JANUARY 2019

THE NEW PLASTICS ECONOMY

A Research, Innovation, and Business opportunity for Denmark

Summary of findings

McKinsey&Company

Innovation Fund Denmark

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EXECUTIVE SUMMARY

Plastics have become deeply integrated into every corner of the modern life. Cheap, light, flexible, and long-lasting, plastic is ubiquitous in nearly every aspect of the economy and consumer life. People interact with plastics daily, particularly in packaging—the largest application of plastics globally. As more consumers in developing countries are armed with increased spending power, the global demand for plastic will continue to grow, likely doubling in the next 20 years.

It is no secret that alongside the widespread use of plastics is an alarming waste threat. Globally, about 260 million tons of plastics were discarded after use in 2016. Of this waste, 16 percent was collected for recycling, 25 percent was incinerated, and the remaining 59 percent was landfilled, taken to unmanaged dumps, or leaked into nature.[1] Every year, 8 million tons of plastics end up in the oceans[2]—the equivalent of dumping in a garbage truck every minute.

The environmental risks are high. The current public conversation on plastics has recently focused on microplastics, tiny pieces of plastic that end up in nature. The largest share of microplastics is believed to come from fragments of larger objects that have decomposed—for example, a plastic bottle breaking apart in the ocean—along with microbeads and wear and tear from plastics in use, such as particles from tires and textiles. The Arctic Ocean is a sink for microplastics, with most plastics in the Greenland and Barents Sea[3]—and these microplastics may have consequences for marine life.

In addition to being an environmental challenge, plastic waste is also a significant lost opportunity, as the energy and resources spent on producing plastic are largely wasted after just a single use. Packaging is especially likely to leak out of the value chain and into nature due to its short usage periods, complex design, small size, and low residual value.

Though the plastic waste challenge is well-known across the globe, public and private entities are lacking the infrastructure and technology to manage after-use plastics, including the cultural and regulatory climate to cut down on plastic use, recycle, or end littering. In Denmark, plastic pollution is relatively low, but the country is not shielded from its effects. Denmark and other countries are exposed to plastics pollution transported by ocean currents. Annually, more than 1,000 tons of plastic are collected on the Danish West Coast.[4]

Denmark is tasked with meeting the 2025 and 2030 EU recycling obligations for plastics packaging waste, and the country is currently achieving around a third of the required 50 percent and 55 percent,[5] respectively. Most Danish plastics waste is incinerated—57 percent of Denmark's plastics waste is burned for heating and energy, 18 percentage points above the EU average.[6] Only 13 percent of all plastics waste are recycled in Denmark, while an additional 28 percent is exported for recycling, and the last 2 percent is landfilled. There are clear and significant opportunities to increase recycling and reconsider the continued plastics incineration in Denmark, as incineration is at odds with both a circular economy concept and the goal of transforming Denmark into a low-CO_2 emission society by 2050. The initial steps on changing our current use of plastics have already been taken in Denmark, as the Danish government put forward the first Danish strategy on plastics in December 2018. The strategy lays out 27 initiatives that support a more circular use of plastics and a vision to eliminate plastic pollution in Denmark.

Globally, organizations are addressing the plastic-waste challenge by putting forth the concept of a new plastics economy,[7] in which they rethink the role of plastics in society. This ambitious vision includes research and innovation aimed at smarter use, full recycling of all consumer and industrial plastics, development of sustainable plastics, and the elimination of pollution from plastics in use. Turning this vision into reality implies research, innovation, and business opportunities that stakeholders in Denmark can take advantage of, positioning the country as a frontrunner in the new plastics economy. There are clear benefits: Capturing the full economic potential

of our plastics waste stream could save Denmark over DKK 1.6 billion a year in saved costs from importing virgin plastics rather than recycling domestic plastic waste. Additionally, Denmark would benefit economically from cutting the environmental costs of pollution and creating value from new technology and newly created jobs.

To resolve these challenges, a first step is for governments, businesses, and the broader community of participants to close gaps on the knowledge of the long-term effects of plastics. For example, we do not fully understand the impact of plastics in the environment on both animals and humans, including how toxic microplastics are to biological systems and organisms. We also have an incomplete picture of the technical and economic potential of recycling technologies and a limited understanding of how to influence sorting and littering. It is also crucial for stakeholders to work together. Academics, industry leaders, and regulators can jointly define a research and innovation agenda that will close those knowledge gaps. Together, they can also identify necessary regulatory changes and create a schedule for implementing current and future regulations. There are both medium- and long-term changes Denmark can make. In the medium term, Denmark could meet the EU 2030 targets by using the innovation potential within production, use, sorting, collection, and recycling of plastics and moving toward developing national standards for waste collection. In the long term, Denmark can support the creation of a functioning market for recycled plastics and sustainable plastics.

We hope our findings aid in the effort to chart a new, less wasteful course for Denmark and the world. By moving in this direction, we envision a future in which plastics can again become a solution to problems rather than a cause of them.

