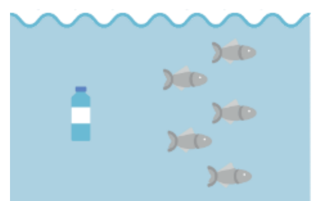
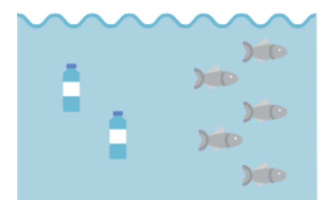
McKinsey&Company

Plastics Recycling –
No time to Waste

PLASTICS EUROPE CONFERENCE

16 January 2019

Without significant change, plastics waste production will increase by 75% to 460 MTA until 2030, CO_2 emissions will overtake aviation

	2016		2030 (Business as usual)
Total plastics waste MTA	260		460
CO_2 emissions[1] MTA	600 (80% of aviation)		1,050 (135% of aviation)
Oil & gas consumption for plastics production Share of global production	7% of global consumption[3]	40% of oil demand growth	11% of global consumption[3]
Plastic leakage to environment and ocean[2] Ratio of plastic to fish	 1:5		 2:5

1 Global airline industry with CO2 emissions of ~780 MTA in 2012; CO_2 emissions associated with plastics production; 2 Quantity of fish in oceans today: 812 MTA. Sources: EMF 2014, Jambeck et al. (2015); 3 Not Including process energy oil equivalent

SOURCE: McKinsey plastic waste stream model; expert interviews

Plastics waste has become an unavoidable challenge for the chemicals industry, the environment and society as a whole

McKinsey was one of the first to table the growing challenge of plastic waste

- Plastics pollution on land and in the ocean has become a key issue
- Despite their versatility and ecological advantages, plastics with negative perception

Abstracting from emotions – the size of the challenge is accelerating

- Globally ~260 MTA of plastics waste today, to increase by 75% to ~440 MTA by 2030
- Many countries have imposed bans on single-use plastic products or import restrictions

We believe there is opportunity window for petrochemical industrial leaders to act

- We have done analysis to understand waste flows and recycling technologies
- Translated into potential solution scenarios as a basis for discussion

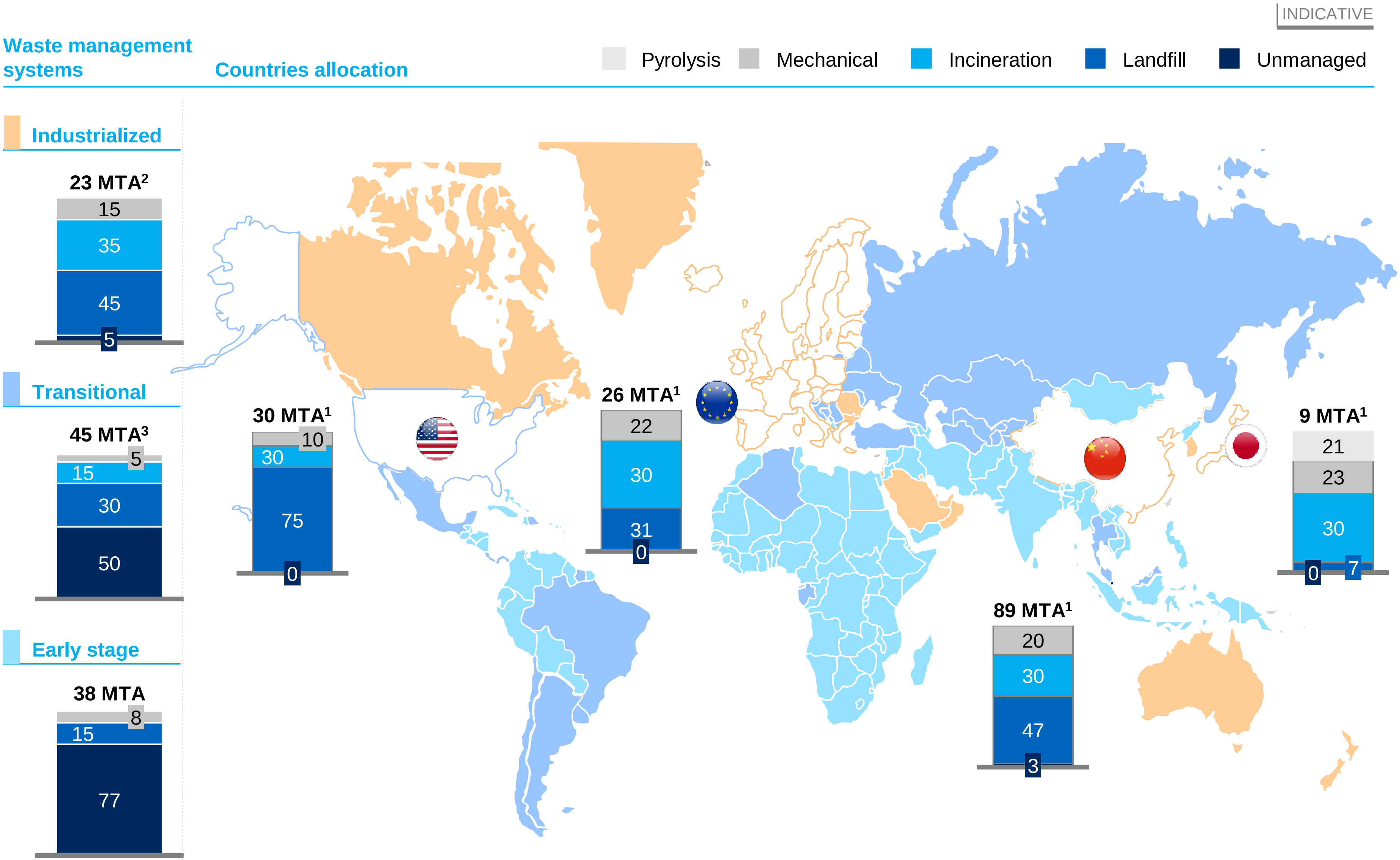
Cooperation with leading institutions , e.g.,

ELLEN MACARTHUR FOUNDATION · NEW PLASTICS ECONOMY · WORLD ECONOMIC FORUM

Proposed agenda

- **What have we done in recent months and what we found**
- What we think this could mean to you

