Today's Webinar Will Begin Shortly:

Technology Trends Decarbonizing the Chemicals Industry

QUESTIONS?

Use the questions box on your screen

AUDIO ISSUES?

Use the global dial-in number in your confirmation email

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Research Director

Lux Research

Agenda

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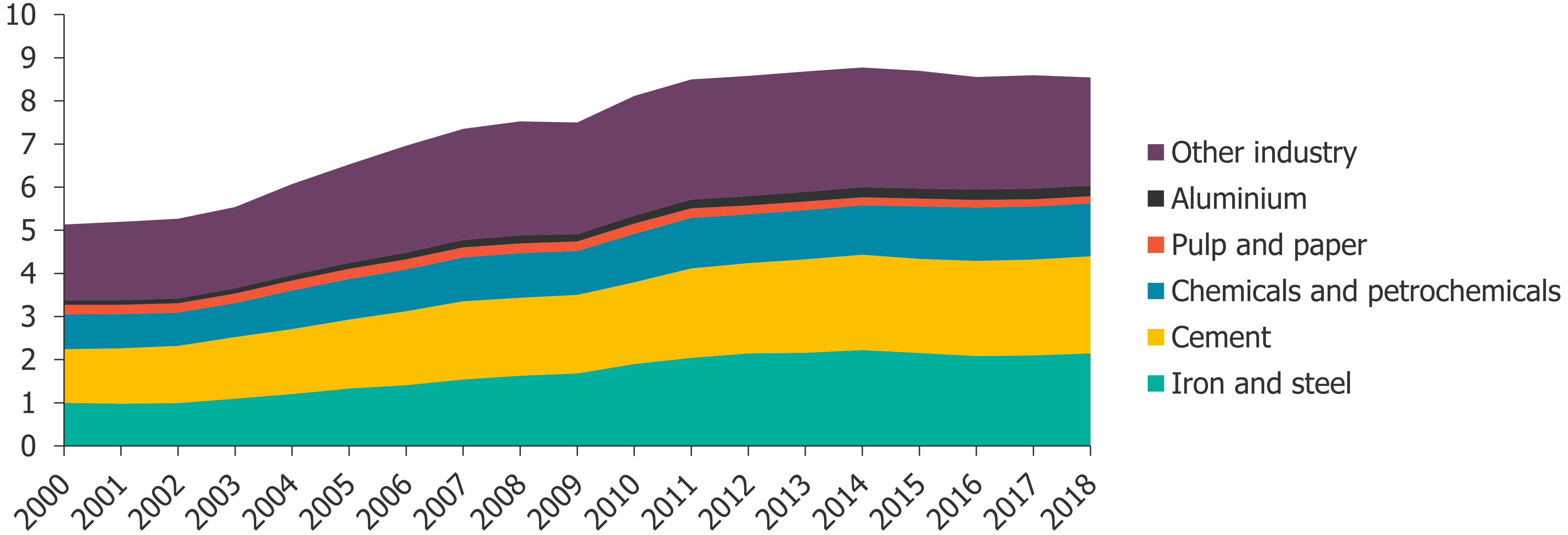
How does the chemicals industry stack up on emissions?

