Moving Towards a Circular Economy for Hydrocarbon Raw Materials

Jonathan P. Bourne
FRSC, FCIM

Nexant

PRA Annual Conference 2019

10th September 2019

Moving Towards a Circular Economy for Hydrocarbon Raw Materials

Jonathan Bourne
Vice President

Energy & Chemicals Advisory

T: +44 20 7950 1597
M. +44 77 6620 6278
E. jbourne@nexant.com

1 King's Arms Yard
London
EC2R 7AF
United Kingdom

Introduction - The Circular Economy

What can we do about recycling for the intermediate and specialty chemicals sectors?

Waste Plastics to Fuel and Chemicals

Technology perspective and examples

Summary and Conclusions

Regulations and sustainability strategy

Introduction

The Circular Economy

Environmental pollution occurs when people do not collect and dispose of waste properly

Yangtze River, China

Source of image: https://imgur.com/r/wtf/noKQM

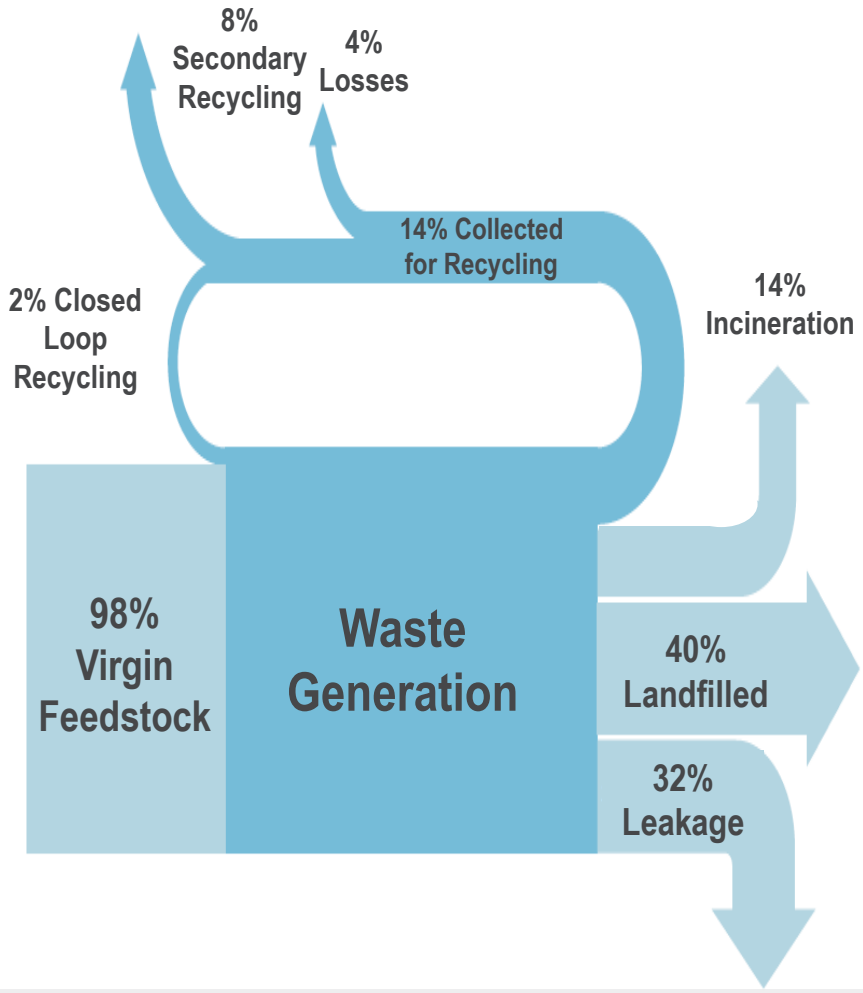
Ten rivers account for up to 90 percent of global plastic pollution in our oceans

- At least half of these run through China and the Yangtze River alone carries approximately 55 percent of plastic waste deposited into the oceans
- Large populations living nearby long rivers in countries with poor waste management tend to deposit the most plastic pollution
- As population continues to grow, with inadequate waste management systems, the volume of waste entering our environment continues to increase

