



TECHNICAL BRIEFING | APRIL 2026

Harnessing energy productivity for industrial competitiveness in a low carbon world



MISSION
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Energy
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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.

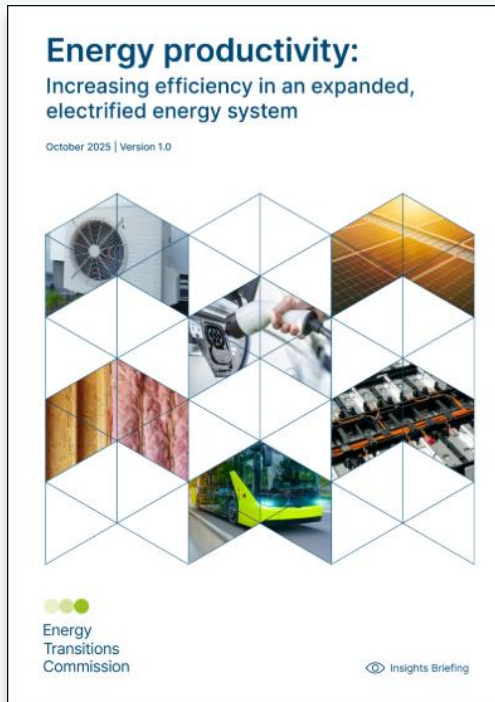
We hope this briefing provides a practical roadmap—and a catalyst—for the leadership needed to unlock energy productivity across the world's most critical sectors.

Lord Adair Turner
Co-Chair, Energy Transitions Commission

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

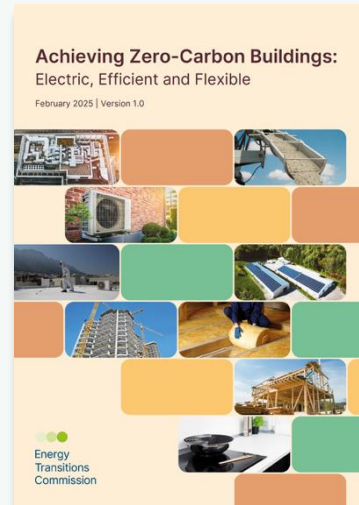
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'Unlocking Energy Productivity in Energy-Intensive Sectors' is part of the wider series of ETC reports on energy productivity



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



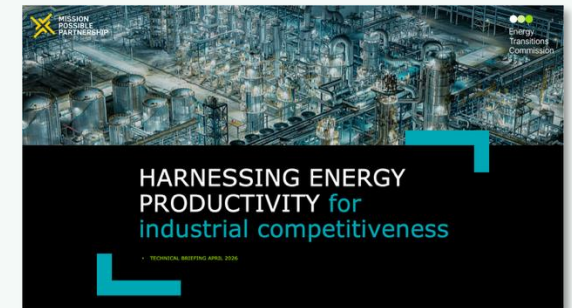
Launched February 2025

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

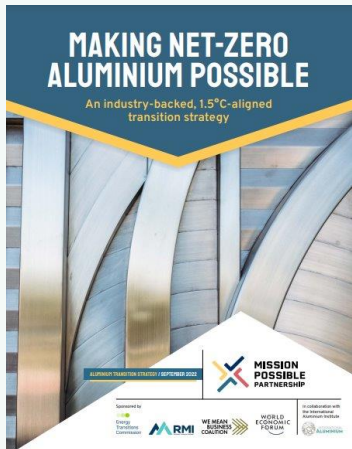
Mission Possible Partnership developed seven detailed sector transition strategies (STS) in 2022, with an additional report by Systemiq on Chemicals, which modelled decarbonisation outlooks under across sectors, including assumptions on energy productivity potential (e.g. increasing materials durability 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



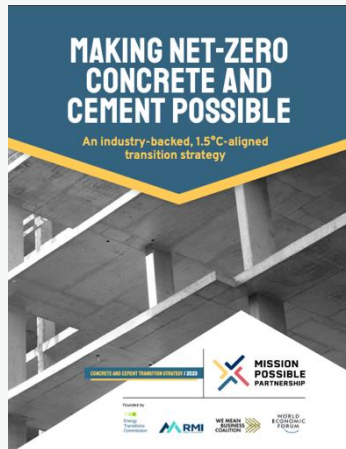
Aluminum



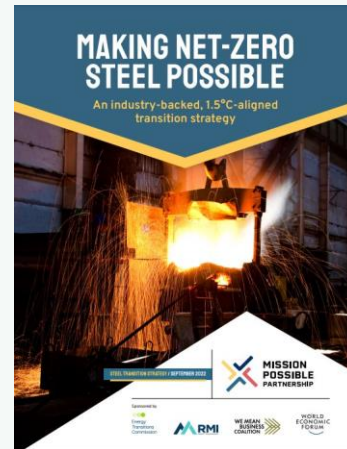
Chemicals



Concrete/Cement



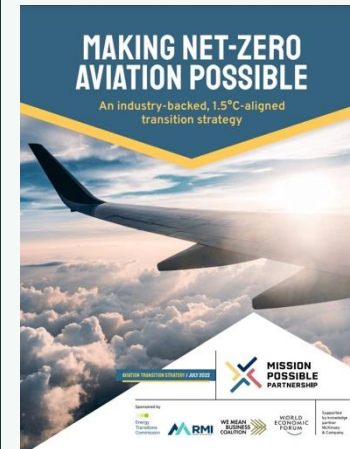
Steel



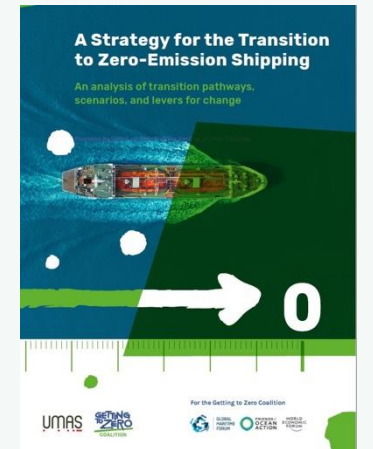
LONG DISTANCE TRANSPORTATION



Aviation



Shipping



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.

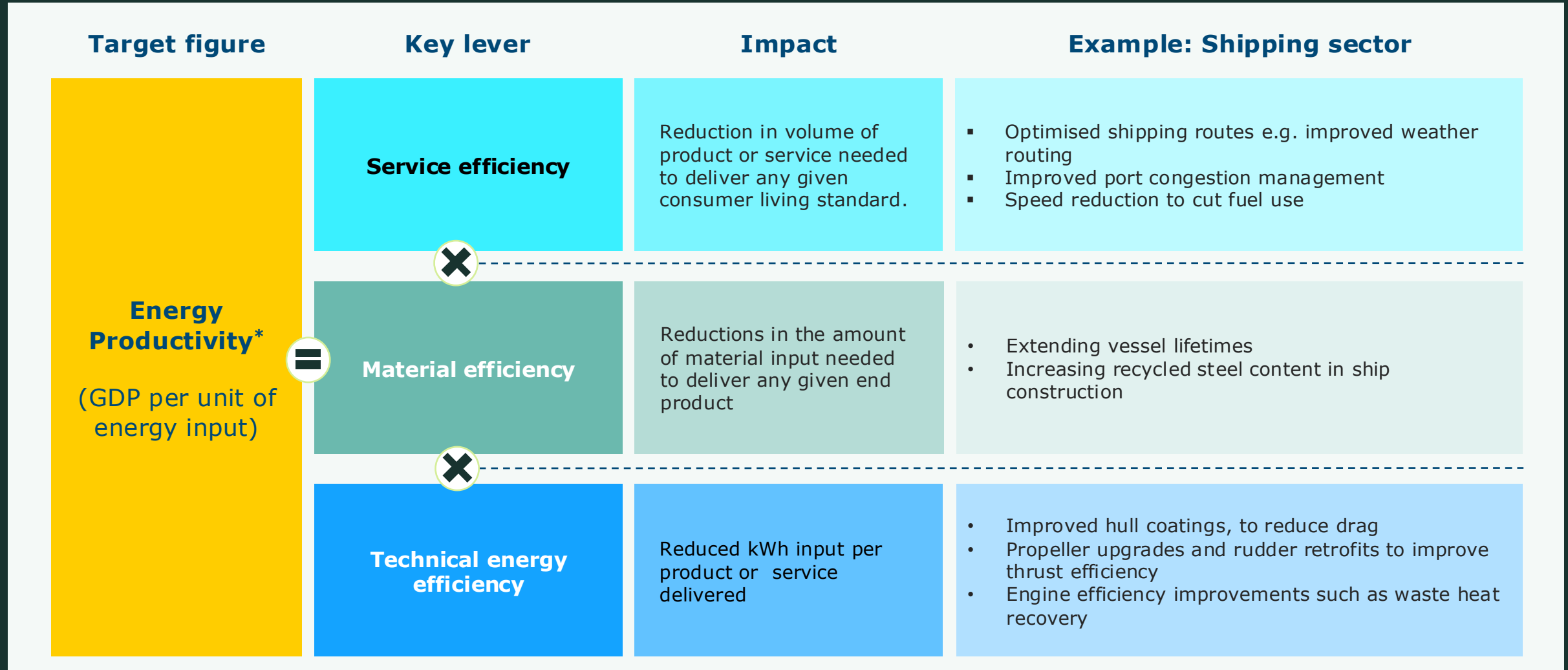


Technical efficiency improvements and greater product utility can improve the productivity of energy use in heavy industry (aluminium, steel, cement, plastics) and transportation (shipping and aviation), lowering overall system needs.

- 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.



Three levers to increase energy productivity – shipping as example sector

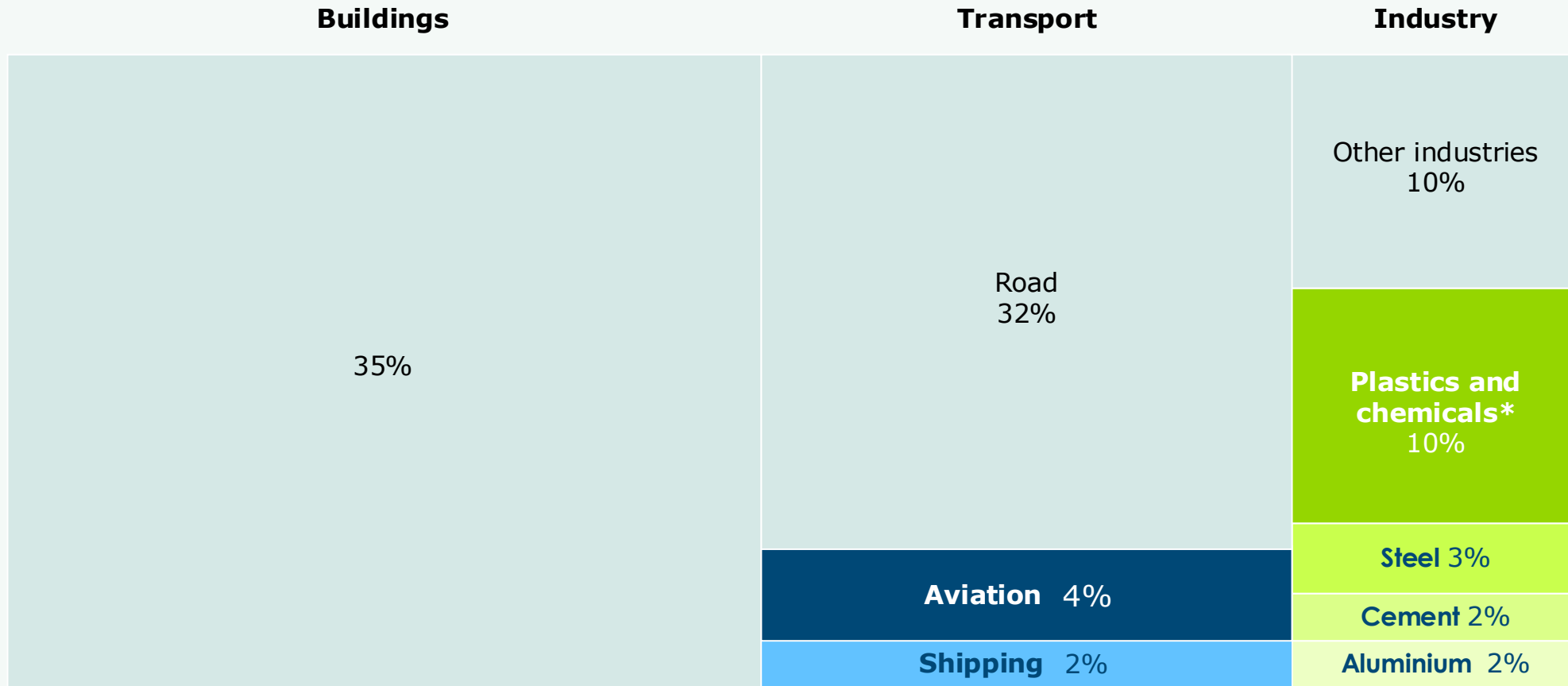


*Energy productivity is the inverse of energy intensity (energy input per unit of GDP), intensity is used for instance in many IEA reports. Source: Systemiq analysis for the ETC.

~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

%



Key

Not the focus of this technical briefing



* Including Benzene, Butadiene, 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

