TECHNICAL BRIEFING | APRIL 2026

Harnessing energy productivity

for industrial competitiveness in a low carbon world

MISSION POSSIBLE PARTNERSHIP

Energy Transitions Commission

The productivity leap

As we navigate the complex path to a cleaner world, energy productivity, the economic value generated per unit of energy consumed, must become a central pillar of growth strategy.

Put simply, we must deliver greater prosperity and better standards of living to people around the globe by using energy more efficiently. Creating more value from lower energy and material inputs is an environmental imperative as well as an economic opportunity. The materials, chemicals and fuels that power modern economies are fundamental to competitiveness, resilience and long-term economic strength.

Demand for industrial outputs will expand dramatically in the next decade, driven by rising global prosperity, urbanisation, industrialisation in emerging economies and a warming climate. By 2050, aviation and cooling services are projected to increase by 150%, while road transport demand could rise by 70%. Demand for the core materials that underpin our everyday lives, including aluminium, cement, chemicals and steel, is expected to grow by up to 100%.

Meeting this growth while transforming the foundational systems on which it is built is the defining challenge of our time. At the Energy Transitions Commission and Mission Possible Partnership, our work is anchored in four priorities which must be achieved within the next decade. **Double down -** doubling the rate of energy efficiency improvement to 4% by 2030; **Triple up** - tripling global renewable power capacity by 2030; **Electrify –** scaling clean electrification of final energy demand; and **Build Clean Now,** moving clean industrial capacity from ambition to execution. Energy productivity has a vital role to play.

Energy-intensive industries rely on global supply chains and long-lived industrial assets. Transforming them is a complex challenge. Despite this, the transition to low-carbon solutions is underway with more than 1,000 commercial-scale clean industrial projects under development using a mix of direct and indirect electrification, sustainable fuels, and carbon management solutions. Without improvements in energy productivity, the industry transition could require a much larger expansion of energy supply and infrastructure, with corresponding cost. With it, we can reduce the need for investment in upstream energy infrastructure and in capital-intensive clean industrial assets, lower production cost and counter the green premium that exists in some industries.

This briefing makes a clear case: energy productivity is crucial to keeping the cost of decarbonisation low speeding up industry transformation and enhancing industrial competitiveness in a low-carbon world. Implementing key efficiencies could reduce final energy demand by up to 45% compared to business-as-usual. The three efficiency levers are:

- Technical efficiency - reducing the kWh input required to deliver the same product or service.
- Service efficiency - reducing the volume of product or service required to deliver the same standard.
- Material efficiency - reducing the material input to deliver a given product.

The benefits are substantial. In aluminium, secondary production through recycling is approximately 95% less energy-intensive than primary production; in steel, recycled production can reduce energy use by around 60–80%. In cement, reducing clinker content is the biggest lever to lower energy requirements at the production stage, but optimising building design represents a major lever to reduce the need for energy-intensive materials in the first place. In aviation, improvements in aircraft weight, aerodynamics, and operations could reduce fuel demand by around 25%, saving an estimated $135 billion annually by 2050.

Improving energy productivity will strengthen competitiveness over this decade. As industries adopt higher-cost, low-carbon energy and carbon management solutions, reducing fuel and material volumes directly lowers exposure to green premiums. System-wide, enhanced productivity could reduce global energy investment needs by an estimated $15 trillion over the next quarter of a century.

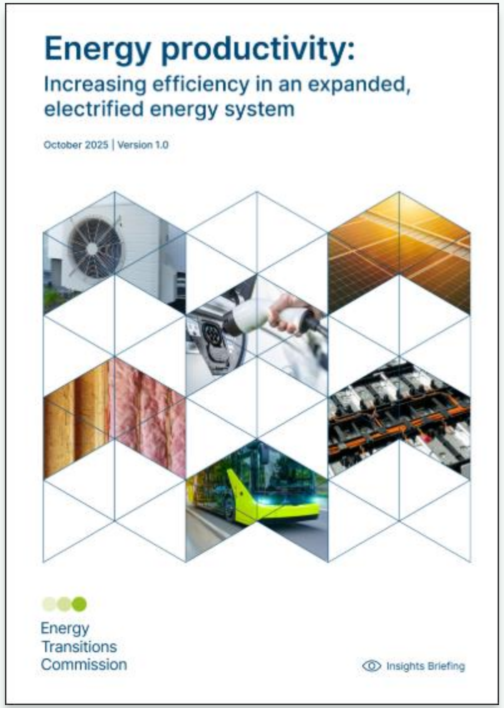
The technologies exist. The economics are compelling. What is now required are clear policy signals on carbon pricing, standards and infrastructure that reward energy productivity, reduce energy demand and system costs, and unlock final investment decisions in efficient and clean industrial assets.

We hope this briefing provides a practical roadmap—and a catalyst—for the leadership needed to unlock energy productivity across the world's most critical sectors.

Lord Adair Turner
Co-Chair, Energy Transitions Commission

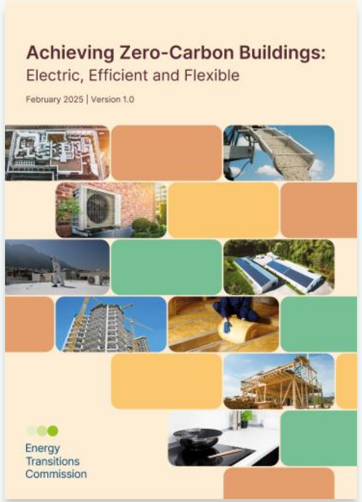
Faustine Delasalle
CEO, Mission Possible Partnership
Vice-Chair, Energy Transitions Commission

'Unlocking Energy Productivity in Energy-Intensive Sectors' is part of the wider series of ETC reports on energy productivity



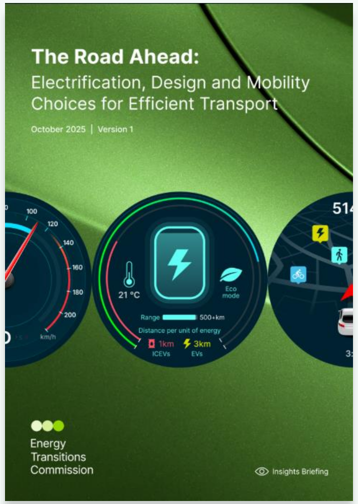
Launched October 2025

An economic-wide overview of the potential for energy productivity, laying out key priority actions, future final, primary and useful energy demand; impact on living standards, costs and resources; implications for COP28 target, and of rebound effects and AI



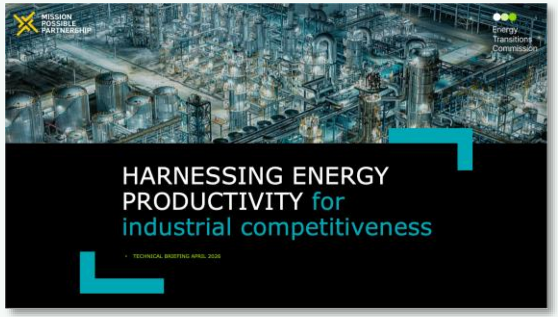
Launched February 2025

Buildings, encompassing both in-use structures and those under construction.



Launched December 2025

Road transport, covering both passenger and freight aspects.



THIS TECHNICAL BRIEFING

Launched April 2026

Heavy industry and long-distance transport, consolidating insights from the Mission Possible Partnership (MPP) analysis.

ETC's Energy Productivity work is distinct from published reports in energy efficiency in several ways

1. Energy services and GDP can grow while energy input declines
   The report brings clarity that it is possible to grow energy productivity: increasing energy services (and GDP) while using less energy overall.

2. Productivity beyond just efficiency
   Beyond technical efficiency - in the form of electrification and high-efficiency equipment, which remain the main levers - productivity includes improvements in how we use materials (e.g. recycling and re-use) and how services are delivered (e.g. shared mobility, smart controls).

3. A sharper definition of maximum annual improvement potential, to meet the doubling of annual improvement in energy efficiency target from COP28 (reiterated at COP30)
   This analysis breaks down the aggregate target by sector and technology, clarifies the difference between primary and final energy, and highlights where rapid progress can be made in next decade.

Mission Possible Partnership is distinct in its singular focus on advancing clean industry

- Mission Possible Partnership (MPP) is an independent organisation advancing global clean industry transformation. Since 2019, we have been working exclusively with some of the most energy-intensive industries: aluminium, aviation, cement, chemicals, shipping and steel, to cut their nearly 25% of global GHG emissions.
- We mobilise business, finance, government and civil society leaders to speed up the shift to clean materials, chemicals and fuels. Having charted industry-endorsed sectoral pathways to net-zero, we continue to forge new territory, lifting the barriers to enable a critical mass of clean industrial projects to break ground by 2030. By accelerating projects, we can scale up clean value chains and unlock exponential growth in clean commodities markets to produce the building blocks of modern society and power economic growth.
- Operating around the world, we have a unique view on the state of the clean industrial transformation. We map progress on 'deep decarbonisation' projects, ones that use technologies to reduce emissions by at least 70-80%, through our Global Project Tracker, which is the reference point for the pipeline of commercial-scale clean industrial projects worldwide. Where near-zero technologies have been slower to scale, complementary approaches are driving additional near-term progress. This is particularly relevant for the materials and high-value chemicals sectors.

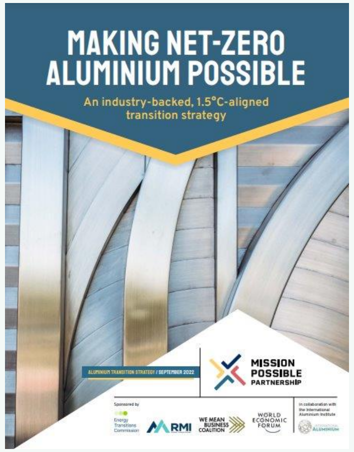
Assessment of energy productivity for energy-intensive sectors is based on detailed sector transition strategies developed by Mission Possible Partnership

Mission Possible Partnership developed seven detailed sector transition strategies (STS) in 2022, with an additional report by Systemiq on Chemicals, which modelled decarbonisation outlooks under across sectors, including assumptions on energy productivity potential (e.g. increasing materials durability and reuse, increasing recycling rates, improving energy consumption based on best available technologies, etc.) Since 2022, we have seen new sector developments, but the STSs still provide a reasonable estimate for long-term outlooks.

ENERGY-INTENSIVE SECTORS

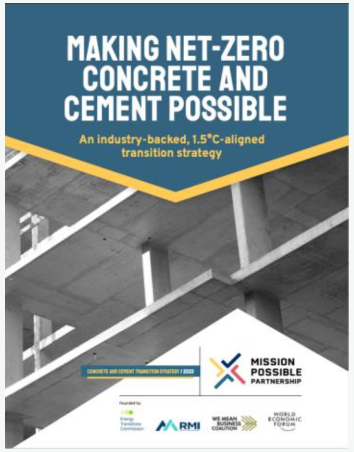
HEAVY INDUSTRY

Aluminum

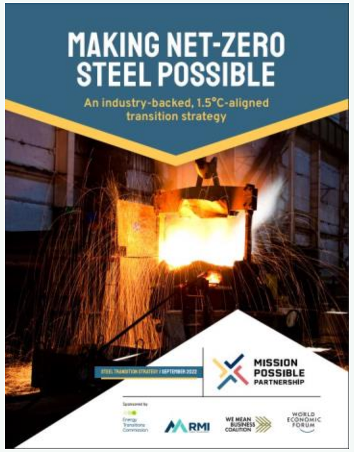


Chemicals

Concrete/Cement

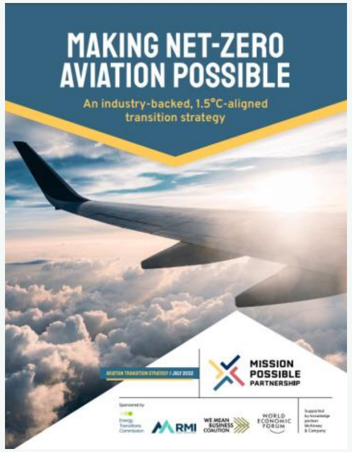


Steel

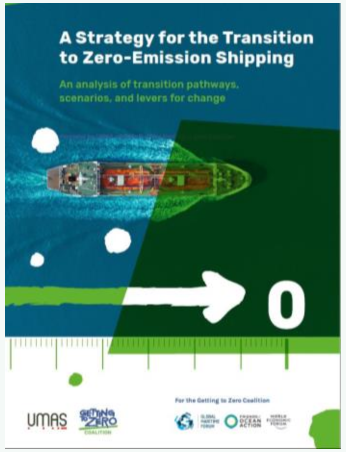


LONG DISTANCE TRANSPORTATION

Aviation



Shipping



Note: The 7 Sectorial Transition Strategy from Mission Possible Partnership were: Aluminium, Ammonia, Concrete/Cement, Aviation, Shipping, Steel and Trucking. On this report we make use of 6 of them - we address the trucking sector in the report "The Road Ahead"; and we address growth in Ammonia demand as a sustainable shipping fuel under the Shipping sector.

The world can deliver a doubling of global GDP and expand energy services while requiring less primary and final energy through higher productivity – delivering this in heavy industry is crucial to reducing costs and enhancing competitiveness

- Demand is set to grow. Heavy industry and long-distance transport demand (aviation and shipping) are projected to grow from now to 2050: steel, aluminium, cement, plastics and chemical* demand are projected to grow by 25–100%; aviation demand by ~150%; shipping by ~45%.
- Low-carbon fuels may increase energy use. Transitioning to a net-zero system by 2050 requires these sectors to rely more on low carbon fuels, such as hydrogen and sustainable fuels and carbon capture and storage (CCS). This shift will likely increase primary energy demand, the energy required at the source before conversion losses occur, as these are all energy-intensive solutions.
- Improving energy productivity across all sectors, however, can significantly reduce the costs of decarbonisation and streamline the system-wide integration of these low-carbon technologies (e.g., by reducing required volumes of hydrogen, carbon capture and renewables and associated energy infrastructure pressure).
- Overall energy demand can still reduce, increasing productivity. Across energy-intensive sectors, productivity actions can reduce final energy demand (energy inputs after conversion losses) by 25–45% vs. a 2050 baseline, which assumes no changes from today's efficiency standards.
- Reducing costs. As sectors shift to higher-cost low-carbon fuels and CCS, green premiums are likely. Energy productivity can counterbalance some of the initial green premium by reducing fuel requirements, material intensity and system losses whilst ensuring greater competitiveness in decarbonisation pathways.

* Including Benzene, Butandiene, Ethylene, Propylene, Toluene, Xylene but excluding all Ammonia uses and Methanol and E-methanol for shipping use

Technical efficiency improvements and greater product utility can improve the productivity of energy use in heavy industry (aluminium, steel, cement, plastics) and transportation (shipping and aviation), lowering overall system needs.

- Higher productivity is achieved through three sets of actions: technical efficiency (e.g. fuel switching or higher efficiency processes), service efficiency (e.g. improved logistics) and material efficiency (e.g. recycling, longer building lifetimes). Key opportunities differ by sector:
  - In aluminium production, material efficiency by increasing secondary output via higher scrap collection and reduction of production waste
  - In plastic and chemicals service efficiency through reduction of single-use plastics via reuse, substitution and elimination
  - In cement, service and material efficiency via safely lowering the level of concrete per building, cement per unit of concrete, and clinker per unit of cement brings the biggest opportunity
  - In steel, a mix of material efficiency through higher scrap intake coupled with technical efficiency via increased production of steel in electric arc furnaces.
  - In aviation and shipping, technical efficiency in aircrafts and vessels by, for instance, making them lighter and more aerodynamic, with some additional gains via service efficiency by via better routing and increased utilization
- Improve system integration. As heavy industry and transport sectors decarbonise, low-carbon electricity, hydrogen and Carbon Capture (CCS) and associated infrastructure (e.g. grids) will be required. Improving the energy productivity of these sectors can reduce these requirements, lowering overall costs.

* Including Benzene, Butandiene, Ethylene, Propylene, Toluene, Xylene but excluding all Ammonia uses and Methanol and E-methanol for shipping use

Three levers to increase energy productivity – shipping as example sector

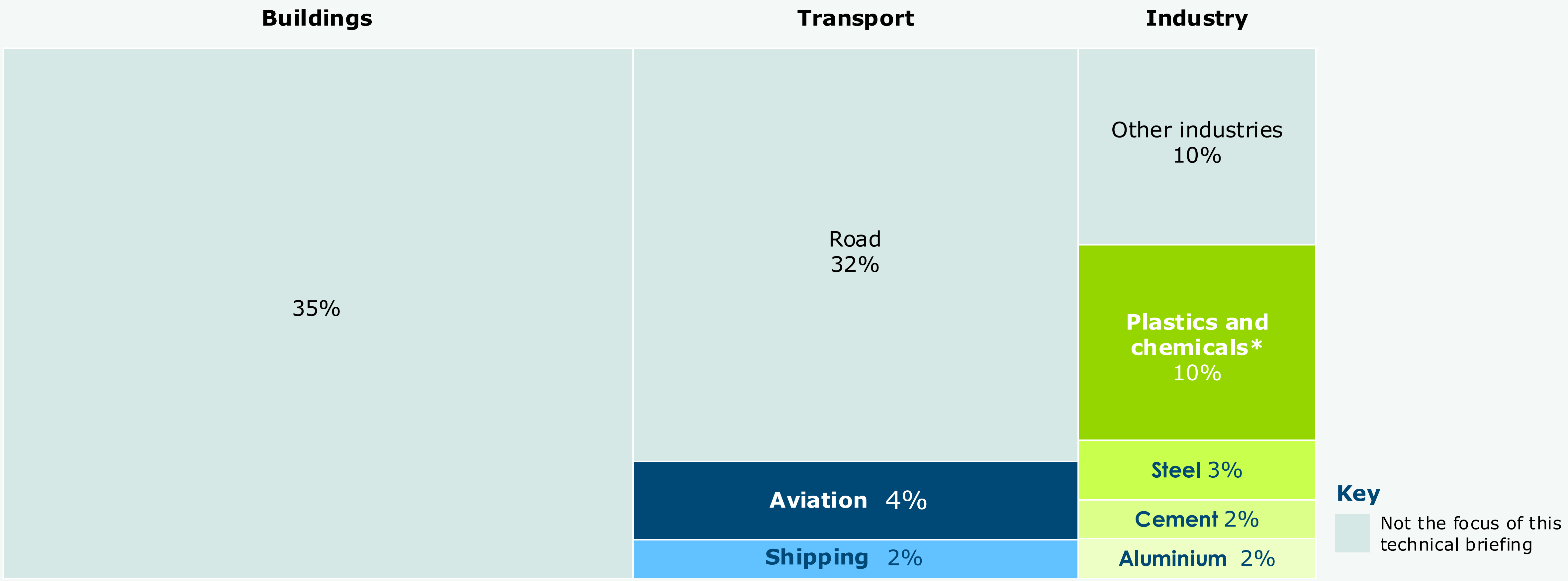
Target figure	Key lever	Impact	Example: Shipping sector
Energy Productivity* (GDP per unit of energy input) =	**Service efficiency**	Reduction in volume of product or service needed to deliver any given consumer living standard.	▪ Optimised shipping routes e.g. improved weather routing ▪ Improved port congestion management ▪ Speed reduction to cut fuel use
×	**Material efficiency**	Reductions in the amount of material input needed to deliver any given end product	• Extending vessel lifetimes • Increasing recycled steel content in ship construction
×	**Technical energy efficiency**	Reduced kWh input per product or service delivered	• Improved hull coatings, to reduce drag • Propeller upgrades and rudder retrofits to improve thrust efficiency • Engine efficiency improvements such as waste heat recovery

*Energy productivity is the inverse of energy intensity (energy input per unit of GDP), intensity is used for instance in many IEA reports.
Source: Systemiq analysis for the ETC.