ACKNOWLEDGMENTS AND ABOUT THIS REPORT

This report was developed by a joint team from Innovation Fund Denmark and McKinsey & Company. The work was overseen by a steering committee consisting of representatives from major stakeholders in the Danish plastics economy as well as Innovation Fund Denmark and McKinsey & Company.

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This document is an abbreviated summary of findings. The full report is available online at **innovationsfonden.dk.**

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SUMMARY OF FINDINGS

1. THE GLOBAL PLASTICS CHALLENGE

In the past several years, it has become clear that the plastic waste issue has grown into a crisis. As plastic pollution continues to grow, public awareness of the problem has increased as well. Much of the conversation is centered on addressing the challenge—all stakeholders, from chemical and plastic producers to consumer goods companies, waste-management companies, and various regulatory agencies, are part of the solution.

The public concern is already translating into new regulations on plastics in the European Union and elsewhere, and major players in various industries—including companies in the consumer-packaged-goods (CPG) industry—are ramping up efforts to increase recycled content, improve design for recyclability or reuse, and reduce their plastics consumption. Most recently, China has banned the import of plastic waste, which has caused a major disruption to the global plastic waste value chain. Until its import ban, China imported about 70 percent of world's traded plastic waste (amounting to 8.9 MT in 2012).[8] This makes the challenge of what to do with waste even more pressing to all of the Western world.

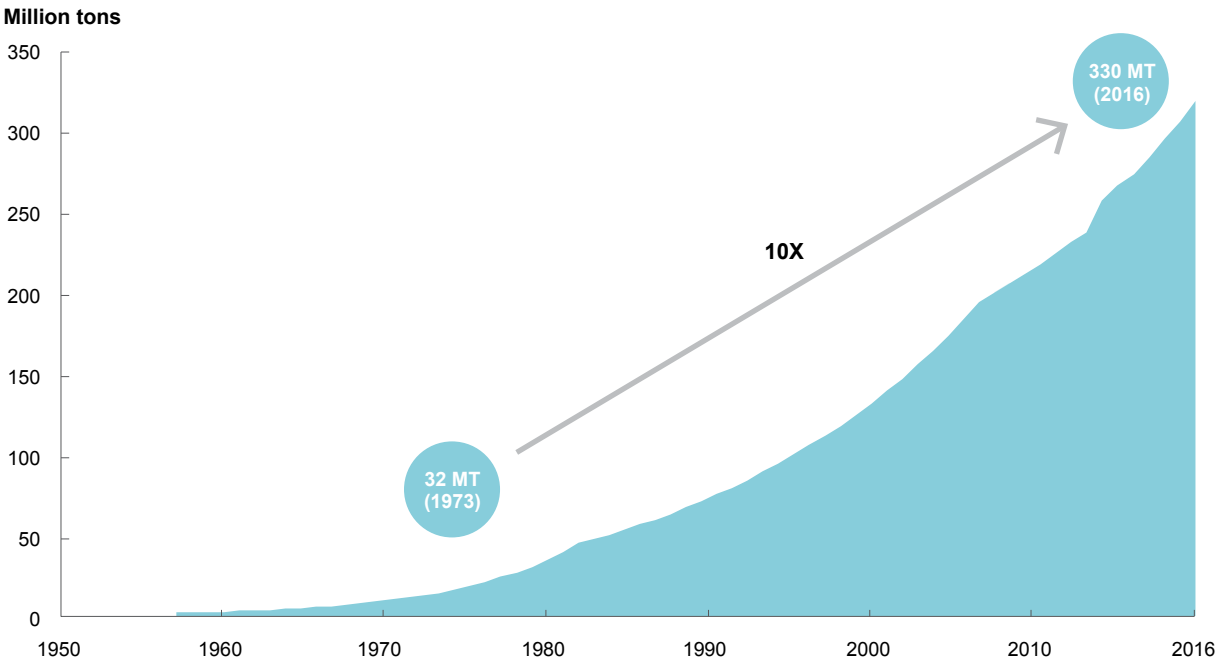
Despite the known issues, global production of plastic has continued to rise due to its low cost, many benefits, and increasing global demand, which has been driven by the emergence of a consumer middle class in large emerging economies. Since 1973, plastics production has increased tenfold (Figure 1).

Unless global society addresses the plastic pollution challenge now, the amount of plastics produced is set to double in 20 years, which will add to an already growing pollution problem. This also means that the

FIGURE 1

In the past 40 years, global plastics production has increased tenfold.

Growth in global plastics production, 1950–2016, million tons annually



SOURCE: World Economic Forum, Ellen MacArthur Foundation and McKinsey & Company, *The New Plastics Economy—Rethinking the future of plastics* (2016); Plastics Europe, "Plastics—The Facts 2013" (2013); Plastics Europe, "Plastics—The Facts 2015" (2015); McKinsey plastic waste stream model

resources spent on plastics will increase as well, rather than being directed elsewhere. The other challenge will be adjusting waste practices, which currently include massive landfilling and incineration, both of which lead to carbon dioxide emissions and pollution.