We have developed a model that covers global plastics waste

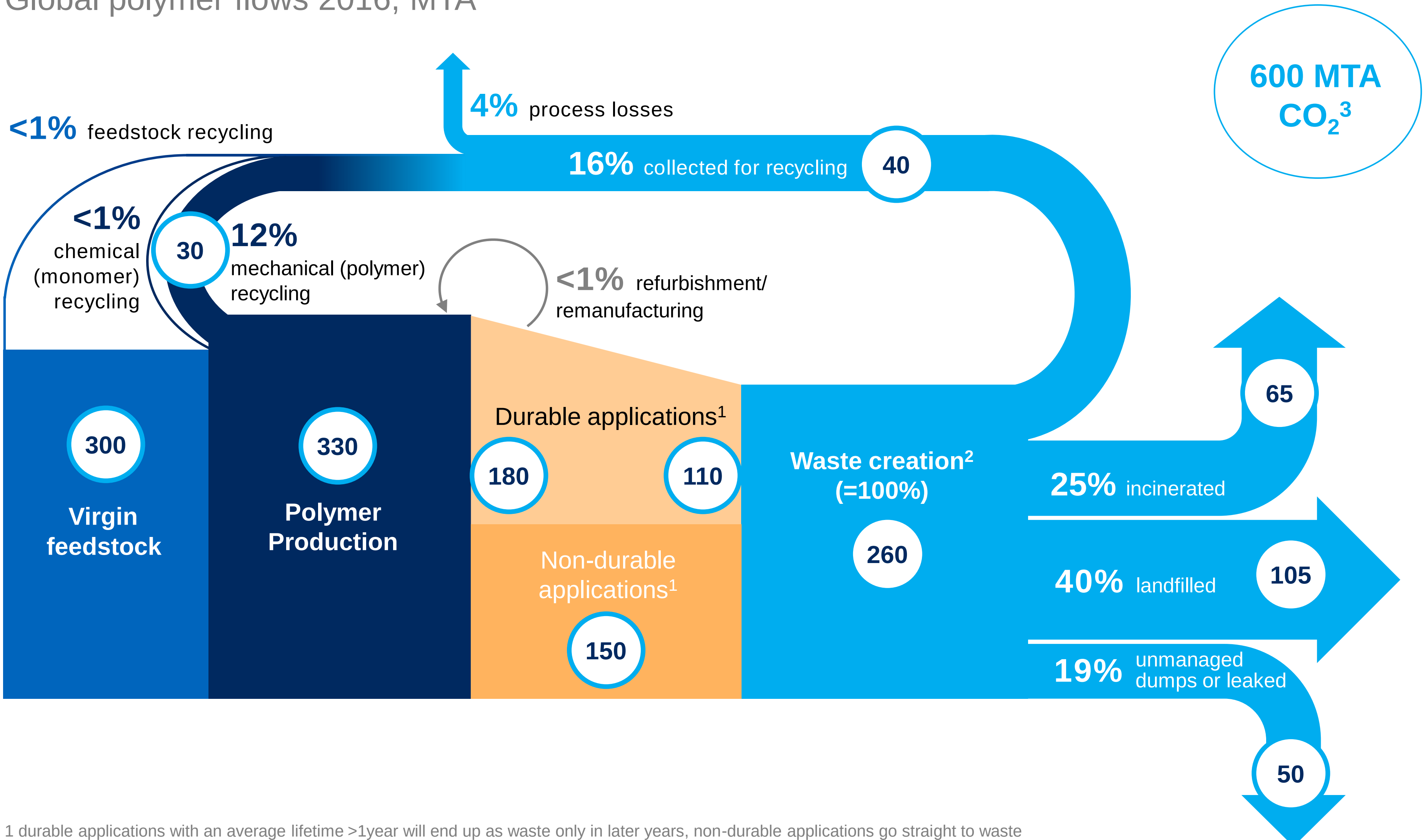


1 Waste management data for the US, the EU, China and Japan were modeled based on actual available 2016 data
2 Overall 2016 plastic waste production for industrialized countries, excluding the EU, Japan and China
3 Overall 2016 plastic waste production for transitional countries, excluding the US

SOURCE: IHS, ICIS, Plastics Europe, Worldbank, McKinsey plastic waste stream model

Today, ~60% of plastic waste is not recovered or processed

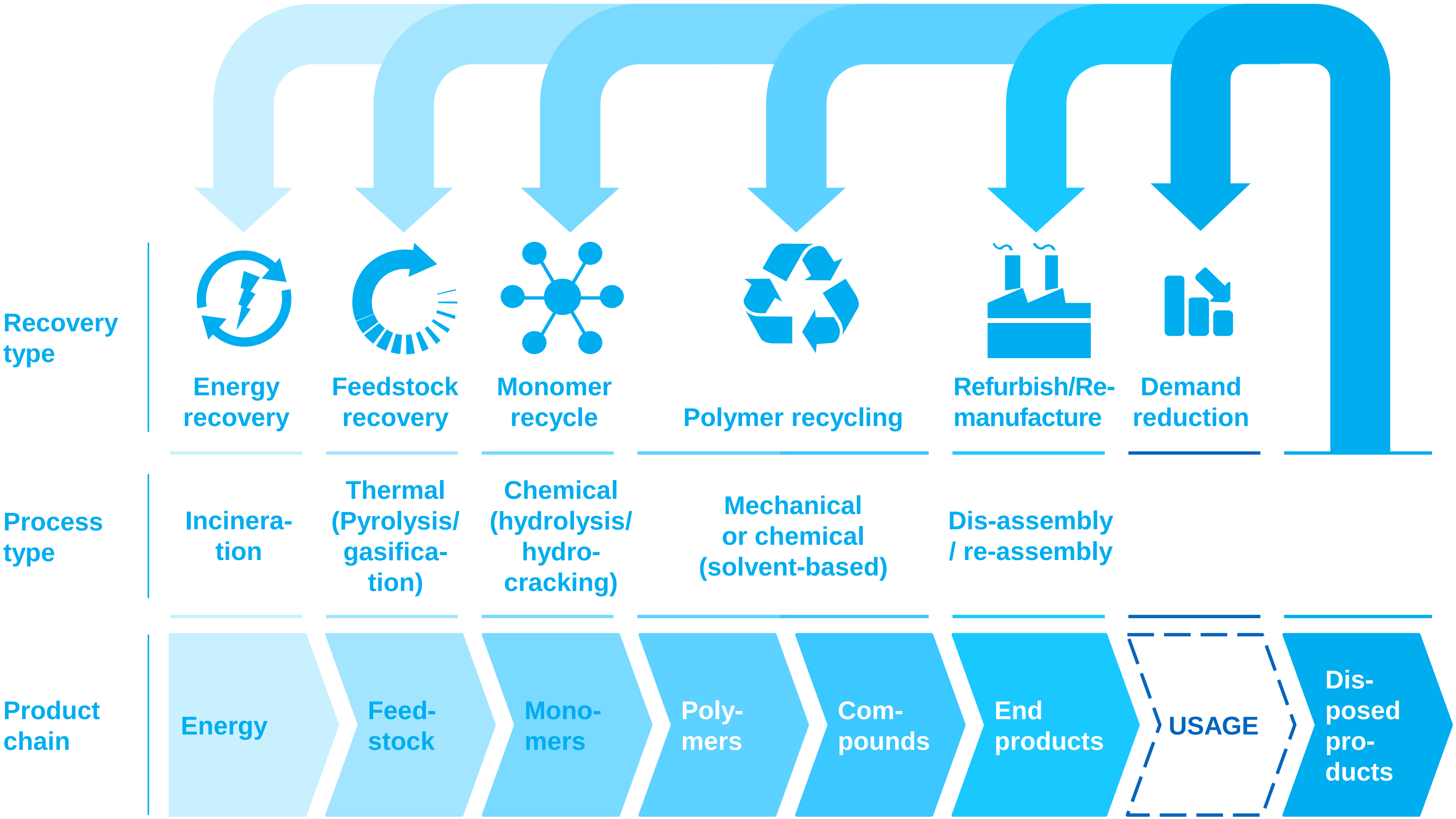
Global polymer flows 2016, MTA



1 durable applications with an average lifetime >1year will end up as waste only in later years, non-durable applications go straight to waste
2 150 MT mixed plastic waste from nondurable applications that end up as waste in same year plus 110 MT of mixed plastic waste from production in previous years
3 Total CO2 production per annum including virgin plastics production but excluding plastic processing