~25% of total potential productivity gains in final energy by 2050 is in energy-intensive industries

Productivity gains in final energy by 2050, sectoral split

%



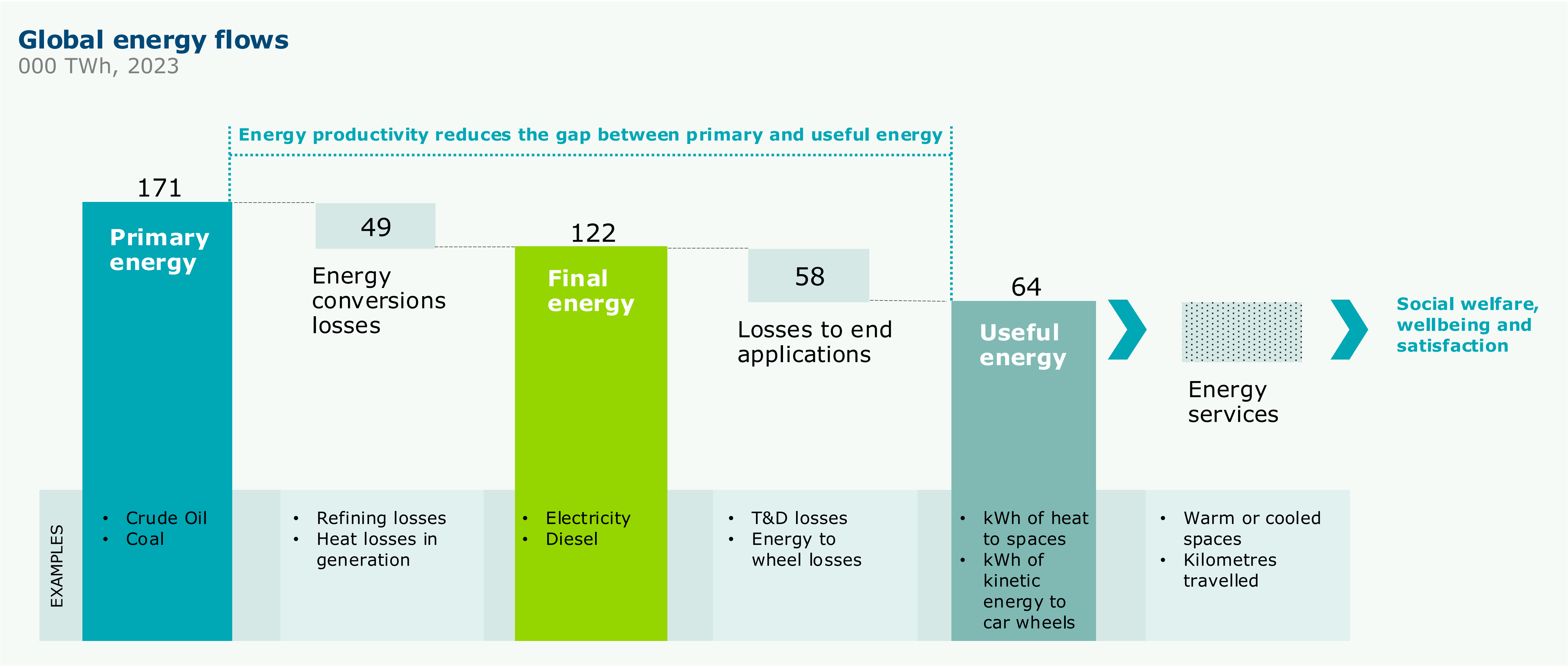
* Including Benzene, Butandiene, Ethylene, Propylene, Toluene, Xylene but excluding all Ammonia uses and Methanol and E-methanol for shipping use
Note: Does not include energy demand for low-carbon fuels production nor CCS for Net-Zero, as these impact primary energy demand. Include embodied fossil fuels in plastics and chemicals.
Source: IEA (2025) World Energy Outlook; MPP (2023) Hard-to-Abate Sector Transition Strategies; ETC(2023), Fossil Fuels in Transition; Systemiq analysis for ETC.

CHAPTER 01

Economy-wide opportunity

The economy-wide opportunity, definitions and key concepts: from primary energy to energy services

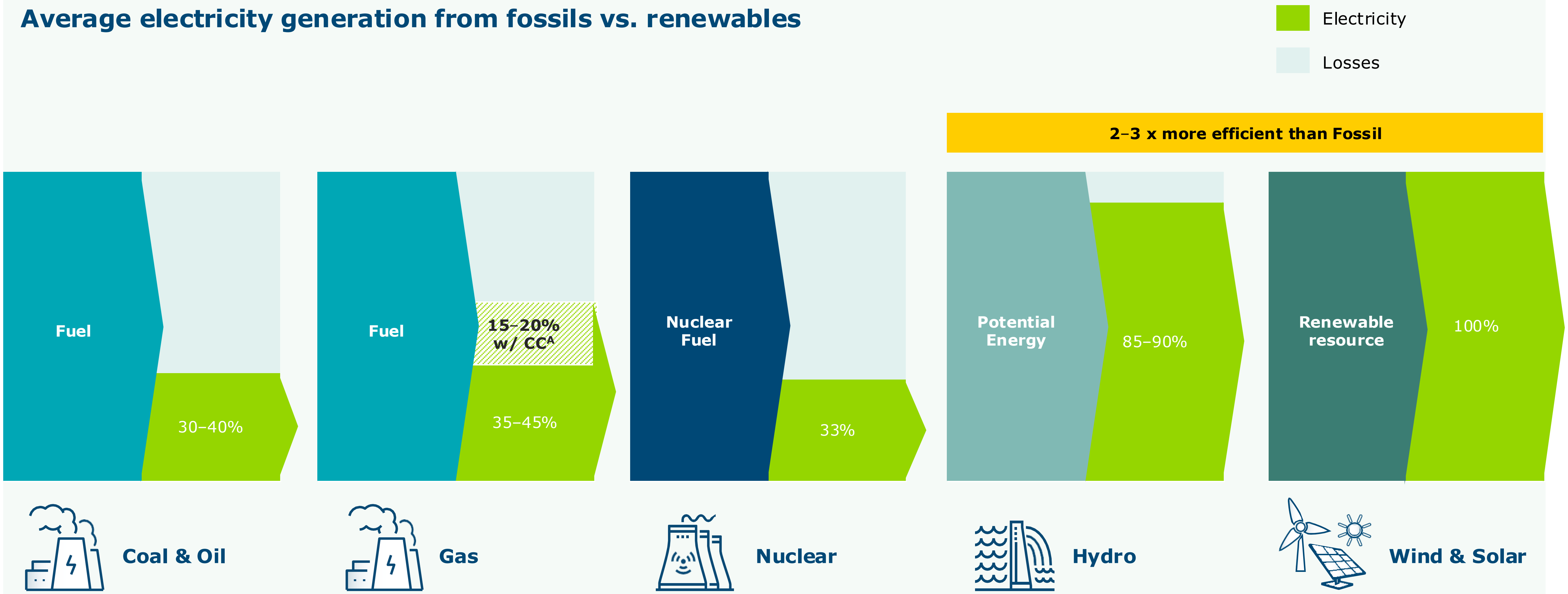
Global energy flows can be measured in primary, final, and useful energy – but it is useful energy that closely translates into services that people need



Source: Systemiq analysis for the ETC, IEA (2025) World Energy Review, IEA (2024) World Energy Outlook, International Institute for Applied Systems Analysis, IIASA PFU Dataset. Available at https://tntcat.iiasa.ac.at/PFUDB/dsd?Action=htmlpage&page=about. [Accessed May 2025].

Generating electricity with renewables compared to fossil fuels is 2–3 times more efficient

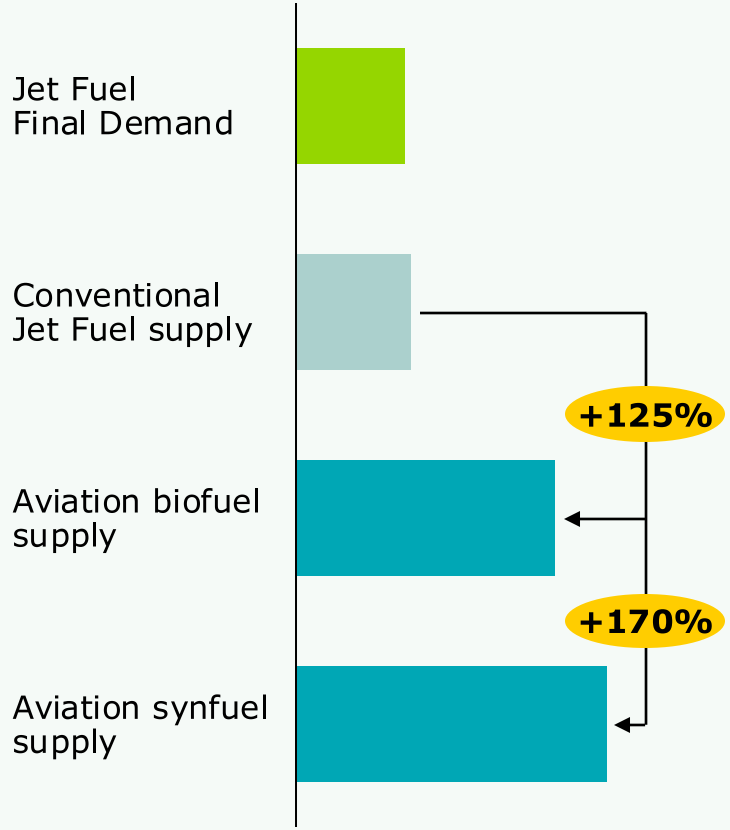
Average electricity generation from fossils vs. renewables



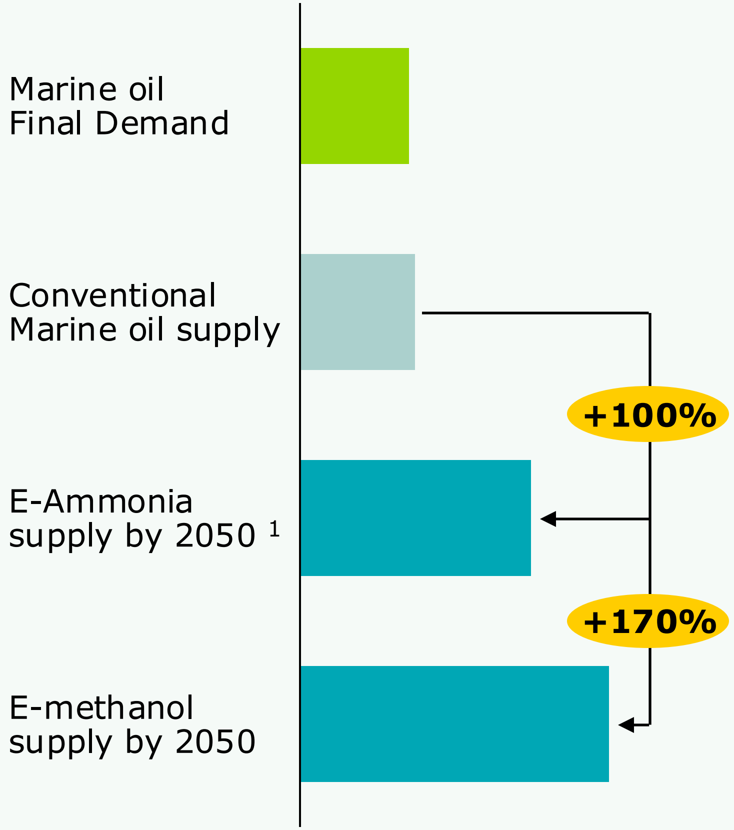
Note: A) CC = Combined Cycle
Source: RMI (2024), Clean Tech Revolution; Buck Feng (2023) Power Plant Efficiency: Coal, Natural Gas, Nuclear, and More, IEA (2008) Energy Efficiency Indicators for Public Electricity Production from Fossil Fuels.

However, decarbonisation routes in some sectors will increase primary energy needs (through switching to new fuels and CCS)

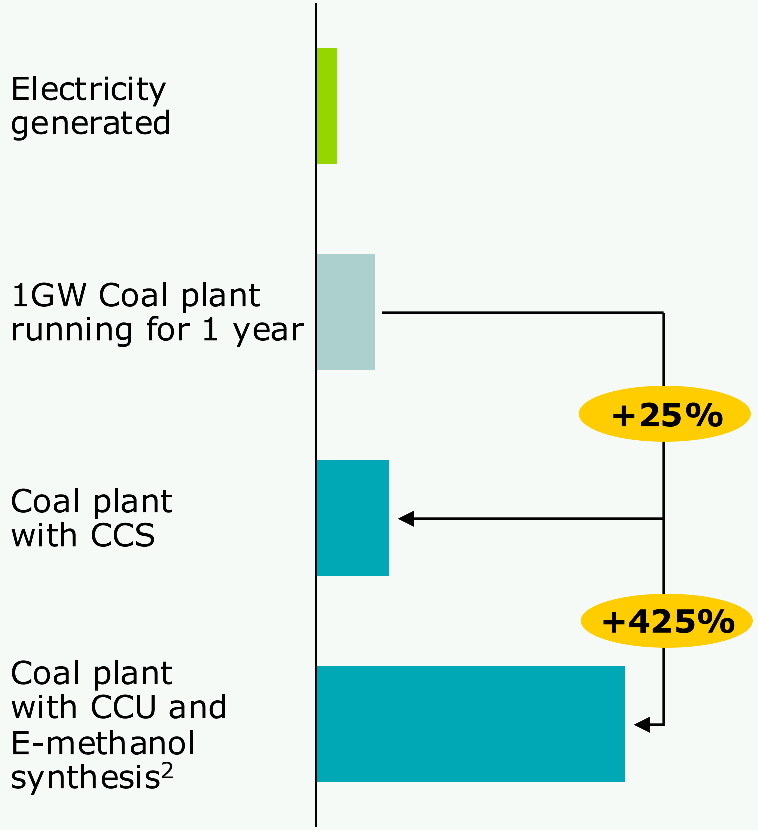
Aviation Case Study
TWh



Shipping Case study
TWh



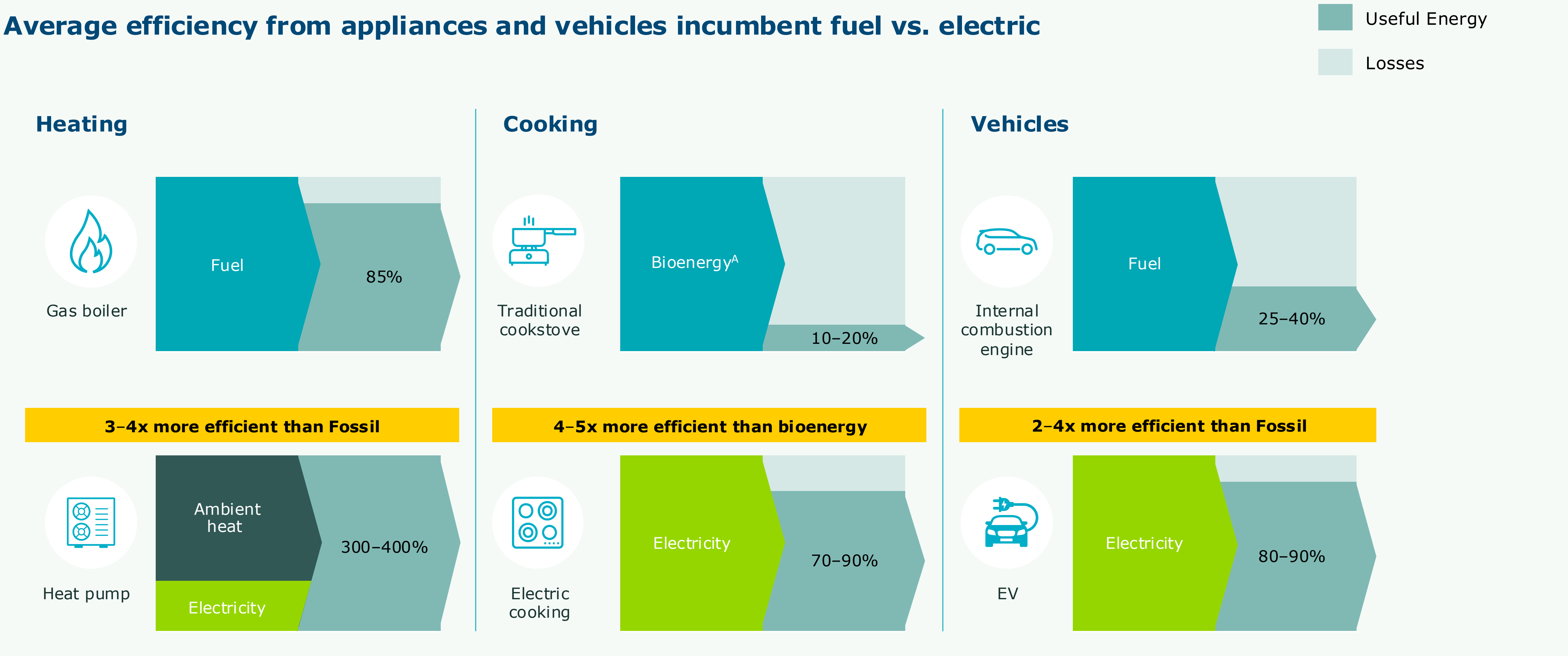
CCS Case study
TWh



1 Assumed Proton Exchange Membrane Fuel Cells (PEMFC); 2 Additional steps for CCU include hydrogen production via electrolysis (50-55 kWh/kg of H2), CO2 capture and compression (0.5-1.5 KWh/kgCO2) and methanol synthesis (1-2 Kwh/kg MeOH); 100% capture and conversion to methanol is assumed (theoretical maximum)
Sources: Mission Possible Partnership (2023) Sector Transition Strategy, World Resources Institute (2022) 6 Things you Know About Direct Air Capture; IEA (2013). Technology Roadmap: Carbon Capture and Storage, IEA (2019). The Future of Hydrogen, ECN (2017). Techno-economic and environmental assessment of methanol synthesis using captured CO_2 and renewable hydrogen

Electrification maximises useful energy – heat pumps, electric cooking and EVs use 2-5 times less energy than alternative technologies

Average efficiency from appliances and vehicles incumbent fuel vs. electric

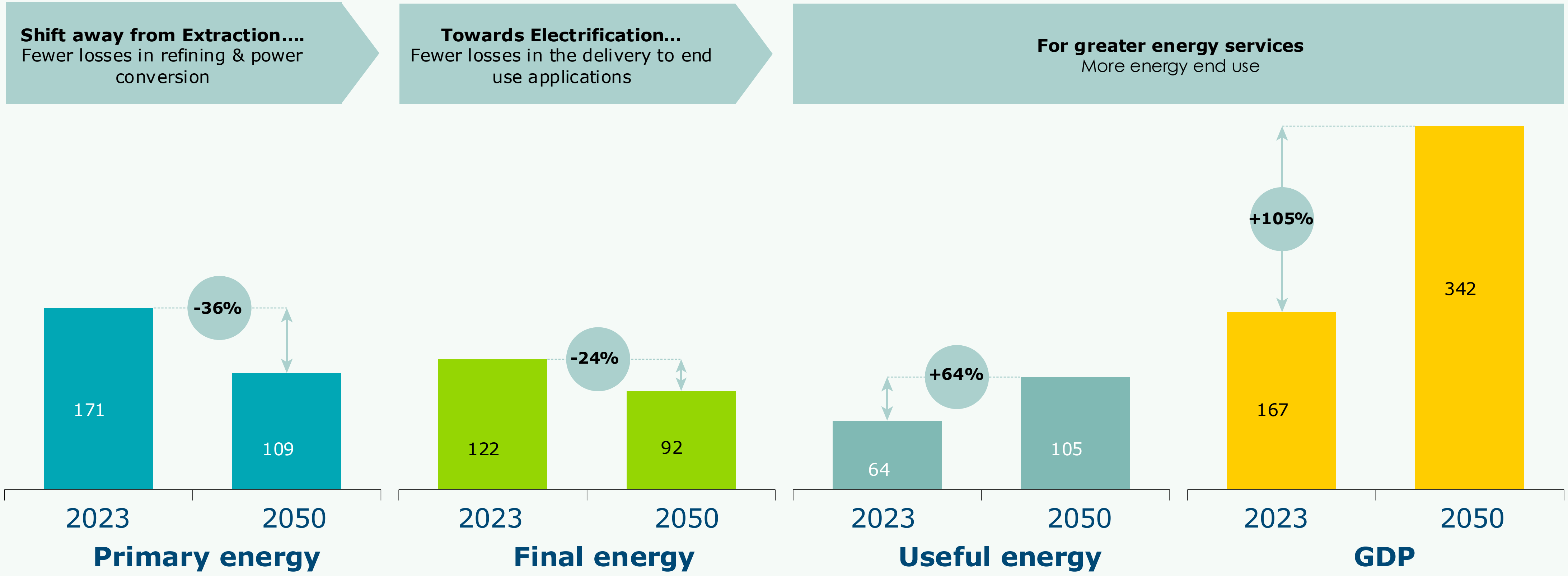


Note: A) Bioenergy is shorthand for Traditional use of biomass (TUOB)
Source: RMI (2024), Clean Tech Revolution. ETC (2025) Achieving Zero-Carbon Buildings: Electric, Efficient and Flexible

Through productivity actions, the world can deliver a doubling of global GDP and expanded energy services, while requiring less primary and final energy

Net-zero energy demand with productivity levers

Energy in 000 TWh; GDP in constant 2021 $ trillion



Source: Systemiq analysis for the ETC; IEA (2025), World Energy Outlook; MPP (2023), Hard-to-Abate Sector Transition Strategies; ETC (2025), Achieving Zero-Carbon Buildings; ETC (2023), Fossil Fuels in Transition; BNEF (2023), Electric Vehicle Outlook; Systemiq (2022), Planet Positive Chemicals

Productivity growth is achieved alongside growth in energy services

For assumed growth of energy services for each of industry **Go to**
> 03: Sectoral deep-dive

