carbon Atoms

Category	Product	Feedstock
Light Olefins	Ethylene, Propylene, butenes, Butadiene, cis-Isoprene	Syngas, CO ₂ , Methane (including Bio-gas)
Light oxygenates	Methanol, Ethanol, Isopropanol, Acetone, THF	Syngas, biomass
Aromatics and phenolics	Benzene Toluene Xylene (BTX), phenol, cresols, styrene, naphthalene	Low-value petroleum streams, coal tar, biomass
C ₆ + Aliphatic and cycloaliphatic oxygenates	Oxo alcohols, alkyl ethers	Syngas, CO ₂ , hydrogen
N and S heterocycles, Halo-chemicals	Thiophene, pyrrole, imidazole etc and their derivatives; organic halides	Syngas, CO ₂ , ammonia, Sulphur, petroleum and coal residues

Syngas could be derived from Coal, Petcoke, Biomass incl. MSW

“We are sitting on a plastic time bomb”

the Supreme Court of India

- Waste plastics generated as part of MSW in 60 major cities
 ~ 15, 500 TPD
 ie ~ 56 lakh TPA
- Waste plastics added **everyday** which lie littered and uncollected
 6137 TPD*
 *(assuming, 60 % of plastics are recycled)

Waste plastics generated in 4 metros (TPD)

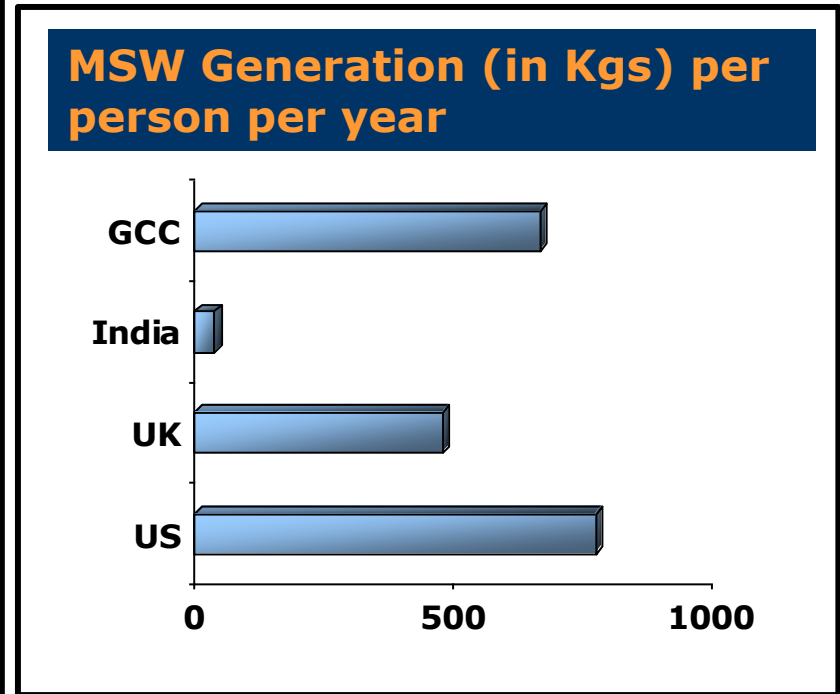
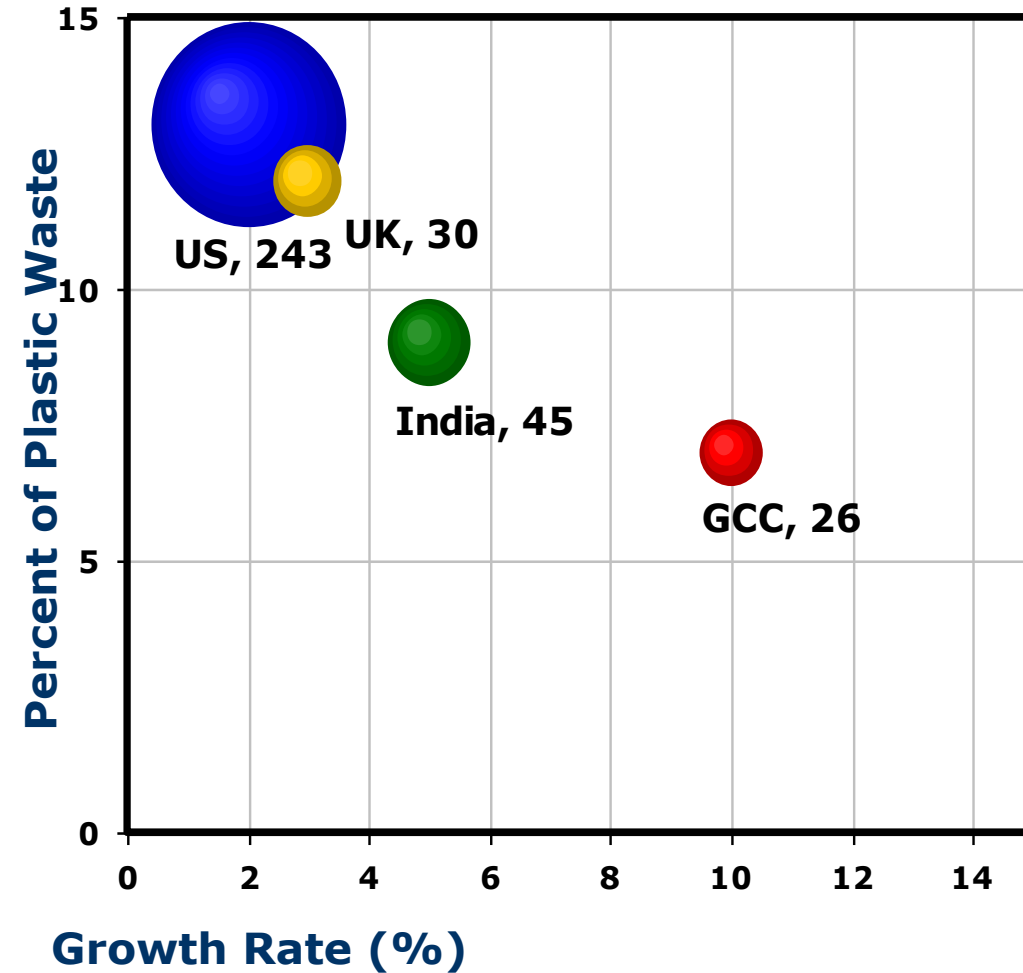
	Total waste plastics generated	Uncollected and littered waste plastics
Delhi	689.5	275.5
Mumbai	408	163.2
Kolkata	425.7	170
Chennai	429.4	171.6