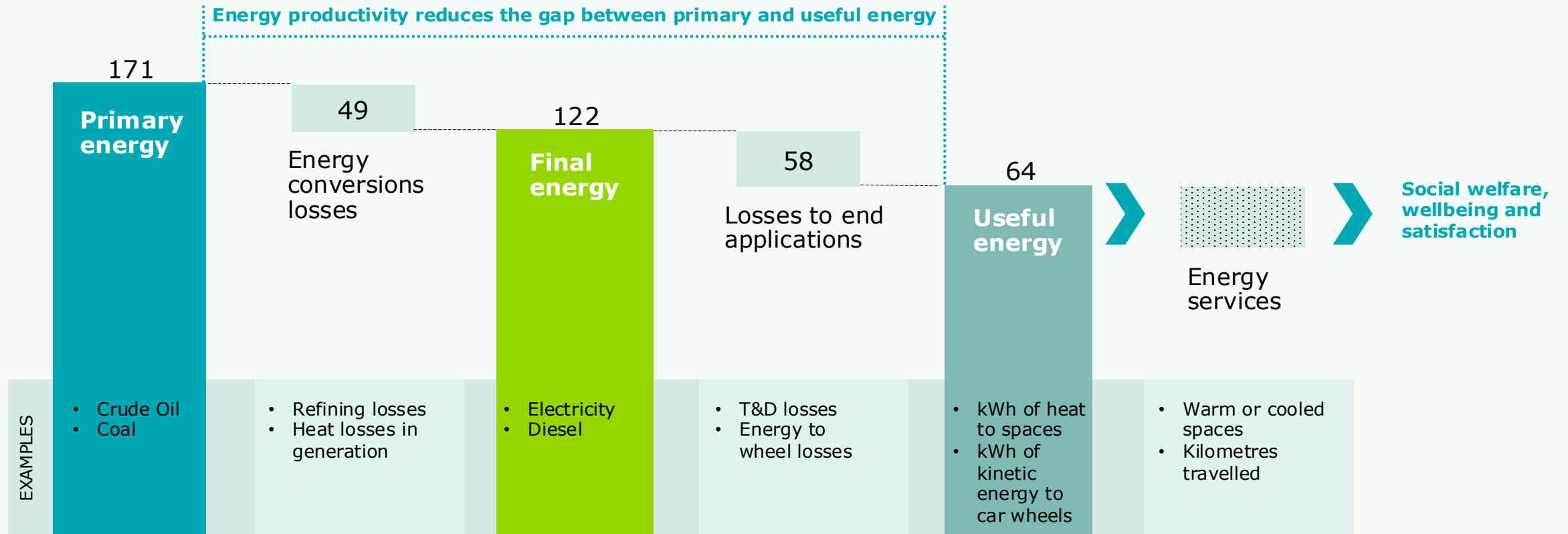
Economy-wide opportunity

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

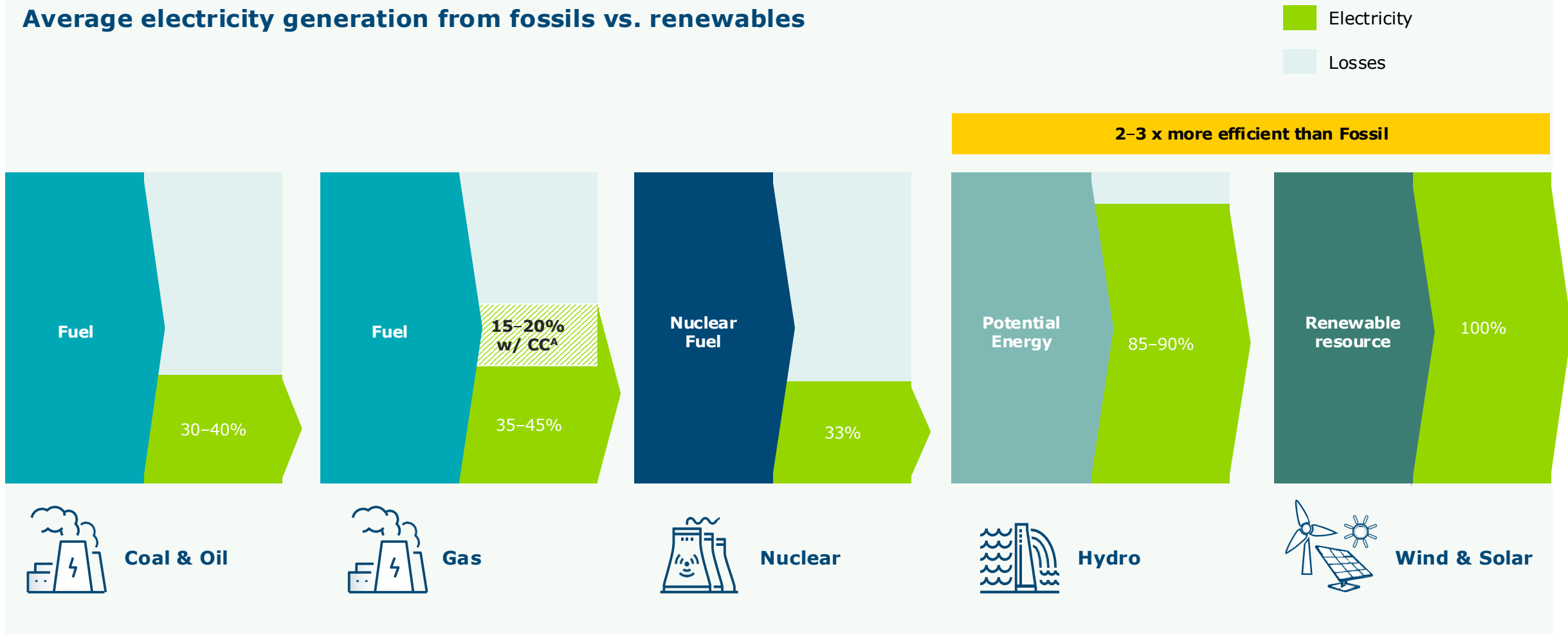
Global energy flows

000 TWh, 2023

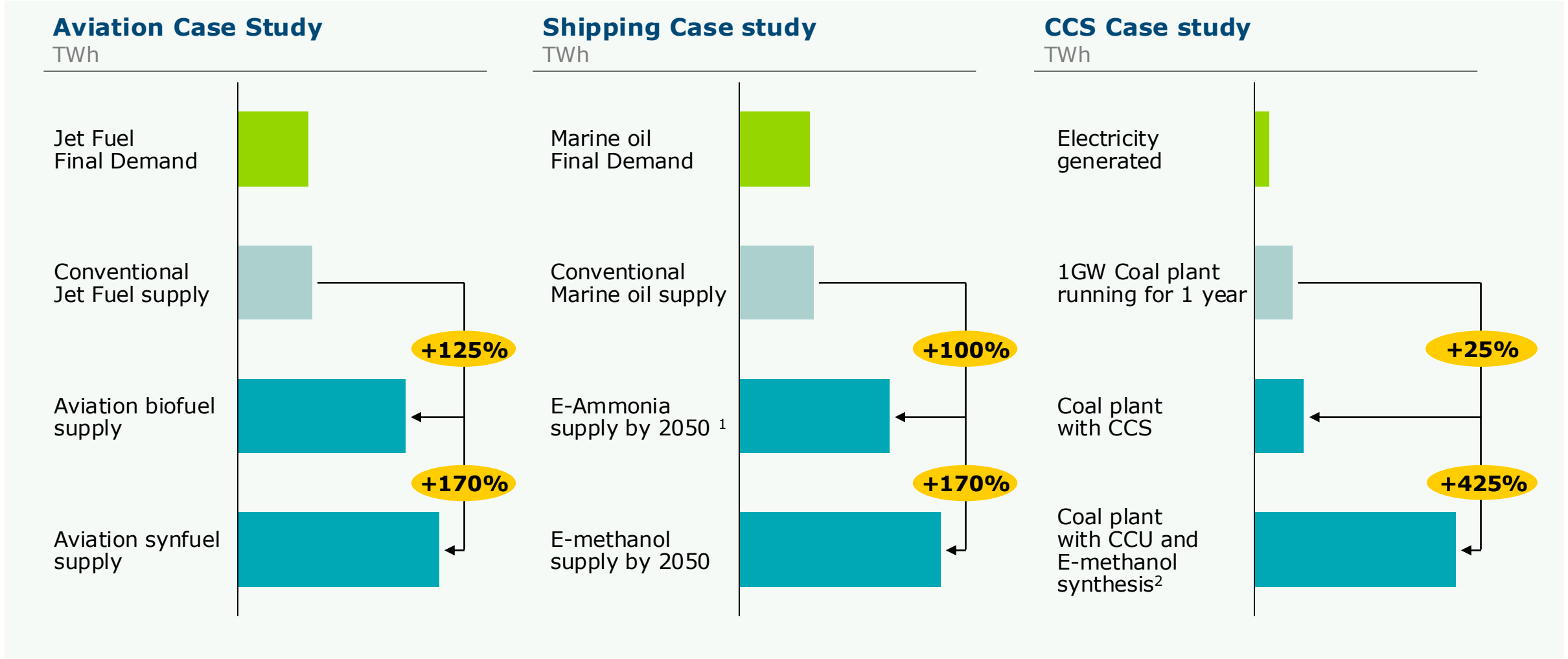


Generating electricity with renewables compared to fossil fuels is 2-3 times more efficient

Average electricity generation from fossils vs. renewables



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



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

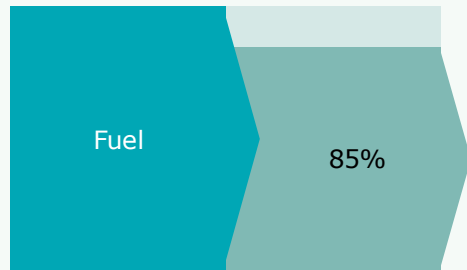
Average efficiency from appliances and vehicles incumbent fuel vs. electric

Useful Energy
Losses

Heating



Gas boiler



3-4x more efficient than Fossil



Heat pump



Cooking



Traditional cookstove



4-5x more efficient than bioenergy



Electric cooking



Vehicles



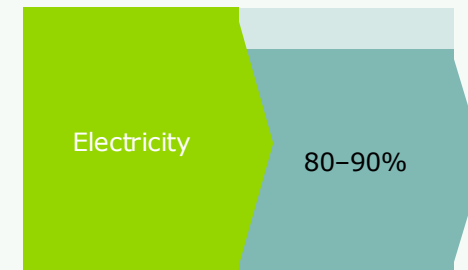
Internal combustion engine



2-4x more efficient than Fossil



EV





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

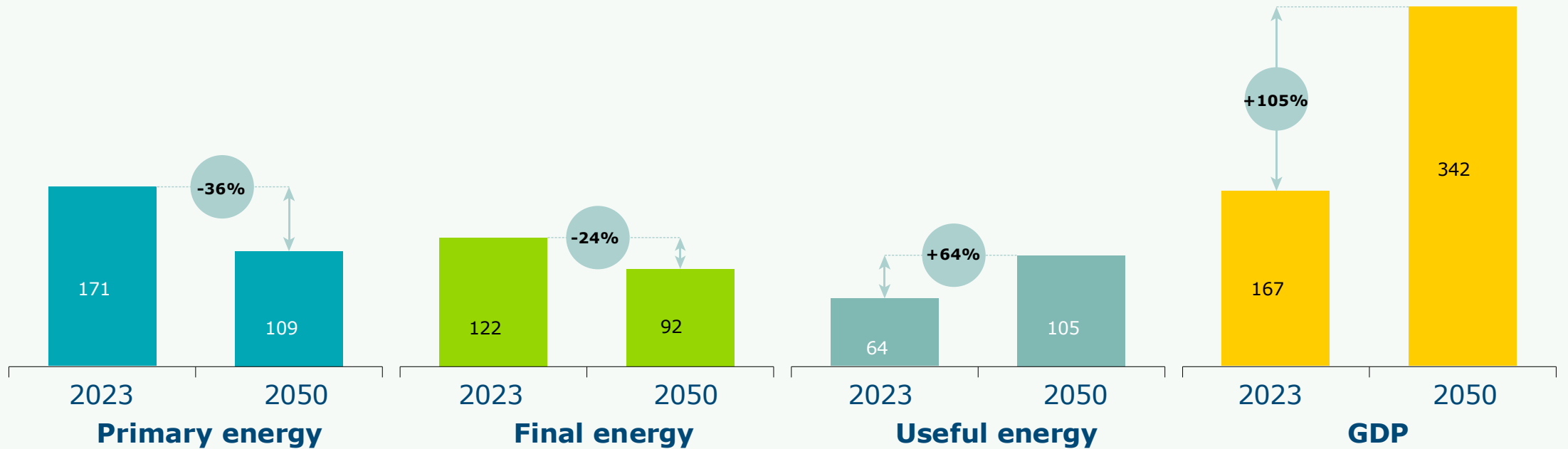
Net-zero energy demand with productivity levers

Energy in 000 TWh; GDP in constant 2021 \$ trillion

Shift away from Extraction....
Fewer losses in refining & power conversion

Towards Electrification...
Fewer losses in the delivery to end use applications

For greater energy services
More energy end use



Productivity growth is achieved alongside growth in energy services

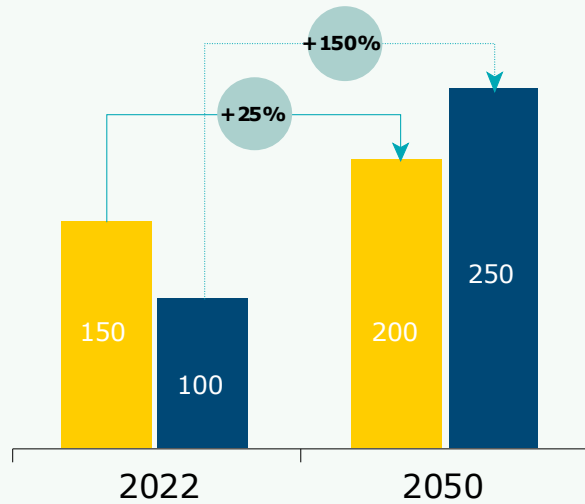
For assumed growth of energy services for each of industry **Go to**
> 03: Sectoral deep-dive

Underlying growth in energy services in specific sectors

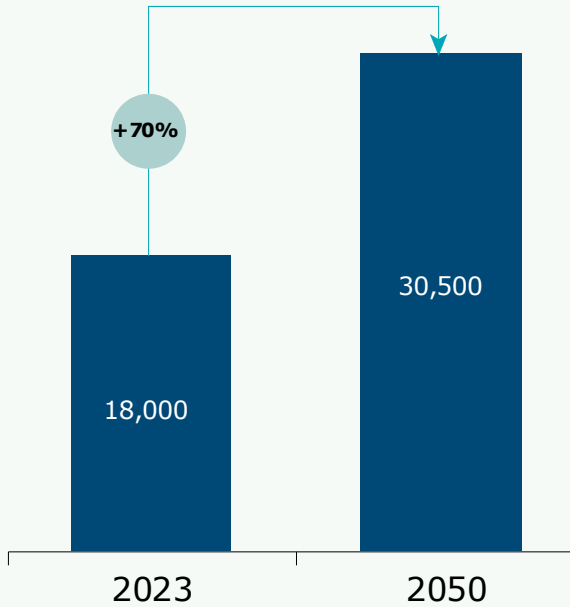
Heated and cooled floor area demand
 Billion m²; IEA NZE Scenario; residential + commercial

■ Cooled floor area
 ■ Heated floor area (space heating)

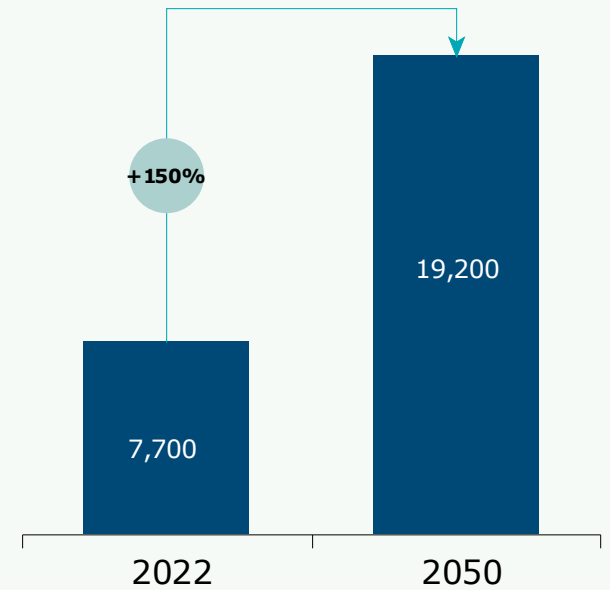
Cooled floor area is growing at a higher rate than heated, driven by 1) **GDP per capita growth**; 2) **increase in building floor area**, particularly in developing economies; 3) **warming climates**



Passenger road transport demand
 Billion km; ETC ACF scenario

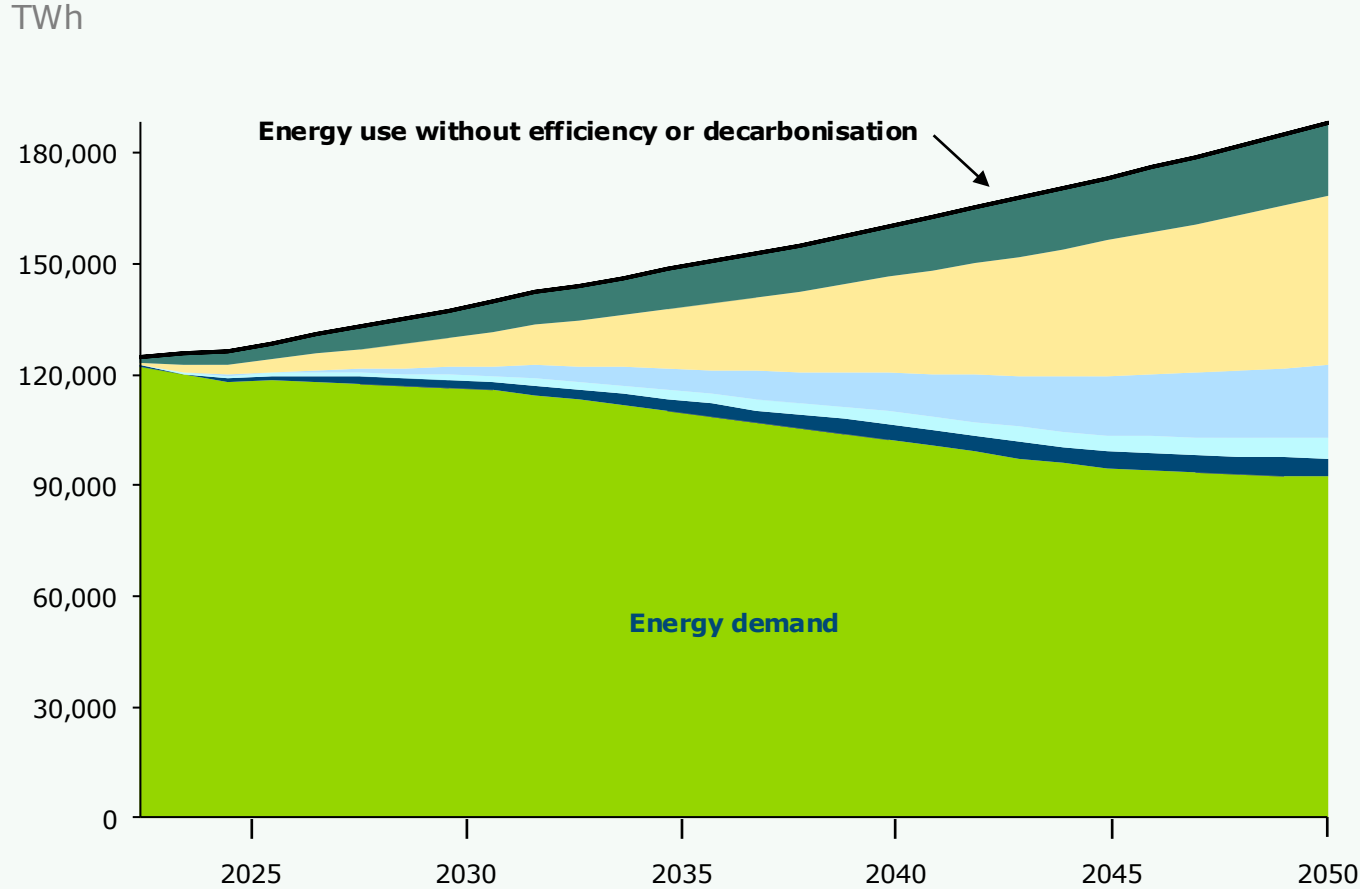


Aviation demand
 Billions revenue passenger km (RPK)



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

Final energy demand vs. productivity levers



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%

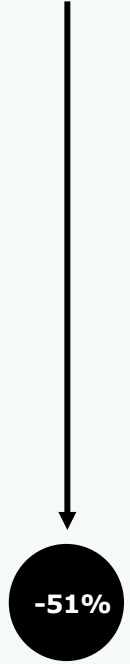
Electrification: Switching to EVs, electric heating and cooking.
- 10%

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.