Industry direct CO2 emissions

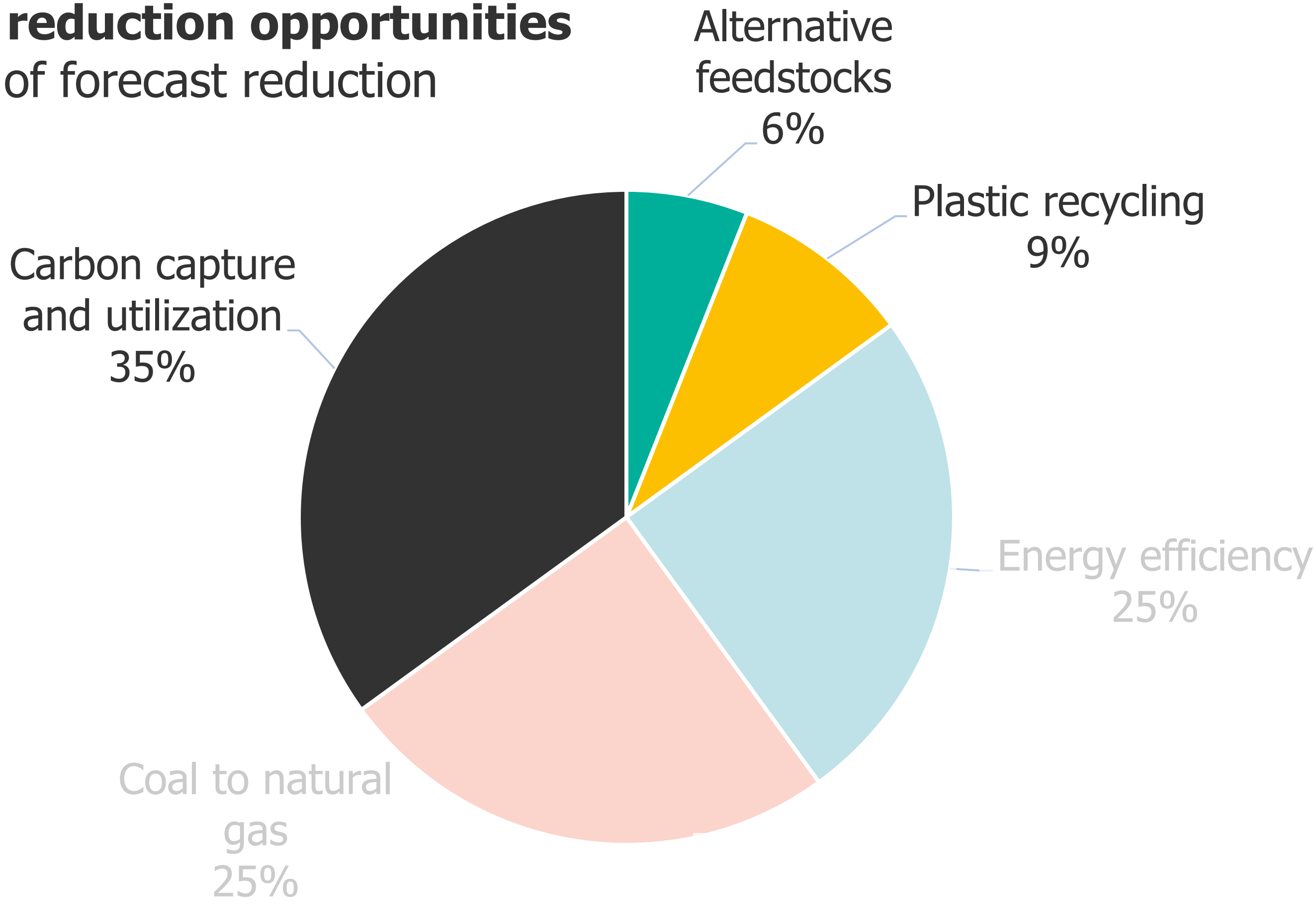
Gt CO2e



 Source: IEA

Decarbonization will depend on both incremental and disruptive innovations

Emissions reduction opportunities
Percentage of forecast reduction



Total reduction:
273 Mt CO_2

CCUS: 95 Mt
Plastic Recycling: 24 Mt
Alternative feedstocks: 16 Mt

Source: IEA.

Let’s pick three leading technologies and see how far we get.

CO_2 to chemicals

Recycling

Bioplastics

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CO_2 TO CHEMICALS

Technology Overview

Description:

Catalytic or microbial conversion of CO_2 into useful chemicals and materials

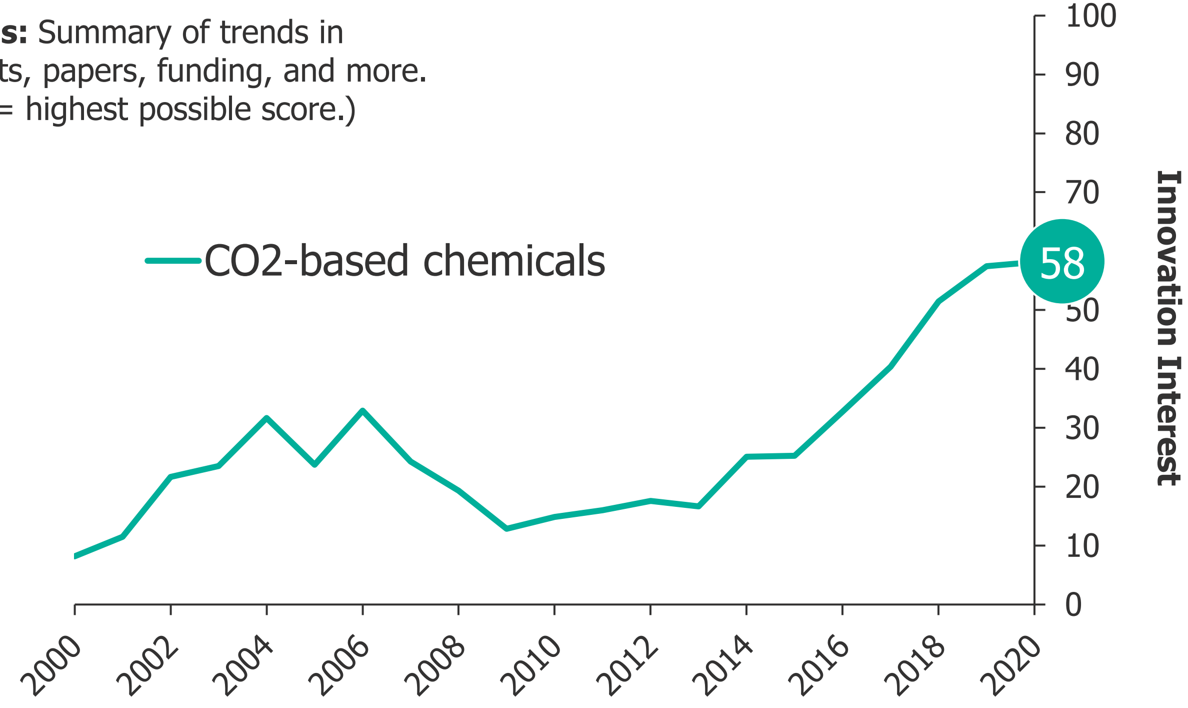
Key Benefits:

- CO_2 utilization can provide the chemical industry with a fresh source of essential carbon feedstock in the transition from fossil resources.
- Highest decarbonization potential of any route.