Source CPCB, **Central Pollution Control Board**





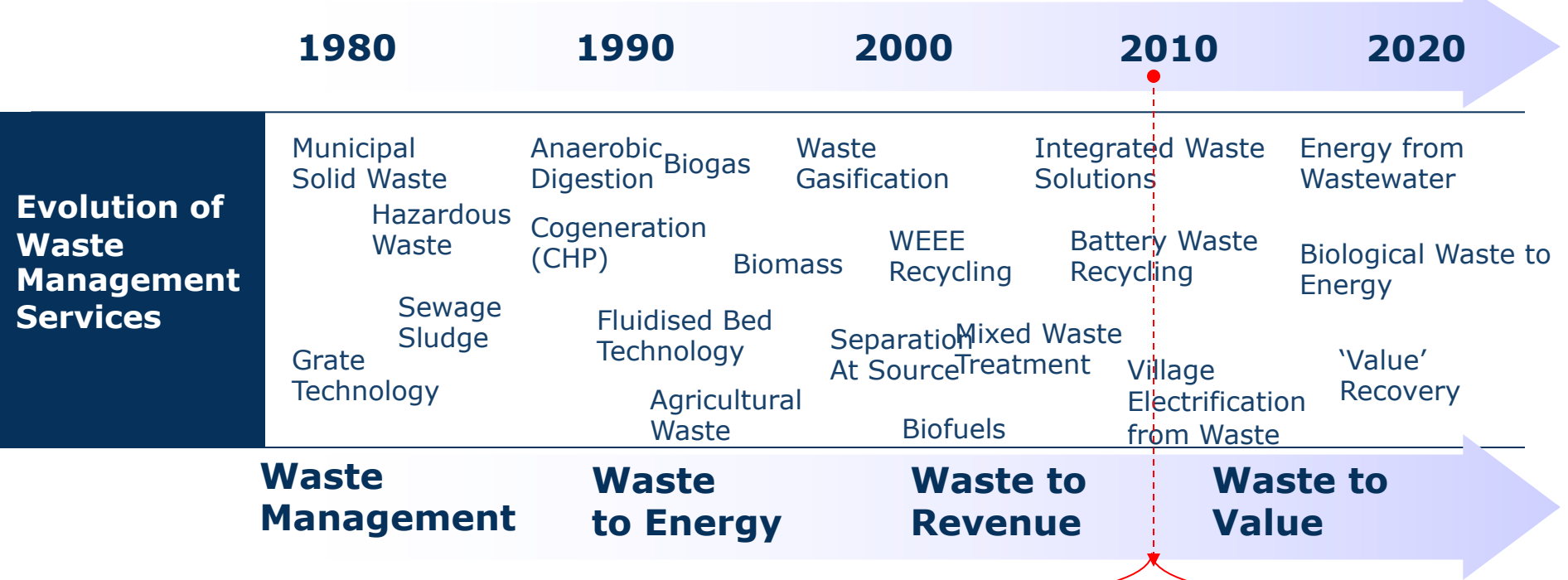
...and India is still climbing the plastic consumption curve



