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Polymers

Bitumen Beyond Combustion (BBC)

Speaker introductions

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Agenda

1. Introduction
2. Imagining a BBC future
3. Polymer essentials
    - Types
    - Markets and opportunities
    - Concerns
4. Polymer production processes
5. Fundamental challenges
6. Insights and conclusions
7. Webinar Series: Recap

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Introduction to the webinar

Recap: Imagining a BBC future

Polymers from bitumen: key questions

- What polymers to make?
- How to make them from bitumen?

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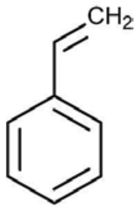
Polymer essentials

What are polymers?

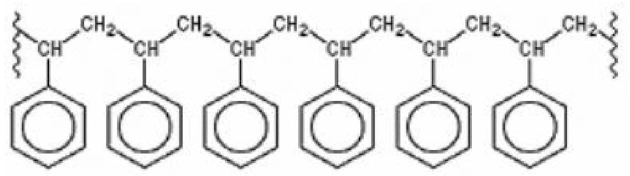
- **Plastics are encountered daily**
  - Plastics - generally a synthetic material made from single / combination of polymer(s) and various additives (e.g. pigment)
  - Consumer / industrial / medical applications
  - Adhesives, bubble-gum, carpeting, clothing, cosmetics, drill muds, flooring/furniture, hygiene products, packaging / bottles, paint, piping, sealants, siding, water treatment etc.



*Example of a **Monomer**: Stryrene (liquid)*

Ref: https://www.thoughtco.com/chemical-structures-starting-with-the-letter-s-4071311

- **Polymers - products used to make plastics**
  - Made from monomers
  - Mono(mer) – 'one' unit
  - Poly(mer) – many units
  - Polymerization: the joining of monomers to create a "polymer chain"
  - Chain length: can be varied by design; can be <u>very</u> long e.g. flocculants (water treatment)
    - The chain can contain more >1 monomer, randomly distributed or not



*Example of a **Polymer**: Stryrene (solid)*

Ref: http://www.rsc.org/learn-chemistry/resource/res00000479/addition-polymerisation?cmpid=CMP00004755

- **Where do polymers come from?**
  - Natural Semi-Synthetic Synthetic

Natural polymers

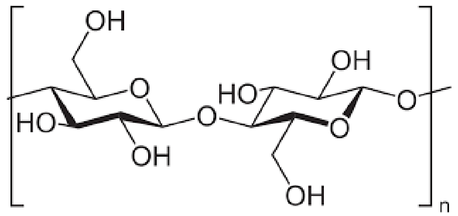
- **Polysaccharide** (storage (energy) / structure)
  - Cellulose (glucose)
  - Other: chitin, cotton, keratin, starch

- **Natural rubber**
  - Poly-Isoprene

- **Polyaromatic**
  - Lignin

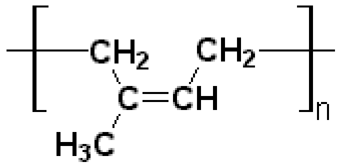
- **Proteins (amino acids)**
  - Silk (glycine, serine, alanine)
  - Gelatin, keratin

Cellulose



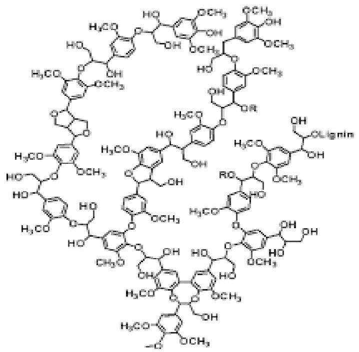
Ref: https://en.wikipedia.org/wiki/Celluloses

Poly-Isoprene



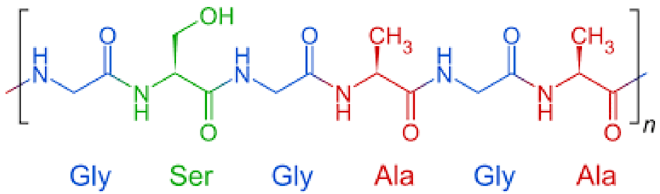
Ref: https://pslc.ws/macrog/exp/rubber/sepisode/meet.htm