Key drawbacks:

- CO_2 derived chemicals are uniformly more expensive and generally don't offer performance enhancements

Y-axis: Summary of trends in patents, papers, funding, and more. (100 = highest possible score.)



CO_2 TO CHEMICALS

Key players

1 CHEMICALS

Mitsui Chemicals	CARBON RECYCLING INTERNATIONAL	HALDOR TOPSØE	opus 12	Dioxide Materials
COVAL Energy	CarbonEnergy Technology	TOTAL	BASF	
sunfire	CEMVITA FACTORY	SEEO2 ENERGY	cert	RENEW CO_2
b.fab	OCO	ThalesNano energy		Johnson Matthey
	AIR CO			

2 POLYMERS

covestro	AsahiKASEI	NEWLIGHT TECHNOLOGIES	EMPOWER MATERIALS	أرامكو السعودية Saudi Aramco
ECONIC				

3 CARBON ADDITIVES

Solid Carbon Products	C2CNT	Carbon Upcycling Technologies	CleanCarbon Technologies	

4 PROTEINS

novonutrients food from CO_2	Deep Branch	AIR PROTEIN™	Avecom	
SOLAR FOODS	UCDI Utilization of Carbon Dioxide Institute Co., Ltd.			

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CO_2 TO CHEMICALS

Econic Technologies

Econic develops catalysts that react CO_2 with a range of epoxides to form polyols.

Econic claims differentiation through its tunable catalyst system.

Econic plans to sell its catalysts to large chemical companies.

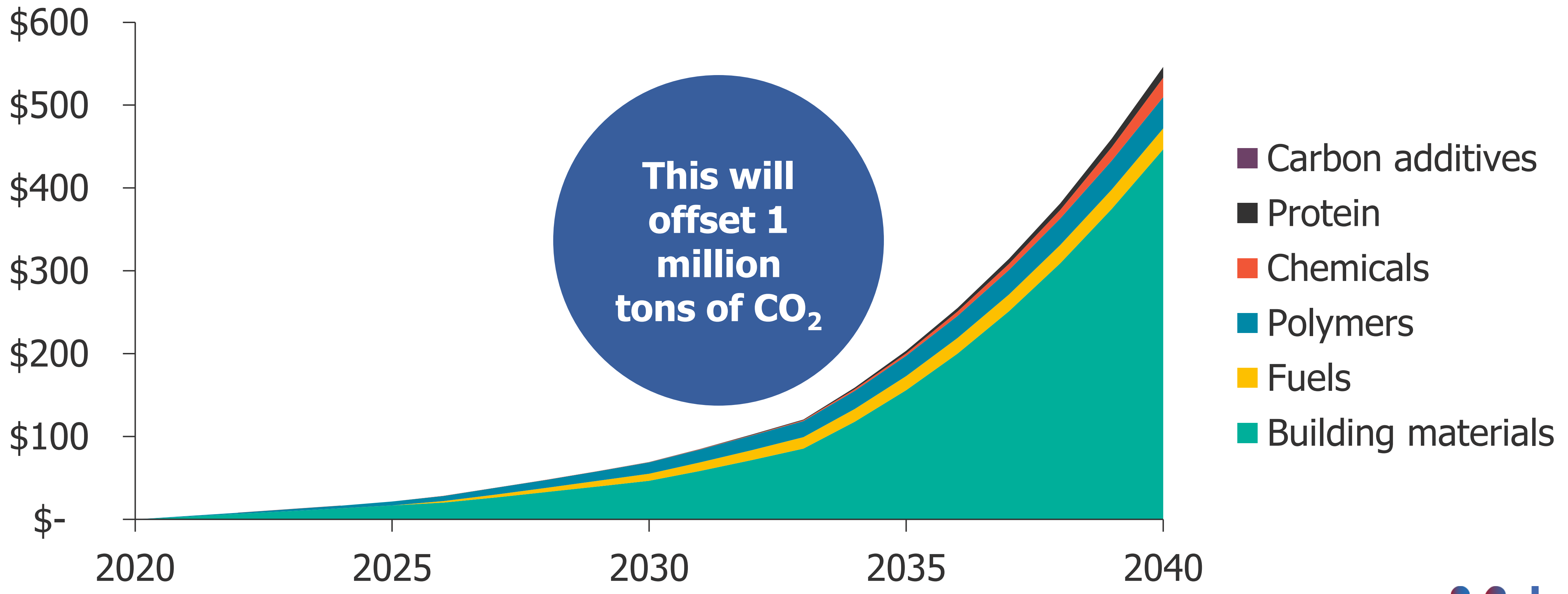
Image Source: Econic Technologies

LUX TAKE

Econic is smart to sell catalysts versus compete directly with polyol and polyurethane producers.

