McKinsey & Company

Issues and Insights into the Next Generation Materials for Sustainability

June 20th, 2023

Key messages

Global Backdrop	1	Biggest capital reallocation of our lifetime
	2	From transition to addressing the quadrilemma
	3	An integrated challenge across food, energy, and materials
	4	Dramatic innovation is required to hyperscale
Sustain-ability in Chemicals	5	Sustainability along chemicals in 4 domains
	6	Circular plastics value pool of 15-45 Bn by 2030, but investment required
	7	Bio-based chemicals essential for aggressive decarbonization of sector, but unclear winner with technology / costs
	8	Decarbonized materials increasingly required for scope 3 commitments of end-use industries
	9	Companies innovating in materials intended for use in sustainability-related end-use sectors command ~4x premium over conventional sectors
Forward looking…	10	Generative AI in chemicals is nascent, but potential applications endless

1. This is the biggest capital reallocation of our lifetime

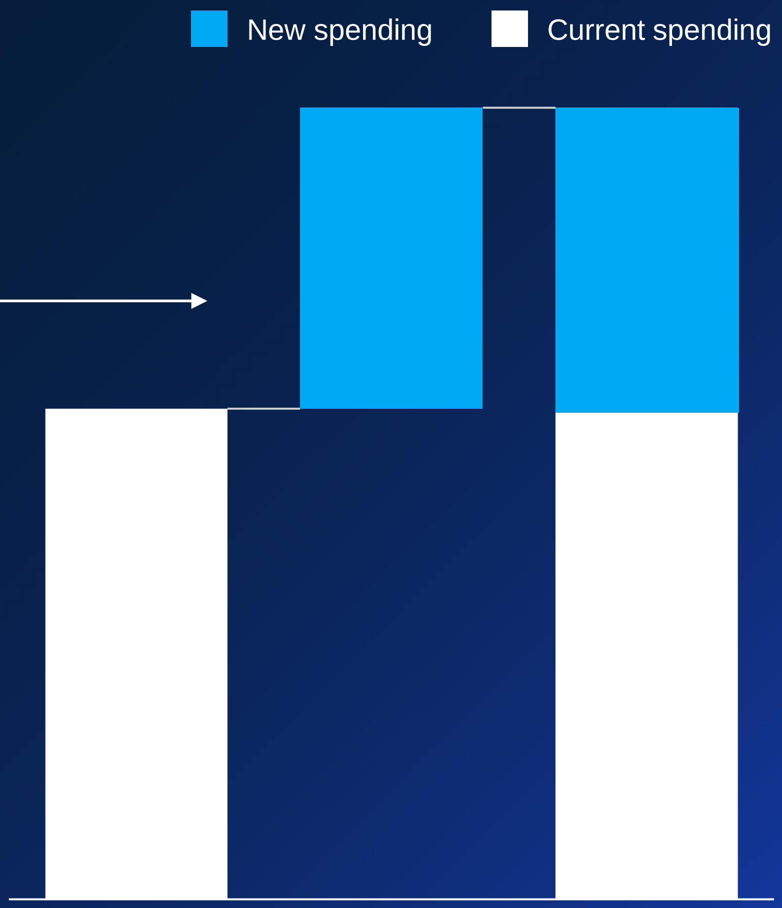
Annual investment expected to reach Net Zero (climate change mitigation)

$9.2tn

Total **global** annual spending in the net-zero scenario

$3.5 New spending on low-emissions assets and enabling infrastructure

$5.7 Spending today on physical assets



Source: The net-zero transition: What it would cost, what it could bring. McKinsey Global Institute, 2022. Based on the NGFS Net Zero 2050 scenario, a hypothetical scenario and not a projection

1. While this decade is critical, the world is off-track by every metric and will likely overshoot a 1.5C scenario

Mitigation

Adaptation

Finance

Loss & Damage

Needed by 2030	Status in 2022
-40-45% CO_2e from 2019[1]	**+10-12%** CO_2e from 2019
$150-200B Per year[3]	**~$30-35B** Per year[4]
$300B Per year[5]	**<$0.35B** Per year[6]
~$4T Per year[7]	**$500B** Per year[7]

1. UNFCCC WGIII (2022)
2. Climate Action Tracker (2022)
3. Projected annual costs of developing country adaptation ($160-340bn), UNEP (2022)
4. $29B to developing countries in 2022 (UNEP 2022)
5. Projected L&D costs for vulnerable regions (Markandya & Gonzalez-Eguino, 2018 – as quoted by European Parliament)
6. 2022 commitments (Denmark, Belgium, Germany, Scotland, New Zealand, Austria, Wallonia)
7. Flows of climate finance only - Climate Policy Initiative (2021)

2. Recent events have highlighted that the transition must address broader objectives beyond emissions reduction

Amid an energy crisis, Germany turns to the world's dirtiest fossil fuel

"…with Russia cutting natural gas deliveries to Europe, and with no quick options to replace that energy, Germany is warily turning to its most reliable — and environmentally polluting — fossil fuel."

NPR, Sept 2022

Households across the U.K. are about to experience an 80% jump in energy costs

The latest price cap — the maximum amount that gas suppliers can charge customers — will take effect Oct. 1, just as the cold months set in.

NPR, Aug 2022

Russia's invasion of Ukraine exposure E.U.'s energy vulnerabilities

E.U. sees adequate winter energy, but seeks longer-term independence. The [EU's] energy commissioner said the Russian invasion of Ukraine had exposed vulnerabilities in European energy supplies.

NY Times, Feb 2022

U.S., Europe Tussle Over Frenzy of Clean-Energy Subsidies

Multinational companies are racing to invest billions of dollars in the U.S. to capture generous clean-energy incentives…sparking a move by some to come up with their own green subsidies."

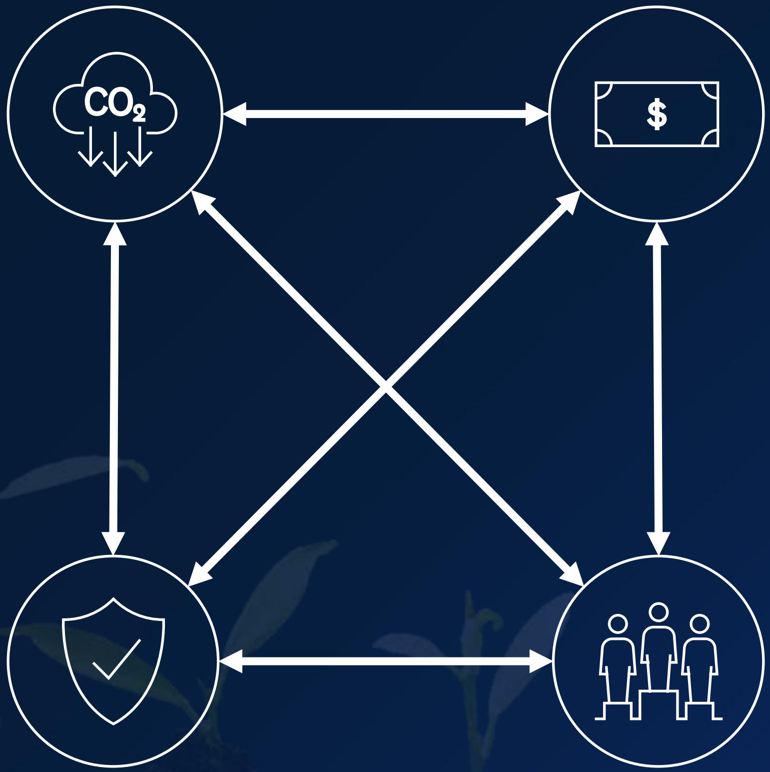
Wall Street Journal, Jan 2023

Lower emissions | **Affordability** | **Security** | **Competitiveness**

2. A successful net-zero transition must address the emerging quadrilemma

Lower emissions

Reducing greenhouse gas emissions to net zero and managing physical risk



Affordability

Guaranteeing our pathways are economically feasible and allow for affordable energy and materials access across countries and income levels

