Energy Transitions Commission

Energy productivity

ETC Commissioners meeting

27th June, 2024

Overview

- Introduction to the ETC's work on Energy Productivity
- Energy productivity in buildings
- Energy productivity in transport
- Energy productivity in the aviation and cement heavy industry sectors
- Where to next for the Energy Productivity workstream

ETC 2024 work programme

Extending our influence in the global climate debate

- Disseminating ETC insights & recommendations
- Leveraging exsisting knowledge
- Informing the influencers

Delivering action through future COPs

- Ambition and format of NDCs
- COP 29, 30, 31

Building the clean energy system faster

	Main reports	*Shorts*
Power system transformation – barriers to clean electrification	Grids Energy storage & flexibility	Offshore wind Power demand growth
Energy productivity	Buildings decarbonisation	Road transport HTA sectors (MPP)
	Energy Productivity across the economy	

Building the ETC regional network

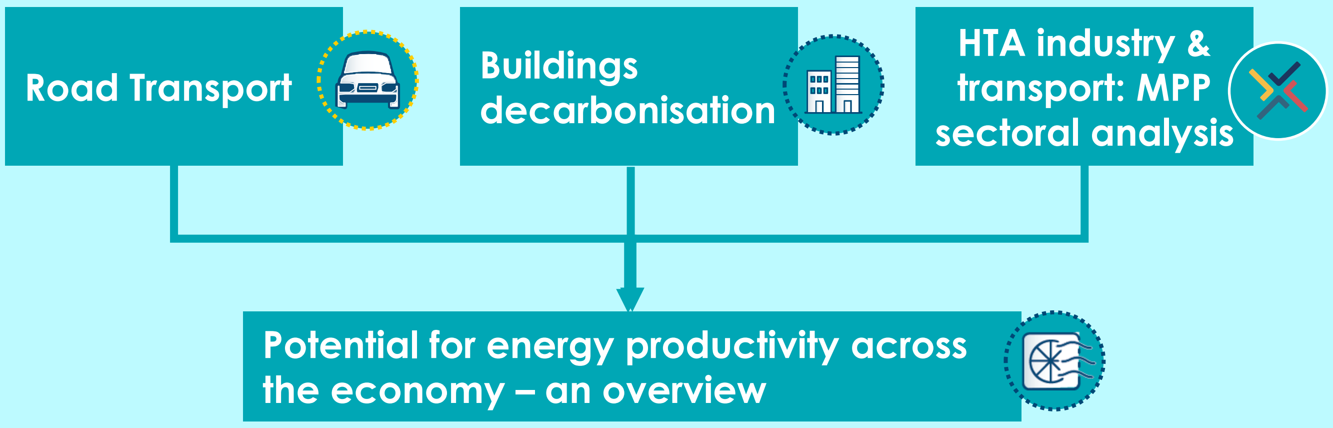
Supporting the MPP

MISSION POSSIBLE PARTNERSHIP

Supporting the ETC members

Overview of energy productivity will bring together three pieces of analysis

2024 ENERGY PRODUCTIVITY SERIES

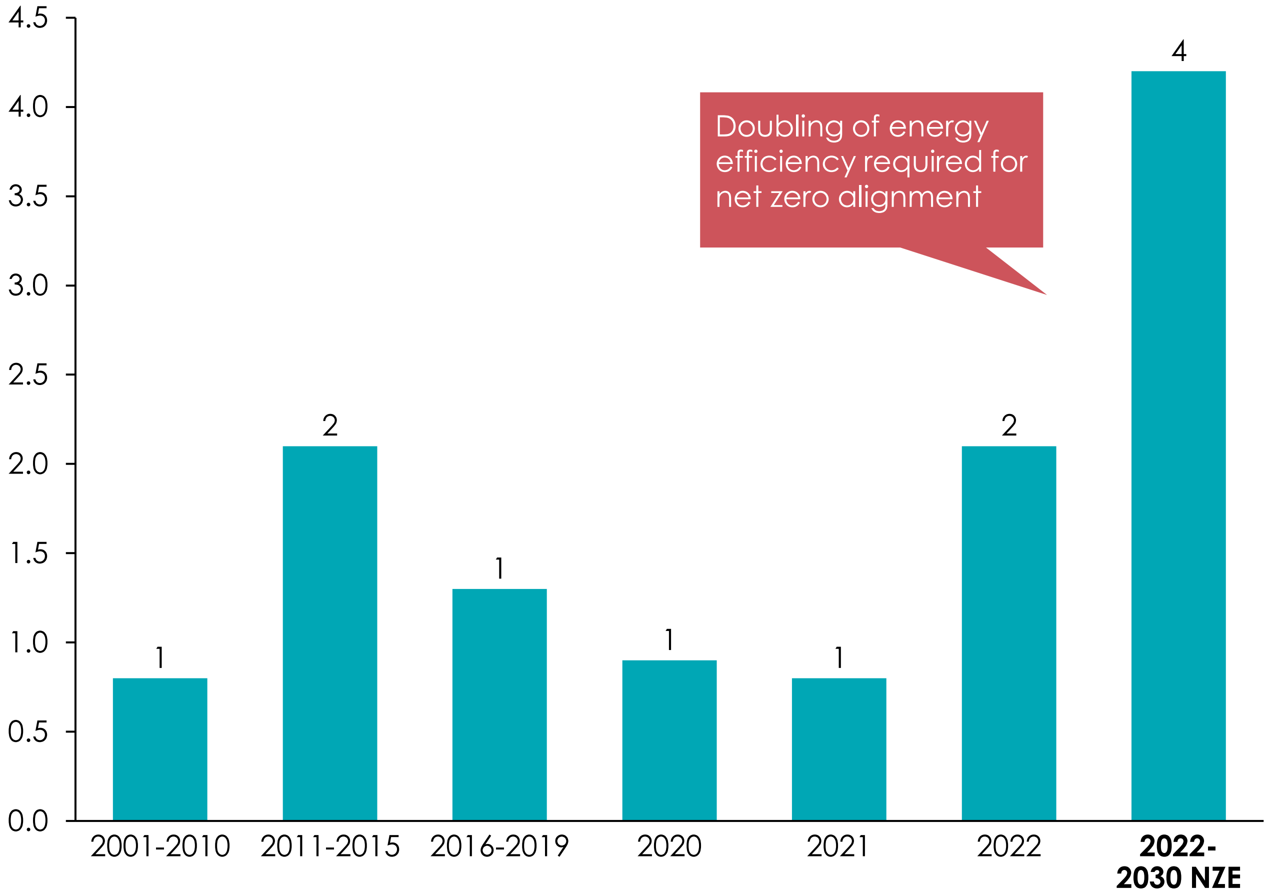


The overview of energy productivity potential will draw on three inputs:

- **Buildings**, encompassing both in-use structures and those under construction.
- **Industry and long-distance transport**, consolidating insights from the Mission Possible Partnership (MPP) analysis.
- **Road transport**, covering both passenger and freight aspects.

To be aligned with a Net Zero Scenario, a doubling of energy efficiency from historical rates of 2% to 4% is required

Primary energy intensity improvements, historical and rates assumed in the Net Zero Scenario, 2020 – 2050, %



- Energy efficiency is **the largest measure to avoid energy demand** in a decarbonized world

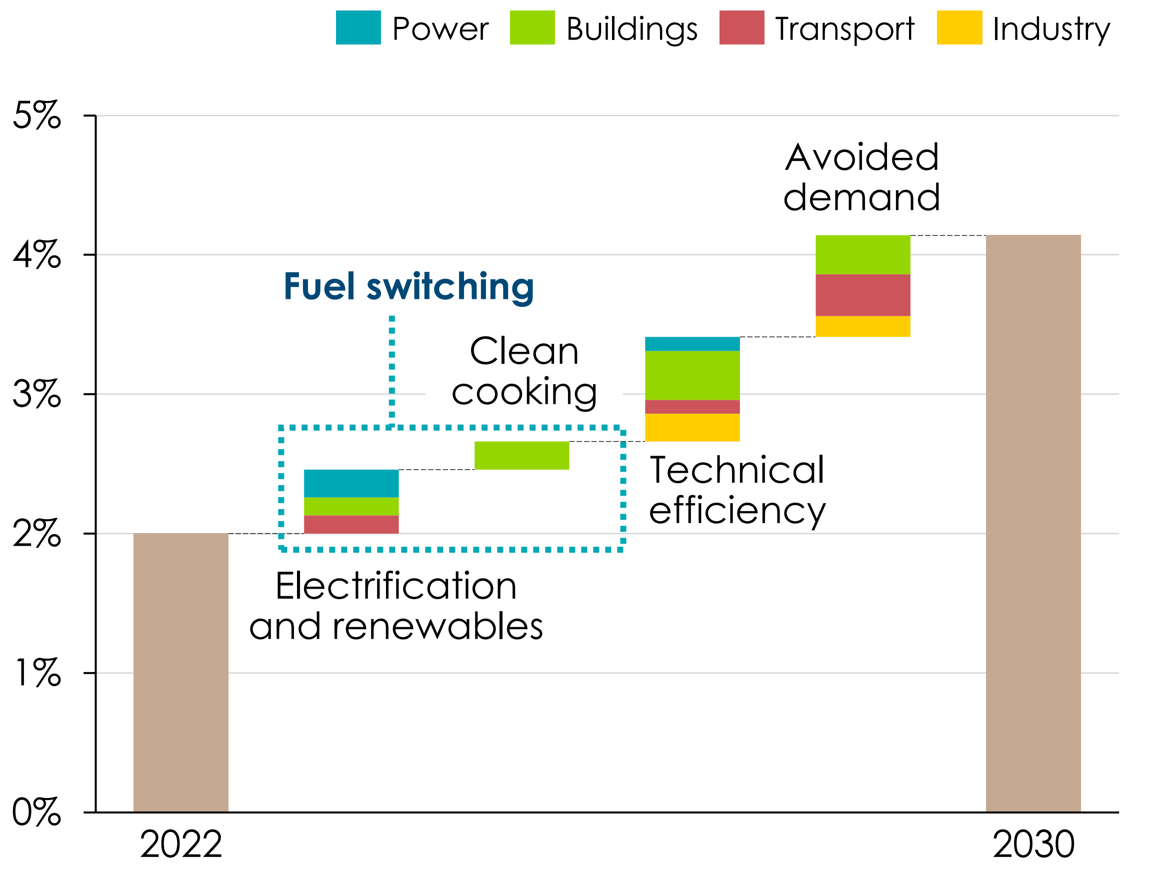
- To get on track with a Net Zero scenario, energy efficiency needs to increase from **2% today to 4%**

At COP 28, commitment was made to **collectively double the global average annual rate of energy efficiency** improvements to 2030, but it is unclear how exactly this should be achieved

Source: (IEA 2023) *Energy Efficiency* and COP28 UAE (2023) *Global Renewables and energy efficiency pledge*

In practice, this means improved efficiency in power, buildings, transport and industry

Average annual rate of total energy intensity reduction by contributor



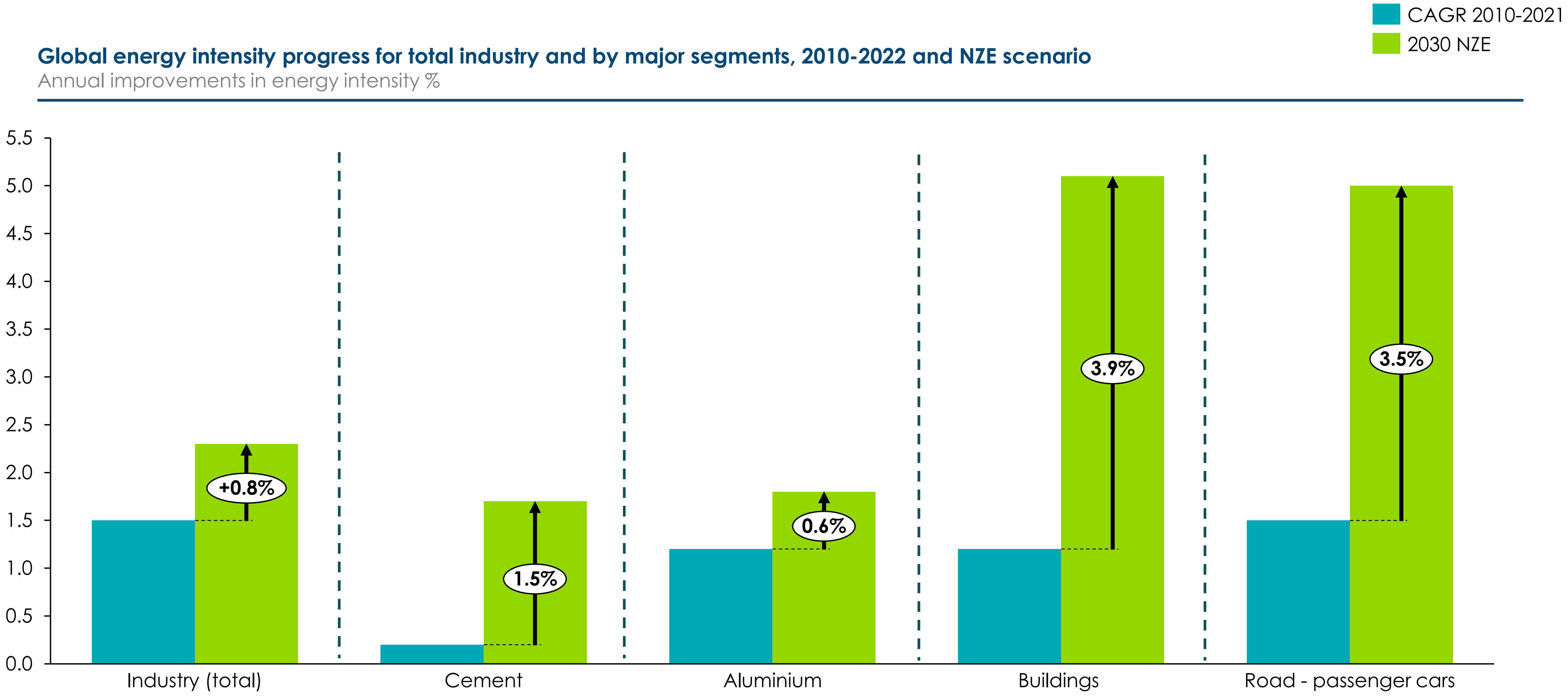
Major drivers of energy productivity improvements are

- **Power**, as renewables (100% efficiency) displace thermal fossil generation (~30-60% efficiency)
- **Buildings** as:
  - Clean cookstoves replace biomass-based cooking
  - Electrification and efficiency improvements increase in new and existing buildings
- **Transport**, through electric vehicles (75%+ efficiency) replacing Internal Combustion Engines (25% efficiency)
- **Industry**, through increased electrification and other energy productivity improvements

Focus of today's session

Source: IEA (2023) *Net Zero Roadmap - Update*

IEA projections for NZE in 2030 require more improvements in buildings and road then the industrial sectors for energy efficiency



Source: (IEA 2023) *Energy Efficiency 2023*

Energy productivity – higher living standards per energy use – can be achieved in 3 ways

Pre-read

Energy Productivity
Less energy used for same living standard

A — Energy process efficiency
Less energy per production process

B — Material efficiency
Less primary material input required per product / service

C — Service efficiency
Better utilisation of products and services to achieve same living standard

Living standard / Energy = Energy using process / Energy × Product / Service / (Primary) material × Living standard / Product / Service

To assess possibilities to increase the energy efficiency in the MPP sectors, we used the (extended) ETC energy productivity framework

Target figure	Key lever		Guiding question	Reduced quantity	Example
Energy Productivity (living standard per energy input) =	Energy process efficiency ×		How can we decrease the energy input per (production) process?	Process energy	Shift to less energy-intense production technology, incremental energy efficiency increase
	Material efficiency ×		How can we decrease the material input per product?	Material	Recycling and use of recycled content, reduce primary material use while maintaining specs of product
	Service efficiency	Demand efficiency ×	How can we decrease the demand without sacrificing living standard?	Demand (for specific service)	Behavior changes, e.g. switch to train journey instead of airplane
		Product efficiency	How can we increase the utilization of the product?	Product	Reuse, sharing of products, increased product lifetime

Electrification and technological progress will drive improvements in process energy efficiency

Pre-read

	Key lever	Examples
Process energy efficiency (Produced unit/service per energy input)	**Incremental Improvements of essential unchanged technology / production system**	• Energy efficiency improvements in airplane engine • Reduction in coal/ gas use per tonne of steel production
	Change in energy efficiency due to shift of technology	• Electrification of transportation and buildings sectors • Usage of hydrogen as reduction agent in steel production • Renewable electricity generation

Increased energy productivity has three main beneficial impacts

1) **Lower size of the challenge** of the energy transition by reducing need for renewable energy and managing peak demand

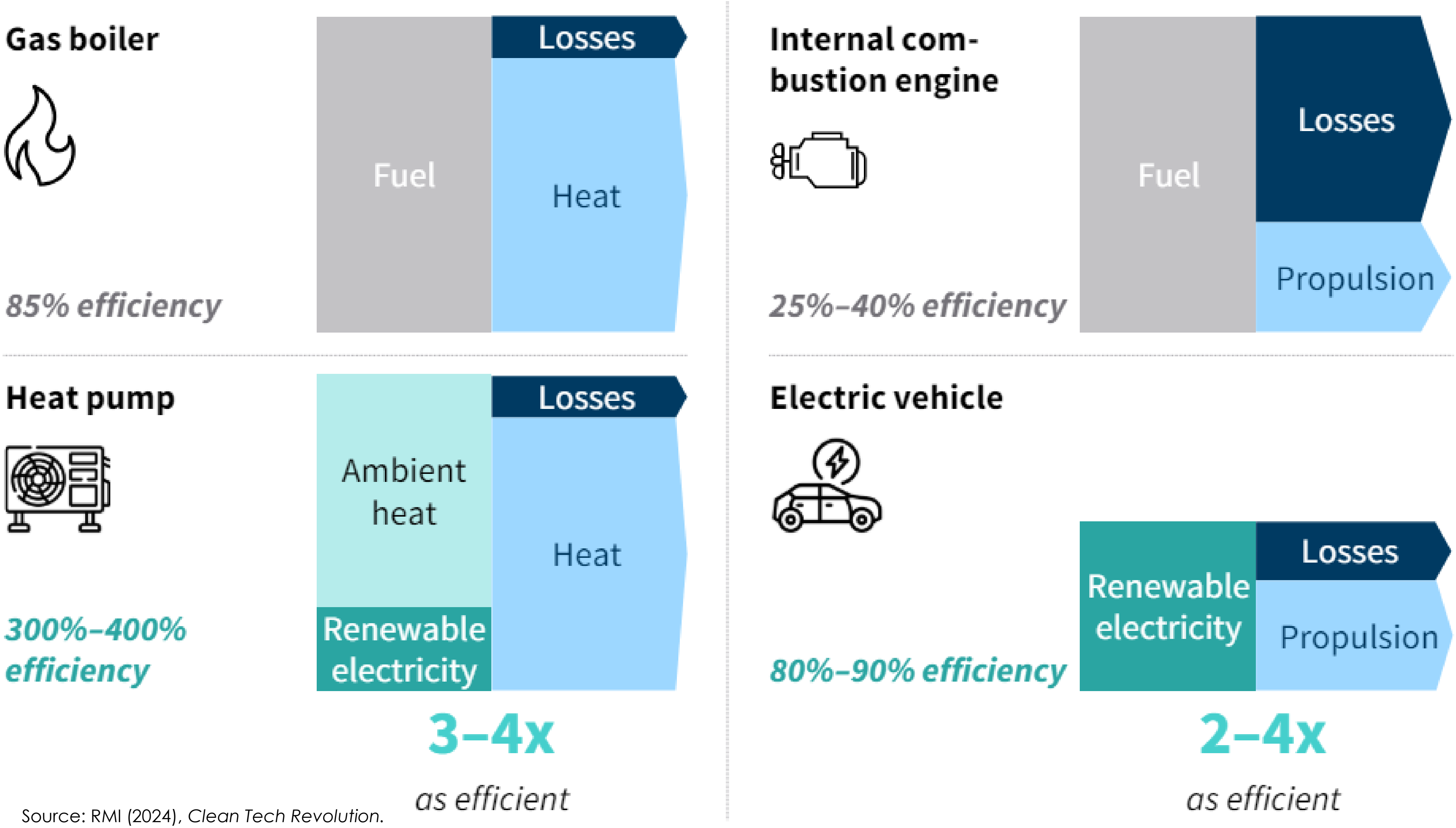
2) **Reduce** emissions while the transition is underway before electrification occurs

3) **Decreased investment costs** for production of renewable energy (hydrogen, electricity and biomass)

4) **Reduced negative impacts** on other planetary boundaries (e.g. less demand for rare metals)

