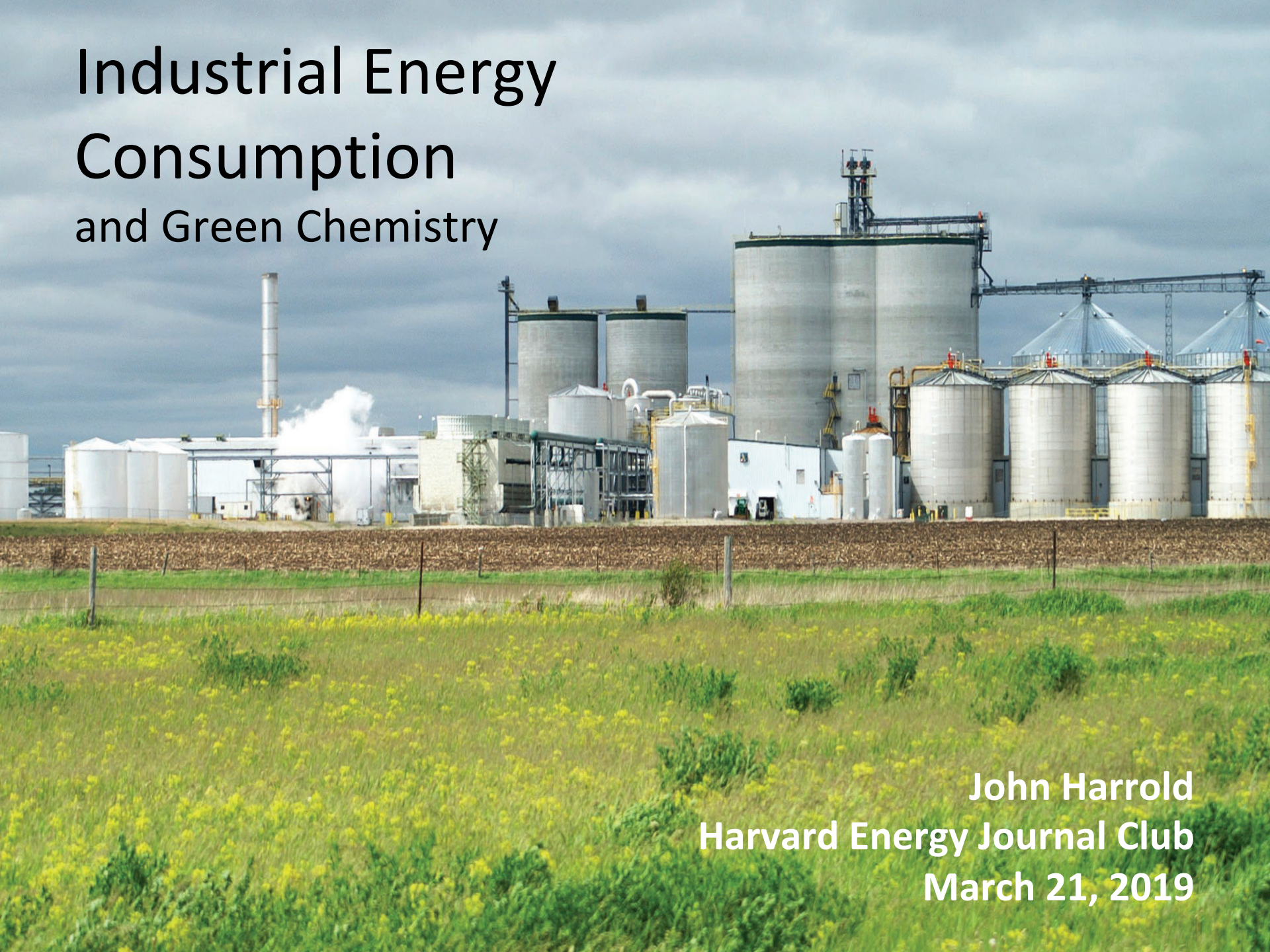
Industrial Energy Consumption

and Green Chemistry



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Harvard Energy Journal Club

March 21, 2019

Industrial energy consumption

1) Overview of energy consumption
    a) Totals
    b) Subsectors of indusial uses
    c) Combined Heat and Power
2) Examples of manufacturing
    a) Paper
    b) Bulk Chemicals (Zinc Oxide)
3) Green Chemistry Approaches
4) Conclusions and Questions

Annual Energy Outlook 2019

with projections to 2050

Independent Statistics & Analysis
U.S. Energy Information Administration

#AEO2019

January 24, 2019
www.eia.gov/aeo

Annual Energy Outlook 2019
with projections to 2050

January 2019

U.S. Energy Information Administration
Office of Energy Analysis
U.S. Department of Energy
Washington, DC 20585

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What is the Reference case?

- The AEO2019 Reference case represents EIA's best assessment of how U.S. and world energy markets will operate through 2050, based on many key assumptions. For instance, the Reference case projection assumes improvement in known energy production, delivery, and consumption technology trends.

- The economic and demographic trends reflected in the Reference case reflect current views of leading economic forecasters and demographers.

- The Reference case generally assumes that current laws and regulations that affect the energy sector, including laws that have end dates, are unchanged throughout the projection period. This assumption is important because it permits EIA to use the Reference case as a benchmark to compare policy-based modeling.

- The potential impacts of proposed legislation, regulations, or standards are not included in the AEO2019 cases.

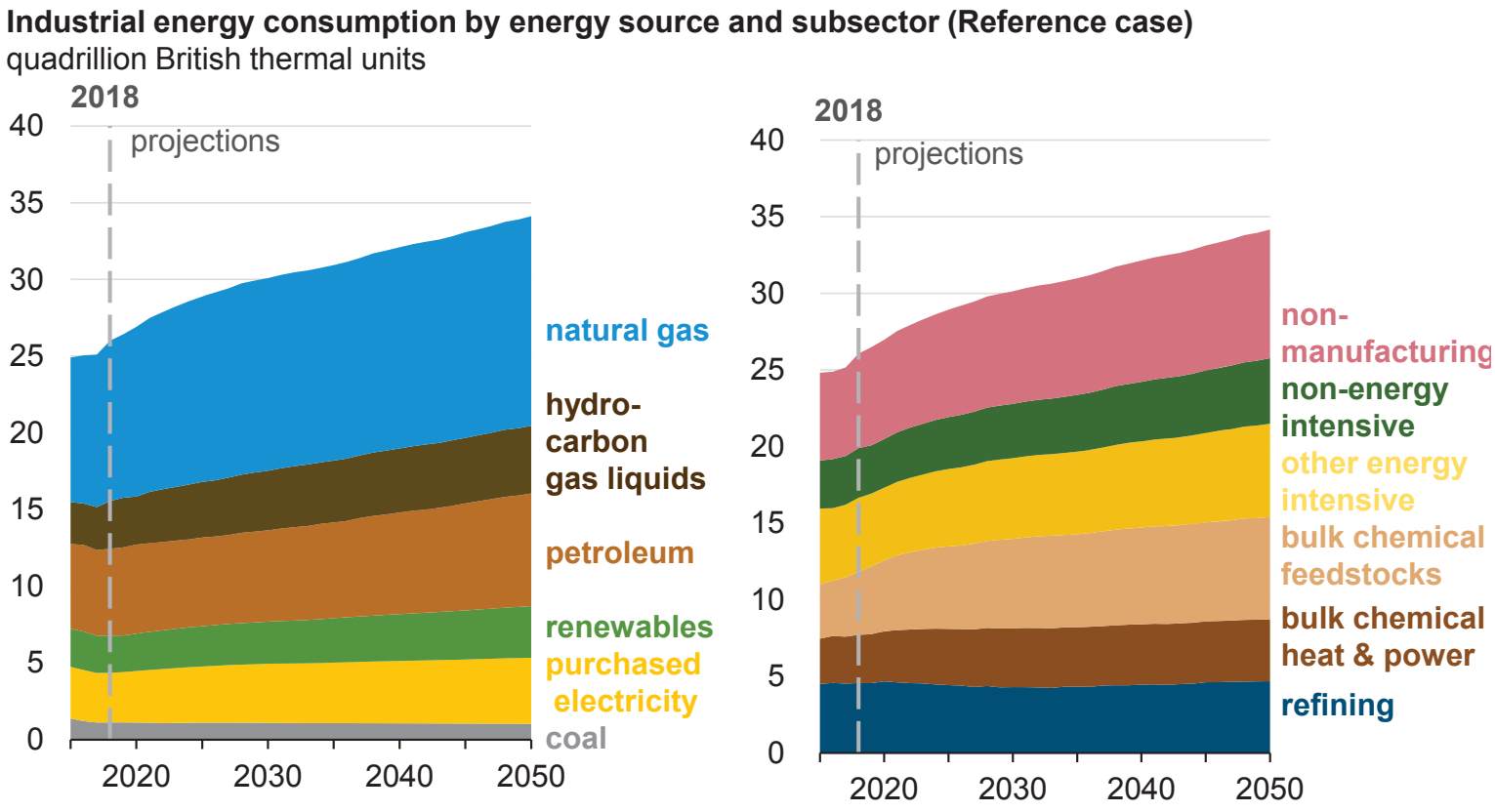
- The Reference case should be interpreted as a reasonable baseline case that can be compared with the cases that include alternative assumptions.