Security

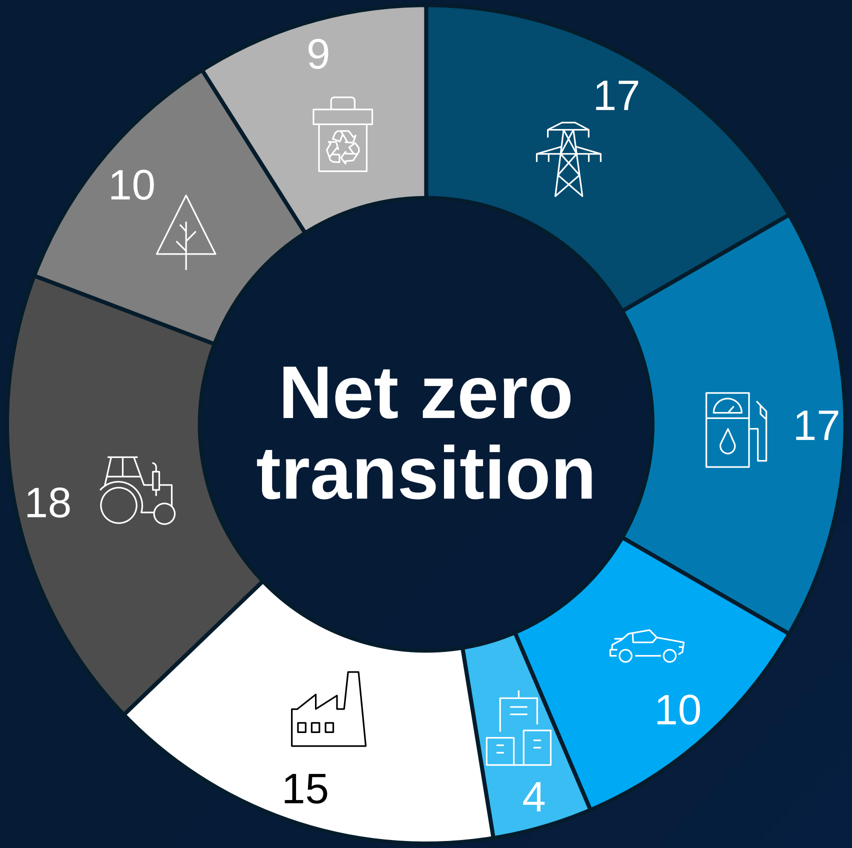
Ensuring geopolitical stability and system resiliency & reliability

Competitiveness

Strengthening competitiveness of nations and companies

3. This is an integrated challenge – across food, energy, and materials

Global GHG emissions in 2019 by sector[1], Percent of global GtCO2e p.a.



Energy emissions

Emissions from power, fuel generation, mobility, and buildings sectors

48% of global GHG emissions

Material emissions

Emissions from industry sector (e.g., steel, cement)

15% of global GHG emissions

Food & land use emissions

Emissions from agriculture, forestry, and waste sectors

37% of global GHG emissions

1. Non-CO2 emissions are converted into carbon dioxide equivalents according to their 20-year global warming potential (GWP20). Includes emissions from Carbon dioxide, Methane, Nitrous oxide, and other highly-potent GHGs such as hydrofluorocarbons (HFCs) and chlorofluorocarbons (CFCs)

Source: McKinsey Energy Insights Global Energy Perspective 2022 ; Sustainability Insights EMIT database

4. Dramatic innovation is required to hyperscale the next 300 decacorns

2005 –2015 | **2020–2030**

Historical	R&D	Demonstration	Early adoption	Mature
Solar 12x	Long Duration Energy Storage 15-20x	Renewable Hydrogen 300x	Batteries 20-80x	Solar 7x
	Carbon Removals 150x	Carbon Capture, Utilization, and Storage 30x	Advanced Fuels 10-15x	Wind 4x
			Alternative Proteins 10-15x	

Source: McKinsey Platform for Climate Technologies

4. All of this is leading to creation of new market niches and leaders across sectors

Investable themes – addressable market size in 2030, including venture, PE, and infra capital ($B)

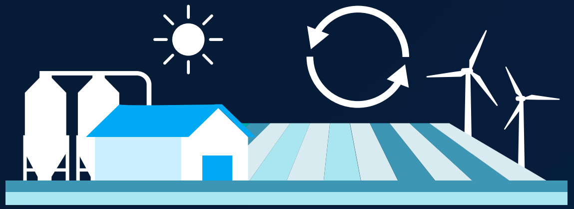
Preliminary, Not Exhaustive

Addressable market size	Sector	Themes
$2,300-2,700B	**Transport**	• Electrification • Micro-mobility • Infrastructure for electric vehicles • Sustainable aviation
$1,300-1,800B	**Buildings**	• Sustainable design, engineering, and construction advisory • Green building materials • High efficiency building equipment • Green building technology and operations
$1,000-1,500B	**Power**	• Renewable power generation • Grid modernization and resiliency • Flexibility and energy storage solutions • Power system technology and analytics • Decommission and thermal conversion
$1,100-1,200B	**Water**	• Municipal water supply • Industrial water supply
$800-1,300B	**Agriculture and land/forest mgmt.**	• Land and forest management • Agriculture production • Alternative proteins and food waste reduction • Sustainable agricultural inputs • Sustainable agricultural equipment
$760-1,070B	**Consumer**	• Consumer electronics • Sustainable packaging • Sustainable fashion
$650-1,150B	**Oil and Gas de-carbonization and sust. fuels**	• Electrification of upstream and downstream • Efficiency improvements • Direct emissions elimination • Sustainable fuels
$650-850B	**Hydrogen**	• Production • Transmission • End use
$280-380B	**Waste**	• Enablers of materials re-use ecosystem • Industrial and mature materials processing • Nascent and emerging materials processing innovation
$250-290B	**Industrials**	• Steel • Aluminum • Cement • Mining • Chemicals
$80-200B	**Carbon management**	• CCUS • Carbon offsets markets • Carbon tracking and measurement

5. Chemicals and materials play a role in sustainability along 4 dimensions

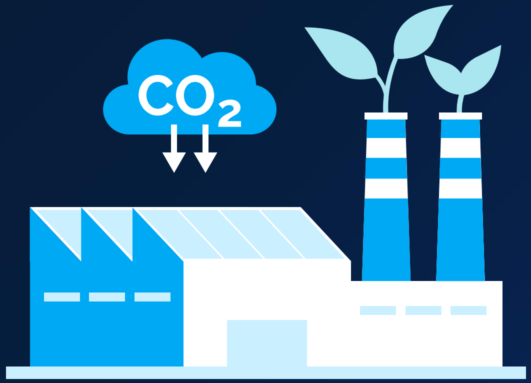
Circularity

Plastics recycling through mechanical or chemical routes



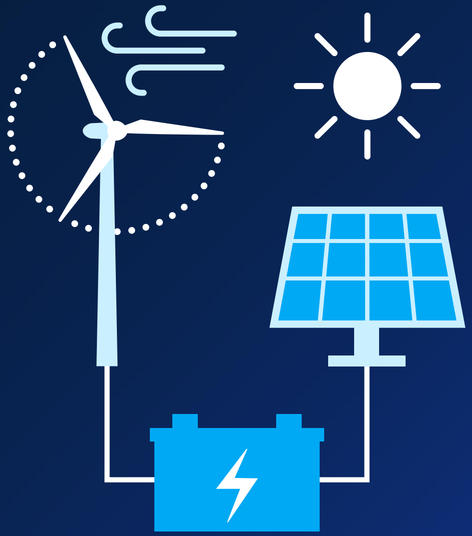
Bio-based materials

Reducing emissions and waste through bio-based materials/renewable inputs



Decarbonized materials

Lowering footprint across all scopes of emissions



Enabling down-stream industries

“Handprint” effect of chemical outputs necessary for the energy transition

6. Going forward, we expect four key forces to influence the evolution of premia for high-quality circular plastics

Trend of driver

■ High negative ■ Neutral ■ High positive ↑ Accelerating ↔ No change ↓ Decelerating