5) **Decreasing energy bills**, while maintaining health and comfort

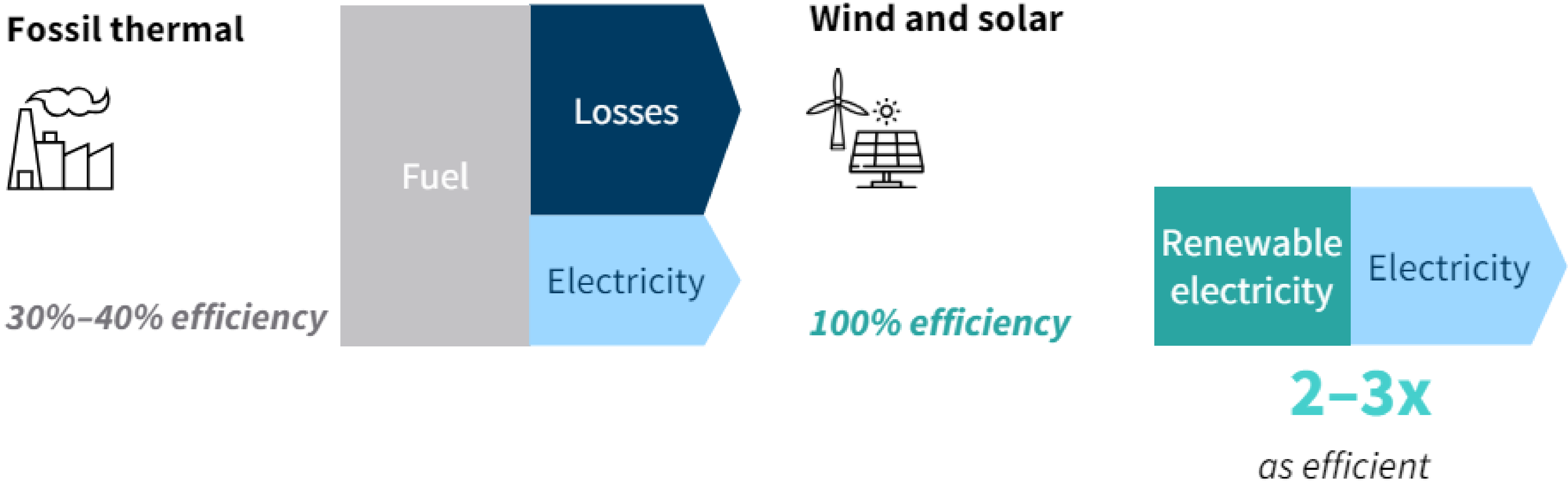
Electrification is energy efficiency – heat pumps and EVs use 2-4 times less energy



Source: RMI (2024), *Clean Tech Revolution.*

And generating that electricity with renewables compared to fossil fuels is also 2-3 times more efficient

Electricity generation from fossils vs renewables



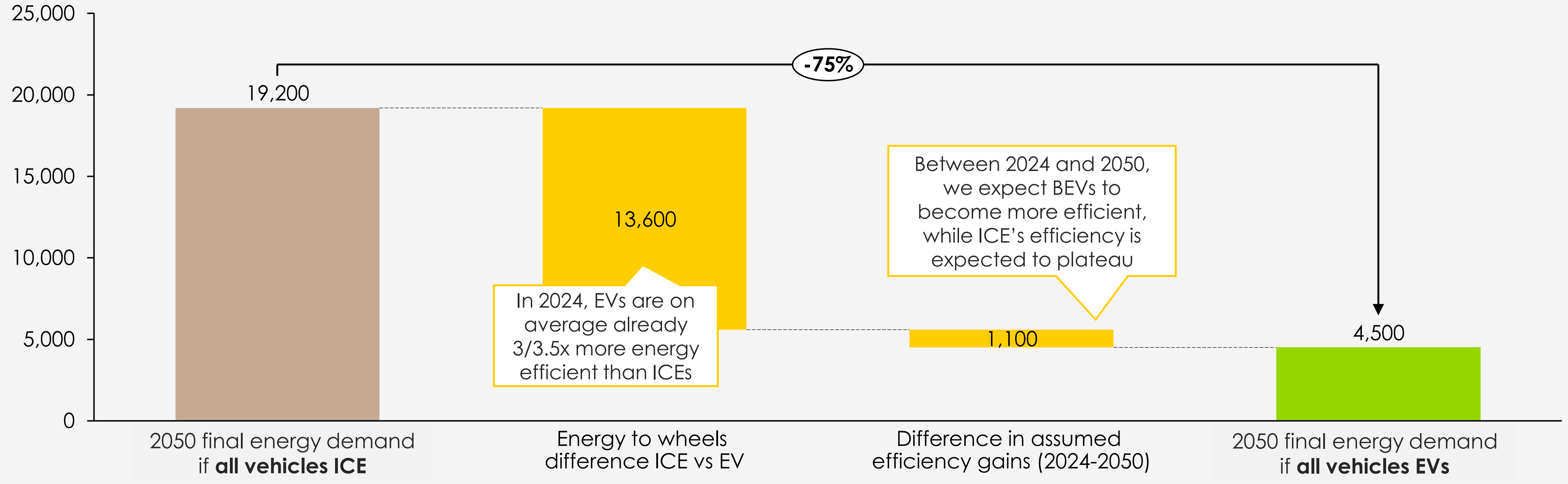
Source: RMI (2024), *Clean Tech Revolution.*

Adding this up: Electrifying road transport would reduce final energy demand by 75% without any other energy productivity improvements (1/2)

PRELIMINARY ANALYSIS

Electric vehicles are already on average 3 times as efficient as gasoline, and could become 4 times as efficient by 2050

Final Energy Demand under a full ICE and a full EV scenario in 2050
TWh

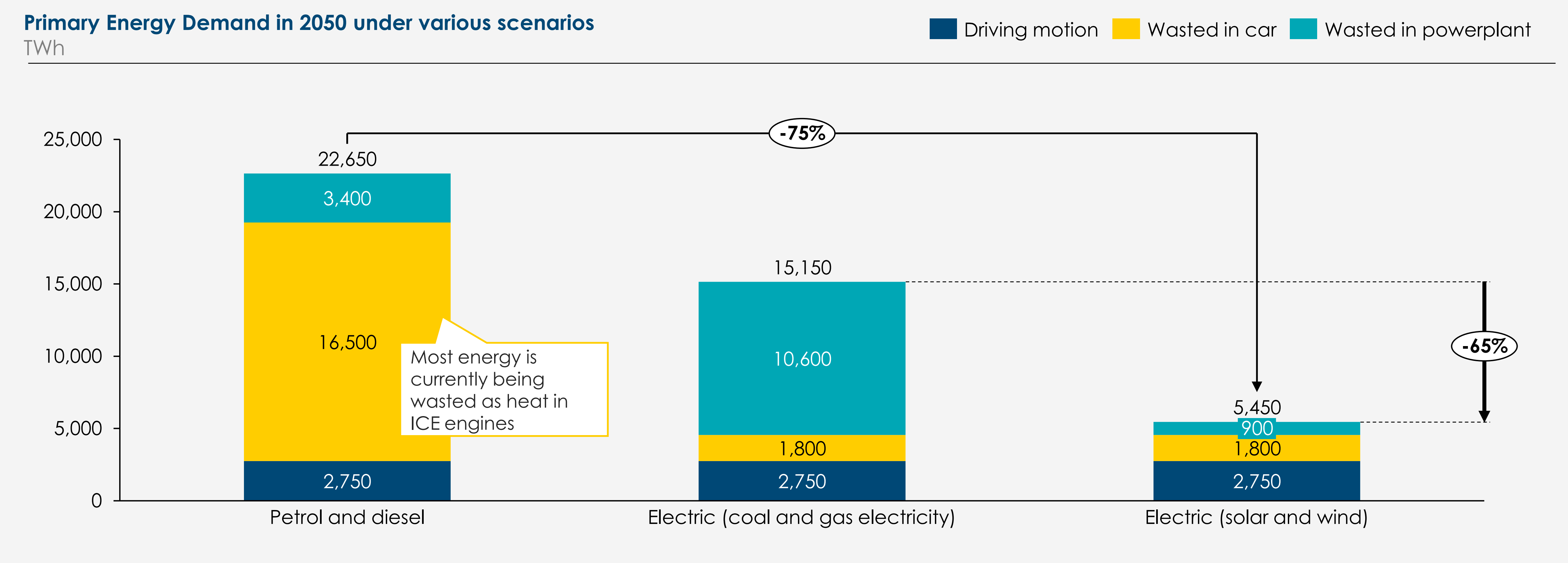


Notes: For Final Energy Demand, demand for transport of ~30,500bn km in 2050, with a fleet of 1.8Bn vehicles; In 2024, new BEVs consume on average 20 kWh/100km, and new ICEs 7.4 Lge/100km. We consider efficiency improvements of 1.6% p.a. for BEVs and 0.7% p.a. for ICEs, respectively reaching 12.9 kWh/100km and 6.1 LGE/100km in 2050. There are 9.3 kWh per Lge (Liter of gasoline equivalent). 5% electricity efficiency losses are assumed as well.
Sources: Systemiq analysis for the ETC.

For maximum efficiency at primary energy level (and minimum emissions) electric vehicles should be powered by low-carbon electricity (2/2)

PRELIMINARY ANALYSIS

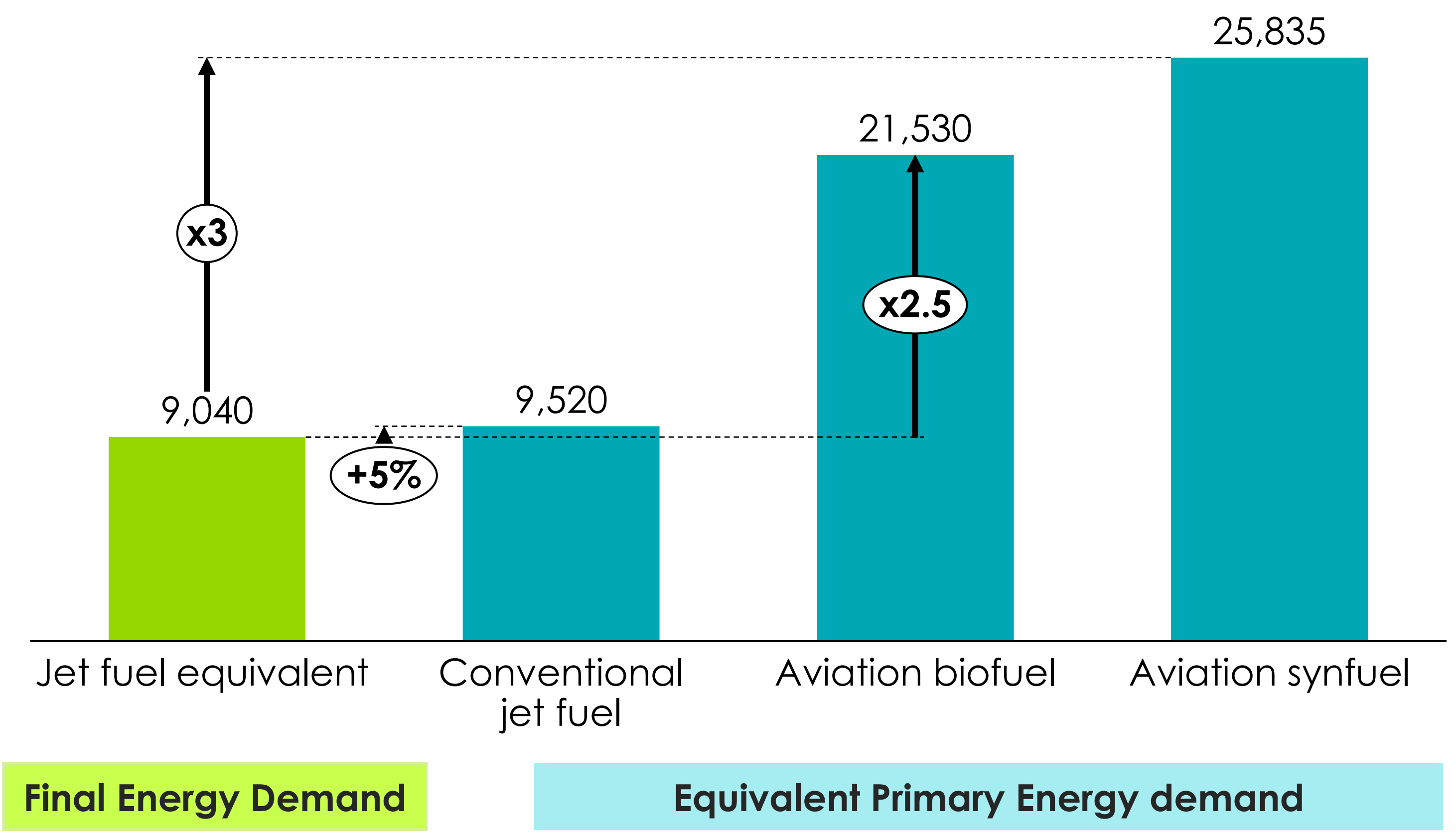
Electric vehicles combined with low-carbon energy will reduce our overall primary energy demand by ~75%



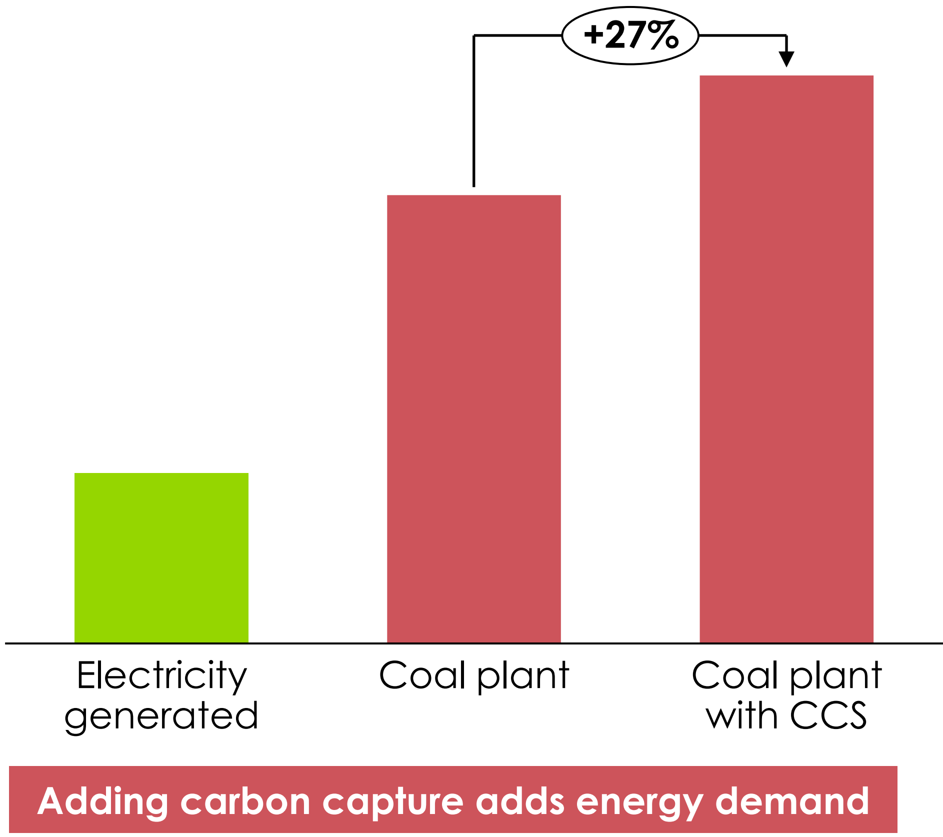
Notes: For Primary Energy demand, energy efficiency of 85% from fossil fuel extraction to tanker, energy efficiency of 30% for fossil fuel power and 83% for renewables power (e.g., electricity conversion and transmission losses). Focus only on passenger vehicles. We assume the average energy-to-wheel energy requirement in 2050 is 9 kWh/100km for a medium size car, excluding auxiliaries. We assume demand for transport of ~30,500bn km in 2050. 5% electricity efficiency losses are assumed as well.
Sources: Systemiq analysis for the ETC.

However, unlike electrification, switching to new fuels and CCS does not mean efficiency

Final versus primary energy demand to produce all of aviation Jet fuel demand in 2050
TWh



Primary energy required for coal plant with & without CCS
TWh energy for 1 GW coal plant running for 1 year



Sources: Mission Possible Partnership (2023) Aviation Sector Transition Strategy, World Resources Institute (2022) *6 Things you Know About Direct Air Capture*

Buildings – operational energy

Key messages

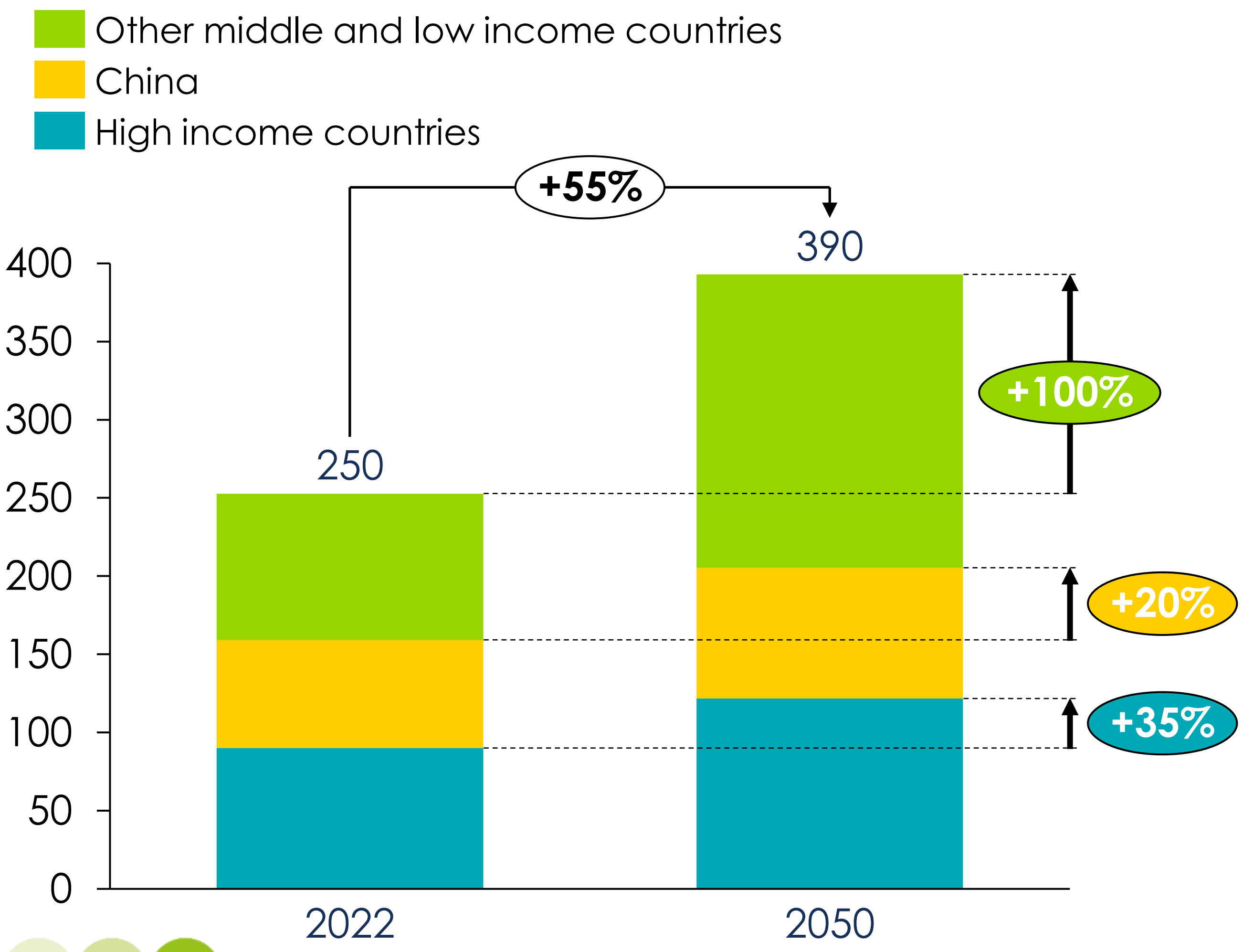
Pre-read

- Electrification is efficiency – we have the solutions we need to electrify building heating
- Heat pumps can technically work in most buildings
- Heat pumps are increasingly becoming economic even without fabric improvements
  - Rebalancing power prices is a more effective lever to improving cost competitiveness against boilers
- This means we can challenge the "fabric first" approach for most existing properties
  - Insulation will still be very important for comfort, but the need for deep insulation is less than was previously thought
  - Low-medium effort/cost insulation (e.g., draught proofing, roof insulation, cavity wall insulation) will be sufficient in most cases; and can be done after a heat pump is installed
- However, the fabric first approach is still critical for new builds – there is a huge opportunity to improve building codes for new buildings incorporating passive heating / cooling techniques
- Better insulation is also very important for thermal inertia in buildings, to enable pre-heating and ease peak load challenge
- Given a strong shift to electric technologies, the actual technical efficiency of these is also a key lever, with big potential for improvements
- Technologically-enabled behaviour change from smart systems (e.g., sensors in commercial buildings, creating tailored heating schedules in homes) can also play a role in reducing unnecessary demand, although the impact is uncertain
  - However, there is a risk of a rebound effect as homeowners experience other efficiency gains

The buildings energy demand challenge: a 50% increase in global floor area and the electrification of fossil fuel heating will create significant demands for electricity grids