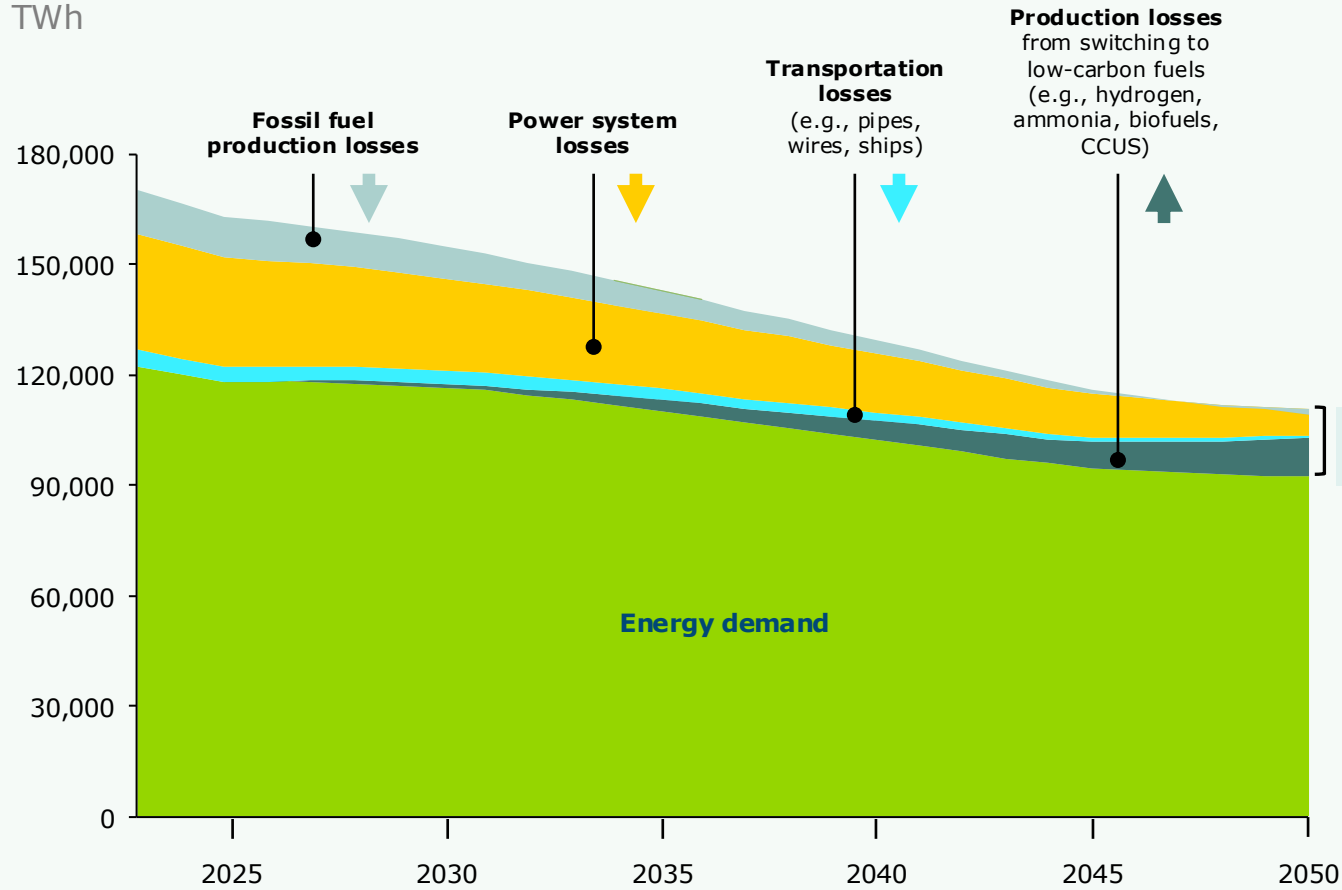
○ Key opportunities for energy-intensive sectors are in **demand reduction** (via recycling and better operations) and **sector-specific** (via enhanced designs)



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

Primary energy demand

TWh



Energy production losses

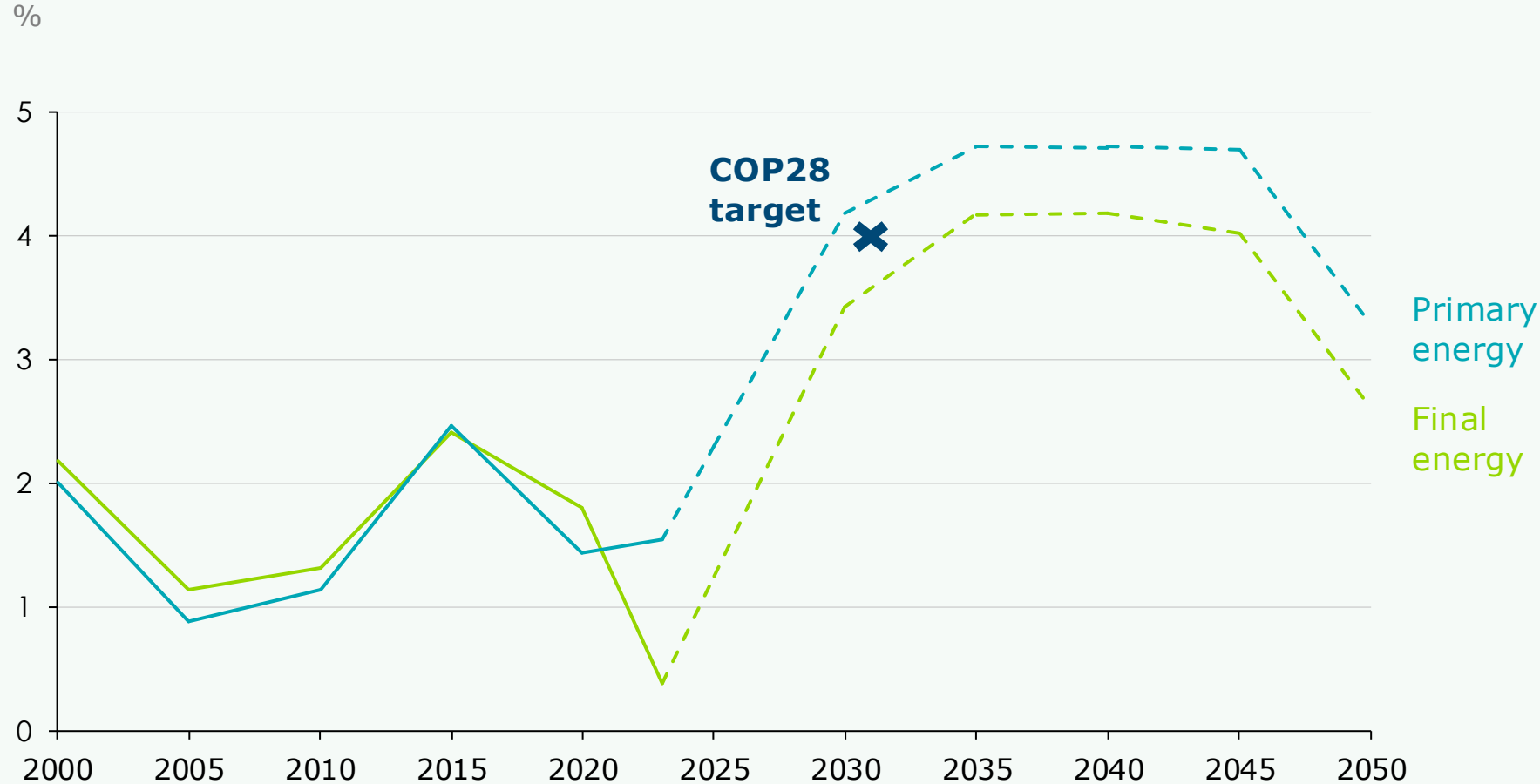
Reduction of primary losses driven by:

- **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



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

5-Year CAGR Energy productivity improvement projection



- **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



CHAPTER 02

Summary findings

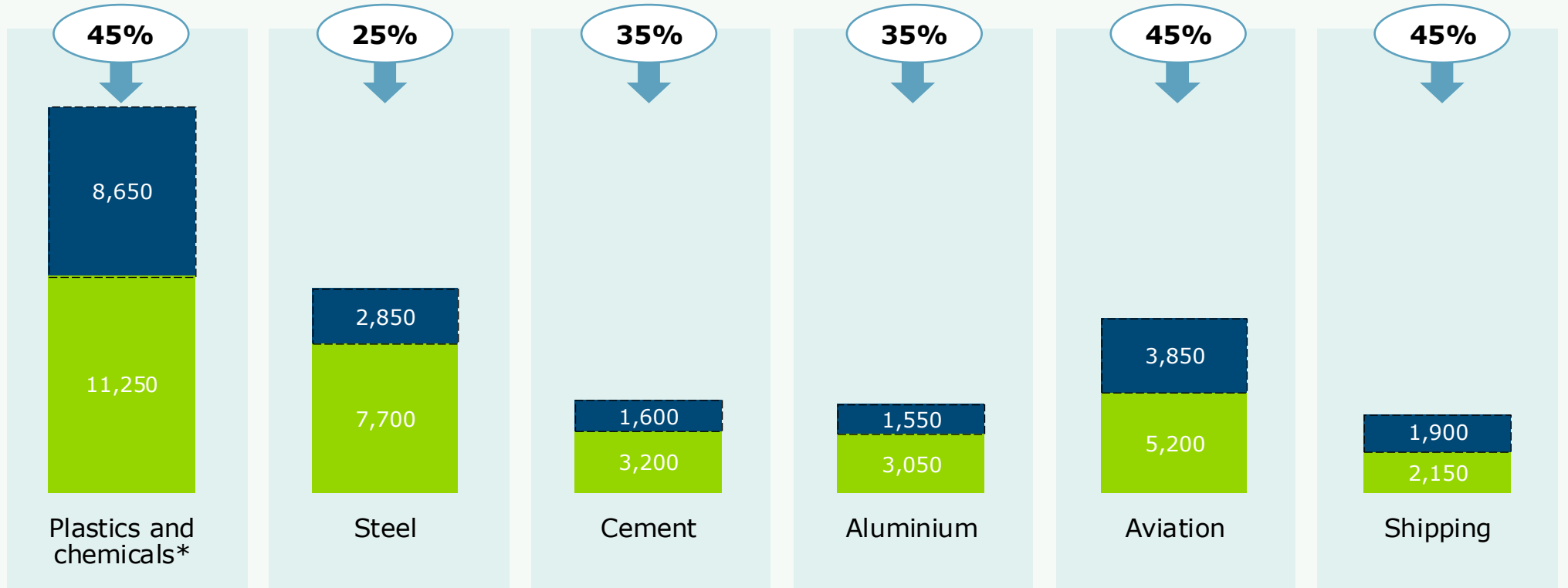
Productivity in energy intensive industries

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

Final energy demand in 2050

TWh

%
Reductions
per sector



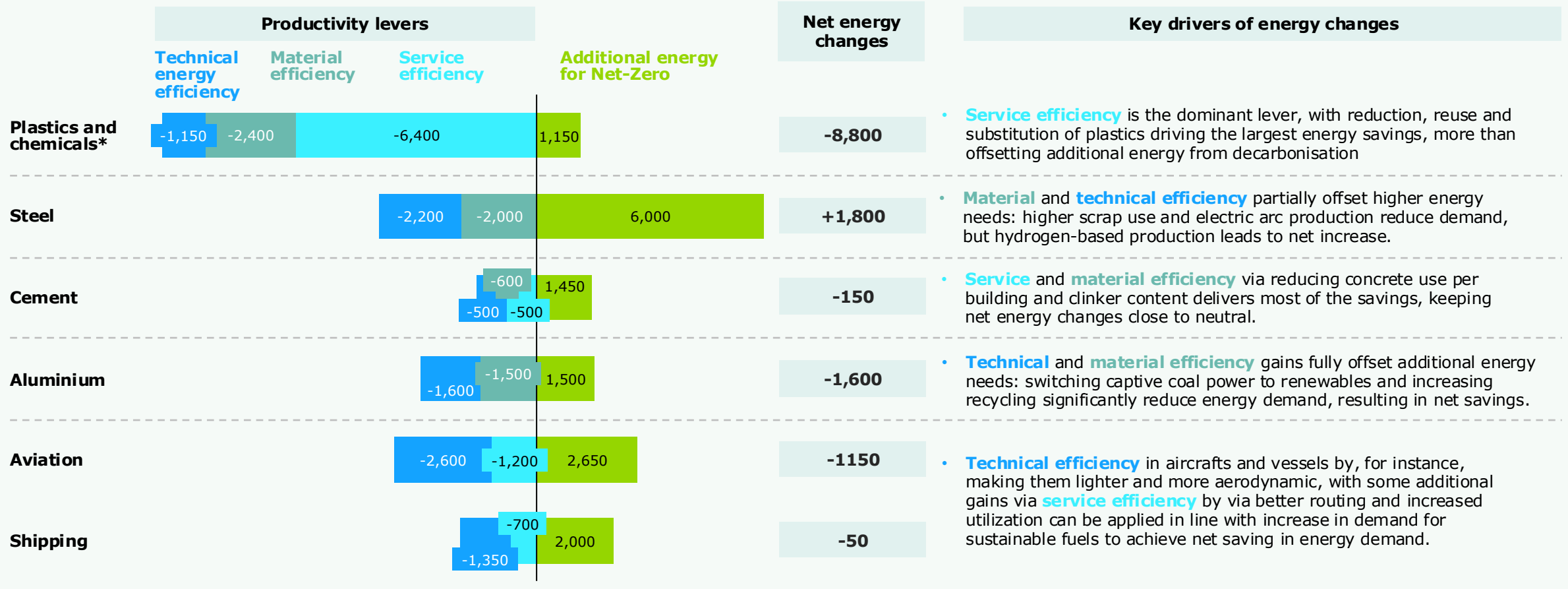
Mapping the three productivity levers across energy-intensive industries highlights key actions by sector

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.	<ul style="list-style-type: none"> Demand reduction of plastics through reuse, substitution or elimination 		<ul style="list-style-type: none"> Using less concrete per building via better design 		<ul style="list-style-type: none"> Weather routing Autopilot upgrade Speed reduction 	<ul style="list-style-type: none"> Optimised approach / departure procedures for take-off and landing
	Material efficiency =	Reductions in the amount of material needed to support consumer living standards.	<ul style="list-style-type: none"> Increase in chemicals recycling rates 	<ul style="list-style-type: none"> Scrap usage increase 	<ul style="list-style-type: none"> Using less clinker in cement by partially replacing clinker with SCMs 	<ul style="list-style-type: none"> Maximising secondary production Circular product design 		
	Technical energy efficiency X	Reduced kWh input per energy service delivered.	<ul style="list-style-type: none"> Switch to steam cracking Switch to electric boilers 	<ul style="list-style-type: none"> Switch to EAFs and electro-winning Switch to DRI 	<ul style="list-style-type: none"> Switch wet kiln with dry kiln with preheaters Deploying waste heat recovery 	<ul style="list-style-type: none"> Switch captive generation to renewable sources 	<ul style="list-style-type: none"> Auxiliary power Enhanced aero-dynamics, Higher thrust efficiency 	<ul style="list-style-type: none"> Engine efficiency increase Enhanced aero-dynamics Light-weighting of airplane

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



* Including Benzene, Butadiene, 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

X% Average change in fuel price or fuel volume

Clean Commodity
"Green Premium"

Shipping



Fuel saving productivity levers

Service efficiency

Technical energy efficiency

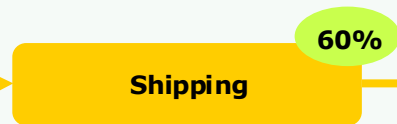
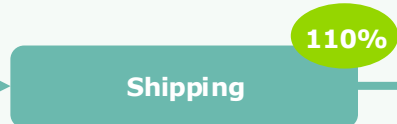
Without Energy Productivity

With Energy Productivity

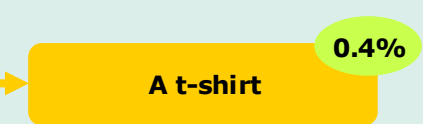
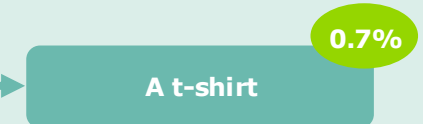
Better operations -16%



Expenditure increase to industry



End Consumer Product (assuming 100% substitution)



From \$0.13-0.23 cost increase in a \$35 t-shirt from Bangladesh to London

Aviation



Without Energy Productivity

With Energy Productivity

Better operations -13%



From \$120-\$200 cost increase on a \$500 return ticket from London to New York

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	
<p>Service efficiency</p>	<p>- \$12 bn/year in the bottled water business</p>	<p>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).</p>
<p>Material efficiency</p>	<p>- \$25 bn/year in aluminium power bills</p>	<p>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).</p>
<p>Technical energy efficiency</p>	<p>- \$135 bn/year in SAF expenditure</p>	<p>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.</p>