Forces	Effect on market	Trend	Rationale	
Brand owner action	High positive	↑	Brand owners have made circular plastics commitments in response to consumer pressure and are making material progress on delivering (e.g., recycled content up 3x 2018-2021)	"" Most brand owners feel obliged to have a sustainability agenda […] Recyclability and waste management are the main themes at the moment […] **Sustainability expert**
Regulation	High positive	↑	Countries implementing recycling targets, e.g., EU wanting to achieve a 65% recycling rate by 2030, and restricting/banning landfill option	"" One of the key drivers in developed markets will be quotas (…), EU put forth a 65% recycling target by 2030, up from 20% today **Expert on recycling**
Feedstock quality and availability	Neutral	↔	Waste generation exceeds volume being recycled, but the challenge to source high quality feedstock remains; sorting and collection technologies are in the process of being developed globally	"" Plastic waste feedstock appears to be the constraint for growth in recycling as both mechanical and advanced recyclers compete for material **Expert on recycling**
Technology	High positive	↑	Introduction of new advanced recycling technologies can enable new streams of plastic waste being recycled at scale and higher quality of output	"" We are seeing gradual improvements in sorting technology, which is a key enabler for improving recycling economics **Packaging expert**

1. Includes China

Source: Expert interview and analyst reports

6. Technology: Development and scaling of advanced recycling technologies can be necessary to unlock high-quality supply

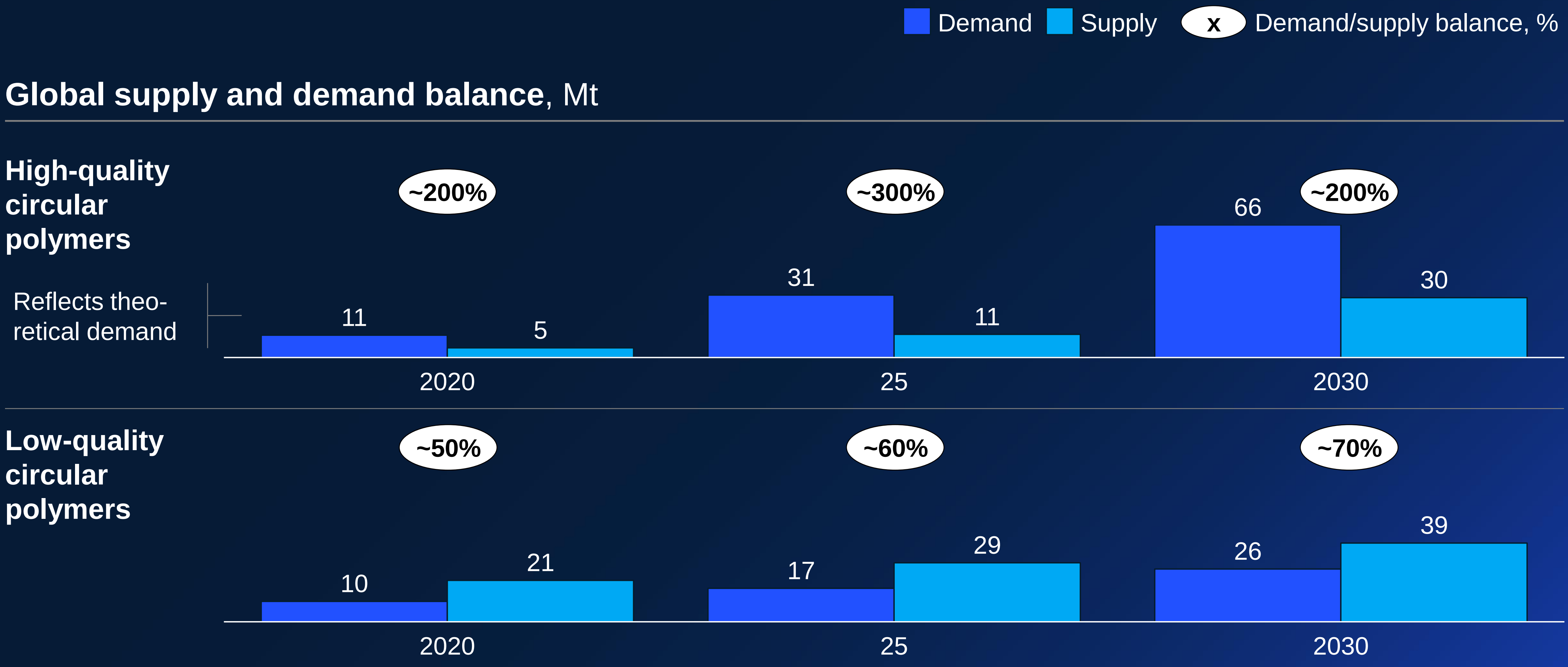
NOT EXHAUSTIVE

Category	Type	Technology	Description	Considerations	Input	Maturity	Examples
Mechanical recycling	**Mechanical**	Pelletize	Waste is sorted, shredded, cleaned and **pelletized for reuse** in new products	+ Mature technology – Output heavily dependent on input quality – Mono-material required	All rigid plastic types		acp, Plastipak
Advanced recycling	**Feedstock recycling / Conversion (to feedstock)**	Pyrolysis	Plastic waste is **converted to liquid oil** feedstock through thermal degradation (350-900°C) in the absence of oxygen	+ Production of virgin quality + Rapidly growing market – Energy intensive – High CAPEX	Mixed Plastics/fuels		BRIGHTMARK, PLASTIC ENERGY, fuenix
		Gasification	Plastic waste is **converted to syngas** through reactions with a gasifying agent at high temperature (500-1300°C). Current technology is mainly open loop, with syngas as the final product	+ Production of virgin quality – Energy intensive – High OPEX / CAPEX – Limited synergy with plastic production	Plastic municipal waste /fuels		Enerkem, PLAGAZI, Fulcrum
	Monomer recycling / Decomposition (to monomer)	Depolymeri-zation[1]	Plastic waste **is converted into monomers** by breaking polymer bonds	+ No need for cracking stage – Nascent technology – Applicable to selected plastic types only	PS, PET, PA, PMMA		agilyx, EASTMAN, PYROWAVE, ioniqa
	Dissoluton (to polymer)	Solvent based purification	**Specific polymers are dissolved in a solvent**, impurities removed, after which the polymer is recovered through precipitation	+ Production of virgin quality polymers – Requires homogeneous imput – Nascent technology	PP, PS, EPS		PURECYCLE TECHNOLOGIES, Polystyvert

1. Currently primarily pyrolysis and solvolysis techonologies

Source: PlasticsEurope.org; PlasticsShift.com;" Recent Advancements in Plastic Packaging Recycling: A Mini-Review", Beghetto et al.