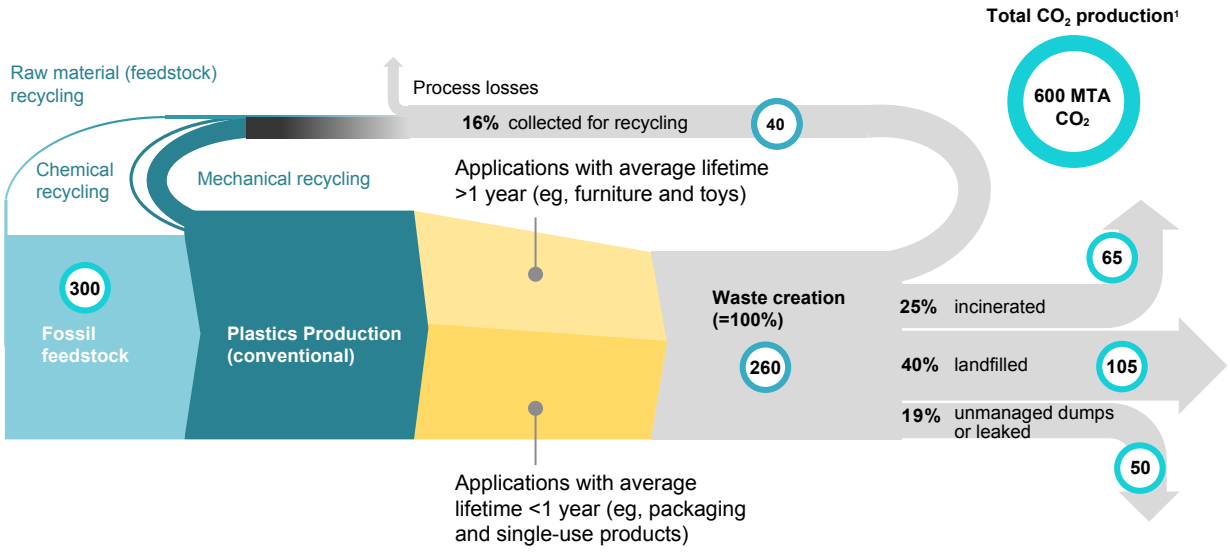
Currently, the global plastics flow creates around 260 million tons of waste annually. Only 16 percent of this is collected for recycling. Around 40 percent is put into landfills, where it will, over a very long time, degrade into microplastics and likely end up in waterways. Approximately 25 percent of plastic waste is incinerated, which from a circular economy perspective is the "least bad" way to dispose of plastic if it cannot be recycled (Figure 2). While incineration is effective in eliminating trash from the natural environment—and provides a source of heat and power—in this case, plastics are recycled at the lowest level of value recovery, meaning most of the energy that went in to producing the plastic is lost.

These findings help illuminate the size and significance of the plastic waste challenge. While conversations on the crisis are happening at every level, building great momentum around the world to solve the problem and establishing a new plastics economy requires a daunting amount of effort. It will require new technologies, new regulation, and the rapid mobilization and partnership of both the public and private sectors. In addition, there are numerous knowledge gaps that need to be closed to direct resources and efforts to where they can create the most impact. In this report, we view these challenges and solutions from a Danish perspective to help stakeholders understand and take advantage of the research and business opportunities that will best position Denmark for meaningful change.

FIGURE 2

Today we create 260 million tons of plastic waste—the vast majority is not recycled

Global plastics flows 2016, million tons annually (MTA)



[1] Total CO_2 production annually, including virgin plastics production but excluding plastic processing.

SOURCE: McKinsey plastic waste stream model

2. THE PLASTICS CHALLENGE IN DENMARK

Denmark has historically had an effective waste-management system where waste is collected and managed at the municipal level. Because of this, the country has traditionally had relatively low levels of plastic waste pollution. However, Denmark, like all countries, is deeply affected by the plastic waste challenge in several ways.

Our western coastline is exposed to plastic litter as ocean currents transport waste from elsewhere and causes accumulation. As a result, more plastic waste washes up on the Danish West Coast than many other European shores. In fact, a total of 1,000 tons of plastic waste is collected on Denmark's western coast every year (Figure 3).