SOURCE: McKinsey plastic waste stream model

Several recovery processes and technologies to recover hydrocarbons

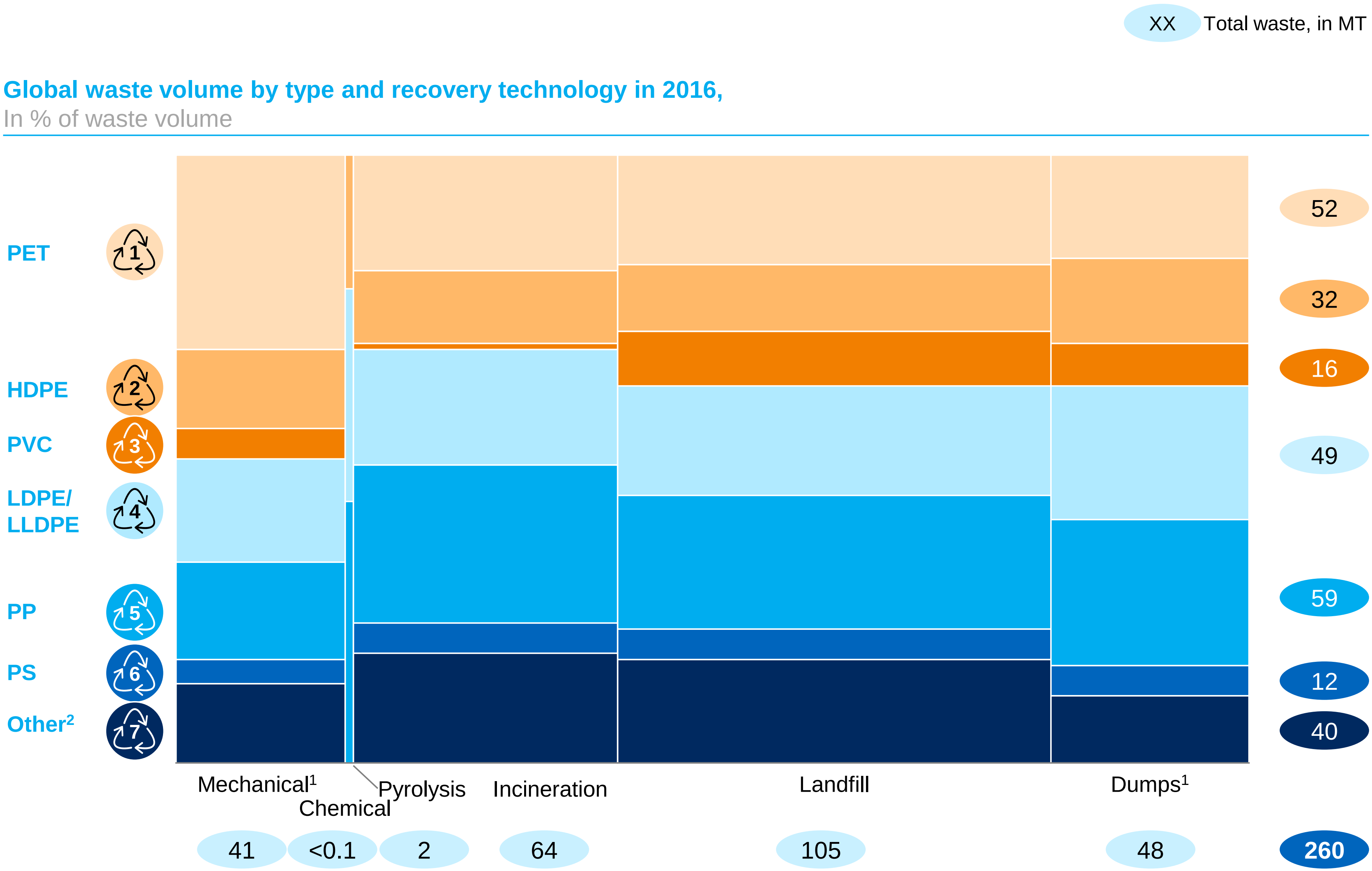


- **Mechanical recycling will not be sufficient** as a technology to sustainably close the loop, as polymer **quality decreases with each recycling loop**
- **Chemical or feedstock recycling** are required to “reset” plastics to **virgin quality** latest after several cycles

SOURCE: McKinsey analysis

Mechanical recycling is the most established recycling technology today

Global waste volume by type and recovery technology in 2016,
In % of waste volume

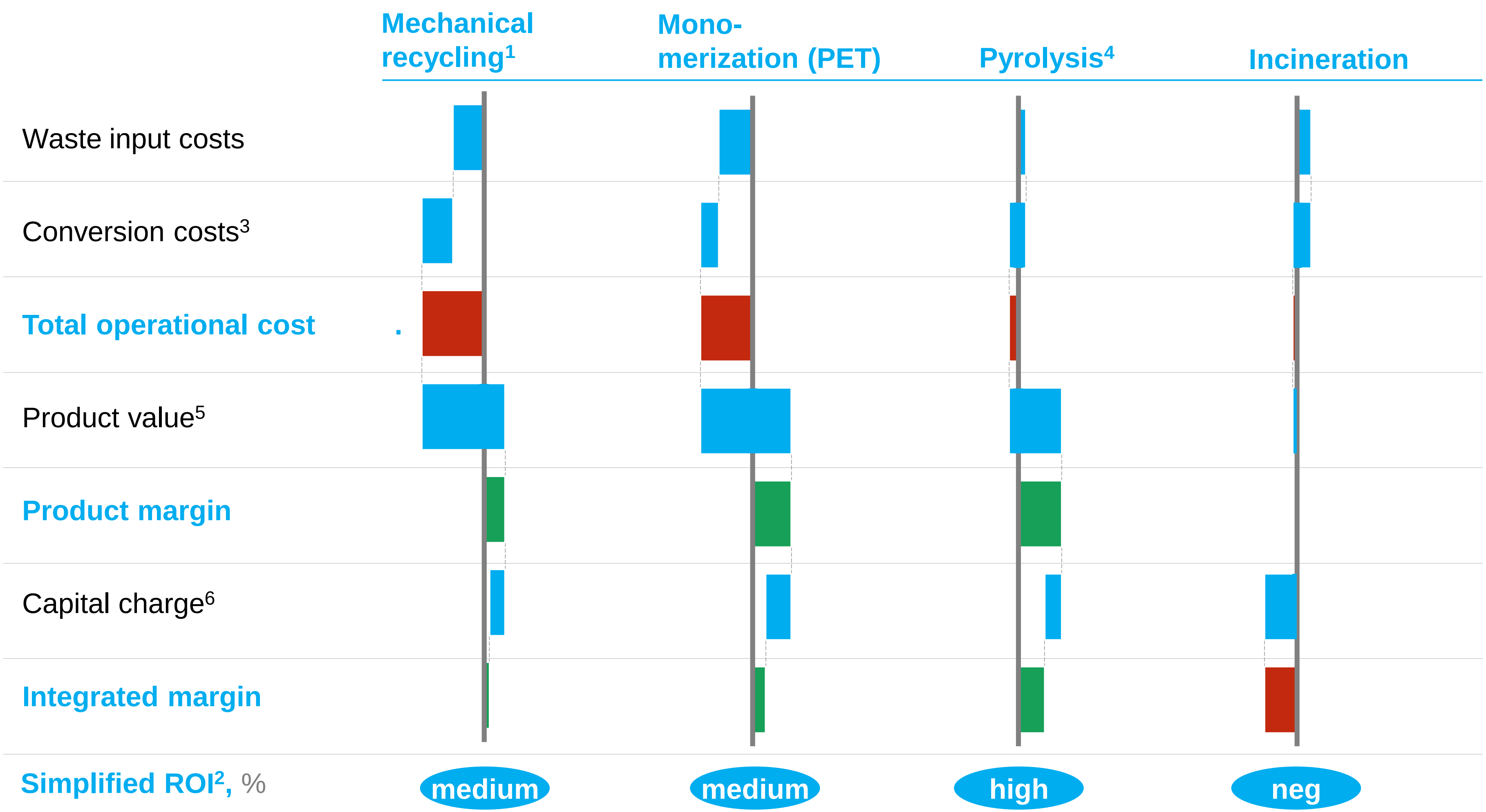


1 Mechanical recycling rates already adjusted by sources from informal sector (dump collection)
2 Rubbers, ABS, Epoxy resins, PMMA, PC, EVA, SAN, Nylon