6. As a result of these dynamics, we expect the S/D imbalance for high-quality circular plastics to persist through 2030



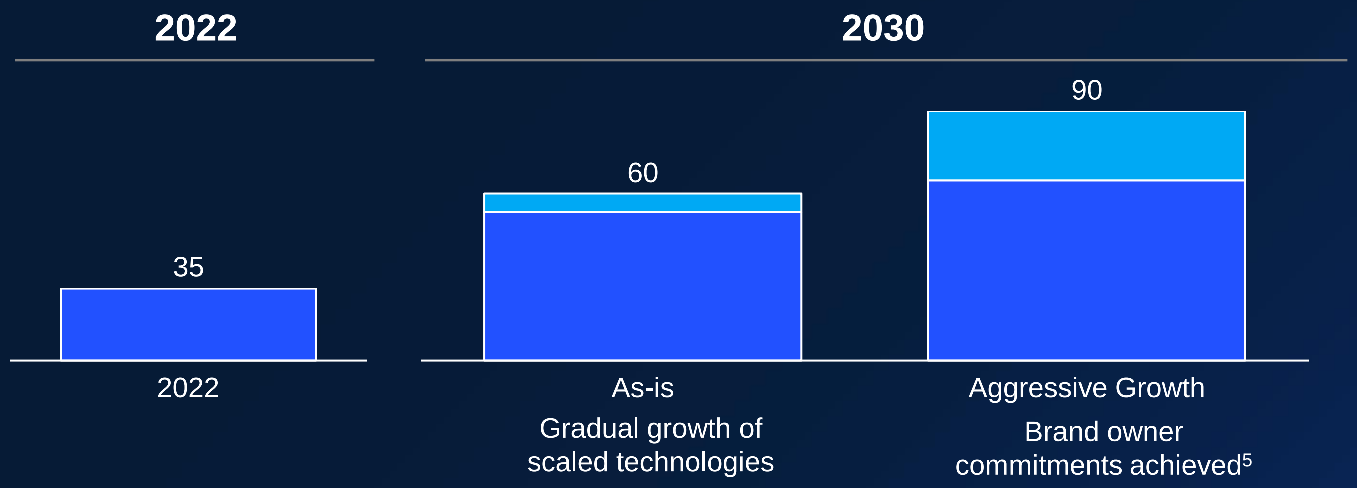
Source: McKinsey Green Materials team

6. A. Significant value pool of $15-45 B likely to exist by end of decade

Illustrative

Advanced recycling | Mechanical recycling[4]

Plastic recycling volumes by scenario, million tons per year



	2022	As-is	Aggressive Growth
Recycle rate[1]	~13%	~20%	~30%
Value pool (EBITDA margin)[2]	$8B	$18B	$46B
Investment to capture[3]		$26B	$75B

$15-45B

2030 annual value pool (EBITDA margin)

$25-75B

Investment likely needed to capture value

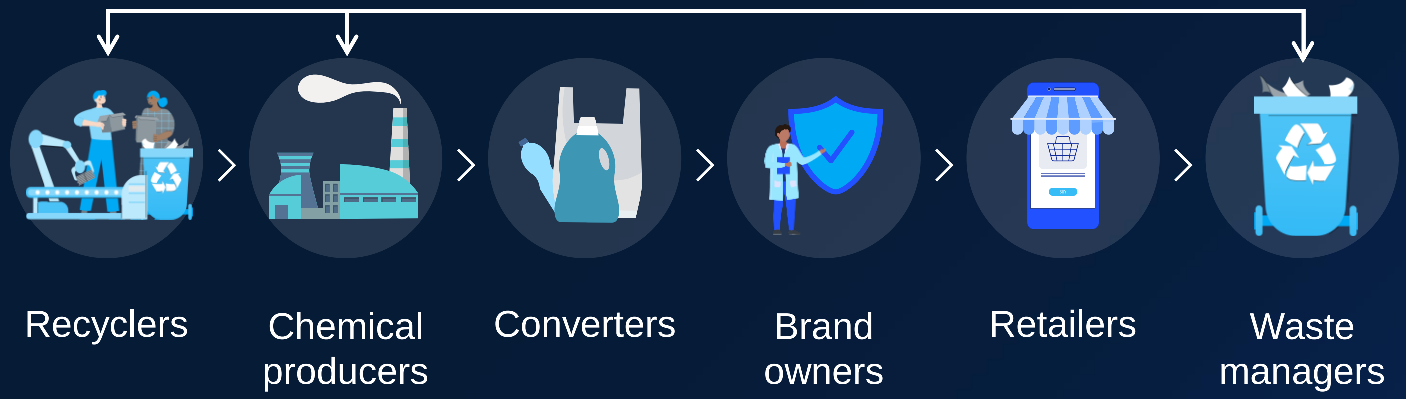
1. Not taking into account fiber applications
2. Assumes EBITDA margin of $120/ $600 and $1000 per ton for low/high quality mechanical and advanced recycling respectively
3. Assumes investment cost of $750/$1050 and $1500 per ton for high/low quality mechanical and advanced recycling respectively. Not including collection/sorting infrastructure
4. Includes ~25MT of high quality mechanical recycling and ~35MT of low quality mechanical recycling
5. 26% recycled content in packaging applications globally

Source: McKinsey CI Circular

6. A. Potential Win-win models likely to emerge through collaboration across value chain

Non exhaustive

New critical interfaces emerging



Policymakers and alliances

New models for consideration

Waste and Chemical partnerships
- Feedstock supply agreements
- Collection expansion (e.g., residential and municipal film)
- Infrastructure investments

Chemical and Brand partnerships
- Supply agreements
- Consumer incentives / education

Critical potential unlocks
- Collaboration on key interfaces (e.g., attainable waste specification)
- Win-win economics
- Long-term agreements to de-risk investment

7. Bio-based chemicals provide a path to partial decarbonization for the chemicals industry

There is a pressing need to decarbonize in a hard-to-abate industry

Fossil-based chemicals constitute for large majority of the chemicals industry's CO_2e emissions

Bio-based chemicals could solve the issue at the source

By taking out CO_2 from (or avoiding emissions to) the atmosphere

The path forward may be challenging

- There are no clear winners for emerging conversion technologies
- Feedstock may be scarce
- While bio-feedstocks solve for scope 3 emissions, they may not address scope 1 or 2 emissions

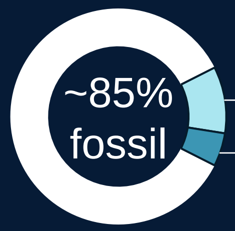
Source: Expert interviews, McKinsey

7. An aggressive emissions reductions scenario for the chemicals sector would require significant growth in the share of bio-based feedstocks

One potential future pathway to 70% emissions reduction for chemicals sector:

Feedstock today largely fossil-based, green alternatives hard to expand…

Today



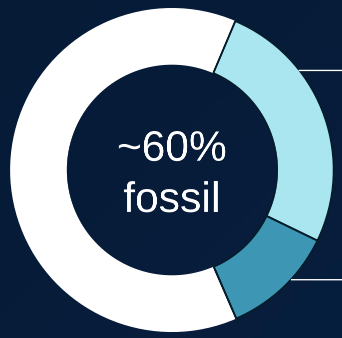
~10% Recycling: not easy to scale, limited in principle

~5% Biomass[2]: competition with fuels, land use issues

and ~0% CO_2-based: scalable but requires low-cost energy and subsidies

… scale-up of sustainable feedstocks by increasing recycling significantly …

2030

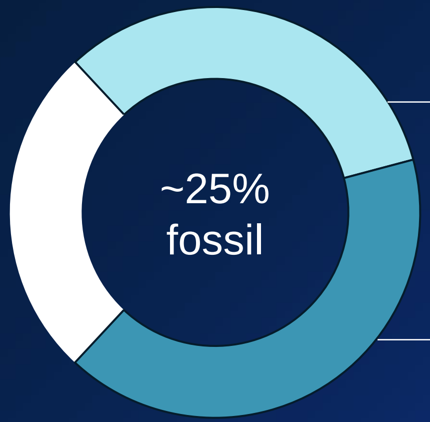


~25-30% Recycling: increased collection and sorting rate required

~10-15% Biomass & CO_2-based mostly from municipal and industrial waste; strong competition from different sectors, sourcing for chemicals at competitive price limited

… followed by strong increase of biomass and CO_2-based feedstocks

2050



~30-35% Recycling: incl. growth of plastics wastes and new recycling technologies (monomeric, chemical)

~40-45% Biomass and CO_2-based: broader availability of biomass with other sectors transitioning to other net-zero alternatives and increased availability of green electricity

Total chemicals demand[1] in naphtha-equivalent

Today	2030	2050
~0.5 Gt p.a.	~0.75 Gt p.a.	~0.95 Gt p.a.