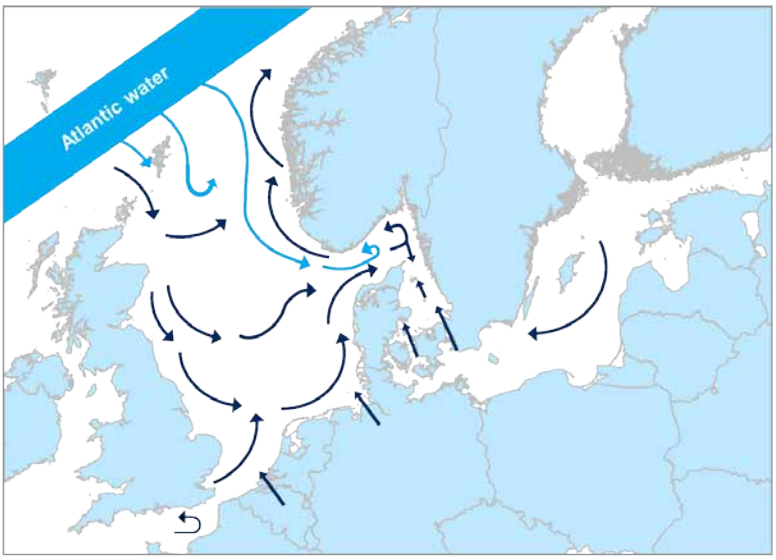
Most plastic waste in nature comes from plastic packaging, which over time is decomposed into small particles of microplastics. Other sources may include worn-off plastic textiles and tires, as well as spilled

FIGURE 3

While Danish pollution is low, Denmark is still exposed to marine waste from elsewhere, with up to 1,000 tons per year on the Danish West Coast

Transport via ocean currents and local circulation causes waste accumulation in Skagerrak

Circulation of ocean currents in the North Sea and Skagerrak



1,000 tons of waste—mostly plastics—wash onto the Danish West Coast annually

The ocean currents **create a local circulation in the Skagerrak region that functions as an accumulation area for marine litter**

Coastal areas in **Skagerrak receive ~10% of all marine litter in the North Sea,** despite only covering about 2% of the total coastline

[1] Based on OSPAR + MARLIN data 2002–2012.

SOURCE: Nordic Council of Ministers, "Marine Litter in Nordic Waters" (2015); UNEP, "Marine Litter—An analytical overview" (2005); KIMO Denmark, Danish EPA press release (March); J. Strang, Z. Tairova, and R. d'A Metcalfe, "Status on beach litter monitoring in Denmark" (2015)

raw materials from plastic production. Uncertainty remains on microplastics sources. The Arctic waters have become a sink for microplastics. Surprisingly large quantities of microplastics have been detected in the ocean around Greenland, despite Greenland's low population (Figure 4).

FIGURE 4

The Arctic Ocean is a global sink for microplastics as plastic waste decomposes and is transported below the surface

Plastics concentration in the Arctic Ocean

The Arctic Ocean **constitutes a global sink for plastic debris** as it transfers plastics to the ocean interior

A significant fraction of plastics in the Arctic come from far away, as **Nordic ocean currents provide long-range transport for plastics waste**

Surface ice-free waters in the Arctic Polar Circle were slightly polluted with plastic debris, despite extremely low population density

The uniqueness of the Arctic ecosystem makes the potential ecological implications of exposure to plastic debris a special concern

SOURCE: Cozar et al., "The Arctic Ocean as a dead end for floating plastics in the North Atlantic branch of the Thermohaline Circulation" in Science Advances vol. 3 no. 4 (2017); Nordic Council of Ministers, "Marine Litter in Nordic Waters" (2015)

3. A VISION FOR DENMARK AS A FRONT-RUNNER IN THE NEW PLASTICS ECONOMY

Denmark has a strong tradition of cross-sector collaboration and an effective waste-management infrastructure, both of which provide an important foundation for the country to realize an ambitious vision for the new plastics economy. Denmark has also undertaken other environmental initiatives successfully—for example, building a renewable energy infrastructure—which arms stakeholders with the experience and knowledge necessary to address the plastic pollution challenge.

The vision for Denmark could include five crucial elements (Figure 5).

Defining and acting on this vision could not only help Denmark catch up to existing international regulations, particularly in recycling targets—where the country is significantly behind—but also see important economic benefits.

The savings from not importing new plastic raw material could save the Danish economy as much as DKK BN 1.6 per year. Most of these savings would come from recycling domestic plastic waste rather than importing more expensive new plastic raw material. Innovative practices and new business models in waste management could strengthen the

FIGURE 5

Denmark can aspire to become a front-runner in the New Plastics Economy and capture the value of plastics through research and innovation

Elements of a vision for Denmark

1 Recycle 100% of plastics with a view to capturing the full value of waste streams for both household and industrial plastics, enabled by a functioning market for reused and recycled plastics

2 Minimize or phase out plastics that are difficult to recycle and/or collect

3 Find alternatives for plastics that, when used as intended, could result in direct pollution (for example, textiles and artificial turf)

4 Eliminate need for new fossil-based plastics by reducing consumption, administering a high rate of recycling, and developing new, sustainable bio-based plastics

5 Create policies to stop plastics pollution of the oceans through the EU and global forums, as Denmark cannot solve the plastics challenge alone

current waste-management industry both in Denmark and beyond and give Denmark a leading role in solving the plastics challenge. It is also notable that building up the plastics recycling industry in Denmark could help create more jobs at higher income levels than landfilling or incineration. As the country develops technologies to aid in plastic waste elimination—from technologies related to decreasing consumption, collecting, sorting, and recycling to new materials and product designs—there is an opportunity to monetize these for exporting and use in other countries. Denmark could therefore gain growth while playing a part in solving the global plastics challenge.