CO_2 to polyols will displace just 1 million metric tons of CO_2 in 2030 – the most of any CO_2 to chemicals technology

Global CO_2 utilization market
Market size (billion dollars, USD)



CO_2 TO CHEMICALS

Technology outlook

Driving force

Great potential to decarbonize basic chemicals

Limiting Factor

High energy costs driven by poor conversion efficiency

Key Trend

Pivot towards partnerships with concrete players to sink emissions

Long term outlook

More fundamental R&D is needed at an academic level

PLASTIC RECYCLING

Technology Overview

Description:

Conversion of waste plastic into useful products though mechanical, chemical, or thermal routes

Key Benefits:

- Simultaneously diverts waste from landfill while offering emissions reductions of up to 50% over conventional plastics

Key drawbacks:

- Conventional mechanical recycling is limited to serving non-food applications
- The real sustainability benefits of any emerging approaches – like pyrolysis – are not settled

Lux Tech Signal

Y-axis: Summary of trends in patents, papers, funding, and more. (100 = highest possible score.)

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PLASTIC RECYCLING

Key players

1 PYROLYSIS

Waste to oil

- PLASTIC ENERGY
- nexus FUELS
- PyrOil
- Recycling Technologies
- RES POLYFLOW
- VADXX
- ReVital POLYMERS
- Polymer Research Technologies Ltd.
- PYROWAVE
- GREENMANTRA TECHNOLOGIES
- RENEWLOGY
- QUBE ENERGY
- LEITNER
- Arqlite — Innovation for the planet
- urjas
- WASTECAPITAL
- PRI

2 DEPOLYMERIZATION

Waste to chemicals

- ioniqa
- CARBIOS
- gr3n
- CUMAPOL POLYESTER UPGRADING
- loop INDUSTRIES
- PRT PET REFINE TECHNOLOGY Co.,Ltd.
- GARBO your innovative partner
- ac
- IBM
- EASTMAN
- perpetual
- bp
- سابك sabic

3 MECHANICAL AND SOLVENT-BASED

Waste to materials

- APK
- cleyond
- PURECYCLE TECHNOLOGIES
- saperatec back to values
- ZENROBOTICS
- SADAKO TECHNOLOGIES
- QCP QUALITY CIRCULAR POLYMERS

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PLASTIC RECYCLING

Ioniqa

Developed a catalytically accelerated glycolysis-based depolymerization process.

Key component of Ioniqa's process is an in-house-formulated magnetic particle catalyst.

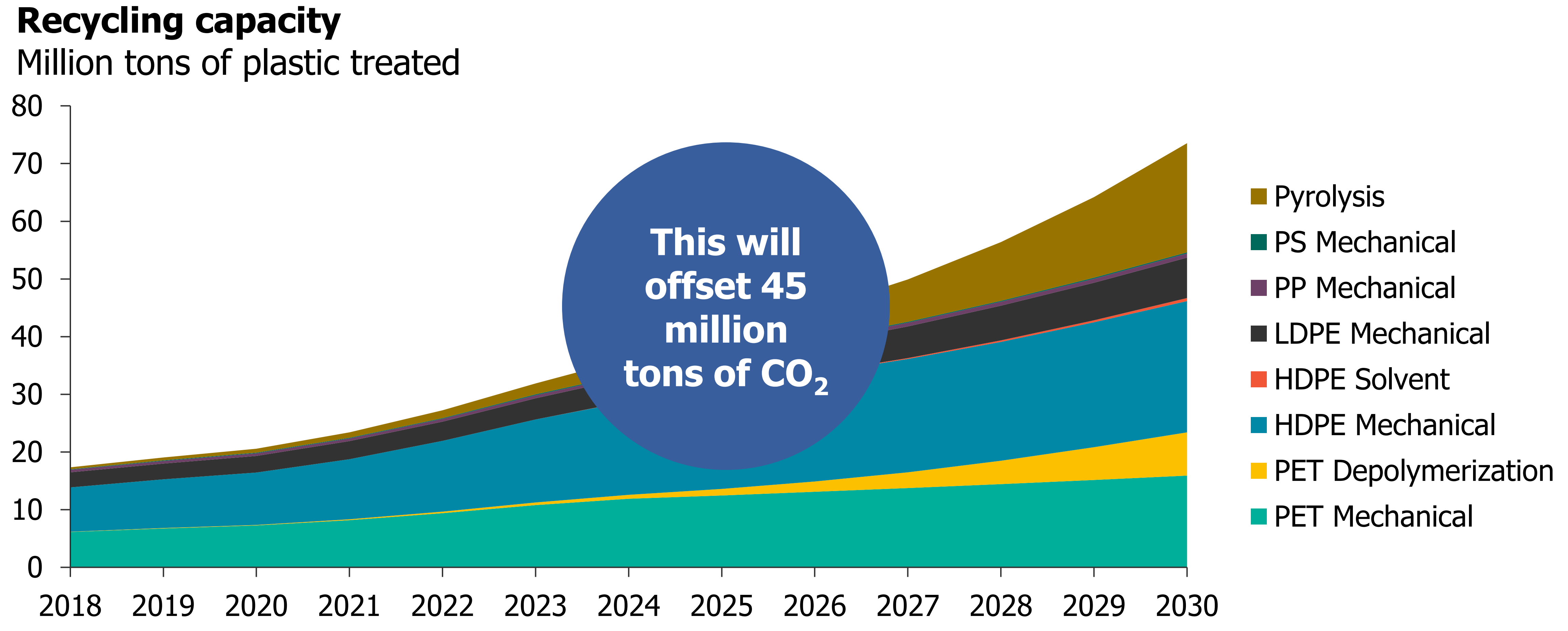
Has finished the construction of its 10,000-ton input facility in Geleen, Netherlands, and now plans to demonstrate continuous operations for several months