1. Chemicals demand expected to increase until 2050
2. Includes oleochemicals and petrochemicals

Source: IHS, IEA, McKinsey Chemical insights, IPPC, McKinsey analysis

7. There are 3 primary sources for bio-based chemicals, each with important tradeoffs

Not Exhaustive

Preferred feedstock types from land use change perspective

Biomass type[1]		Techn. maturity	Availa-bility	Ease of use	Decar-bonization potential
Sugar biomass	**1st gen** (e.g., starch crops such as corn and sugar crops such as sugar beet or sugar cane juice)	●	◑	●	◔
	2nd gen (e.g., primary lignocellulosic from agriculture such as wheat straw)	◕	◕	◑	◕
Woody biomass	**2nd gen** (e.g., primary lignocellulosic from forestry, residues from forestry & nature)	◔	●	◔	◑
Oil biomass	**1st gen** (e.g., oil crops such as rape seed)	●	◑	●	◔
	2nd gen (e.g., waste fats and oils, primary lignocellulosic from agriculture)	●	◔	●	◕

Key takeaways

2nd generation biomass from land use change perspective **preferred over 1st generation** biomass (e.g., avoiding deforestation)

Often **trade-off** between technological maturity, availability, ease of use and decarbonization potential (e.g., 2nd gen may require additional conversion steps)

Transparency on sources of biomass required to estimate full decarbonization potential (with major regional differences possible)

1. 1st generation is edible biomass produced for use as feedstock, 2nd generation is non-edible biomass from residues or waste products

Source: McKinsey analysis

7. Biomaterials has a large potential market size driven by bio-based commodity building blocks

3

Feedstock	Specialty segment	Current market, $Bn[4]	Vol Growth, %[4]
Sugar crops	Biopolymers	8	10+
	Enzymes	6	3-4
	Food/Feed ingredients[2]	45	2-4
	Hydrocolloids	44	3-4
	Bio-based commodity building blocks	*1,000+[3]*	
Woody/Crop/ Plant biomass	Lignosulfonates	1	1-2
	Man-made cellulosic fibers	12	2-4
	Pine chemicals	4	4-5
	Cellulosics	10	0-3
Fat & oils	Flavors & Fragrances	43	3-4
	Oleochemicals	17	2-4
	Personal Care products	23	3-4

1.Pharma, Plant Protein, Biogas, and Agchem not included
2.Does not double-count enzymes or hydrocolloids
3.Petrochemical Global Market ~2.6$T
4.Overall market, not necessarily bio

Source: IHSM, European Bioplastics, Bernstein

7. Broad adoption of bio-based chemicals will require navigating challenges in order to reap their many benefits

Challenges

Feedstock sourcing and food competition

Over 20% of the Earth's surface is currently used for agricultural production to meet global food and livestock fodder demand; using food-grade feedstocks for biochemical production would require displacement of agricultural land

Water & fertilizer pollution

Some biomaterials (e.g., food processing waste) can pollute the soil / water

Land use changes and associated emissions

The conversion of cropland for bio-feedstock has associated direct (agricultural expansion for bio-feedstock) and indirect (indirect agricultural area changes – such as crop substitution) emissions.

Benefits

Reduce carbon footprint

Ability for "quick wins" in reducing carbon footprints by ~50% or more in many applications

Minimize waste

Turning to bio-based materials can reduce waste in landfills (biodegradable, compostable)

Improve performance

Many bio-derived products perform better than fossil-based counterparts (e.g., biotech products with superior heat conduction necessary for fast charging of EVs)

Appeal to consumers

Downstream customers want products that are green and renewable – and are willing to pay for them

Innovate

Biotech provides a unique platform to develop novel chemicals and materials to solve sustainability-related and purely technical problems

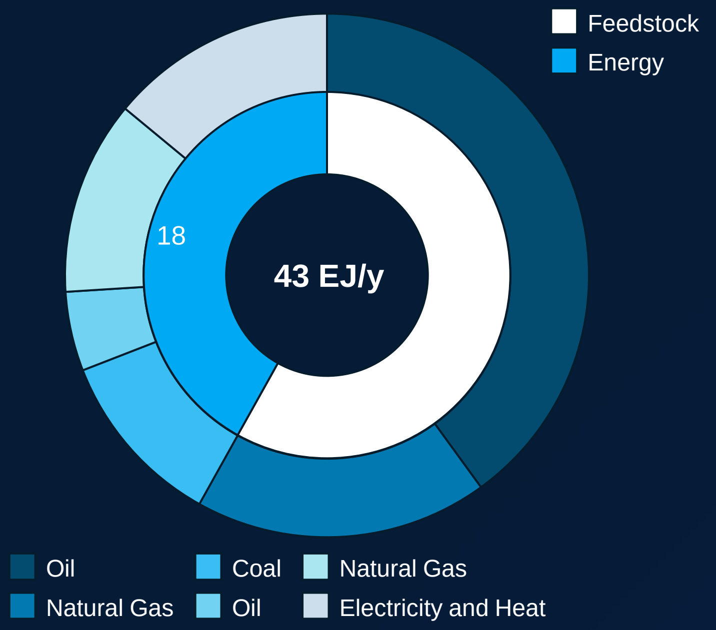
Hedge risk

Chemical companies can hedge their dependence on fossil fuels by utilizing bio-feedstocks

8. The chemical industry emits 7% of global emissions

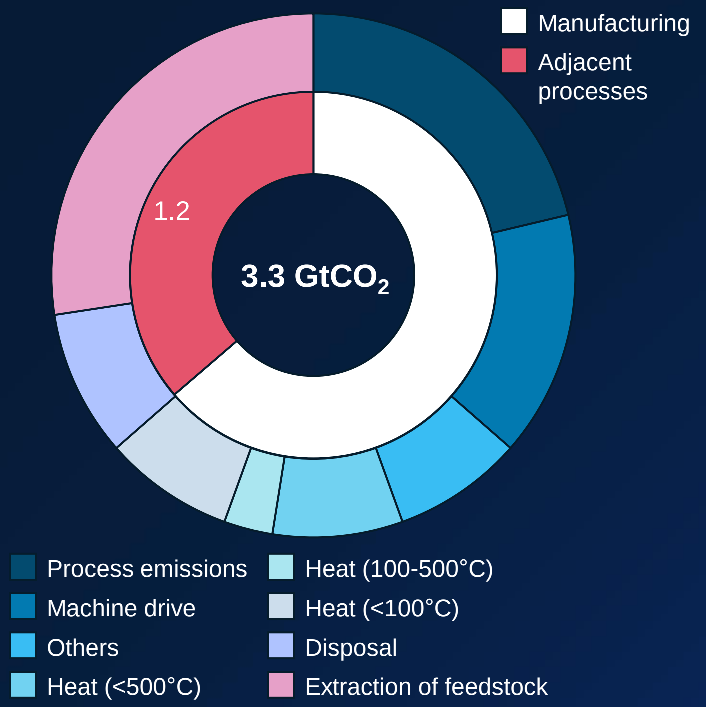
Environmental sustainability exposure of the chemical industry