Lignin



Ref: http://www.icfar.ca/lignoworks/content/what-lignin.html

Silk

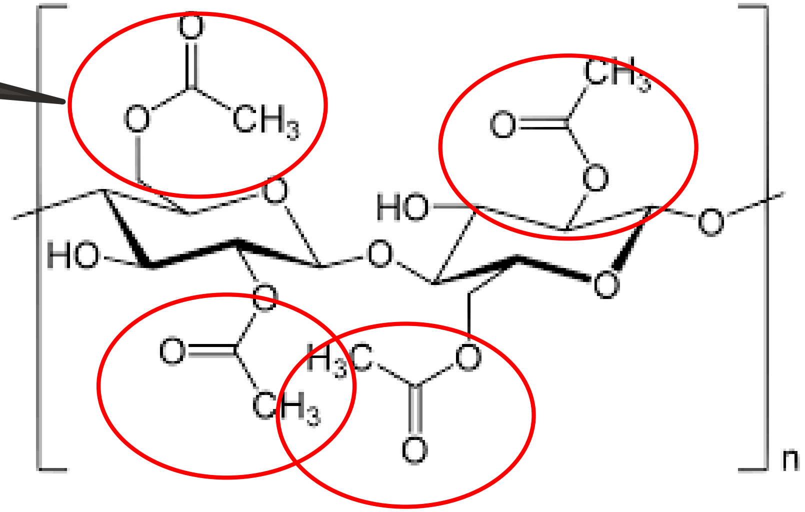


Ref: http://wwwchem.uwimona.edu.jm/courses/CHEM2402/Textiles/Animal_Fibres.html

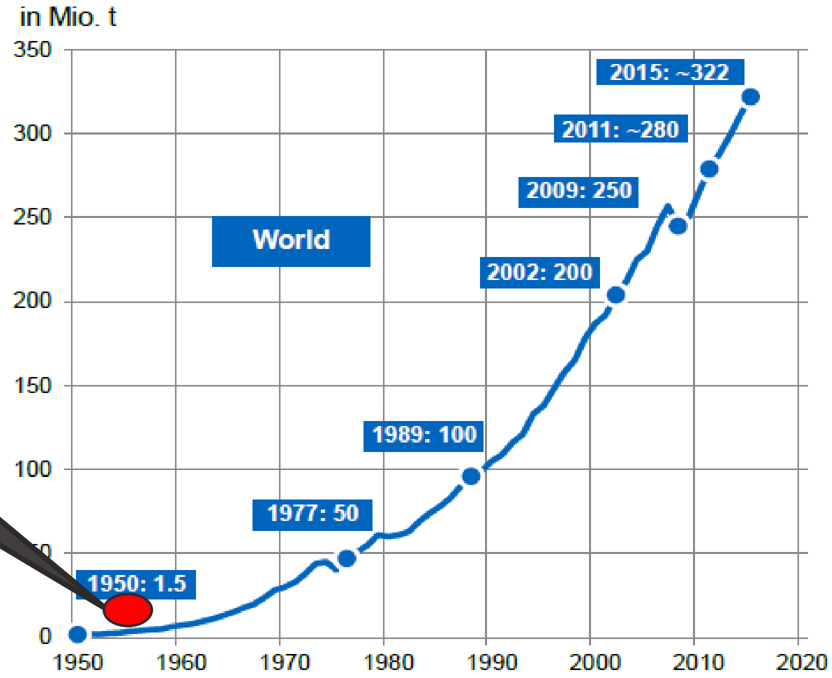
Semi-Synthetic polymers

- **Example**
  - Cellulose acetate (chemically modified cellulose)
  - Feed: purified natural cellulose from cotton linters or wood pulp
  - Use
    - Cigarette filters
    - Lego bricks (1949 - 1963)
    - Magnetic tape (IBM)
    - Photographic film (Eastman Kodak)

- **Transition - 1950’s**
  - Natural to synthetic polymers
    - 1950: 2 million tons
    - 2015: 380 million tons
  - Enabler
    - Rapid development in synthetic chemistry / material science
    - Example:
      - Tupperware – developed by Earl Tupper in 1937 at DuPont
      - Teflon – Du Pont (1938)



Transitioning



World Plastics Consumption (1950 – 2015). Source: Plastics Europe, Ass. Of Plastics Manufacturers, Berlin, Aug, ‘16, pg. 1.