LUX TAKE

Ioniqa's catalyst selectivity gives it an advantage in the race toward valorizing polyester textile waste streams: Its magnetic catalyst selectively targets PET even in the presence of other plastics.

PLASTIC RECYCLING

Recycling capacity will grow to 73 million tons



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Technology outlook

Driving force

Meeting issues of emissions and waste simultaneously

Limiting Factor

Collecting and sorting waste

Key Trend

Chemical companies directly building mechanical recycling capacity

Long term outlook

Next gen catalytic pyrolysis is needed for widespread adoption

BIOPLASTICS

Technology Overview

Description:

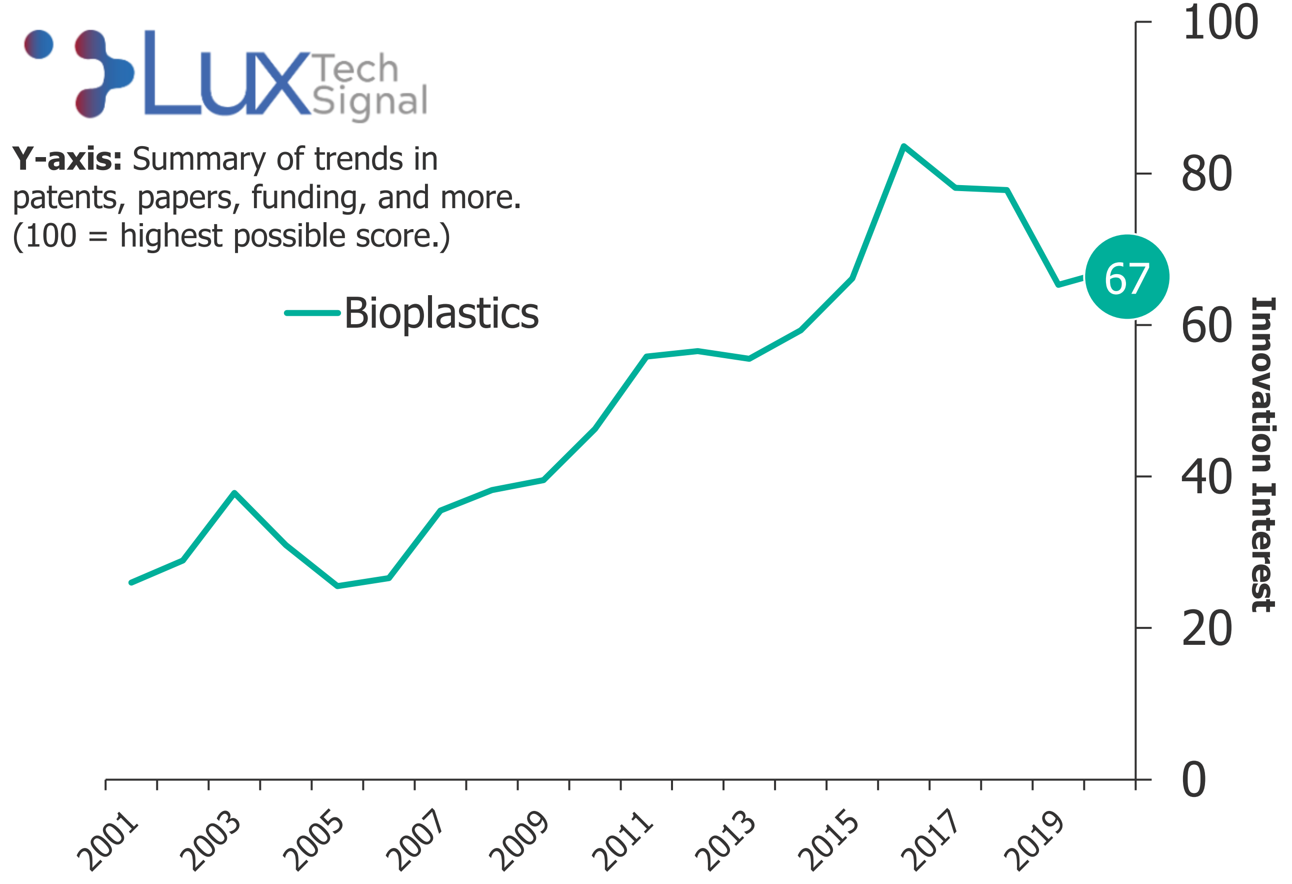
Conversion of sugars and waste biomass into conventional and novel plastics