Size of the bubble corresponds to the MSW generation in Million Tons.



Plastic Waste Processing Timeline



Keppel Seghers
a rich source of energy

REMONDIS®
Waste-to-Value
Convert organic process waste stream into renewable resources and operating profit

ENVIROSERV
WASTE MANAGEMENT

BATREC

STENA

ENERGOS

VEOLIA
ENVIRONMENTAL SERVICES

Green energy: environmental and economical profit!

SIMS RECYCLING SOLUTIONS

PAQUES

Source: Gulf Petrochemicals and Chemicals Association (GPCA), 2013



Plastics disposal options Opportunities and challenges



Most Eco Friendly

Recycling

Waste to Energy

Landfilling

Least Eco Friendly

- Efficient & low carbon way (Recycling 1 ton of PET saves 1.5 tons of CO₂)
- Reduces reliance on virgin material

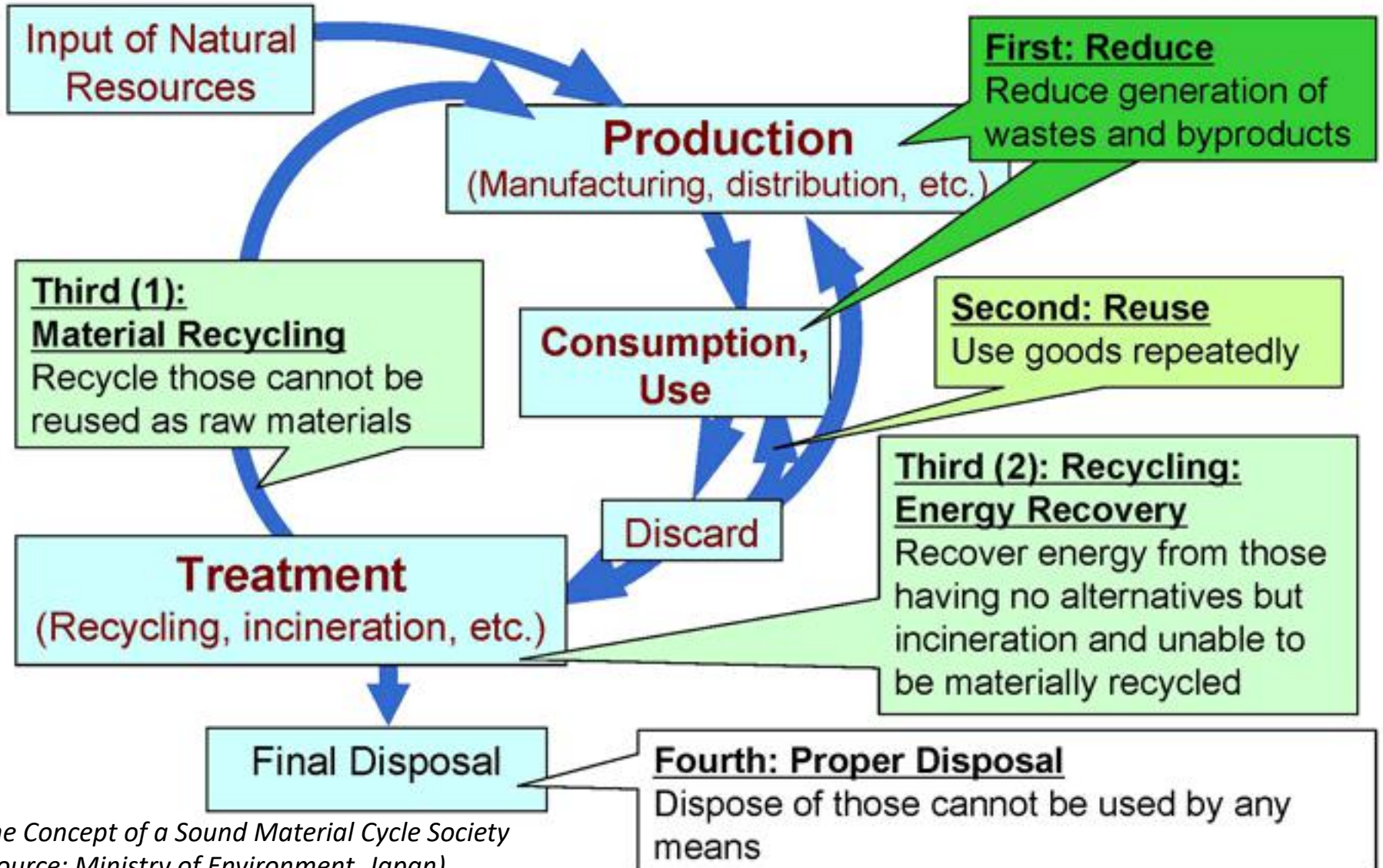
- Global WTE market at \$3.5 billion
- 400 plants in Europe & 100 in Japan, US 89, Asia 70
- GCC with highest per capita waste generation is promising but cheap fossil fuel and low landfill rates are deterrent!