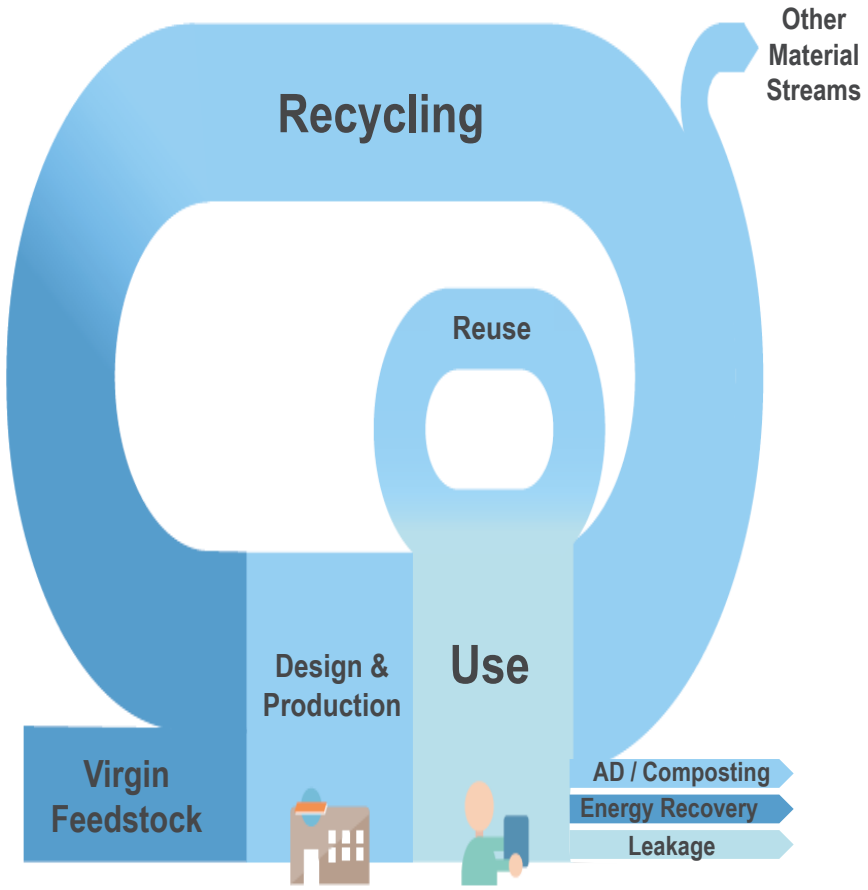
Waste has no value, so what can we do about it?

Ambitions to reduce waste will require monumental change in both consumer behavior and infrastructure

Current Status of Circular Economy



Future Circular Economy



The ideal circular economy will greatly reduce the amount of virgin feedstocks we use

Source: Adapted from the Ellen MacArthur Foundation: The New Plastics Economy, Rethinking the Future of Plastics, 2016

Recycling options depend on the quality of the source material, and the products decrease in value with declining quality of feeds

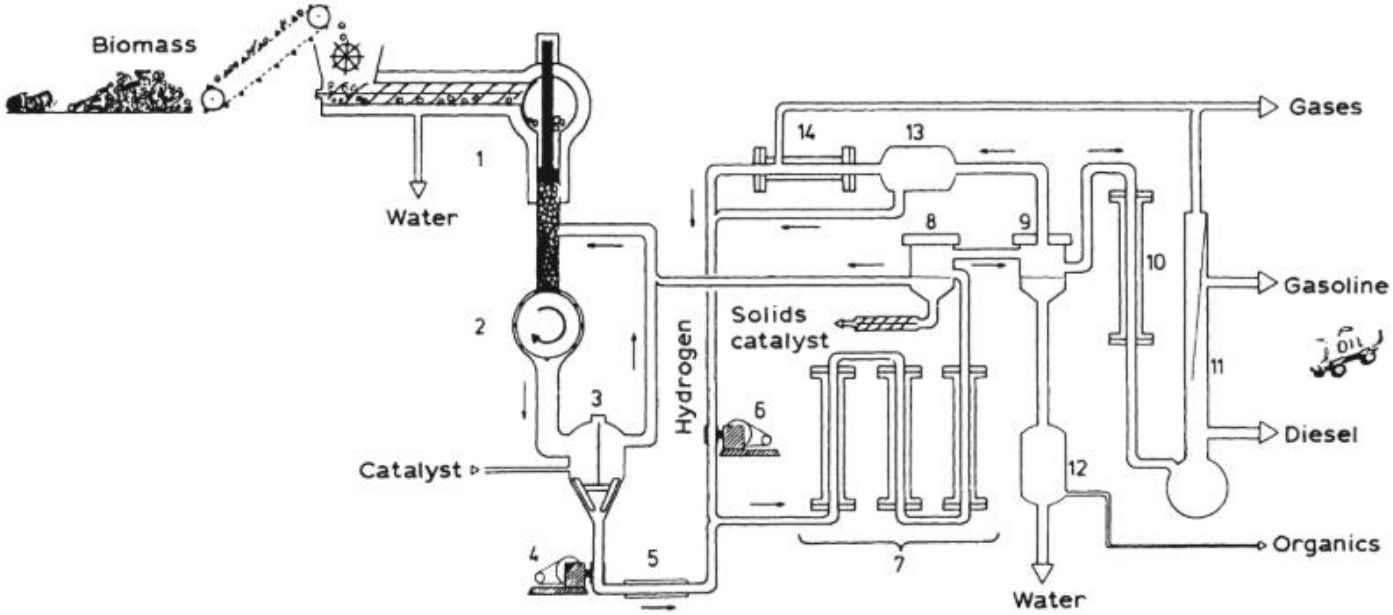
Primary Recycling	Industrial and manufacturing scrap (pre-consumer) is re-melted and reused (maintaining high quality). This remolding of fairly uncontaminated in-house scrap has been intrinsic to plastics conversion for some time
Secondary Recycling	Post-industrial and post-consumer waste streams are processed into products with similar or decreased properties compared to the original application, as they are subject to higher contamination
Tertiary Recycling	Production of fuels, basic chemicals, and/or monomers by thermal or chemical conversion of post-industrial and post-consumer plastic waste. Pyrolysis and chemolysis are examples
Quaternary Recycling	To recover the energy content of post-industrial and post-consumer waste by incineration (WTE) or gasification, often considered resource recovery rather than part of recycling technologies