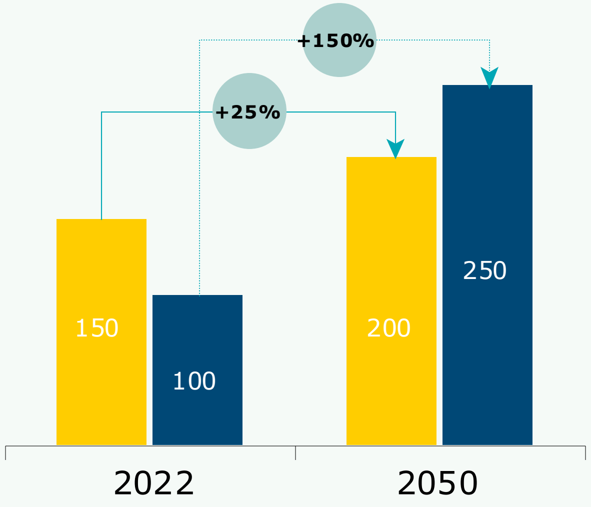
Underlying growth in energy services in specific sectors

Heated and cooled floor area demand
Billion m2; IEA NZE Scenario; residential + commercial

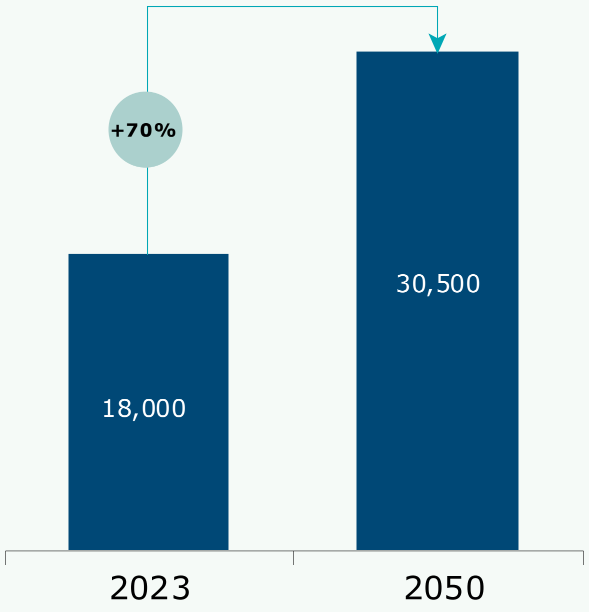
Cooled floor area

Heated floor area (space heating)

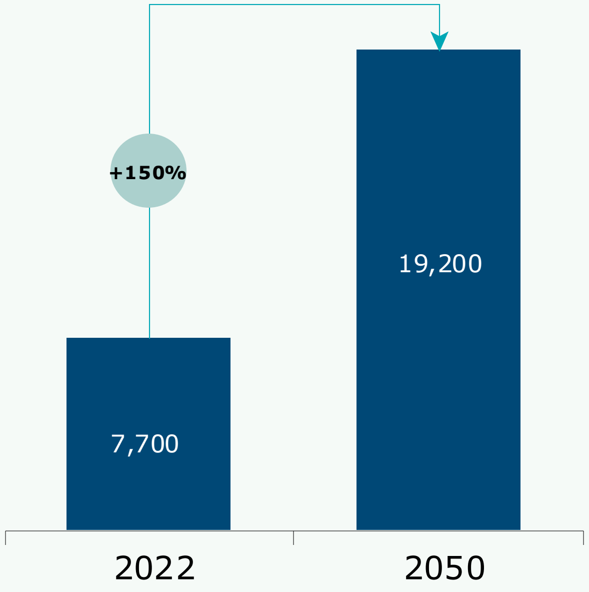
Cooled floor area is growing at a higher rate than heated, driven by 1) **GDP per capita growth**; 2) **increase in building floor area**, particularly in developing economies; 3) **warming climates**



Passenger road transport demand
Billion km; ETC ACF scenario



Aviation demand
Billions revenue passenger km (RPK)

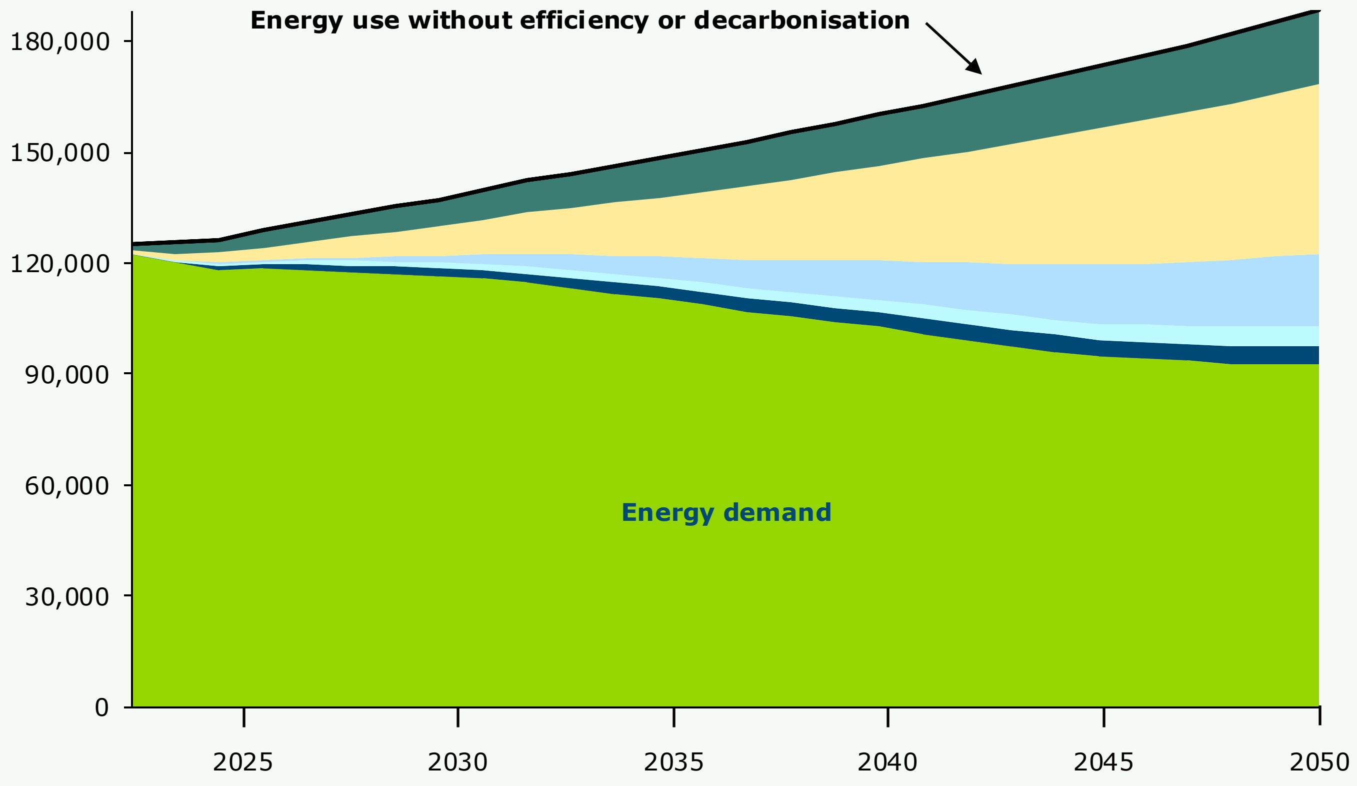


Note: Revenue passenger km represents the number of paying passengers carried on scheduled flights multiplied by the number of km those seats were flown. ACF = Accelerated but Clearly Feasible Scenario.
Source: IEA (2023), World Energy Outlook 2023; ETC (2023), Fossil Fuels in Transition; Maersk Mc-Kinney Moller Center for Zero Carbon Shipping (2022), We show the world it is possible.

Productivity actions can reduce final energy demand 25% from today; 50% compared to business-as-usual

Final energy demand vs. productivity levers

TWh



Key Actions — % reduction potential compared to 2050 energy without efficiency or decarbonisation

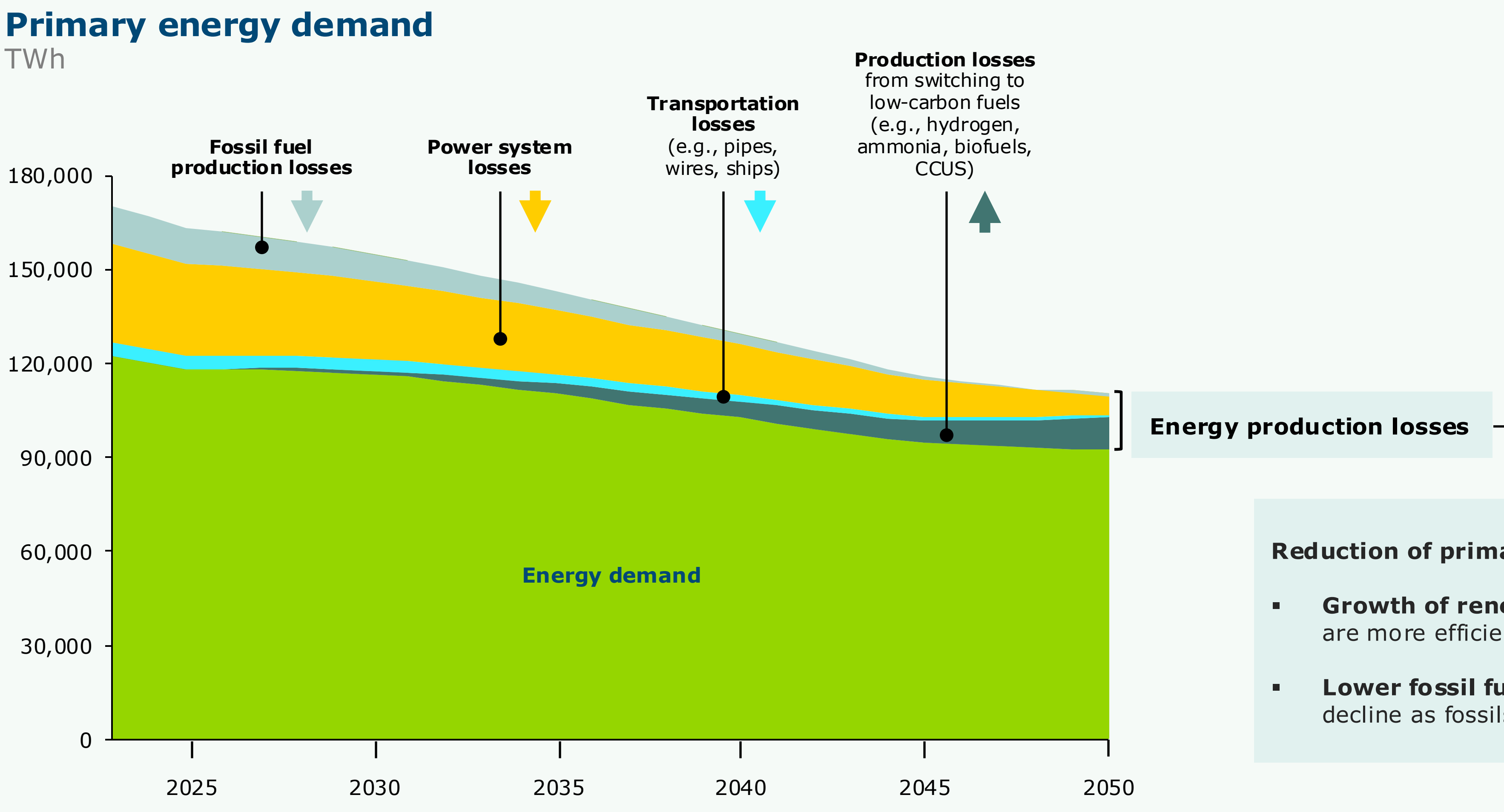
- **- 11%** — **Demand reduction:** Services (e.g. public transport), reducing & re-using (e.g. plastics & chemicals) and better operations (e.g. aviation).
- **- 24%** — **Electrification:** Switching to EVs, electric heating and cooking.
- **- 10%** — **Improving efficiency of key electrical equipment:** AC, heat pumps, EVs, industrial motors, lighting and other.
- **- 3%** — **Better insulation in buildings:** Better buildings codes and fabric improvements.
- **- 3%** — **Sector specific:** Mainly heavy industry and long-distance transportation.

-51%

Key opportunities for energy-intensive sectors are in **demand reduction** (via recycling and better operations) and **sector-specific** (via enhanced designs)

Source: Systemiq analysis for the ETC; IEA (2025), *World Energy Outlook*; MPP (2023), *Hard-to-Abate Sector Transition Strategies*; ETC (2025), *Achieving Zero-Carbon Buildings*; ETC (2023), *Fossil Fuels in Transition*; BNEF (2023), *Electric Vehicle Outlook*.

Primary energy declines overall as fossil fuels fall but low-carbon fuels raise energy demand in heavy industry and transport

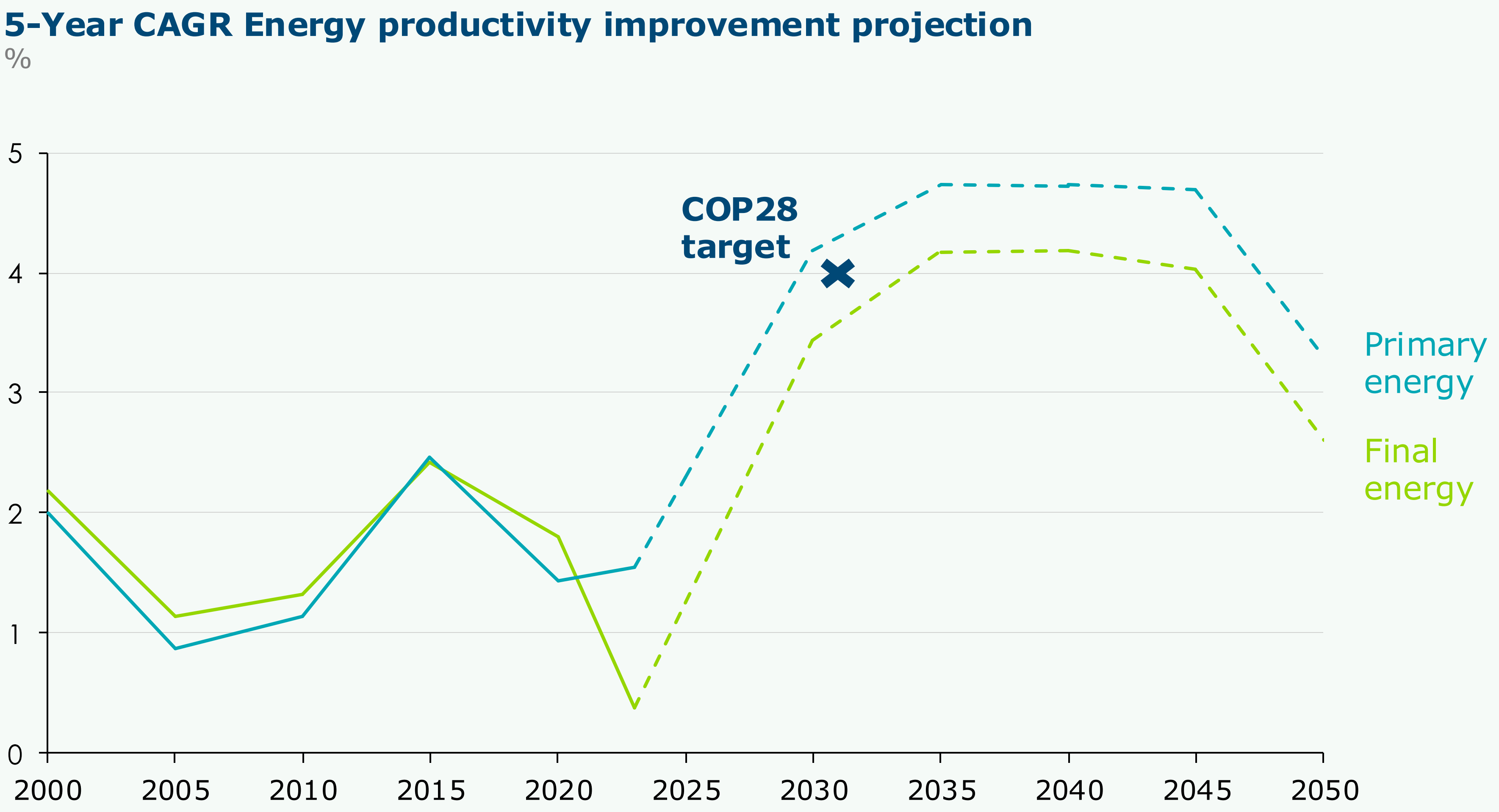


Reduction of primary losses driven by:

- **Growth of renewables in the power system**, which are more efficient than fossil generation
- **Lower fossil fuel conversion losses** (e.g. in refining) decline as fossils phase down

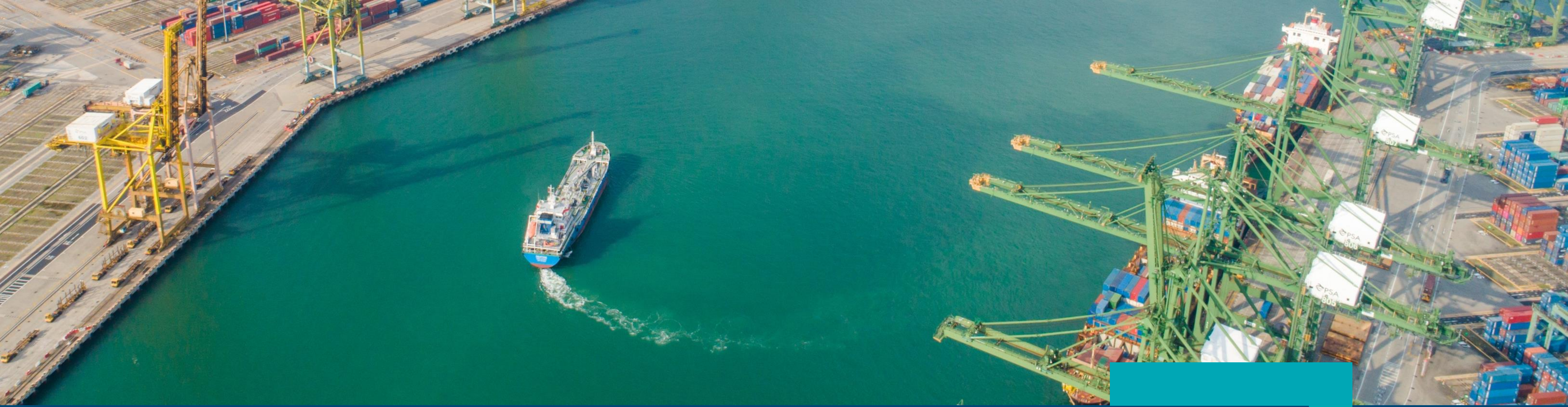
Source: Systemiq analysis for the ETC; IEA (2025), World Energy Outlook; MPP (2023), Hard-to-Abate Sector Transition Strategies; ETC (2025), Achieving Zero-Carbon Buildings; ETC (2023), Fossil Fuels in Transition; BNEF (2023), Electric Vehicle Outlook.

Electrification and other energy productivity actions can double energy productivity. After most sectors electrify, annual gains will slow – though other efficiency actions remain important.



- **Energy productivity gains vary over time**; recent years have not seen significant improvements
- **COP28 (reiterated at COP30) target** of doubling annual improvements in primary energy efficiency from ~2% to ~4% by 2030 is technically achievable
- **However, there is a clear opportunity for a one-off increase** driven by electrification and renewables
- **After mid-2040s, pace of improvement decreases** due to most of the economy already been electrified and decarbonised, and a slow down in GDP growth projection

Note: CAGR = Compound annual growth rate. Source: Systemiq analysis for the ETC; World Bank Group, GDP, PPP (constant 2021 international $). Available at:: https://data.worldbank.org/indicator/NY.GDP.MKTP.PP.KD. [Accessed August 2025]. Our World in Data, Global GDP over the long run. Available at: https://ourworldindata.org/grapher/global-gdp-over-the-long-run. [Accessed on August, 2025]; IMF Real GDP Annual Growth. Available at: https://www.imf.org/external/datamapper/datasets/WEO. [Accessed on August 2025]; IEA (2024), World Energy Outlook 2024.