Key Benefits:

- Reduce CO_2 emissions associated with oil feedstocks
- Some bioplastics can biodegrade, potentially reducing need for landfilling

Key Drawbacks:

- Costs are high, making drop-in replacements unattractive
- Biodegradation is does not work consistently



BIOPLASTICS

Key Players

1 POLYETHYLENE TEREPHTHALATE (PET)

Monomer(s): monoethylene glycol and terephthalic acid

2 POLYETHYLENE (PE)

Monomer(s): Ethylene

3 POLYETHYLENE FURANOATE (PEF)

Monomer(s): monoethylene glycol and furandicarboxylic acid

4 POLYTRIMETHYLENE TEREPHTHALATE (PTT)

Monomer(s): propanediol and terephthalic acid

5 POLYAMIDES (PAS) (NON CASTOR OIL DERIVED)

Monomer(s): diamines and diacids or lactams

6 POLYAMIDES (PAS) (CASTOR OIL DERIVED)

Monomer(s): diamines and diacids or lactams

7 POLYLACTIC ACID

Monomer(s): lactide or lactic acid

8 POLYBUTYLENE SUCCINATE

Monomer(s): butanediol and succinic acid

9 POLYBUTYLENE ADIPATE TEREPHTHALATE (PBAT)

Monomer(s): butanediol, adipic acid, and terephthalic acid

10 POLYHYDROXYALKANOATES (PHAS)

BIOPLASTICS

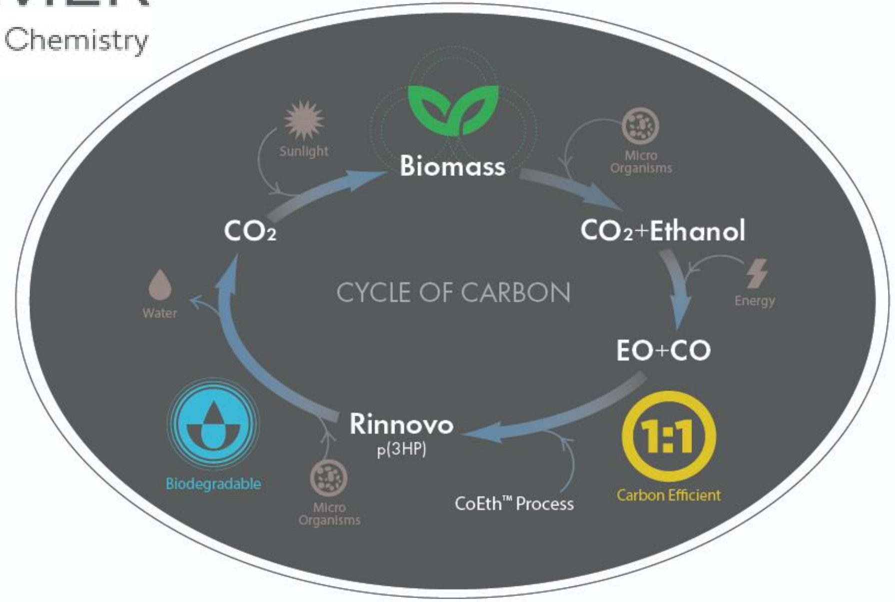
Novomer

Targets poly(3-hydroxypropionate) (P3HP), a type of polyhydroxyalkanoate (PHA)

Claims its thermocatalytic route to PHA is cheaper and easier to scale than biological routes to PHAs

Aims to build an 80,000 tpa demonstration facility for P3HB by 2024

NOVOMER
Catalyzed Chemistry



LUX TAKE

While high potential, scale up is likely to be a challenge – it remains to be seen if Novomer can create the market demand for it’s scaled up products.