Synthetic polymers

- **Synthetic polymers**
  - Produced from monomers
  - Monomers: produced from (petro)-chemical feeds / intermediates

- **Polymer development was / continues to be driven by**
  - Demand for improved product
  - Advantage of synthetics: range of monomers offers the opportunity for molecular design
  - Technology development in refining / petrochemical sectors
  - Geographic availability of natural polymers e.g. natural rubber (tire industry)
  - Politics / economics / society

- **Global production of major polymers**
  - 1950: 2 million tons
  - 2015: 380 million tons

Common modern synthetic polymers

PA - Polyamides (e.g. Nylon)
PE (LD, LLD, MD, HD) - Polyethylene series
PET - Polyethylene terephthalate
PP – Polypropylene
PS - Polystyrene
PUR – Polyurethane
PVC - Polyvinyl chloride
SBR - Styrene Butadiene Rubber

Market segments

- **Commodity plastics**
  - Ease of use, convenience

- **Engineering plastics**
  - Mechanical / thermal performance

- **High performance plastics**
  - Mechanical / thermal performance

PET *– Polyethylene terephthalate*

PS *- Polystyrene*

PVC *- Polyvinylchloride*

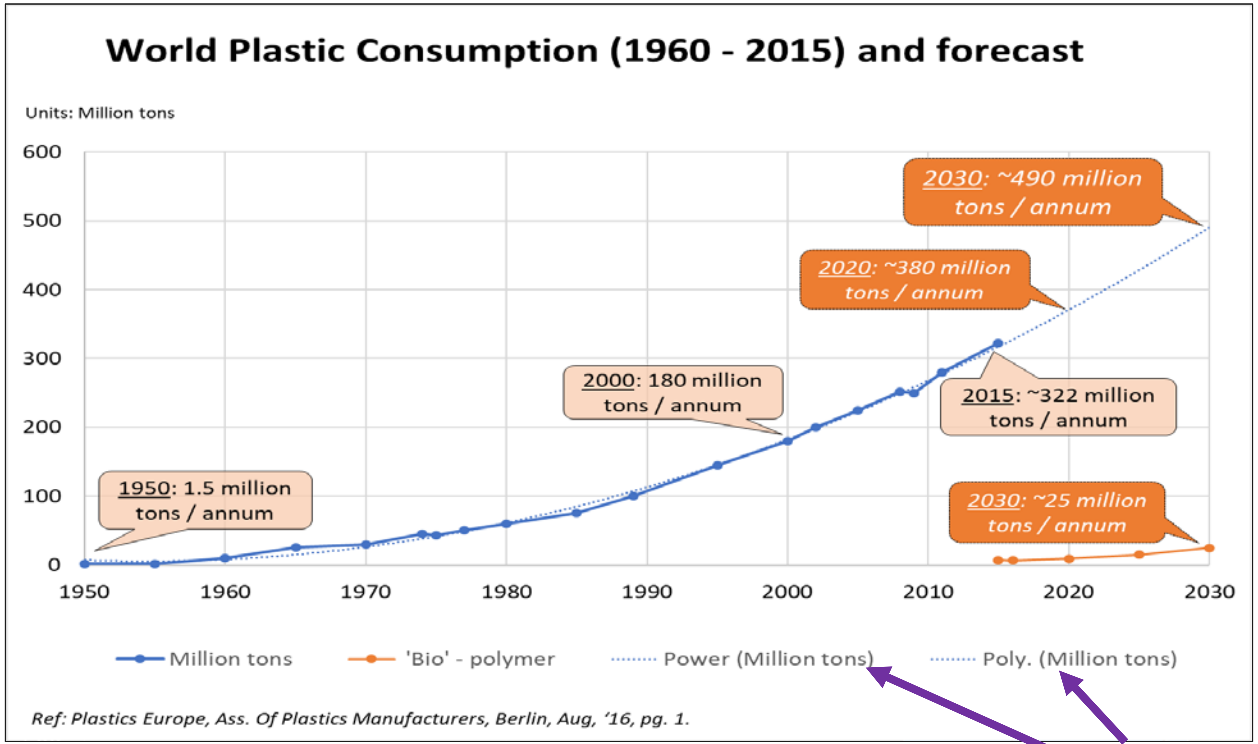
PC *- Polycarbonate*

PUR *– Polyurethane foam*

SBR *- Styrene Butadiene Rubber*

Opportunity

- Plastics / polymers - an essential part of everyday life
- Global plastics market (forecast): US$ 654 billion (2020). By 2030, expected to grow to US$ 1 trillion
- Growth (2015 – 2020): 3.9%
  - Drivers: population, urbanisation, growing middle class, environmental aspects (bio-polymer)



Polymer	Mt/y (1)	Bitumen bpd (2)	% Split
PP	68	1,256,000	23%
LD, LDPE	64	1,182,000	22%
PP & A	59	810,000	15%
HDPE	52	961,000	18%
PVC	38	315,000	6%
PET	33	445,000	8%
PUR	27	381,000	7%
PS	25	498,000	9%
Total	**407**	**5,350,000**	100%

(1) Ref.: R. Geyer, J.R. Jambeck, K.L. Law, Production, use, and fate of all plastics ever made, Sci. Adv. 2017; 3:e1700782 (19 Jul 2017)

(2) Alberta Innovates - rough approximation

NOTE: Given the rate of change in the polymer sector, challenges of obtaining / verifying market data, the table to be read for illustrative purposes

What do power and poly refer to here?