Industrial

Energy consumption in the industrial sector increases between 2018 and 2050 across all cases. Increases in industrial energy use from increasing shipments are partially offset by efficiency gains. Consumption of all energy sources except coal increases, while coal consumption declines.

Overview of energy consumption

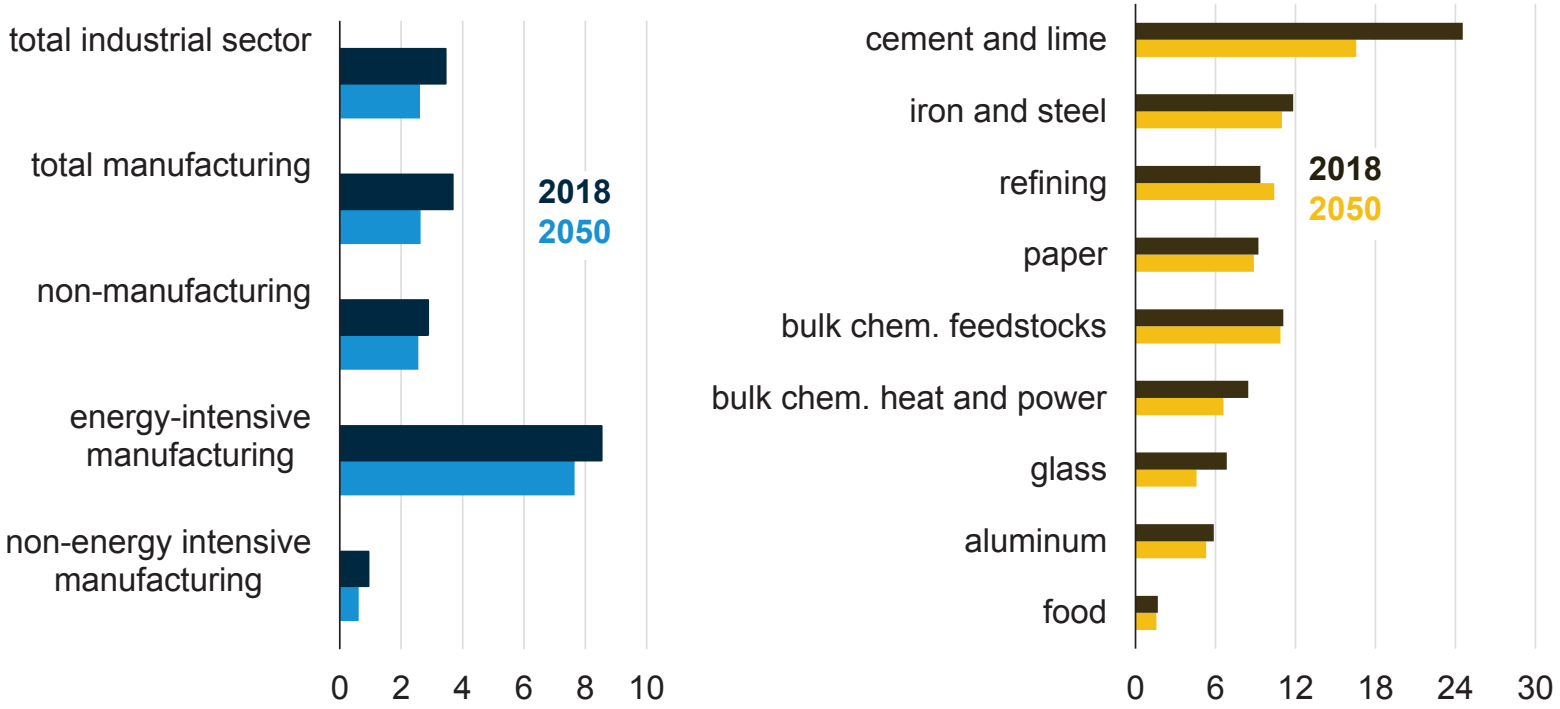
Industrial sector energy consumption increases at a similar rate for most fuels in the Reference case—