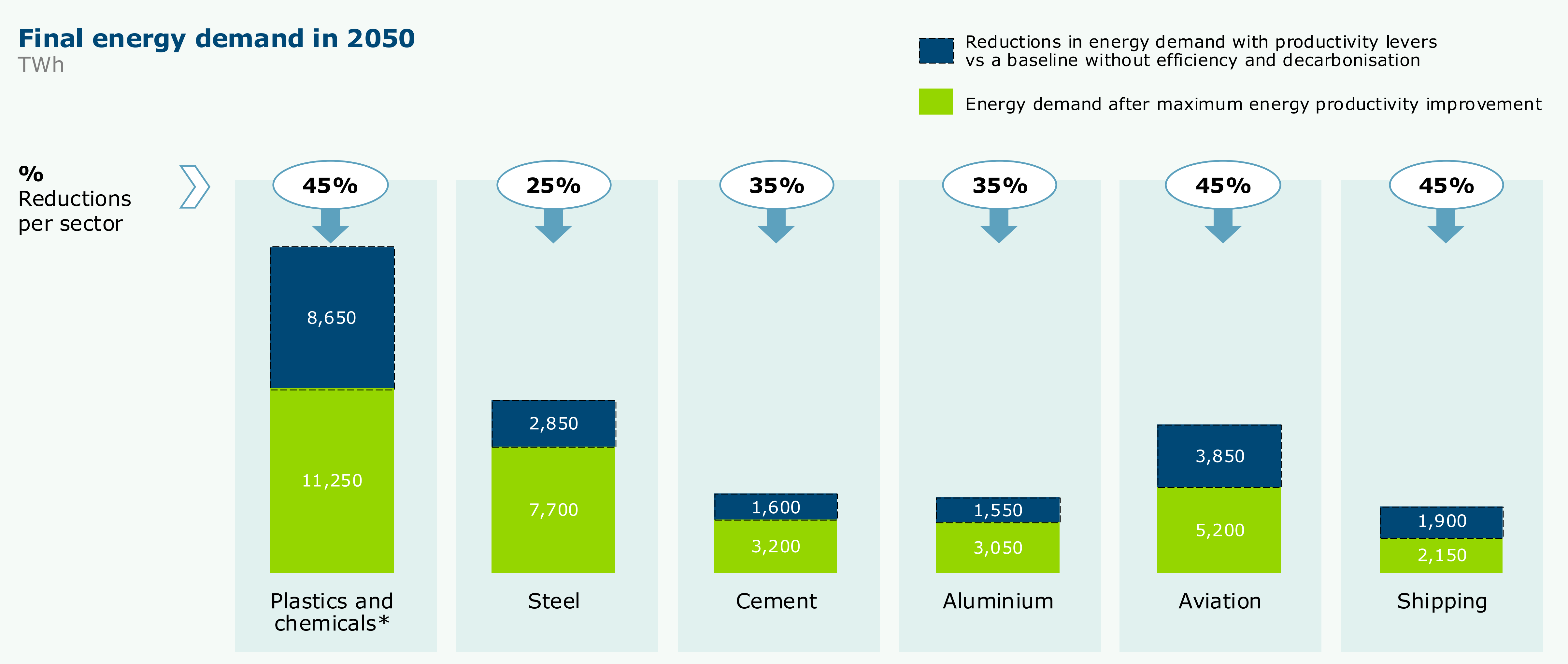


CHAPTER 02

Summary findings

Productivity in energy intensive industries

Energy-intensive sectors can be 25-45% more productive in their final energy consumption



* Including Benzene, Butandiene, Ethylene, Propylene, Toluene, Xylene but excluding all Ammonia uses and Methanol and E-methanol for shipping use
Note: Does not include energy demand for low-carbon fuels production nor CCS for Net-Zero, as these impact primary energy demand. Include embodied fossil fuels in plastics and chemicals.
Source: IEA (2025) World Energy Outlook; MPP (2023) Hard-to-Abate Sector Transition Strategies; ETC(2023), Fossil Fuels in Transition; Systemiq analysis for ETC.

Mapping the three productivity levers across energy-intensive industries highlights key actions by sector

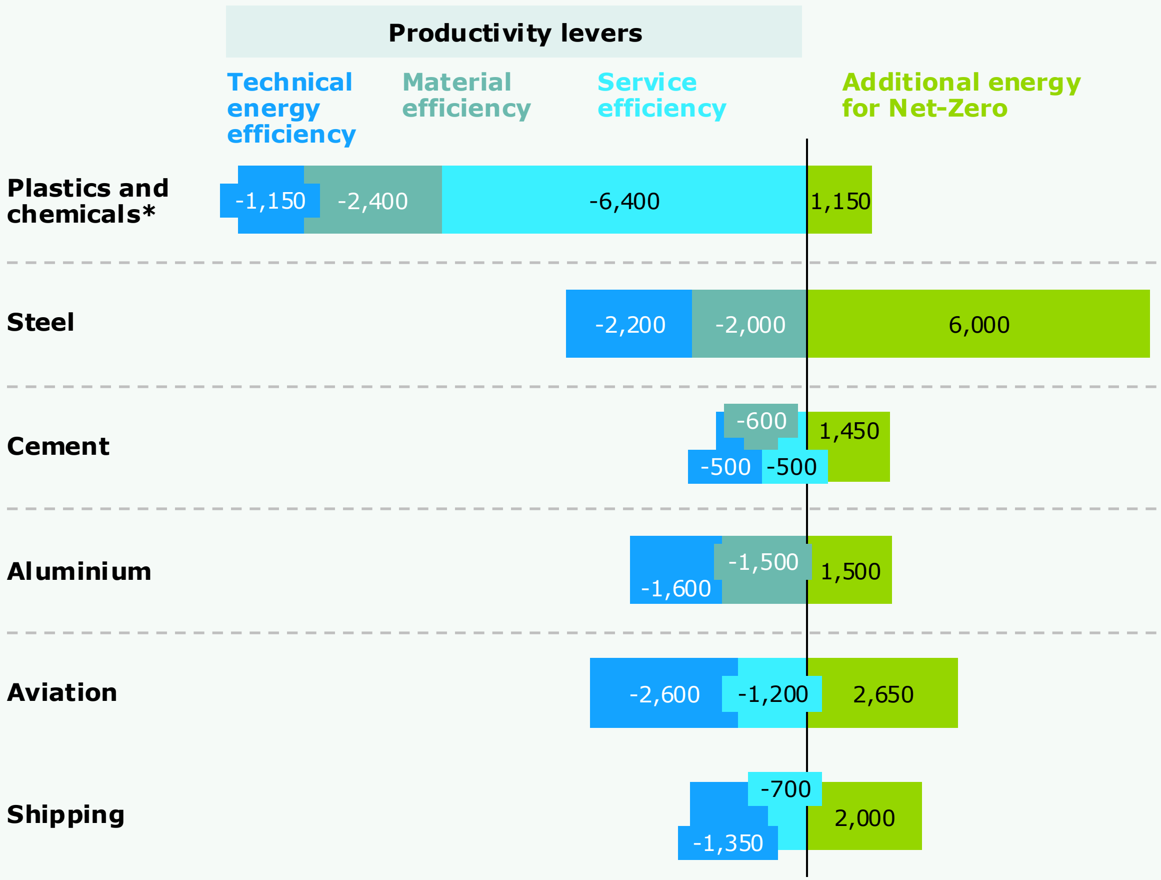
Target figure	Key lever	Impact	Examples: Plastics and chemicals*	Steel	Cement	Aluminium	Shipping	Aviation
Energy Productivity[A] (GDP per unit of energy input) =	**Service efficiency** x	Reduction in volume of product or service needed to deliver any given consumer living standard.	• Demand reduction of plastics through reusage, substitution or elimination		• Using less concrete per building via better • design		• Weather routing • Autopilot upgrade • Speed reduction	• Optimised approach / departure procedures for take-off and landing
	Material efficiency x	Reductions in the amount of material needed to support consumer living standards.	• Increase in chemicals recycling rates	• Scrap usage increase	• Using less clinker in cement by partially replacing clinker with SCMs	• Maximising secondary production • Circular product design		
	Technical energy efficiency	Reduced kWh input per energy service delivered.	• Switch to steam cracking • Switch to electric boilers	• Switch to EAFs and electro-winning • Switch to DRI	• Switch wet kiln with dry kiln with preheaters • Deploying waste heat recovery	• Switch captive generation to renewable sources	• Auxiliary power • Enhanced aero-dynamics, • Higher thrust efficiency	• Engine efficiency increase • Enhanced aero-dynamics • Light-weighting of airplane

* Including Benzene, Butandiene, Ethylene, Propylene, Toluene, Xylene but excluding all Ammonia uses and Methanol and E-methanol for shipping use
Note: A) Energy productivity is the inverse of energy intensity (energy input per unit of GDP), intensity is used for instance in many IEA reports.
Source: Systemiq analysis for the ETC.

Across most energy-intensive sectors, decarbonisation increases energy demand, but this is offset by energy productivity actions, crucial to lowering the costs of decarbonisation.

Additional energy required for net-zero vs productivity savings in primary energy demand by 2050

TWh

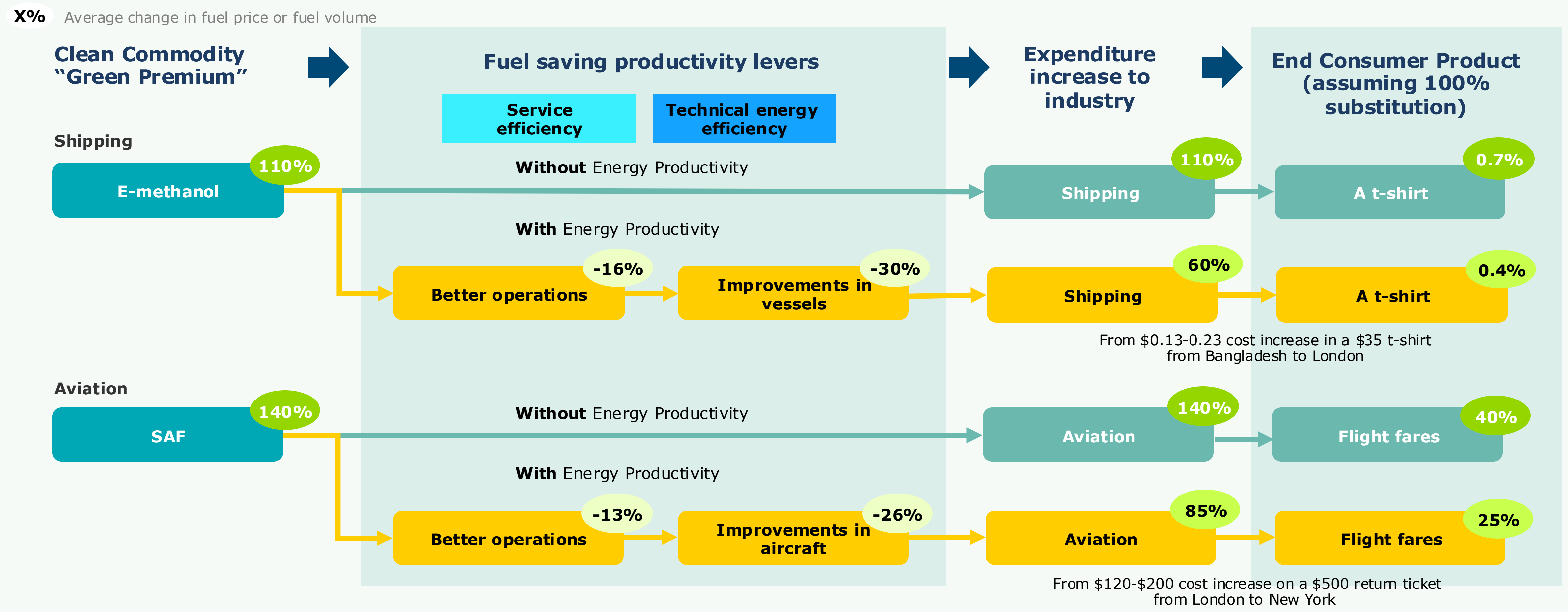


Sector	Net energy changes	Key drivers of energy changes
Plastics and chemicals*	-8,800	• **Service efficiency** is the dominant lever, with reduction, reuse and substitution of plastics driving the largest energy savings, more than offsetting additional energy from decarbonisation
Steel	+1,800	• **Material** and **technical efficiency** partially offset higher energy needs: higher scrap use and electric arc production reduce demand, but hydrogen-based production leads to net increase.
Cement	-150	• **Service** and **material efficiency** via reducing concrete use per building and clinker content delivers most of the savings, keeping net energy changes close to neutral.
Aluminium	-1,600	• **Technical** and **material efficiency** gains fully offset additional energy needs: switching captive coal power to renewables and increasing recycling significantly reduce energy demand, resulting in net savings.
Aviation	-1150	• **Technical efficiency** in aircrafts and vessels by, for instance, making them lighter and more aerodynamic, with some additional gains via **service efficiency** by via better routing and increased utilization can be applied in line with increase in demand for sustainable fuels to achieve net saving in energy demand.
Shipping	-50	

* Including Benzene, Butandiene, Ethylene, Propylene, Toluene, Xylene but excluding all Ammonia uses and Methanol and E-methanol for shipping use
Note: A) Energy productivity is the inverse of energy intensity (energy input per unit of GDP), intensity is used for instance in many IEA reports.
Source: Systemiq analysis for the ETC.

"Green premiums" emerge as energy-intensive sectors decarbonise; but consumer price impacts are expected to be small

Cost of decarbonisation in shipping and aviation with and without energy productivity



Note: Assuming shipping accounts for 3% of a t-shirt cost and that jet fuels are 25-30% of plane ticket's price
SAF = Sustainable Aviation Fuel
Source: ETC (2025) Global trade in the energy transition: Principles for clean energy supply chains & carbon pricing; MPP (2022) Making Net-Zero Aviation Possible – Technical Appendix; MPP (2025) Clean industry: transformational trends

Energy productivity actions can help limit overall cost increases, leading to specific cost savings within sectors.

Examples here are not comprehensive; total savings of higher energy productivity could be much higher per sector

Productivity lever	Cost reduction case studies	
Service efficiency	**- $12 bn/year** in the bottled water business	Reduction of plastic consumption - via substitution and re-use, rather than new virgin production - **can be cheaper than single use production by up to ~20%** per beverage bottle, despite higher costs of secondary production from recycled materials. Applied to global consumption of water bottles, at 600 billion of bottles per year, this would save water brands $12 bn/year (~5% of the global water bottled market).
Material efficiency	**- $25 bn/year** in aluminium power bills	Aluminium can be infinitely recycled and secondary production is 95% less energy intensive than primary production. **Expanding secondary production further than business-as-usual by 2050 alongside implementation of other resource efficiencies** - such as increases in manufacturing efficiency and product lifetimes, can result in **$25 bn/year savings in power bills by 2050** (~12% of today's production costs of aluminium).
Technical energy efficiency	**- $135 bn/year** in SAF expenditure	Technical efficiency improvements in aircrafts, such light-weighting, **can reduce aviation fuel demand by ~25% by 2050**. With SAF projected production costs by 2050 varying between 625-2350 $/ton, technical efficiency improvements would save **$135 bn/year in 2050** – this is almost half of today's fuel expenditure in aviation.

Note: More detail on cost calculations in the annex at the end of this document
Source: Mission Possible Partnership (2022) Making Net-Zero Aviation Possible; Systemiq (2022) Planet Positive Chemicals; ETC (2025) Carbon in an Electrified Future; bevi (2025) Every bottle counts: Beverage industry impact report; Mission Possible Partnership (2022) Making Net-Zero Aluminium Possible; Travel Daily News (2024) Airline industry will spend $291bn on fuel in 2024, $100bn more than five years ago; Custom Market Insights (2026) Global Bottled Water Market 2024–2033;

CHAPTER 03

Sectoral deep-dives

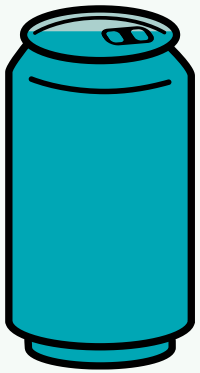
Energy intensive sectoral deep-dives

Aluminium

Energy intensive sectoral deep-dives

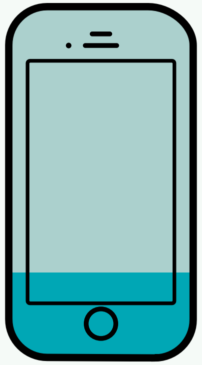
Aluminium is used across a wide range of everyday products and critical infrastructure

Approx. % aluminium by weight



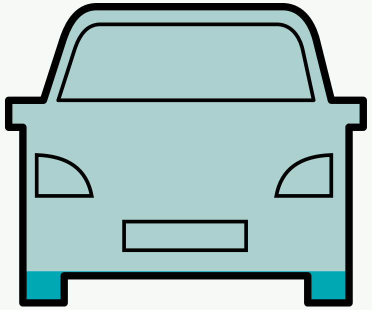
Drinks can

~97%



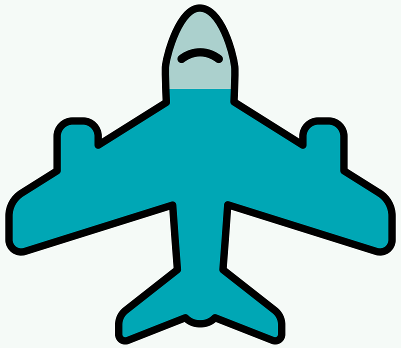
Smartphone

~24%



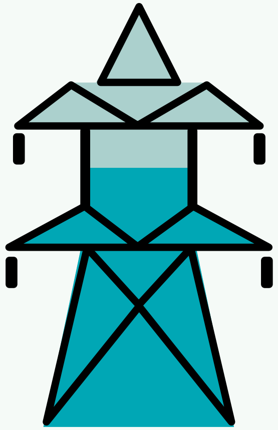
Car

~10-12%



Aircraft-body

~60-80%



Power lines

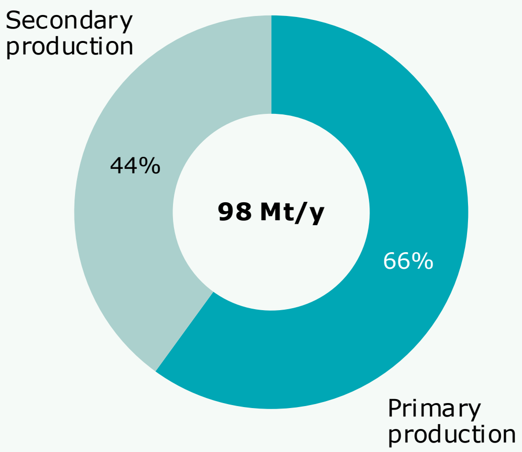
~70-85%

Source: Aluminum Association (2015) International Alloy Designations and Chemical Compositions Limits for Wrought Aluminum and Wrought Aluminum Alloys; American Ceramic Society (2017) What's really inside your smartphone: A pile of raw minerals and serious social consequences; European Aluminium / Ducker Worldwide (2022) Aluminium Content in Passenger Vehicles (Europe); NASA (2018) Aerospace Materials Characteristics; Southwire (2026) ACSR Aluminum Conductor Steel Reinforced.

Aluminium production = 100 million tonnes today, highly electrified but mainly coal-based

Production

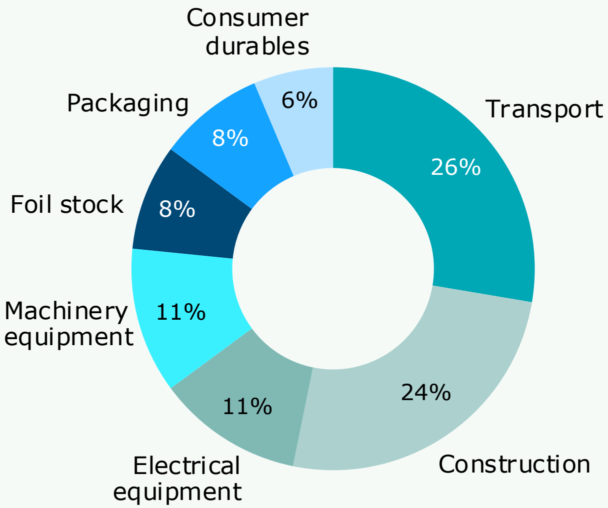
Global aluminium supply (2020)



Aluminium is a lightweight, malleable, and corrosion-resistant material with high electrical and thermal conductivity; around 70% of aluminium scrap is collected and can be used for secondary production

Demand

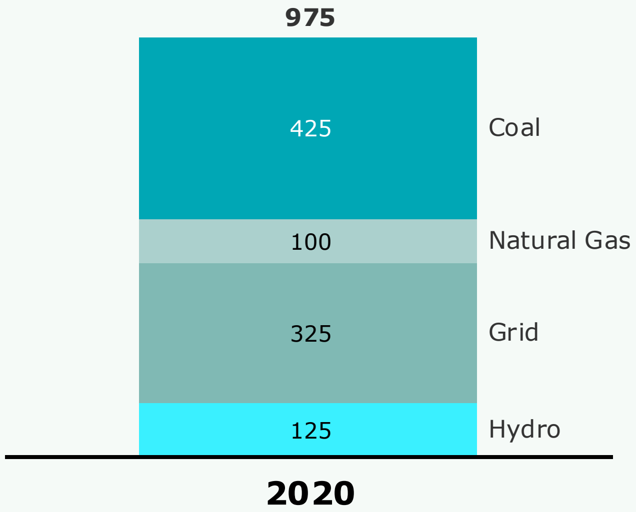
Global aluminium demand (2020)



Around half of aluminium demand comes from transport and construction, anchoring demand to large, long-lived capital stock (vehicles, buildings and infrastructure)

Energy supply

Smelter power demand mix
TWh



Smelting is most energy intensive part of aluminum production. The aluminum sector emits ~1 GtCO2e/year, with ~70% coming from Scope 2 emissions, i.e. power supply

Source: MPP (2022), Aluminium Sector Transition Strategy

There are three main efficiency levers to reduce energy demand in aluminium

TOTAL renewable energy demand

=

DEMAND FOR SERVICES
(e.g. buildings, cars, cans, etc)

x

MT OF ALUMINIUM
Service (e.g. car, buildings)

x

ENERGY
Mt of aluminium

1. Service efficiency

Not relevant: baseline demand set to increase

2A. Material efficiency

Can we make aluminium more lightweight or extend its lifetime?