- Predominantly used method, particularly in the developing countries
- Water Contamination due to leachate
- Landfill gases contributing to global warming



The 3Rs

Reduce, Reuse, Recycle



*The Concept of a Sound Material Cycle Society
(Source: Ministry of Environment, Japan)*



Recycling Makes Sense, But...



Advantages

Reduces air and water pollution

Saves energy

Reduces mineral demand

Reduces greenhouse gas emissions

Reduces solid waste production and disposal

Helps protect biodiversity

Can save landfill space

Creates jobs

Disadvantages

Can cost more than burying in areas with ample landfill space

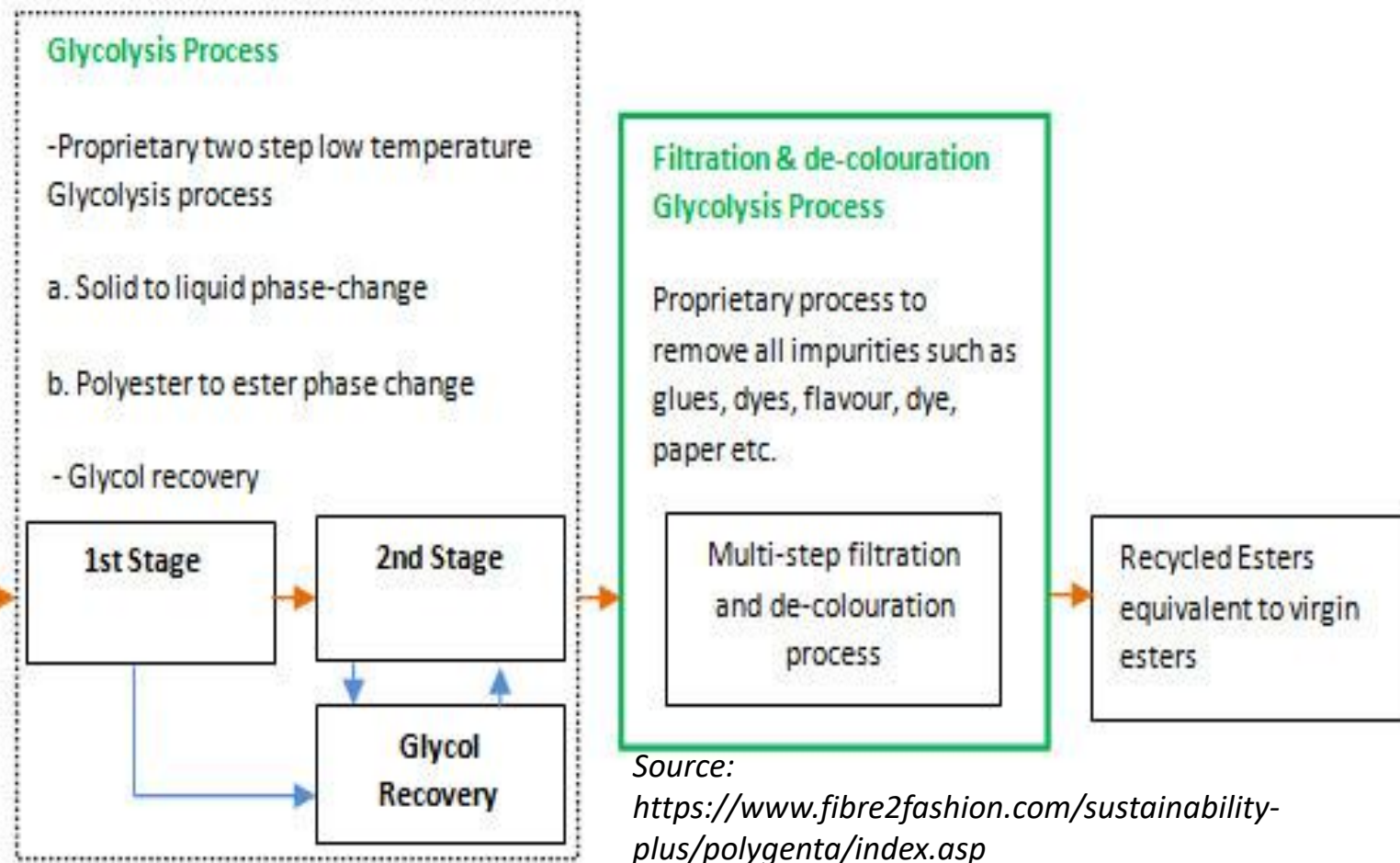
Owners may lose trade-in value to scrap dealers