Waste Plastics to Fuel and Chemicals

Technology Perspective and Examples

Waste to oil technology has been around for many years but failed to commercialize due to technical, economic and scale-up problems

- In 1982, the Greater Manchester City Council collaborated with the University of Manchester to develop a process for the conversion of municipal waste to synthetic crude oil to alleviate the waste disposal problem.
- The process used direct hydrogenation of cellulosic and plastic materials to produce gaseous and liquid hydrocarbons in the presence of solid catalysts under relatively mild operating conditions.
- Whilst some of the same shortcomings still exist today, new research has seen the commercialization for new pyrolysis systems.



Tertiary recycling can be considered complementary to plastics recycling

- **Plastics to Fuel** (PTF) technologies use pyrolysis to break polymers down to reusable fuels and/or cracker/refinery feeds

- **Plastics to Chemicals** (PTC) technologies (or chemolysis) depolymerize polymers to their base monomers

- Many PTF and PTC technologies have been around for many years, some commercially, but they have faced a ***number of challenges***, limiting their applicability
  - Feedstock quality and availability
  - Product quality
  - Low oil prices
  - Low calorific value product yields
  - Economy of scale

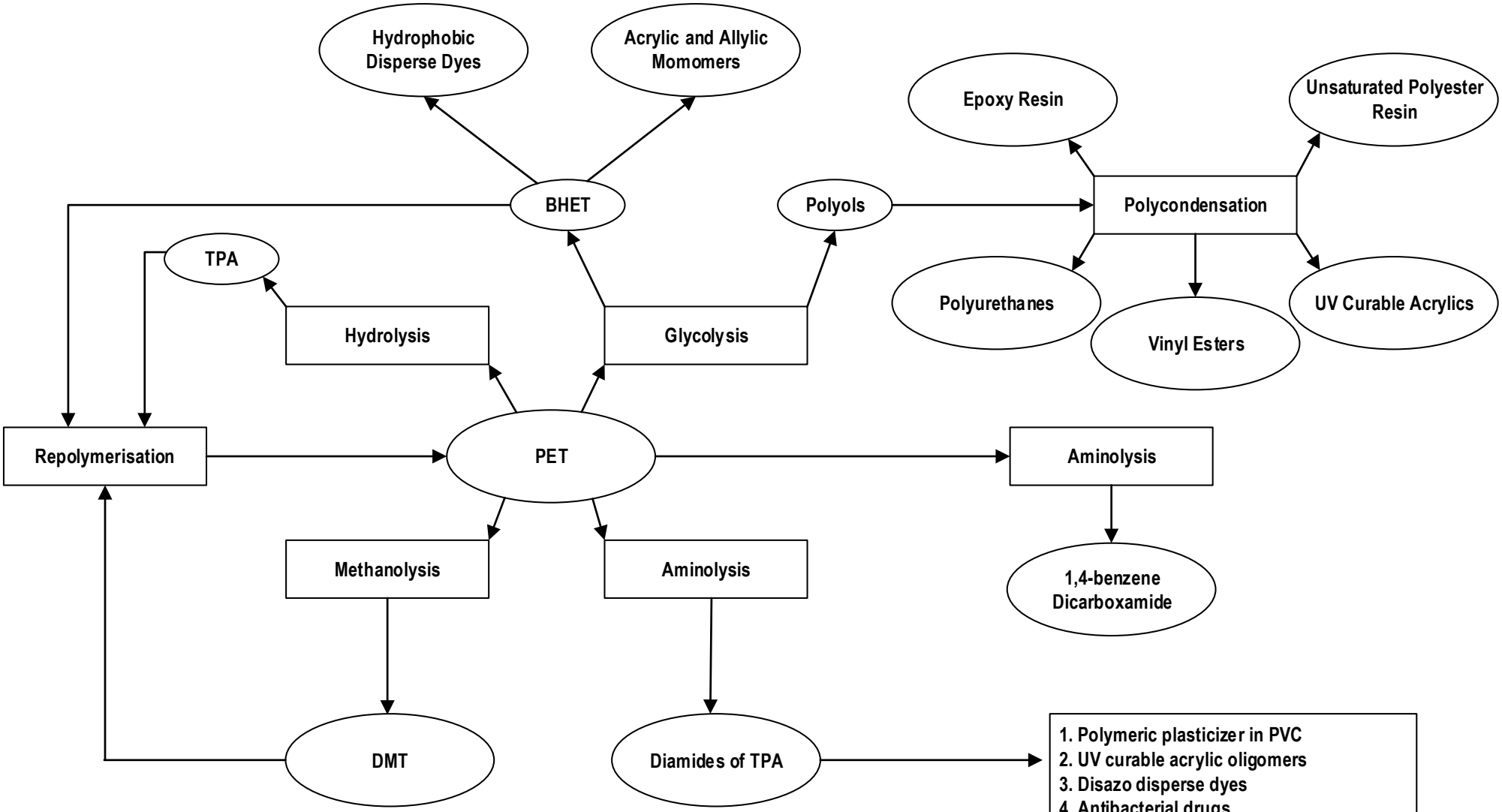
Where systems are in place for mechanical recycling (i.e., PET, HDPE), this remains the most attractive alternative for them. PTF and PTC are good options where this is more difficult