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

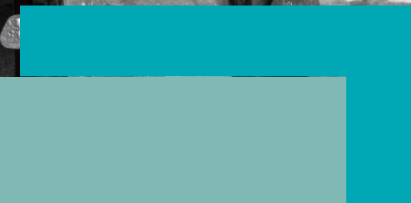
Sectoral deep-dives

Energy intensive sectoral deep-dives



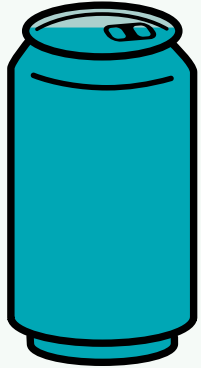
Aluminium

Energy intensive sectoral deep-dives

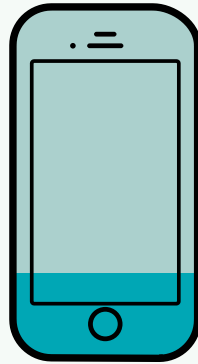


Aluminium is used across a wide range of everyday products and critical infrastructure

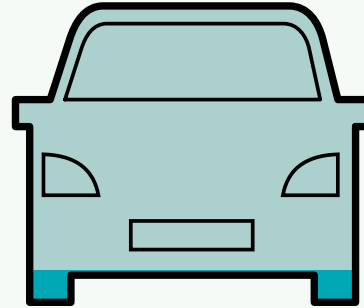
Approx. % aluminium by weight



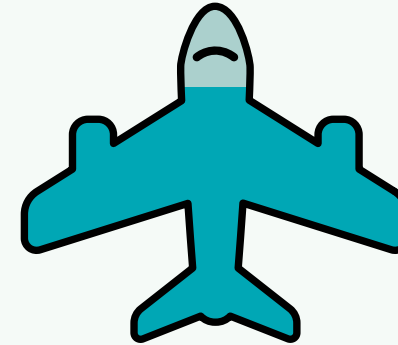
Drinks can
~97%



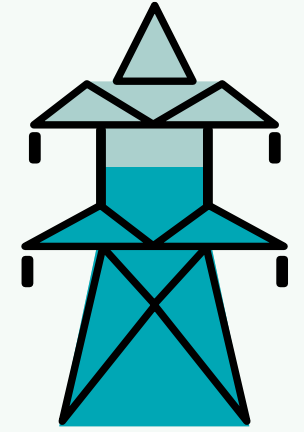
Smartphone
~24%



Car
~10-12%



Aircraft-body
~60-80%

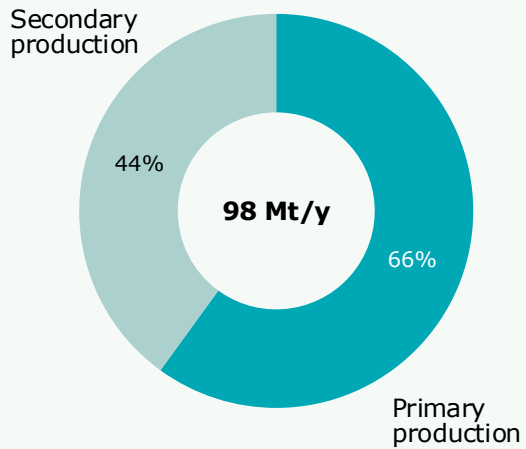


Power lines
~70-85%

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

Production

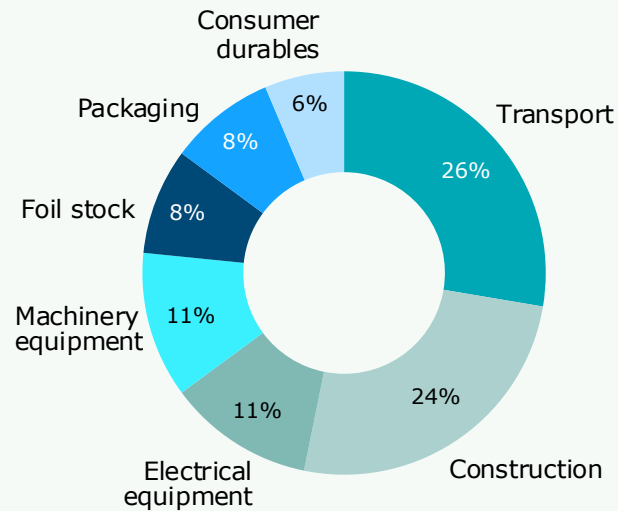
Global aluminium supply (2020)



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

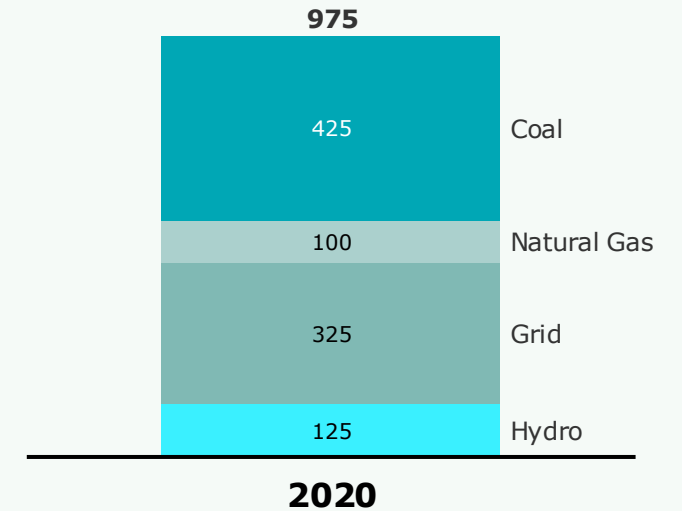
Global aluminium demand (2020)



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

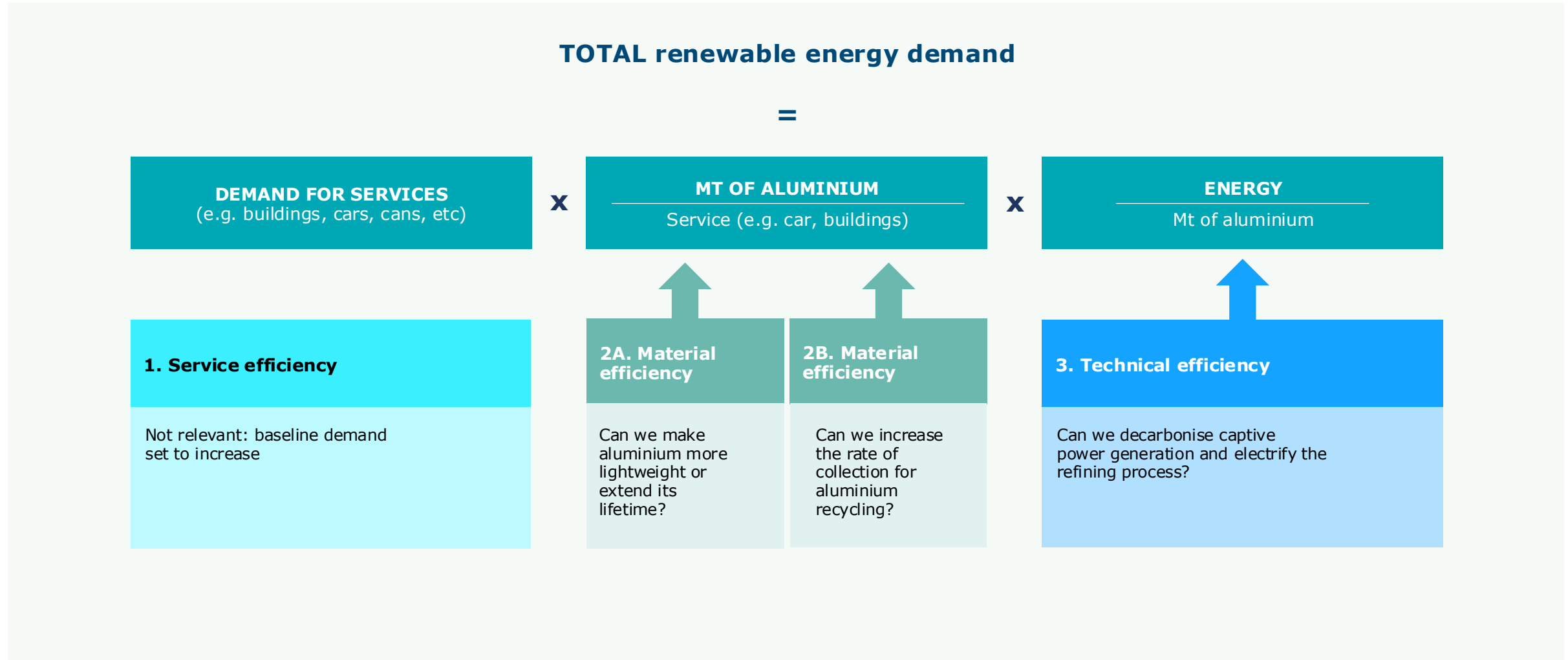
Energy supply

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

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



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

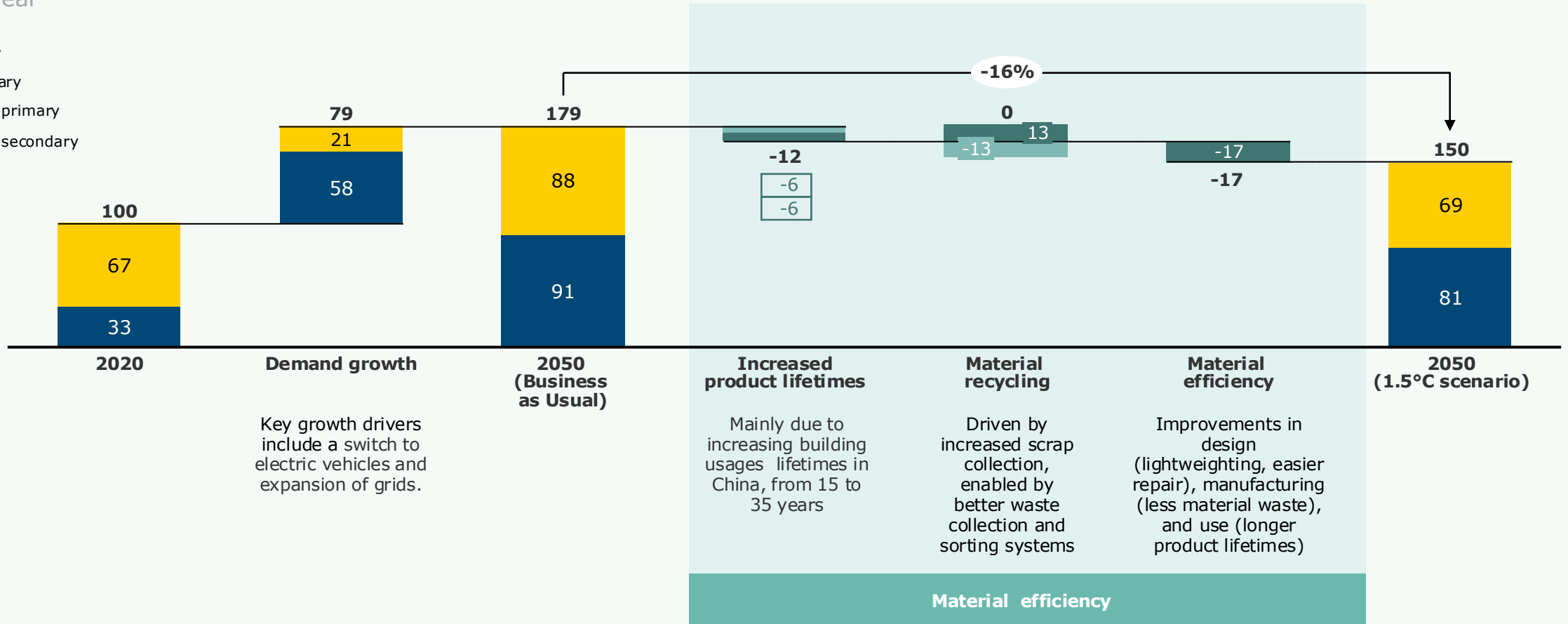
Productivity lever	Description
Material Efficiency	<ul style="list-style-type: none">• Maximising secondary production• Circular product design• Manufacturing loss reduction• Increased product lifetimes• End-of-life repair and reuse
Technical Efficiency	<ul style="list-style-type: none">• Switch captive 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)

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

Demand for aluminium

Mt per year

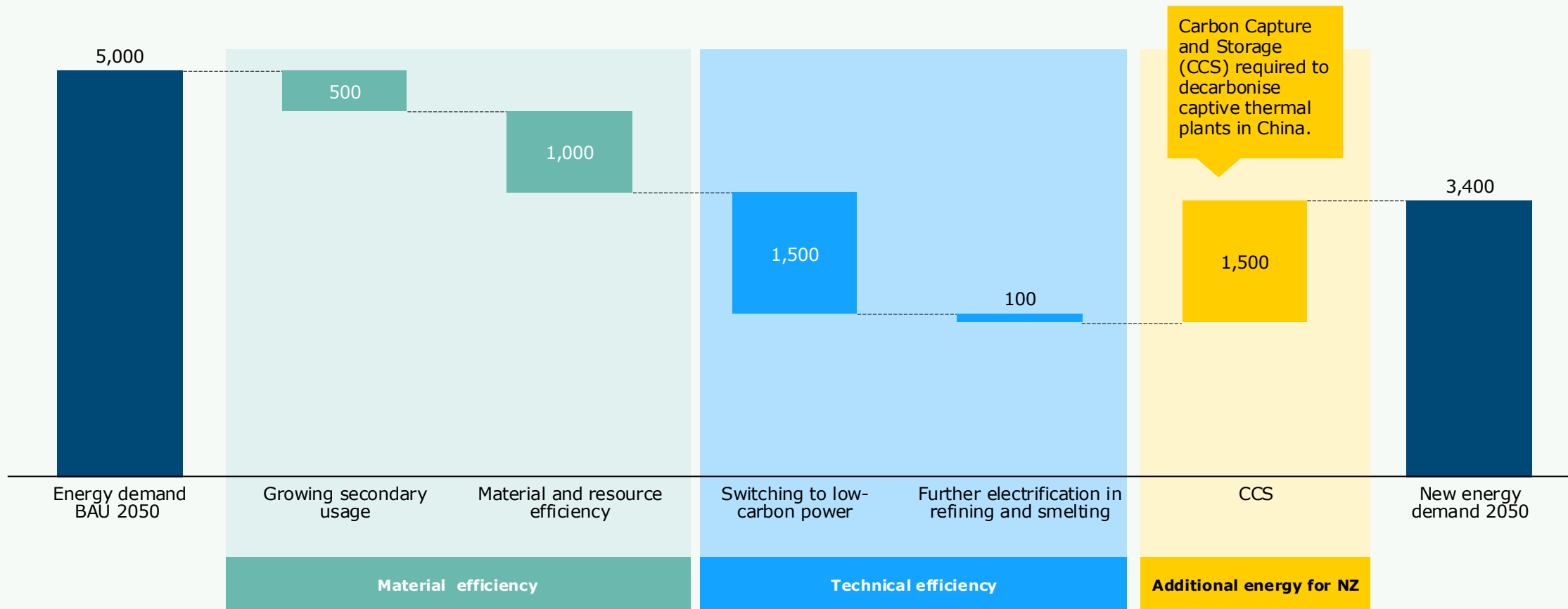
- Primary
- Secondary
- Shift in primary
- Shift in secondary



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



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**

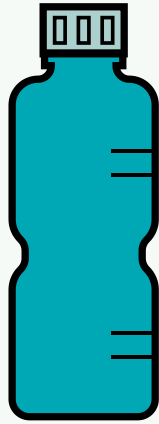


Plastics & chemicals

Energy intensive sectoral deep-dives

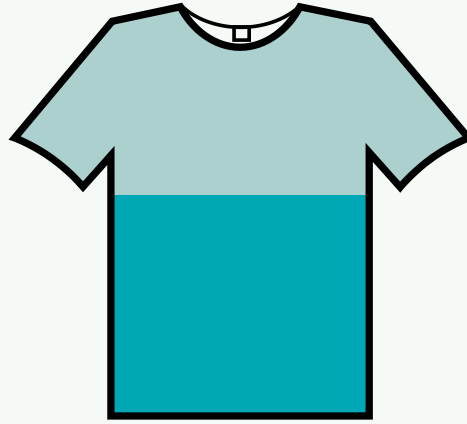
Plastics and chemicals* are used across a wide range of everyday products

Approx. % plastics and chemicals by weight



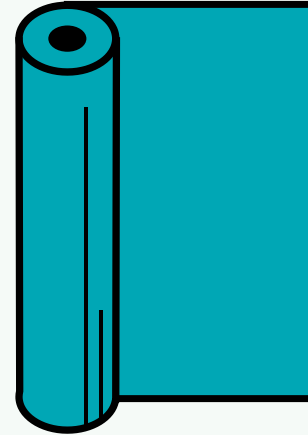
Plastic water bottle

~90-95%



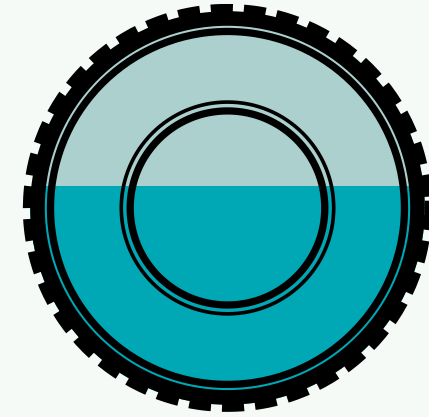
Polyester t-shirt

~60-100%



Cling film

~100%



Car tyre

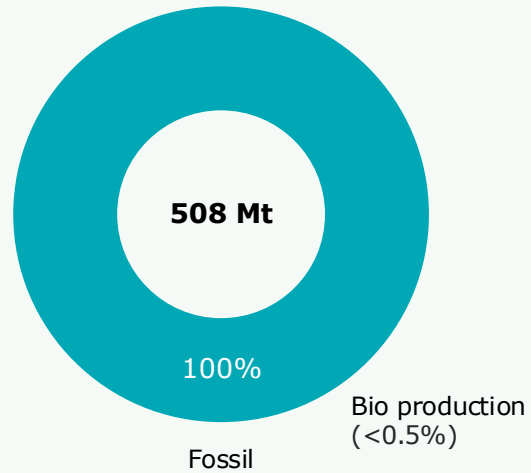
~50-65%

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

Production

Plastics and chemical demand (2020)