A significant element in technology development would be chemical recycling, a process in which the monomers are reused as building blocks for new plastics rather than burned. This technology is especially useful for recovering value from plastics that cannot be mechanically recycled. This is expected to become a large industry, and Danish specialty chemical companies have an opportunity to benefit from growth in these technologies; for example, by exporting niche solutions to larger companies abroad.

Benefits from reduced pollution of the environment will likely have socioeconomic advantages, such as avoiding the potential health threat of microplastics and negative effects of plastic pollution to the tourism and fishing industries (in Denmark as well as Asian countries, which are more exposed to plastic pollution), lower clean-up costs, and lower carbon-dioxide emissions. While the socioeconomic benefits are still to be quantified, the benefit of tackling the plastic waste challenge is reflected in a strong public motion for action on plastic pollution. This is also the case in Denmark, where 99 percent of the population thinks it is important or very important to act on plastics in nature.[9]

4. HOW TO REALIZE AN AMBITIOUS VISION

Moving in the direction described above requires cross-sector collaboration among many Danish stakeholders. To start, we suggest a potential set of goals for the short, medium, and long term (Figure 6).

Some of the most important knowledge gaps to address in the short term are related to the sources and distribution of plastics in nature, the measurement and characterization of microplastics, the use and development of recycling technologies, and the impact of plastics pollution—both on individual organisms and on society at large. Closing these gaps will require that both academic and industrial research address these questions, and that the magnitude of the opportunity to make a difference is made clear to institutions involved in directing and funding research and innovation.

In the medium term, Denmark can strive to collect and recycle more plastic waste. Compared to those of most other European countries, collection rates in Denmark are low because the standard is to incinerate waste rather than reuse it (Figure 7).

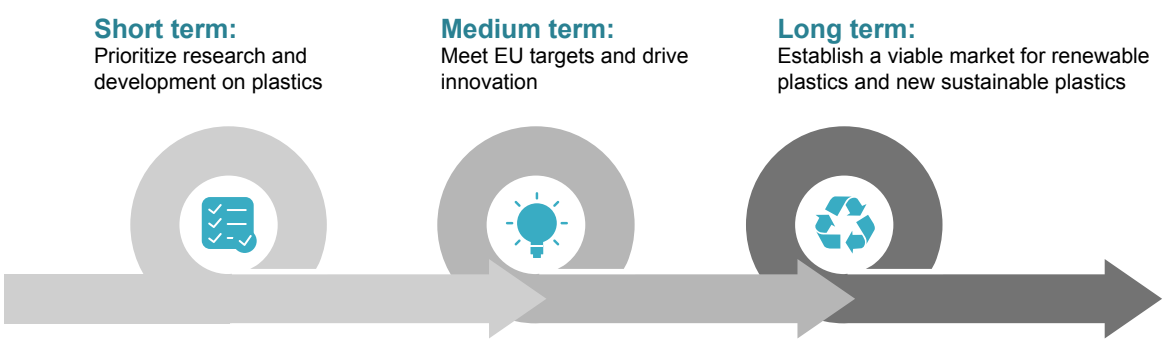
The recycling rate for plastics packaging in Denmark does not yet live up to the 2025 and 2030 EU targets of 50 percent and 55 percent, respectively (Figure 8).

Shifting the approach from incineration to recycling will require governments and private-sector organizations to find efficient, sustainable ways of collecting, sorting, and recycling waste based on new technologies, changes in market mechanisms, and political changes. Currently, Danish municipalities do not have an aligned approach to sorting plastics; rather, each municipality

FIGURE 6

A set of aspirational targets for the short, medium, and long term can guide efforts needed today and in the future

Potential targets for the short, medium, and long term



Short term:
Prioritize research and development on plastics

Bring academia, industry, and regulators together to define a research and innovation agenda to close key knowledge gaps

Define regulatory changes and implementation schedule of existing regulation

Medium term:
Meet EU targets and drive innovation

Align collection criteria across municipalities and reduce waste creation, specifically for plastics that are difficult to recycle

Develop innovations in necessary recycling technologies and supporting technologies for sorting and collection (eg, traceability, use of AI, and robotics) as well as innovations for reuse and repair; develop new business models

Long term:
Establish a viable market for renewable plastics and new sustainable plastics