SOURCE: McKinsey plastic waste stream model

Economics of all technologies assessed

Recycling technology economics in Europe, In USD/ton resin input

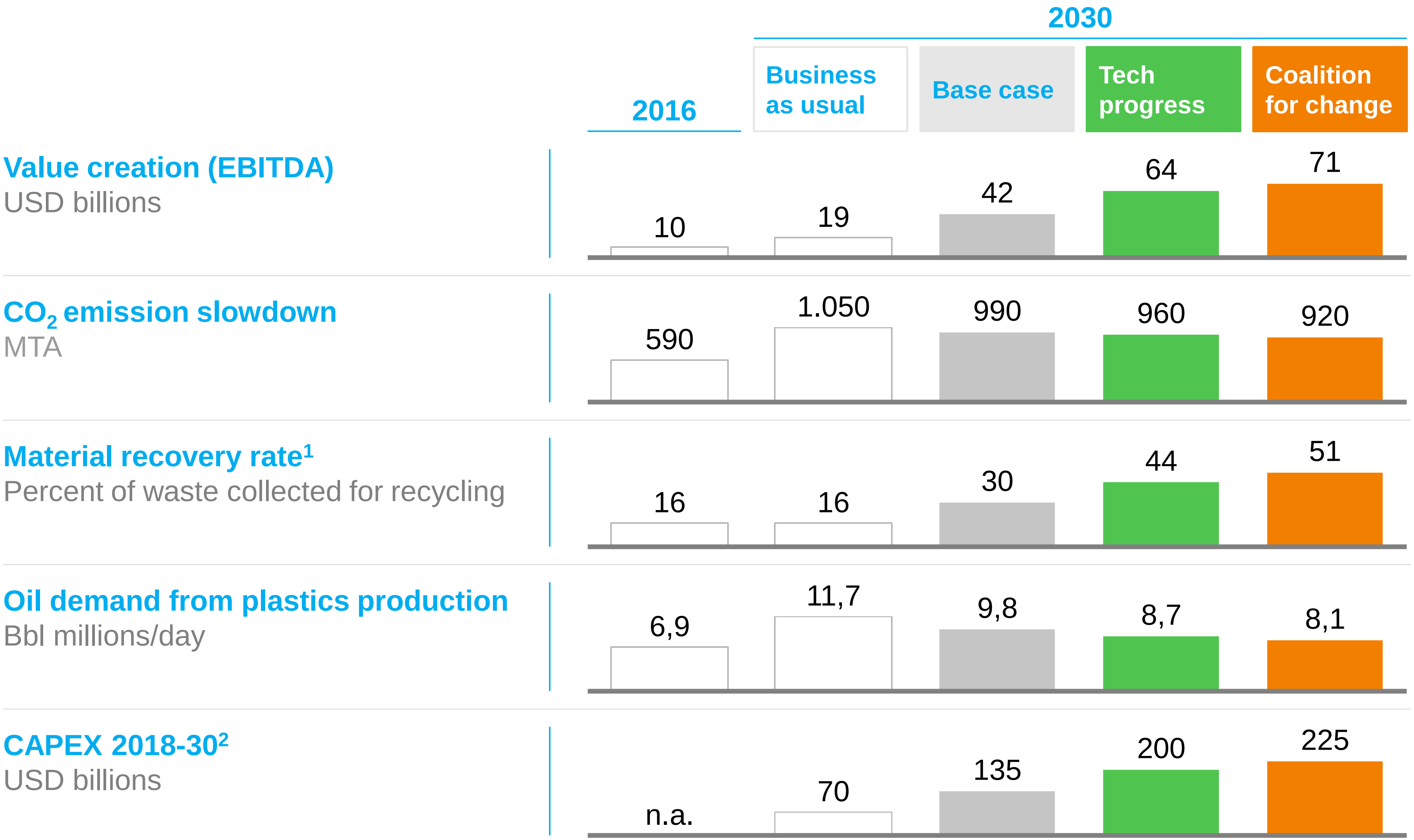


1 Mechanical recycling economics as a regional average of PET, PE, PP and PC recycling   2 Calculated as EBITDA margin over CAPEX   3 including labor, energy, maintenance and other cost   4 Pyrolysis based on average data available on different pilot facilities;   5 Product value of mechanical recyclates based on weighted average for PET, PE, PP and PVC resins taking into account virgin prices and historical discount factors   6 Based on publications by AWS Eco plastics, Green Fiber, LyondellBasell, Shaw Industries, Cynar, Plastic Energy, Res Polyflow, Hanser plastics and various expert interviews

SOURCE: McKinsey plastic waste stream model, Expert interviews

Normalized @75$/BBL OIL

Value creation potential and increased circularity



1 Share of processed plastic waste for recovery to total plastic waste - for mechanical recycling, monomer and pyrolysis
2 Excludes capital required for renewal of existing facilities at end of lifetime

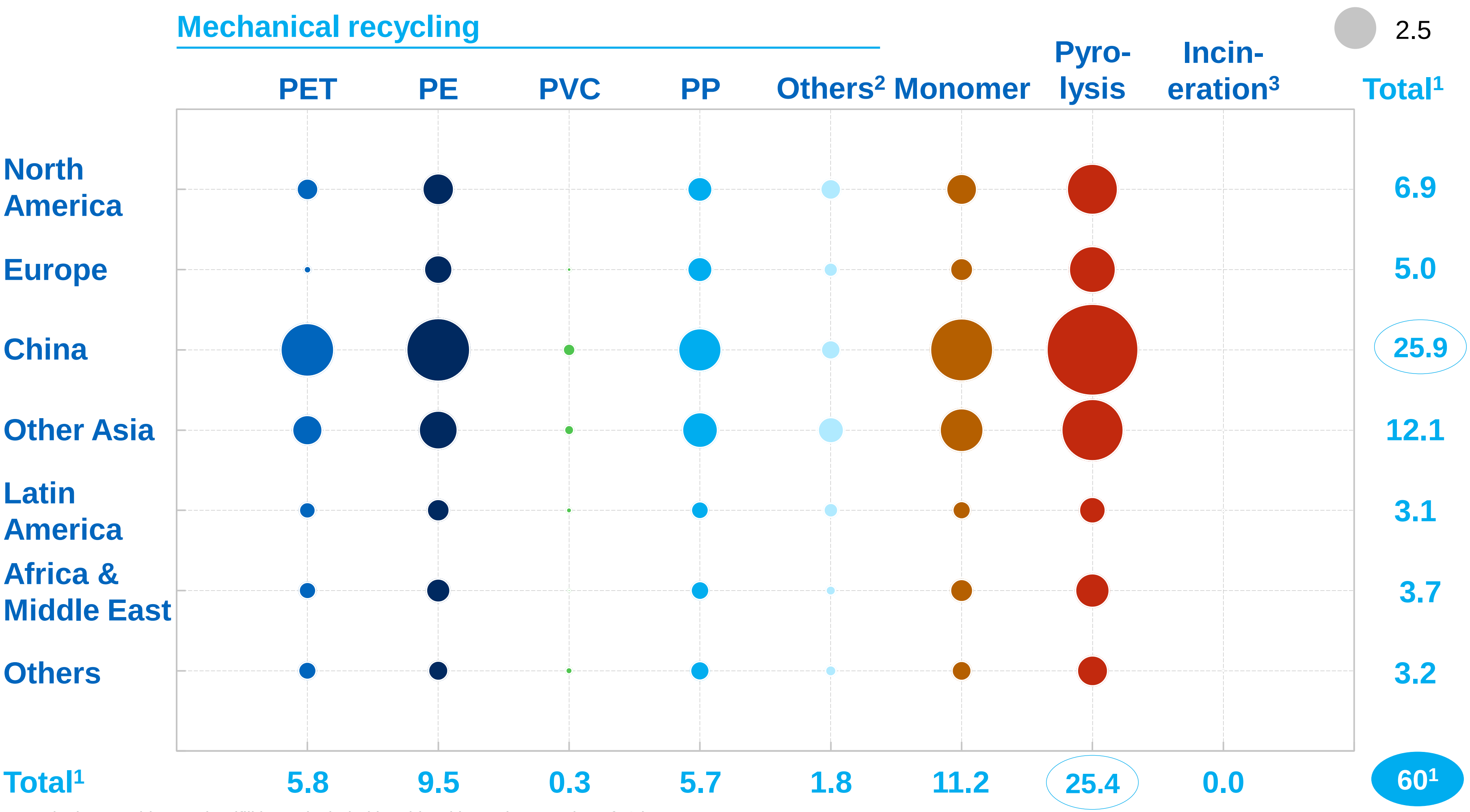
SOURCE: McKinsey plastic waste stream model