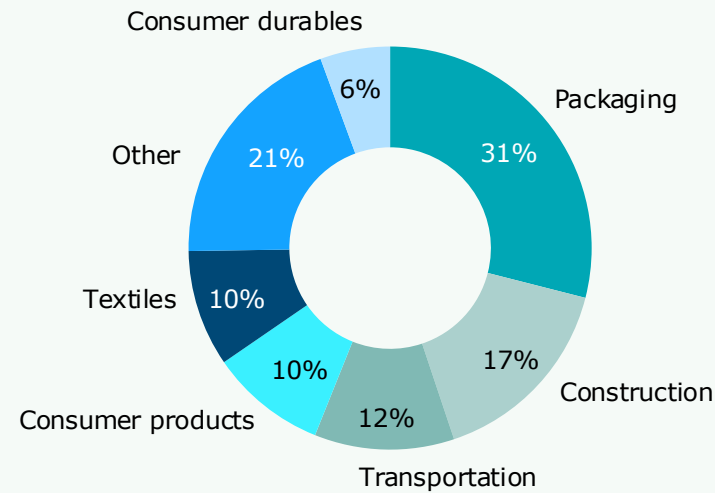
Mt



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)

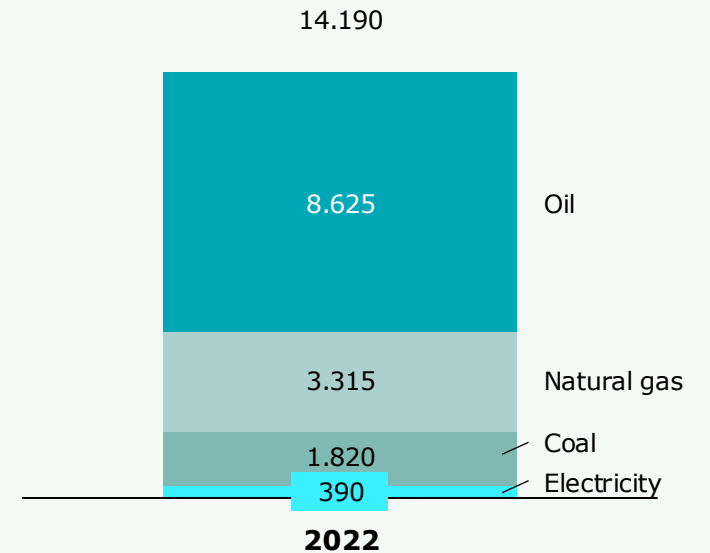


Plastics represent ~60-70% of petrochemical output by volume. The remaining outputs are chemicals, paints, bitumen, lubricants and other non-energy uses

Energy and Feedstock supply

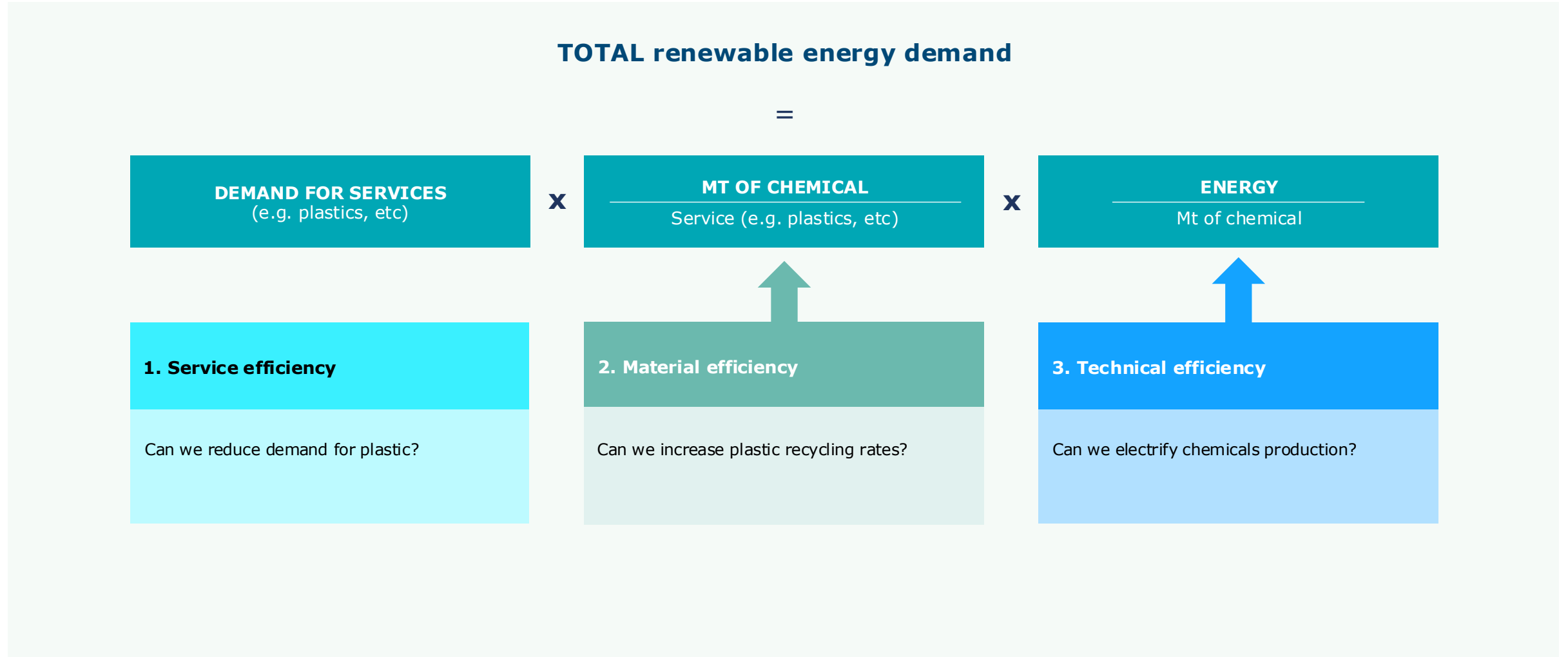
Chemicals energy demand (2022)

TWh



The chemical sector emits 2.3 Gt CO₂eq, of which two-thirds sit in Scope 3, driven by fossil feedstock extraction and end-of-life disposal (energy supply includes ammonia)

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



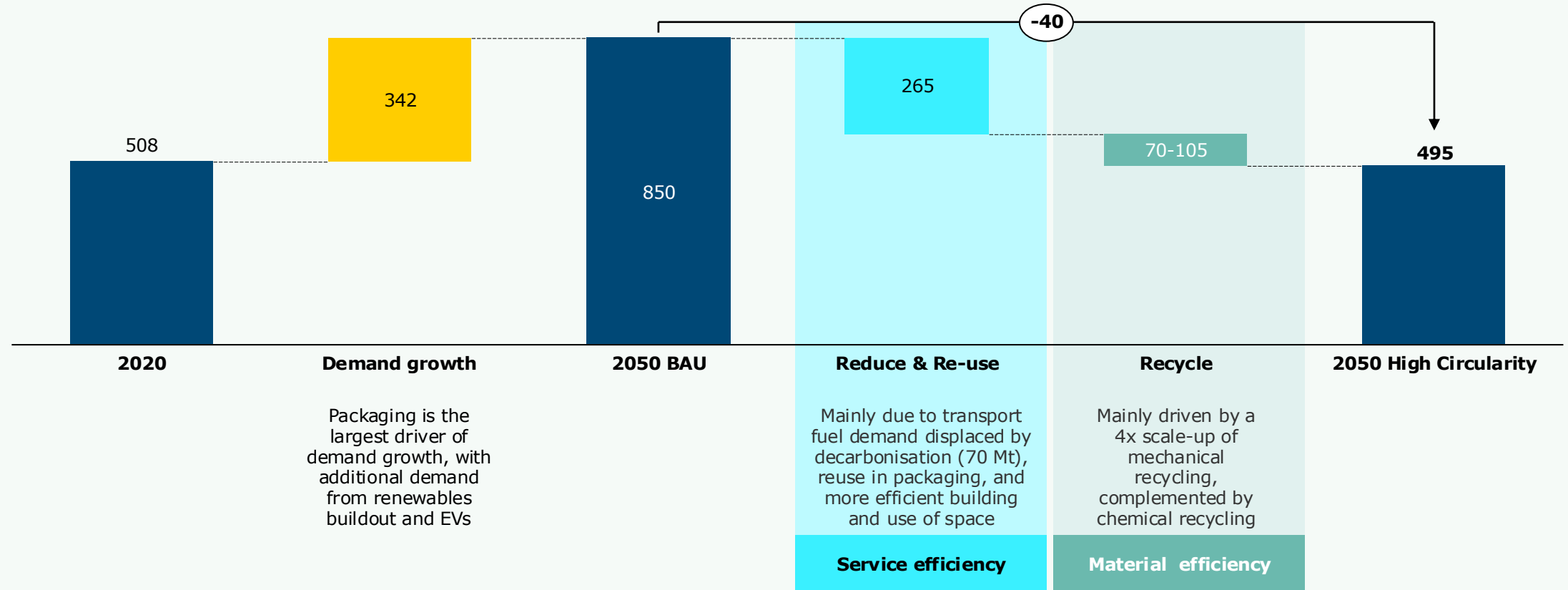
Increasing service and material efficiency is enabled by demand reduction and increased recycling

Productivity lever	Description
Service efficiency	<ul style="list-style-type: none">• Demand reduction of plastics through reuse, substitution or elimination
Material efficiency	<ul style="list-style-type: none">• Increase in recycling rates of chemicals and plastics
Technical energy efficiency	<ul style="list-style-type: none">• Electrification of chemicals production (e.g. steam cracking and electric boilers)

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

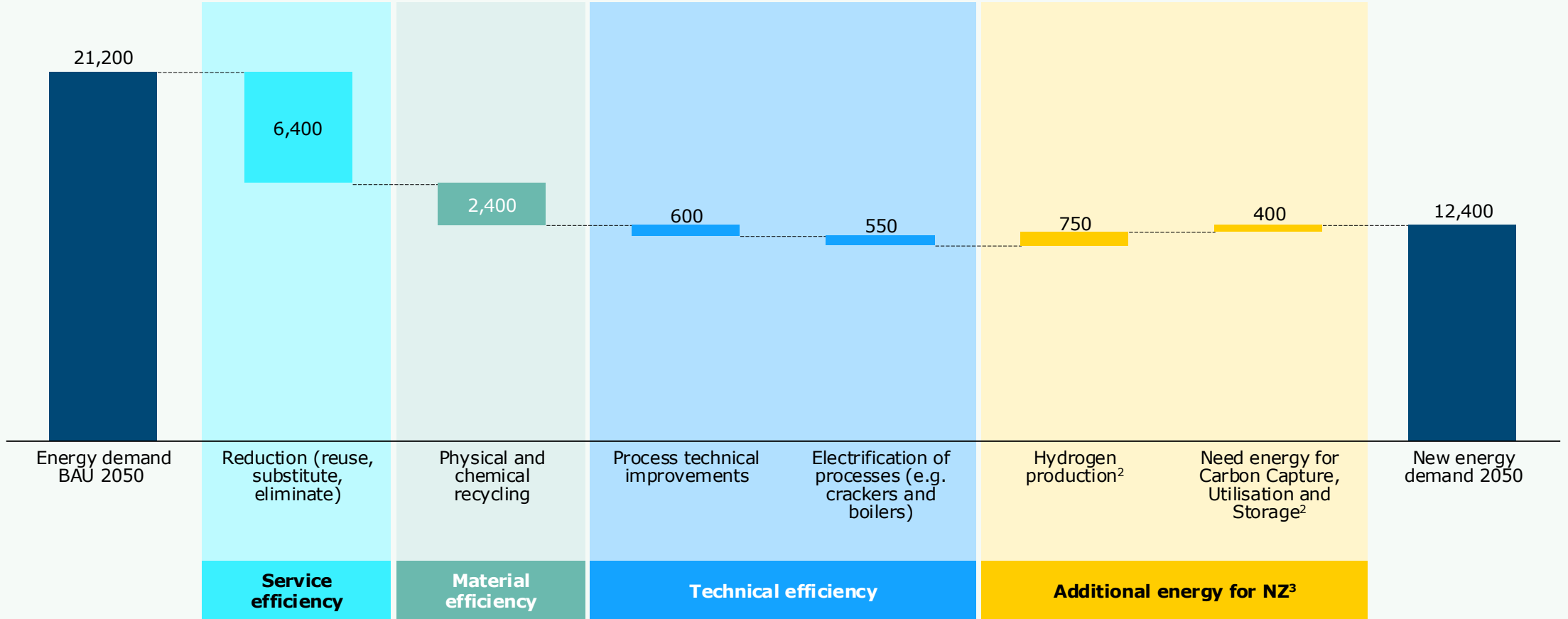
Mt



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, Butadiene, 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 sorting 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.

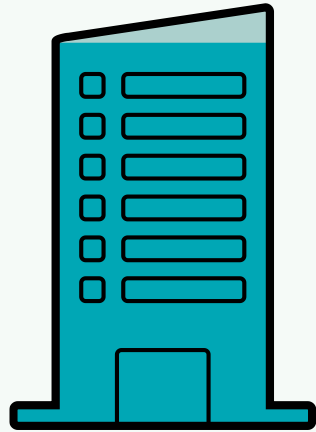


Concrete/cement

Energy intensive sectoral deep-dives

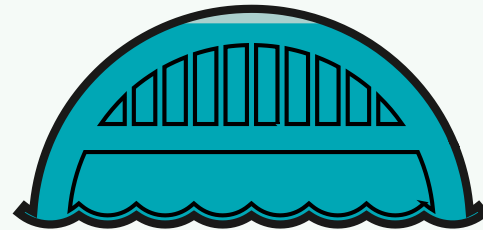
Concrete is used across a wide range of buildings and critical infrastructure.
Cement is a key input to concrete.

Approx. % concrete by weight



**Apartment building
(concrete)**

~80-90%



Bridge (concrete)

~90-95%



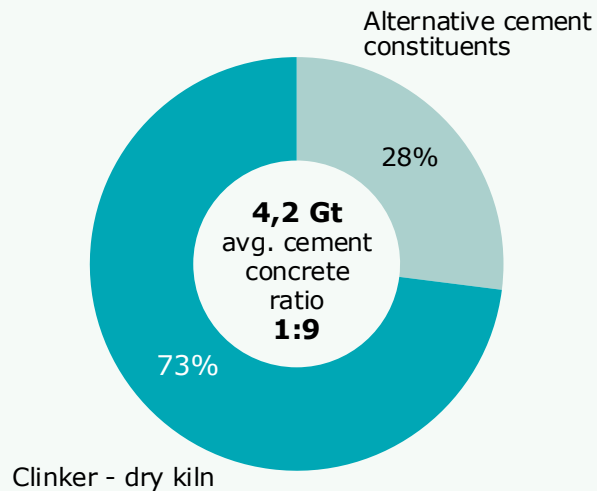
**Wind turbine
foundation**

~90-98%

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

Production

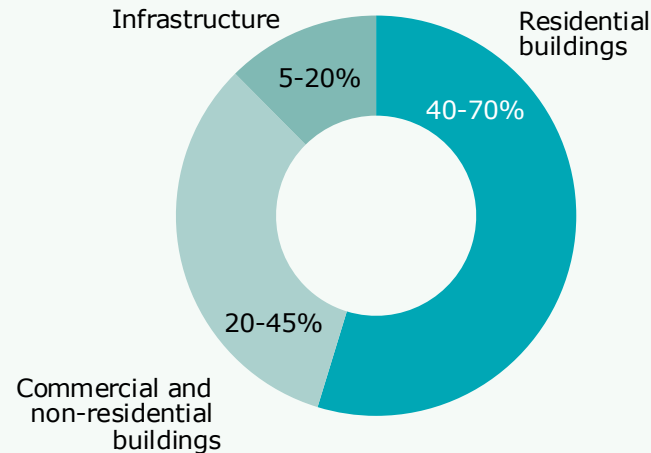
Global cement production by technology, 2020