Reduces profits for landfill and incinerator owners

Source separation is inconvenient – a hassle - for people who are not used to it



Recycling PET Bottles (Polygenta Technologies Ltd)

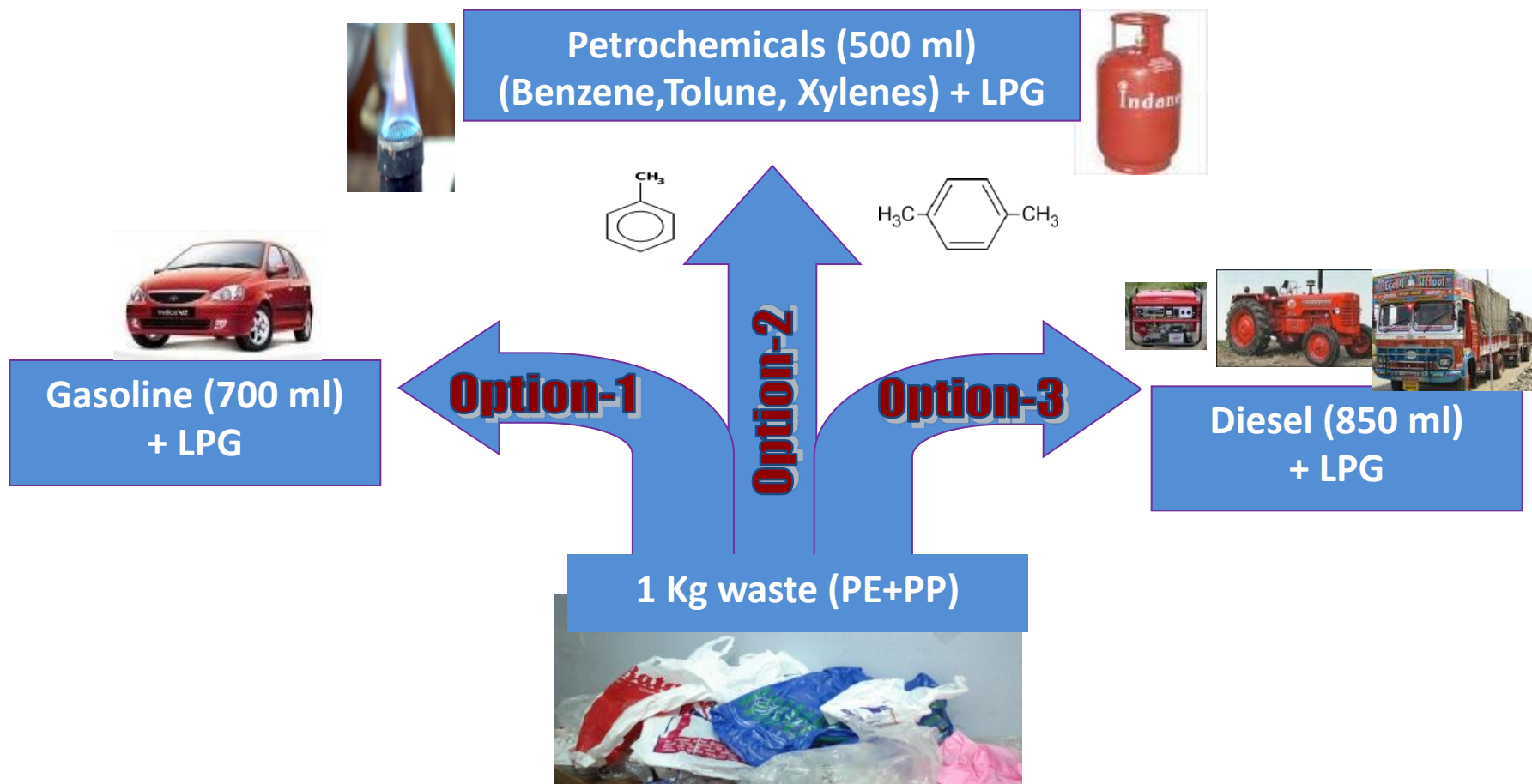


Source:
<https://www.fibre2fashion.com/sustainability-plus/polygenta/index.asp>

500 million bottles per year converted to 10,000 tons of premium PFY

CSIR-IIP- GAIL Technology

Waste polyolefins to fuel and aromatics



- Catalytic production of either *gasoline or diesel or aromatics* along with *LPG*
- From polyolefinic wastes (e.g. HDPE, LDPE, PP etc)
- Liquid fuel meeting Euro IV/VI specifications., Aromatics rich in BTX



Waste Plastic to Diesel

1000 kg/day demonstration unit at CSIR-IIP



Creating Future Fuels



1 TPD plant at CSIR-IIP

- *A one ton per day (1 TPD) demo unit for converting waste plastics to diesel has been set up at CSIR-IIP, Dehradun to facilitate commercialization of the technology*
 - *With pre-treatment facility*
 - *Plant inaugurated on 27 August, 2019*
 - *Technology demonstration available to potential external partners by June 2021*

Plants of capacity 10 tons or higher likely to be economically viable



Waste Plastic to Diesel Engineering Challenges



- Pre-treatment and clean up before feed to pyrolyzer
- Variability of feed – altered rheology, thermal conductivity, heat capacity
- Thermal management and heat integration of process
- Control logic
- Safety and operability



Not just polyolefins to diesel



- By-product LPG can be converted to Propylene
- By-product naphtha can be converted to BTX
- Process can be repurposed for a range of petrochemicals downstream