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Concerns with existing polymers

Definitions

- **Biodegradable**
  - A materials deterioration both chemical / mechanical (size) by natural means (air, light, micro-organisms)
  - Biodegradable materials and products of biodegradation are not necessarily compostable nor environmentally safe

- **Compostable**
  - Materials that break-down chemically under composting and anaerobic digestion conditions
    - Domestic composting: $<55^{o}C$ (unstable), lower humidity and oxygen levels
    - Industrial composting: $55\text{-}60^{o}C$, high humidity, oxygen. European Standard EU 13432

Move this slide up?

Plastic / polymer waste

- **Beverage bottles**
  - Polyethylene Terephthalate (PET)
  - Properties
    - Flexible / strong, light, non-toxic, 100% recyclable / not biodegradable
    - Recycling complexity increases with mixed waste
  - Volume
    - USA: ~50billion plastic water bottles / annum. 153 disposable bottles / person / annum
  - Waste (globally)
    - 2015: 6,300 million tons plastic waste. Landfill 79%; incinerated 12%, 9% recycled

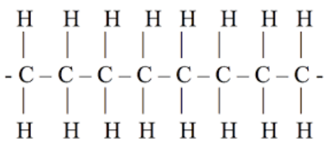
- **Carpets**
  - Not biodegradable, highly complex mix of inseparable materials (adhesives, anti-statistics, pigments, UV stabilizers (fading)
  - European Union
    - 1.6 million tons are disposed of, 960ktpa (60%) landfilled
    - Germany: 400ktpa incinerated, landfilling prohibited
      - *Reference: http://changingmarkets.org/wp-content/uploads/2017/04/German-Carpet-Report-ENG.pdf*
  - United States
    - 2014: produces 1 billion m^2 of carpet / rugs
    - *Reference: https://changingmarkets.org/about/*

Slow degradation - synthetic polymers

- **Degradation mechanisms**
  - Mechanical: river / sea action
  - Chemical
    - Microbial / aerobic / anaerobic
    - Photo-chemical: sunlight (UV)
    - Thermal: cold / heat

- **Design**
  - Synthetic polymers are typically not designed to degrade
  - Modern polymers
    - Chemically different to natural polymers
    - Most modern polymers largely biochemically inert
    - Degradability: function of the polymers chemical composition / structure