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

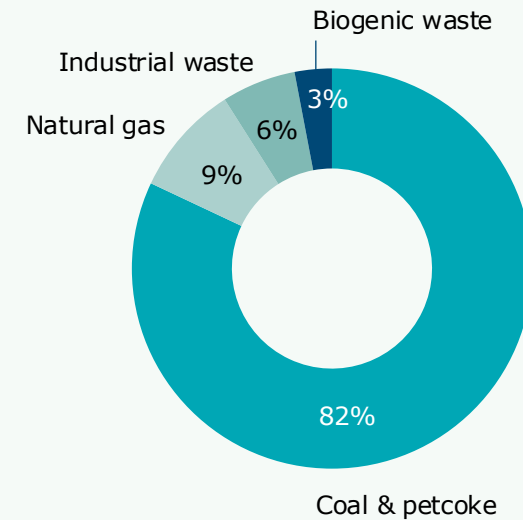
Concrete end use by mass ratio, 2020



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

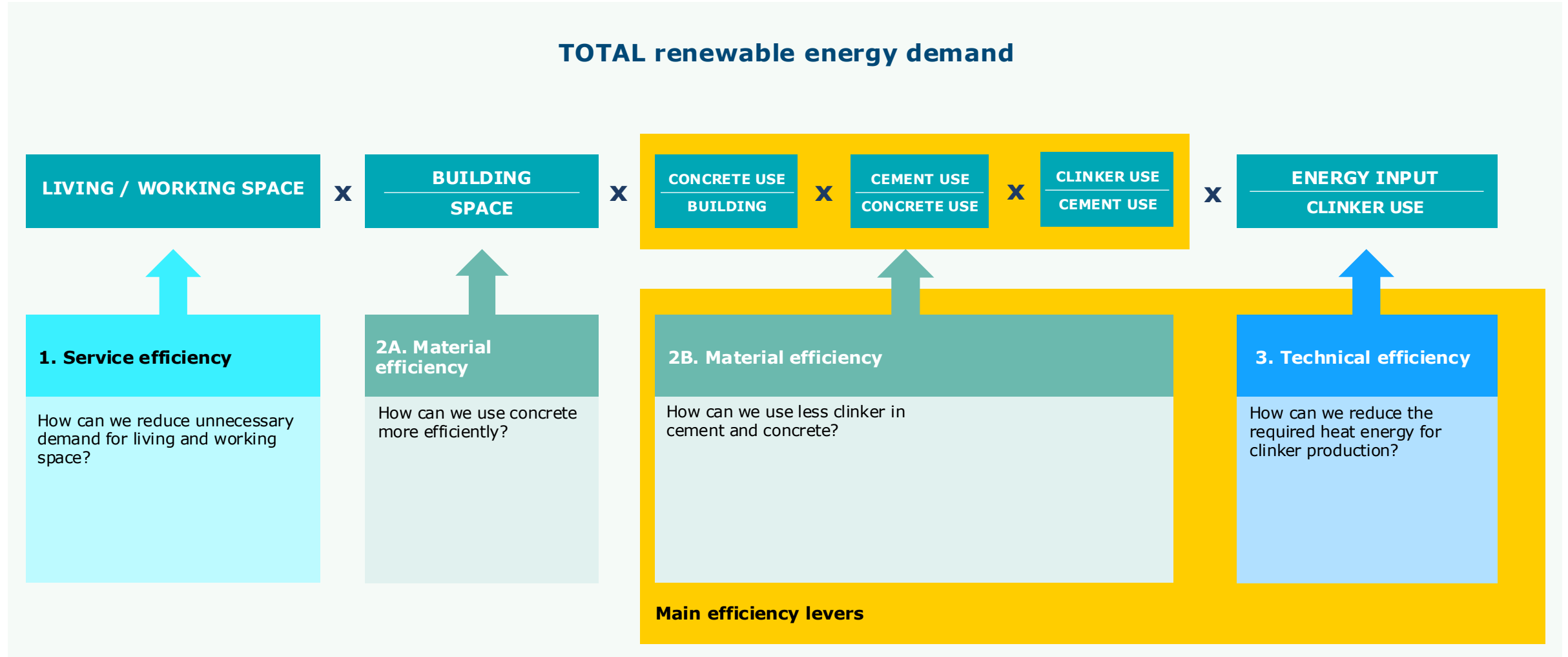
Energy supply

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)

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



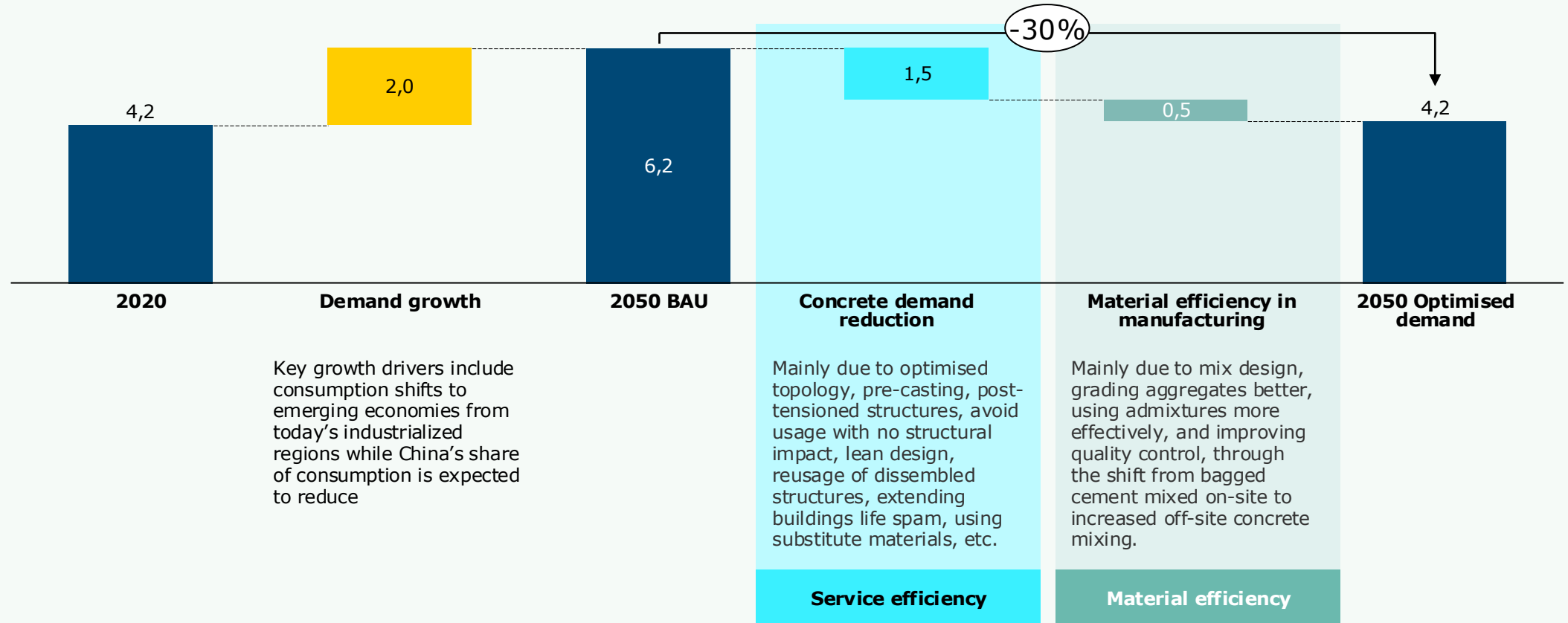
Reducing cement content per building and required energy for clinker production is critical to minimise renewable energy input for concrete

Productivity lever	Description
Service efficiency	<ul style="list-style-type: none">• Using less concrete per building via better design
Material efficiency	<ul style="list-style-type: none">• 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	<ul style="list-style-type: none">• 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

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

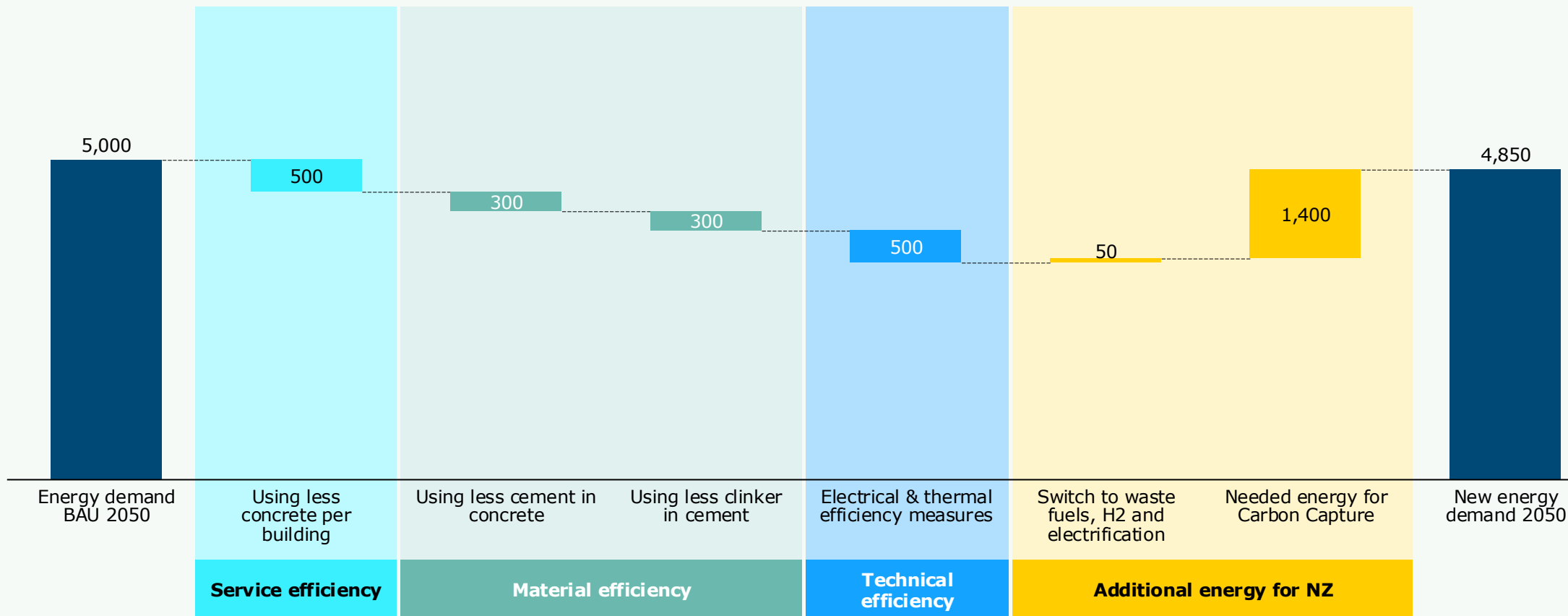
Gt



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

Primary energy demand in 2050 and impact of productivity levers

TWh



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

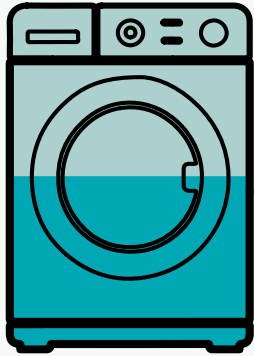


Steel

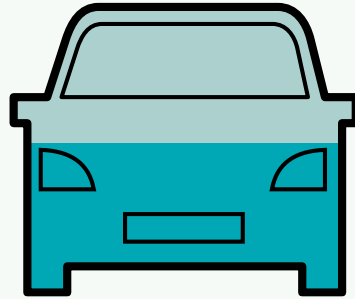
Energy intensive sectoral deep-dives

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

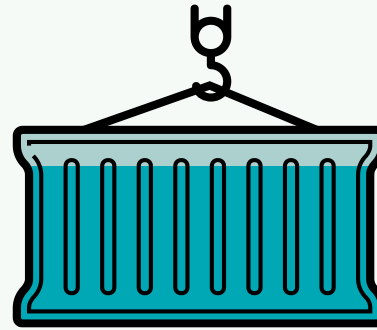
Approx. % steel by weight



Washing machine
~40-50%



Car
~50-65%



Shipping container
~80-95%



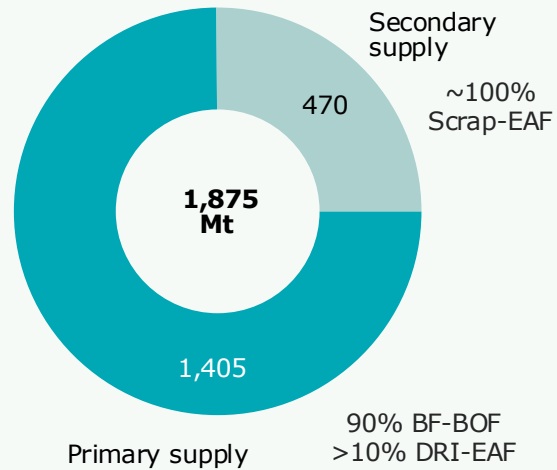
Wind turbine
~65-80%

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

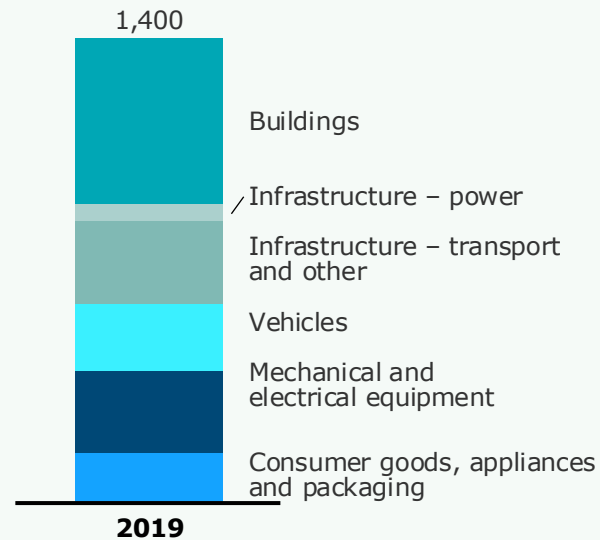


Primary production emits ~2.1 t CO₂ per tonne of crude steel. Secondary (scrap-based) production emits ~0.5 t CO₂/t. The sector emits ~7% of global GHG emissions

Demand

Global end-use steel demand, 2019

Mt/y

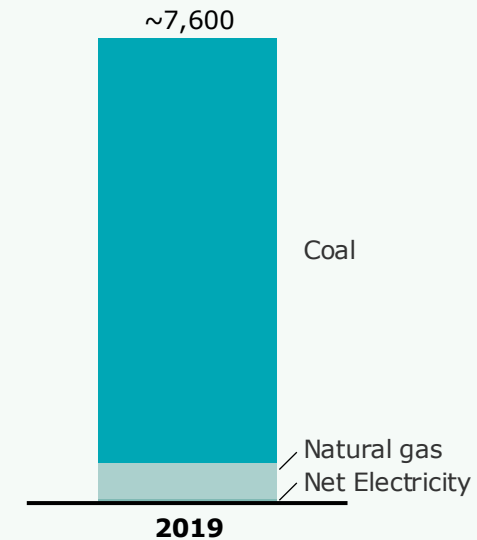


Demand is dominated by buildings and infrastructure. Even with high recycling rates, scrap alone cannot meet future demand, so decarbonising primary steel remains critical