—and bulk chemicals and nonmanufacturing are the fastest-growing industries

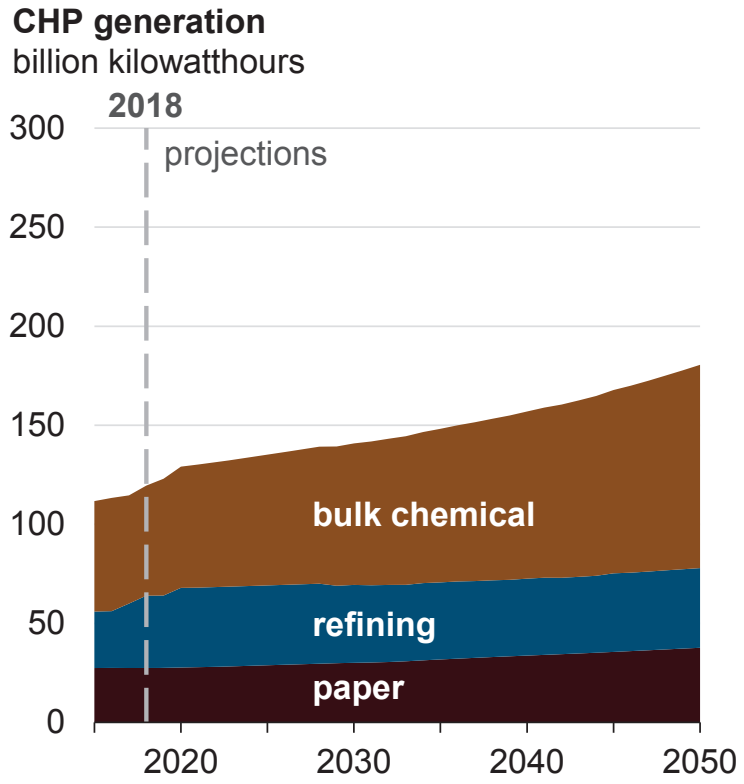
Energy Intensity by subsector

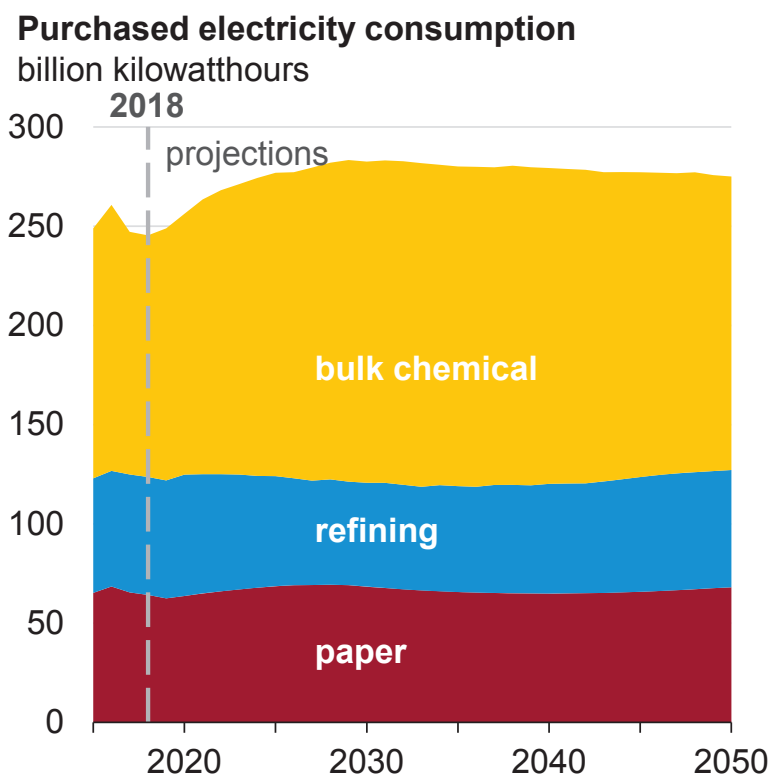
Energy intensity by subsector and energy intensive manufacturing industry (Reference case)
trillion British thermal units per billion 2009 dollar shipments



Self-generation from combined heat and power (CHP), especially for bulk chemicals, grows—

CHP and purchased electricity consumption for three industries with most installed CHP (Reference case)





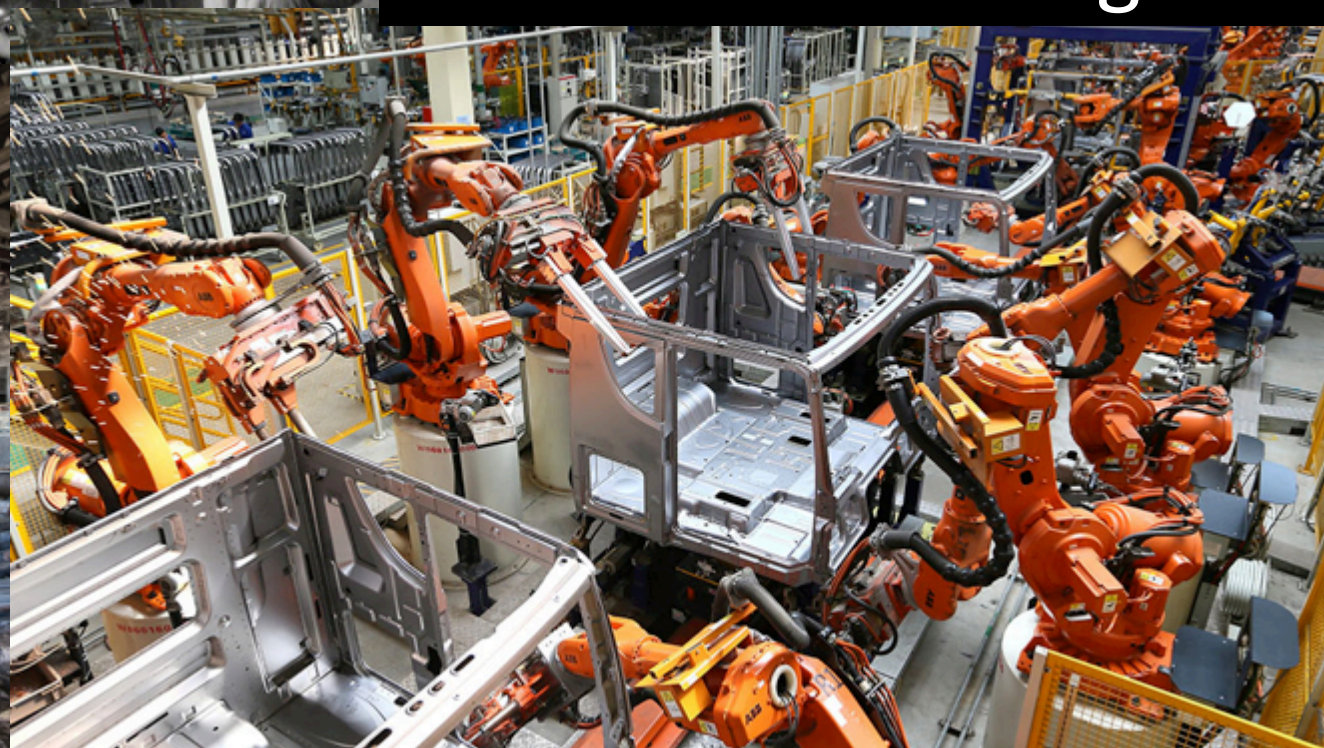
—even though electricity purchases for major CHP users remain flat during the projection period in the Reference case

Table 7-1. World industrial sector: major groupings and representative industries

Industry grouping	Representative industries
Energy-intensive manufacturing	
Food	Food, beverage, and tobacco product manufacturing
Pulp and paper	Paper manufacturing, printing and related support activities
Basic chemicals	Inorganic chemicals, organic chemicals (e.g., ethylene propylene), resins, and agricultural chemicals; includes chemical feedstocks
Refining	Petroleum refineries and coal products manufacturing, including coal and natural gas used as feedstocks
Iron and steel	Iron and steel manufacturing, including coke ovens
Nonferrous metals	Primarily aluminum and other nonferrous metals, such as copper, zinc, and tin
Nonmetallic minerals	Primarily cement and other nonmetallic minerals, such as glass, lime, gypsum, and clay products
Nonenergy-intensive manufacturing	
Other chemicals	Pharmaceuticals (medicinal and botanical), paint and coatings, adhesives, detergents, and other miscellaneous chemical products, including chemical feedstocks
Other industrials	All other industrial manufacturing, including metal-based durables (fabricated metal products, machinery, computer and electronic products, transportation equipment, and electrical equipment)
Nonmanufacturing	
Agriculture, forestry, fishing	Agriculture, forestry, and fishing
Mining	Coal mining, oil and natural gas extraction, and mining of metallic and nonmetallic minerals
Construction	Construction of buildings (residential and commercial), heavy and civil engineering construction, industrial construction, and specialty trade contractors

[294]Delivered energy is measured as the heat content of energy at the site of use. It includes the heat content of electricity (3,412 Btu/kWh) but does not include conversion losses at generation plants in the electricity sector. Delivered energy also includes fuels (natural gas, coal, liquids, and renewables) used for combined heat and power facilities (cogeneration) in the industrial sector.