2B. Material efficiency

Can we increase the rate of collection for aluminium recycling?

3. Technical efficiency

Can we decarbonise captive power generation and electrify the refining process?

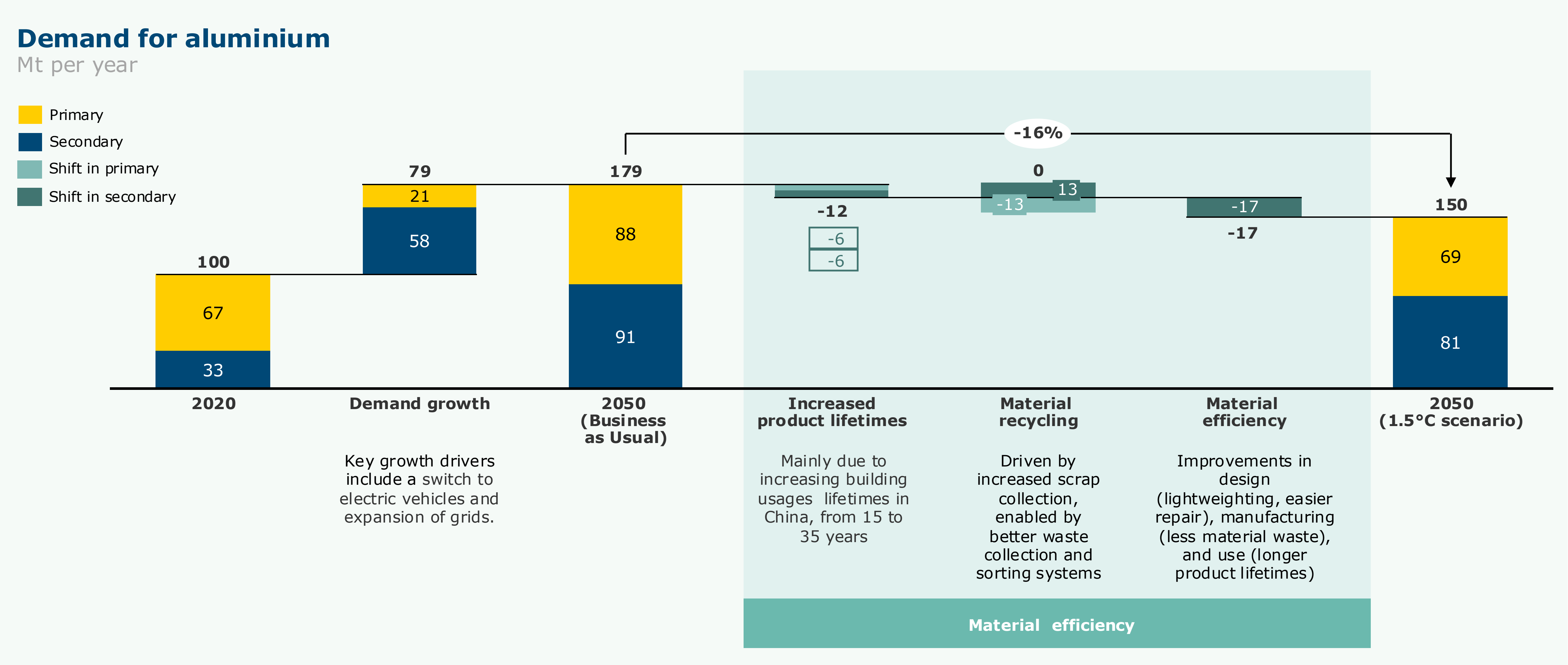
Source: MPP (2022), Aluminium Sector Transition Strategy

Decarbonising power in smelting and refineries plus increasing material utilisation and recycling, are key to reducing aluminium energy demand

Productivity lever	Description
Material Efficiency	• Maximising **secondary production** • **Circular product design** • Manufacturing **loss reduction** • Increased **product lifetimes** • End-of-life **repair and reuse**
Technical Efficiency	• Switch captive power generation to **low-carbon sources** • Deploying **near-zero- emissions refining and smelting** technologies (e.g. electric boilers, concentrated solar thermal, mechanical vapor recompression, electric calcination)

Source: MPP (2022), Aluminium Sector Transition Strategy

Increasing product lifetimes, recycling and design improvements can drive significant reductions in overall aluminium demand

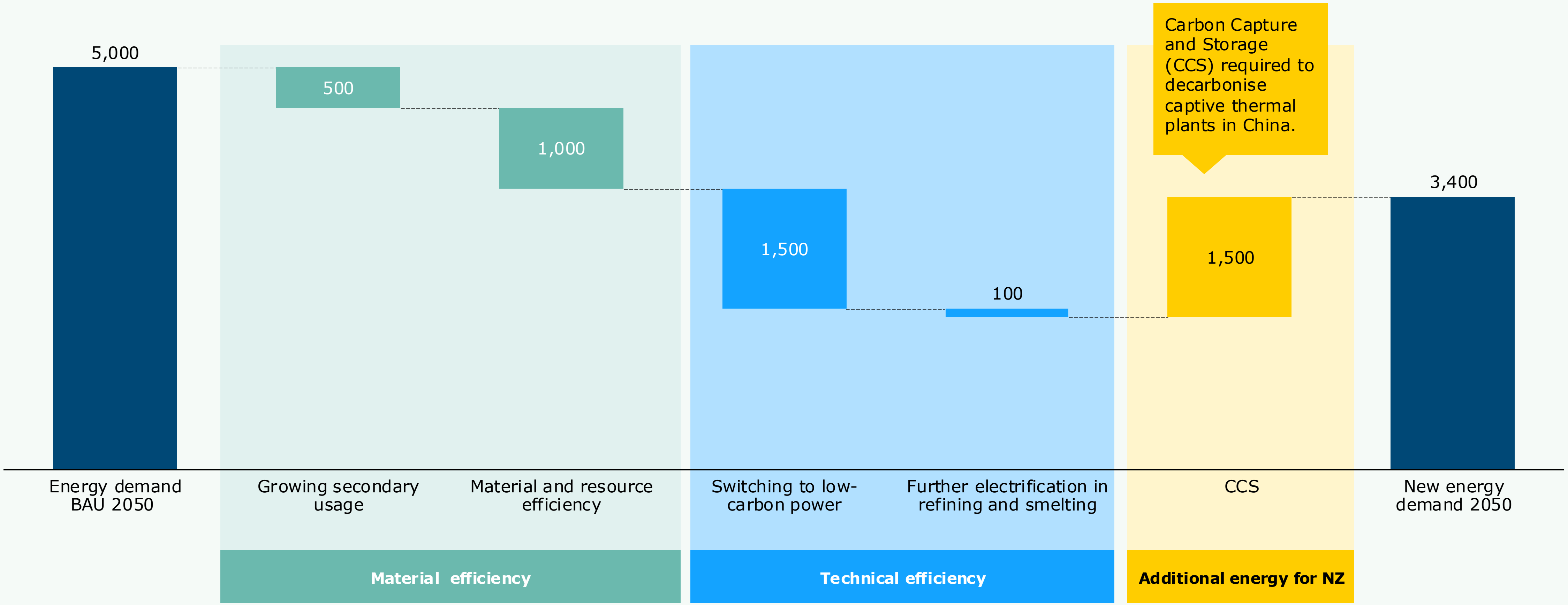


Source: MPP (2022), Aluminium Sector Transition Strategy

Productivity levers in aluminium more than offset an increase in energy demand from CCS - required to decarbonise captive thermal power

Primary energy demand in 2050 and impact of productivity levers

TWh



Source: MPP (2022), Aluminium Sector Transition Strategy

Productivity enablers for aluminium include site specific plans for power decarbonisation and increase collection rates for recycling

Productivity enablers

1. **Increase aluminium performance (e.g. enhancing product design, lifetime and decreasing production waste)**, especially in secondary production, via industry commitments or government procurement standards
2. Increase of **cross-sectoral collection rates** to improve recycling and scrap downcycling
3. Development of **site-specific plans for decarbonisation of power**, particularly focusing on decarbonisation of power over the next decade
4. Work with producers and regulators to **integrate aluminium smelters into electricity, CCS and hydrogen grids**

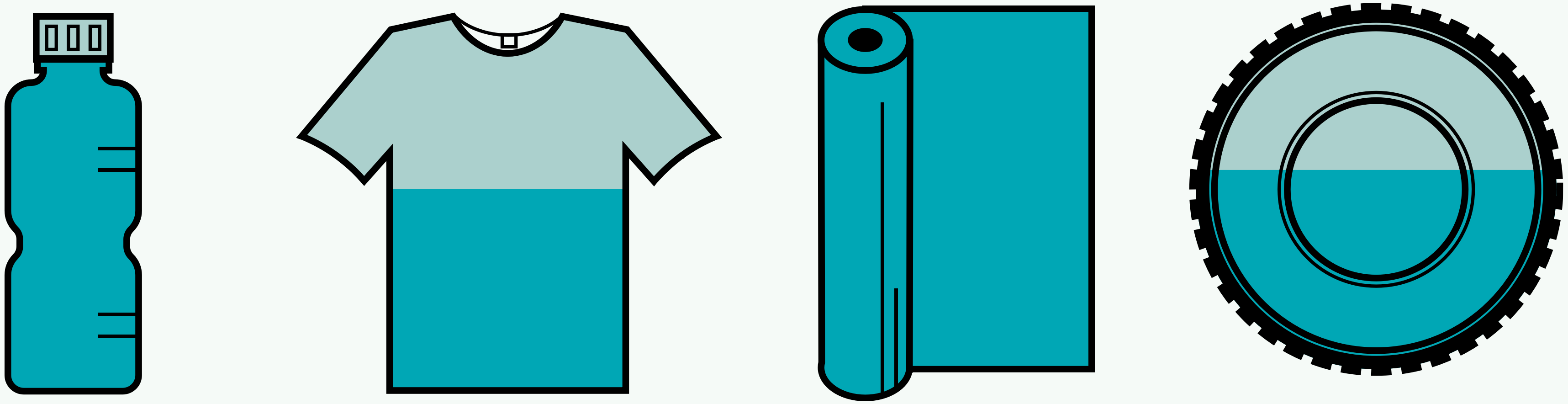
Source: MPP (2022), Aluminium Sector Transition Strategy

Plastics & chemicals

Energy intensive sectoral deep-dives

Plastics and chemicals* are used across a wide range of everyday products

Approx. % plastics and chemicals by weight



Plastic water bottle	Polyester t-shirt	Cling film	Car tyre
~90-95%	**~60-100%**	**~100%**	**~50-65%**

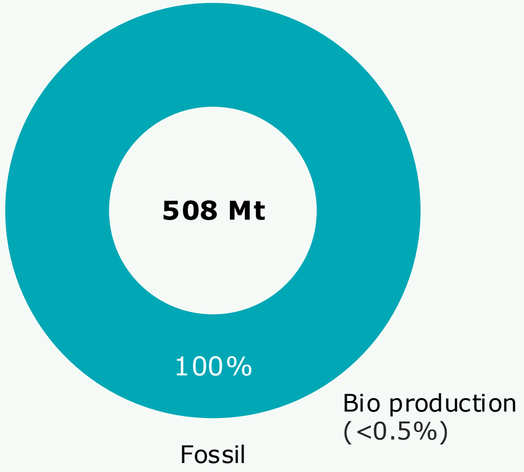
* Including Benzene, Butandiene, Ethylene, Propylene, Toluene, Xylene but excluding all Ammonia uses and Methanol and E-methanol for shipping use

Source: PlasticsEurope (2022) Eco-profiles of plastics; Textile Exchange (2023) Preferred Fiber & Materials Market Report; European Tyre & Rubber Manufacturers Association (ETRMA) (2022) Tyre Industry Data; Ellen MacArthur Foundation (2016) The New Plastics Economy; Systemiq analysis for ETC

Plastics and chemical* production = 500 Mt today, almost entirely fossil-based, with plastics making up ~70% of output

Production

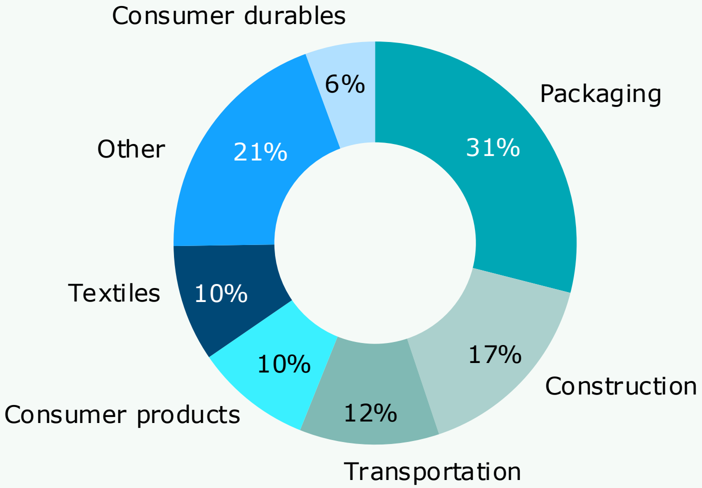
Plastics and chemical demand (2020)
Mt



Plastics and chemicals are derived from oil and gas, absorbing ~14% of global oil and ~8% of gas production.

Demand

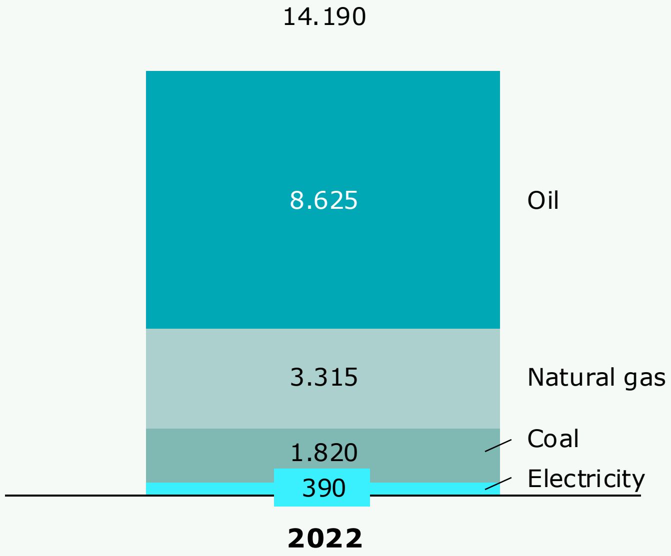
Share of plastic application (2019)



Plastics represent ~60-70% of petrochemical output by volume. The remaining outputs are chemicals, paints, bitumen, lubricants and other non-energy uses

Energy and Feedstock supply

Chemicals energy demand (2022)
TWh



The chemical sector emits 2.3 Gt CO_2eq, of which two-thirds sit in Scope 3, driven by fossil feedstock extraction and end-of-life disposal (energy supply includes ammonia)

* Including Benzene, Butandiene, Ethylene, Propylene, Toluene, Xylene but excluding all Ammonia uses and Methanol and E-methanol for shipping use. Source: Systemiq (2022) Planet Positive Chemicals; ETC (2025) Carbon in an Electrified Future; OECD (2022) Global Plastics Outlook

All three efficiency levers can reduce energy demand in the plastic and chemical* sector

TOTAL renewable energy demand

=

DEMAND FOR SERVICES (e.g. plastics, etc)	x	MT OF CHEMICAL / Service (e.g. plastics, etc)	x	ENERGY / Mt of chemical
1. Service efficiency		**2. Material efficiency**		**3. Technical efficiency**
Can we reduce demand for plastic?		Can we increase plastic recycling rates?		Can we electrify chemicals production?

* Including Benzene, Butandiene, Ethylene, Propylene, Toluene, Xylene but excluding all Ammonia uses and Methanol and E-methanol for shipping use. Source: Systemiq (2022) Planet Positive Chemicals; ETC (2025) Carbon in an Electrified Future

Increasing service and material efficiency is enabled by demand reduction and increased recycling

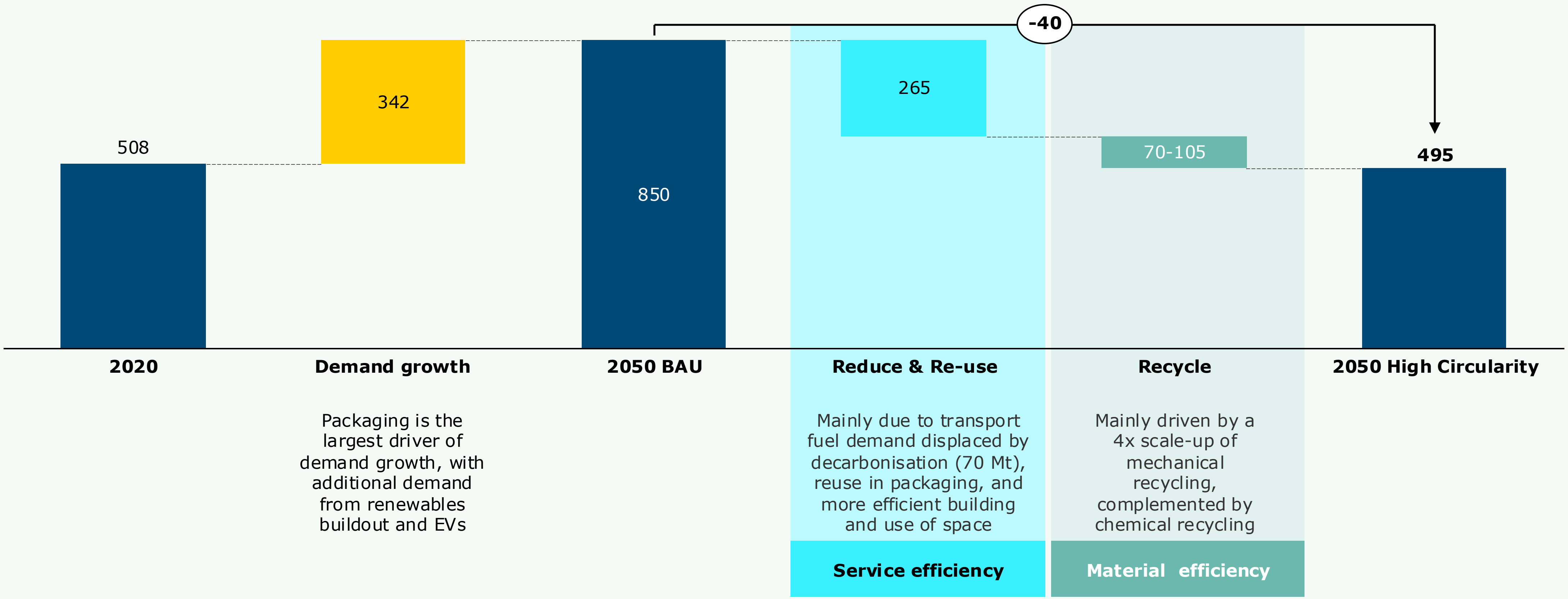
Productivity lever	Description
Service efficiency	• Demand reduction of plastics through reusage, substitution or elimination
Material efficiency	• Increase in recycling rates of chemicals and plastics
Technical energy efficiency	• Electrification of chemicals production (e.g. steam cracking and electric boilers)

Source: Systemiq (2022) Planet Positive Chemicals; ETC (2025) Carbon in an Electrified Future

Plastics and chemical* demand is set to increase with BAU, but adopting high circularity could see 2050 demand close to today's levels