Significant value creation potential – Pyrolysis and Asia

Normalized @75$/BBL OIL

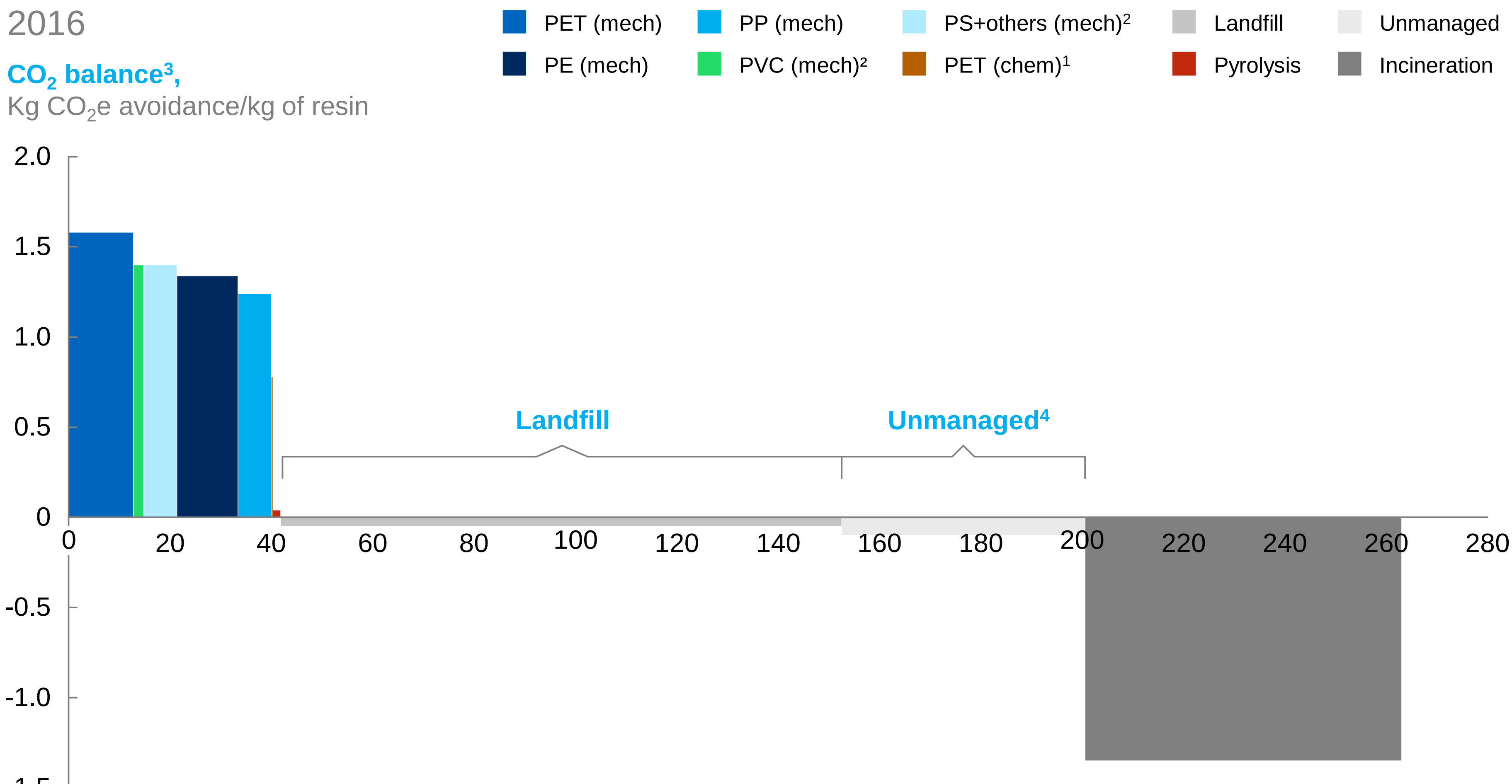
Value creation growth (EBITDA estimate) 2016-30

USD bn, excluding landfill



1 Totals do not add up as landfill is not included in table with a value creation of -2 bn
2 Others including PS and smaller plastic types
3 Despite no value creation, increase in total volume by 74 MTA between 2016 and 2030 expected
SOURCE: McKinsey plastic waste stream model

CO_2-perspective favors mechanical recycling



In 2017, total reduction in emissions achieved through recycling (mechanical, monomerization and pyrolysis) estimated at **~55 $MTCO_2e$**

1 0.9 $kgCO_2e$ avoidance/kg of resin but hardly in use today - thus, low visibility in chart
2 CO_2 emission balance assumed to correspond to average balance of mechanical recycling for PE, PP and PET
3 CO_2 balance calculated based on simplified approach estimating emissions for recovery process minus avoided emissions
4 Unmanaged waste with minimally higher CO2 emission due to exposure to sunlight which causes formation of methane and ethane gases as a CO2 equivalent

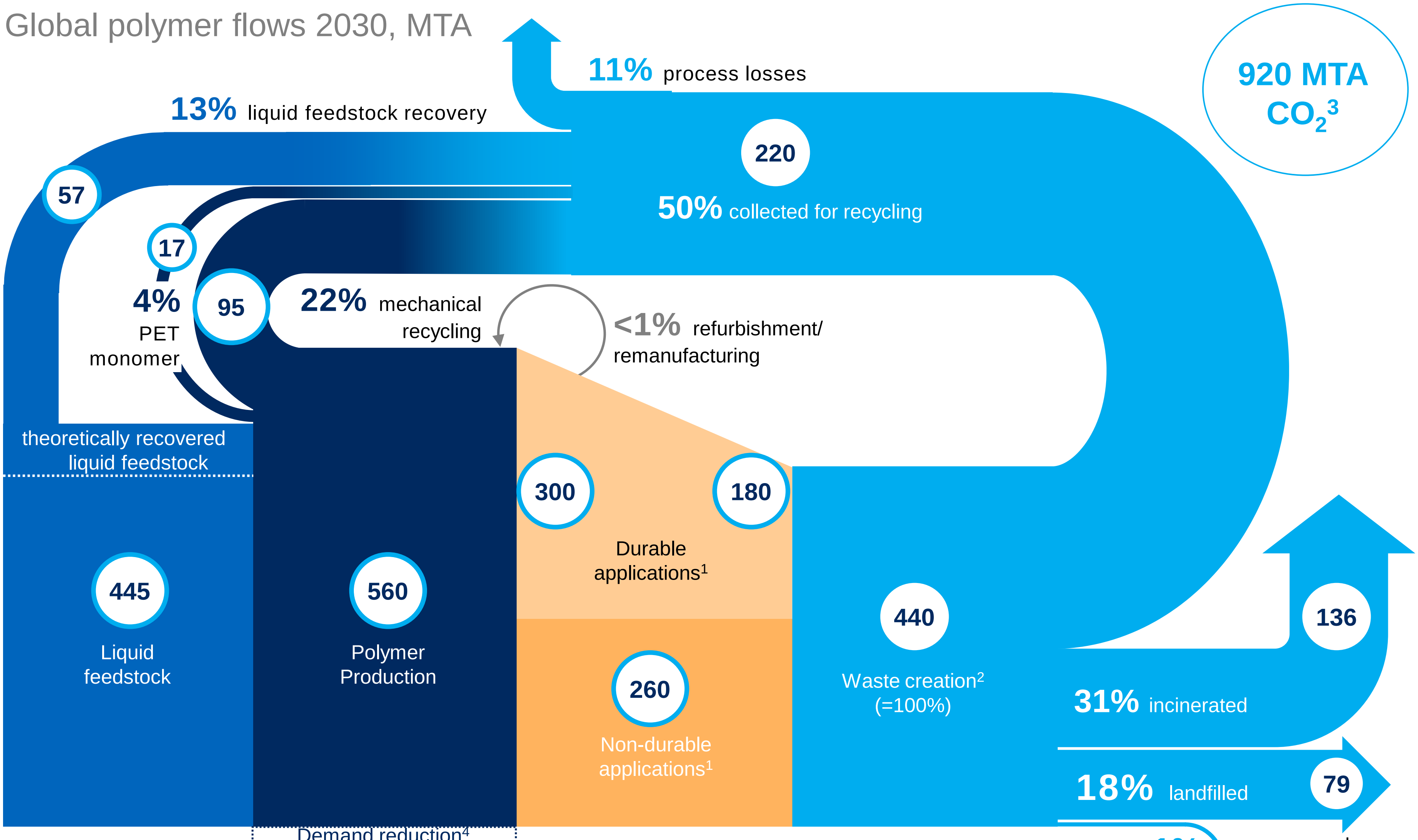
SOURCE: Ecoprofiles Plastics Europe, EPA WARM model v14, McKinsey analysis