- Plenty of opportunity for creative process development combining petrochemicals waste (C/H~1:2), purified bio-gas (C:H~1:4) and ligno-cellulosic biomass (C:H:O~7:10:5) to generate a wide range of industrial chemicals



Assam: Plastic Waste As School Fees!



- Akshar Forum is a a small school in the village of Pamohi in Guwahati
- Underprivileged students trained to 'earn a livelihood by being responsible'
- Students pay fees in the form of plastic waste
- Idea was born out of Akshar Forum's recycling program

Chhattisgarh: Food for Trash



- Ambikapur Municipal Corporation Initiative
- City in Surguja district of Chhattisgarh
- 'Garbage Cafe' offers free meals to anyone who collects plastic waste and deposits it to the Municipal Corporation
- Free meal for every kilo of trash a person can provide
- Free breakfast for 500 grams of waste collected



Dehradun: Plastic Bank



- Innovative and community oriented plastic waste collection model
- Encourages communities to know their waste better
- Supports segregation, collection, transportation and recycling
- Engages communities and stakeholders like bulk waste generators, urban local bodies etc.
- Spurs community driven behaviour change and social action



Social Development
for Communities
FOUNDATION

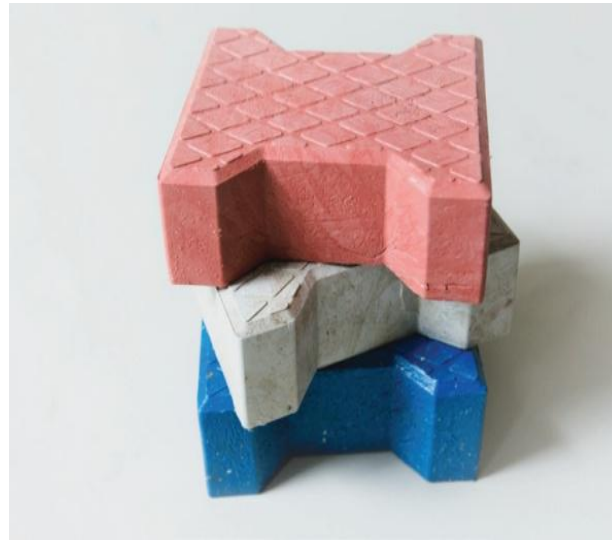


Waste Plastic to Tiles

CSIR-National Physical Laboratory



- Can also use **non-polyolefin plastics** and **multilayer packaging**
- Toilets and shelters, pavement tiles
- Numerous technical challenges like **mechanical strength, flame retardancy, water permeability, UV protection** and **antistatic response** add to the novelty of the concept
- **Multiple licensees; available across India today**