Plastics and chemical* demand analysis between 2020 and 2050

Mt



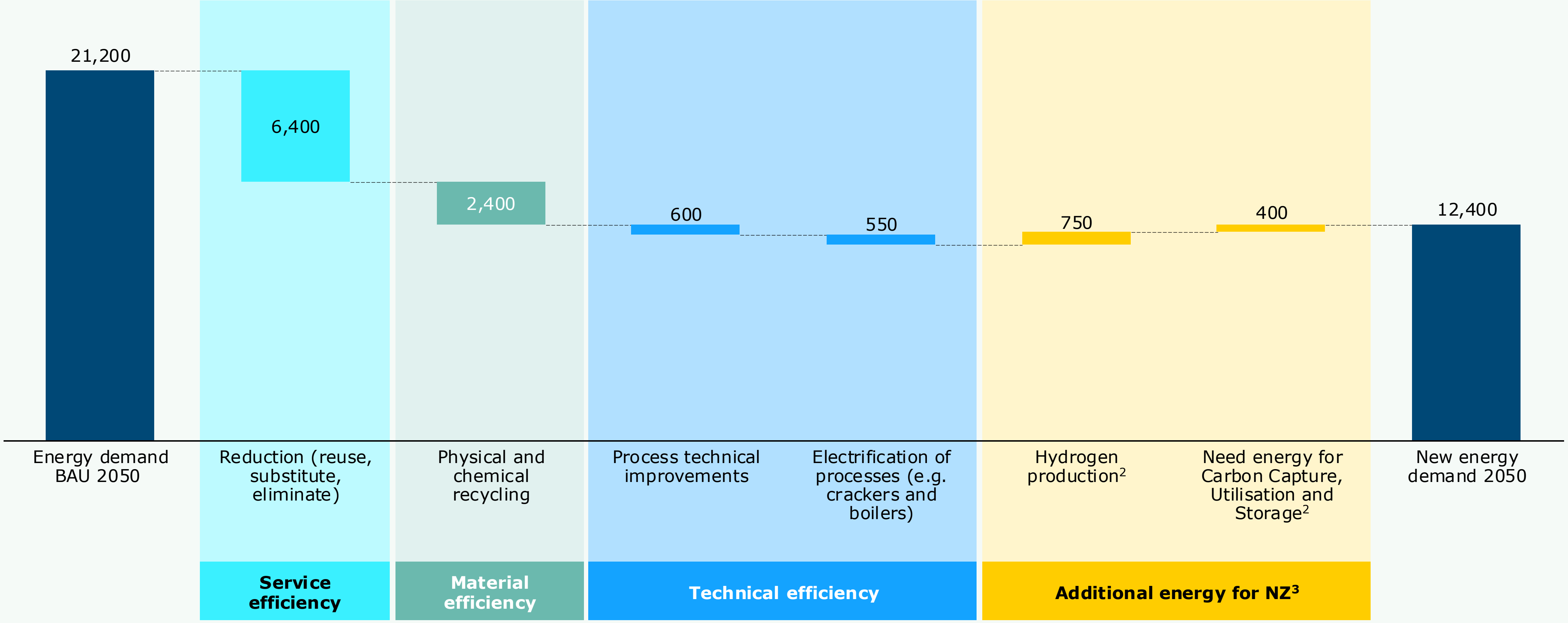
* Including Benzene, Butandiene, Ethylene, Propylene, Toluene, Xylene but excluding all Ammonia uses and Methanol and E-methanol for shipping use

Source: Systemiq (2022) Planet Positive Chemicals; ETC (2025) Carbon in an Electrified Future

Service and material efficiency drive productivity in plastics and chemicals*, more than offsetting additional energy demand required for decarbonised production

Primary energy demand in 2050 and impact of productivity levers

TWh



*Including Benzene, Butandiene, Ethylene, Propylene, Toluene, Xylene but excluding all Ammonia uses and Methanol and E-methanol for shipping use; 1) Primary energy demany in plastics and chemicals is ~15% energy input and ~85% feedstock; 2) Hydrogen is used to produce olefins & aromatics (MTX), with carbon molecules partially coming from CCUS; CCUS estimates includes energy needed for utilization of captured carbon. 3) Biomass conversion to chemicals have a limited role and contributes to minor increase in energy demand which is not depicted.

Source: Systemiq (2022) Planet Positive Chemicals; ETC (2025) Carbon in an Electrified Future

Scaling circularity in plastics and chemicals* requires supportive policies, cross-value chain collaboration and investment in collection and sorting infrastructure

Productivity enablers

1. **Provide the right incentives for circularity** by setting targets for recycled content and banning/including fees on single-use items
2. **Support infrastructure that enables re-use and recycling** by supporting scale-up of re-use models (e.g. overcome high upfront costs) and scaling up collection and sortation infrastructure for recycling
3. **Implement policies to support the business case** via Extended Producer Responsibility (EPR) schemes, which attributes responsibility for the entire lifecycle of products to producers, and carbon pricing, extending it to incineration to limit waste on unabated linear systems
4. **Foster Collaboration Across Value Chains** via R&D, partnership with recyclers, data sharing for traceability, etc.

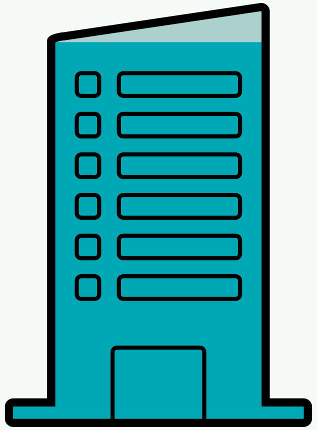
* Including Benzene, Butandiene, Ethylene, Propylene, Toluene, Xylene but excluding all Ammonia uses and Methanol and E-methanol for shipping use
Source: Systemiq (2022) Planet Positive Chemicals; ETC (2025) Carbon in an Electrified Future

Concrete/cement

Energy intensive sectoral deep-dives

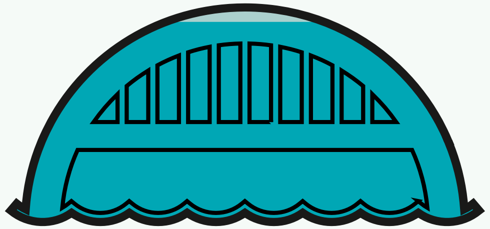
Concrete is used across a wide range of buildings and critical infrastructure. Cement is a key input to concrete.

Approx. % concrete by weight



Apartment building (concrete)

~80-90%



Bridge (concrete)

~90-95%

Wind turbine foundation

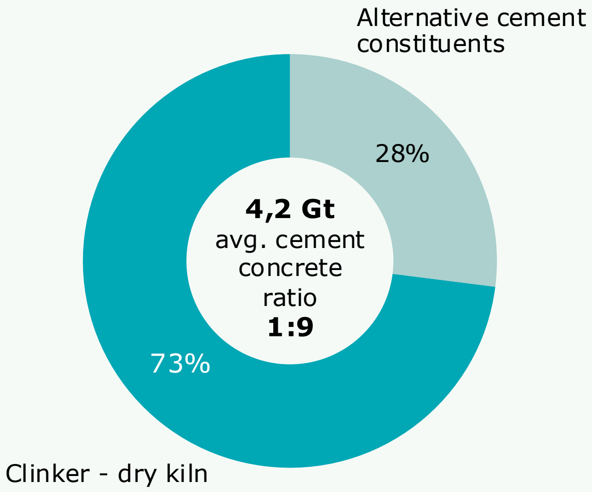
~90-98%

Source: Hammond, G. & Jones, C. (2011), *Inventory of Carbon & Energy (ICE), University of Bath,* FHWA (2018), *Bridge Preservation Guide, NRMCA (National Ready Mixed Concrete Association), bridge case studies*, Vestas (2021), Life Cycle Assessment of Vestas Wind Turbines

Cement demand is 4.2 Gt/year, mainly from coal-based energy production and primarily used in residential and commercial buildings

Production

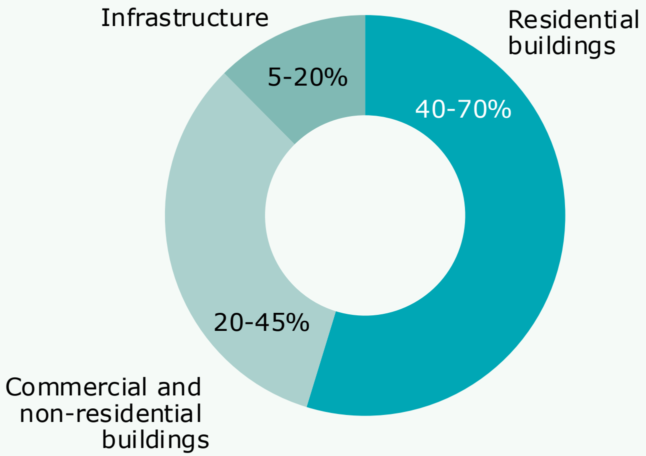
Global cement production by technology, 2020



Cement is a vital input to concrete production. Both are produced in localised markets; being bulky and low-value, they are not economical to transport over long distances

Demand

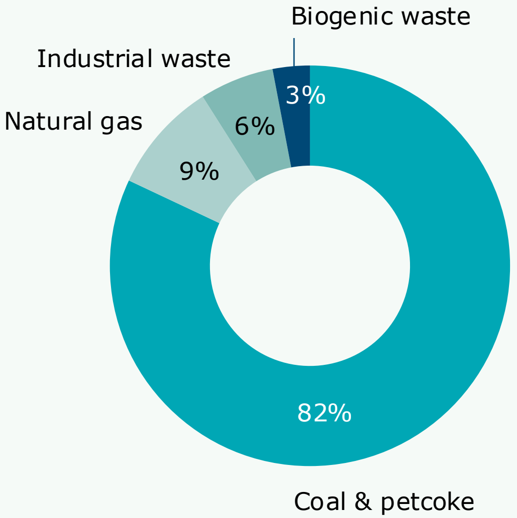
Concrete end use by mass ratio, 2020



Concrete is the world's most widely used material after water, playing a fundamental role in the construction of most modern buildings and infrastructure

Energy supply

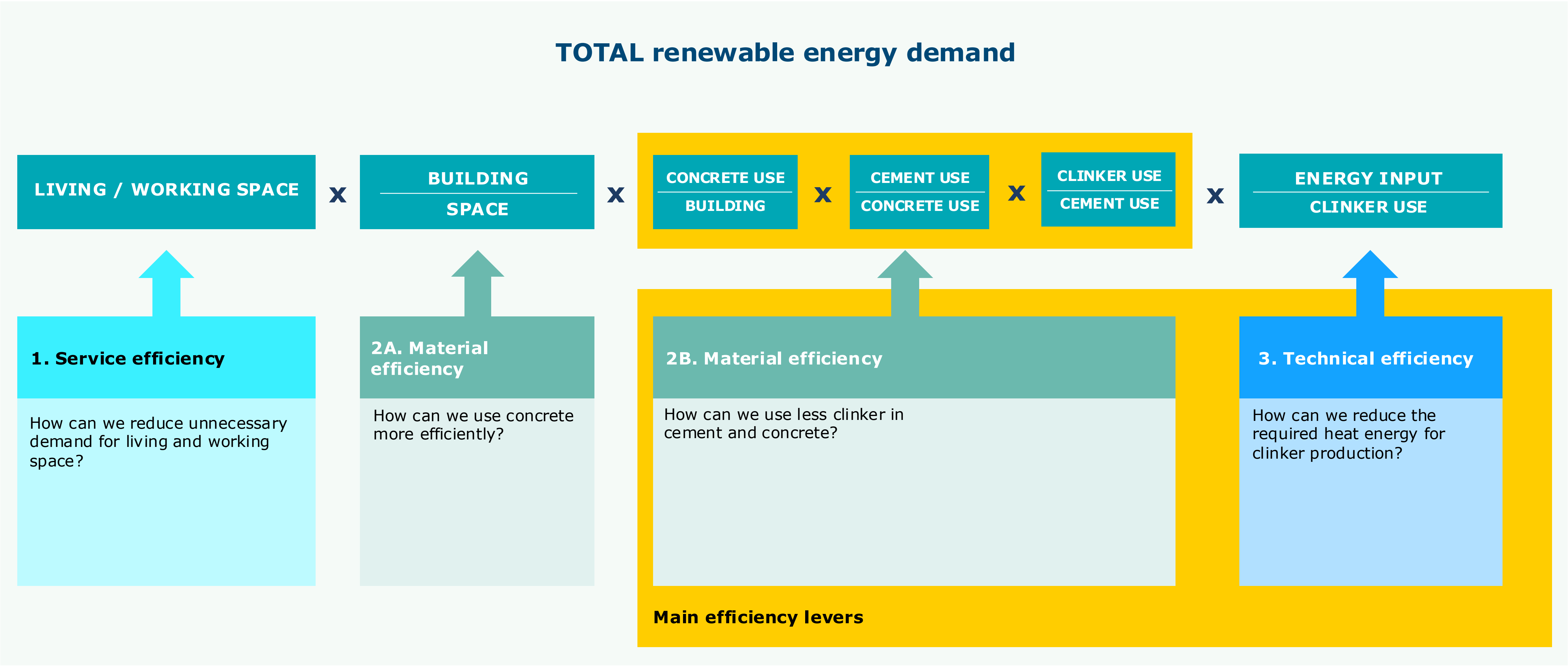
Kiln heat fuel mix, 2020



Coal and petcoke remain the dominant kiln fuels. Kiln heat drives ~35% of sector emissions, the remainder largely comes from process emissions in clinker production (an input to cement)

Note: Petcoke (petroleum coke) is a refining by-product used as kiln fuel; Kiln is a high-temperature furnace used to make clinker; Clinker is the intermediate nodules made in the kiln, later ground to produce cement
Source: MPP (2023) Making Net-Zero Cement and Concrete Possible; IEA(2020) Global cement production by technology in the Sustainable Development Scenario, 2000-2070; NRMCA (2026) About Concrete (accessed March 2026)

Product and material efficiency are most relevant to reduce energy demand in the concrete sector



Note: Clinker is the main constituent of cement
Source: MPP (2023) Making Net-Zero Cement and Concrete Possible

Reducing cement content per building and required energy for clinker production is critical to minimise renewable energy input for concrete

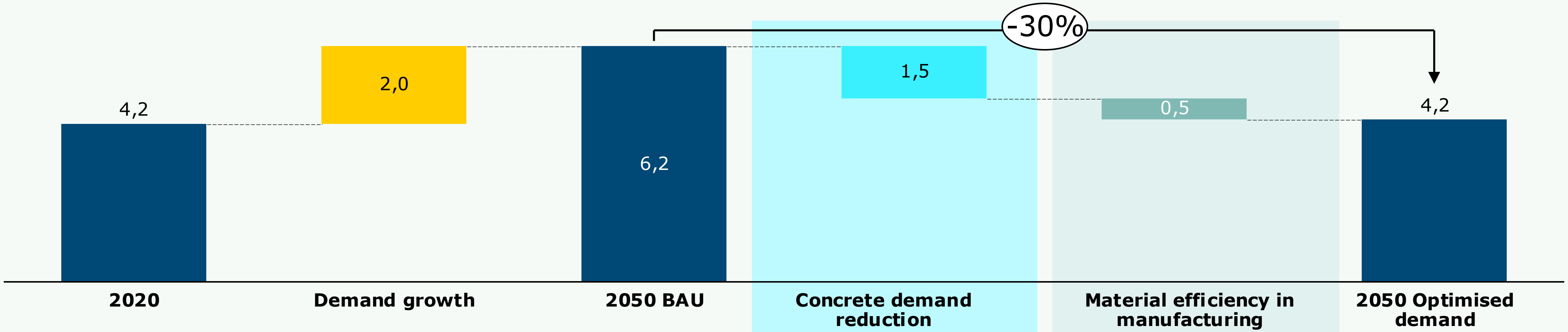
Productivity lever	Description
Service efficiency	• Using less concrete per building via **better design**
Material efficiency	• Using less clinker in cement by partially **replacing clinker with supplementary cementitious materials (SCMs)** • Using less cement in concrete through a **more efficient mixing of cement**
Technical energy efficiency	• **Replacing wet kiln (where raw materials are processed as water-based slurry)** with dry kiln technology that process dry powder and use preheaters • Deploying **waste heat recovery** • Switching to more **efficient grinding**

Source: MPP (2023) Making Net-Zero Cement and Concrete Possible

Housing and infrastructure growth in emerging economies drives demand in cement and concrete sectors, but it is possible to manage with less resources

Cement demand analysis between 2020 and 2050

Gt



Demand growth: Key growth drivers include consumption shifts to emerging economies from today's industrialized regions while China's share of consumption is expected to reduce

Concrete demand reduction: Mainly due to optimised topology, pre-casting, post-tensioned structures, avoid usage with no structural impact, lean design, reusage of dissembled structures, extending buildings life spam, using substitute materials, etc.

Service efficiency

Material efficiency in manufacturing: Mainly due to mix design, grading aggregates better, using admixtures more effectively, and improving quality control, through the shift from bagged cement mixed on-site to increased off-site concrete mixing.

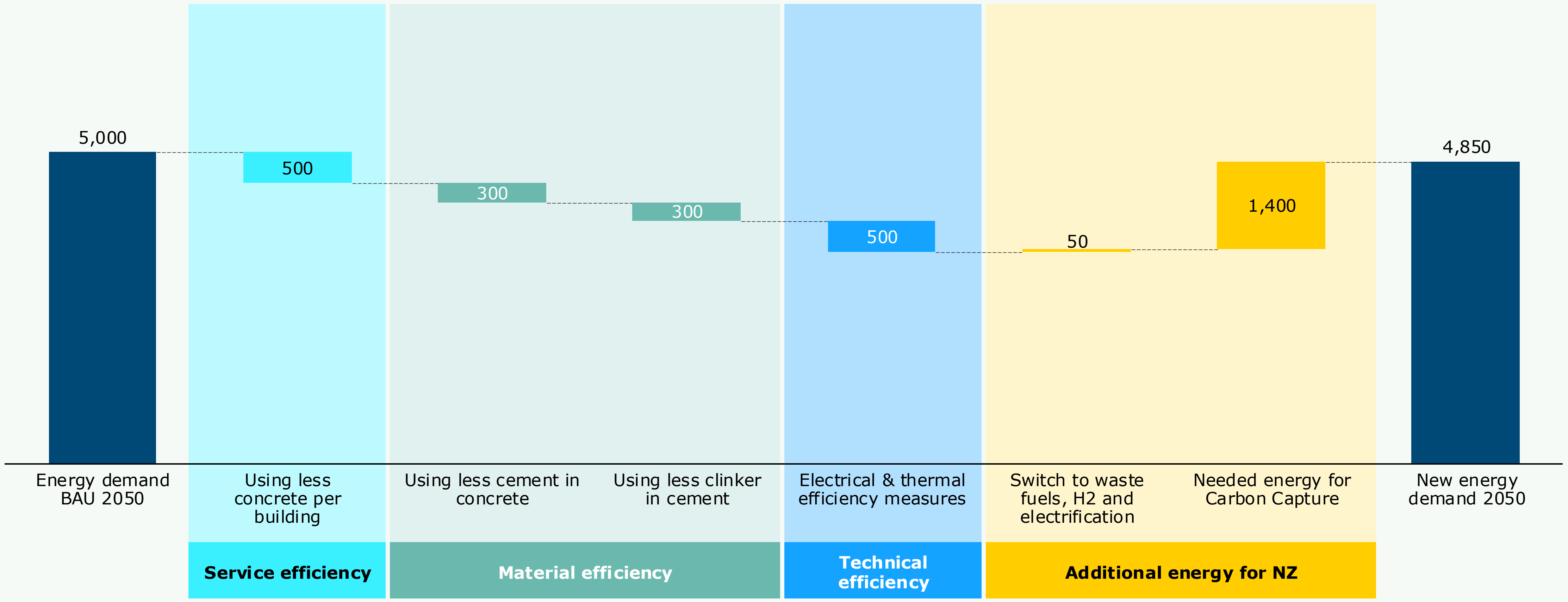
Material efficiency

Source: MPP (2023) Making Net-Zero Cement and Concrete Possible

Material efficiency is the most important lever to reduce energy demand for concrete

Primary energy demand in 2050 and impact of productivity levers

TWh



Source: MPP (2023) Making Net-Zero Cement and Concrete Possible

Material productivity in cement will only scale with clear standards and investment incentives

Productivity enablers

1. **Implement market based mechanisms** (e.g. green procurement with standards on buildings performance) to incentivise supply side material efficiencies
2. **Investment into R&D for alternative chemistries**
3. **Investment into infrastructure for bulk cement mixing** to reduce overapplication
4. **Develop performance based standards** reduce the clinker-to-concrete ratio effectively
5. **Set mandatory emission targets** or via climate-aligned investment principles

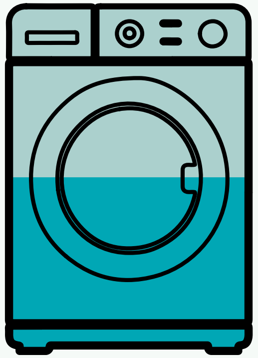
Source: MPP (2023) Making Net-Zero Cement and Concrete Possible

Steel

Energy intensive sectoral deep-dives

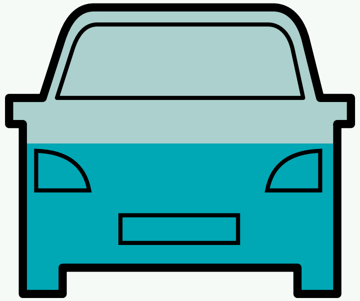
Steel is used across a wide range of everyday products and industrial applications

Approx. % steel by weight



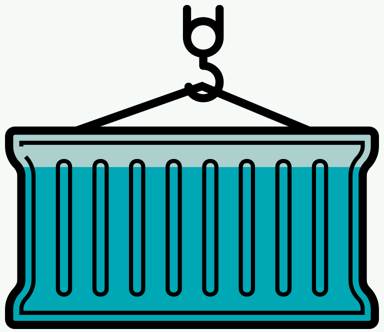
Washing machine

~40-50%



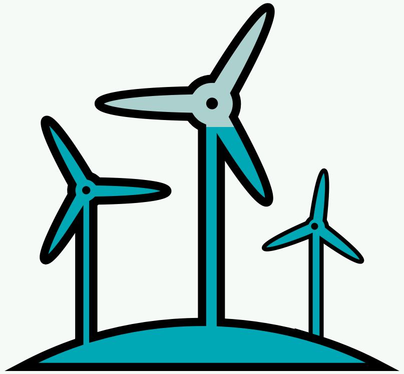
Car

~50-65%



Shipping container

~80-95%



Wind turbine

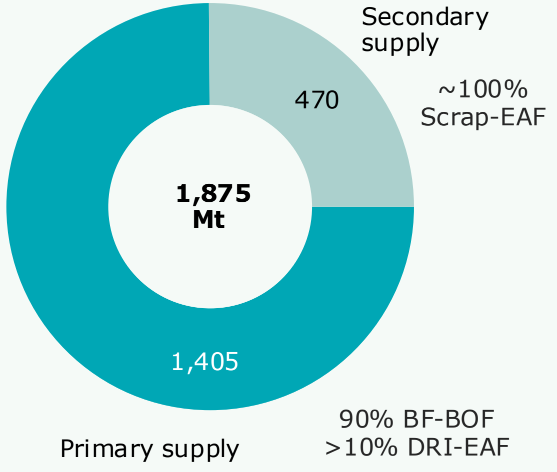
~65-80%

Source: Garcilaso et al. (2007) A Life-cycle Comparison of Clothes Washing Alternatives; WorldAutoSteel (2026) Recycling Steel and Iron Used in Automobiles; Buchanan (2018) Lightweighting Shipping Containers: Life Cycle Impacts on Multimodal Freight Transportation; USGS (2026) What materials are used to make wind turbines?