Today Pyrolysis is an option for lower quality, mixed plastic streams

- **Pyrolysis technology, used in PTF (and PTC), is relatively simple and can be used for mixed plastics streams, including multi-layer packaging**
  - Best for addition polymers (difficult to depolymerize)
  - Also good for polymers that are not mechanically recycled
  - Notably, however, mixed streams can produce varied results which may require further separation
  - Nexant has previously identified **30 companies working on PTF technologies**, and it is likely that there are many more. Processes are very diverse
  - Liquids can be fed to steam crackers or refineries
- **De-polymerization (or chemolysis), used in PTC, processes a single polymer stream to its base monomers**
  - Generally limited to condensation polymers
  - Yields a pure product to be re-polymerized, generally suitable to be used a feedstock for the production of virgin resin
  - Technologies are available for several polymers, including Polyethylene Terephthalate (PET), Polystyrene (PS or EPS), Polyurethane, Polyvinyl Chloride (PVC), Nylon, Polycarbonate, Polymethyl Methacrylate (PMMA)
  - PTC technologies are also diverse, and as with the PTF technologies, there are most likely **many more companies than Nexant has so far identified (more than 34)**

Pyrolysis process can be integrated with refineries or steam crackers

End products in the coatings industry can be derived via a number of chemical processes using recycled plastic feedstock

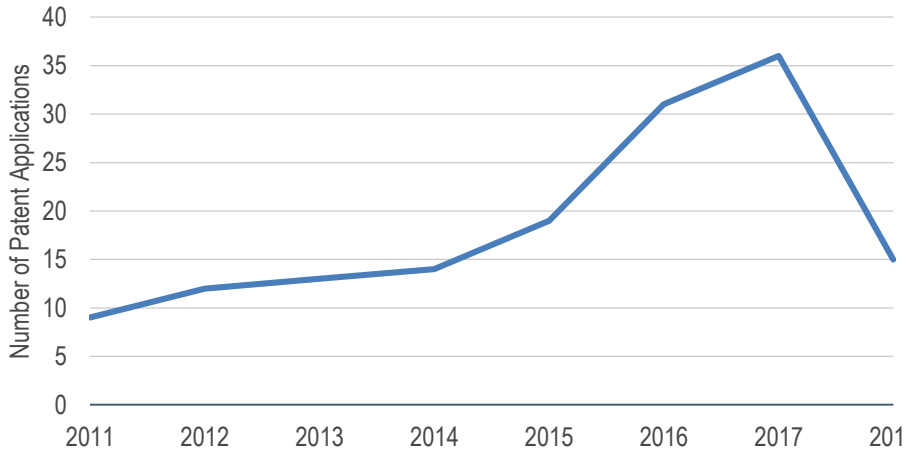


Source of Figure - George, N., et al, Recent Developments in the Chemical Recycling of Postconsumer Poly(ethylene terephthalate) Waste, Ind. Eng. Chem. Res., 2014

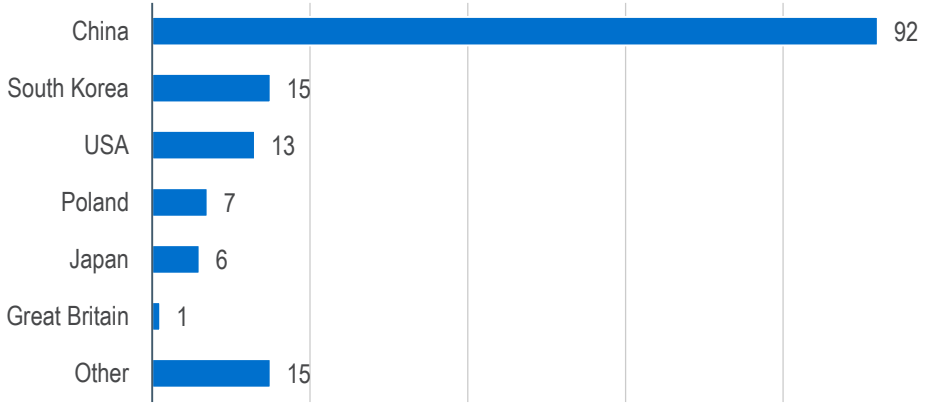
Increasing number of patent applications relating to plastic pyrolysis since 2010