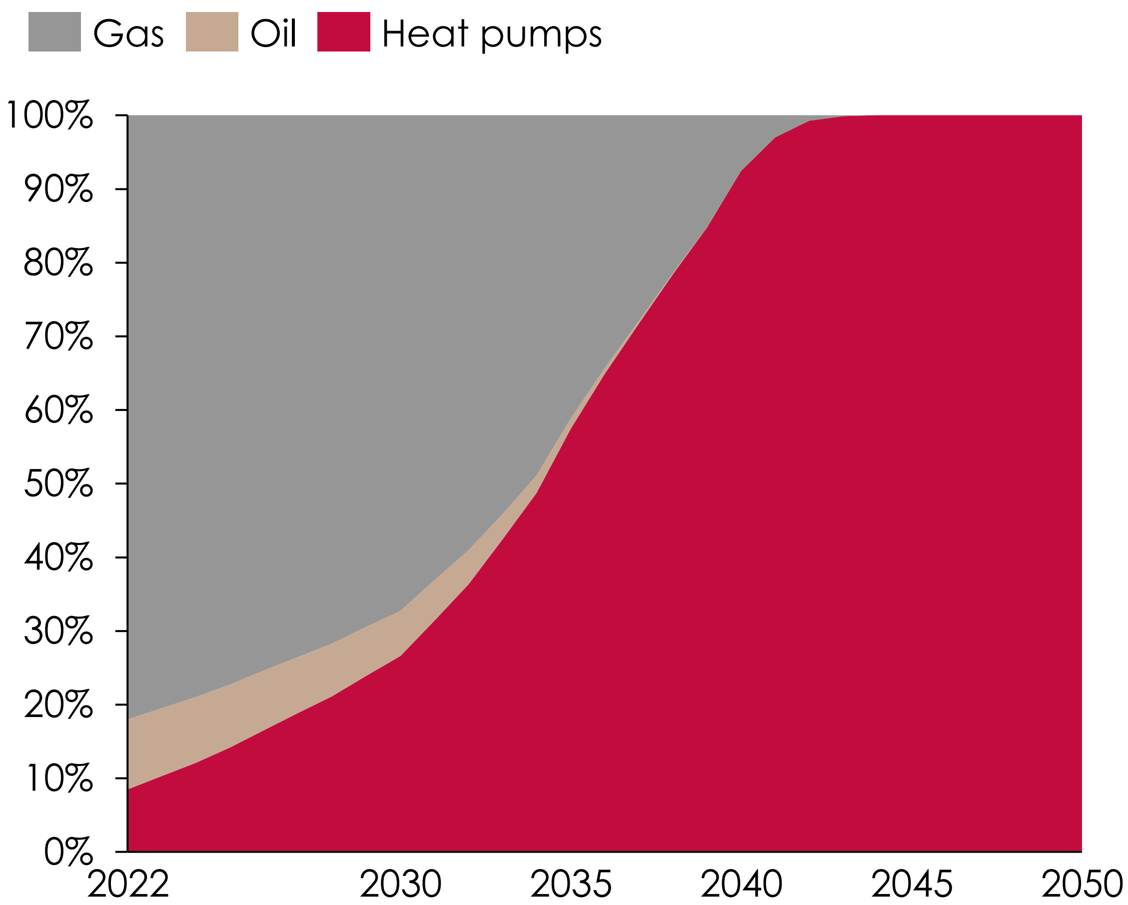
Growth in global floor area by region

2022-2050; Billion m2; IEA NZE Scenario



Transition of existing gas and oil boiler stock to heat pumps in Europe and North America – ETC projections

% of stock of existing



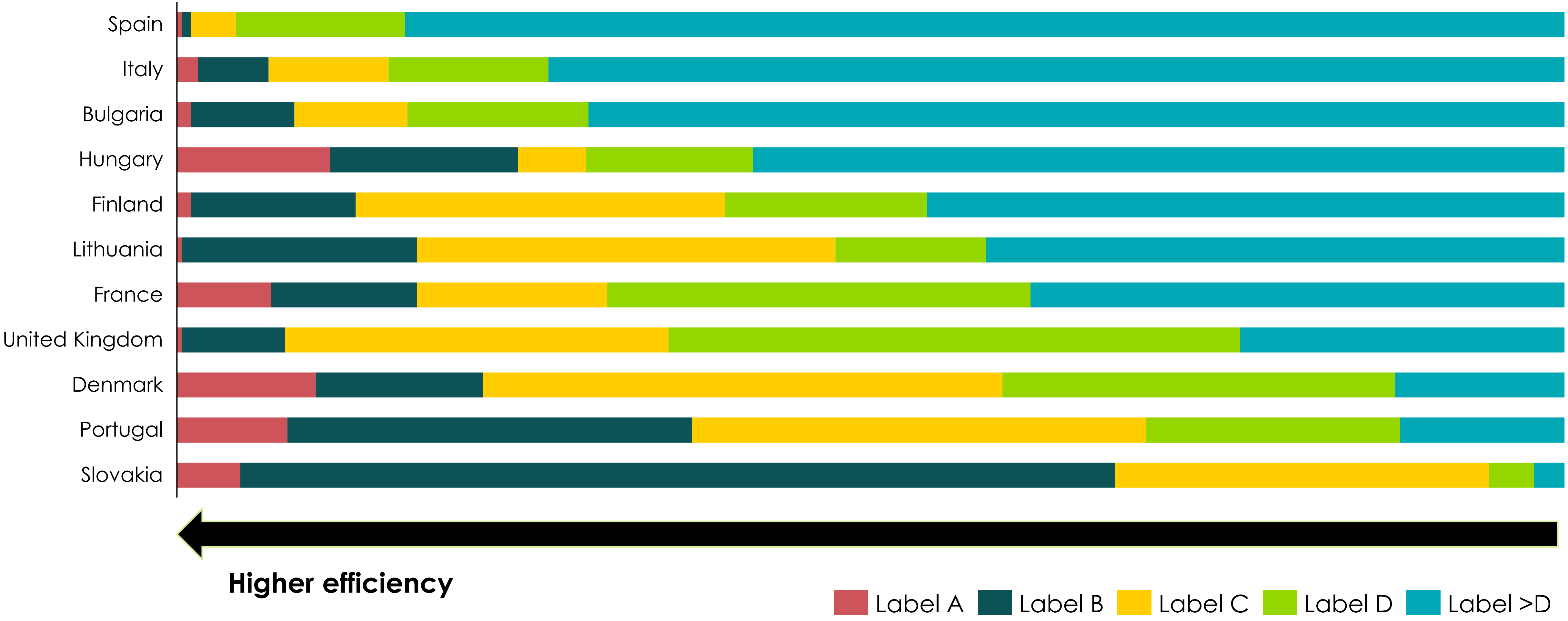
Source: IEA (2023), *World Energy Outlook 2023*; Systemiq analysis for the ETC (2023), *Fossil Fuels in Transition.*
Note: *RHS is ETC's Ambitious but Clearly Feasible scenario.*

Existing building stock varies massively, with lots poor-performing; this has significant implications for comfort, health and energy loss

Note: the definition of EPC bands varies across countries so cannot be directly compared

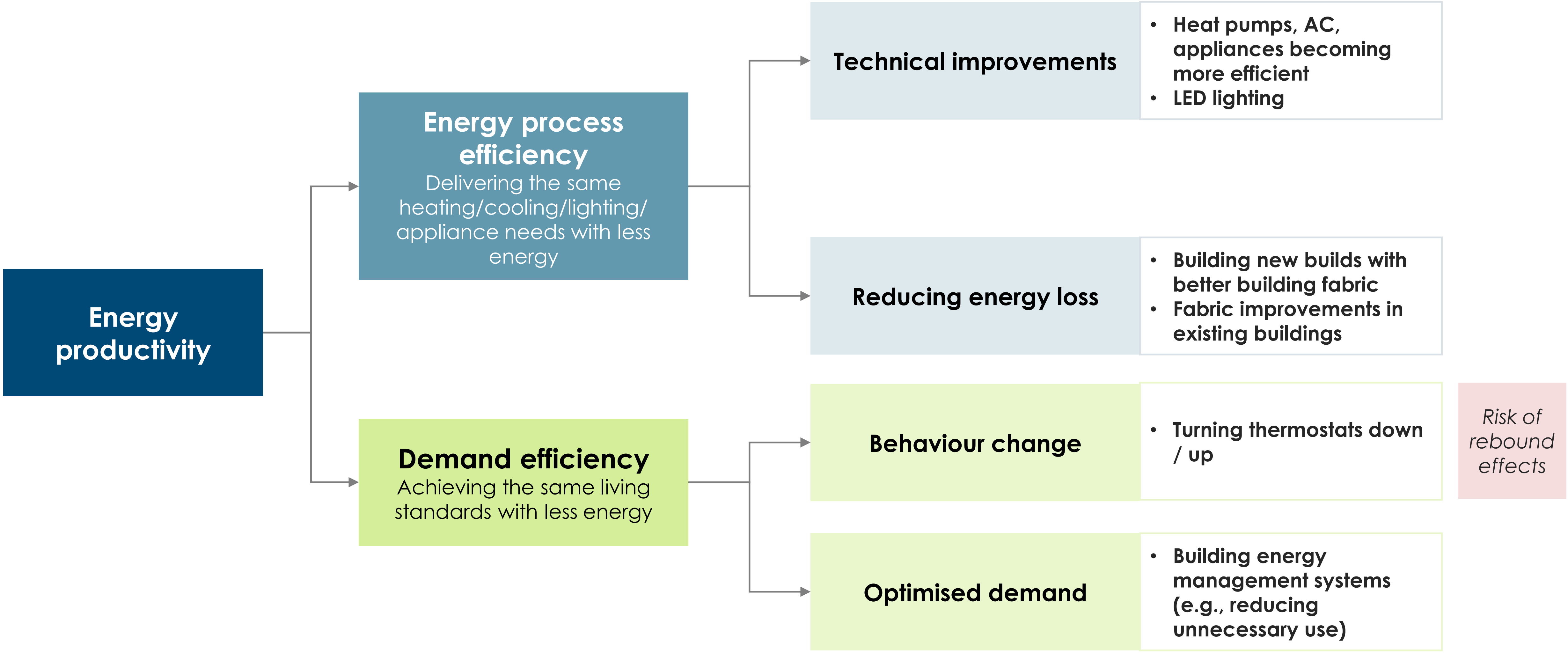
Distribution of Energy Performance Certificates

% of residential building stock, 2014



Source: Eurostat (2016) EU buildings factsheets 2016

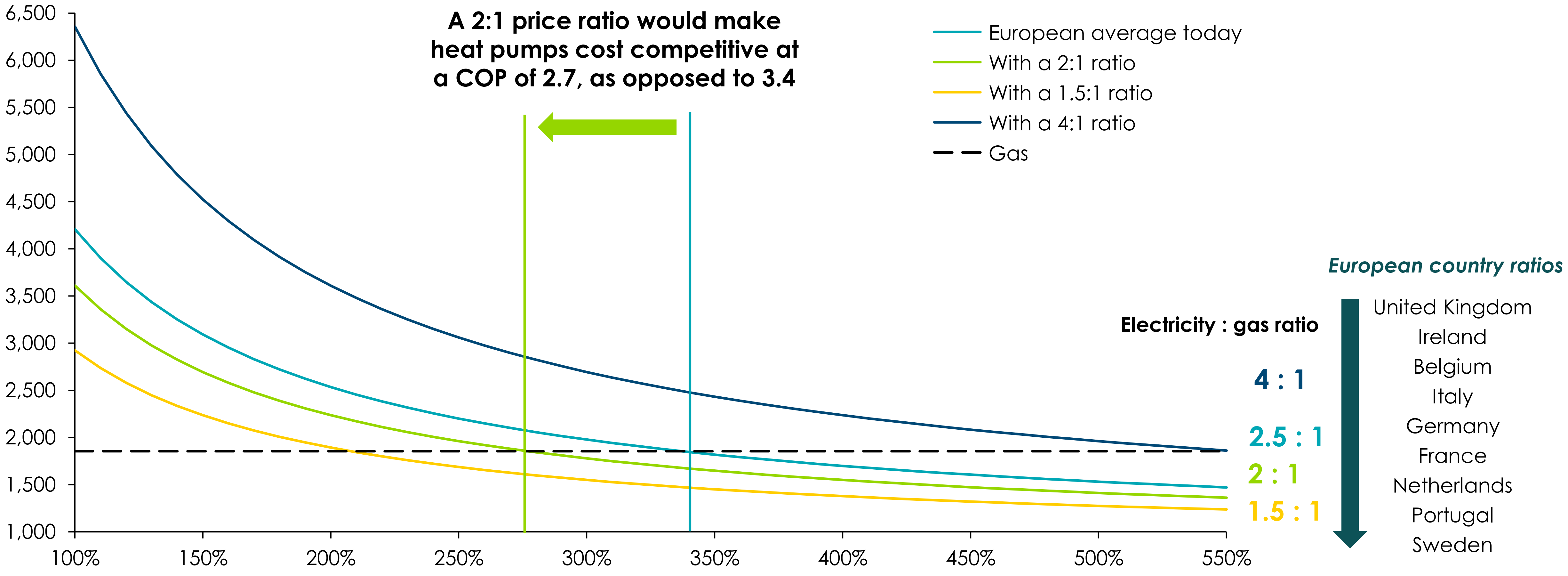
Beyond electrification of fossil fuel heating, there are many energy productivity levers possible for buildings operational energy



Note: OEM stands for Original equipment manufacturer
Source: Systemiq analysis for the ETC.

The technical need for insulation for heat pumps has generally been overstated, and the economic need can also be addressed by rebalancing power prices

Equivalent annual costs (capex + fuel costs) at different electricity to gas price ratios
€ a year



Sources: Systemiq analysis for the ETC (2023); Eurostat for Europe electricity and gas prices; Energy Information Administration for US prices.
Note: Assumes an average heat demand of 11,500 KWh a year per household, based on an average across the US and select European countries. Fuel prices reflect averages from 2023. Assumes a discount rate of 5%.

"Fabric first" approach prioritises optimising building fabric first, before heating system changes; but there is growing recognition that this shouldn't be the default for existing buildings

Fabric first approach

1. Building fabric improvements → 2. Heating system changes

What's changed?

1. Urgency of net zero timelines
2. Relative gas / electricity prices
3. Carbon intensity of electricity

Is "fabric first" still the right strategy?

New builds + extensions

Always

- Passive heating + cooling
- Air tight construction

For the poorest performing buildings, and where low-cost efficiency measures can be deployed

In most cases

- Draught proofing
- Roof insulation + cavity wall
- Double glazing

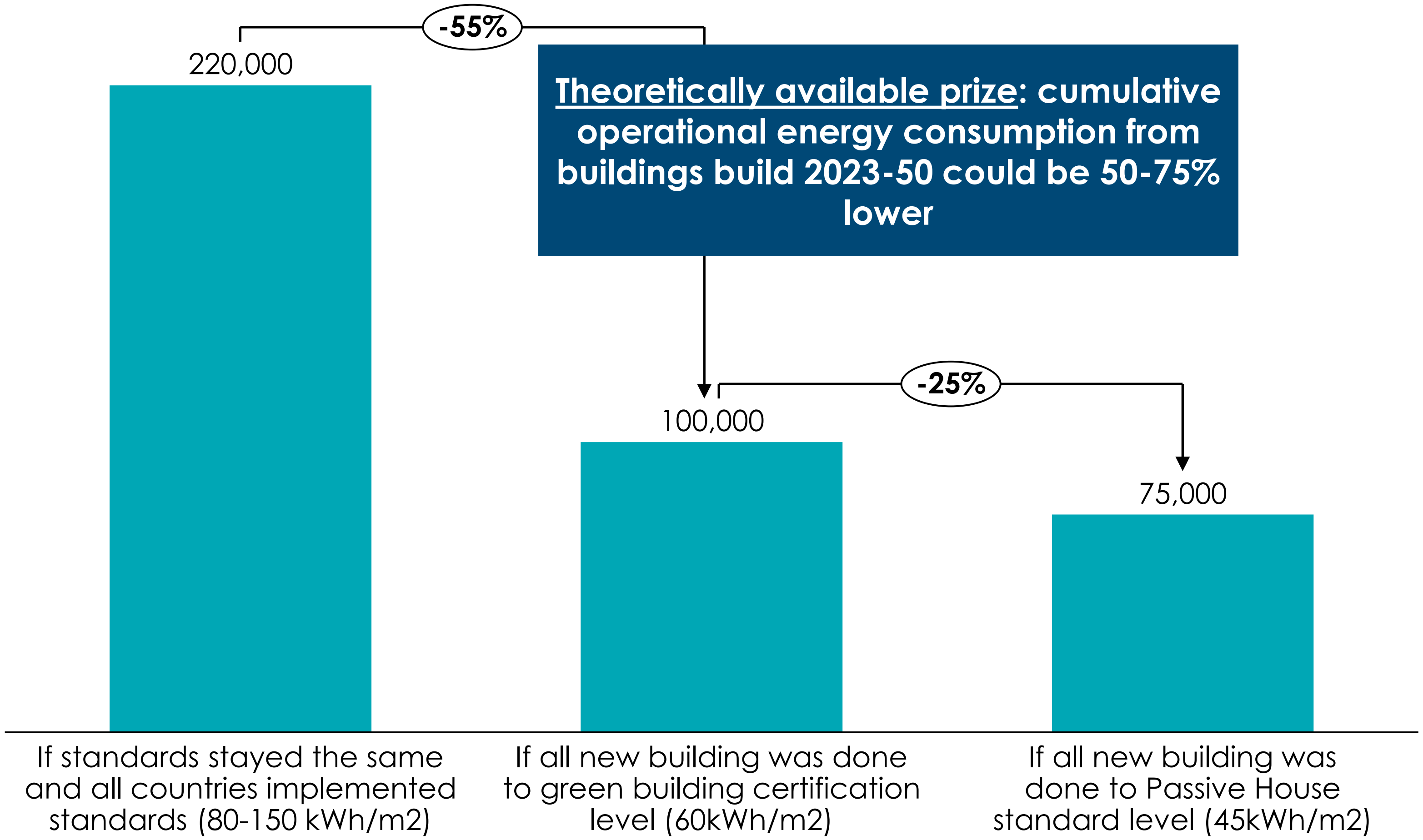
The average property

Does not need to be the default

Where appropriate + cost effective

The most optimal and lowest cost opportunity to improve building fabric is in the design stage; this means building codes should push energy intensity improvements in new builds

Global cumulative household energy consumption, new residential buildings from 2023 to 2050
TWh



Approach:

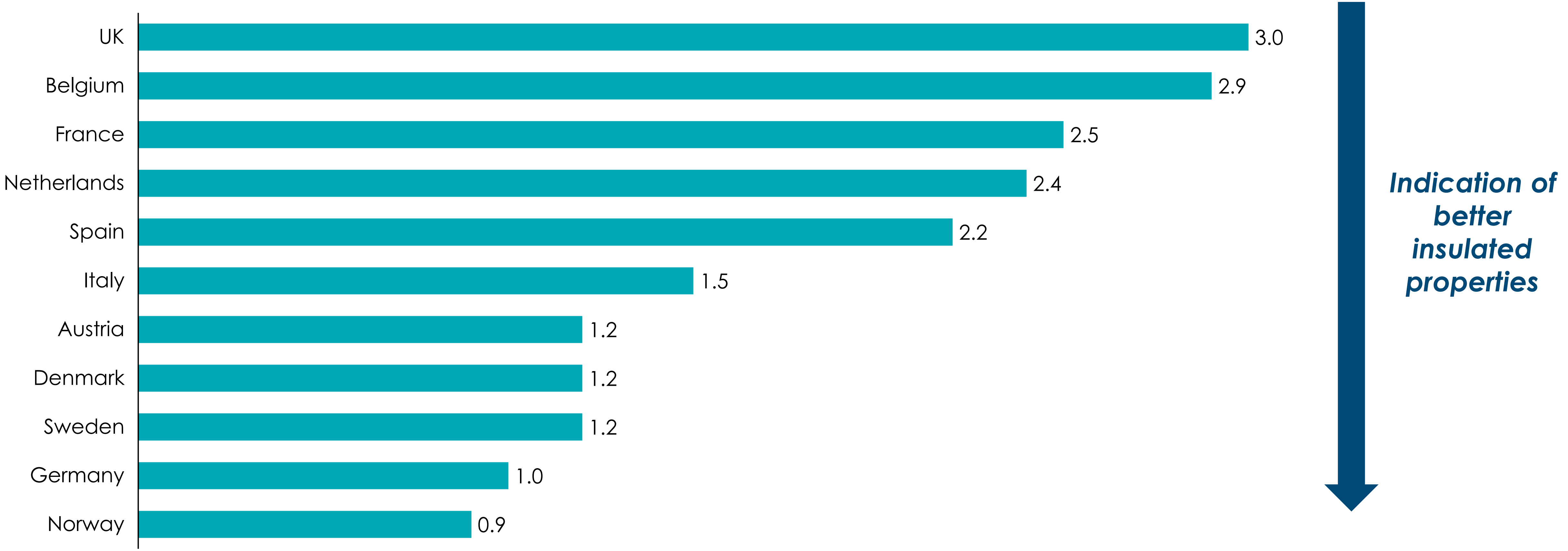
- In a given year, typical household energy use (kWh/m2) x increase in global floor area (m2) = operational energy use from new builds
- Cumulative total to 2050, assuming new builds consume the same kwh/m2 every year from their construction to 2050

The key question is how much of this theoretical potential can in practice be achieved and by when?