Waste plastics to tiles



Waste Plastic Bags + Bottles
shredded
in to small pieces



Shredded Plastic mixed with
fillers
and moulded into tiles



Tiles used for
building structures

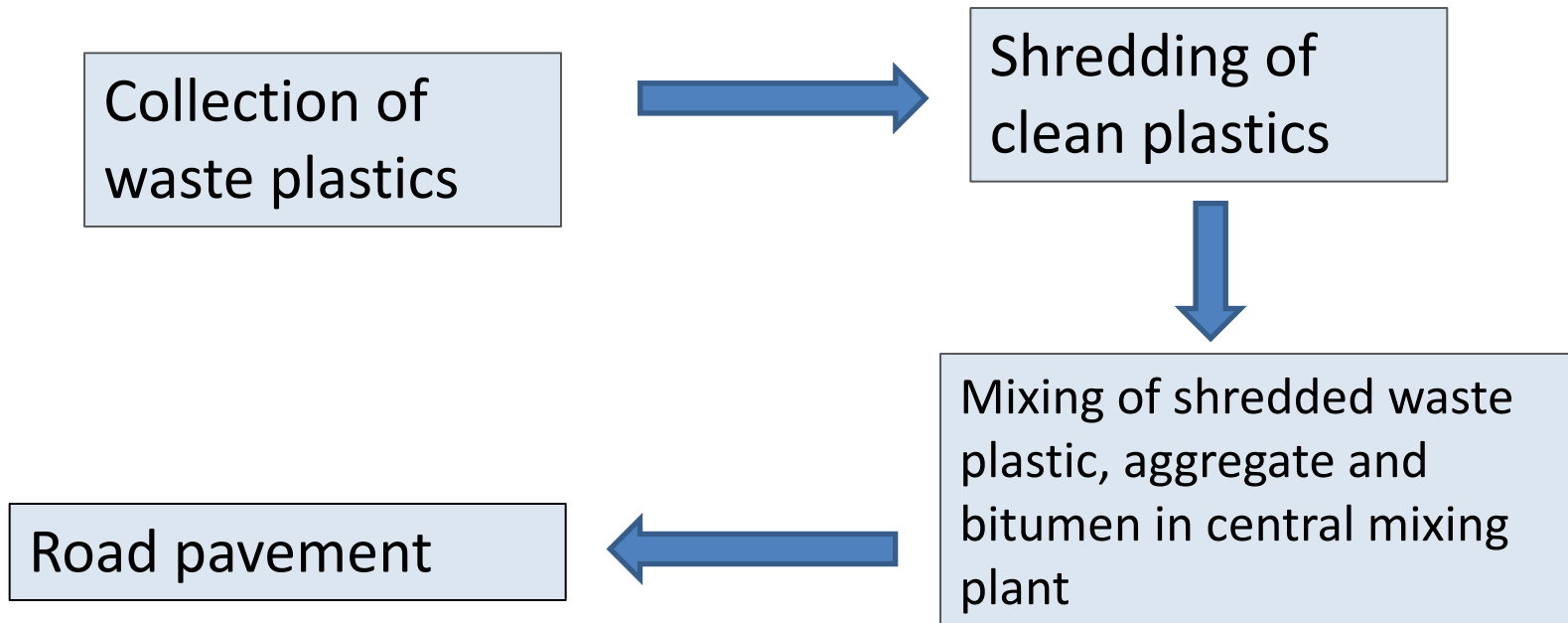




Waste Plastics in road construction (CSIR-Central Road Research Institute)



- Plastic is coated over stones - improving surface property of aggregates.
- Coating is performed at the road laying temperature
- Weight of plastics used is 6-8 % of bitumen
- Wide variety of plastics can be used (they soften/flow temp