Steel production is 1,875 Mt today, predominantly coal-based primary production (75%), with buildings and infrastructure driving demand

Production

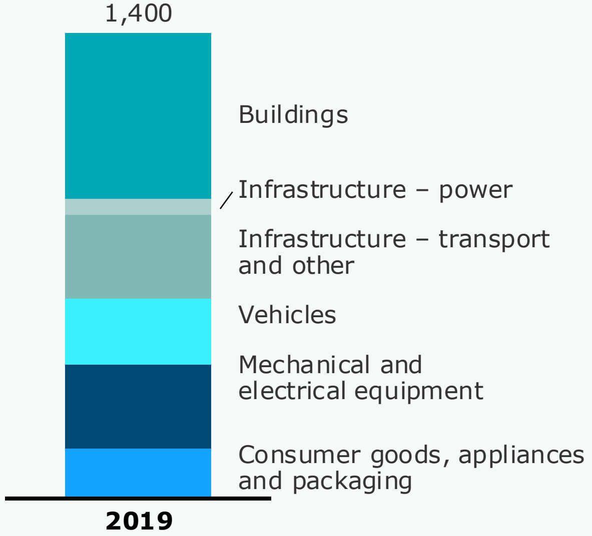
Global crude steel supply, 2020
Mt/y



Primary production emits ~2.1 t CO_2 per tonne of crude steel. Secondary (scrap-based) production emits ~0.5 t CO_2/t. The sector emits ~7% of global GHG emissions

Demand

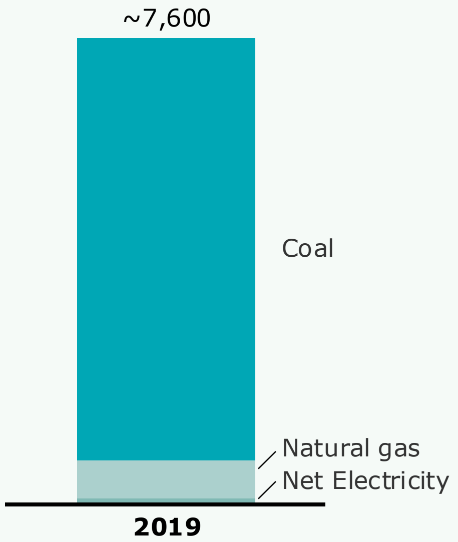
Global end-use steel demand, 2019
Mt/y



Demand is dominated by buildings and infrastructure. Even with high recycling rates, scrap alone cannot meet future demand, so decarbonising primary steel remains critical

Energy supply

Global steel energy supply per year
TWh/y



Coal is uniquely difficult to displace in steelmaking because it serves as both the energy source and the chemical reductant. The sector is the largest industrial consumer of coal

Note: DRI = Direct Iron Reduction; EAF = Electric Arc Furnace; BF-BOF = Blast Furnace coupled with Basic Oxygen Furnace; Energy supply approximate conversion to TWh on an IEA NCV basis; coal assumes 27 GJ/t and gas 9.7 TWh/bcm
Source: MPP (2023) Making Net-Zero Steel Possible; IEA (2020) Iron and Steel Technology Roadmap; Global Energy Monitor – global Iron and Steel Tracker (Accessed Mar 2026)

There are two main efficiency levers to reduce energy demand in the steel sector

TOTAL renewable energy demand

=

DEMAND FOR SERVICES (e.g. buildings, cars, etc) x **MT OF STEEL** / Service (e.g. buildings, cars, etc) x **ENERGY** / Mt of steel

1. Service efficiency

Not relevant: demand set to increase with buildings and vehicles

2. Material efficiency

Can we use more scrap steel instead of virgin steel?

3. Technical efficiency

Can we electrify, while decarbonising, iron making?

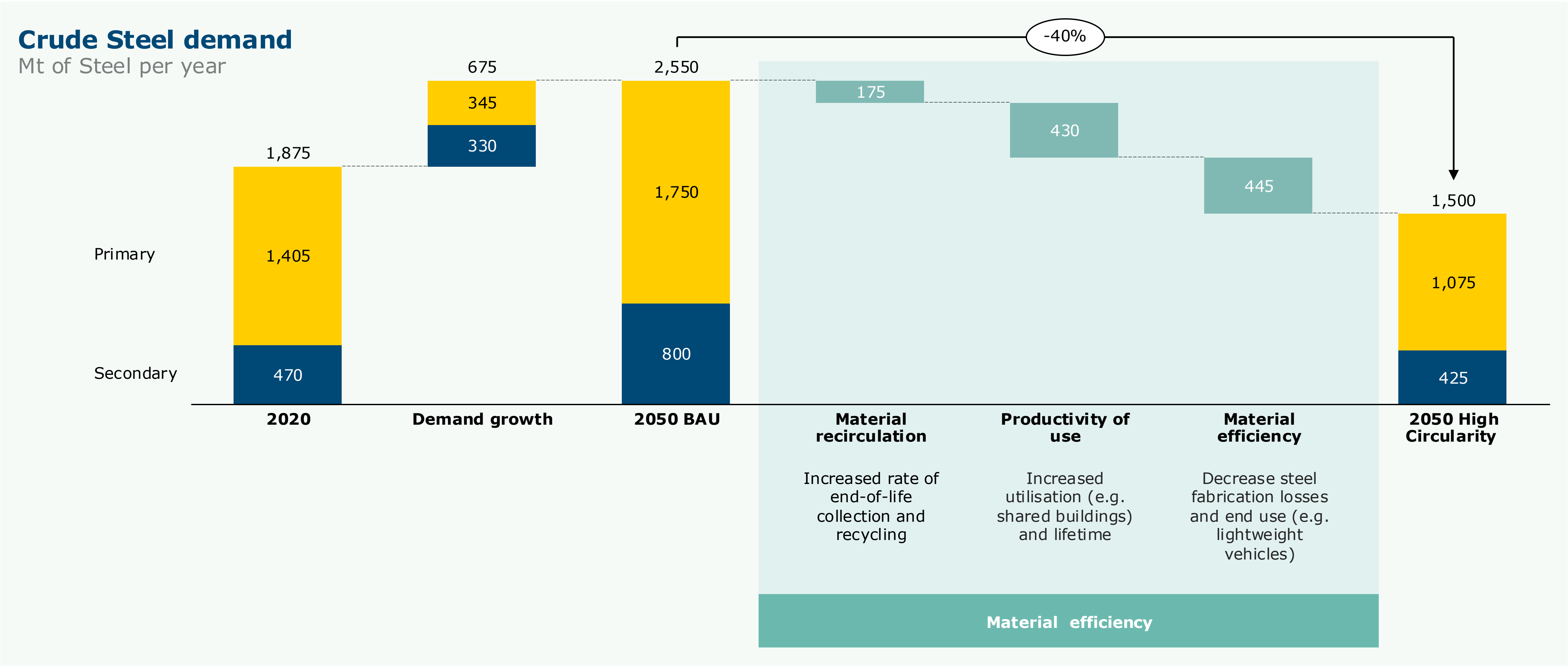
Source: MPP (2023) Making Net-Zero Steel Possible

Increasing scrap usage and shifting to more efficient steelmaking routes are key to reducing steel energy demand

Productivity lever	Description
Material efficiency	• Scrap usage increase: increase secondary production from scrap and % of scrap in primary production
Technical energy efficiency	• Energy efficiency gain from Electric Arc Furnaces (EAFs) and electrowinning in steelmaking compared to the average Blast Oxygen Furnaces (BOF) • Energy efficiency gain from Direct Iron Reduction (DRI) (with natural gas, biomass or hydrogen) compared to the average BF • Energy efficiency gain from smelting compared to the average Blast Furnaces coupled with Blast Oxygen Furnaces (BF-BOF)

Source: MPP (2023) Making Net-Zero Steel Possible

Steel business-as-usual demand is set to grow to 2050, but demand can be reduced by higher circularity

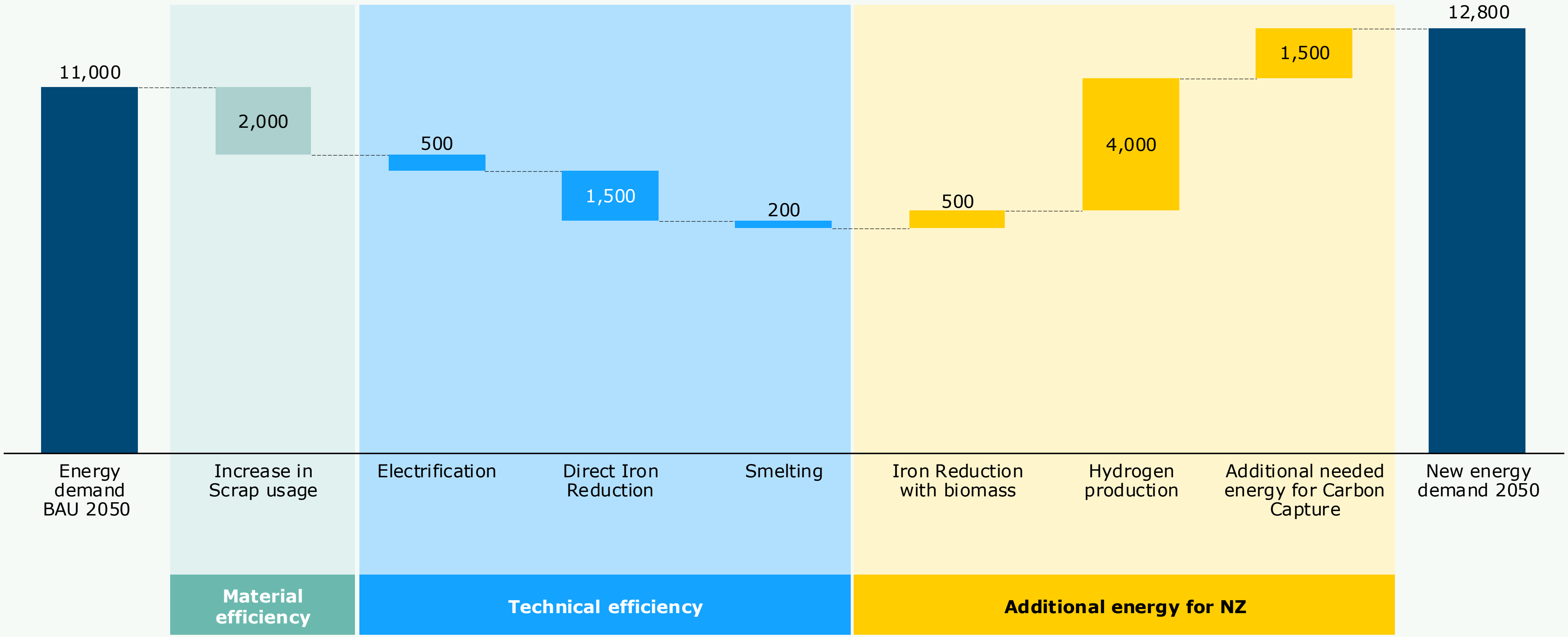


Source: MPP (2023) Making Net-Zero Steel Possible

Material efficiency offers the biggest productivity potential in steel; but hydrogen production and CCUS offsets productivity gains

Primary energy demand in 2050 and impact of productivity levers

TWh



Source: MPP (2023) Making Net-Zero Steel Possible

Enablers for higher productivity in steel includes increase in scrap collection rates and increase in electrification via secondary production

Productivity enablers

1. **Policy incentives** to increase scrap collection and recycling
2. **Stricter rules to limit scrap exports** to countries with lower environmental standards
3. **Increase electrification**, especially downstream iron reduction on steelmaking process, by increasing EAFs production share

Source: MPP (2023) Making Net-Zero Steel Possible

Aviation

Energy intensive sectoral deep-dives

The significant improvements in aviation fuel efficiency over the past 15 years have been outpaced by increasing demand

Global fleet profile

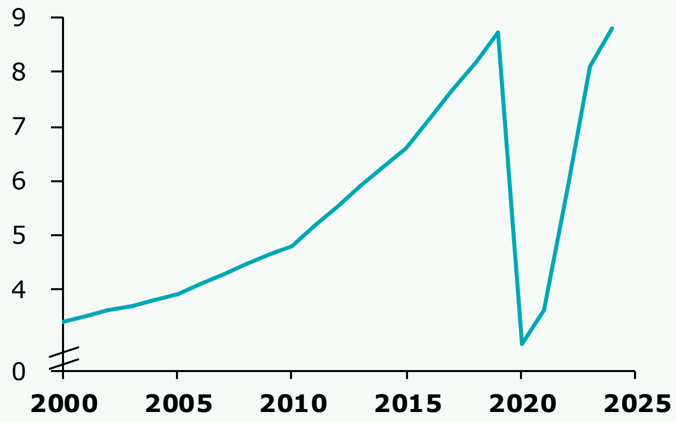
35,550
Aircrafts in global commercial fleet as of June 2025,

~15 years
Average age of global fleet, with a retirement rate of ~1.5% per year

~2.5% p.y.
Average fuel efficiency improvement over 2010–2019, before COVID

Demand

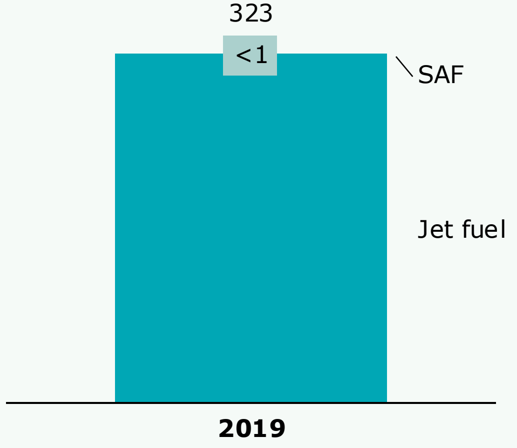
Global passenger demand (RPK) Trillion
RPK/year



Aviation demand grew >6% per year from 2010–2019, and despite a high utilization of 80% in passenger load factor, demand outpaced efficiency gains. In 2023, the sector carried 4.3bn passengers and 223.8bn freight tonne-km

Energy supply

Global aviation fuel production
Mt/y



Aviation is highly dependent on energy-dense liquid fuels, making SAF the main near-term decarbonisation lever

Source: MPP (2023) Making Net-Zero Aviation Possible; ICAO (2023) The World of Air Transport in 2023; IATA (2025) The Global Commercial Aircraft Fleet; ICAO (2024), Annual Report 2024 ; IATA (2023) Air Passenger Market Analysis; IEA (2025), Energy intensity of commercial passenger aviation in the Net Zero Scenario, 2000-2030; IATA (2025) The global commercial aircraft fleet

There are three main efficiency levers to reduce energy demand in the aviation sector

TOTAL renewable energy demand

=

PASSENGER KM x **AIRPLANE KM / PASSENGER KM** x **ENERGY / AIRPLANE KM**

1A. Service efficiency

Can we reduce air travel and logistics demand? E.g. by switching to alternative modes

1B. Service efficiency

Can we increase the utilization/occupancy of the airplane?

3. Technical efficiency

Can reduce the overall energy demand in fuel production, engine use and airplane?

Source: MPP (2023) Making Net-Zero Aviation Possible

Lighter, more efficient aircraft and operational improvements are key to reducing aviation energy demand

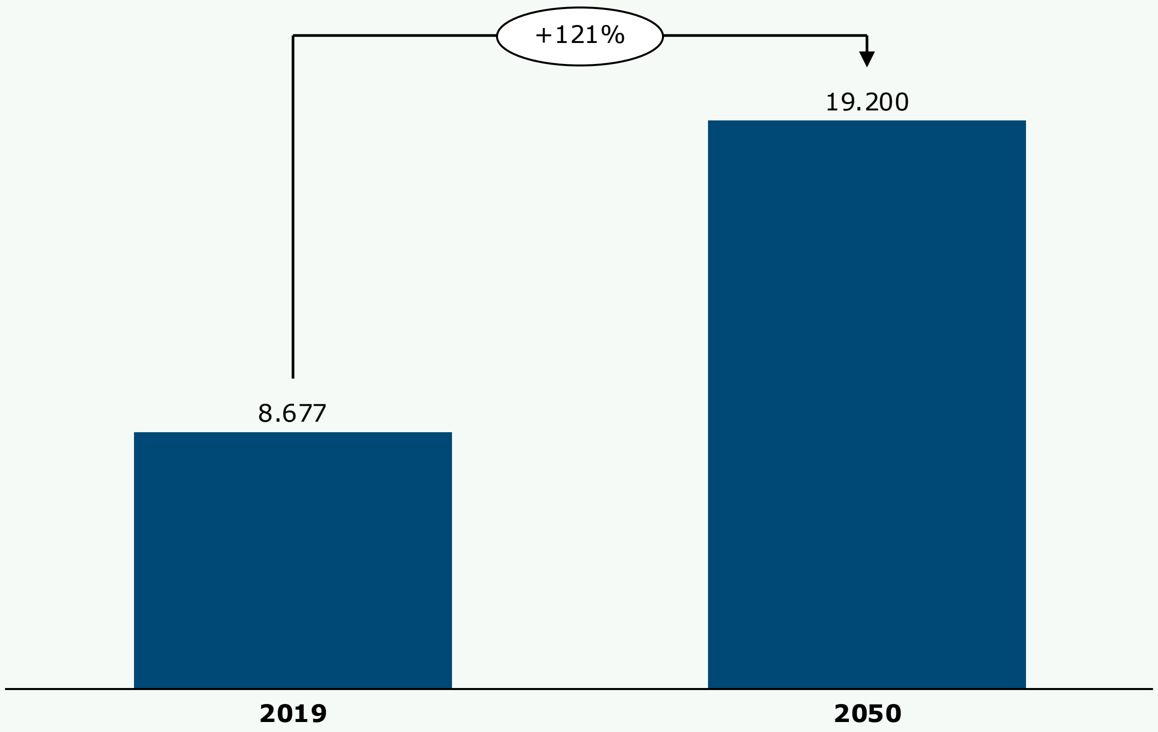
Productivity lever	Description
Technical energy efficiency	• Engine efficiency improvements • Improvements in aerodynamics • Lightweighting of airplane
Service efficiency	• Optimised approach / departure procedures for take-off and landing • Improved congestion management • Modal shifts from regional flights to high-speed trains • Behaviour shift from business travels to increase video conferencing

Source: MPP (2023) Making Net-Zero Aviation Possible

Demand for aviation is expected to more than double by 2050, putting pressure on the growing demand for conventional jet fuels