Source: Systemiq analysis for the ETC (2024); IEA (2023), *World Energy Outlook 2023*.
Note: Typical household energy use (kWh/m2) based on current standards today (~80kWh/m2 in high-income countries, and ~150kWh/m2 in middle and low income)

Insulation is, however, very important to managing daily peak demand challenges; homes with higher thermal inertia can "pre-heat" their homes ahead of peak needs

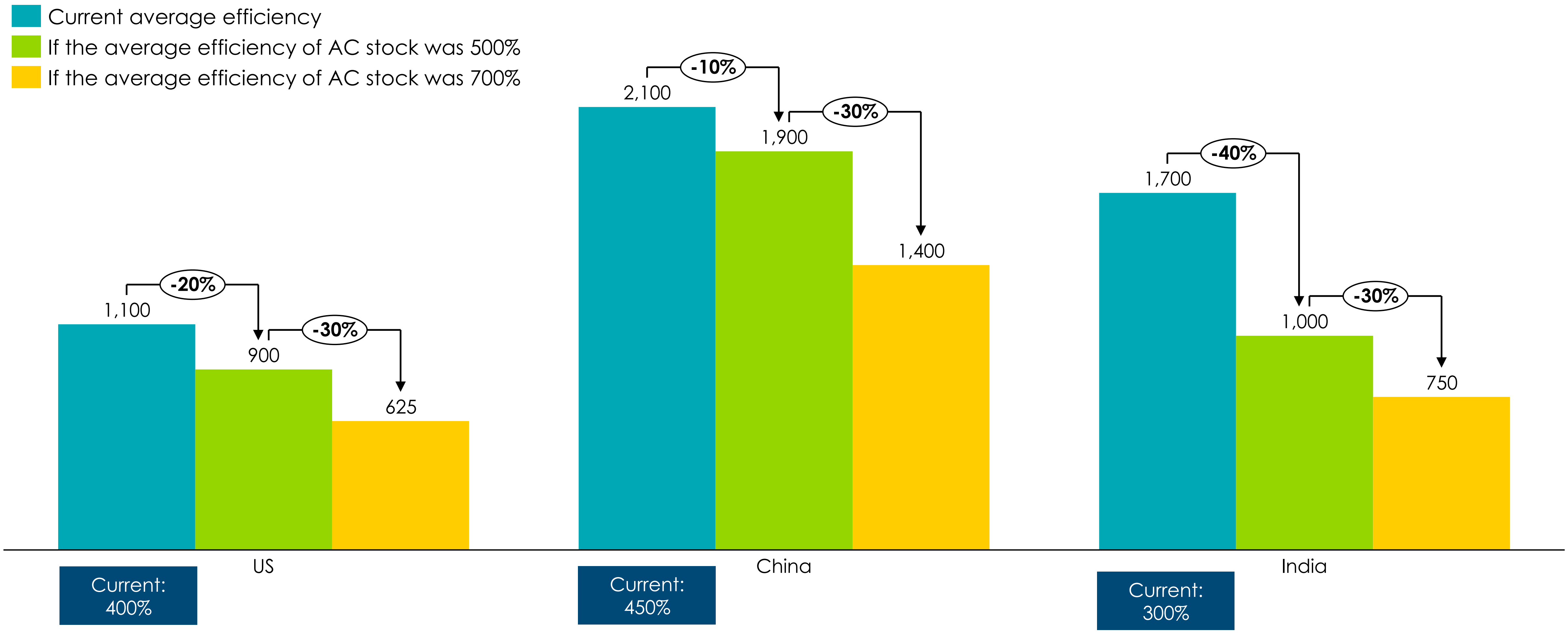
Home temperature loss after 5 hours
°C



Source: Tado
Note: tested in 2019/20 with a temperature of 20C inside and 0C outside

Technical efficiency improvements will also be key; raising the average efficiency of the AC stock could reduce electricity requirements for cooling in key countries by 40-70%

Cooling energy demand under different AC efficiency scenarios, applied to IEA estimates of the number of ACs in 2050
TWh

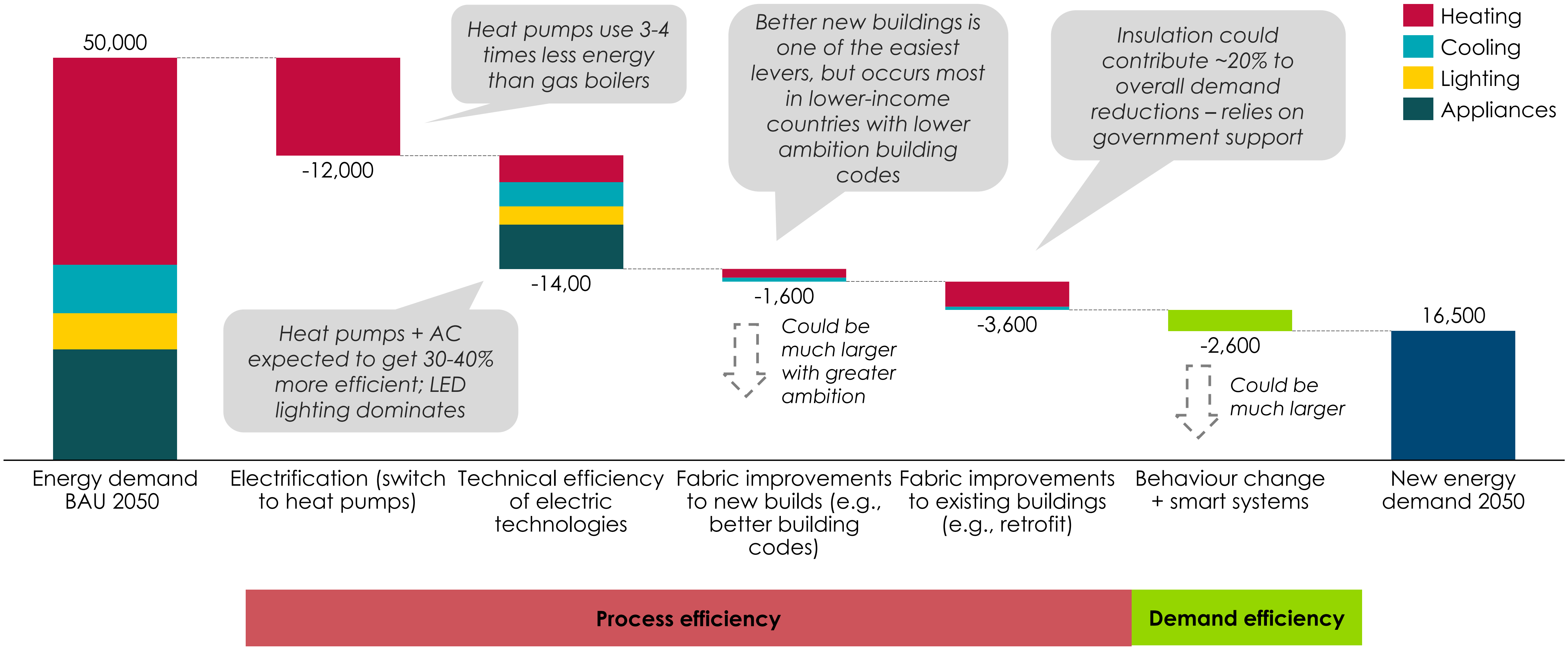


Sources: Systemiq analysis for the ETC (2024); IEA (2023), World Energy Outlook 2023
Note: US average household AC energy consumption assumed at 2,000 kWh/year; for India and China, 1,500 kWh/year is assumed.

Bringing it altogether: energy productivity levers could reduce energy consumption by 60%

Primary energy demand in 2050 and impact of efficiency levers – residential + commercial
TWh

PRELIMINARY ANALYSIS

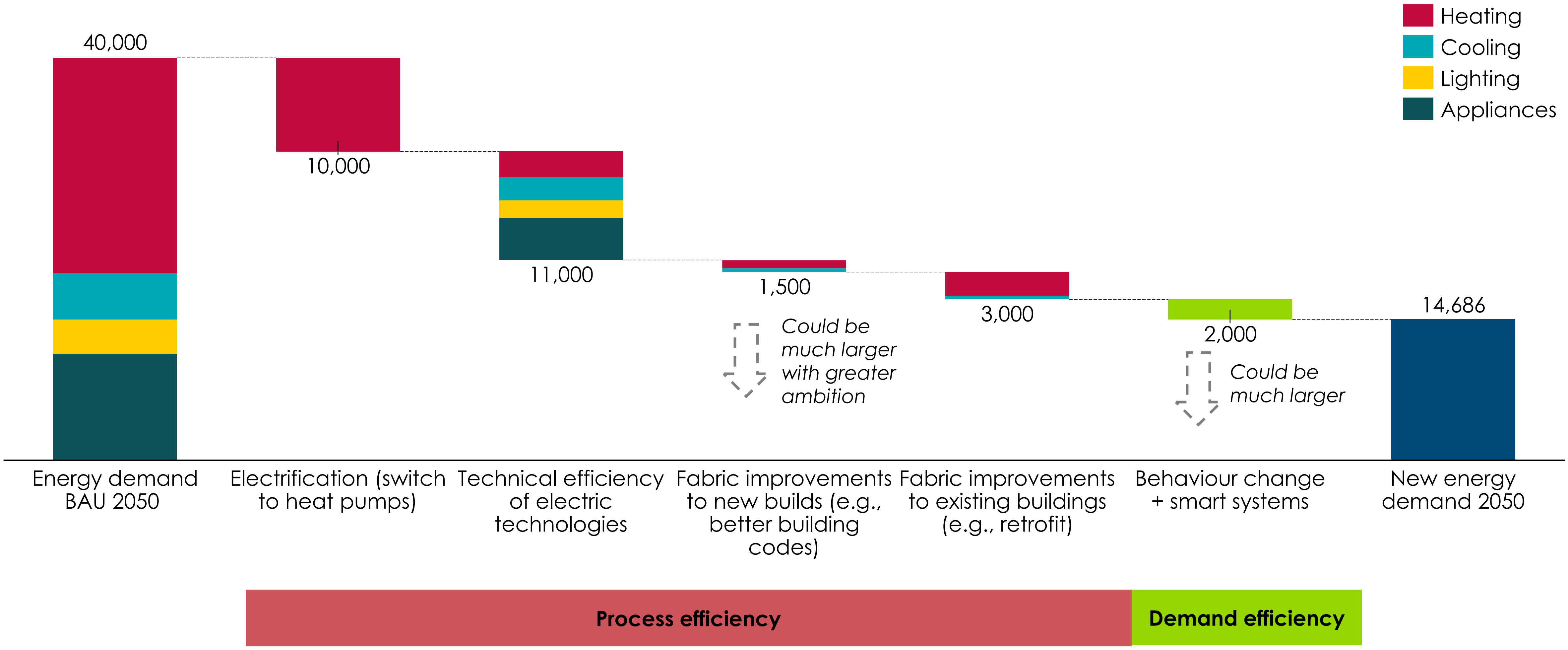


Sources: Systemiq analysis for the ETC (2024); IEA (2023), World Energy Outlook 2023; IEA (2021), *Net Zero by 2050.*
Note: building cooking energy excluded from analysis. For primary energy conversion, 83% efficiency is assumed for renewables power (e.g., electricity conversion and transmission losses), and 85% for fossil fuels to boilers.

Bringing it altogether: energy productivity levers could reduce energy consumption by 60%

Final energy demand in 2050 and impact of efficiency levers – residential + commercial
TWh

PRELIMINARY ANALYSIS



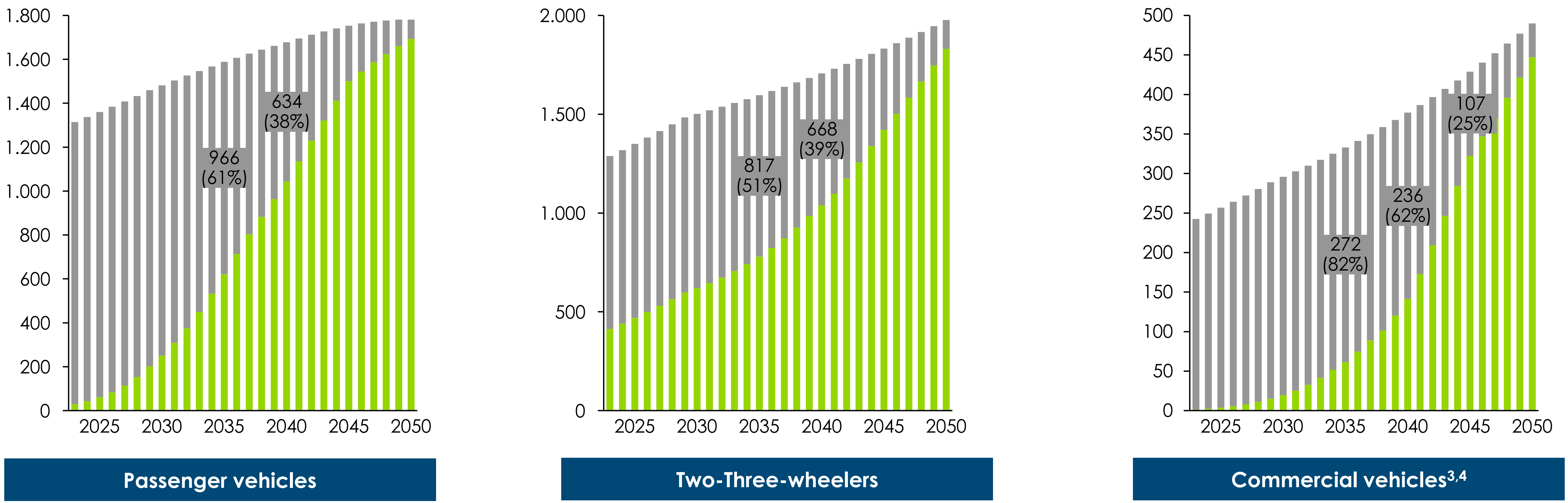
Sources: Systemiq analysis for the ETC (2024); IEA (2023), World Energy Outlook 2023; IEA (2021), *Net Zero by 2050.*
Note: building cooking energy excluded from analysis.

Road transport

Widespread electrification of both passenger and commercial vehicles is expected by 2050, but ICE vehicles are expected to persist on roads

Stock of vehicles in the ACF[1] scenario,
Millions of vehicles

Fossil fuels in Transition report: Accelerated by clearly feasible scenario



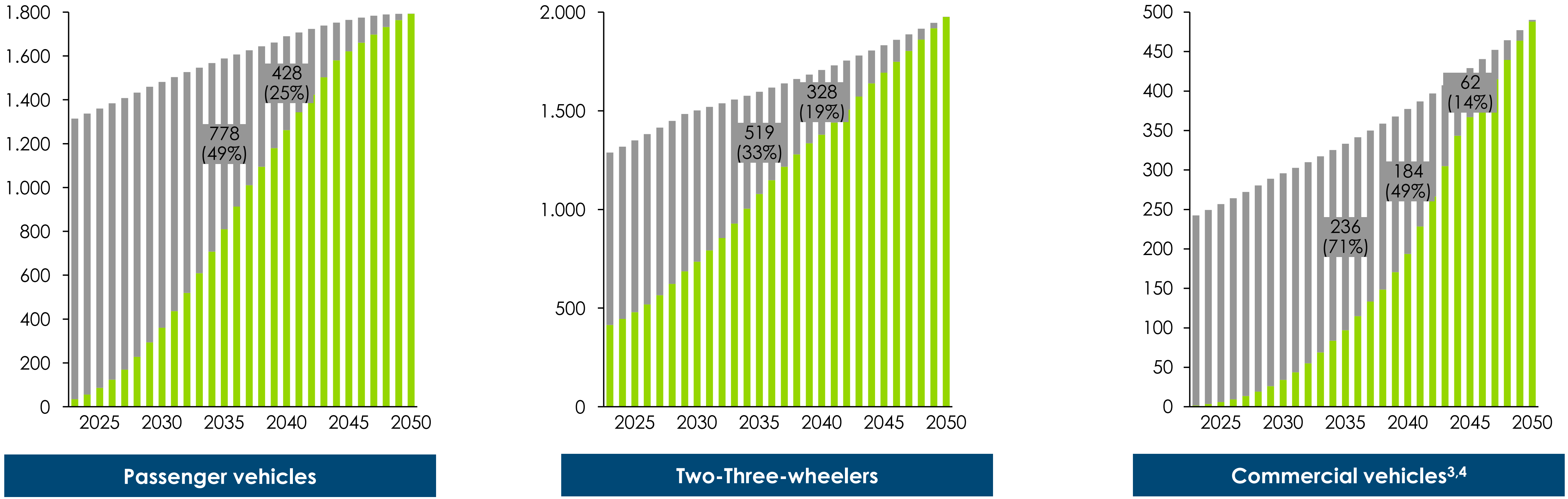
Note: 1. Accelerated but Clearly Feasible; 2. Zero-emission vehicles; 3. Commercial vehicles include light, medium and heavy commercial vehicles; 4. Commercial vehicles include both Battery Electric Vehicles and Fuel-cell Electric Vehicles
Sources: Systemiq analysis for the ETC; ETC (2023), *Fossil Fuels in Transition: Committing to the phase-down of all fossil fuels*

A more aggressive uptake of EVs could see 75% of BEVs on the roads by 2040, but still some ICE stock through the 2030's and 40's

Pre-read

Stock of vehicles in the PBS[1] scenario,
Millions of vehicles

Fossil fuels in Transition report: Possible but stretching scenario

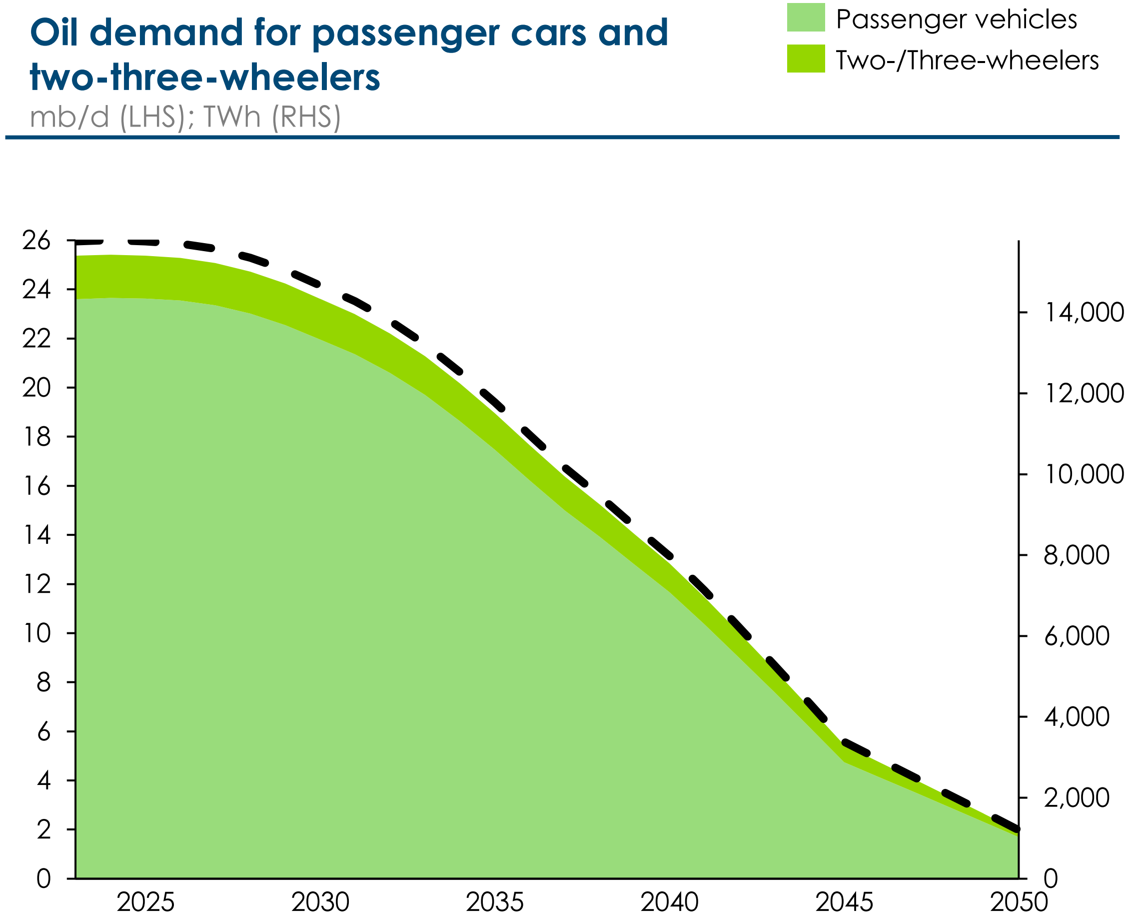


Note: 1. Possible but Stretched; 2. Zero-emission vehicles; 3. Commercial vehicles include light, medium and heavy commercial vehicles; 4. Commercial vehicles include both Battery Electric Vehicles and Fuel-cell Electric Vehicles
Sources: Systemiq analysis for the ETC; ETC (2023), *Fossil Fuels in Transition: Committing to the phase-down of all fossil fuels*

Widespread light-duty vehicle electrification will cause a dramatic reduction in oil demand

Oil demand for passenger cars and two-three-wheelers

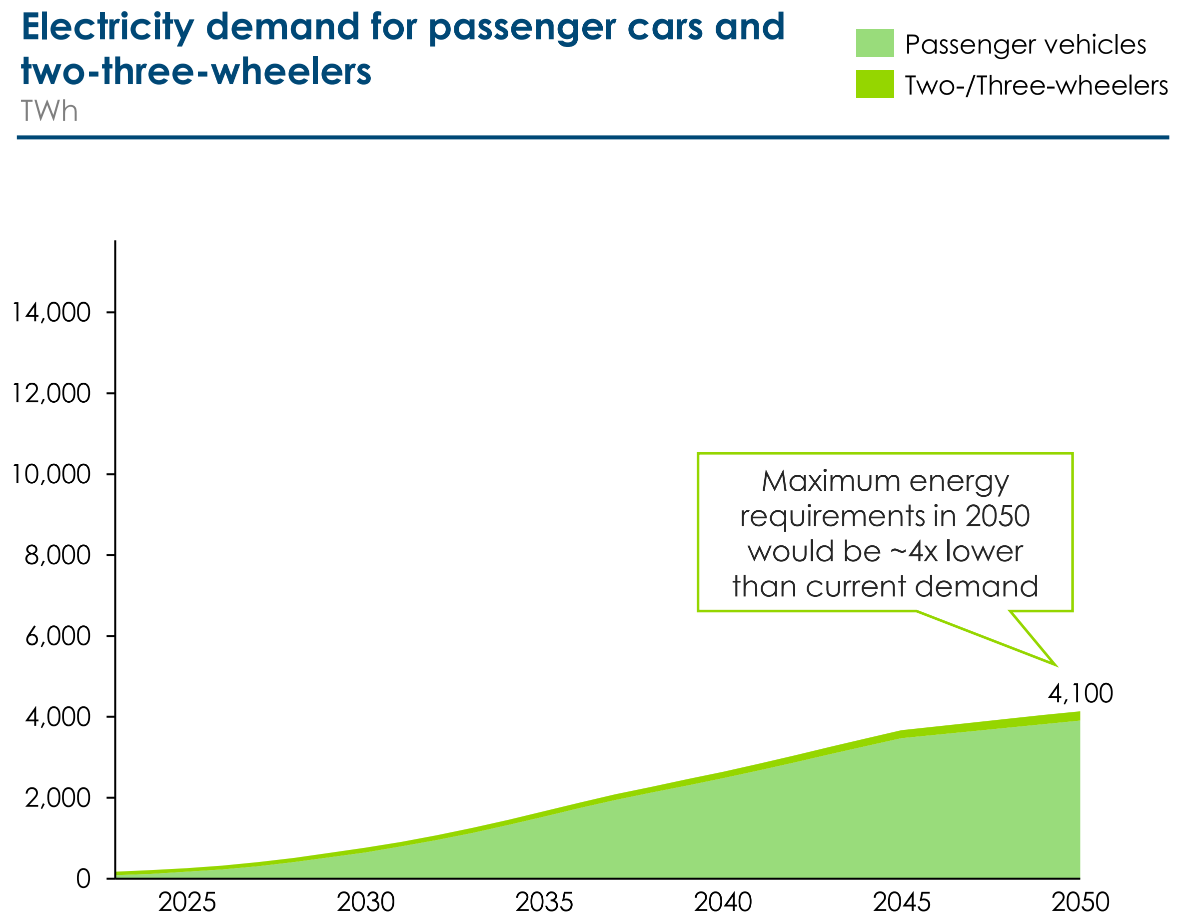
mb/d (LHS); TWh (RHS)