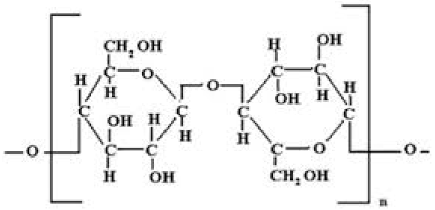
Polyethylene



Ref: https://accendoreliability.com/polyethylene-properties-uses/

versus

Cotton



Ref: http://textilelearner.blogspot.com/2013/04/structure-of-cotton-fiber.html

Opportunity

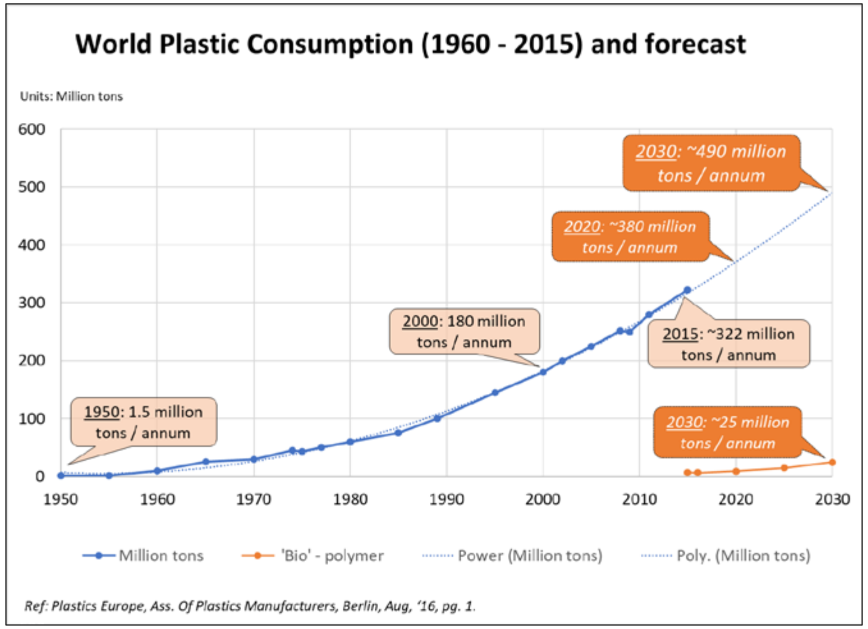
Are the figure and table repeated for emphasis?

- **Plastics / polymers**
  - An essential part of everyday life
  - Global plastics market (forecast): US$ 654 billion (2020)
  - Growth (2015 – 2020): 3.9%
    - Drivers: population, urbanisation, growing middle class, environmental aspects

Does the term ‘biopolymers’ survive?

- **‘Biopolymers’ outlook**
  - Growth(2015-2016): 4.4%
  - 2016
    - 6.6 million tons produced
    - <1% of global polymer production
  - 2021 (forecast)
    - 8.5 million tons

    Ref: nova-Institut GmbH, 20th Feb. 2017, Bio-Based Polymers Worldwide: Ongoing Growth despite difficult market environment
  - 2030 (forecast)
    - ~25 million tons (@ 5% of total polymer)