- China has been the leader in terms of patent applications and patents published, although the number of applications dropped drastically in 2018, perhaps in part due to the ban on waste plastics import
- South Korea and Japan have also been investing significant resources into developing pyrolysis further, and so has the United States
- In Europe, Eastern European countries seem to be leading the research efforts – Poland, Ukraine and Czech Republic in particular
  - Previous leaders – the UK, Germany and Spain – seem to have reduced their efforts since the turn of the decade

Number of Patent Applications for Plastic Pyrolysis, Globally
2011 – 2018



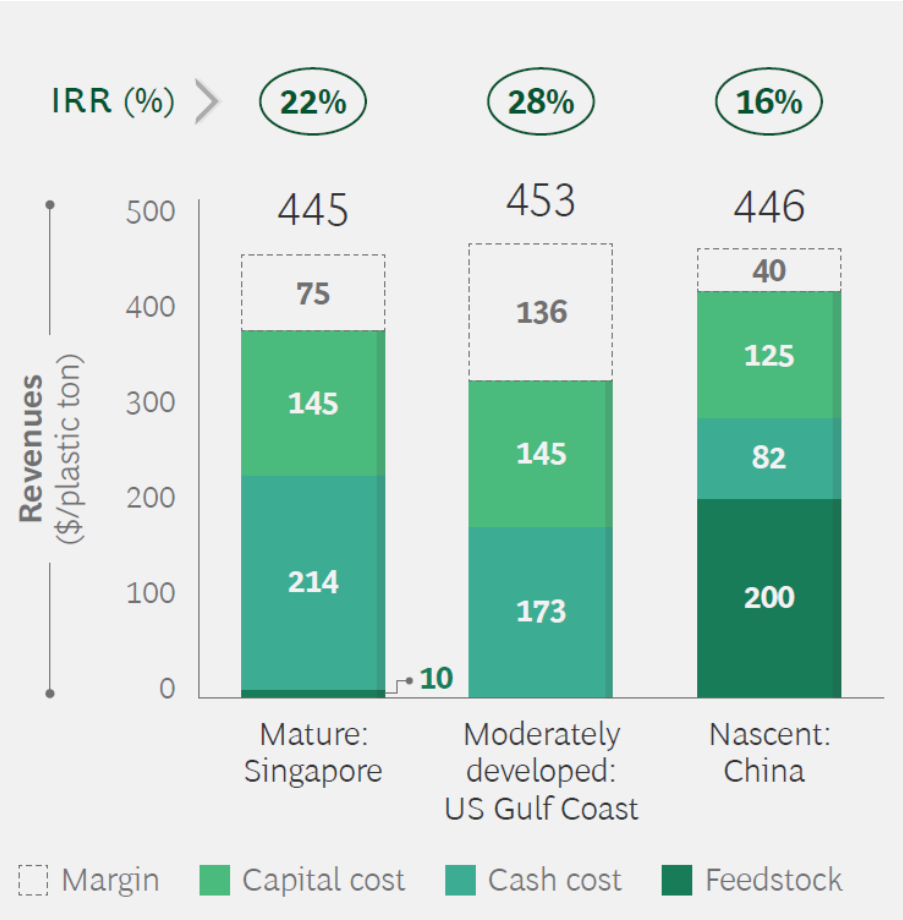
Number of Patent Applications by Country
2011 – 2018



Technologies need to be economically viable in order to replace existing systems

Margins Across Three Market Archetypes

(30 000 tons per year capacity plant)



Source: BCG, A Circular Solution to Plastic Waste Report (July 2019)

In a recent study, BCG found that while the financial and business challenges vary, conversion technologies such as pyrolysis are economically viable in all the market types studied.