ACF, -0.7% efficiency gains

Electricity demand for passenger cars and two-three-wheelers

TWh



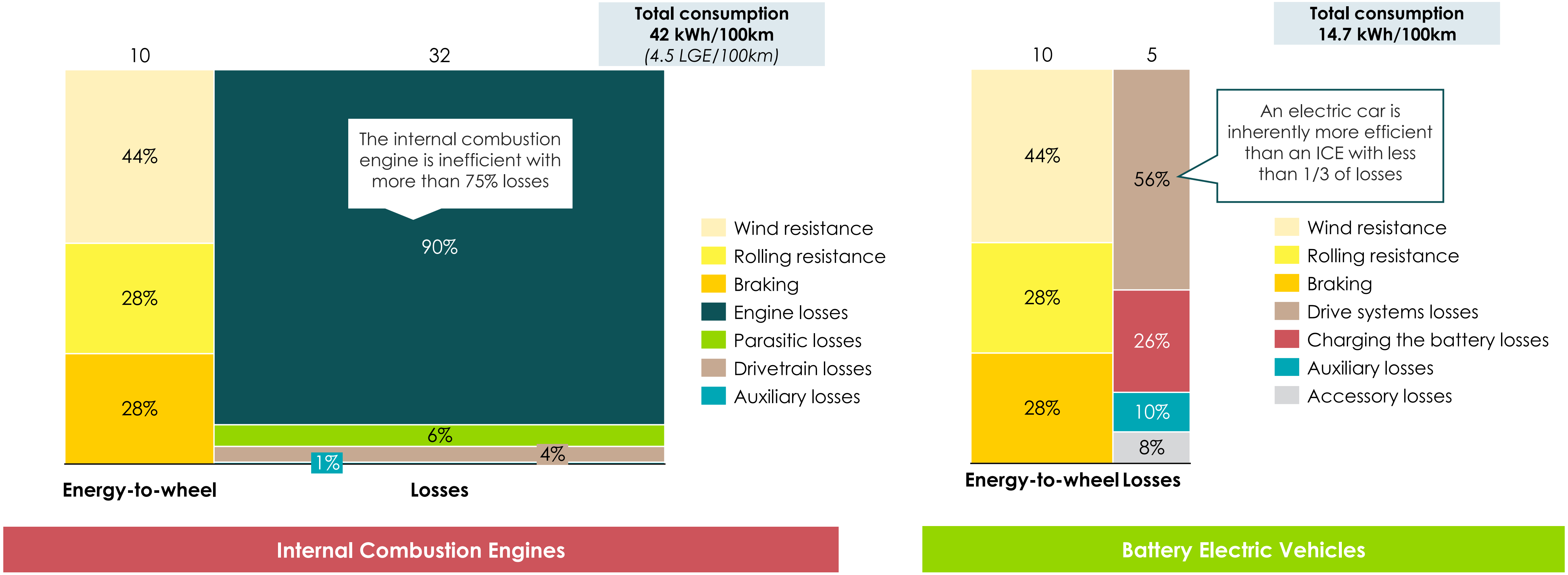
ACF, -1.6% efficiency gains

Note: Other vehicles, such as those used in construction or mining are not included. Aggregate oil demand figures exclude biofuels consumption for road transportation. We consider that the combustion of a barrel of oil equivalent results in 310 kg CO_2. This number doesn't include scope 1 and 2 emissions, otherwise the combustion would lead to ~405 kg CO_2. We assume efficiency gains of 0.7% p.a. for ICEV and 1.6% p.a. for BEV.
Source: Systemiq analysis for the ETC; BNEF (2023), *Electric Vehicle Outlook*, MPP (2022), *Making Zero-Emissions Trucking Possible;* IEA (2023), *Emissions from Oil and Gas Operations in Net Zero Transitions*

Today, when comparing equivalent models, Battery Electric Vehicles (BEVs) exhibit a threefold increase in efficiency compared to ICE vehicles

Comparison of Hyundai Kona and electric Hyundai Kona 2024 energy efficiency

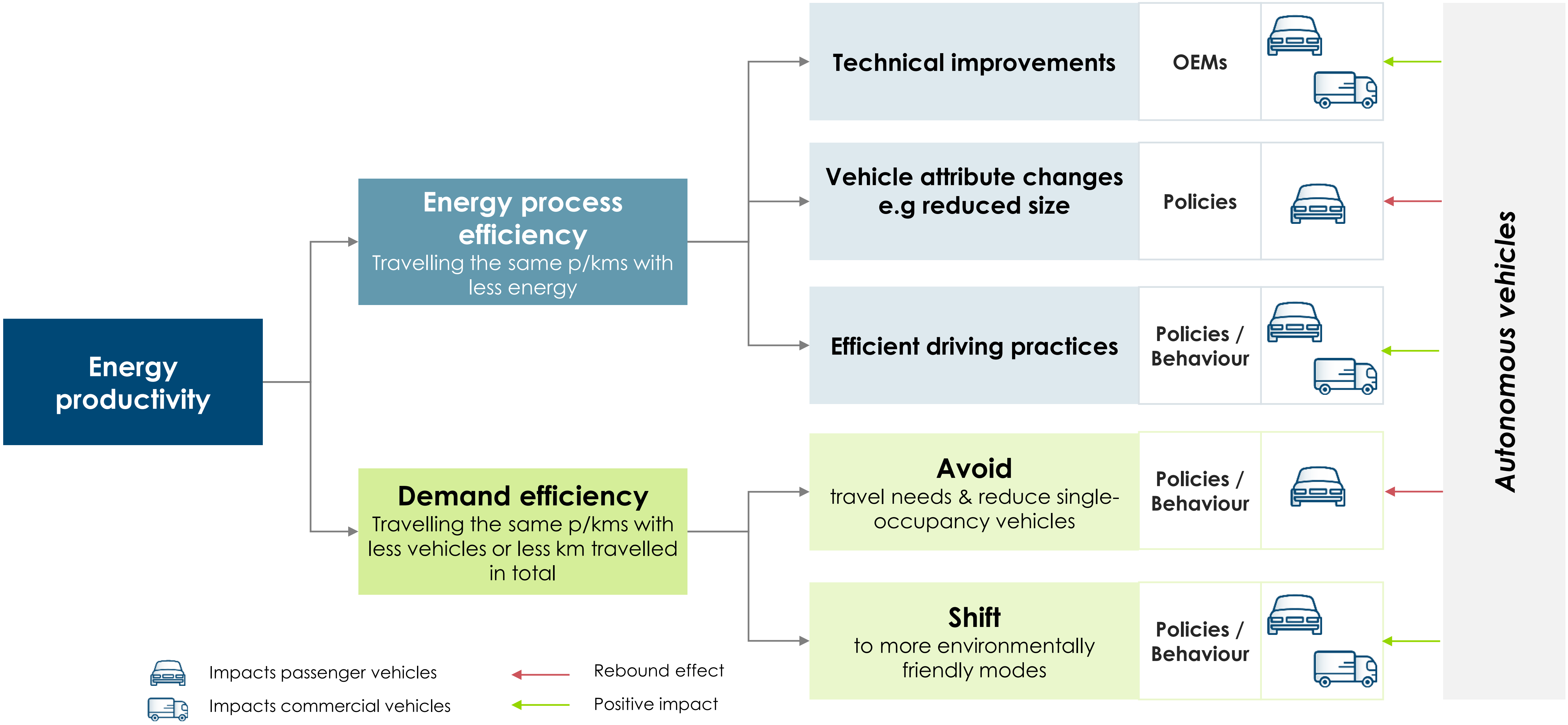
kWh/100km and %



Note: We do not consider regenerative braking and potential energy reduction for EVs. We take a consumption of 14.7 kWh/100km for the Hyundai Kona Electric 2024 and 4.5 Lge/100km for the Hyundai Kona 2024. There are 9.3 kWh per Lge (Liter of gasoline equivalent). Energy use and losses vary from vehicle to vehicle. These estimates are provided to illustrate the general differences in energy flow in different vehicle types during different drive cycles.

Sources: Systemiq analysis for the ETC; US Department of Energy; GFEI (2023), *Trends in the global vehicle fleet 2023*

Road transport productivity report will explore levers beyond electrification



Note: OEM stands for Original equipment manufacturer
Source: Systemiq analysis for the ETC.

Combining various strategies could double Battery Electric Vehicle and Internal Combustion Engine efficiencies between 2024 and 2050

PRE-READ

Category	BEV Lever	ICE lever	Estimated BEV efficiency potential (%)	Estimated BEV efficiency potential (%)
Drive unit improvements	In-wheel motors integrate the electric motor into the wheel hub, enhancing overall efficiency by up to 20% and requiring less space by eliminating the need for a conventional drivetrain	Hybrid powertrains recover a portion of braking losses and improve overall driveline efficiency.	-20%	-20%
Tire rolling resistance	Reducing tire rolling resistance through use of specially designed tires (e.g., Bridgestone)		-18%	
Lightweight technologies	Energy density of Lithium-Ion Batteries will increase by a further 60–80% by around 2035.		-20%	-5%
	Selective use of lightweight materials to replace heavy steel, reduce glider weight by more than 20%.			
Other improvements	Reduce aerodynamic drag coefficient from 0.28 to 0.17 through closer attention to styling, wheel wells, and vehicle rear geometry		-8%	
	Smarter packaging, reducing width by setting front as well as rear wheels completely flush with the sides		-6%	
	Better charging cables, thicker cables, better thermal management systems in car		-5%	
Auxiliaries (excluded in WLTP[1])	More efficient accessories: A/C, seat heating, optimal in-car energy consumption. Auxiliaries can currently increase electric consumption by up to 50%		-(15-25)%	
Total potential improvement			-50% (-2.5% p.a.)	-50% (-2.5% p.a.)

Upper range, the pace of technical innovation for ICEs is likely to slow as a plateau has recently been reached.

Note: WLTP: Worldwide harmonized Light vehicles Test Procedures. There is a growing divergence between real-world and WLTP CO_2 emissions data for internal combustion engine cars and hybrid cars. On-board fuel and energy consumption monitoring (OBFCM) devices should be used, especially for BEVs.

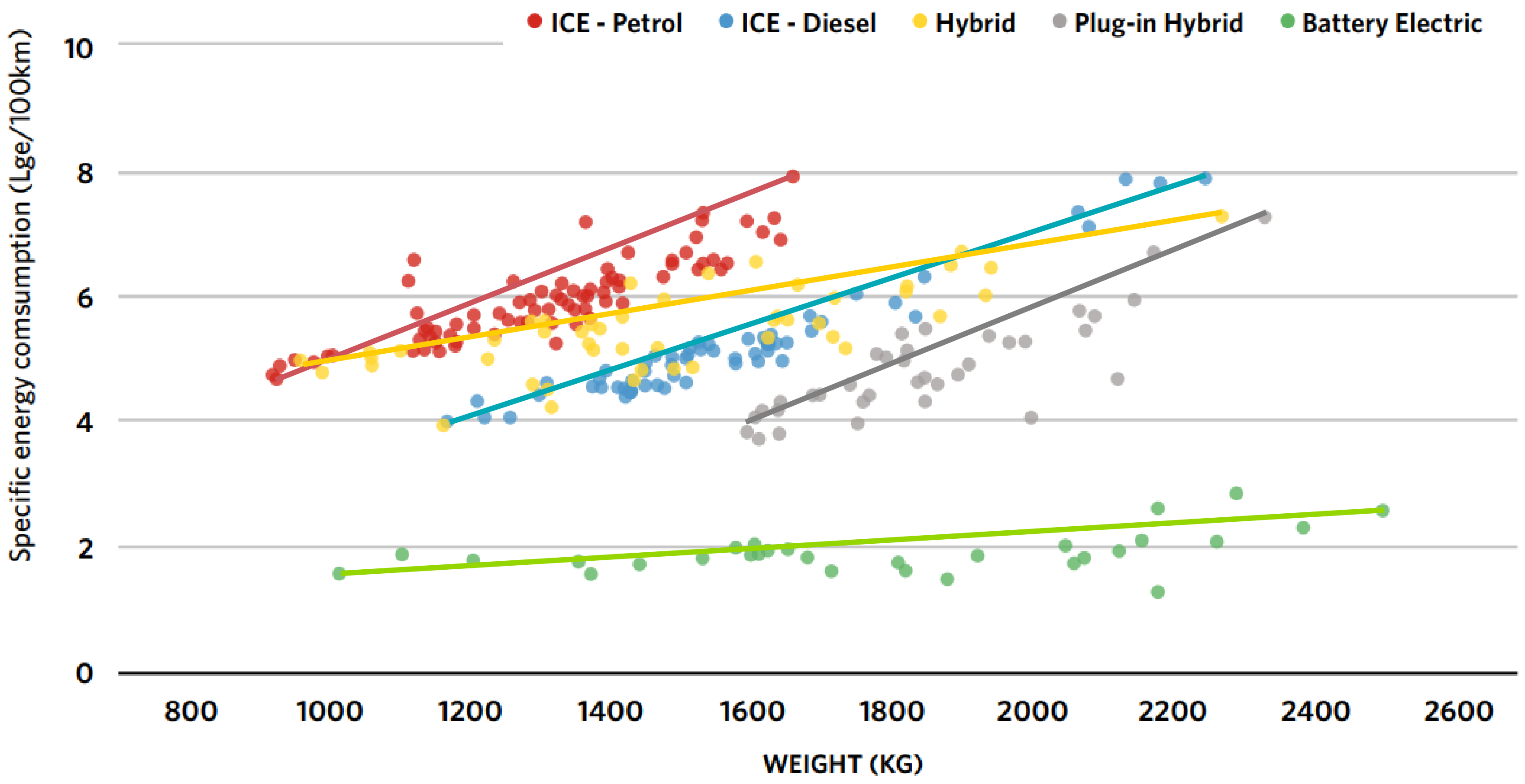
Sources: Systemiq analysis for the ETC from EPRI (2024), *Valuing Improvements in Electric Vehicle Efficiency;* Fraunhofer (2023), Alternative Battery Technologies Roadmap 2030+; Deepdrive (2023); The ICCT (2023), *Real-world performance of battery electric passenger cars in China;* Global Fuel Economy Initiative (2023), *Trends in the global vehicle fleet 2023;* ICCT (2023), *Vision 2050 Strategies to align global road transport well below 2°C*

The heavier the car, the more it consumes, especially for ICEs that are inherently less efficient and lack the energy recovery capabilities of EVs

PRE-READ

Specific energy consumption plotted against vehicle mass, by powertrain for top selling light-duty vehicles in Europe

Lge/100km



In the U.S., a standard **ICE-SUV** weighs 800 kg more and **uses 45% more fuel than a medium car**, while for **EVs, the increase is 33% for the same weight difference**. Reasons are:

1. **BEVs are inherently more efficient**, bigger vehicles therefore lose less energy
2. **Regenerative braking benefits larger BEVs**, offsetting some energy losses in heavier BEVs compared to heavier ICEs.

Notes: ICE-SUV means internal combustion SUV. Specific energy consumption for PHEV was calculated using a utility factor derived from the all-electric range reported in the EEA database using a function reflective of real-world usage (Fraunhofer ISI, 2021), specific energy consumption of elecitricty for driving phased in all-electric mode and specific fuel consumption for other driving phases.

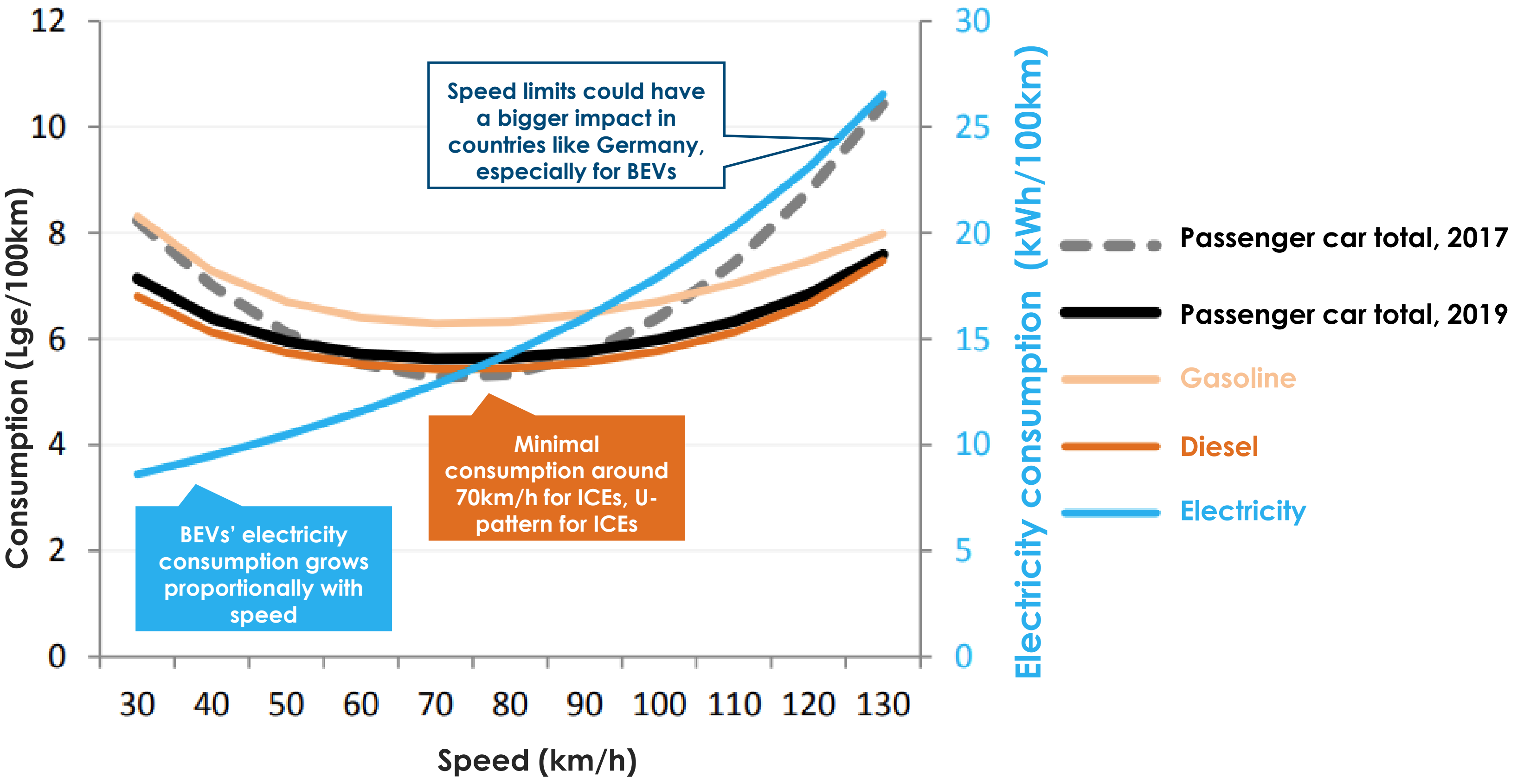
Source: Systemiq analysis for the ETC; Global Fuel Economy Initiative (2023), *Trends in the global vehicle fleet 2023*; IEA (2023), *Energy Efficiency 2023*

Speed greatly impacts efficiency: High speeds degrade ICE performance, while EV energy use increases proportionally with speed

PRE-READ

Relationship between speed and energy consumption for passenger vehicles

Km/h, Lge/100km, kWh/100km



- **ICEs**: The direct impact of reducing the speed on the highway from **130 to 110 km/h corresponds to a fuel saving of 17%** per kilometer driven.
- **BEVs**: the reduction in energy **consumption from 130 to 110 km/h is 24%** for electric cars, even more than for the current fleet of thermal vehicles

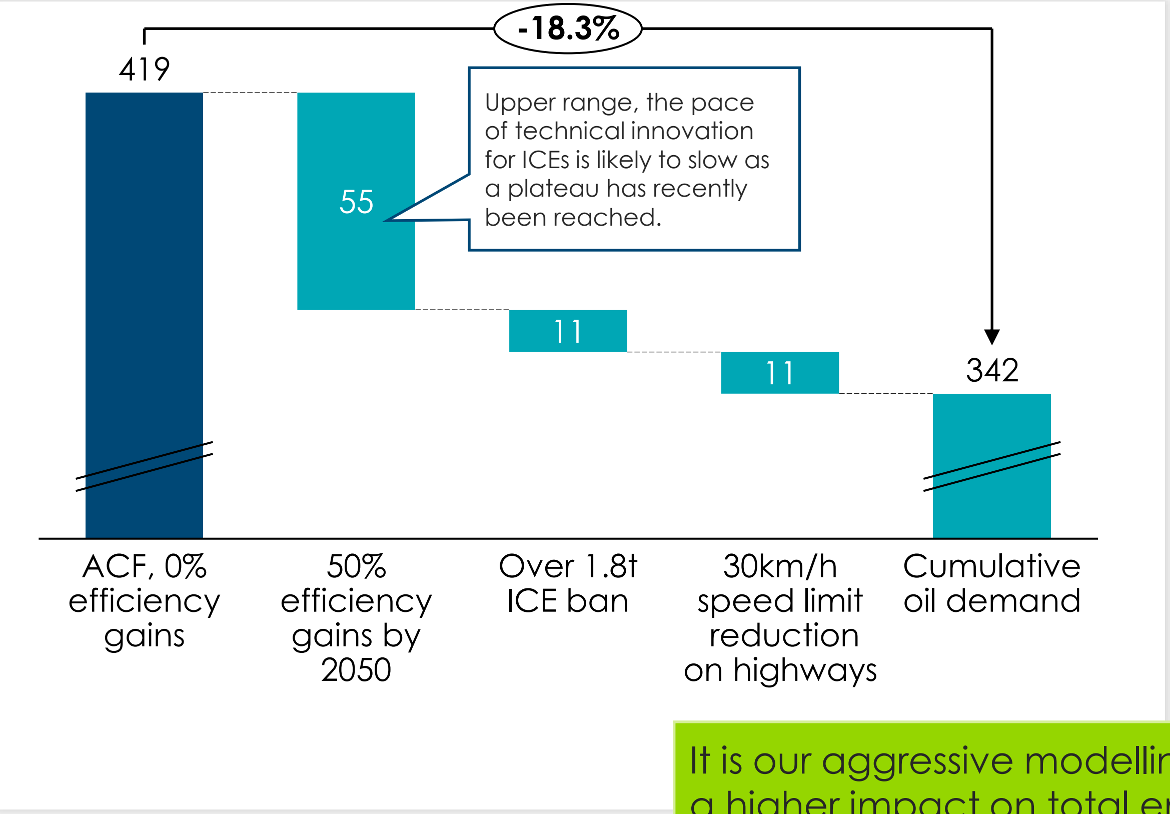
Notes: Lge: liter of gasoline equivalent