Manufacturing



Paper Manufacturing

How It’s Made: Paper

https://www.youtube.com/watch?v=dX8xsVGILPY

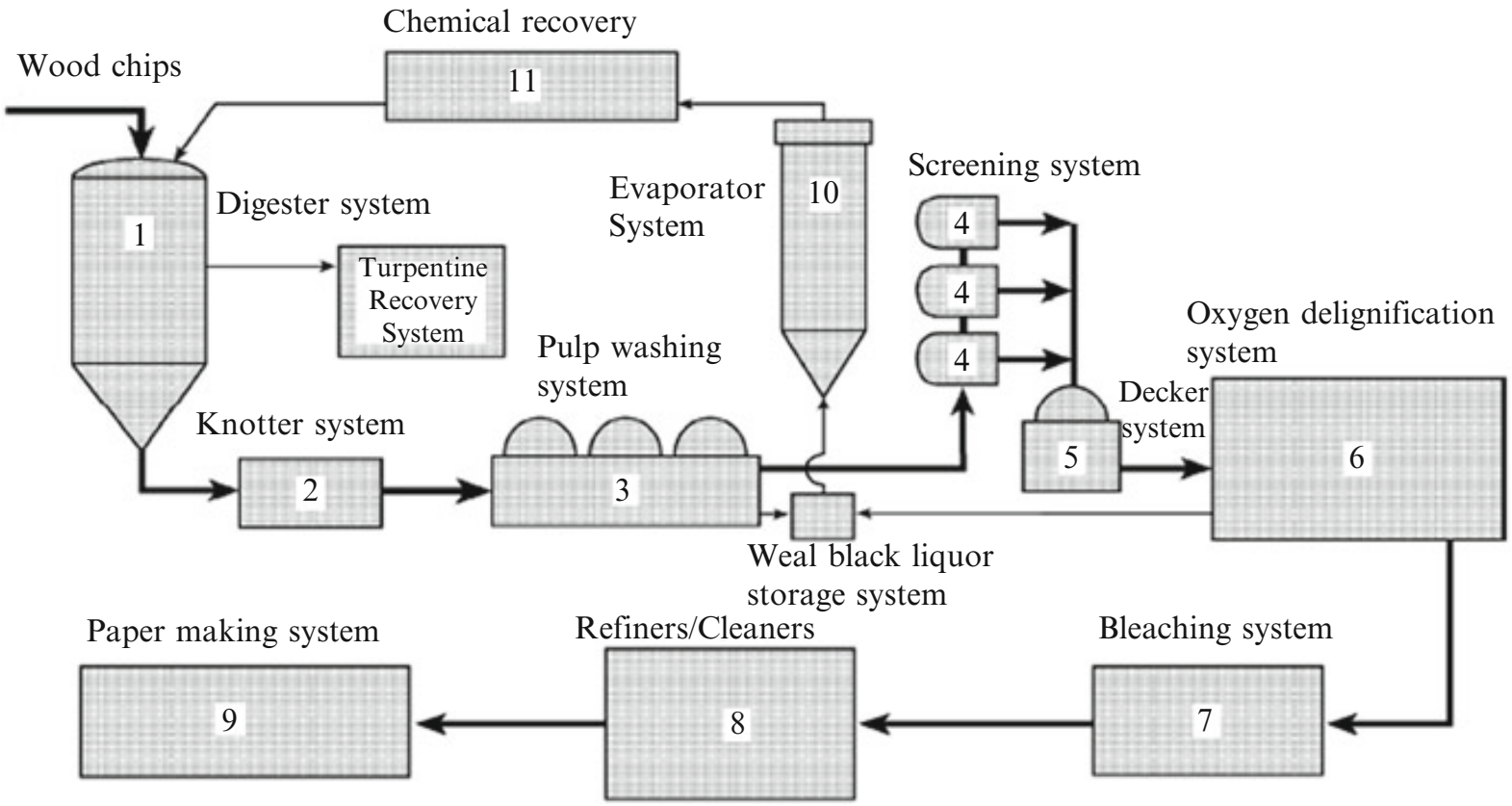
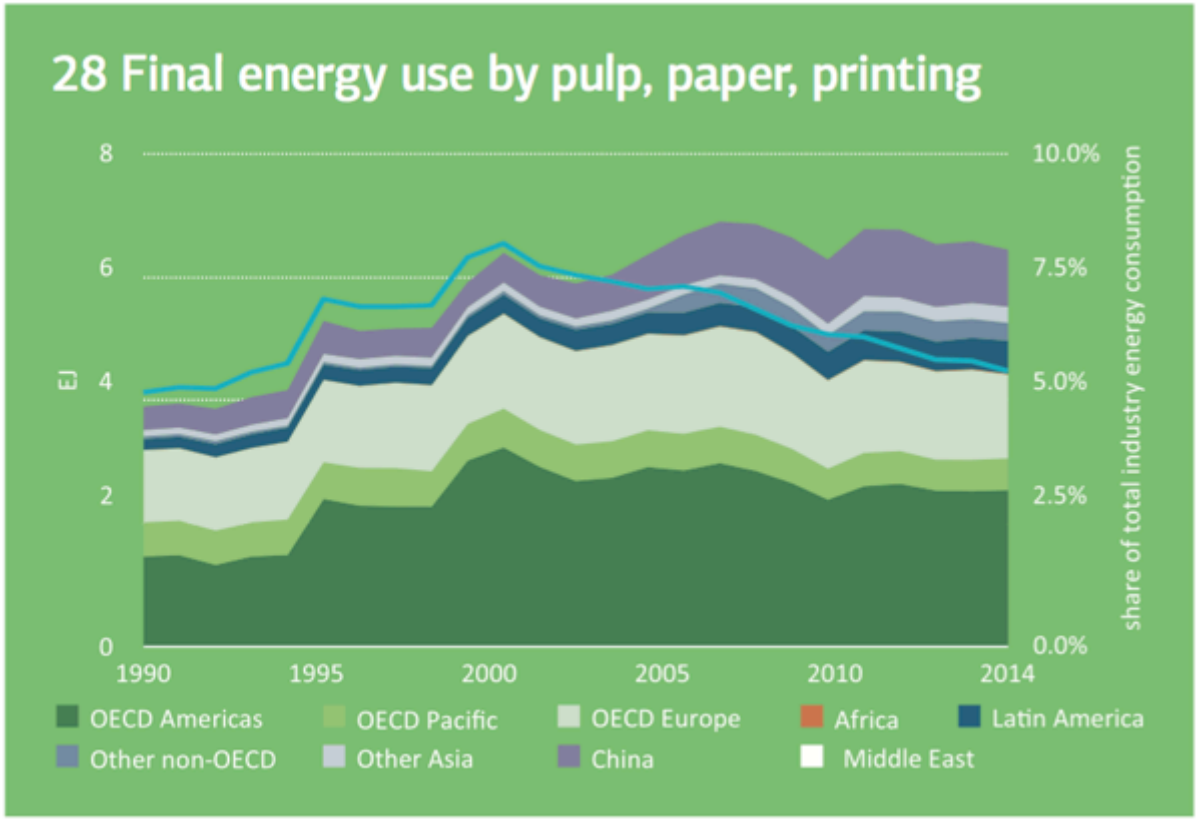


Fig. 2.1 Overview of kraft pulping mill with papermaking system. Based on USEPA (1998)

Table 2.1 Steps involved in the manufacturing of pulp and paper

Operation	Processes
Raw material preparation	Debarking
	Chipping and conveying
Pulping	Chemical pulping
	Semichemical pulping
	Mechanical pulping
	Recycled paper pulping
Chemical recovery	Evaporation
	Recovery Boiler
	Recausticizing
	Calcining
Bleaching	Mechanical or chemical pulp bleaching
Stock preparation and papermaking	Preparation of stock
	Dewatering
	Pressing and drying
	Finishing