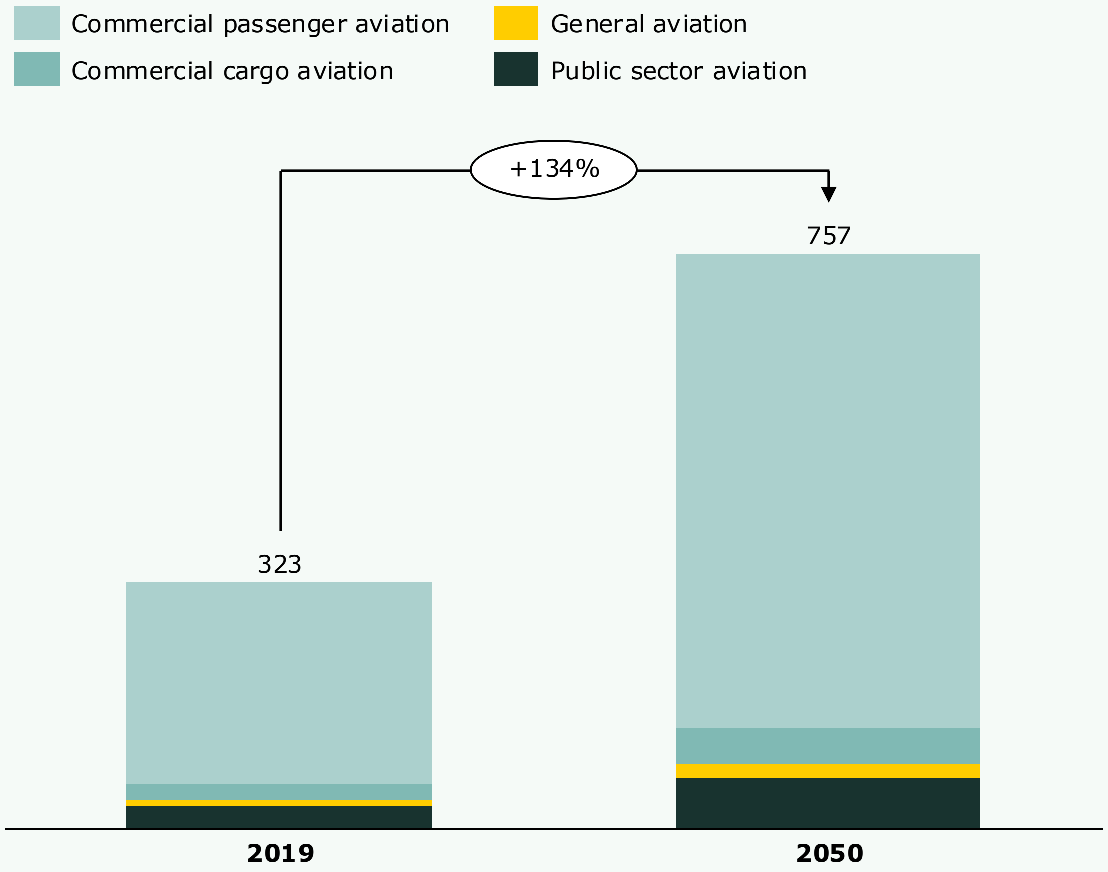
Commercial passenger aviation demand

Billion revenue passenger-km (RPK)



Jet fuel equivalent demand (before efficiency levers)

Mt

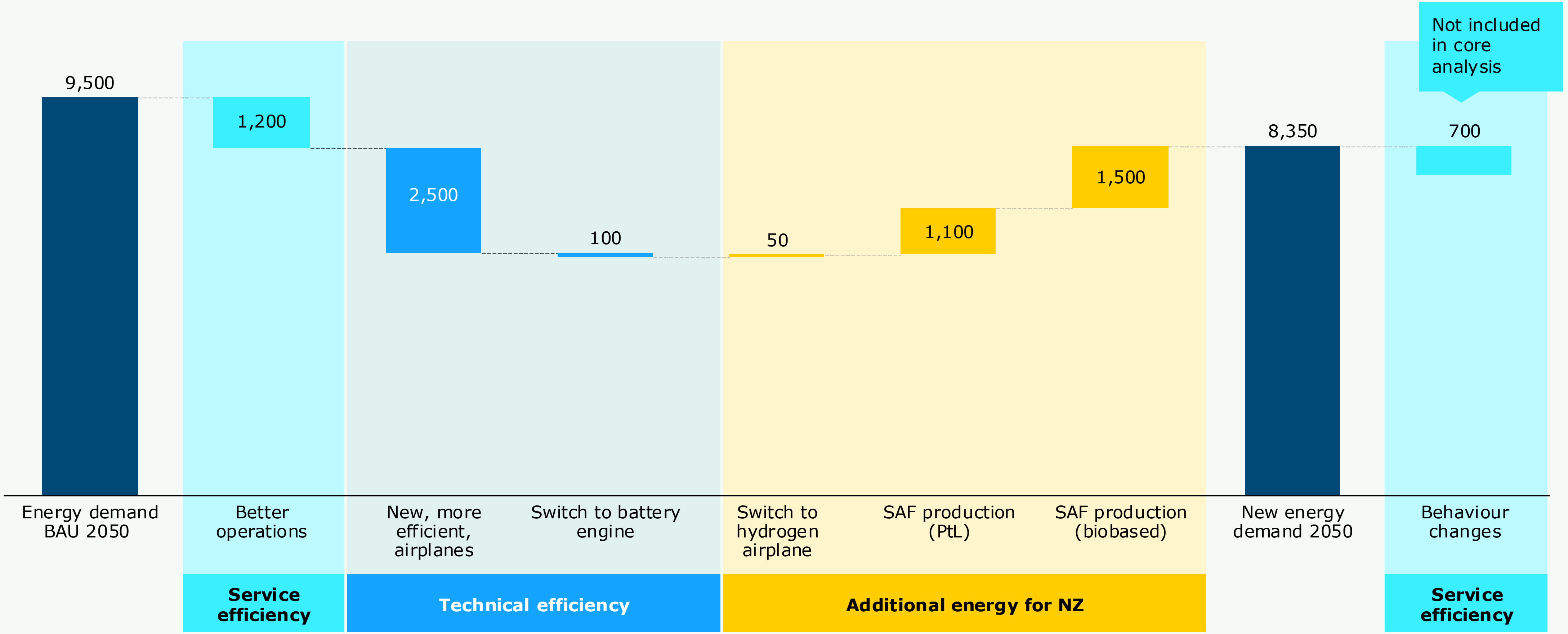


Source: MPP analysis, comparison of CAGRs from IATA (2024) Aviation Net-Zero Co2 Transition Pathways Comparative Review. Note: ICAO = International Civil Aviation Organization, ATAG = Air Transport Action Group, IATA = International Air Transport Association, ICCT = International Council on Clean Transportation, MPP = Mission Possible Partnership, IEA = International Energy Agency. ICAO covers 2018-2050

The single most important lever is to make conventional airplanes more efficient

Primary energy demand in 2050 and impact of productivity levers

TWh



Source: MPP (2023) Making Net-Zero Aviation Possible; Schäfer, A. (2019). "Technological, economic and environmental prospects of all-electric aircraft". Nature Energy. 4 (2): 160–166.

Reducing aviation's energy intensity depends on next-generation aircraft R&D, accelerated fleet renewal, and modal shift for short-haul routes

Productivity enablers

1. **Policy incentives to support R&D efforts:** Funding for original equipment manufacturers (OEMs) and engine suppliers to advance light-weighting, hybrid-electric propulsion, and next-generation airframe and engine efficiency
2. **Accelerate fleet renewal:** Incentivise earlier retirement of older, less efficient aircraft and accelerate delivery of next-gen models (e.g. A320neo, 737 MAX) that offer ~15-20% fuel burn improvement over predecessors
3. **Improve operational efficiency:** Optimise air traffic management, flight routing, and ground operations to reduce fuel burn per flight
4. **Invest in short-haul alternatives:** Expand high-speed rail infrastructure to enable modal shift from aviation on routes under ~500km, where rail is both faster and lower-carbon

Source: MPP (2023) Making Net-Zero Aviation Possible

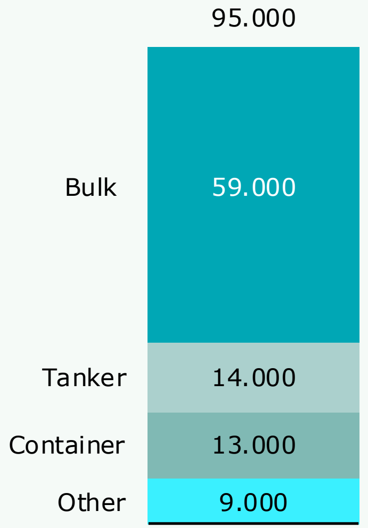
Shipping

Energy intensive sectoral deep-dives

Shipping moves over 80% of global trade, with heavy fuel oil and marine diesel accounting for ~99% of shipping fuel

Production

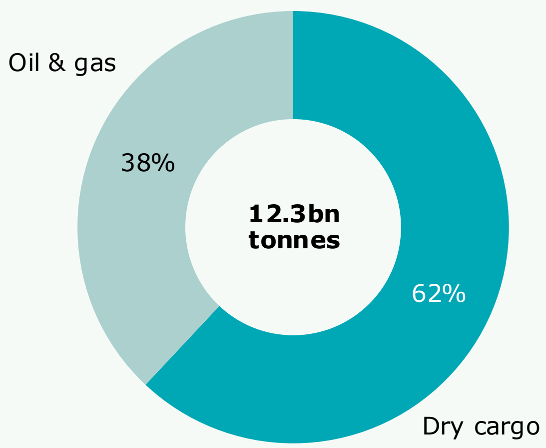
Global shipping transport work by segment, 2018 bn tonne-miles



Shipping moves over 80% of global trade by volume, with bulk, tanker and container segments accounting for ~90% of industry volume

Demand

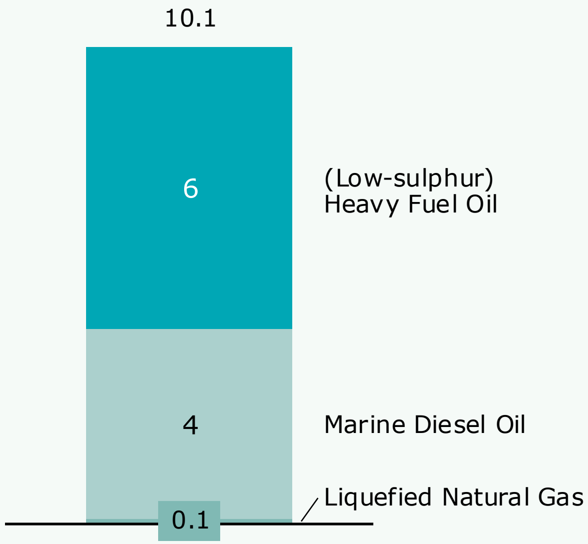
Seaborne trade by cargo type, 2023 World maritime trade volume



Seaborne trade has shifted from liquid to dry cargo, with crude oil's share falling from 29% to 18% since 2000. Dry bulk (iron ore, coal, grain) and containerised goods now dominate

Energy supply

Global shipping energy demand fuel production, 2019 EJ



The sector remains almost entirely dependent on oil-based fuels, with heavy fuel oil and marine diesel accounting for ~99% of shipping fuel

There are three main efficiency levers to reduce energy demand in the shipping sector

TOTAL renewable energy demand

=

PASSENGER & CARGO KM	x	SHIPPING KM / PASSENGER & CARGO KM	x	ENERGY / SHIPPING KM

1A. Service efficiency

Can we reduce passenger and cargo demand travelled?

1B. Service efficiency

Can we increase the utilization of the ship?

3. Technical efficiency

Can reduce the overall energy demand of the fuel production, engine and ship?

Source: MPP (2023) Making Net-Zero Shipping Possible

Shipping vessels can be more efficient via better operations, better routing and maintenance, and technological improvements, in design and engines

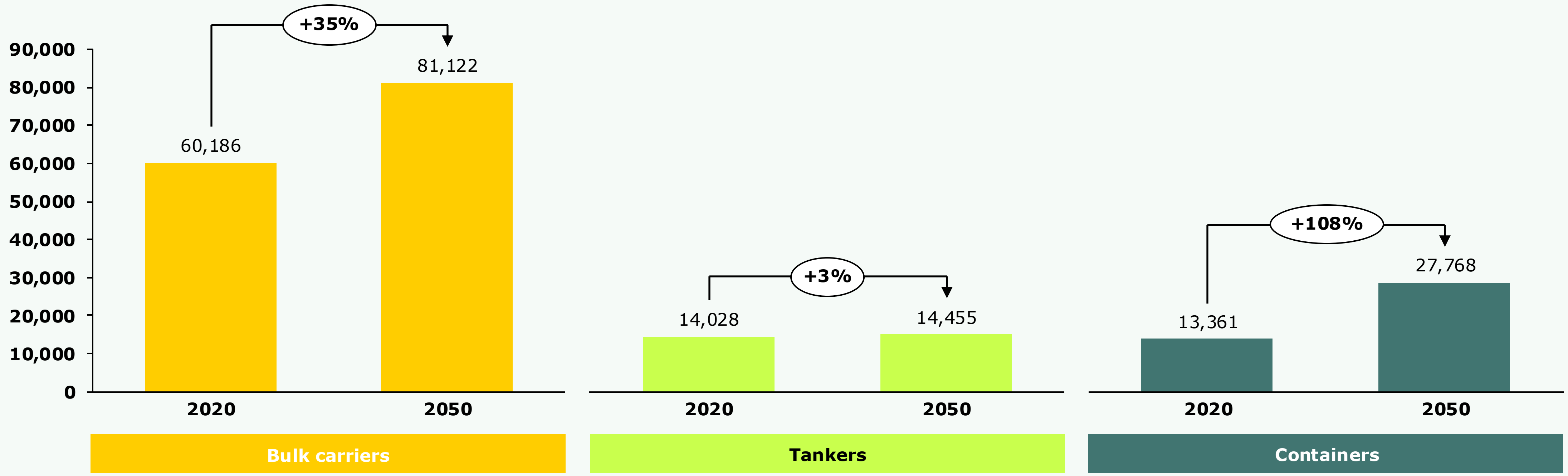
Efficiency lever	Efficiency lever description
Service efficiency	• **Better operations of vessels via:** ○ weather routing, ○ autopilot upgrade, ○ speed reduction, ○ increased frequency in hull cleaning, ○ better engine control ○ better propeller polishing
Technical efficiency	• **Technological improvements in:** ○ auxiliary power, ○ aerodynamics, ○ thrust efficiency (propeller upgrade/retrofit, rudder retrofit), ○ engine efficiency (waste heat recover, common rail, speed de-rating), ○ hydrodynamics (hull coating, water flow optimization)

Source: ICCT (2013) Long-term potential for increased shipping efficiency through the adoption of industry-leading practices

Three segments – bulk, tanker and container – account for around 90% of industry volume and demand is set to increase by 2050

Demand for shipping

Billions-tonnes miles



Bulk carriers: Urbanisation and infrastructure build-out in emerging economies sustain demand for iron ore, grain, and minor bulk. Coal trade declines but is partially offset by growing critical minerals trade.

Tankers: Fossil fuel phase-down broadly flattens tanker demand

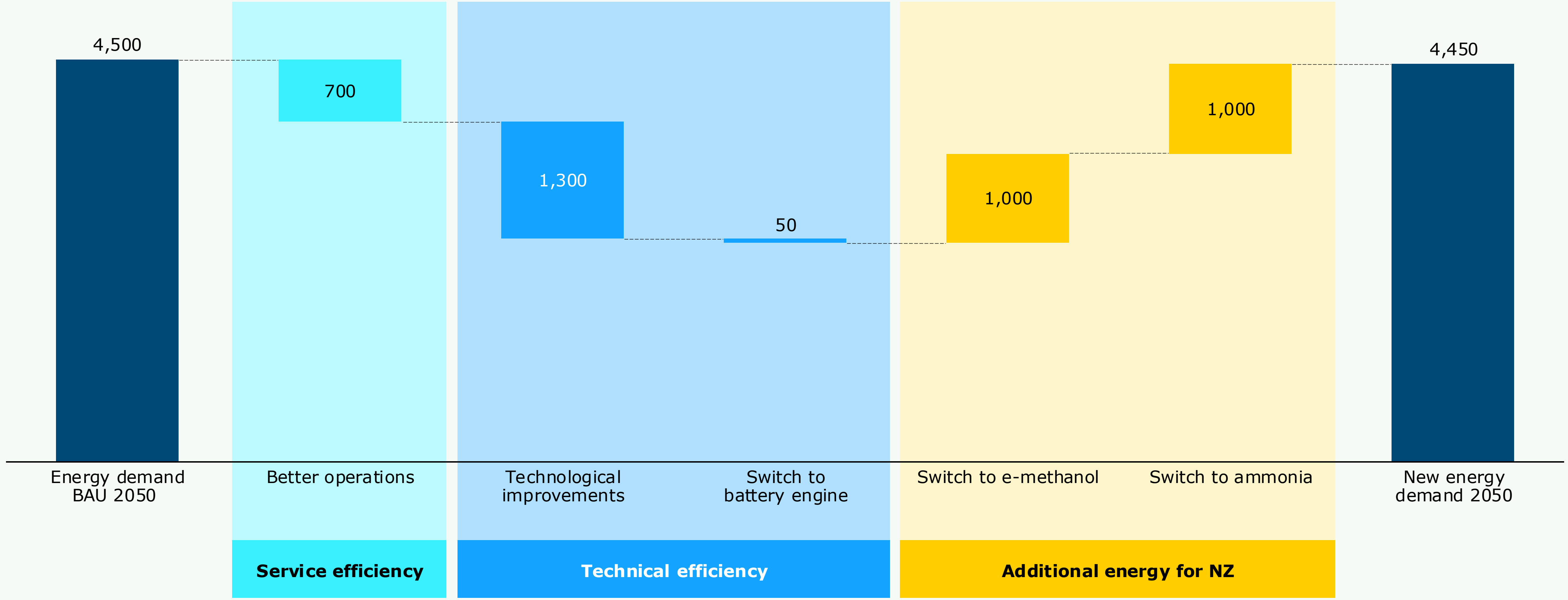
Containers: Container trade tracks GDP and manufactured goods consumption, with growth driven by rising middle-class demand in emerging economies, e-commerce expansion, and increasing containerisation of trade

Source: ETC (2022) Fossil Fuel in Transition; Maersk Mc-Kinney Moller Center for Zero Carbon Shipping (2022), We show the world it is possible
Note: 2020 values estimated from 2018 data using expected CAGR to 2050.

Efficiency gains in shipping counterbalanced by additional energy due to net zero technologies

Primary energy demand in 2050 and impact of productivity levers

TWh



Source: Source: ICCT (2013) Long-term potential for increased shipping efficiency through the adoption of industry-leading practices, MPP analysis
Note: alongside e-methanol there may be a supplementary role for e-Natural Gas

Policy incentives, retrofitting, and operational improvements can drive near-term gains in shipping efficiency

Productivity enablers

1. **Policy incentives to support R&D efforts:** R&D efforts needed from OEMS and engine/parts suppliers
2. **Retrofit, when possible, current vessels** and/or vessels operational parts/systems
3. **Ensure new, more efficient vessels** replace the operation of older less efficient vessels
4. **Promote a decrease in vessels operational speed**
5. **Ensure preventive maintenance** to guarantee vessels operate at maximum efficiency

Source: ICCT (2013) Long-term potential for increased shipping efficiency through the adoption of industry-leading practices

Technical Appendix

Shipping vessels can be more efficient via better operations, better routing and maintenance, and technological improvements, in design and engines

Productivity lever

Cost reduction case study

Productivity lever		
Technical energy efficiency	**-$135 bn/year** in SAF expenditure	
Service efficiency	**-$12 bn/year** in the bottled water business	
Material efficiency	**-$25 bn/year** in aluminium power bills	

SAF	Price ranges – global avg ($/ton)	Share of 2050 demand	Total jet fuel demand in 2050 (Mt)
Power-to-Liquids	625-1480	20%	755
HEFA	985-1420	6%	
Other biofuels	1130-2345	23%	

Beverage bottles	Price – global avg ($/use)
Single use	0.07
Re-usable (at scale scenario)	0.05

Production	Energy demand (GJ/ton of Al)
Primary	66
Secondary	3.3

Material lever	Potential by 2050 (Mt)	Energy gains (GJ/ton of Al)
Shift from Primary to Secondary	13	(66-3.3)
Decrease losses in manufacturing	17	3.3
Increase lifetime	12	50%*66 + 50%*3.3

Share of global production in China by 2050 (%)
>50%
Power prices in China by 2050 ($/MWh)
102

Source: Mission Possible Partnership (2022) Making Net-Zero Aviation Possible; Systemiq (2022) Planet Positive Chemicals; ETC (2025) Carbon in an Electrified Future; bevi (2025) Every bottle counts: Beverage industry impact report; Mission Possible Partnership (2022) Making Net-Zero Aluminium Possible