Source: Systemiq analysis for the ETC; Aurelien Bigo (2020), *Vitesse des déplacements : accélération au 20ème siècle, ralentissement au 21ème ?*; BonPote (2022), *10 reasons to lower speed limits on highways*

Efficiency measures in energy processes could cut cumulative oil consumption by 20% and electricity consumption by nearly 50% by 2050

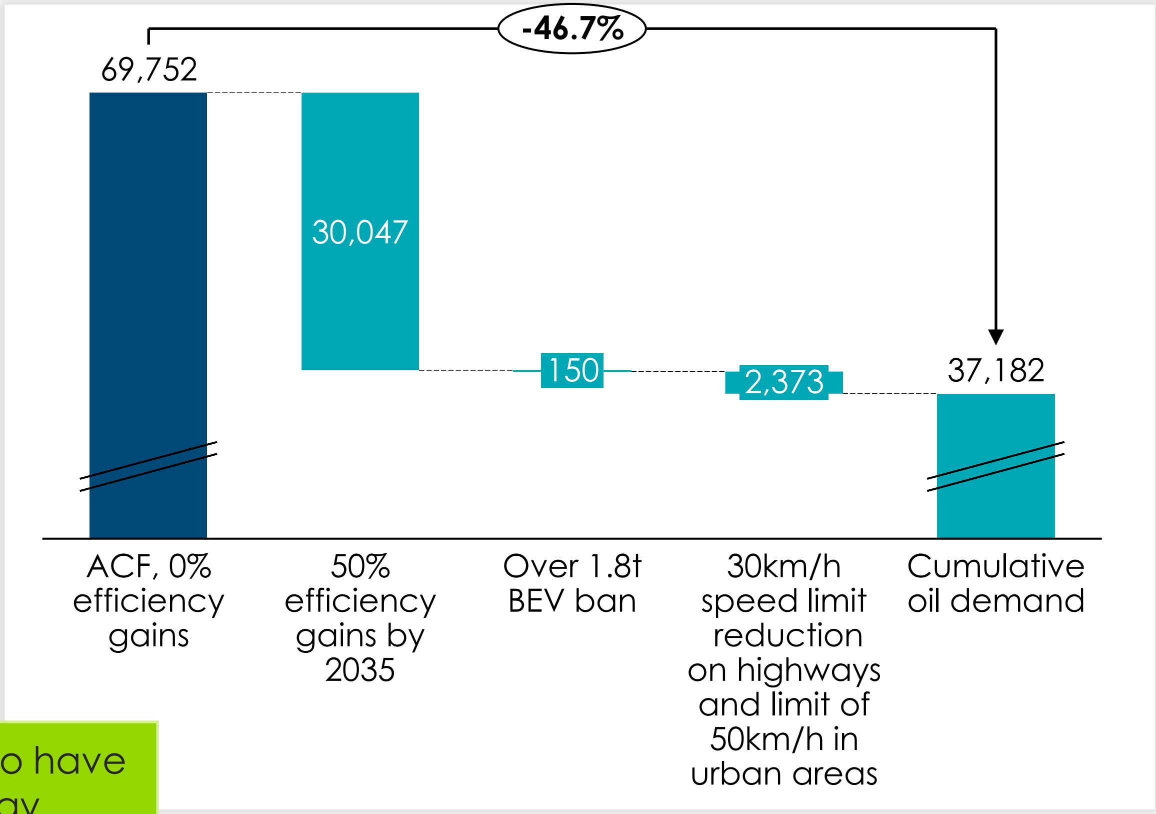
Impact on cumulative oil demand of various scenarios for passenger ICE

Mb/d



Impact on cumulative electricity demand under various scenarios for passenger BEV

TWh



ACF

It is our aggressive modelling to have a higher impact on total energy consumption

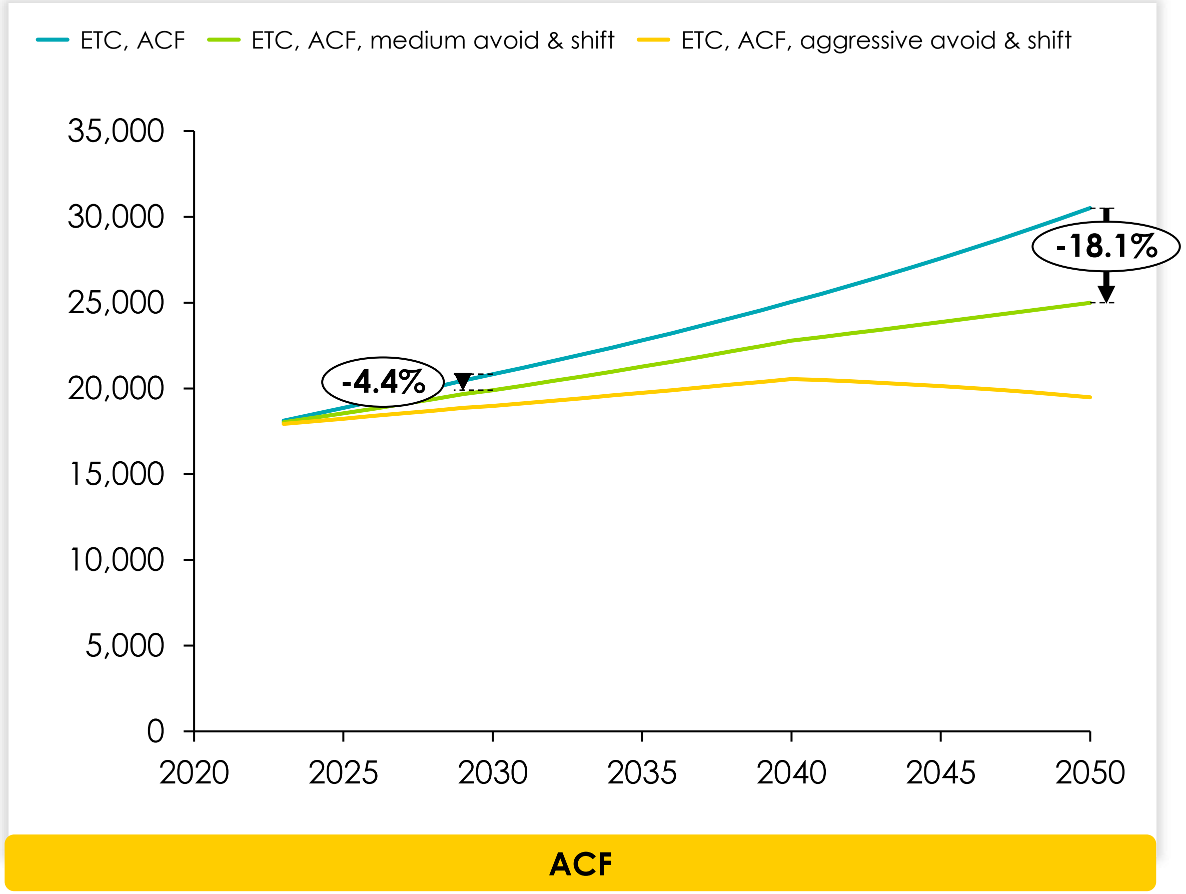
ACF

Note: Other vehicles, such as those used in construction or mining are not included. Ban of ICEs over 1.8t is expected to reduce oil consumption by 3%, and electricity consumption by 0.4% for BEVs.

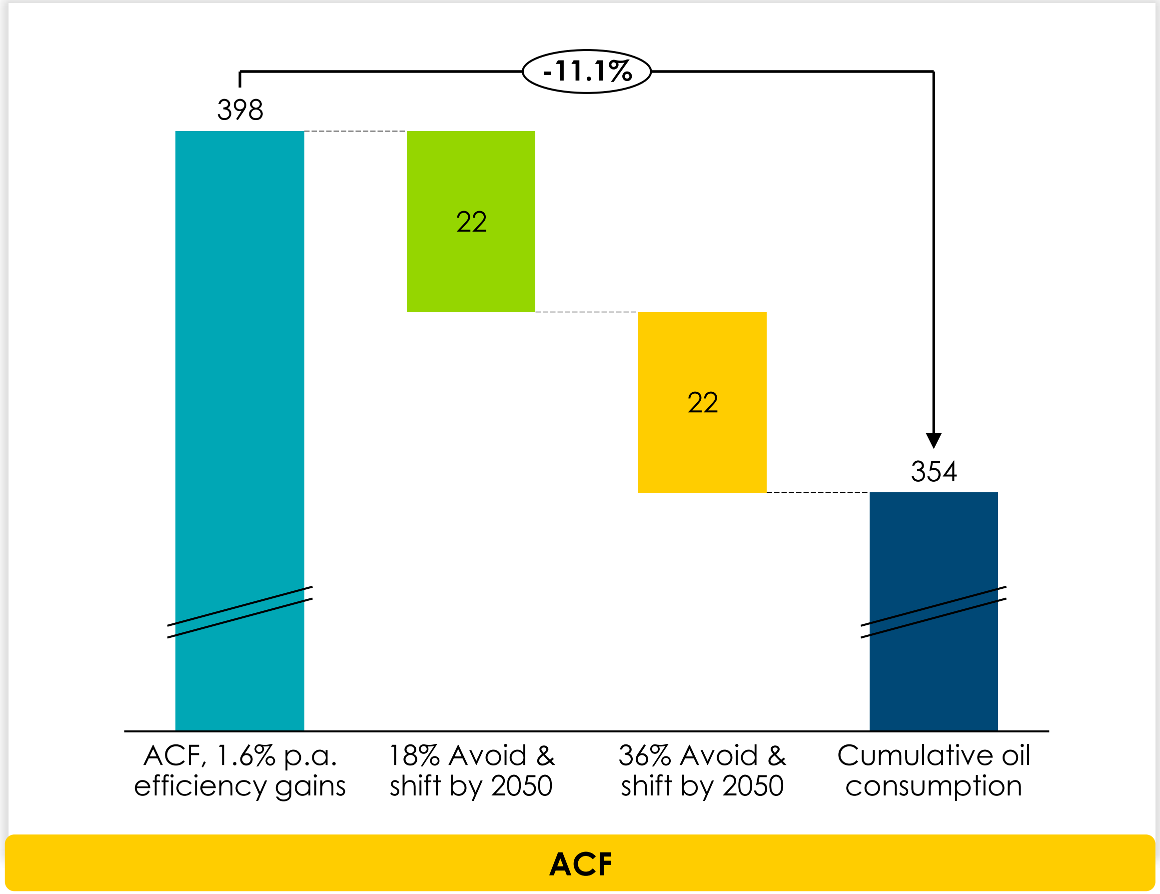
Source: Systemiq analysis for the ETC; BNEF (2023), *Electric Vehicle Outlook*, IEA (2023), *Emissions from Oil and Gas Operations in Net Zero Transitions;* IEA (2024), *Global EV Outlook 2024*

Ambitious avoid and shift measures would only reduce cumulative oil demand by about 10% by 2050

Demand for passenger vehicle transport in various scenarios, 2023-2050
Billions kilometers travelled



Cumulative oil demand vehicle transport in various scenarios, 2023-2050
Mb/d

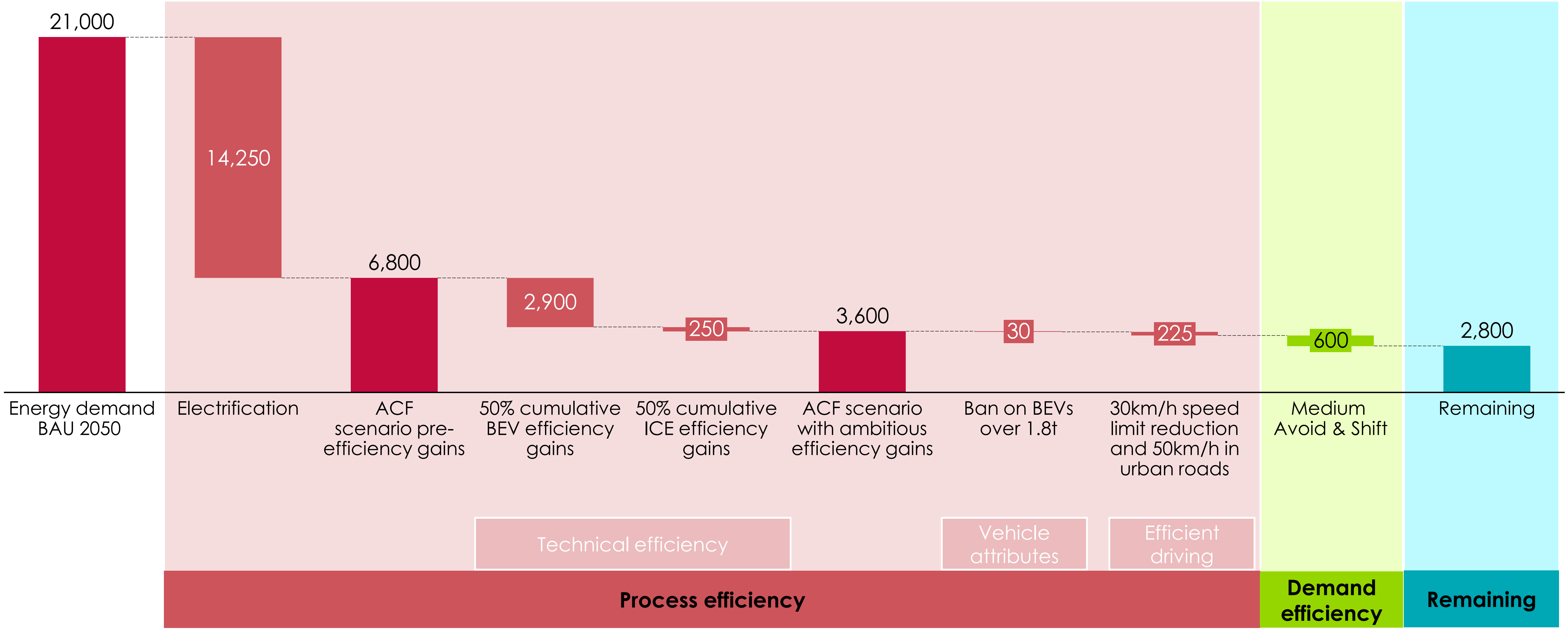


Notes: Efficiency gains of 0.7% p.a. are assumed in this ACF scenario.
Sources: Systemiq analysis for the ETC; IEA (2023), *World Energy Outlook 2023;* ICCT (2023), *Vision 2050 Strategies to align global road transport well below 2°C;* ETC (2023), *Fossil Fuels in Transition: Committing to the phase-down of all fossil fuels*

Switching to electrification is the most crucial factor in reducing energy consumption for passenger vehicle transport by 2050

Final energy demand in 2050 and impact of efficiency levers in the ACF scenario
TWh

PRELIMINARY ANALYSIS

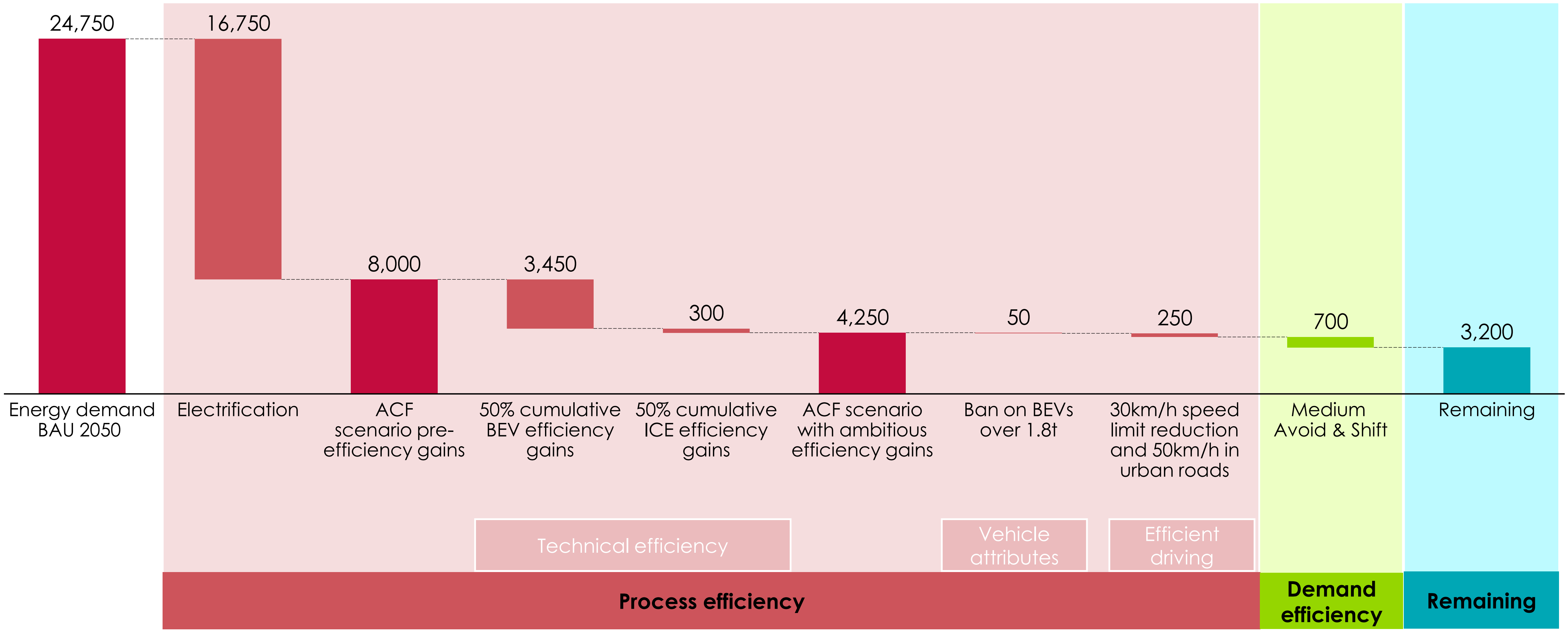


Notes: 1 TWh = 0.0036 EJ. 6% fuel consumption reduction through speed limit reductions, 0.5% reduction in vehicle sizes. In Avoid & Shift, it is assumed that the reduction in demand benefits BEV, leads to a total demand reduction of 18% by 2050, which is proportionally allocated between BEVs and ICEs.
Sources: Systemiq analysis for the ETC.

Switching to electrification is the most crucial factor in reducing energy consumption for passenger vehicle transport by 2050

Primary energy demand in 2050 and impact of efficiency levers in the ACF scenario
TWh

PRELIMINARY ANALYSIS

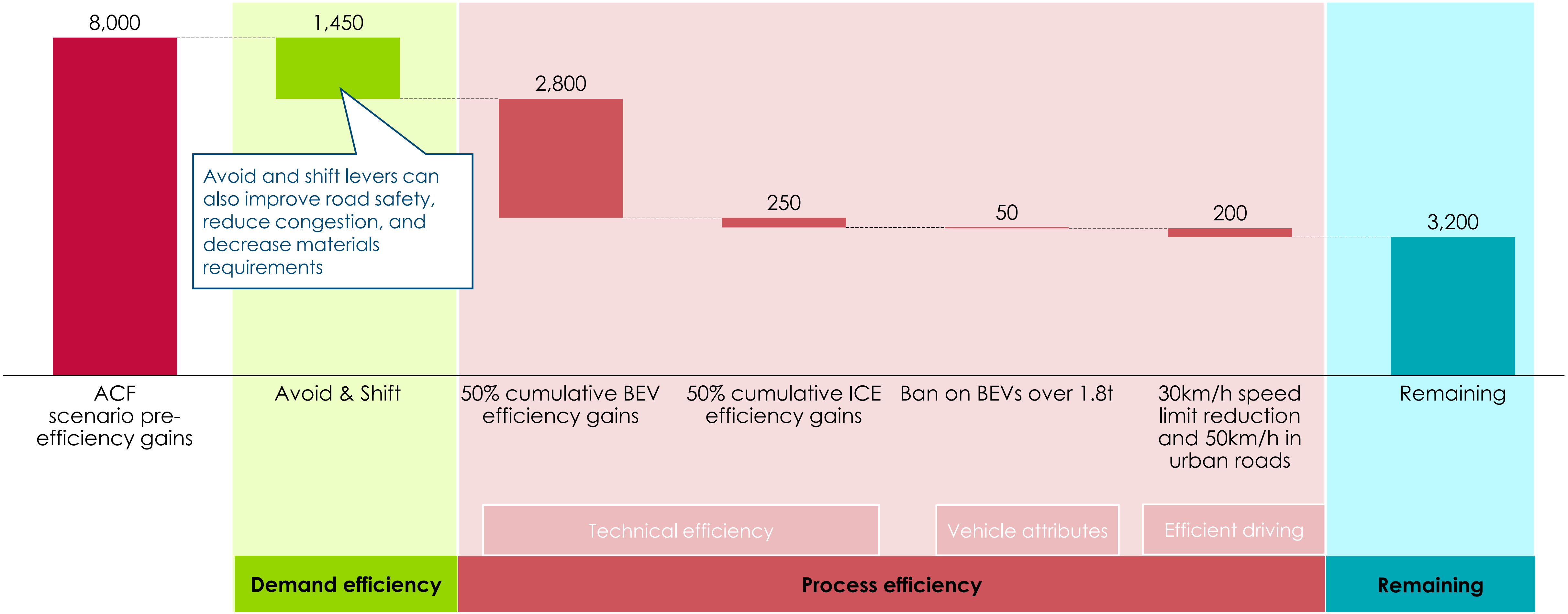


Notes: 1 TWh = 0.0036 EJ. 6% fuel consumption reduction through speed limit reductions, 0.5% reduction in vehicle sizes. In Avoid & Shift, it is assumed that the reduction in demand benefits BEV, leads to a total demand reduction of 18% by 2050, which is proportionally allocated between BEVs and ICEs. For Primary Energy demand, energy efficiency of 85% from fossil fuel extraction to tanker, and 85% for renewables power (e.g., electricity conversion and transmission losses), assuming the energy mix is completely renewable in 2050
Sources: Systemiq analysis for the ETC.