Energy Use in Paper Making



55%

OF FIBRE USED FOR PULP MANUFACTURING GLOBALLY IN 2014 WAS FROM RECOVERED WASTE PAPER, UP FROM 44% IN 2000

Energy Use in Paper Making

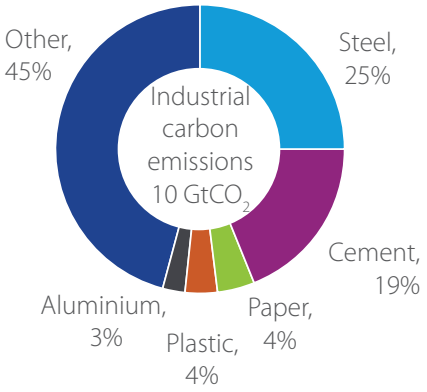
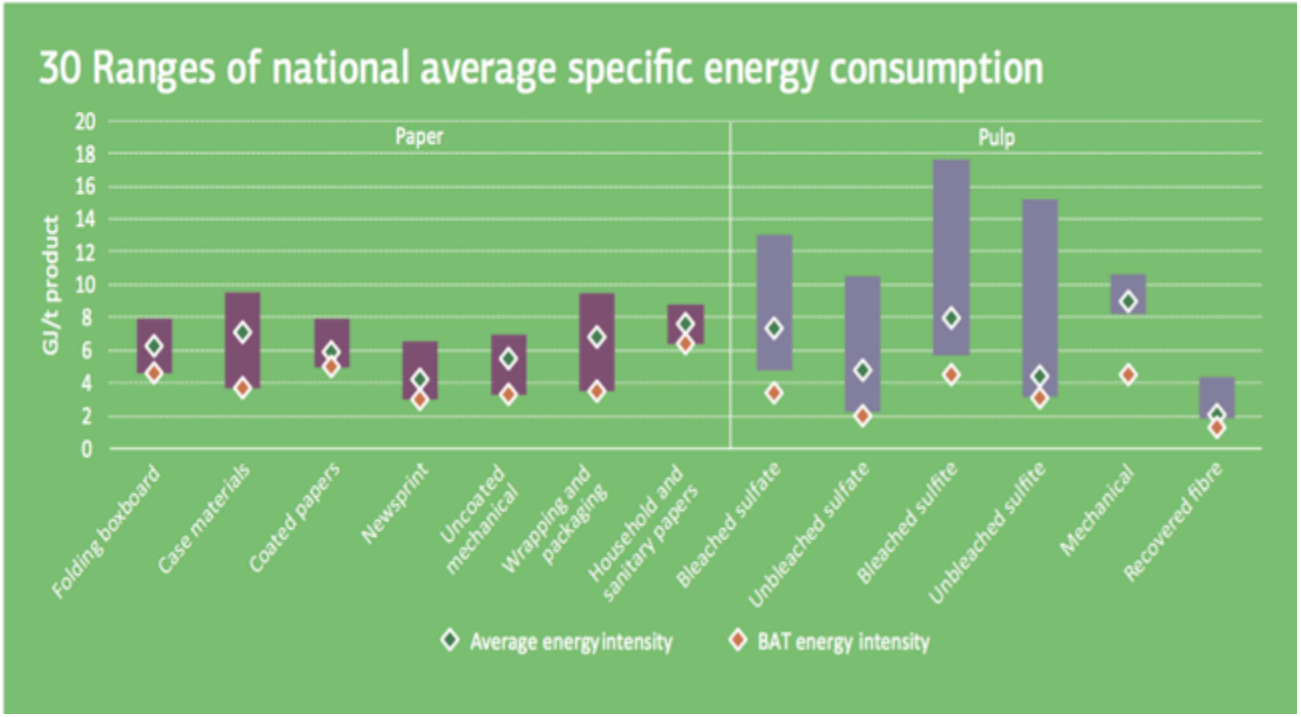


Figure 2.1—**Pie charts showing the sources of global CO_2 emissions**



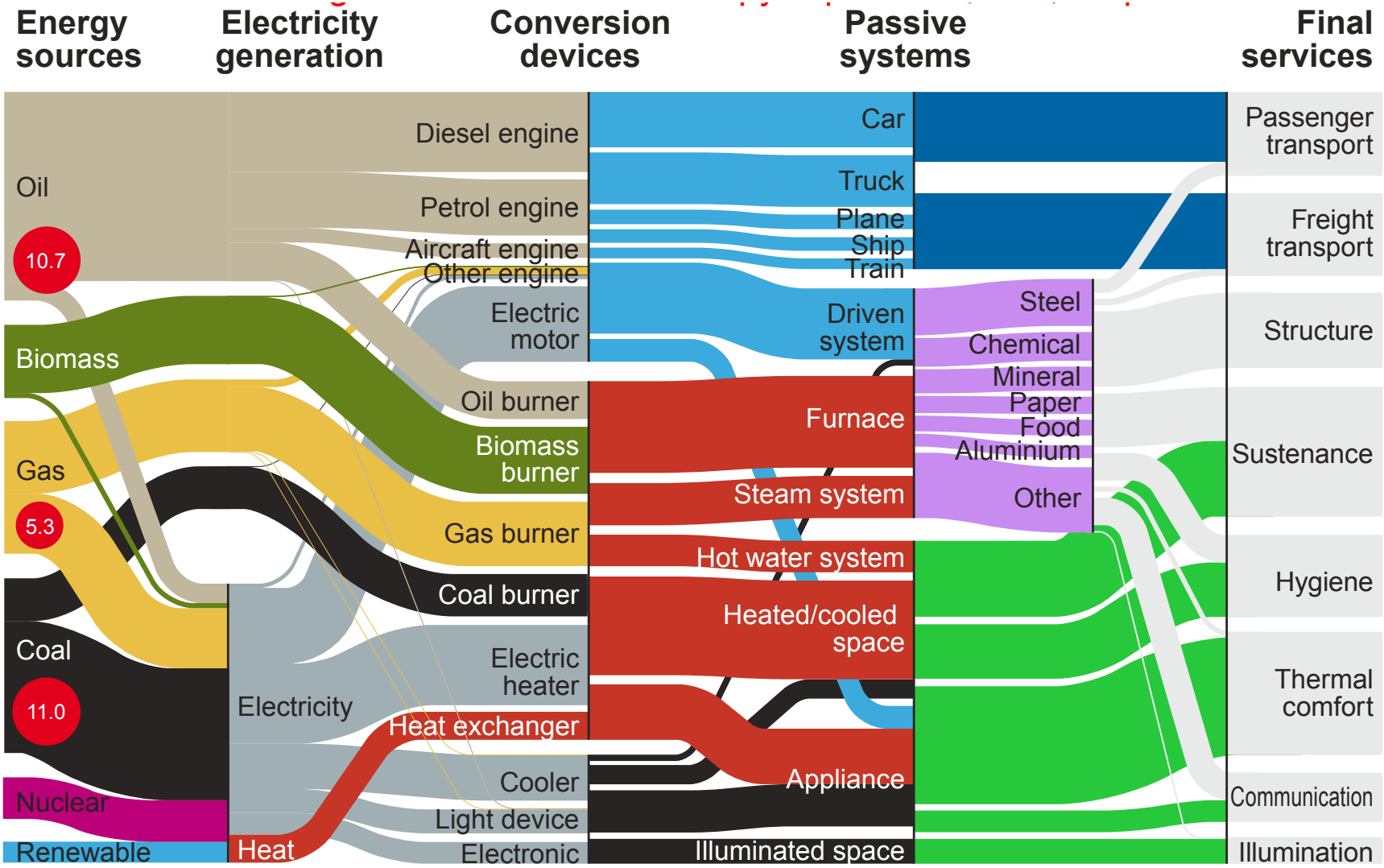
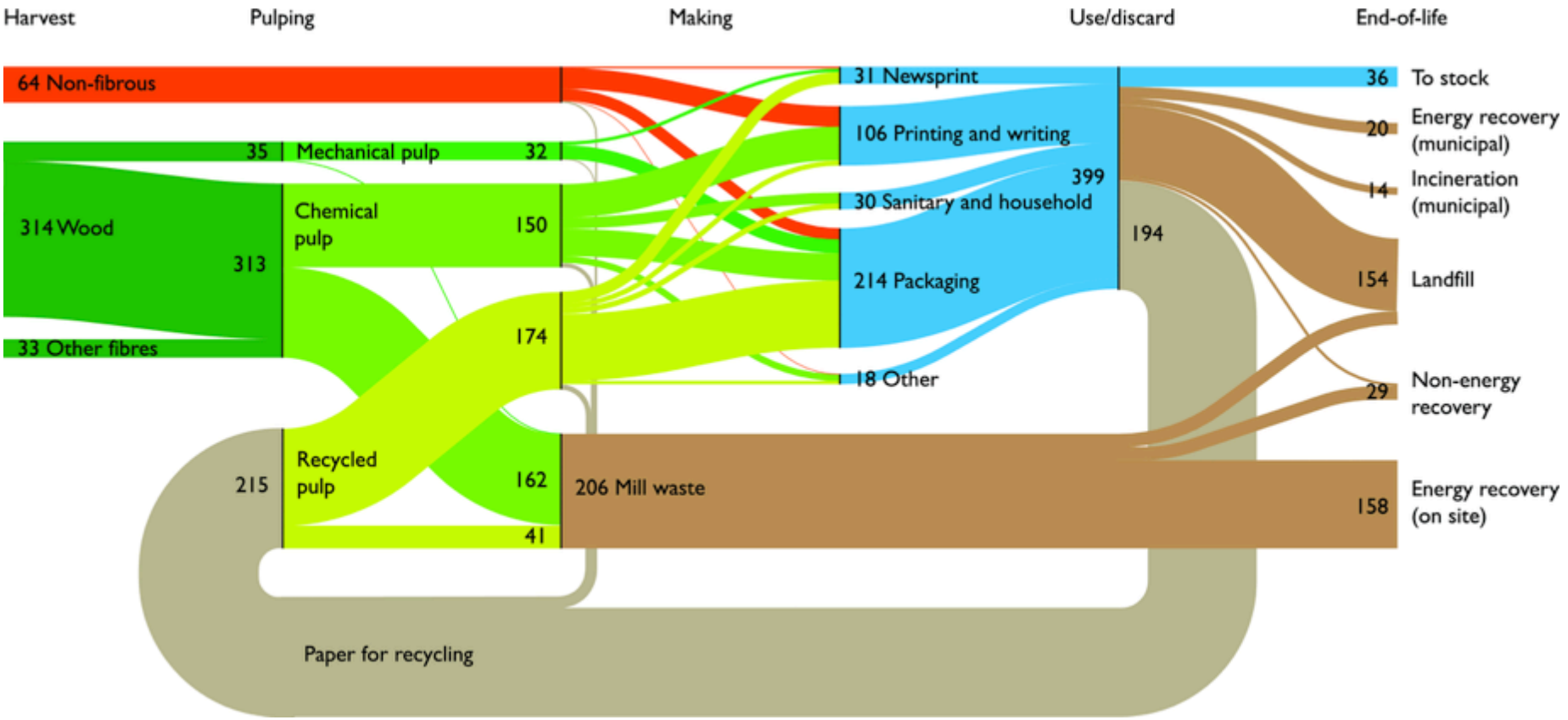