Contents

- What have we done in recent months and what we found
- **What we think this could mean to you**

Potential view on the world in 2030

COALITION FOR CHANGE



1 Durable applications with an average lifetime >1year will end up as waste only in later years, non-durable applications go straight to waste

2 260 MT mixed plastic waste from nondurable applications that end up as waste in same year plus 180 MT of mixed plastic waste from production in previous

3 Total CO2 production per annum including virgin plastics production but excluding plastic processing

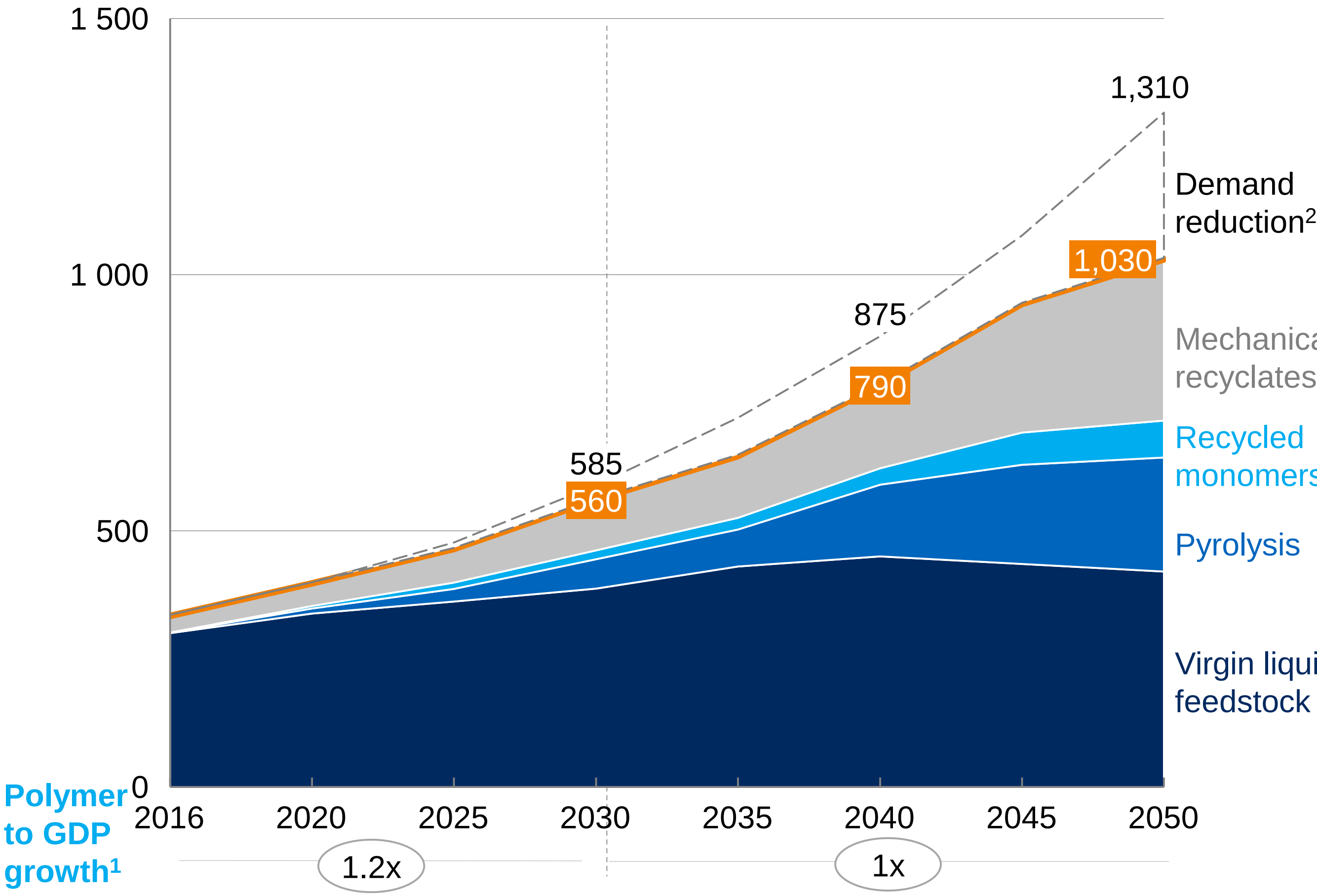
4 20 million tons demand reduction, corresponding to ~3% of overall demand, mostly due to elimination of low value add plastics

SOURCE: McKinsey plastic waste stream model

By 2050, the majority of the petrochemical value chain may be affected by an increase in plastics recovery

Global polymer demand 2016-50 from waste recovery

million tons



	2016 share % of total	2050 share[3] % of total	CAGR 2016-50, in %
Mechanical recyclates	12	30	7
Recycled monomers	~0	7	18
Pyrolysis	<1	22	17
Virgin liquid feedstock	87	41	1
		Σ 100	Ø 3

1 Actual growth after demand reduction, assuming global GDP growth of 3.1% (IHS)
2 IHS forecast, demand if current IHS projections until 2027 for plastic growth continue through to 2050
3 Mechanical recycling limited by downcycling and applicable materials, monomerization limited by applicability to condensates only, pyrolysis limited by likely rise in input costs
4 We modeled 3 different scenarios in addition to BAU, with Coalition for Change (CfC) being the most ambitious one with the most drastic global change in plastics recovery rate and waste mgmt

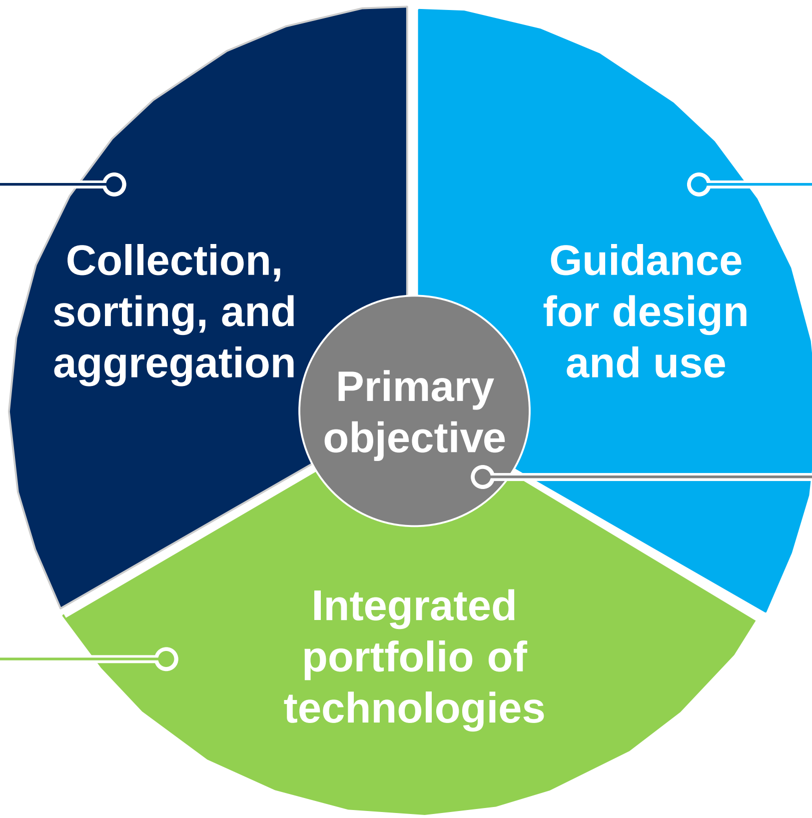
SOURCE: McKinsey plastic waste stream model