The proportional importance of each lever varies based on their order - Avoid & Shift can replace 1,200 TWh in this context instead of 600 TWh

Primary energy demand in 2050 and impact of efficiency levers in the ACF scenario
Twh

PRELIMINARY ANALYSIS



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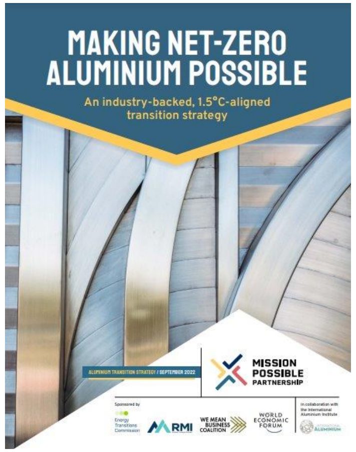
Sources: Systemiq analysis for the ETC.

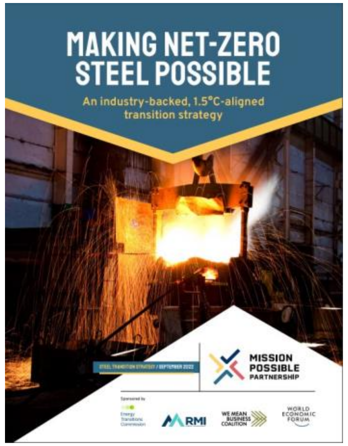
Heavy industry and heavy transport

MPP/Systemiq has developed a sector transiton strategy for all 7 hard to abate (HTA) sectors

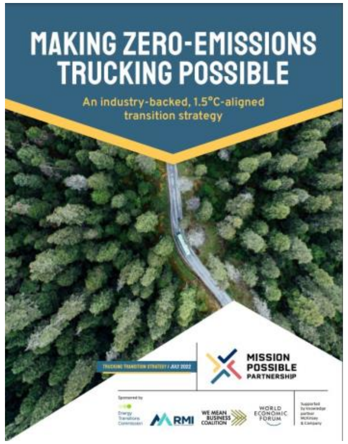
Aluminum



Steel

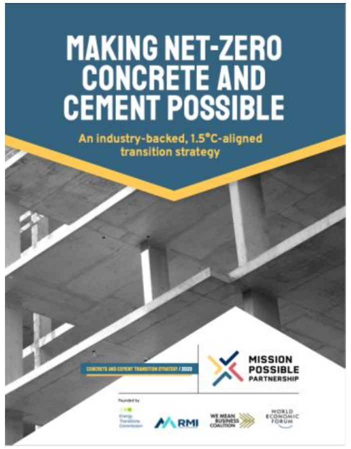


Trucking

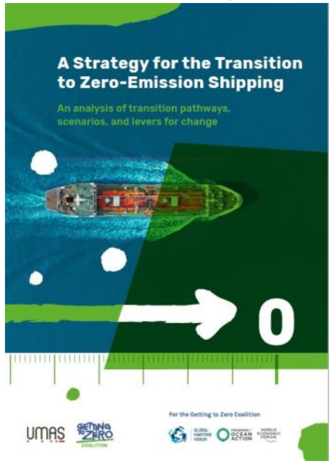


Aviation

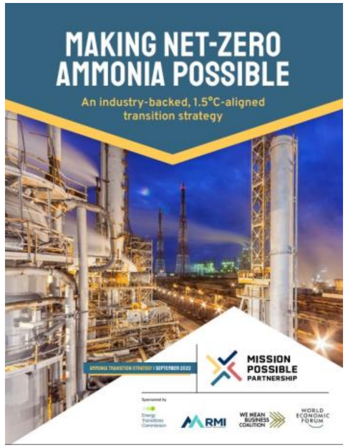
Concrete/Cement



Shipping

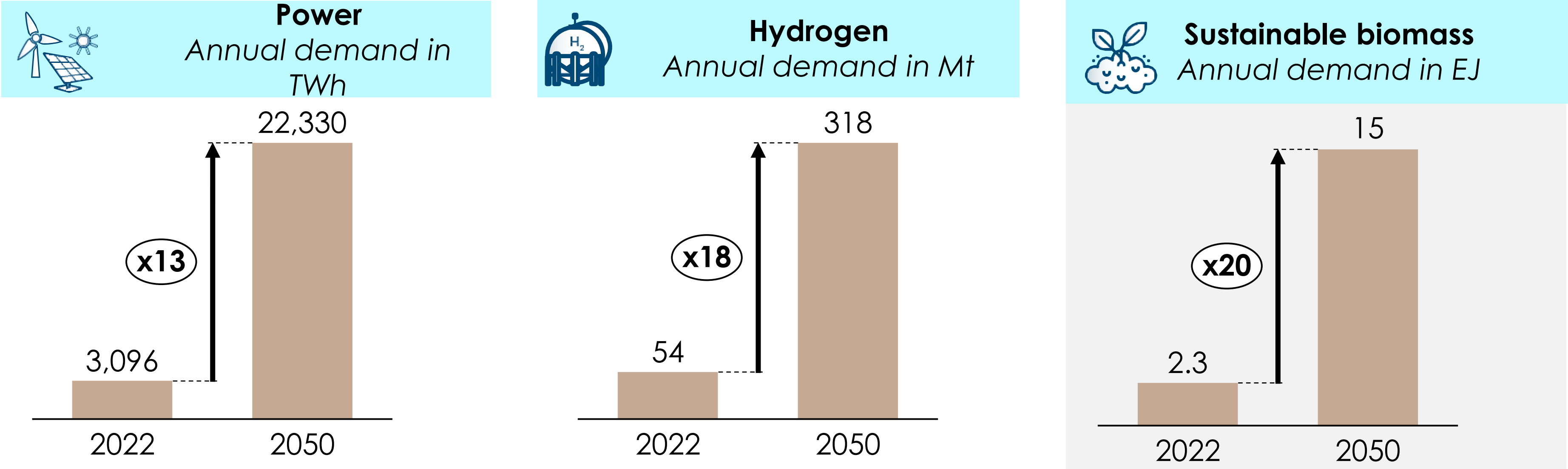


Chemicals

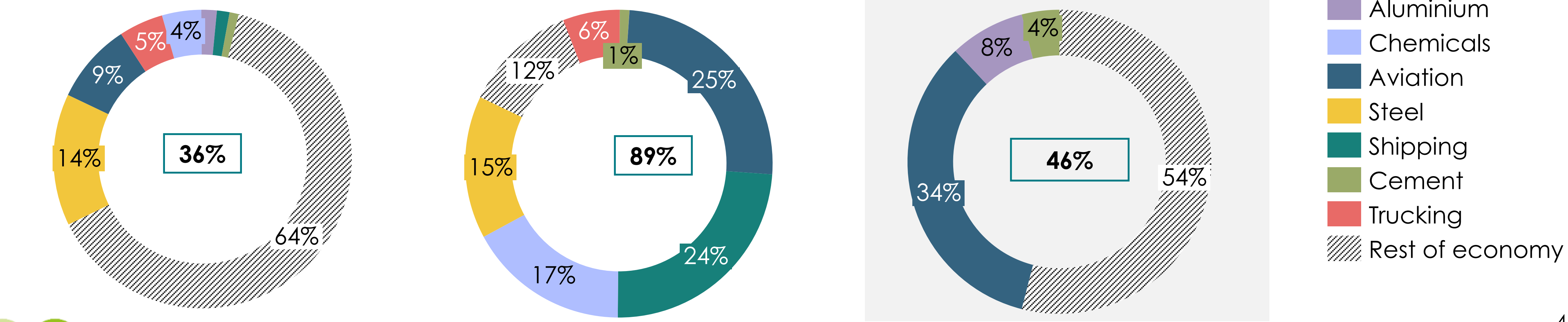


Our HTA sectoral analysis shows that decarbonization will drastically increase demand for renewable energy by 2050

Annual demand from Hard to Abate Sectors 2050



Share of Hard to Abate Sector demand compared to global demand by 2050



Notes: Annual demand from HTA sectors only, with global total based on ETC ACF scenario. Sustainable biomass is a limited resource that needs to be allocated to its most important use-cases, where there is most emissions savings vs. available alternative solutions. The decision was made that no transitional biomass use is considered within the simplistic model describing the shipping transition (exclusively green and blue ammonia, e-methanol). 'Upper boundary' indicates the potentially additional demand from the chemicals and aviation sectors in different decarbonisation scenarios, which rely different assumptions on the 1.5˚C-aligned trajectories. Power numbers includes H2 production. Sources: MPP analysis; Systemiq (2022), Planet Positive Chemicals; Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping (2021), Industry Transition Strategy

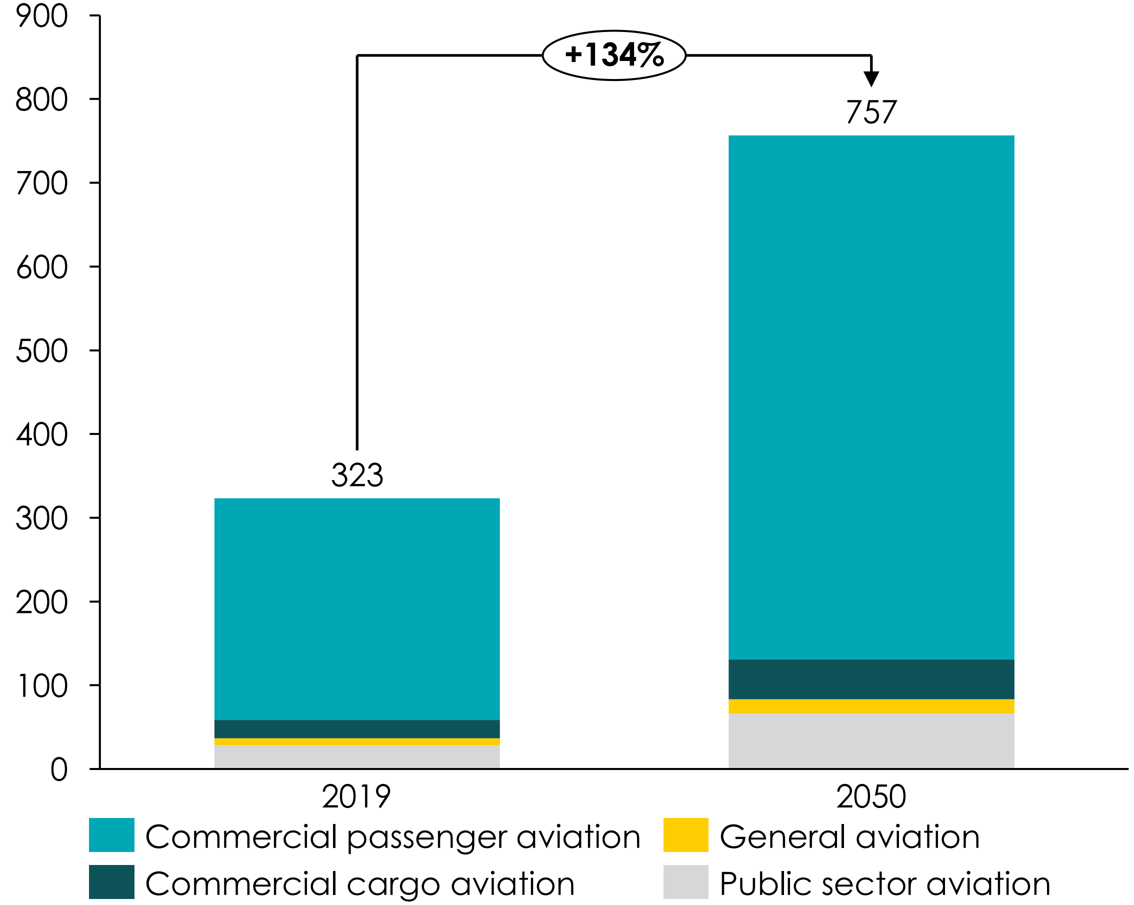
Aviation

Jet fuel demand is expected to grow with an average CAGR of 2.5 % made up primarily by demand in the commercial sector

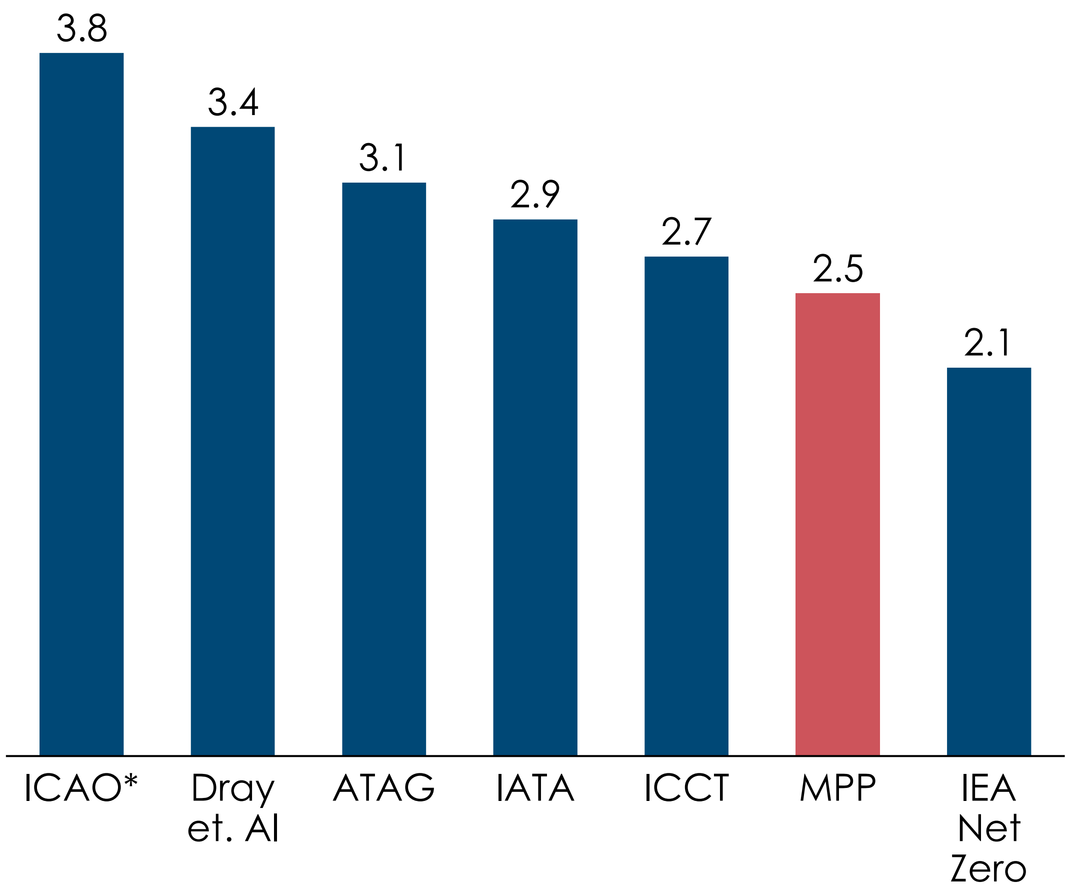
Pre-read

Aviation – demand

MPP Jet fuel equivalent demand (before efficiency levers) by region (BAU) 2019 and 2050, Mt



Assumed CAGR demand growth for commercial passenger aviation across different studies, CAGR (2019-2050)



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

There are 3 main efficiency levers to reduce energy demand in the aviation sector

TOTAL renewable energy demand

$$= \text{Passenger km} \times \frac{\text{Airplane km}}{\text{Passenger km}} \times \frac{\text{Energy}}{\text{Airplane km}}$$

1. Demand reduction

Can we reduce the demand of passenger km?

2. Product efficiency gains

Can we increase the utilization of the airplane?

3. Material efficiency gains

Not relevant: no recycling of fuel possible, negligible recycling of other inputs

4. Process efficiency gains

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

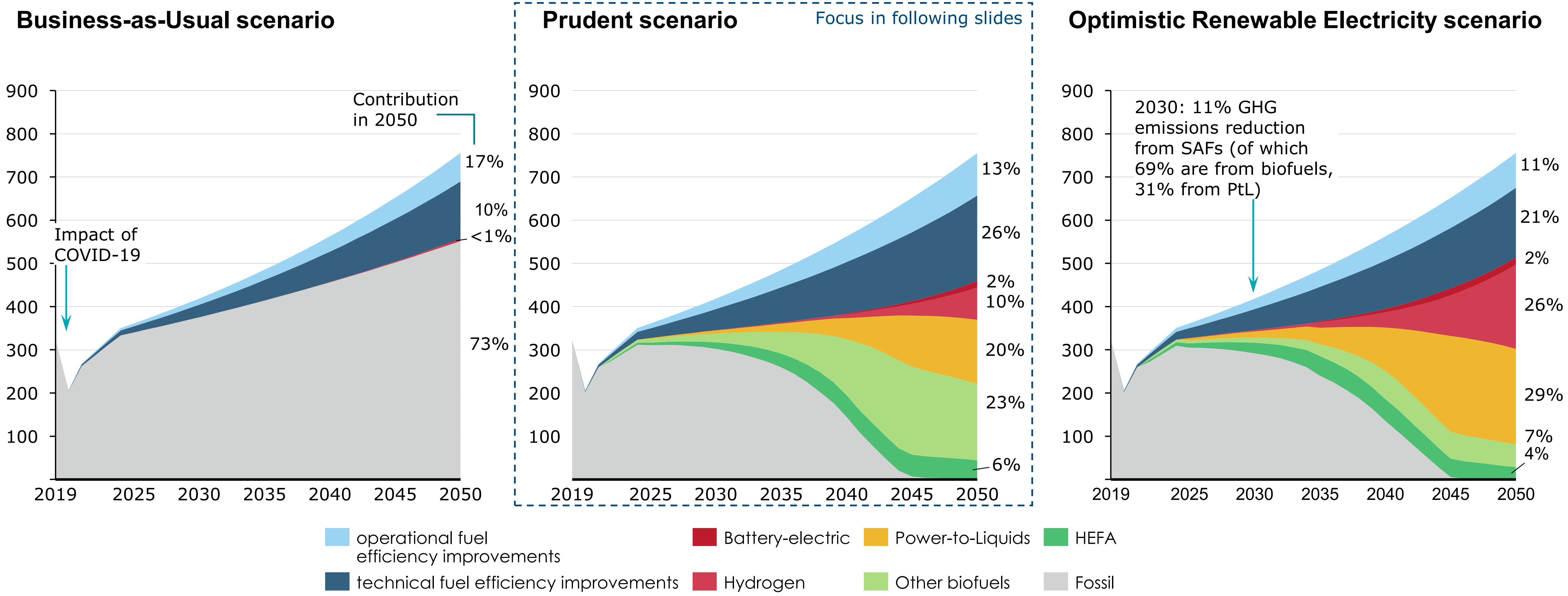
Source: MPP schematic

Global aviation requires a significant change in fuel mix and efficiency levers to achieve decarbonization

Aviation – STS

Aviation decarbonization scenarios

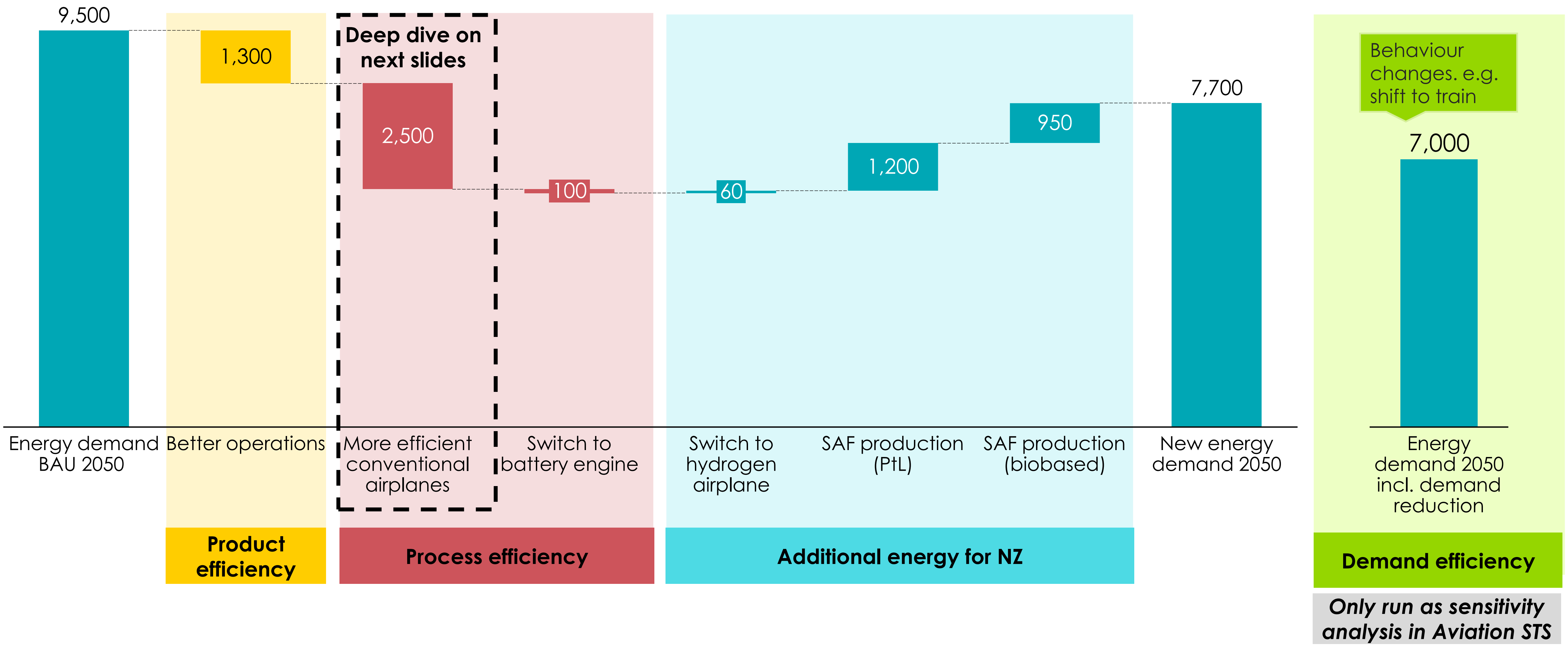
Jet fuel equivalent Mt



Note: Sums may not total 100 due to rounding. Optimistic renewable energy scenario: higher demand of electricity and hydrogen due to PtL domination/ Prudent scenario: biofuel dominated, sufficient supply of sustainable biomass is key challenge. Source: Mission Possible Partnership (2022) Aviation Sector Transition Strategy