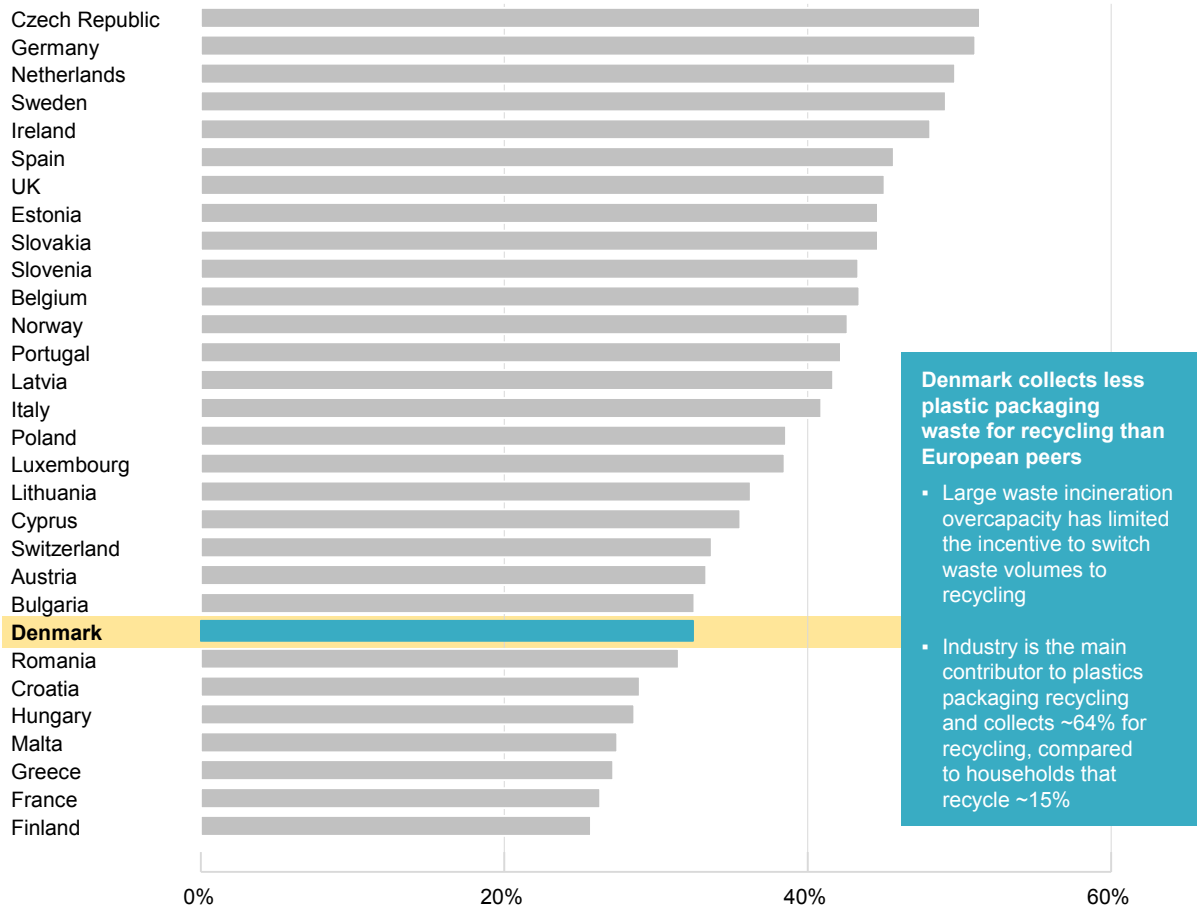
Define and implement a viable market for recycled plastics via a combination of demand and supply measures

Lead development of niche applications of bio-based plastics for high-value products based on existing industry in Denmark

FIGURE 7

Compared to European peers, Denmark ranks low for plastics packaging collected for recycling

Proportion of plastic packaging waste collected for recycling per European country,[1] 2016, percent



[1] Based on waste collected for recycling and not actual quantity of plastics recycled.