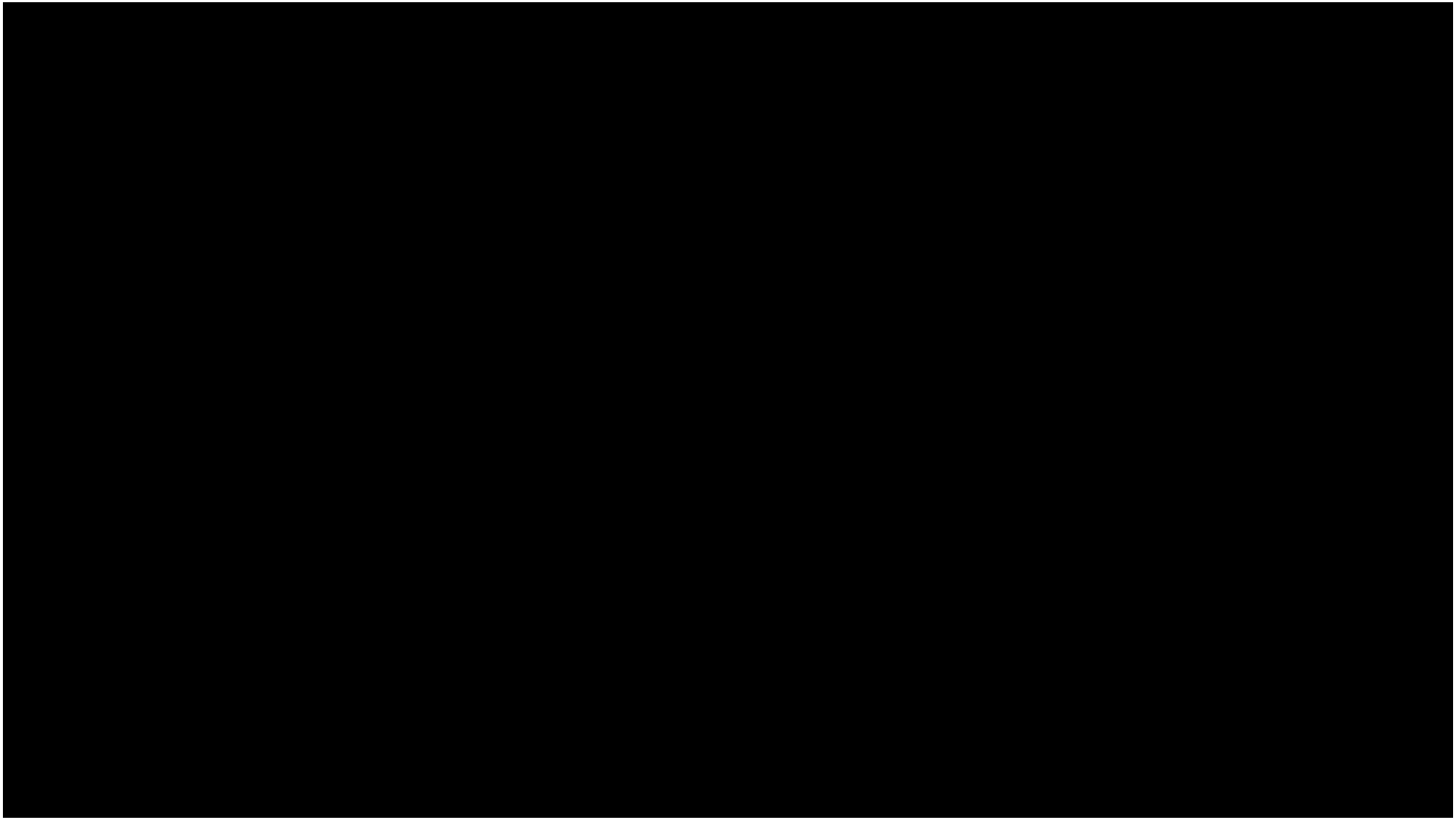
Pyrolysis presents a promising business case, especially for chemical companies, which can adopt a new technology that is close to their core capabilities while simultaneously helping to develop smarter solutions for managing plastic waste.

Several companies are present in Europe and vary in their level of commercialisation, scale, experience and the feedstocks processed

Technology Supplier	Regions Currently Served	Available Design Capacities *(tons per day)*	Development Status	Accepted Feedstocks
Beston *China*	Global	6, 10, 20, 30, 40, 50	Commercial	PE, PP, PS, ABS, PC, PVC, PET, Pure white plastic, Fishing net, Safety net, Pure plastic cables, Plastic bags
Blest *Japan*	Global	0.2 – 2	Commercial since 2012	PE, PP, PS
Cassandra Oil *Sweden*	Sweden, Spain, Denmark	5	Pilot, first commercial plant under construction	PE, PP, PS, PMMS, PC, PVC, PET, Tyres
Cynar *UK*	Ireland, Spain, UK, South America	20	Commercial since 2008	
GB Energy Europe *Czech Republic*	Global	Unknown	Commercial since 2005	PE, PP, Nylon, Teflon, PS, EPS, Fibreglass reinforced plastics, Rubber, Tyres, Electronic waste, Mixed waste from processing of collected paper, Layered plastics
Henan Doing Energy *China*	Global	10, 20, 30, 50, 60, 80, 100	Commercial	PE, PP, PS, ABS, Tyres, Rubber
Licella/Armstrong Chemicals *Australia*	UK	7	Commercial since 2008	End-of-life plastics, Pulp mill residues, Waste oil residuals, Agricultural residues, Purpose-grown energy crops, Sugar cane trash
Plastics Energy *UK*	Spain	20	Commercial since 2014	PE (HDPE, LDPE), PP, PS (GPPS/HIPS only)
Recenso *Germany*	Germany	Unknown	Pilot	Mixed plastic waste
Recycling Technologies *UK*	UK	3	Pilot, first commercial plant under construction	Most residual mixed plastic waste, including film, laminate, black plastic and rigids

Note: The table shows a selection of the key companies engaging in polyolefin pyrolysis in Europe