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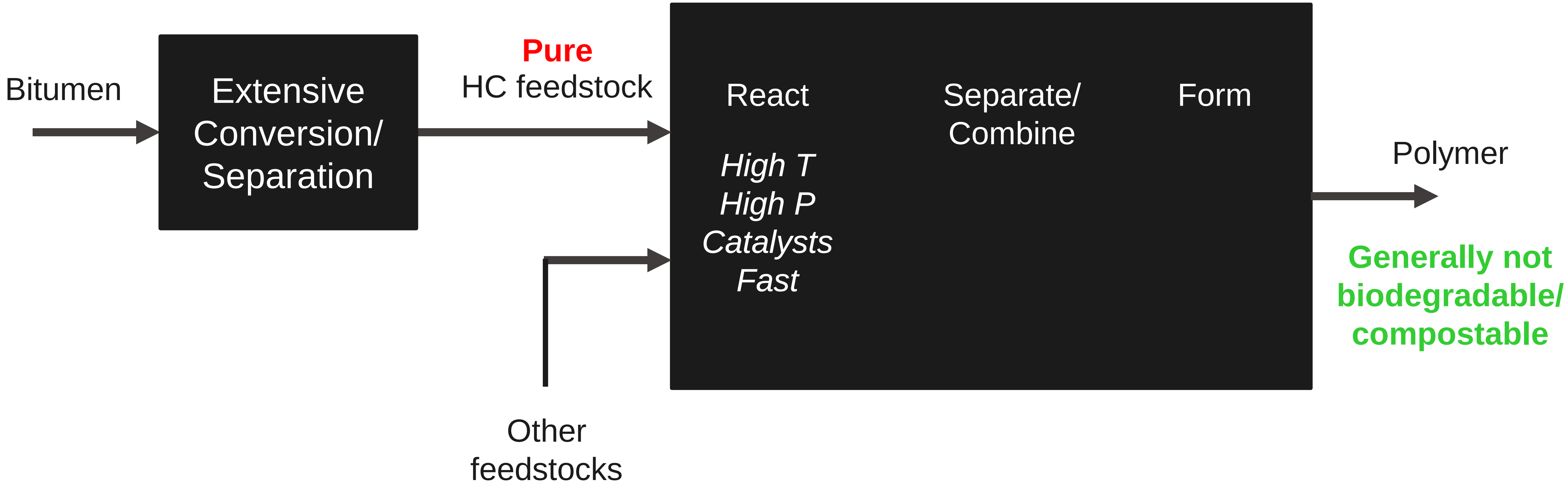
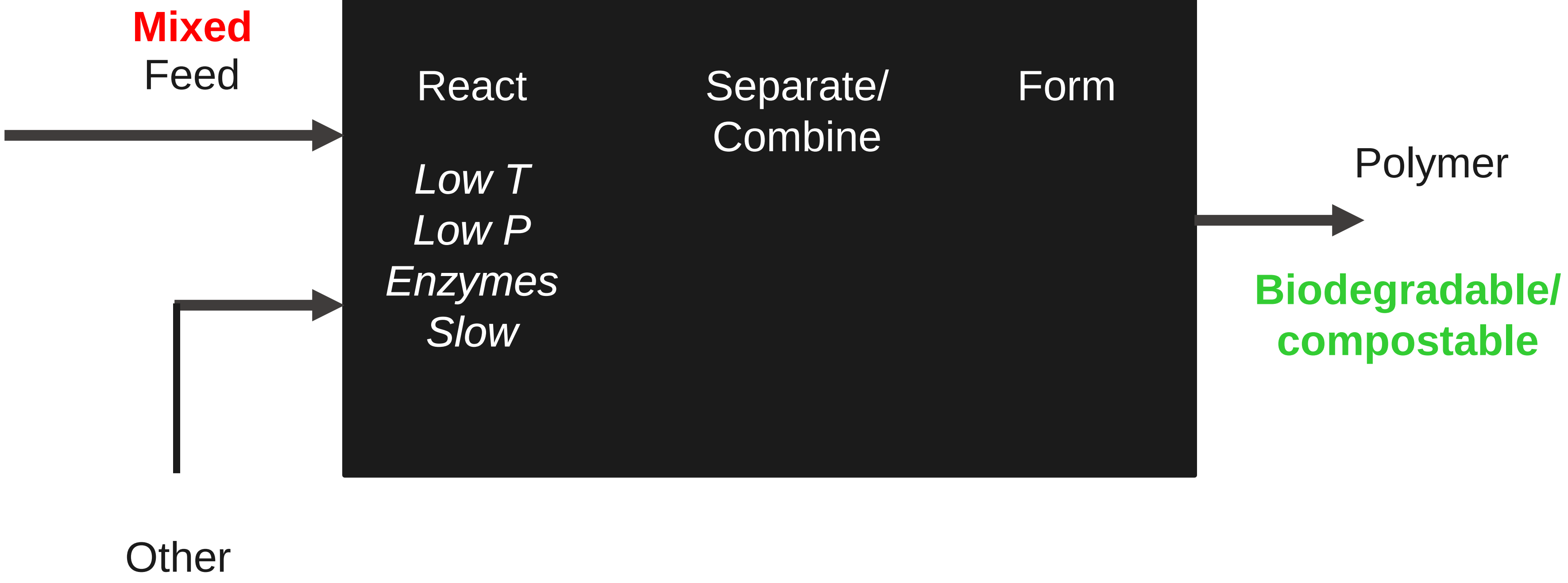
Polymer production processes