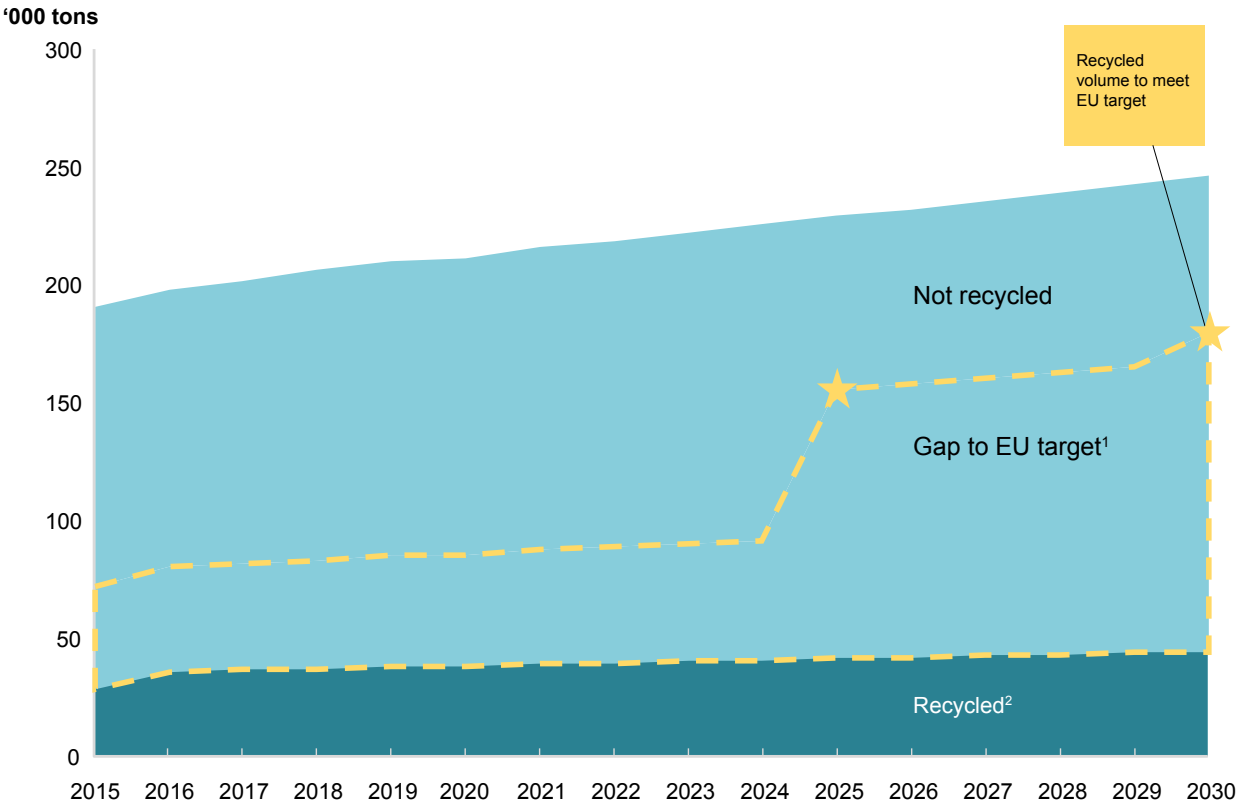
SOURCE: PlasticsEurope: Plastics—the Facts (2017); Plastindustrien, "Så meget plastik genbruges i Danmark" (2018); Ellen MacArthur Foundation and McKinsey & Company, "Potential for Denmark as a Circular Economy," a case study from: Delivering The Circular Economy—A Toolkit For Policy Makers (2015)

defines its own collection criteria. The small-scale approach of waste collection means that there are limited efficiencies of scale, which are necessary to make a good business case for recycling. While municipalities may continue to manage their own collection, policymakers could define standards for

FIGURE 8

To meet the EU 2030 target of 55%, Denmark must triple the amount of plastics recycled

Recycling rate and volumes for plastics packaging, thousand tons



NOTE: Total volume for plastics packaging projected from DEA estimation of total plastic packaging consumption in Denmark for 2015, growth rate estimated by ICIS for all plastics applied toward 2025. Growth rate of 1.5% from 2025 to 2030 is assumed.

[1] New EU legislation from 2018 obliges member states to recycle 50% of plastics packaging waste in 2025 and 55% in 2030.
[2] Current FRIDA estimation from the Danish Environmental Agency projects plastics packaging collected for recycling to increase up to 36% toward 2025, after which current municipal waste plans will be fully implemented (does not include political initiatives after 2015 and technology development). This rate was already achieved in 2016, while the recycling rate in 2015 was 30.5%. Based on expert interviews, we assume the rate of actual recycled plastics to be 50% of plastics collected for recycling—i.e. ~15% for 2015 and ~18% for 2016 toward 2025.

SOURCE: Danish Environmental Agency "Statistik for emballageforsyning og indsamling af emballageaffald 2015" (2015); Danish Environmental Agency "Statistik for emballageforsyning og indsamling af emballageaffald 2016" (2016) ICIS data; expert interviews

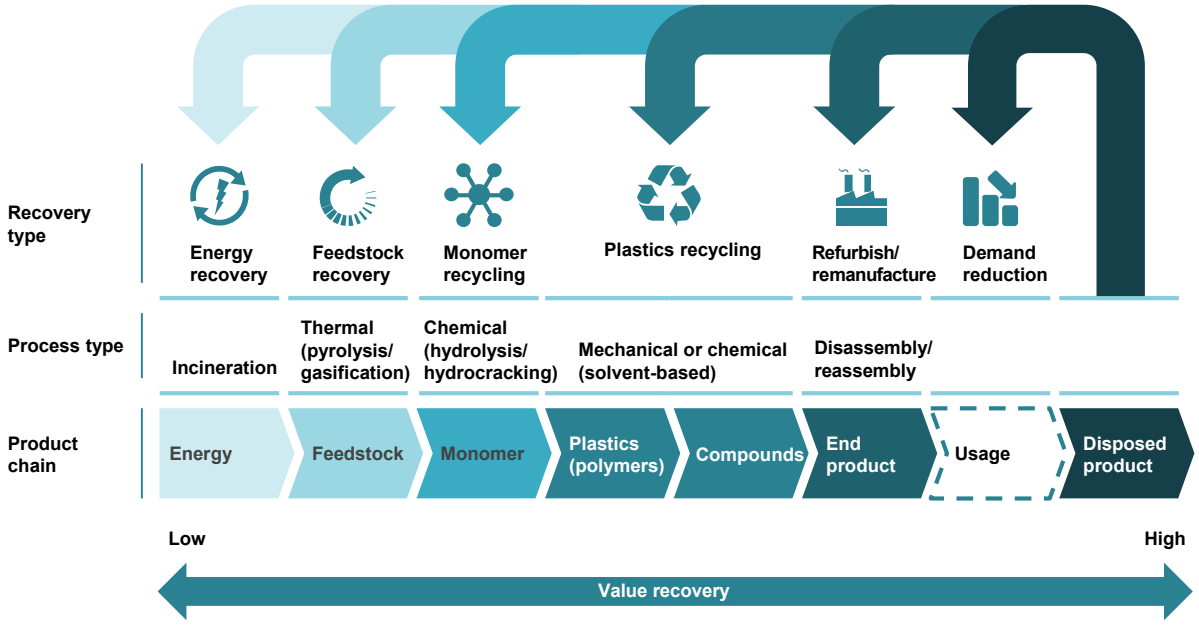
collection criteria that could be used by all of them, such as collecting plastics separately versus mixed with other materials. The strategy on plastics from the Danish government also includes an incentive for more standardization for plastic waste collection. When moving on this incentive, it is helpful to take into account that there are regional differences in terms of population density and different housing types to be flexible enough to enable innovation and accommodate existing municipal facilities. At the same time, policymakers can help by finding ways to make it attractive to companies to source plastic waste from multiple facilities.