10% of global energy demand



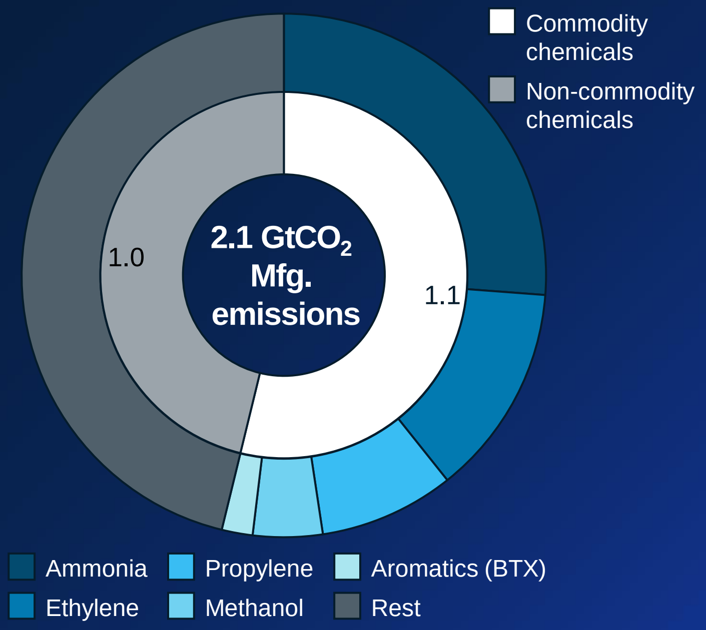
Decades of optimization have gone into possessing of virgin fossil feedstock, energy and circularity transition requires new technologies and optimizations

7% of global emissions[1]



Further exposure to emission policies though emissions released from products (e.g., fertilizer) and after use (e.g., plastics incineration)

>50% emissions from 5 chemicals



Commodity chemicals come with a ~75% share of hard-to-abate emissions, but likely less hard to abate than non-commodity chemicals

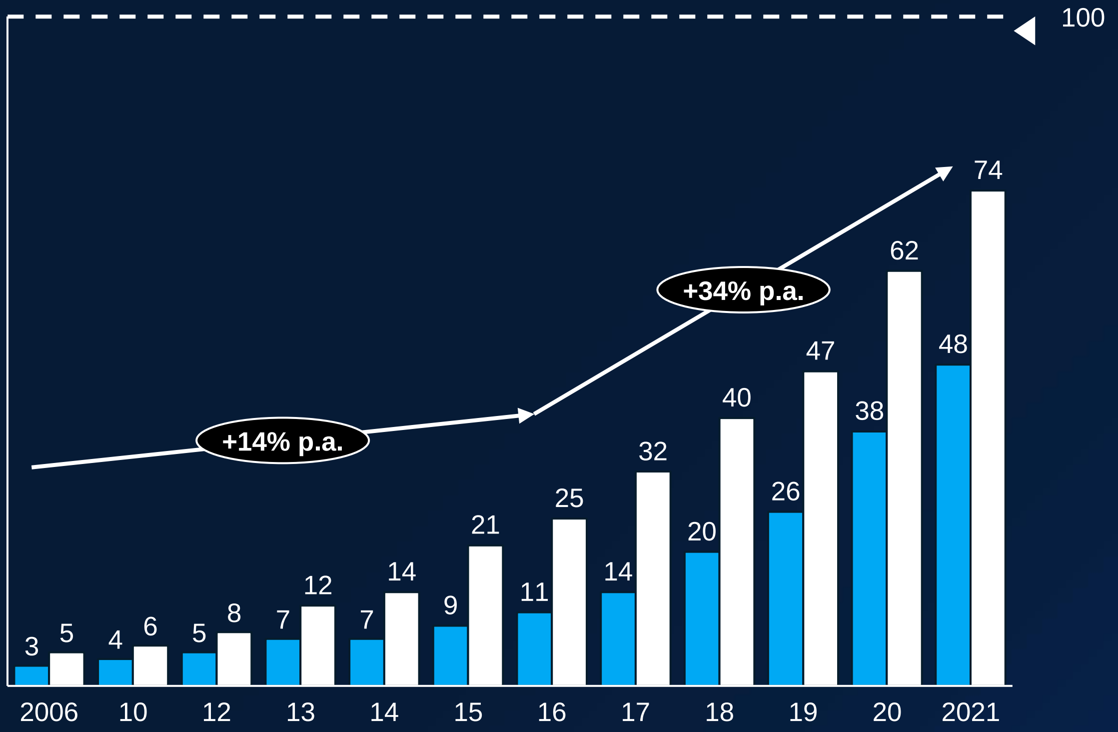
1. Scopes 1 and 2 included in analysis

Source: González-Garay et al (2021), McKinsey

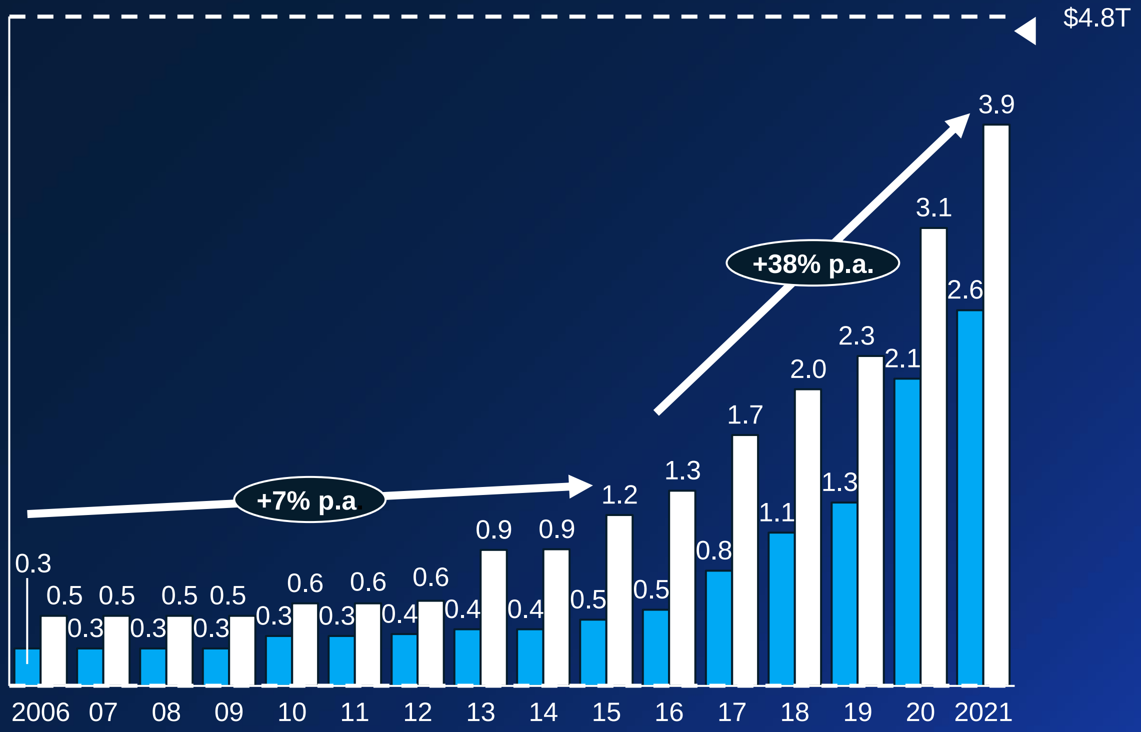
8. Customer pressure: End customers are demanding low-carbon inputs to fulfill their own decarbonization pledges

Scope 3 only | Scope 1, 2, and/or 3

Companies with emissions reduction commitments,
count of top companies across end markets[1]
100% = 100 companies[1]



Revenue with associated commitments,
T USD across end markets[2]
100% = $4.8T 2019 revenue[2]