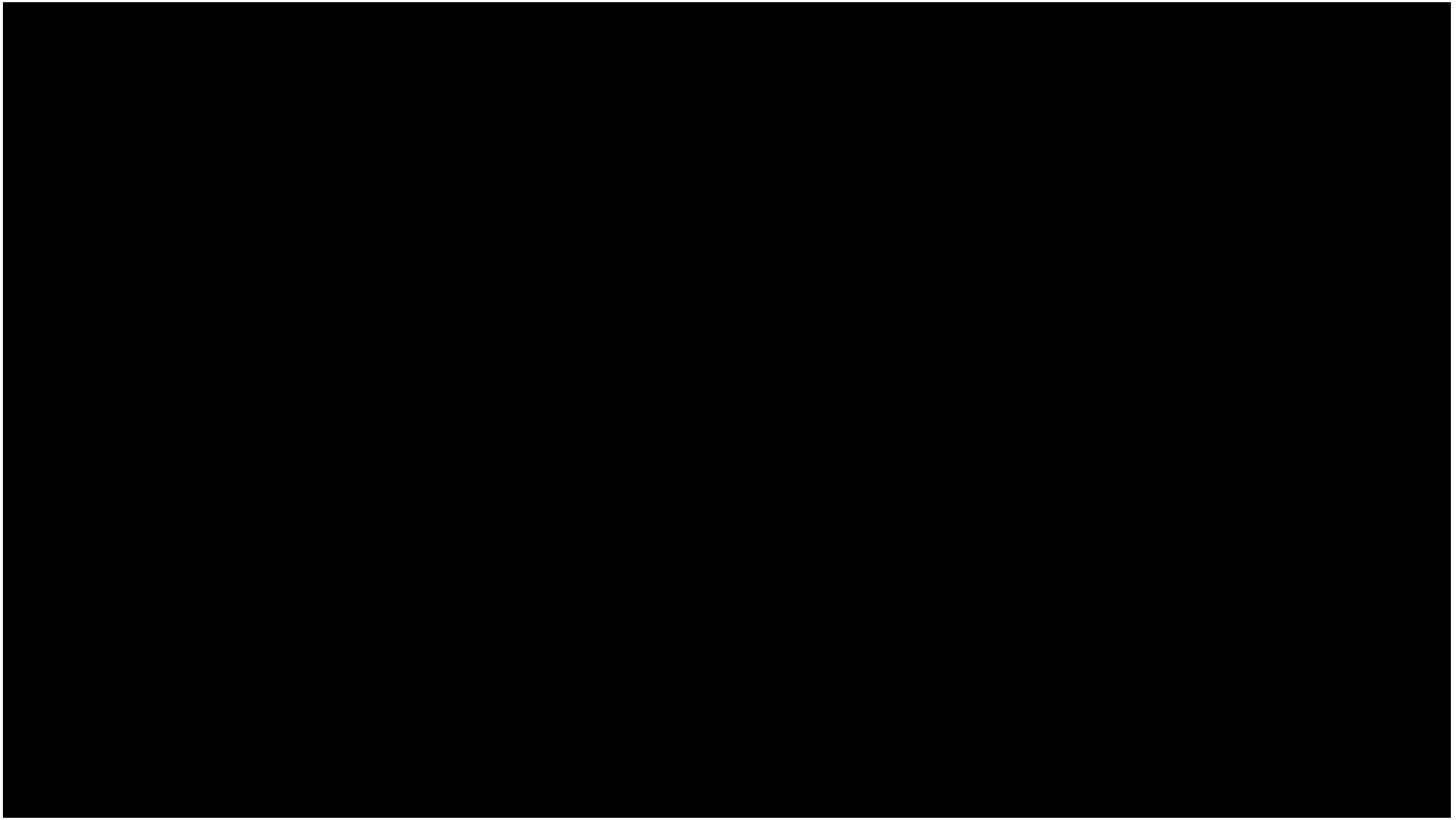
Recycling Technologies - Video



Other example technologies that are being commercialized

- Fulcrum Energy – MSW gasification followed by Fischer Tropsch conversion:
  - Produce high quality fuels (diesel, gasoline, LPG, naphtha) proceeding in Utah
  - Next phase will produce renewable jet fuel
- Pepsi/Alliance – investing in Origin Materials for conversion of cardboard and other waste cellulosic feeds to renewable PX and ultimately a totally renewable PET beverage bottle
- LanzaTech – First commercial plant started up in China in 2018 to convert steel plant waste CO to ethanol. Extensive new investment is being raised for a number of additional projects globally (India, UK, California)
- **Clariter** – Continuous thermal cracking of plastic waste (mainly polyolefin), followed by multistage refining and distillation
  - Produce various product families of solvents, lubricating oils and paraffins waxes