In the long term, Denmark could strive to further develop the market for renewable and sustainable plastics through technology development in alternative plastic production that avoids carbon emissions. In addition, it's important to establish a well-functioning market for recycled plastics, to make it viable to collect and recycle plastics, enabled by stable demand and supply of quality recycled plastics. Policymakers can help the process by focusing on regulations that allow companies to be innovative as they explore changes in how plastic products are designed and manufactured and how industry and consumers use them. The recycling system will also have to develop to accommodate an aspiration of recycling close to 100 percent of all plastic waste. As the system is redesigned, stakeholders can also consider how to ensure that most of the recycling is happening at a higher point in the value chain, where most value is preserved, so that the energy going into production is not wasted (Figure 9).

FIGURE 9

Optimized recycling requires a portfolio of recycling technologies

Overview of recovery technologies throughout the plastics value chain



SOURCE: McKinsey analysis

FIGURE 10

Potential research areas for Denmark in the circular plastics economy

Research areas and examples

Smart use of plastics	▪ Product design that enables increased reuse ▪ New circular business models for plastics ▪ Alternative materials for food packaging
Long-term health and biosystem effects of plastics	▪ Definition and measurement technologies for micro- and nanoplastics ▪ Biosystem and human health effects of microplastics exposure, including critical thresholds and most critical exposure pathways ▪ Technologies to avoid or reduce micro- and nanoplastics in nature
Recycling of plastics	▪ Assessment of potential mechanical recycling of consumer and industrial plastics ▪ Technologies for improved sorting and collection, including AI, robotics, and advanced sensors as well as potential implementation road map ▪ Technologies to detect, measure, and remove substances of concern from plastics ▪ Technologies for recycling of complex plastic waste, e.g., chemical recycling
New sources of plastics	▪ Technology and cost road maps for sustainable bio-based plastics ▪ "Power to X" and other options for fossil-fuel-free plastics, including cost and environmental comparisons

We see increased support and collaboration around research and innovation as the next key step towards achieving leadership in the new plastics economy. This requires stakeholders from across the value chain to set up new collaborations where all involved partners contribute directly with knowledge or financial resources, so all involved have a stake in ensuring a good outcome. The efforts can be focused around main research areas, which could include the smart use of plastics, long-term health and biosystem effects, recycling of plastics, and new sources of plastics (Figure 10).

As a country with a strong tradition in product design, efficient waste management, energy technology development, and cross-sector collaboration, Denmark has a clear opportunity to emerge as a leader in solving the plastics challenge and to participate fully in the new plastics economy.

We hope this report and the supporting fact base will inspire action to address the challenge and capture the opportunity. ■

ENDNOTES

[1] McKinsey plastic waste stream model.

[2] J. R. Jambeck et al., “Plastic waste inputs from land into the ocean,” *Science*, February 13, 2015, pp.768–771.

[3] Cozar et al., “The Arctic Ocean as a dead end for floating plastics in the North Atlantic branch of the Thermohaline Circulation,” *Science Advances*, April 19, 2017, Vol 3, No.4.

[4] KIMO Denmark, Danish EPA press release, March 2018.

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[6] European Commision. *A European Strategy for Plastics in a Circular Economy*, 2015.

[7] World Economic Forum, Ellen MacArthur Foundation and McKinsey & Company, *The New Plastics Economy—Rethinking the future of plastics*, 2016.

[8] International Solid Waste Association, “A report from the ISWA Task Force on Globalisation and Waste Management,” 2014.

[9] Plastic Change, “Danskerne vil bekæmpe plastikspild i naturen,” accessed 2018.