Energy supply

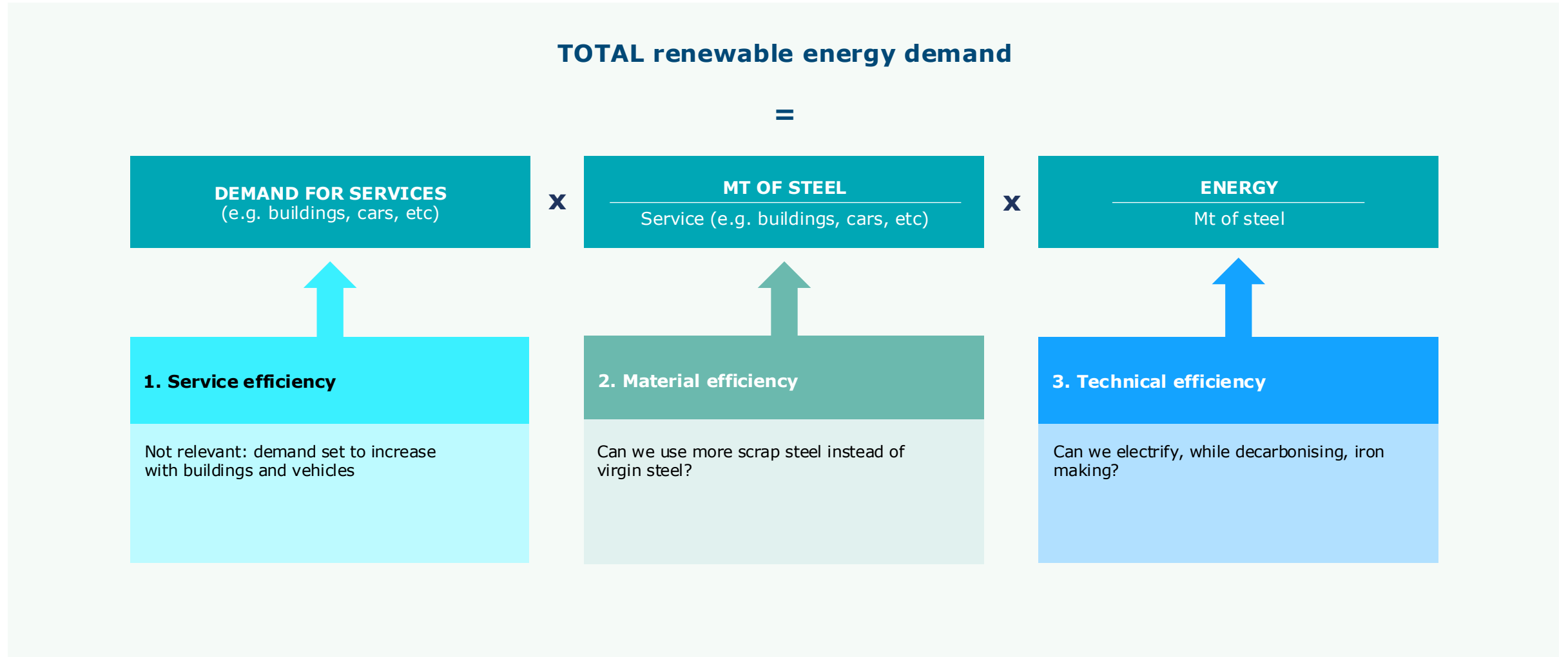
Global steel energy supply per year

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

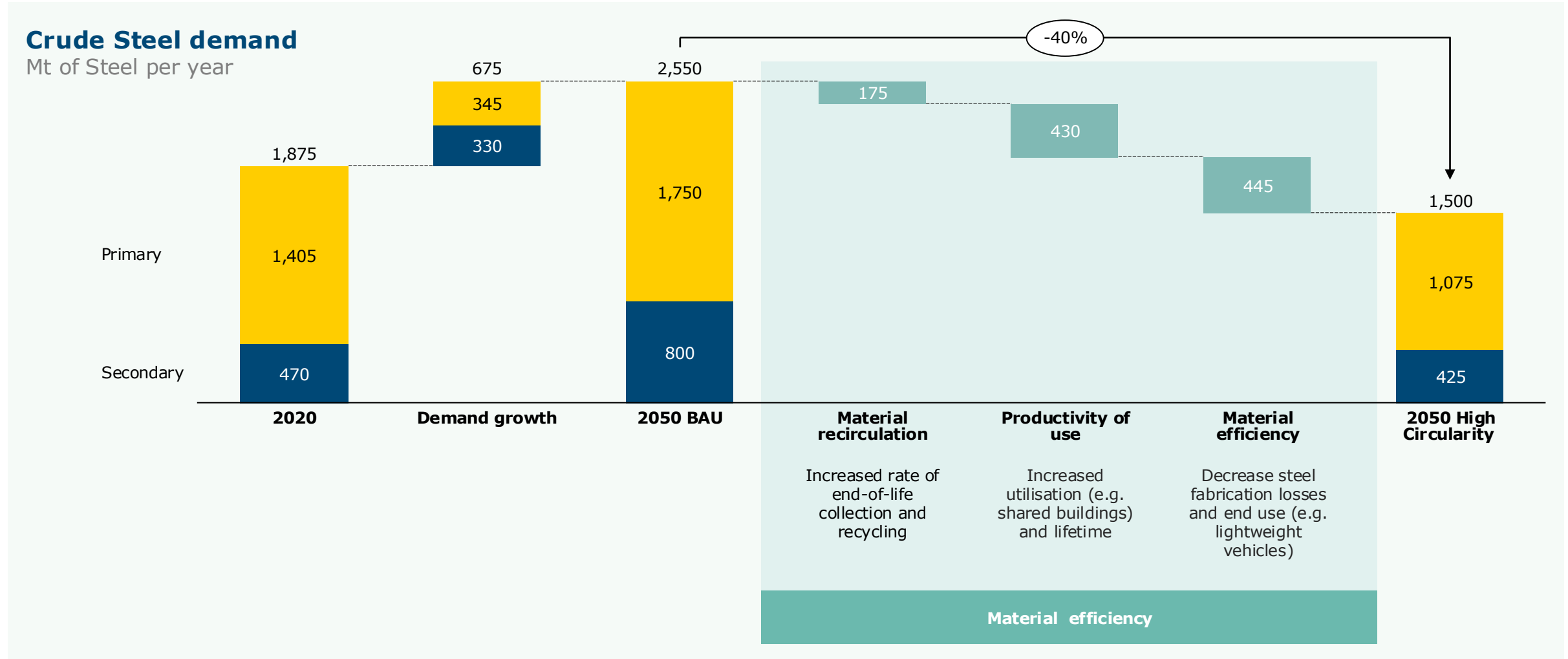
There are two main efficiency levers to reduce energy demand in the steel sector



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

Productivity lever	Description
Material efficiency	<ul style="list-style-type: none">• Scrap usage increase: increase secondary production from scrap and % of scrap in primary production
Technical energy efficiency	<ul style="list-style-type: none">• 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)

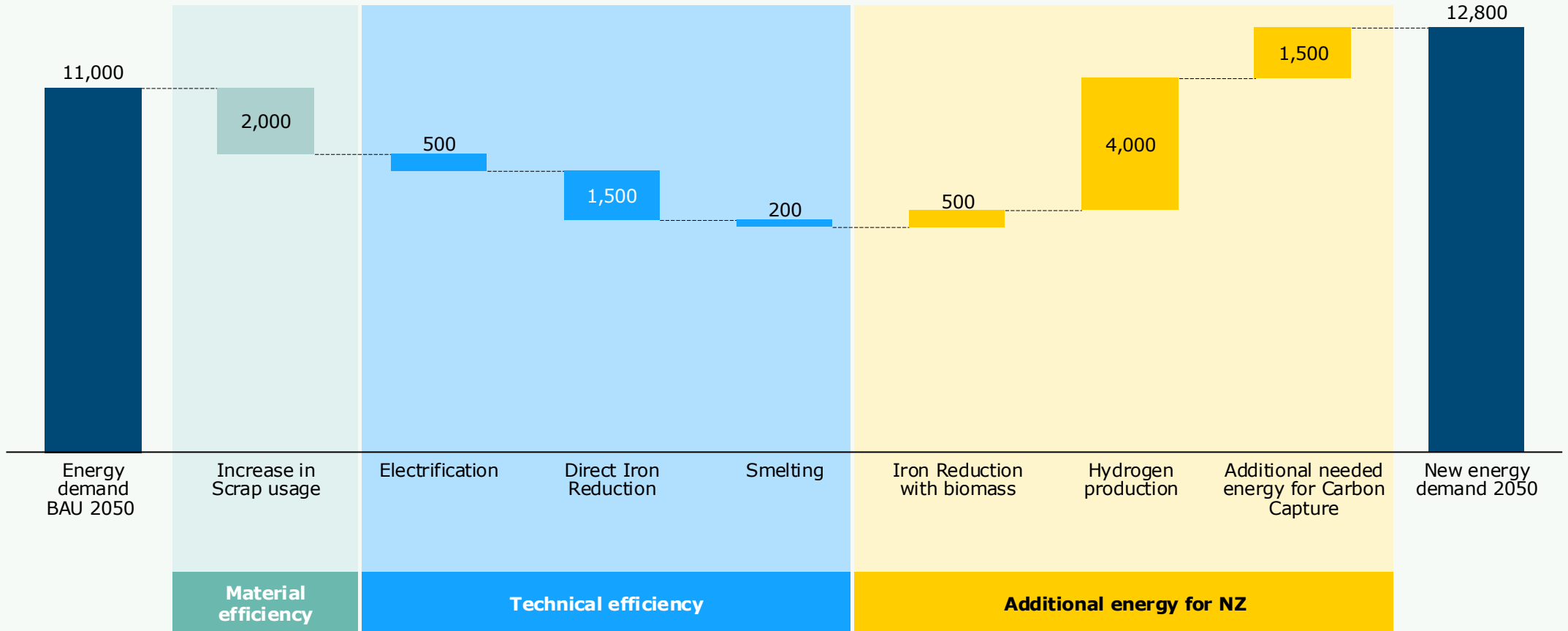
Steel business-as-usual demand is set to grow to 2050, but demand can be reduced by higher circularity



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



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

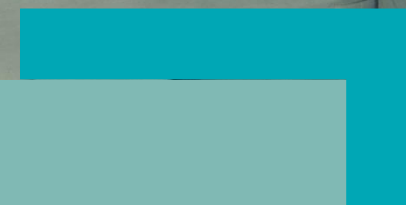
Productivity enablers

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



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

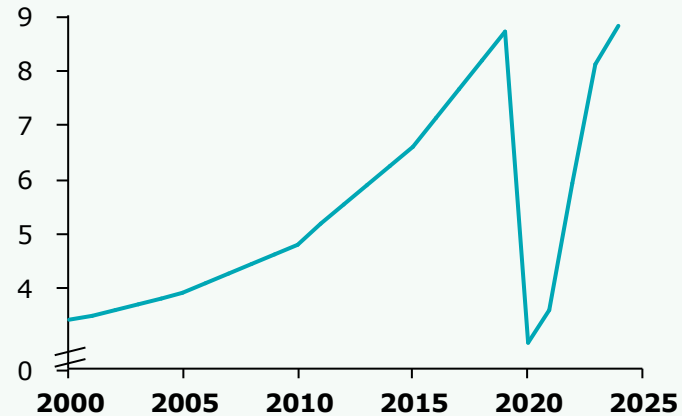
~2.5% p.y.

Average fuel efficiency improvement over 2010–2019, before COVID

Demand

Global passenger demand (RPK) Trillion

RPK/year

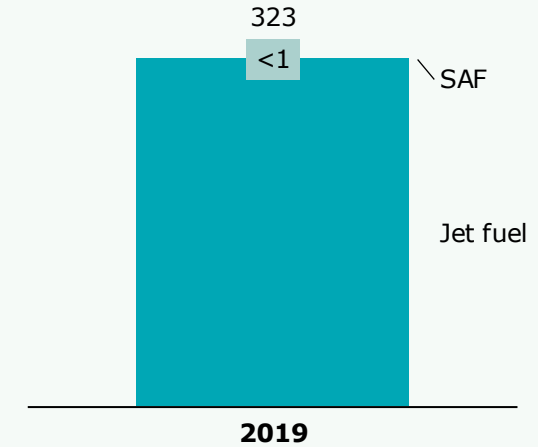


Aviation demand grew >6% per year from 2010–2019, and despite a high utilization of 80% in passenger load factor, demand outpaced efficiency gains. In 2023, the sector carried 4.3bn passengers and 223.8bn freight tonne-km

Energy supply

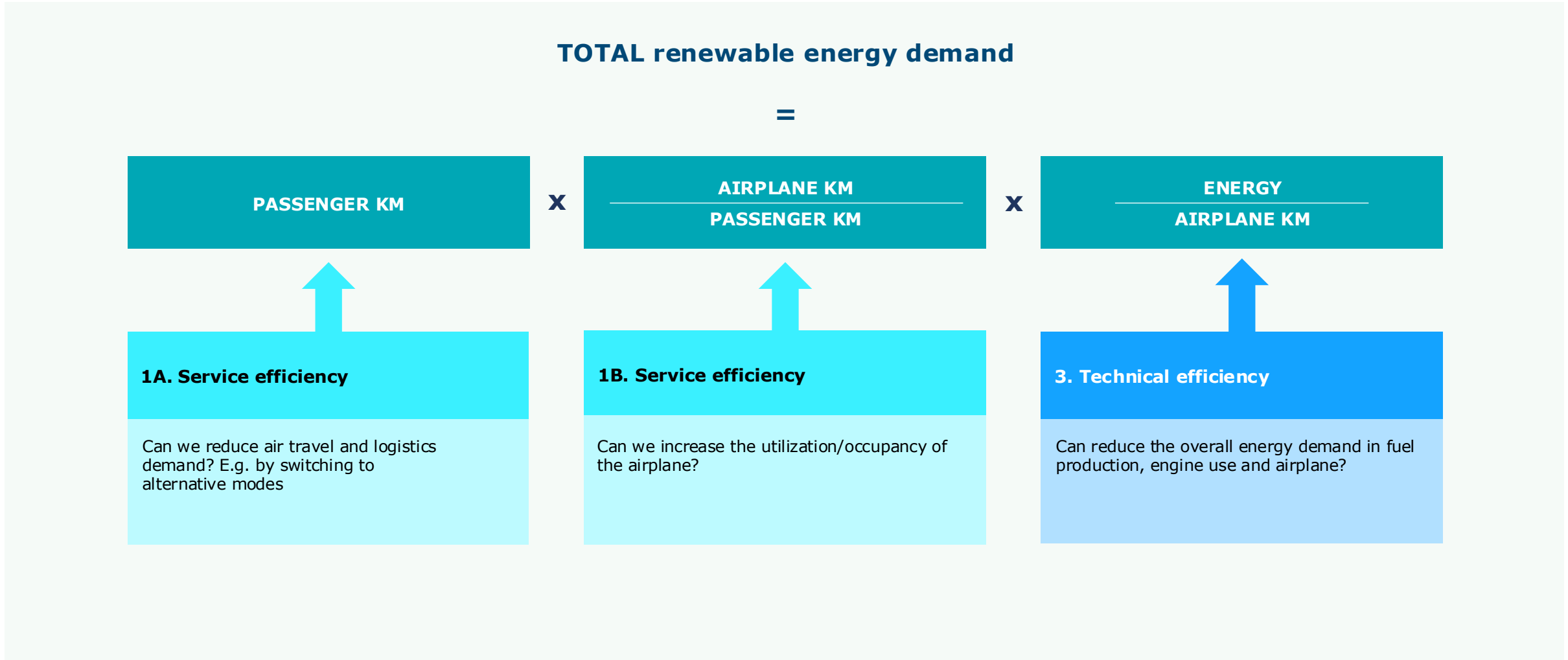
Global aviation fuel production

Mt/y



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

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



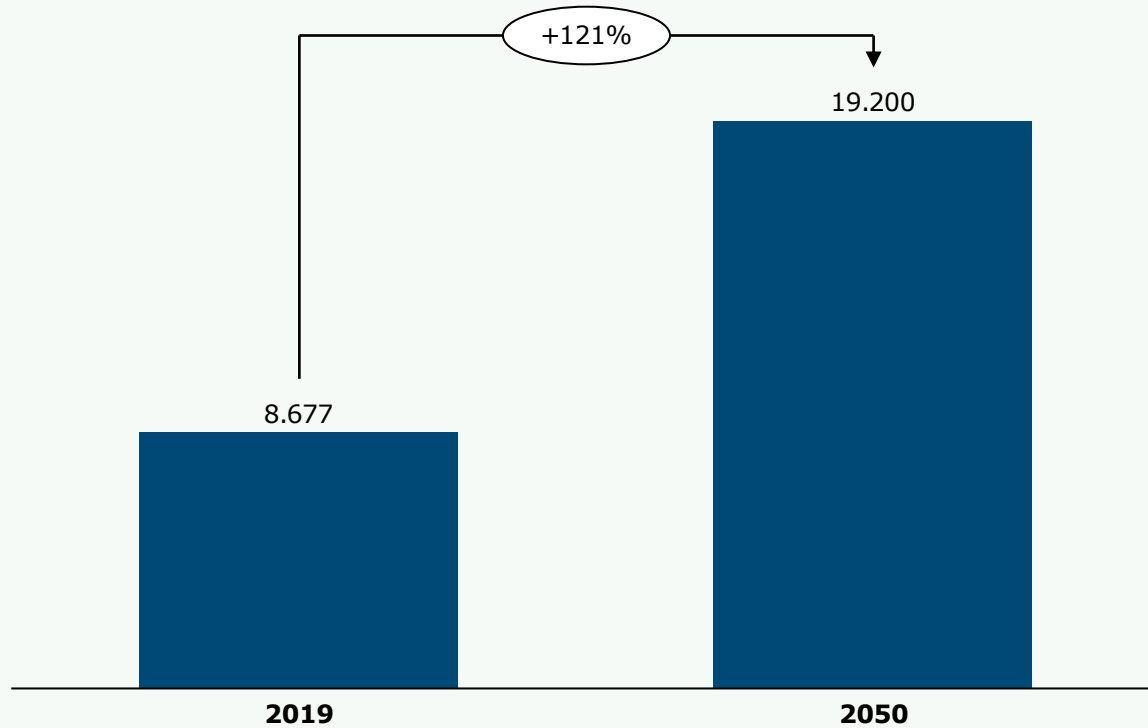
Lighter, more efficient aircraft and operational improvements are key to reducing aviation energy demand

Productivity lever	Description
Technical energy efficiency	<ul style="list-style-type: none">• Engine efficiency improvements• Improvements in aerodynamics• Lightweighting of airplane
Service efficiency	<ul style="list-style-type: none">• 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