Recycling strategies combine three elements – regional/product specific

Key elements of a plastics recycling cell

Securing of cost-effective supply of usable waste to recovery facilities

Design and establishment of optimal cluster of recovery facilities per cell to achieve primary objective



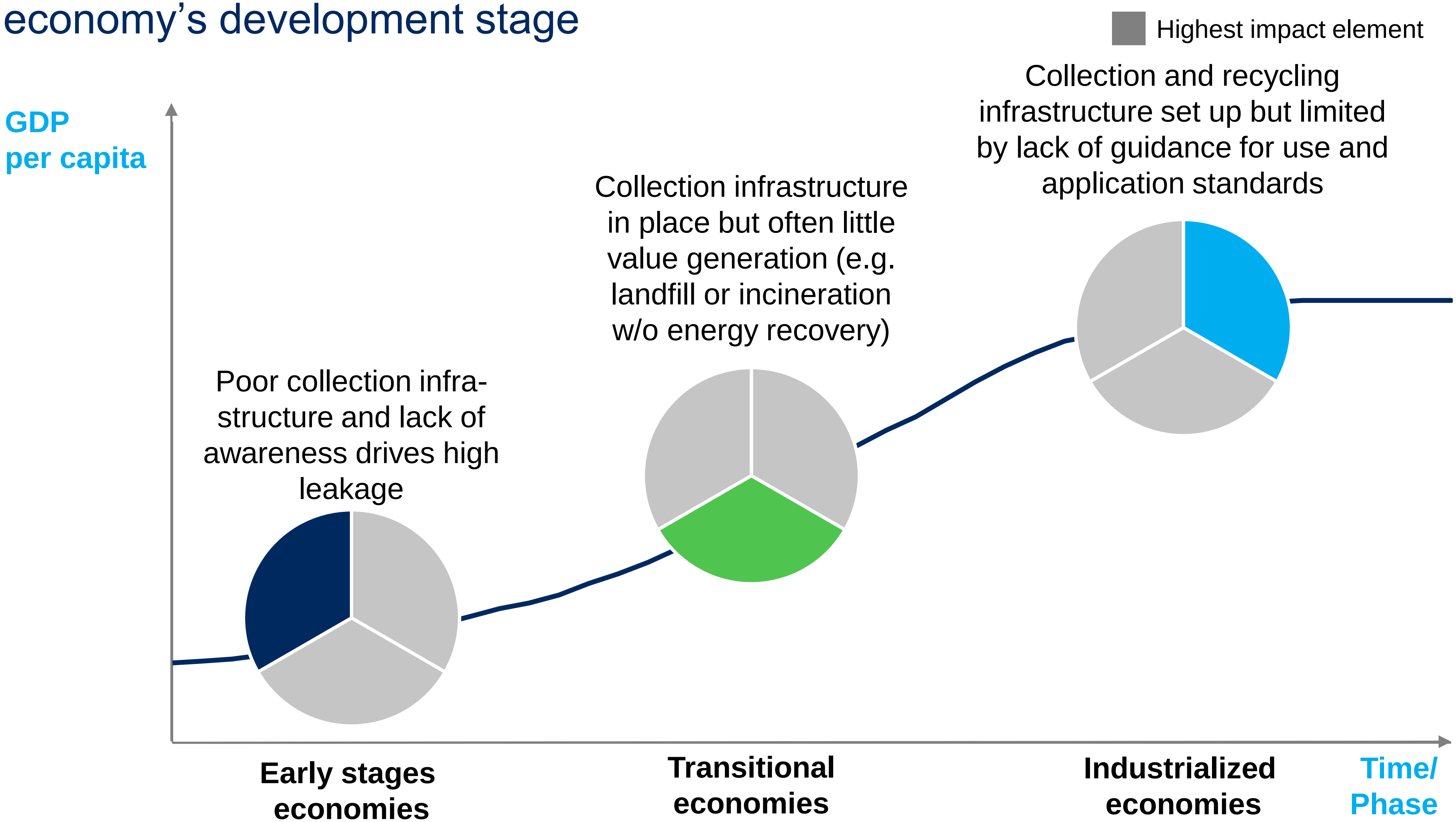
Optimization of recyclability of waste by elimination, standardization and demand incentives

Decision on ultimate target of the system

- Avoidance of landfill or leakage (e.g., into the ocean)
- Economic value creation
- CO_2 minimization

SOURCE: McKinsey analysis

To maximize impact, primary objective needs to be decided based on an economy's development stage



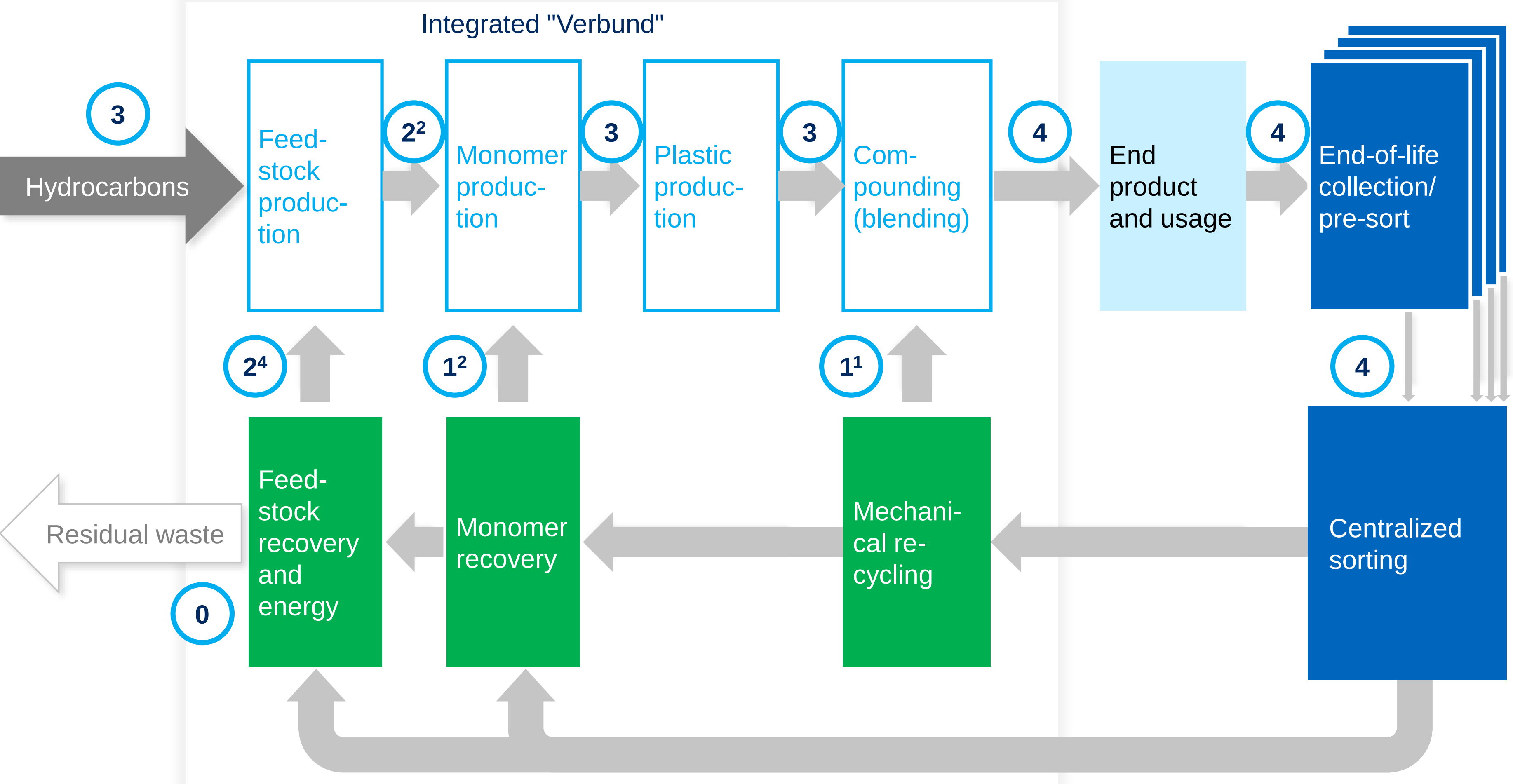
Objective / focus	Reduce leakage/ unmanaged waste	Maximize economic value creation	Maximized circularity (e.g. reducing CO2 emissions)