Bioplastics offer lower CO_2 footprints, but carry other risks

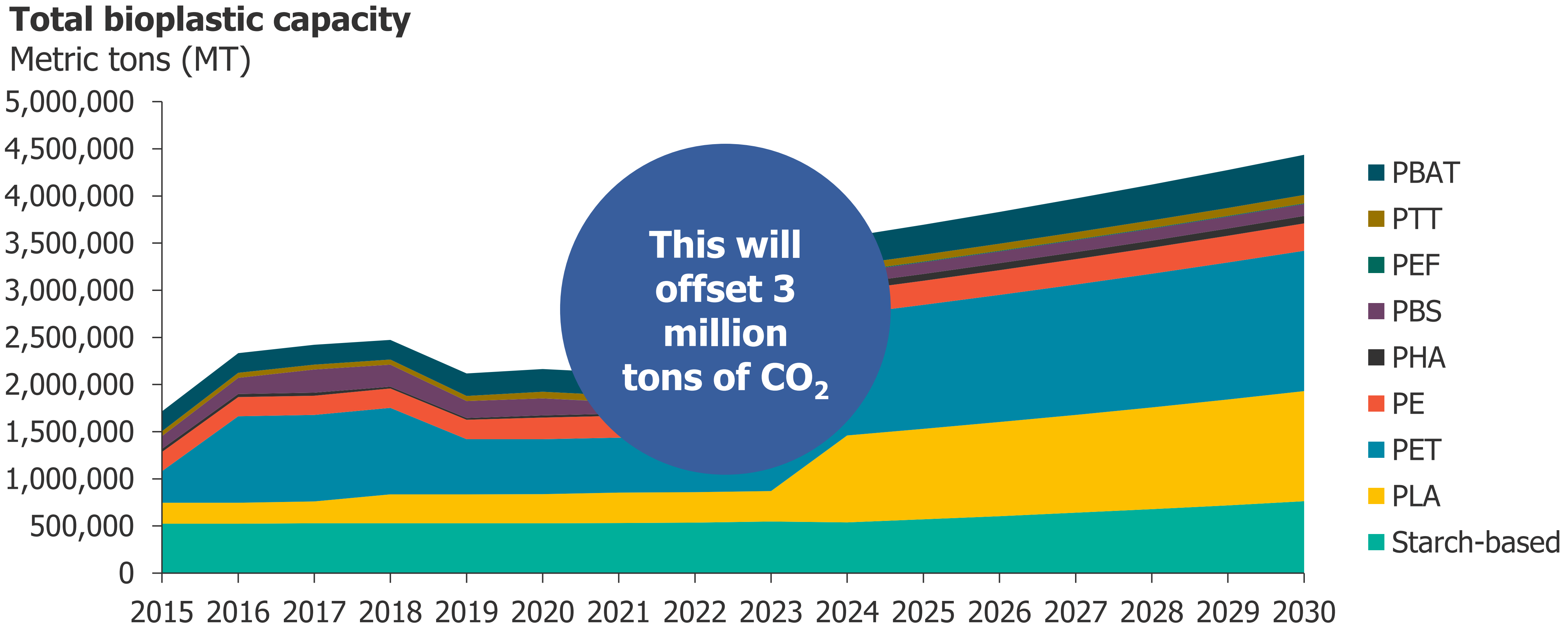
Land Usage

Energy Consumption

Water Consumption

Waste and end of life

Global bioplastic capacity will grow at a CAGR of 7.4% from 2 million MT in 2020 to 4.5 million in 2030



Technology outlook

Driving force

Finding alternatives to petrochemical feedstocks

Limiting Factor

Costs and unclear sustainability credentials

Key Trend

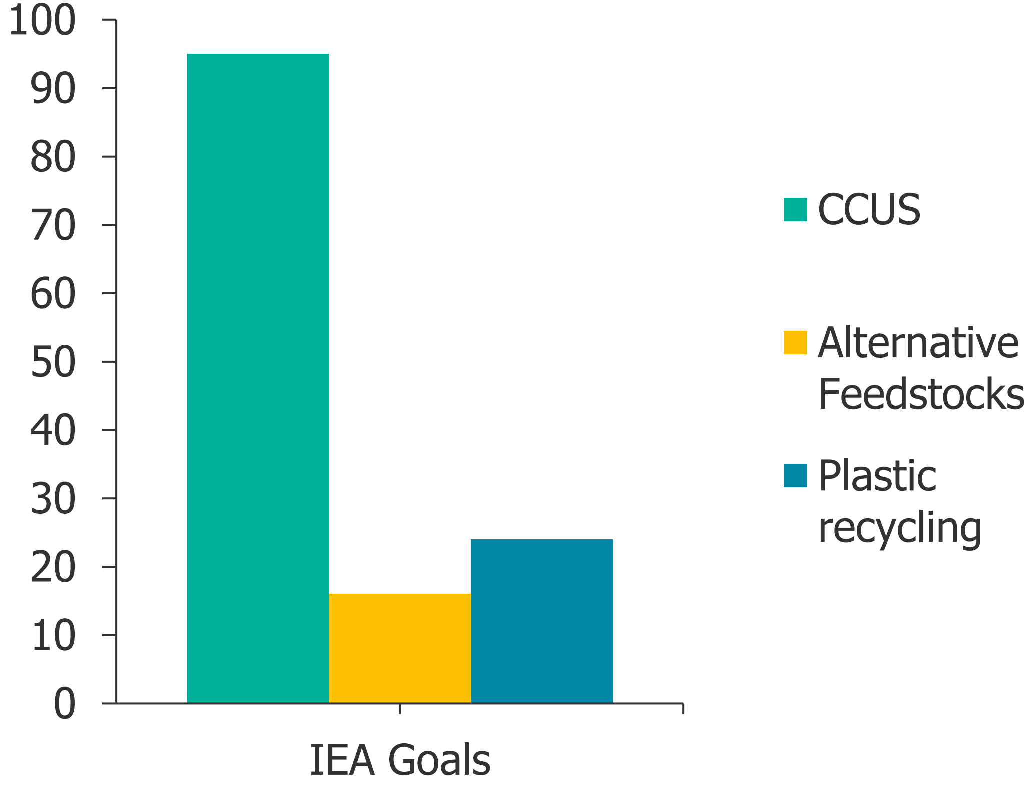
Regulations on single use plastics create an opportunity