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

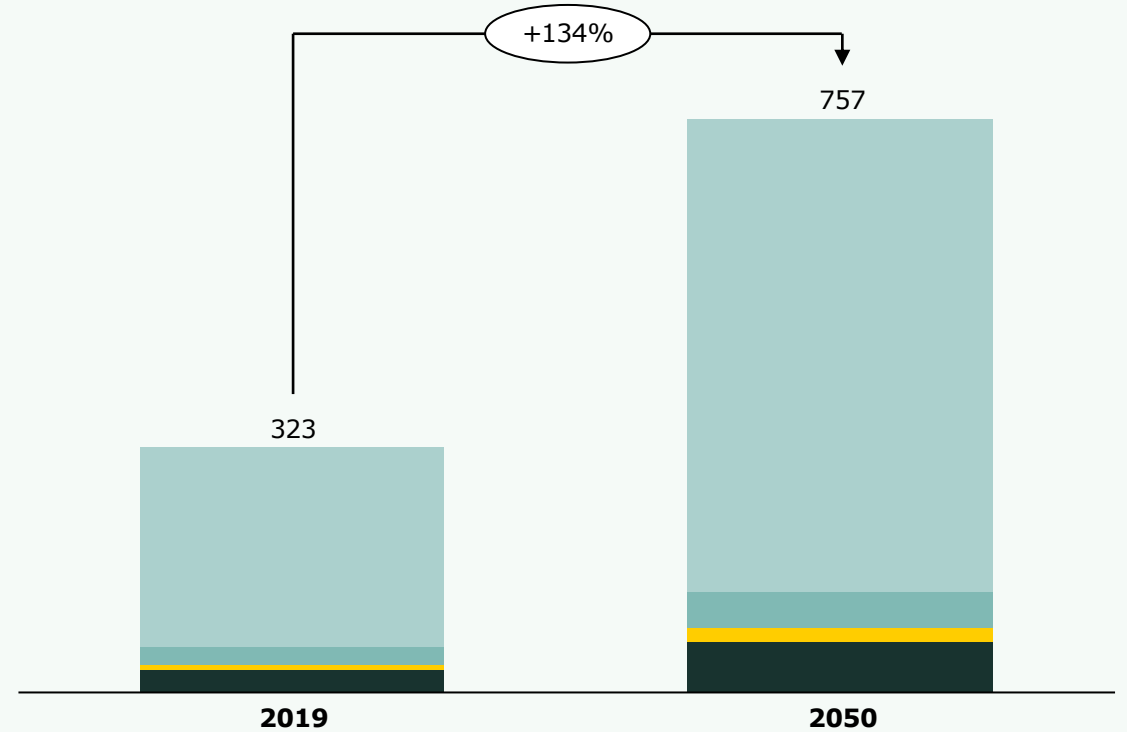
Billion revenue passenger-km (RPK)



Jet fuel equivalent demand (before efficiency levers)

Mt

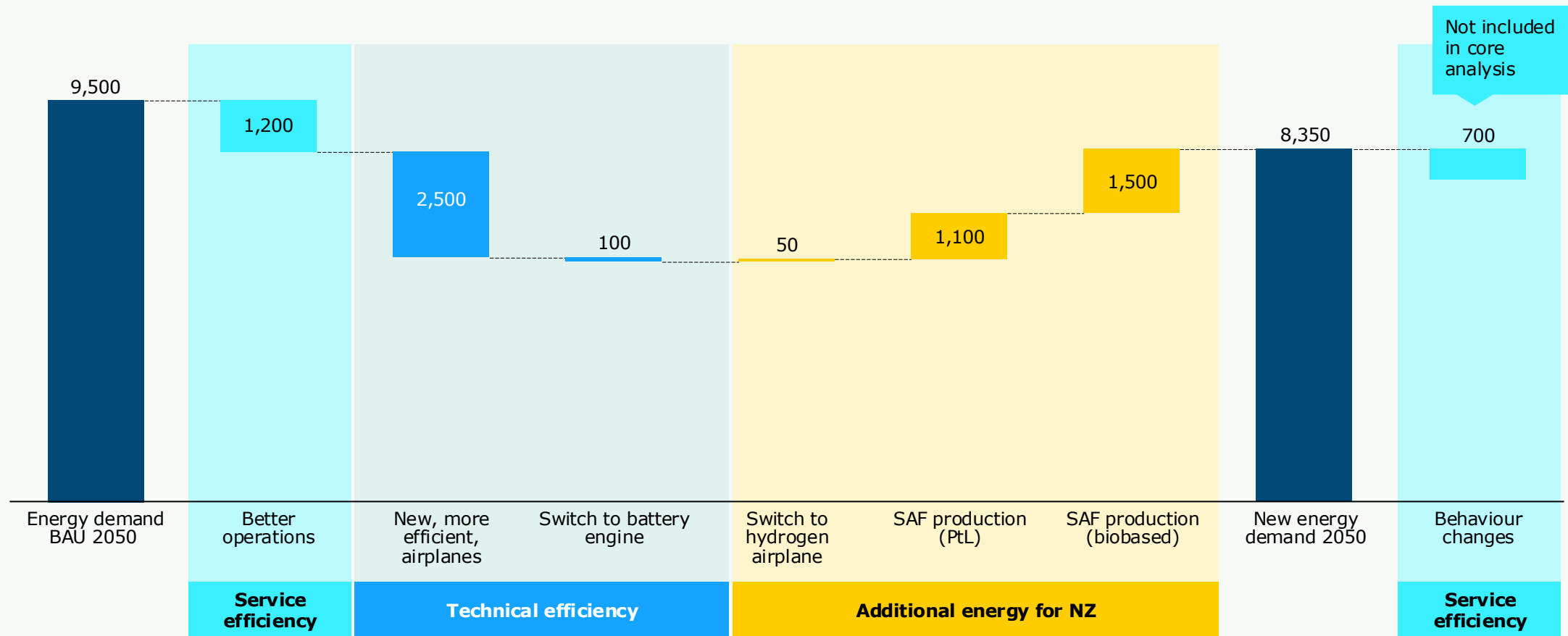
- Commercial passenger aviation
- Commercial cargo aviation
- General aviation
- Public sector aviation



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

Primary energy demand in 2050 and impact of productivity levers

TWh



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



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

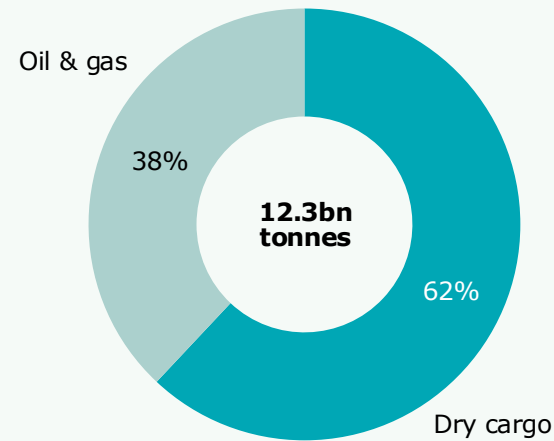
Global shipping transport work by segment, 2018 bn tonne-miles



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

Demand

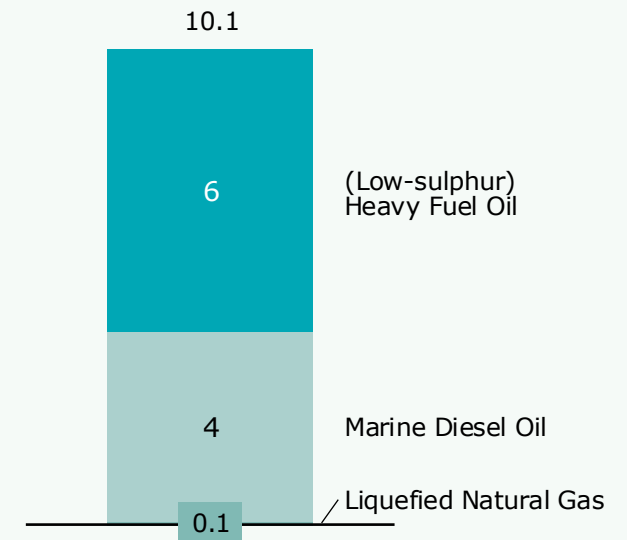
Seaborne trade by cargo type, 2023
World maritime trade volume



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

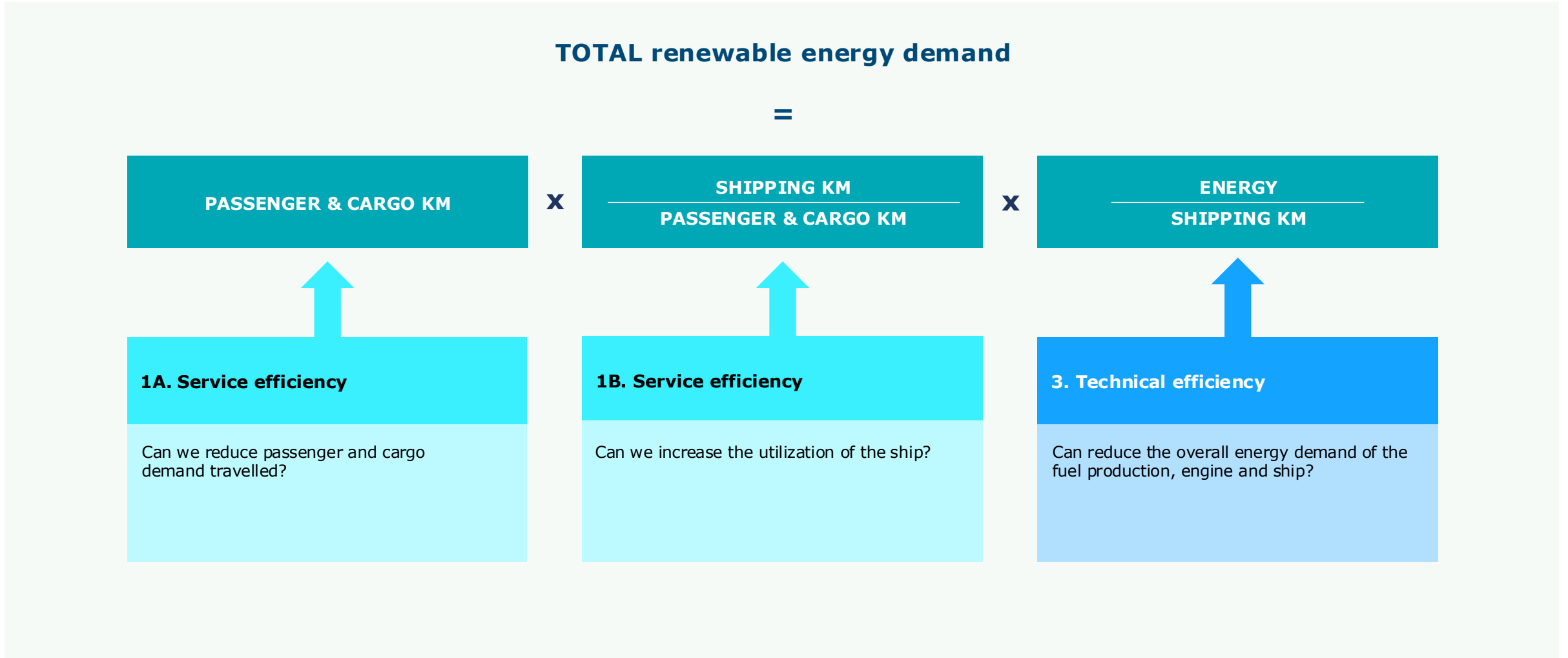
Energy supply

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



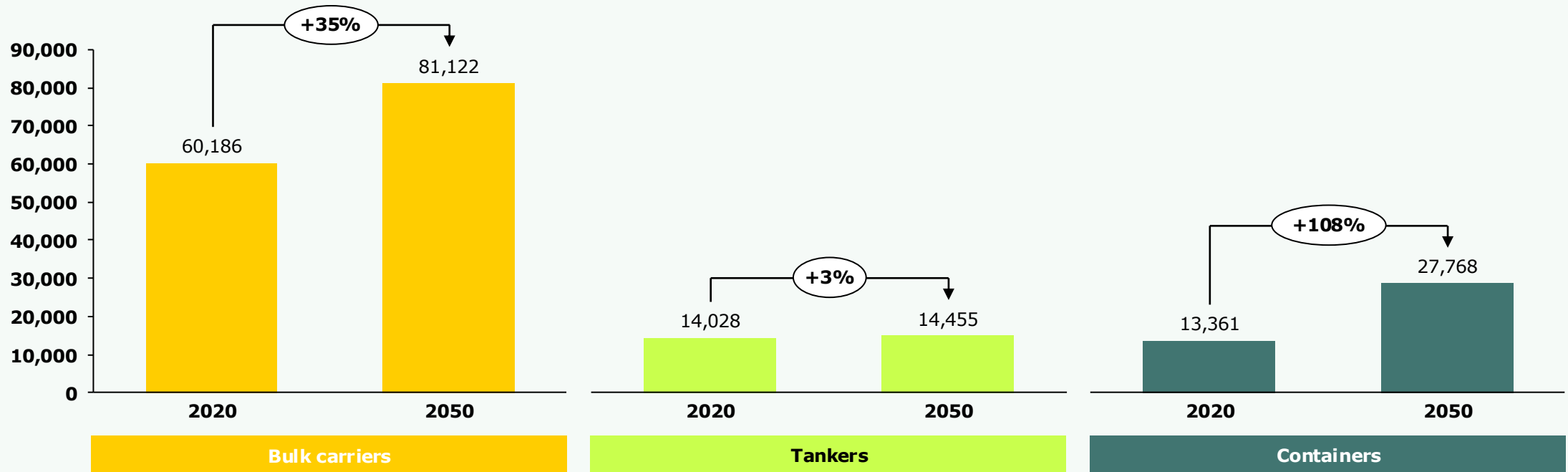
Shipping vessels can be more efficient via better operations, better routing and maintenance, and technological improvements, in design and engines

Efficiency lever	Efficiency lever description
Service efficiency	<ul style="list-style-type: none">• Better operations of vessels via:<ul style="list-style-type: none">○ weather routing,○ autopilot upgrade,○ speed reduction,○ increased frequency in hull cleaning,○ better engine control○ better propeller polishing
Technical efficiency	<ul style="list-style-type: none">• Technological improvements in:<ul style="list-style-type: none">○ 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)

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



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.

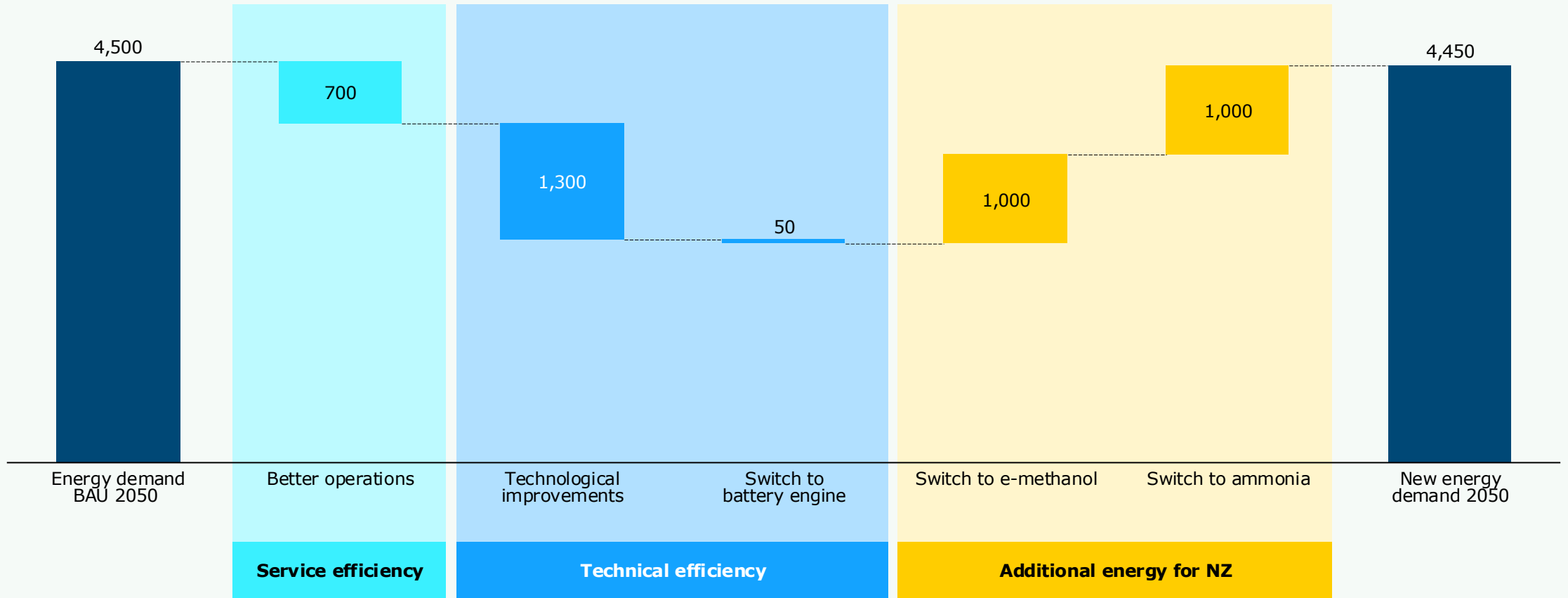
Fossil fuel phase-down broadly flattens tanker demand

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

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

Primary energy demand in 2050 and impact of productivity levers

TWh



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



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					
Technical energy efficiency	-\$135 bn/year in SAF expenditure	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%			
Service efficiency	-\$12 bn/year in the bottled water business	Beverage bottles	Price – global avg (\$/use)				
		Single use	0.07				
		Re-usable (at scale scenario)	0.05				
Material efficiency	-\$25 bn/year in aluminium power bills	Production	Energy demand (GJ/ton of Al)	Material lever	Potential by 2050 (Mt)	Energy gains (GJ/ton of Al)	Share of global production in China by 2050 (%)
				Shift from Primary to Secondary	13	(66-3.3)	>50%
		Primary	66	Decrease losses in manufacturing	17	3.3	Power prices in China by 2050 (\$/MWh)
		Secondary	3.3	Increase lifetime	12	50%*66 + 50%*3.3	102