Figure 2.5—**Sankey diagram of global energy use**[18]

Global energy demand in 2005, total = 475 EJ

Global carbon emissions in 2005, total = 27 Gt CO_2

Global Paper Flow



Global paper flows in 2012 in megatonnes.

Global Life Cycle Paper Flows, Recycling Metrics, and Material Efficiency

Journal of Industrial Ecology, Volume: 22, Issue: 4, Pages: 686-693, First published: 06 June 2017, DOI: (10.1111/jiec.12613)

	Key RD&D challenges	Key RD&D focus areas over the next 5 years
Pulp & Paper	■ Black liquor gasification ■ Lignin extraction ■ Low carbon alternatives to traditional pulping ■ Alternative drying and forming processes	■ Scale up development of gasification designs, including low-temperature steam reforming process and high-temperature entrained flow reactor ■ Develop lignin extraction processes that fulfill technical and economic maturity market requirements ■ Conduct first feasibility studies and pilot testing of this process will bring it closer to commercialization ■ Conduct additional study and testing is needed to bring these alternative processes to the market

Why is this RD&D challenge critical?

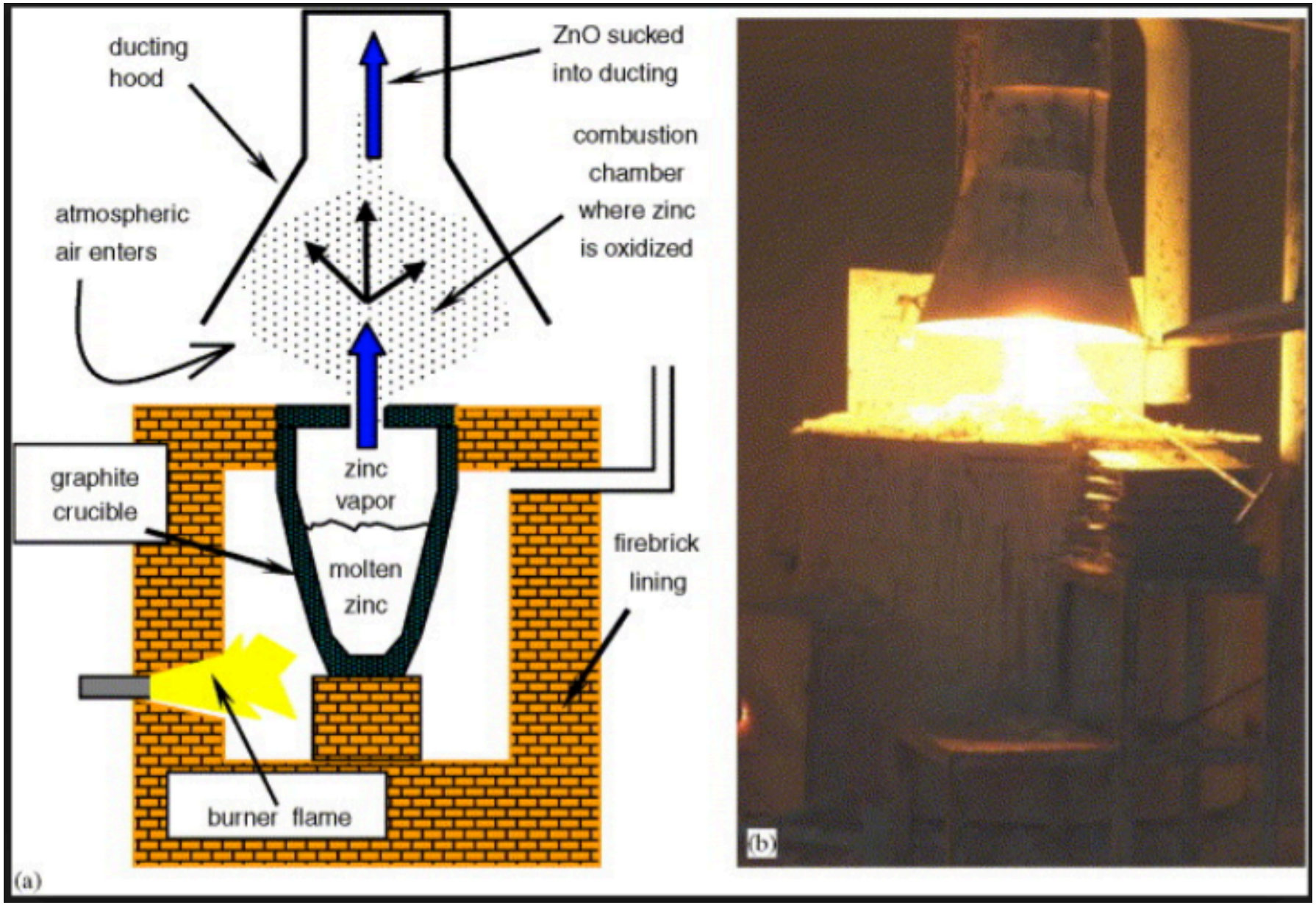
- Gasification of black liquor could increase the flexibility of end-uses for biomass-based by-products from the pulping process.
- Lignin can be isolated as a potential feedstock for new industrial products, such as new chemicals and plastics
- Alternative processes using deep eutectic solvents could have significantly lower carbon footprints for pulping, and could produce additional added value for pulp producers through the sale of pure lignin as a material
- Alternative drying and forming processes with lower water content could reduce energy consumption in these two steps

https://www.iea.org/publications/freepublications/publication/TrackingCleanEnergyProgress2017.pdf