1. Top 20 companies by 2019 global revenue in each of five end markets: apparel, automotive, electronics, fast moving consumer goods (food, home, and personal care), packaging;
2. Sum of 2019 revenue associated with top 20 companies per end market

Note: growth rates are for scope 3 only

Source: CapIQ, Science-Based Targets Initiative, CDP Worldwide, McKinsey ESG Solutions / Sustainability Insights

8. Competitive landscape: Many chemicals companies are making bold investments and commitments to sustainability across the 3 emissions scopes

Non-exhaustive

Overview of emissions targets of leading chemical players

	Timeline to achieve target	Decarbonization target: Scope 1 & 2	Decarbonization target: Scope 3	CDP Score[1]
Arkema	2030	-38%	-	A-
Solvay	2030	-50%	-	B
Clariant	2030, 2050	-40/100%	-14/100%	B
DSM	2030, 2050	-50/100%	-28/100%	A
Ecolab	2030, 2050	-50/100%	-100%	A
AkzoNobel	2030, 2050	-50/100%	-42%	F
Wacker	2030	-33%	-	B
Ajinomoto	2030, 2050	-50/100%	-24%	A
Ashland		-[2]	-[2]	D
Chr. Hansen		-[2]	-[2]	B
DuPont	2030, 2050	-30/100%	-30/100%	A-

	Timeline to achieve target	Decarbonization target: Scope 1 & 2	Decarbonization target: Scope 3	CDP Score[1]
Firmenich	2030, 2050	-55/100%	-19%	A
Givaudan	2030, 2050	-70/100%	-20/100%	A
Johnson Matthey	2030, 2040	-33/100%	-20/100%	B
Eastman	2030, 2050	-32/100%	-	B
The Linde Group	2025	-35%	-	A-
Novozymes	2030, 2050	-50/100%	-11%[3]	B
Sumitomo Chemical	2030, 2050	-30/57%	-	A
	2030	-18%	-	A
Lanxess	2030, 2040	-50/100%	-	A
Croda	2030, 2050	-46/100%	-14%[3]	B
Corbion	2030	-33%	-31%[3]	A

1. A CDP score is a snapshot of a company's environmental disclosure and performance

Source: Company information, McKinsey

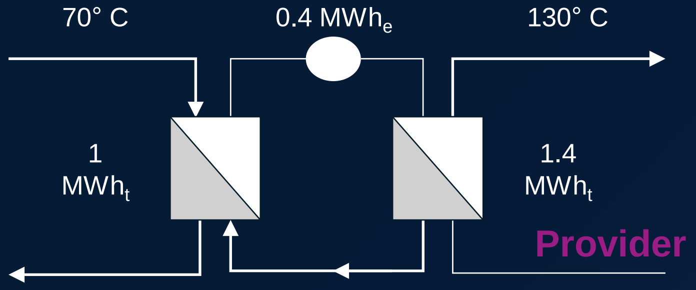
8. Competitive landscape: Chemicals players are adopting novel technologies to accelerate decarbonization efforts

Companies partnering for the first commercial pilot

Supplier of technology

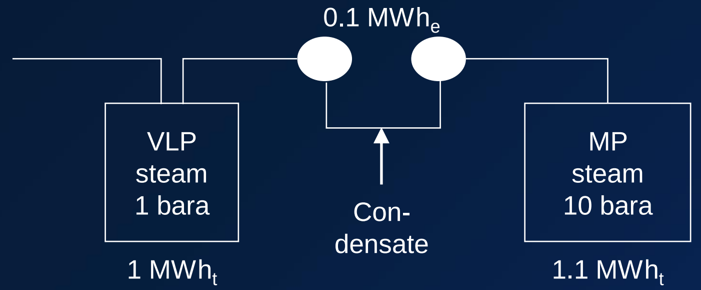
High-temperature heat pump

Waste heat is extracted from the heat source and then lifted with **electricity** and **put to a higher temperature** level to reuse the obtained waste heat in a process which needs high-temperature energy



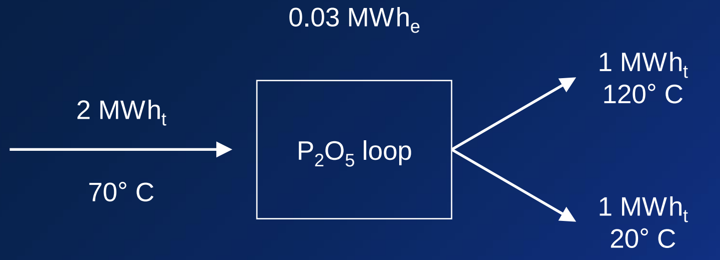
Steam mechanical vapor recompression

Waste steam with too low pressure to be used is **put to a higher pressure** by using electricity. **High pressure steam** can be used for other processes



Heat separation (Q-pinch)

Waste heat is lifted to a higher temperature with a chemical reaction and low electricity input. **Less heat can be recovered** as with a high-temperature heat pump. This is advantageous when electricity is expensive



Companies partnering for the first commercial pilot:

- Wienerberger + DryF + AIT Austrian Institute of Technology
- BlueTerra Energy Experts + Dow
- Borealis + Qpinch

Supplier of technology:

- Heaten
- Piller Blowers & Compressors
- Qpinch

9. Chemicals players aligned with downstream sustainability tailwinds can command significant premiums

Preliminary

Median EV / revenue for representative pure play companies

Sustainability HEADWINDS	NEUTRAL	Sustainability TAILWINDS
• Oil & gas • Single-use plastics • ICE automotive • Guns, ammunition, tobacco • Chemicals w/ increasing regulation	• Consumer • Infrastructure • Automotive • Electronics • Food • Ag • General packaging • Industrial • Bio-based industrial intermediates • Healthcare	• EVs, energy storage • Water reduction • Bio-based consumer products • Energy efficiency • Renewable energy, fuels, feedstocks • Natural ingredients • Carbon capture • Circular packaging

The chemicals industry is poised to support downstream sustainability efforts by supplying critical inputs that help minimize environmental impact

Exposure to sustainability tailwinds commands premium. Investors assign premium for sales that enable end markets and are not solely focused on the sustainability of the chemicals sold

Source: Company investor presentations, Corporate Performance Analytics™, a McKinsey Solution

9. Chemicals players can take advantage of tailwind opportunities to improve their handprint across sectors

Chemicals

Agriculture
- Specialty fertilizers and bio-stimulants driven by environmental considerations

Construction
- High-efficiency insulation materials reducing temp. control needs (i.e., PU and spray-on solutions)
- Inputs for green and more efficient cement (i.e., polycarboxylate-based polymers, PVA, epoxies)
- Admixtures (i.e., PEG, polyacrylic acid, and epoxies) that can improve the environmental impact of concrete

Consumer and retail
- Non-durables solutions adoption
- Bio-degradable plastics (like PLA and PHA)

Energy
- Epoxies & carbon fiber used in wind turbine production
- Polysilicon used in solar panel production
- Polymer electrolyte membrane used in hydrogen cells
- Amines used in carbon capture technology (CCUS)

Industrial
- Specialty polymeric membranes used in water treatment
- Specialty surfactants for industrial cleaning
- Polyolefin and SBS used as impact modifiers in mechanical recycling

Packaging
- Plastics used to replace higher intensity emissions materials (i.e., glass and aluminum)
- Hard-to-recycle materials (i.e., plastic film and rigid packaging) that is recyclable or made from recycled content
- Durable plastics as substitutes for single-use plastics (i.e., PC used in refillable water bottles)

Textile
- Pretreatment materials and dyes reducing hazardous chemicals and quantity used

Transportation
- Nylon, anode and cathode separators and high-performance plastics used in BEV powertrain
- Lightweight plastics, advanced composites, and thermal coatings (for aircraft) to reduce weight and increase vehicle fuel efficiency
- Easier-to-recycle plastics utilized in cars
- Silica used as tire filler as opposed to carbon black as low-carbon option