SOURCE: McKinsey analysis

Vision of an integrated model with resource conservation

CONCEPTUAL

Product flows, MTA



1 Based on max 25% of reground PO could be used in new products, rest would require virgin materials; 2 Ethylene/propylene equivalent; 3 Assuming total 67% yield to ethylene and propylene; 4 Waste-to-energy to supply energy requirement

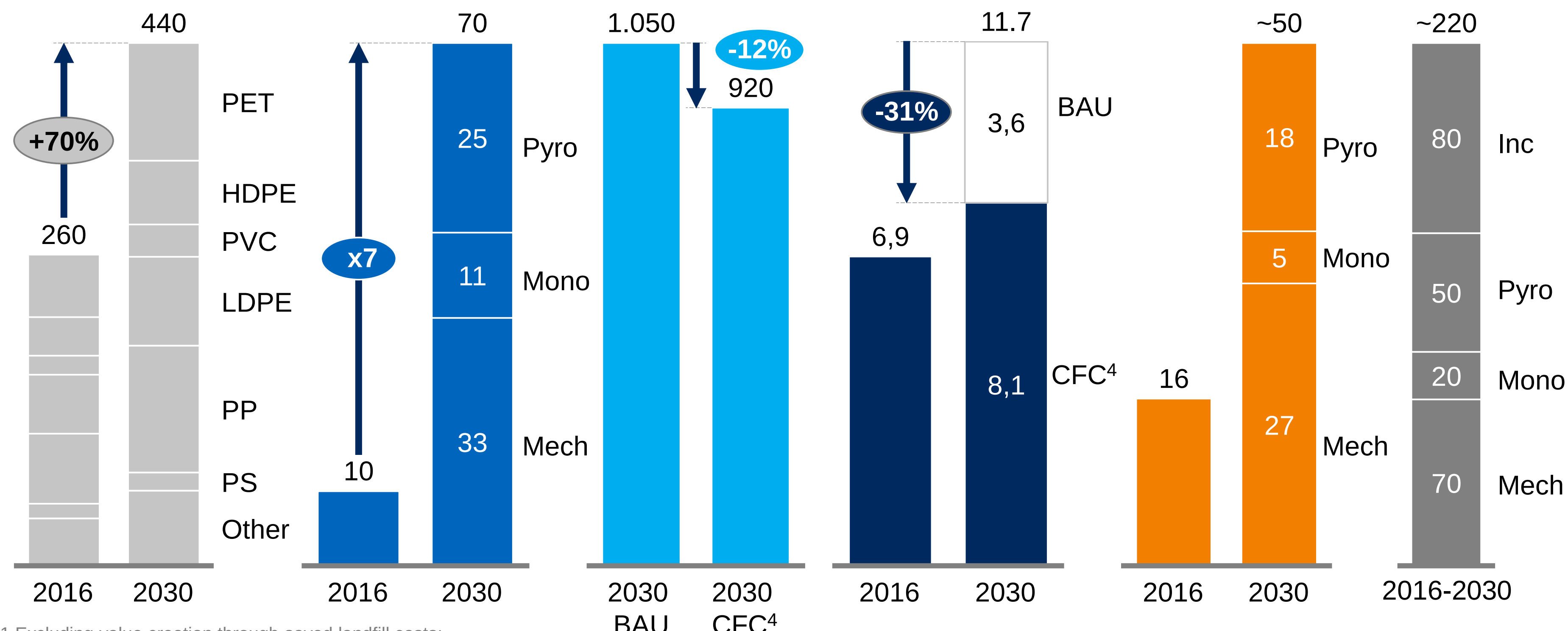
SOURCE: McKinsey analysis

The plastic waste problem has significant potential for value creation AND CO_2 reduction but will require substantial capital investment

COALITION FOR CHANGE[4]

Normalized @75$/BBL OIL

Plastics waste production MTA	**Value creation[1] in recycling (EBITDA)** USD bn	**CO_2 emission reduction** MTA	**Oil demand from plastics production** mn bbl/d	**Recovery rate[2]** % of global waste collected for recycling	**Capital required[3]** USD bn



1 Excluding value creation through saved landfill costs;

2 Share of processed plastic waste for recovery to total plastic waste - for mechanical recycling, monomer and pyrolysis;

3 Investment to build additional (greenfield only) capacity required for 2030 (i.e., without renewal of capacity already existing in 2016); includes capital required for recycling facilities and excludes investment into collection infrastructure, excludes capital required for renewal of existing facilities at end of lifetime

4 We modeled 3 different scenarios in addition to BAU, with Coalition for Change (CfC) being the most ambitious one with the most drastic global change in plastics recovery rate and waste management

SOURCE: McKinsey plastic waste stream model

No time to waste – wrap-up

1. **The magnitude of the challenge is accelerating – need to act at scale sooner rather than later**
2. **Disruptions to the value chain will be product, end-market and regional specific with need for segmented strategy**
3. **Future solution will combine three integrated building blocks – shared between stakeholders**
   - Guidance for design and use
   - Region specific collection, sorting and aggregation approach
   - Portfolio of recycling technologies
4. **Future value creation in the petrochemicals industry may significantly shift from virgin production routes to recycling routes**
   - Plastics recovery will require significant investments
   - Need to make clear business model choice

Further reading and contact

No time to waste: What plastics recycling could offer

Plastics waste is hurting the chemical industry as well as the environment. By taking the lead on recycling, chemical players could add a new dimension to the industry and help solve the problem.

Thomas Hundertmark, Chris McNally, Theo Jan Simons, and Helga Vanthournout

It's not news that the plastics-waste issue is becoming a crisis and that, in the eyes of the public, the chemical producers that make all those plastics are deeply implicated. The public's concern is already translating into new regulations on plastics in the European Union and elsewhere, and major customers, such as the consumer-packaged-goods (CPG) industry, are ramping up efforts to increase recycled content and reduce their plastics consumption. What is news, however, is that chemical-industry leadership has started to declare that its concept of stewardship and sustainability now extends to dealing with plastics waste. It is also increasingly acknowledging that the "use once and discard" model, which the plastics industry has grown up with, should be replaced by a new model where plastics are recycled as much as possible.

This marks a watershed moment for the chemical industry, given that more than one-third of the industry's sales are made up of petrochemicals and plastics production and plastics-related products. But as the industry starts to mobilize, there is a lot of uncertainty about what steps represent the best way forward. We believe that the chemical industry has a central role to play in unlocking

McKinsey on Chemicals

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How plastics-waste recycling could transform the chemical industry

Reusing plastics waste could become an important driver of profitability for chemical companies. Incumbent players need to make the right moves now to tap this opportunity.

Thomas Hundertmark, Mirjam Mayer, Chris McNally, Theo Jan Simons, and Christof Witte

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https://www.mckinsey.com/industries/chemicals/our-insights