Clariter - Video



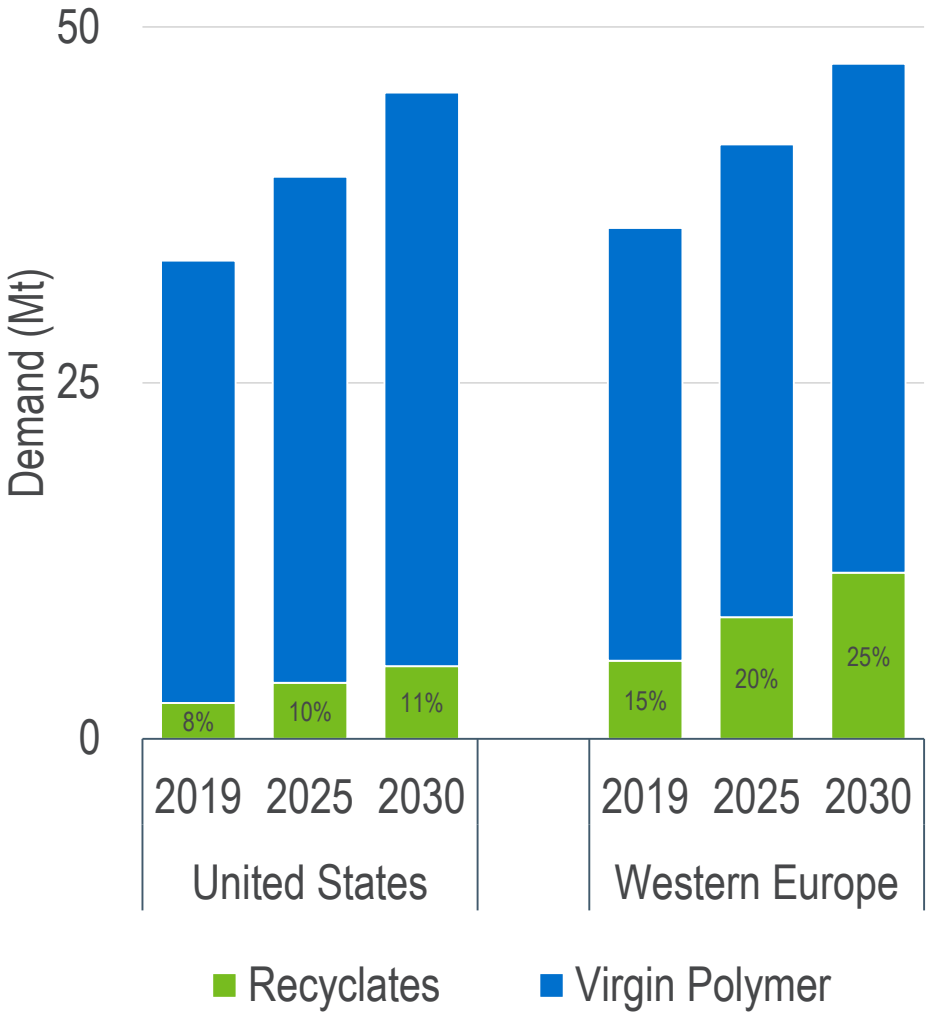
Summary and Conclusions

Regulations and sustainability strategy

Increasing demand for recycling is forecast, especially in Europe

Forecast Recycle Penetration

Nexant forecasts



Developments in waste plastic collection and recycling technologies will allow for greater recycle penetration

- rPE market to grow at 8-9% perm year supported by legislation and strong waste collection and sorting infrastructure
- rPET has highest penetration in W. Europe (~30%). Recycling rates expected to grow with increased bottle collection rates
- Developments in recycling technology to improve recyclability of common plastic items
- Further legislation and corporate efforts will help reduce use of non-recyclable plastics
- Current lack of legislation at federal level is hindering recycle penetration in the U.S.
- Low virgin resin prices due to current oversupply following shale gas

Notes: Demand figures do not include the impact of legislations passed this year, e.g. EU's ban on single-use plastics. Polymers included in analysis: PET, LDPE, LLDPE, HDPE, PP and PVC

Regulation: Human nature requires regulation to drive results and prevent negative behaviour

No major environmental progress has been made without regulation:

- Ozone/CFCs, Acid Rain/SOx and NOx, Lead…..

Europe is most advanced in policy development

- MSW recycling rate target: 55% (2025), 60% (2030) and 65% (2035)
- Specific packaging recycle targets by 2030, Total (70%), plastics (55%), aluminium (60%), ferrous (80%), cardboard (85%) and glass (75%)
- Landfill: No recyclable/recoverable waste (2030)
- Extended producer responsibility: Cost of waste management shared with producers; Producers must design with reusability, reparability, recyclability in mind.

No national laws in the US, however state and local governments set out their own recycling policies. Canada moves to ban single use plastic by 2021, and align similar to EU legislation

In China, there are also no national regulations but they are working to clean up their river pollution

- The “National Sword Policy” was introduced in 2018 which bans all plastic waste imports
- In 2015, an “Action Plan for the Prevention and Control of Water Pollution” was issued aimed to reduce water pollution and improve the quality by 2020 in heavily polluted water areas. By 2030, improvements to the overall water quality.

So what can WE do about it?

- **Demand more recycled content** from suppliers, even on a mass balance basis
- Contribute to circular economy through own **process and product innovation**
- Always **dispose of waste** responsibly!
- **Lobby** Government and Local Authorities to make it easier for **Tertiary Recycling** enterprises to become established
- Update your **Sustainability Strategy** (& maybe Nexant can help!)

Markets and Profitability

Technology and Costs

Special Reports

www.NexantSubscriptions.com