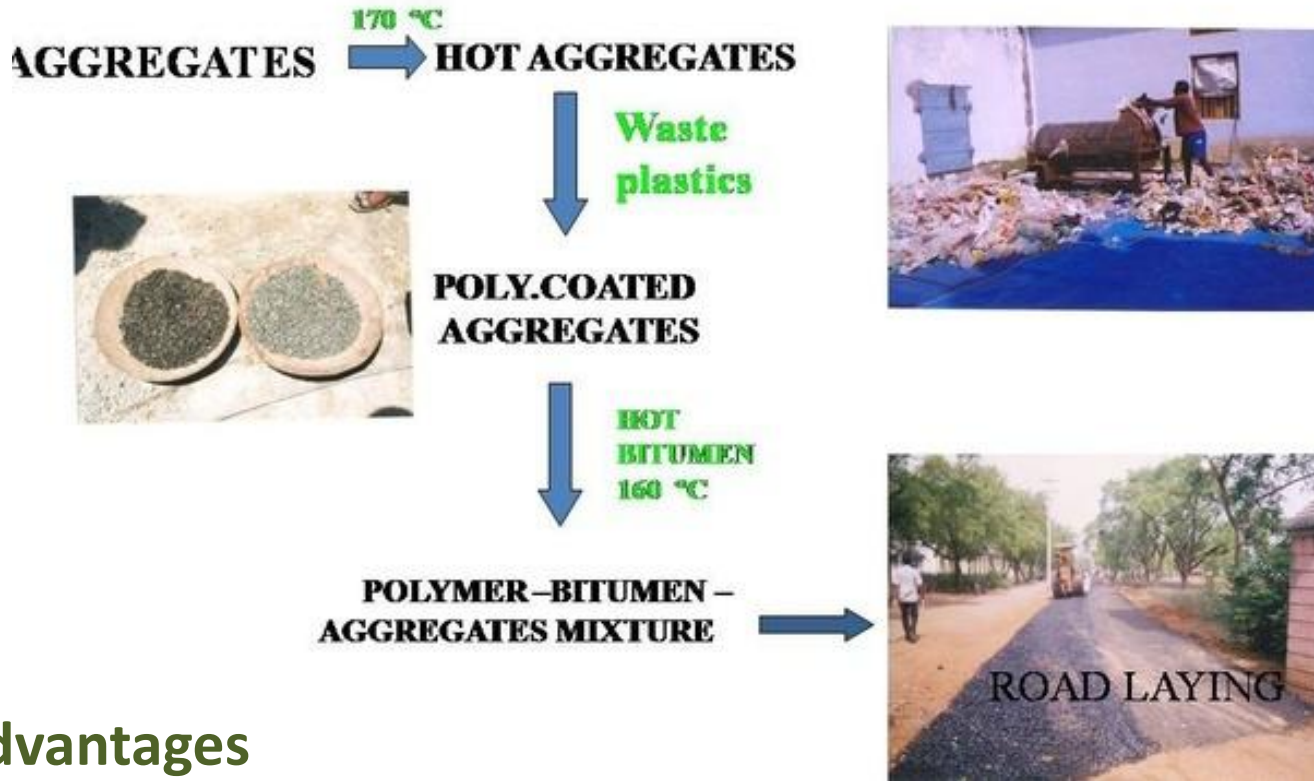




WASTE PLASTICS COATED AGGREGATE- BITUMEN MIX



Creating Future Fuels



- **Advantages**

- Doubles the binding property of aggregates
- Bitumen bonding is stronger than normal
- Coated aggregates show increased stability of the mixes
- Better performance of mix after construction (based on the experience gained for medium level city traffic)
- No evolution of any toxic gases



Challenges Remain



- Other than polyolefins and polyesters, recycling of industrial plastics is limited
- Depolymerization (recovery of monomers from post-consumer and post-industrial polymer waste) remains the holy grail
- Polyurethanes, PVC, fluoropolymers generate hazardous or toxic decomposition products
- A few rare instances of upcycling are known (e.g. Marcus Oil & Chemical, Haldia)



The Dark Side of Waste



- Ragpicker-sorters: child labor, landfill-related health issues
- Incineration and wildfire environmental risks
- Unorganized waste-to-value sector e.g. tyre pyrolysis, plastic pyrolysis plants producing low-quality fuels linked to safety hazards and environmental risks



In Summary

- Whatever we throw away holds the key to sustainability
- Carbon atom management can enable reduction of dependence on petrochemicals import
- 3R framework guides us towards recycling
- Recycling petrochemicals (especially polymers) is technically challenging
- Technologies must be dovetailed to supply chains
- Community initiatives make environmental and economic sense
- Segregation is the starting point



Great Backyard Bird
Count, 2018
64 bird species



World Environment Day, 2017
90+ butterfly and moth species

Thank You