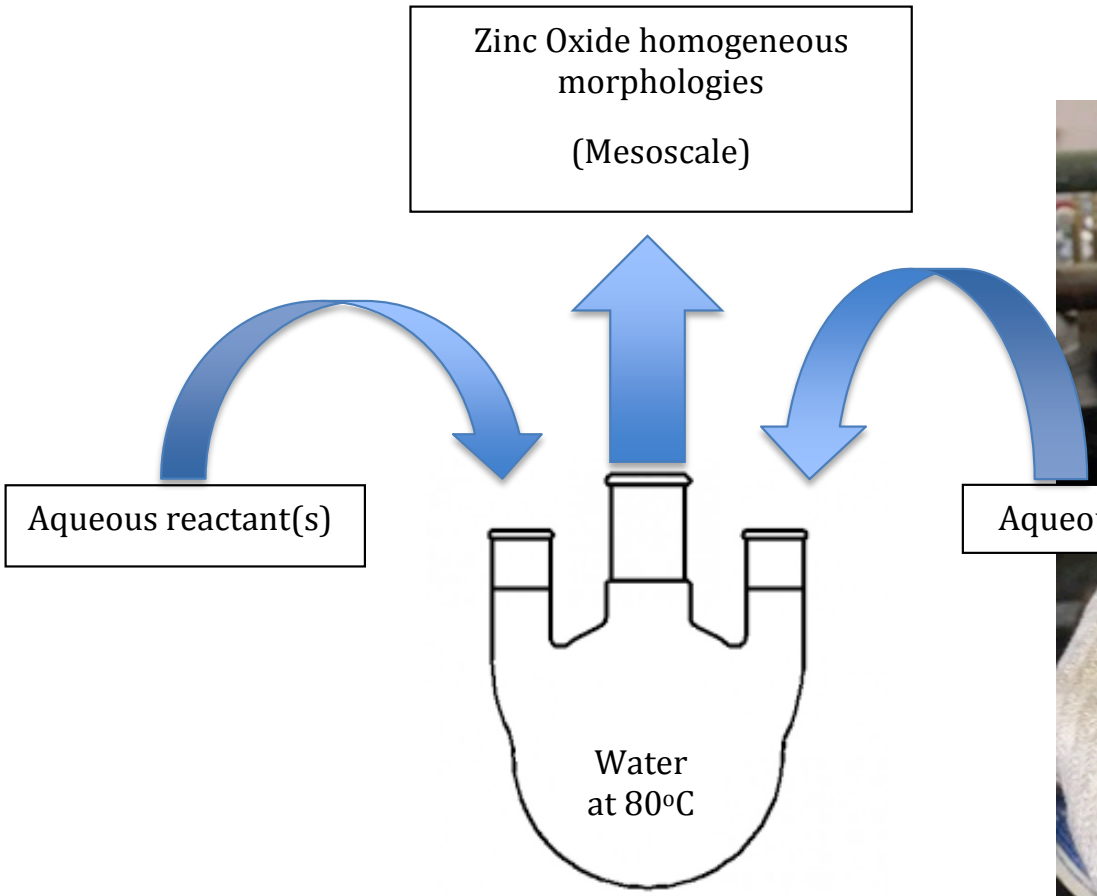
Bulk Chemical Manufacturing

Source: Woot.com

French Method: Zinc Oxide Manufacturing



“Italian” Method: Zinc Oxide Manufacturing



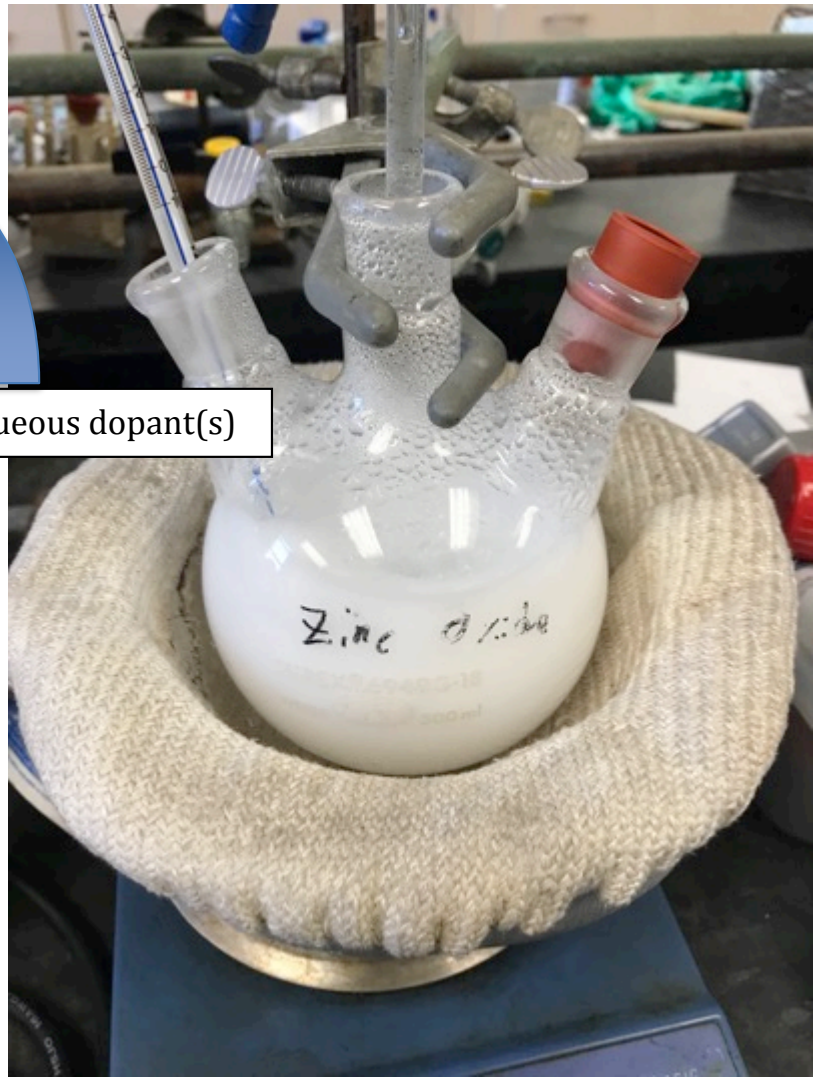
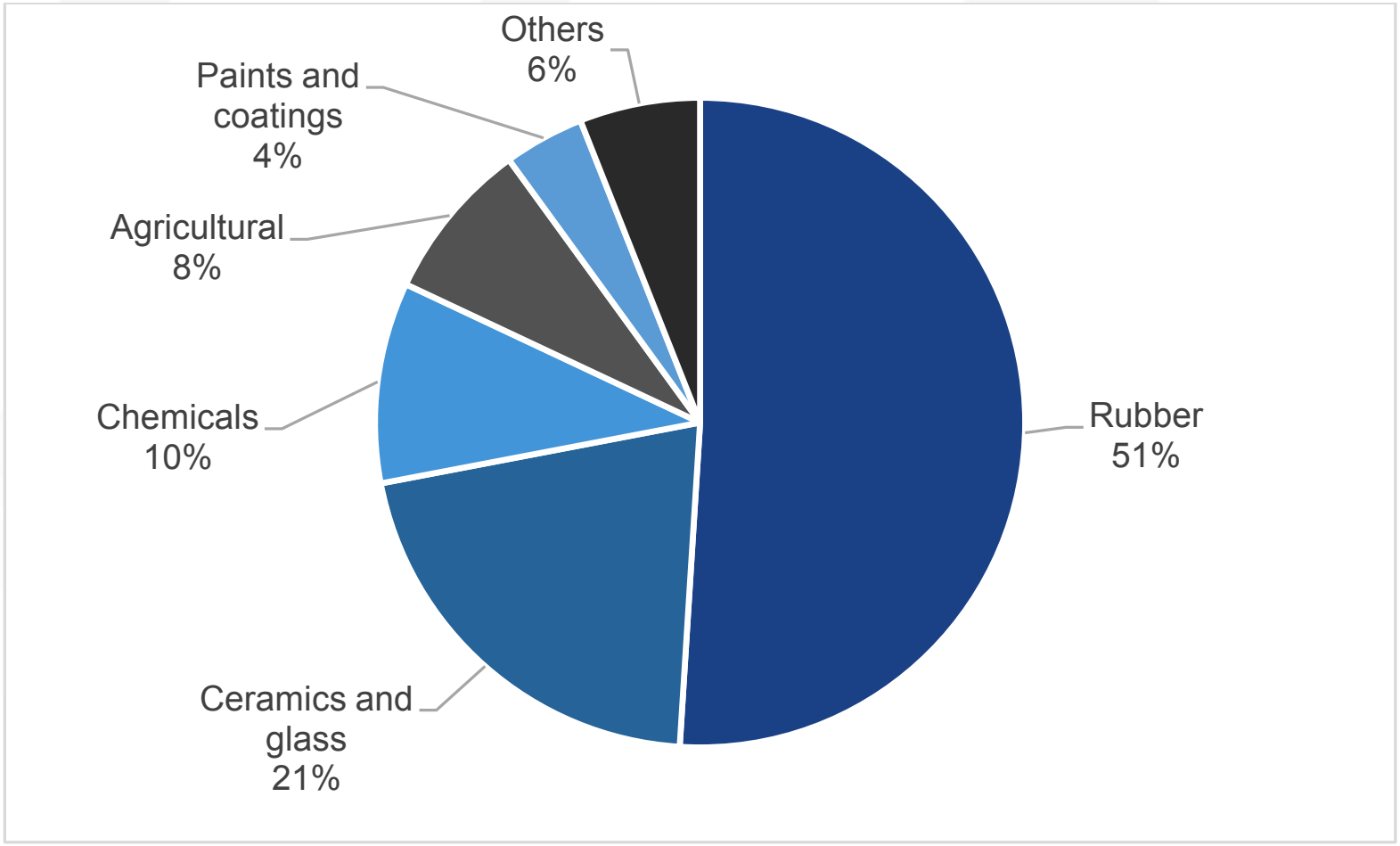
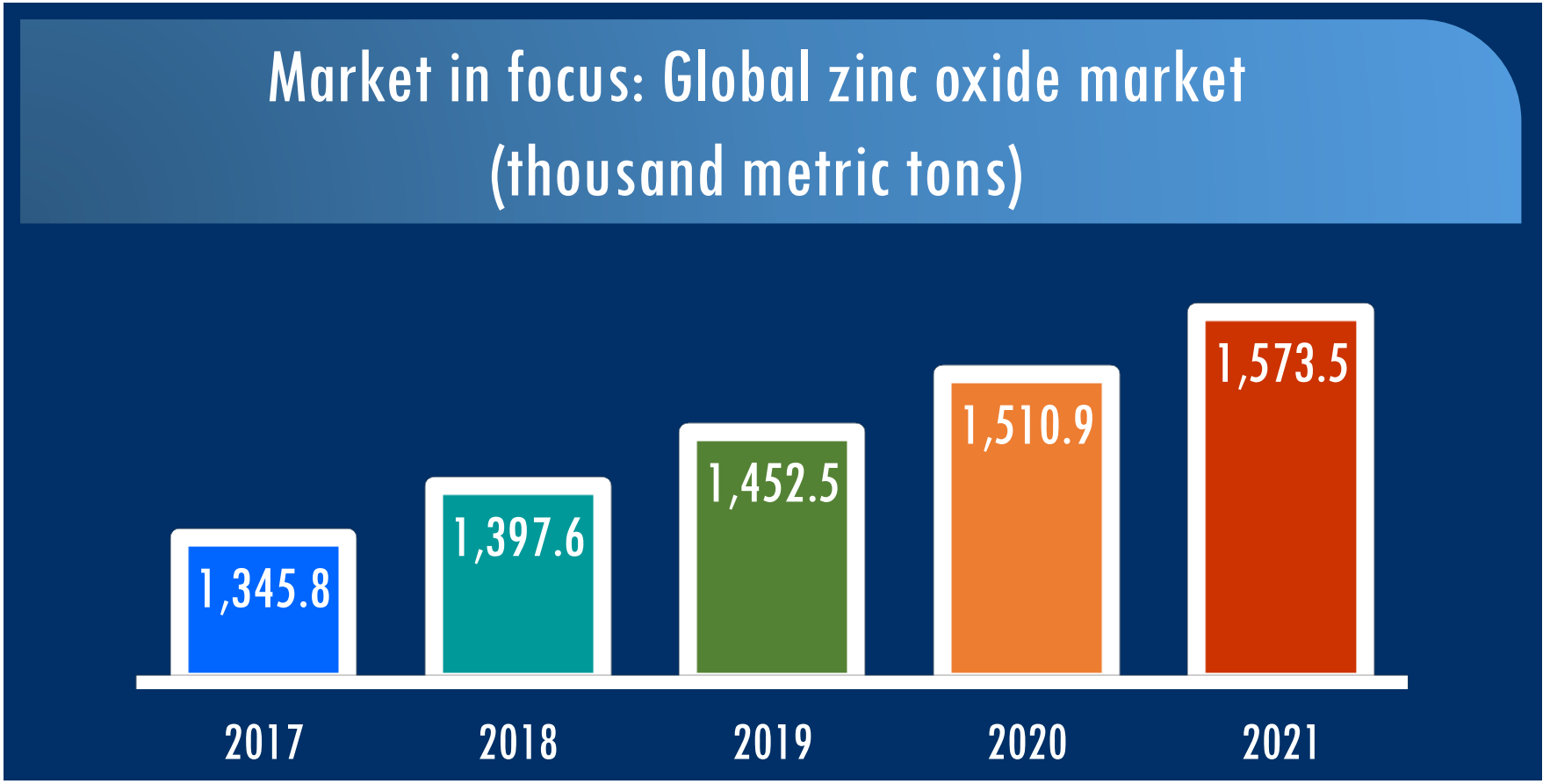


Exhibit 05: Global zinc oxide market by application 2016



Source: Technavio

Source: GLOBAL ZINC OXIDE MARKET 2017-2021 TECHNAVIO.COM



Energy Calculation	estimations		2017	2018	2019	2020	2021
Demand	1 Ton		1345.8	1397.6	145.2	1510.9	1573.5
(kJ)	4.19E+05	French	5.64E+08	5.85E+08	6.08E+07	6.33E+08	6.59E+08
(kJ)	6.74E+04	Italian	9.07E+07	9.42E+07	9.79E+06	1.02E+08	1.06E+08
Reduction in heating	84%						

Source: GLOBAL ZINC OXIDE MARKET 2017-2021 TECHNAVIO.COM

Green Chemistry Approaches

Reducing or removing
- volume of solvents
- environmentally harmful solvents
- environmentally harmful starting materials

Utilizing
- aqueous environments
- Enzymes in cell free environments

Lowering heat required

Utilizing aqueous environments

Biosynthetic pathways (Metabolic engineering)

Source: How Industrial Applications in Green Chemistry Are Changing Our World
https://www.acs.org/content/dam/acsorg/membership/acs/benefits/extra-insights/green-chemistry-applications.pdf

	Key RD&D challenges	Key RD&D focus areas over the next 5 years