Long term outlook

Expect a split between Asia and the rest of the world

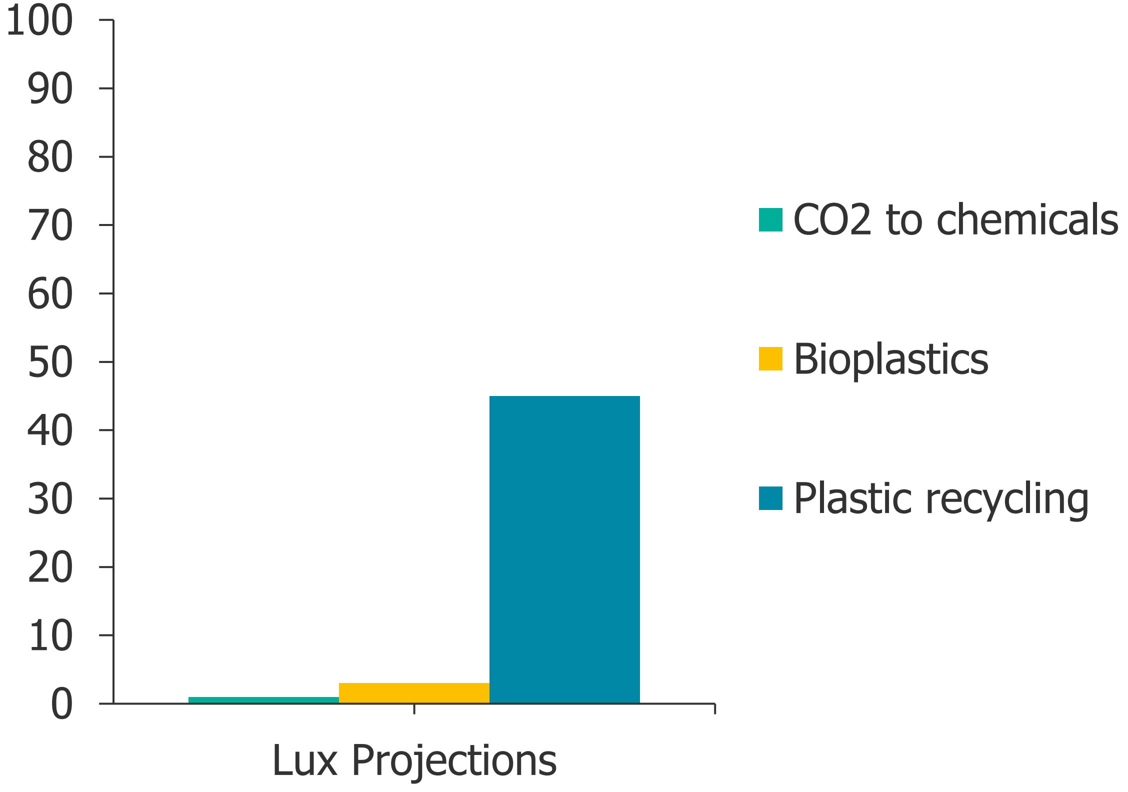
Technologies are falling short of ambitious decarbonization goals

CO_2 emissions reduction IEA goals
Million tons CO_2



273 Mt

CO_2 emissions reduction projections
Million tons CO_2



49 Mt

Agenda

1 | Chemicals CO_2 snapshot

2 | Three technologies driving decarbonization

3 | Decarbonization to dematerialization

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Sustainability and volume growth are opposed to each other.

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Companies will need to divorce revenue growth from volumes

Reduced consumption will become a key design goal in the future in order to save costs and improve sustainability.

KEY ACTIVITES

LUX TAKE: Digital technologies will be critical in creating the business models that decouple volumes and growth.

Only when the vessel actually comes into the dry dock and the water is removed, does the full extent of the repair work become apparent.

We felt we could improve that situation with our data.

– Michael Hindmarsh
Incubator Lead (UK), AkzoNobel

AkzoNobel

DryDoQ Insights
Predicts hull surface condition (corrosion, fouling) to inform dry docking decisions

Key Takeaways

1. Decarbonization of chemicals is a complex task, requiring both incremental and disruptive innovation
2. Chemical companies need to learn to navigate upstream and downstream systems
3. New business models will emerge to decouple revenue growth and volume growth

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Thank you

A link to the webinar recording will be emailed within 24-48 hours

UPCOMING WEBINARS

- **August 24th:** Top Technology Innovations Driving Growth in the Food and Beverage Industry
- **September 21st:** The Hospital of the Future

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