Making conventional airplanes more efficient is single most important lever

Primary energy demand in 2050 and impact of efficiency levers
TWh

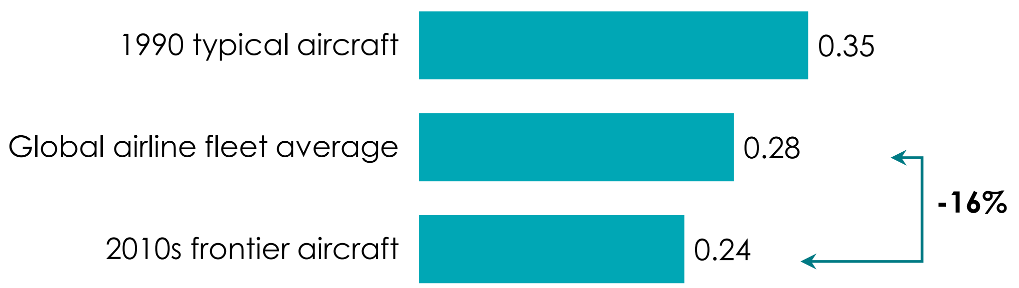


Source: Schäfer, A. (2019). "Technological, economic and environmental prospects of all-electric aircraft". *Nature Energy*. **4** (2): 160–166., MPP analysis

Up to 20 % more efficient technologies in new airplanes leading to regular efficiency improvements

Aviation – Process efficiency

Fuel efficiency for widebody aircraft, kg fuel use/RPK



Fuel efficiency for narrowbody aircraft, kg fuel use /RPK

- **Replacing with most efficient aircrafts currently in service:** 16 – 21 % improvement without introducing any new technology (average airplane lifetime: 20-30 years)
- Frontier aircrafts are optimizied for
  - **Lower weight**
  - **Better aerodynamics** (e.g. blended winglets)
  - **More efficient engines** (e.g. higher bypass ratio, electric taxing)
- And **further innovation** in these areas are being explored to increase efficiency further

Note: g CO_2/RPK is advantageous for widebody aircraft given their operational focus on transporting passengers on long distances.

Source: ICCT, *CO_2 Emissions from Commercial Aviation: 2013, 2018, and 2019*, October 2020

Increasing energy process efficiency is the largest lever enabled by SAF price premium and R&D investments

Efficiency lever	Efficiency lever description
Energy process efficiency	• Engine efficiency improvements • Improvements in aerodynamics • Lightweighting of airplane
Product efficiency	• Optimized approach / departure procedures • Improved congestion management
Demand efficiency	• Modal shifts from regional flights to high-speed trains • Behavior shift from business travels to increase video conferencing

Efficiency enablers

1. **Policy incentives to support R&D efforts:** R&D efforts needed from OEMS and engine/parts suppliers
2. **Certainty about switch from fossil fuel to SAFs** through policies (e.g. blending mandates, carbon pricing) as future fuel price increase main driver for efficiency improvements.
3. **Alternative to short-haul flights:** Investment into high-speed railway system to incentivize shift from airplane to train

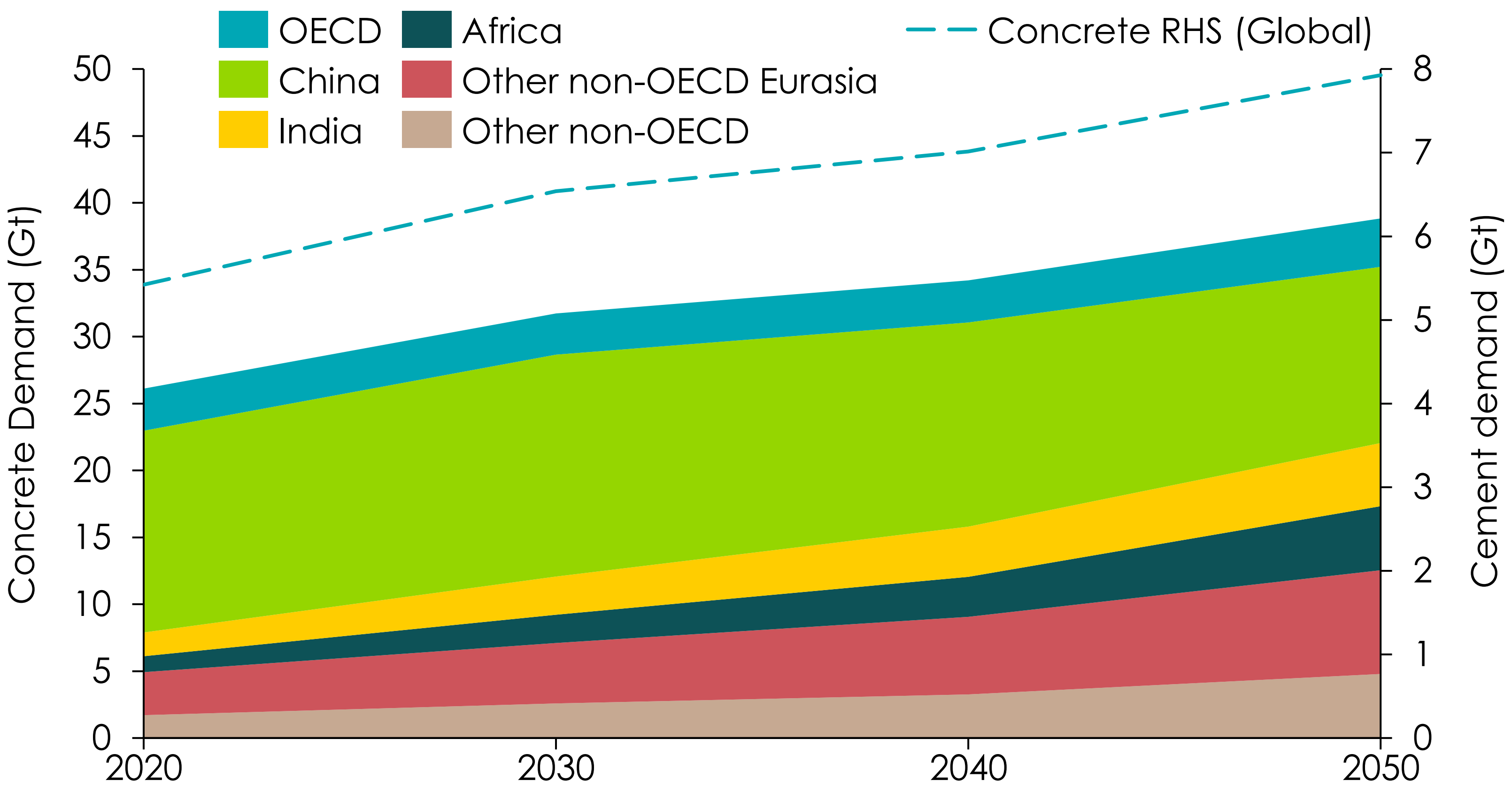
Concrete

Housing and infrastructure growth in emerging economies drive demand in cement and concrete sectors

Pre-read

Cement – demand

Cement and concrete demand, Gt/yr in a no **action scenario**



- China's share of consumption is expected to reduce, as consumption shifts from today's industrialized regions to emerging economies
- Without efficiency gains, demand for cement is projected to increase 40% from 4.2 gigatons in 2020 to 6.2 gigaton in 2050

Source: Demand - GCCA Roadmap for total level cement demand, with estimations of region breakdowns based on Rhodium Group 2024, **End use -** Material Economics Industrial Transformation 2050, Cembureau 2021 Activity Report, WBCSD Low Carbon Technology Roadmap for the Indian Cement Sector: Status Review 2018, Climate Works Decarbonizing Concrete.

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

Cement – efficiency levers

Total renewable energy demand ≈

Living / working space x Building / Space x Concrete use / Building x Cement use / Concrete use x Clinker use / Cement use x Energy input / Clinker use

1. Demand reduction

How can we reduce the demand for living and working space?

2. Product efficiency gains

How can we use concrete more efficiently?

3. Material efficiency gains

How can we use less clinker in cement and concrete?

4. Process efficiency gains

How can we reduce the required heat energy for clinker production?

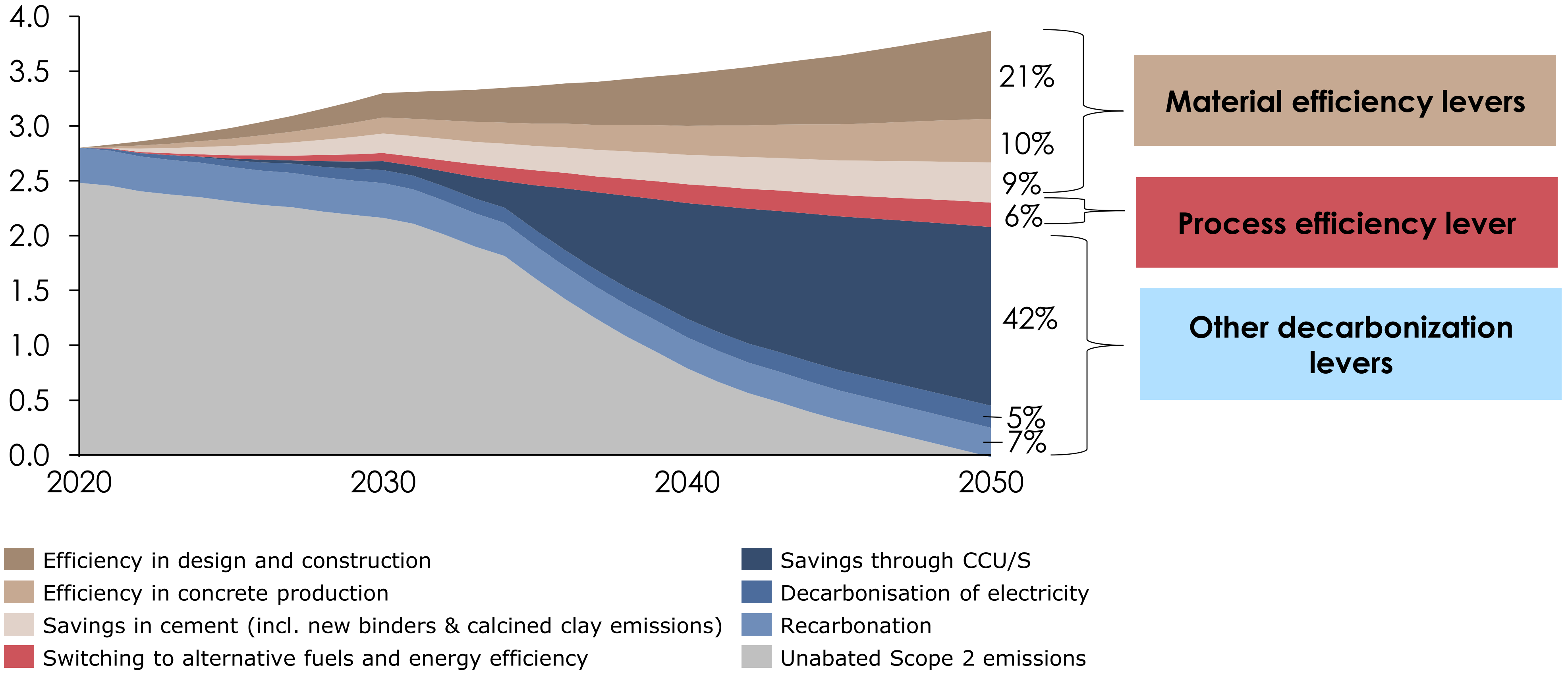
Main efficiency levers

Efficiency and CCUS key levers in decarbonization of the cement sector

Cement – STS

Annual GHG emissions in a decarbonization pathway[1]

Gt CO_2

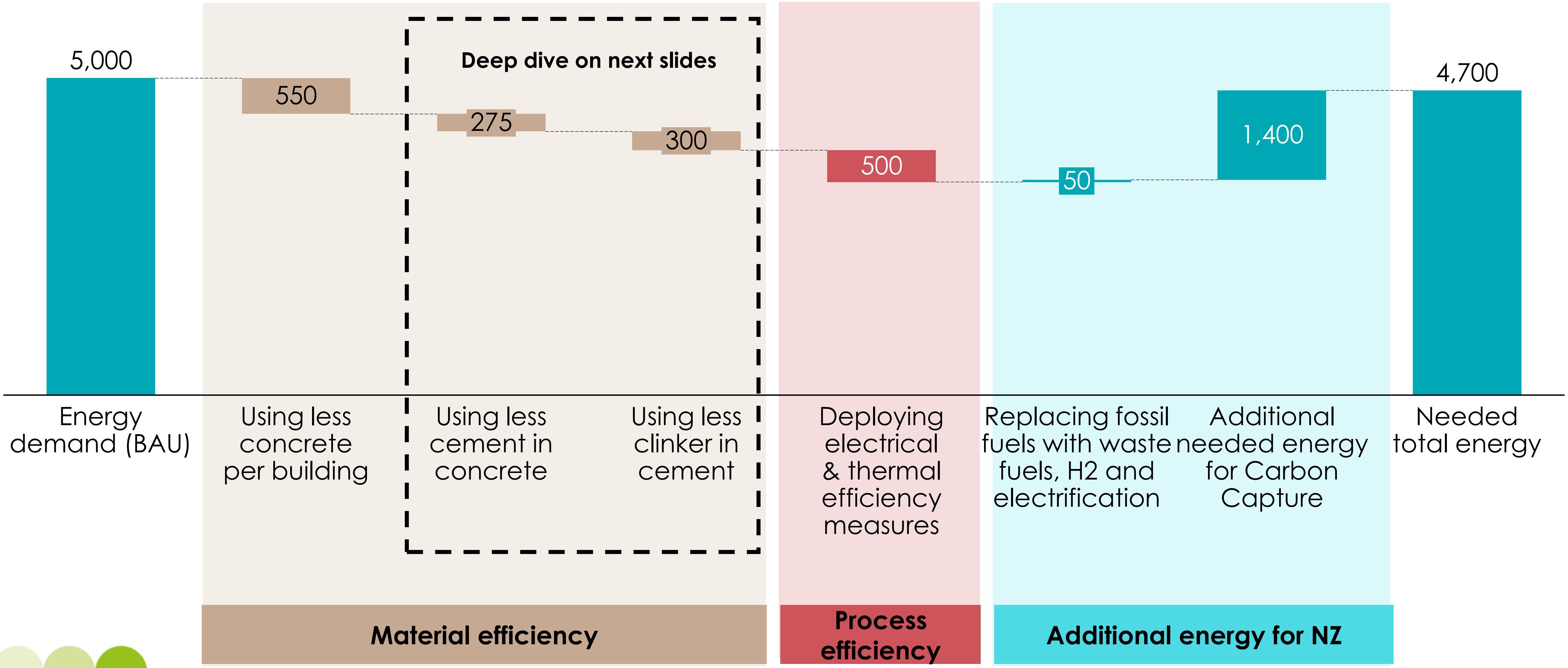


Notes: Includes scope 1 and 2 emissions. Scope 3 upstream would add approximately 3.8 Gt CO_2e of cumulative emissions from 2022 to 2050. "Savings and binders" include switching to new binders. Decarbonisation of electricity involves electricity demand for kilns, grinders and carbon capture.

Source: MPP Analysis (2022)

Material efficiency most important lever to reduce energy demand for concrete

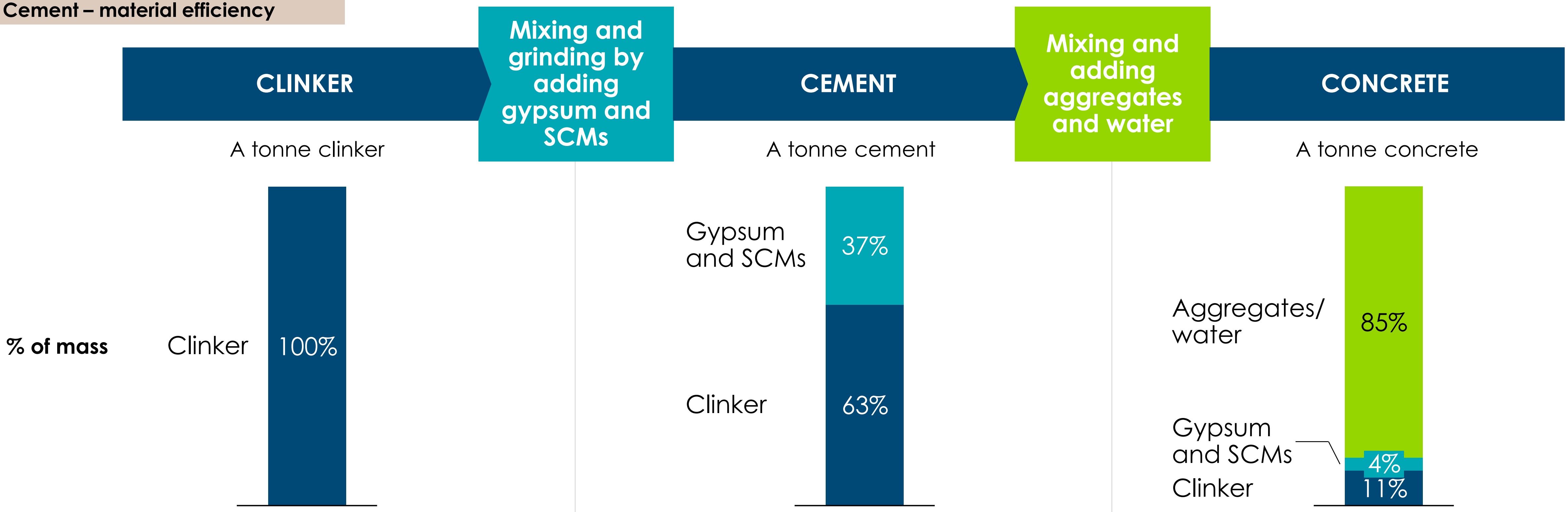
Primary energy demand BAU vs NZE efficiency levers 2050
TWh



Source: Based on MPP Sector Transition Strategy

Clinker content can be reduced by replacing clinker with supplementary materials and better mixing of concrete

Cement – material efficiency



Key efficiency lever

Using less clinker in cement by partially replacing clinker with SCMs
Clinker content can be reduced to 52% but performance based concrete standards are needed.

Using less cement in concrete through more efficient mixing of cement and industrialization.

SCM = Supplementary Cementious Materials (e.g. Fly ash and ground granulated blast-furnace slag, ground limestone, natural pozzolans, calcinated clay, recycled concrete, biomass ashes and silica fumes)
Source: MPP Concrete STS

Reducing clinker content per building and required energy for clinker production critical to minimize renewable energy input for concrete

Efficiency lever	Efficiency lever description
Material Efficiency	• Using less concrete per building via **better design** • Using less clinker in cement by partially **replacing clinker with SCMs** • Using less cement in concrete through a **more efficient mixing of cement**
Energy process efficiency	• **Replacing wet klin** with dry klin technology • Deploying **waste heat recovery** • Switching to more **efficient grinding**

Efficiency enablers
1. Setting **mandatory emission targets** & **market based mechanisms** to incentivize 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

Where we want to go with this work

The major levers of energy efficiency will be explored across remaining sectors

Initial findings and hypotheses for the potential for energy efficiency levers

Sector	Process efficiency	Material efficiency	Service efficiency
Buildings	High	Negligable	Medium
Road Passenger	High	Negligable	Medium
Aviation	High	Negligable	Medium
Concrete	Medium	High	Negligable
Aluminium	Medium	Medium	High
Chemicals	Medium	High	High
Ammonia	Medium	Negligable	High
Steel	Medium	High	Medium
Shipping	High	Medium	Medium
Road Commercial	High	Negligable	Medium

Still to be fully analysed

Potential to increase energy efficiency

- Negligable
- Medium
- High

Exploration of remaining sectors according to ETC framework needed

1) Exploration of remaining other sectors according to developed energy productivity framework

- Chemicals, Aluminium, Ammonia, Aviation, Steel, Shipping, Road Commercial

2) Exploration cross-cutting actions/policies that could facilitate energy efficiency levers

3) Assumptions on how changing production technologies might change final energy demand while delivering the same energy service

4) How this can practically relate to “increasing the pace of energy efficiency from 2% to 4% per annum”