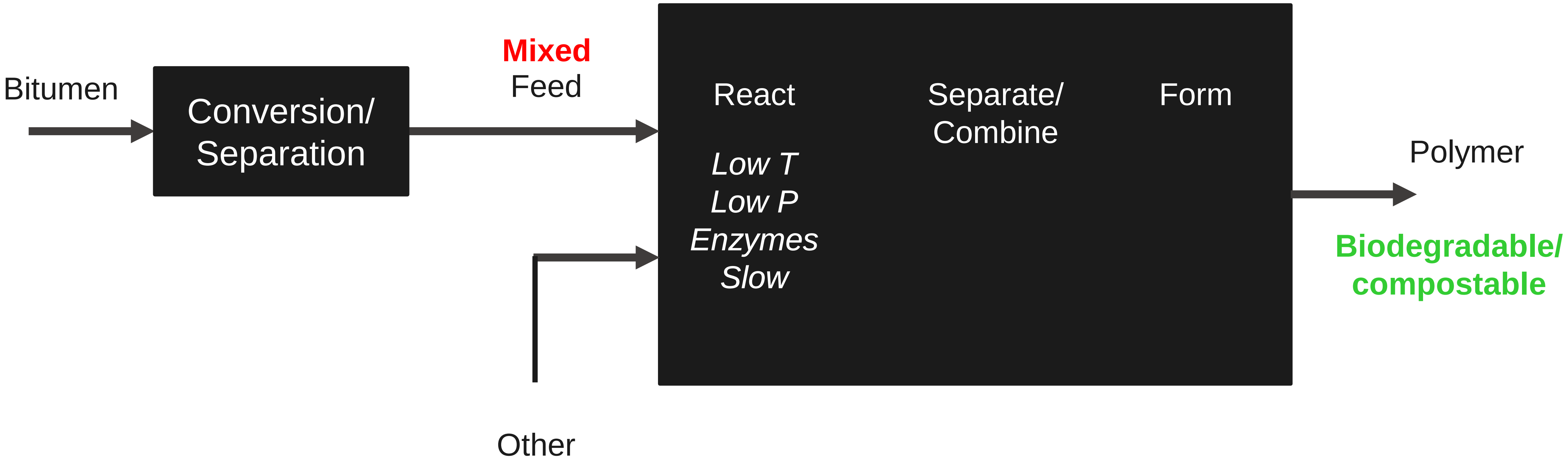
Current **synthetic** polymer production processes: Schematic flowsheet with Bitumen as feedstock