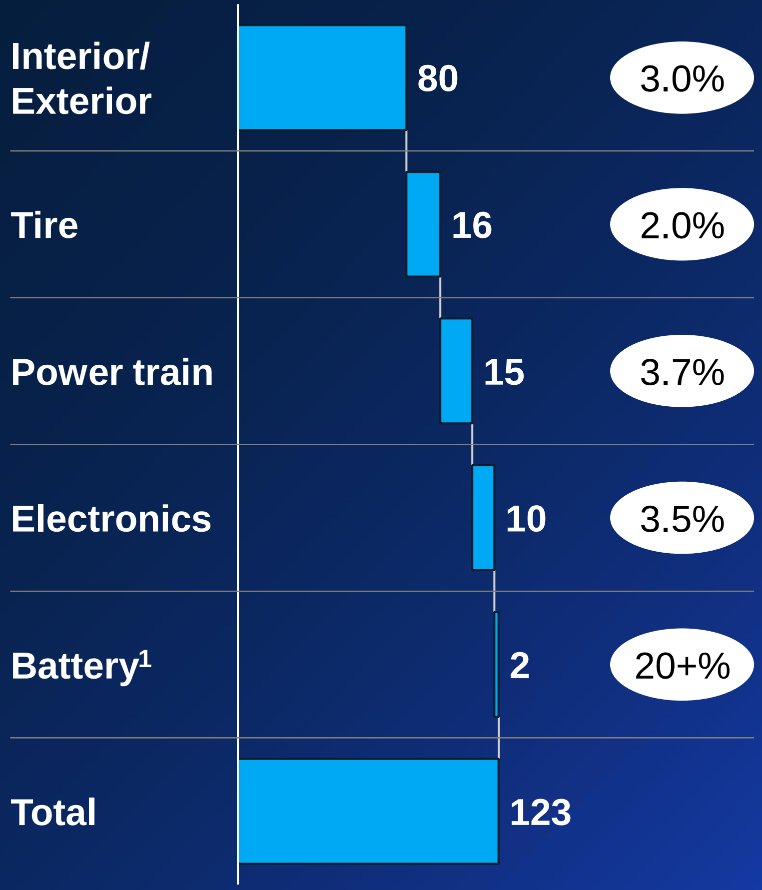
9. EV example: Different sustainability-linked materials required for emerging sectors

Transportation sector deep-dive

Sustainability focus | Favorable | Neutral/shifting value pools | Unfavorable | % 2021-30 CAGR

Market dynamics	Implications for chemicals
Electrification: EV to grow at 20+% CAGR to reach 80+% penetration by 2035	↑ Higher demand in battery chemicals ↑ Higher demand for high value plastics ↓ Lower demand for lubricants and catalysts
Fuel efficiency and emission reduction for IC cars: Improvement of fuel efficiency by light weighting cars	↑ Higher demand for low carbon material, e.g., recycled plastics → Possible shifts for lightweight plastics and advanced composites
Digitalization and innovation: Development of autonomous light vehicles and trucks	↑ Sensors and electronic materials, e.g. antennae material, drives demand for polymers, e.g. PBT
Sourcing: Supply chains shift to near-shore production for both strategic items , e.g. Micro chips, and low spec parts including plastics	→ No significant change in global volumes but demand shift to US and Western Europe

Chemicals market size for EVs, $B 2021



1. Exclude cathode active materials

10. Generative AI: how real is this?

An explosion of interest

8X

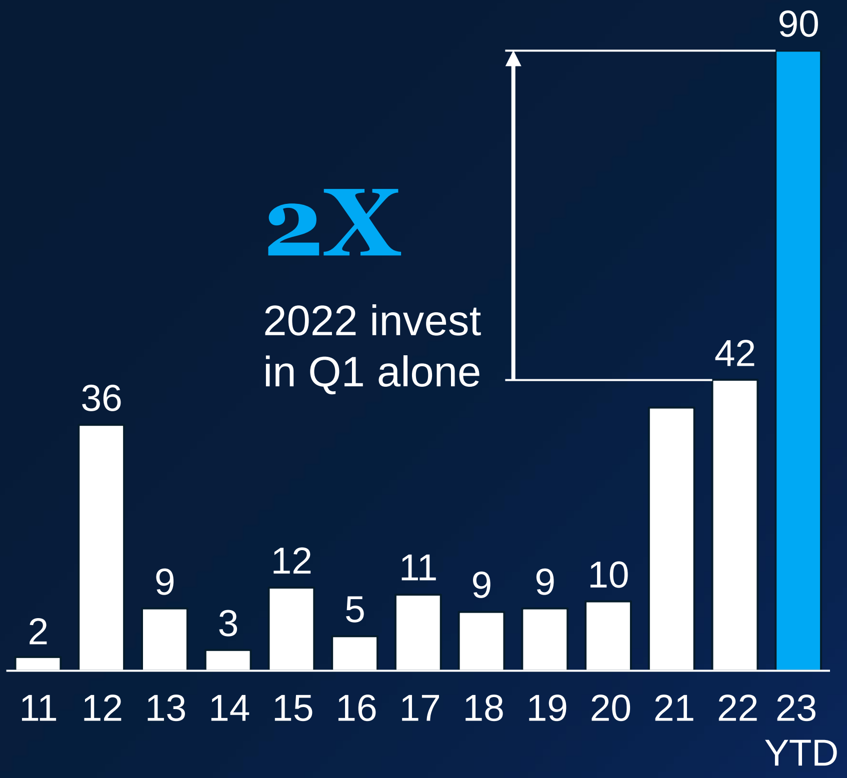
growth in search for "Generative AI" in 2022[1]

~80%

of current AI research is focused on GenAI today

Investors pouring into GenAI

GenAI median VC pre-money valuation, USD m



Fastest-growing adoption ever

Time to reach 1 million users

1. Between Jan & peak Dec 2022

Source: Economist, Google Trends, Tooltester, Pitchbook

10. GenAI has four kinds of applications for Chemical companies, leading to reinvention of major processes worldwide

Classifying

Analyzing large data sets and classifying and converting unstructured data into model features

Creating

Generating content to use across functions and in customer interactions

Collaborating

Analyzing inputs through bots to uncover new opportunities and brainstorming ideas

Synthesizing

Interpreting large amounts of internal and external data and summarizing it in a easy-to-use way

10. Our initial view of emerging hero use cases in the Chemicals value chain

Non-exhaustive

Example GenAI use-cases in Chemicals operations

Molecule or chemical formula discovery

Synthesize lab data, R&D materials and molecular database information to recommend a new molecular composition for producing an end-product with specific/improved properties

Knowledge extraction advisor bot

Interactive knowledge management bot to synthesize scientific materials and extract insights to assist researchers in data processing and knowledge extraction

Product anomalies detection

Synthesize camera images or videos and live sensor data to detect anomalies and interpret potential root causes

10. For Chemicals, there are several high value innovative use cases, most requiring high efforts to implement

Key messages

Global Backdrop

1. Biggest capital reallocation of our lifetime
2. From transition to addressing the quadrilemma
3. An integrated challenge across food, energy, and materials
4. Dramatic innovation is required to hyperscale

Sustain-ability in Chemicals

5. Sustainability along chemicals in 4 domains
6. Circular plastics value pool of 15-45 Bn by 2030, but investment required
7. Bio-based chemicals essential for aggressive decarbonization of sector, but unclear winner with technology / costs
8. Decarbonized materials increasingly required for scope 3 commitments of end-use industries
9. Companies innovating in materials intended for use in sustainability-related end-use sectors command ~4x premium over conventional sectors

Forward looking…

10. Generative AI in chemicals is nascent, but potential applications endless

Thank you