Chemicals and Petro-chemicals	■ Naphtha catalytic cracking ■ Use of biomass-based feedstocks ■ Electricity-based hydrogen for ammonia & methanol	■ Explore avenues for further commercial deployment and increasing throughput ■ Promote further research to reduce energy consumption and costs in current biomass-based chemical production ■ Further research to bring down costs and increase capacity of electrolysers

Why is this RD&D challenge critical?

- This technology shows energy savings compared with the widely used steam cracking process
- CO_2 emissions associated with feedstocks for chemical production can be avoided using biomass to produce light olefins, methanol and ammonia
- Ammonia and methanol production through renewable electricity-based processes removes all direct carbon emissions.

https://www.iea.org/publications/freepublications/publication/TrackingCleanEnergyProgress2017.pdf

For more information

U.S. Energy Information Administration homepage | https://www.eia.gov/

Short-Term Energy Outlook | https://www.eia.gov/outlooks/steo/report/

Annual Energy Outlook | https://www.eia.gov/outlooks/aeo/

International Energy Outlook | https://www.eia.gov/outlooks/ieo/

Monthly Energy Review | https://www.eia.gov/totalenergy/data/monthly/

Today in Energy | https://www.eia.gov/todayinenergy/

Thank you!

- Comments?
- Questions?
- Inspiration?