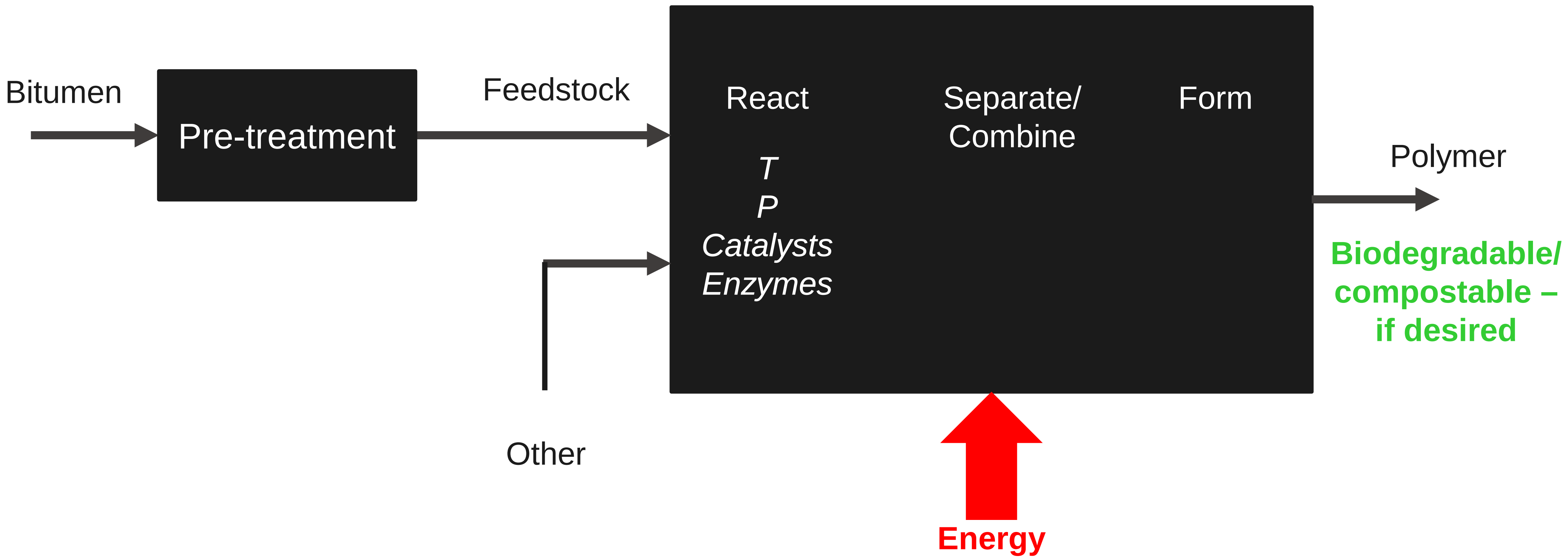
Natural polymer production processes: Schematic



Potential polymer production processes: Schematic flowsheet with Bitumen as feedstock



Polymer production processes:
Generic flowsheet with Bitumen as feedstock



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Technical challenges

Challenges to produce polymers from bitumen

- **Choice of polymers**
  - Meeting expectations: performance, cost, biodegradability / compostability, reuse, recyclability, end-of-life disposition, environment, and social acceptance
    - Conventional synthetic polymers: inherently challenged
    - Unconventional synthetic polymers (e.g., cross-linked, protein-based, and ‘irregular’ polymers): promising

A — A — A — A — A — A

A — C — B — C — A — B

- **Selection of polymer pathways and flowsheets for complex bitumen feedstock**
  - Conventional synthetic polymers: integrated with traditional bitumen refining
  - Unconventional synthetic polymers: largely undeveloped

- **Quantification of energy requirements and GHG emissions**

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Insights and conclusions

Insights and conclusions: Polymers

- Synthetic polymer industry: large, global, and growing
- Current major synthetic polymers: environmental and other concerns
- New (biologically inspired and irregular polymers) and their processes may lead to fundamentally new approaches and uses of bitumen

27

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Webinar Series Recap

Closing remarks:
BBC Webinar Series Recap

- Rising populations and prosperity drive large-scale demands for materials (e.g., housing, vehicles, consumer goods)

- Producing materials from bitumen (‘BBC products’) diversifies Canada’s oil sands sector

- BBC products pose fruitful business, scientific, technical, environmental, and social challenges

- Four major BBC product categories (with >100,000 bpd bitumen requirements) have emerged to date:
  - Carbon fibres and their combination products
  - Asphalts and asphalt transportation
  - Polymers
  - Vanadium for electricity storage

- Alberta Innovates supports the development of these and other BBC products, their production, and uses

Questions?

Quick Links

View the reports
https://albertainnovates.ca/wp-content/uploads/2018/04/BBC-Report-1.pdf

https://albertainnovates.ca/wp-content/uploads/2018/04/BBC%20-%20Report%202.pdf

News release
https://albertainnovates.ca/bitumen-beyond-combustion-program-invests-2-million-in-research/

View all webinars
https://vimeo.com/cosia

Talk to us

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