Energy
Transitions
Commission

Energy productivity in the road transport sector

Key insights

ETC Representatives Meeting

19th September 2024

ETC 2024 work programme

Extending our influence in the global climate debate

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

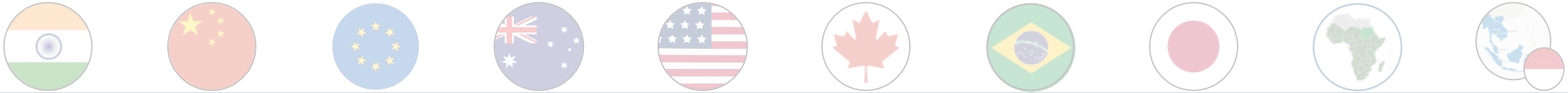
Delivering action through future COPs

- 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



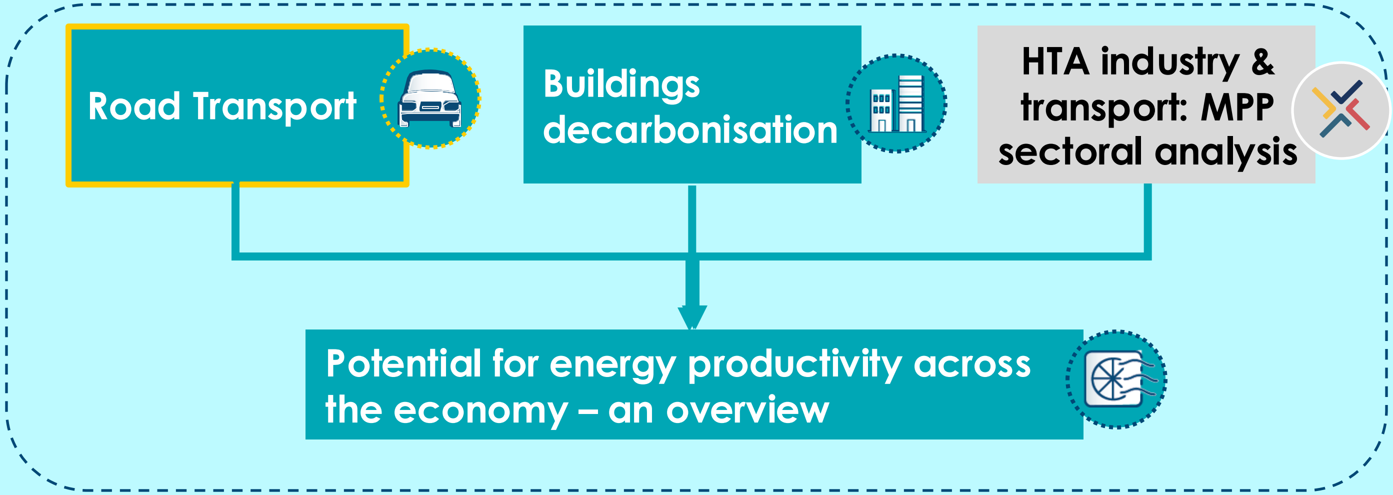
Supporting the MPP

MISSION POSSIBLE PARTNERSHIP

Supporting the ETC members

The road transport productivity deepdive will feed into the synthesis of overall energy productivity potential

2024 ENERGY PRODUCTIVITY SERIES



Road Transport

Buildings decarbonisation

HTA industry & transport: MPP sectoral analysis

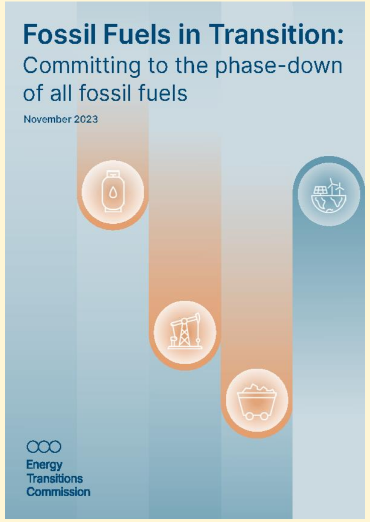
Potential for energy productivity across the economy – an overview

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.

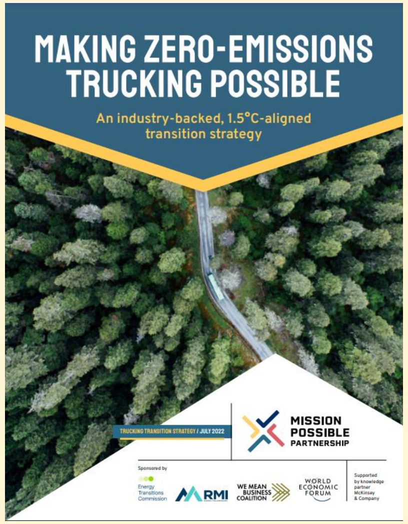
ROAD TRANSPORT DEEPDIVE

This report will build on…



Fossil Fuels in Transition:
Committing to the phase-down of all fossil fuels
November 2023

Energy
Transitions
Commission



MAKING ZERO-EMISSIONS TRUCKING POSSIBLE

An industry-backed, 1.5°C-aligned transition strategy

TRUCKING TRANSITION STRATEGY / JULY 2022

MISSION POSSIBLE PARTNERSHIP

Sponsored by
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RMI
WE MEAN BUSINESS COALITION
WORLD ECONOMIC FORUM

Supported by knowledge partner McKinsey & Company

To assess energy productivity potential in the road sector, we use the 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
=	× 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
	× 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

Not a key focus of this work as covered in 2023 ETC Materials Report

Report structure

The report aims to assess whether, alongside supply-side decarbonisation via electrification, it is possible to further reduce cumulative emissions through energy productivity improvements, whether relating to the declining fleet of Internal Combustion Engines (ICE) vehicles, the increasing fleet of electric vehicles, or both.

This report is structured in 5 Chapters:

1) **The primary role of electrification**, which is both the key to supply-side decarbonisation and the most important driver of energy productivity improvement – both at the final energy level and at the primary energy level, provided power generation is itself decarbonised.

2) **Potential improvements in energy process efficiency**, achieved through improved energy efficiency of both ICE and EV vehicles, reductions in vehicle size, or changes in driving style.

3) **Potential improvements in service efficiency**, achieved via better urban design and modal shift, where the potential is significant but inherently difficult to assess.

4) **The impact of autonomous vehicles** on both energy process efficiency and service efficiency, which could be either positive or negative.

5) **Conclusions on aggregate potential and a summary of key policies to seize this potential**.

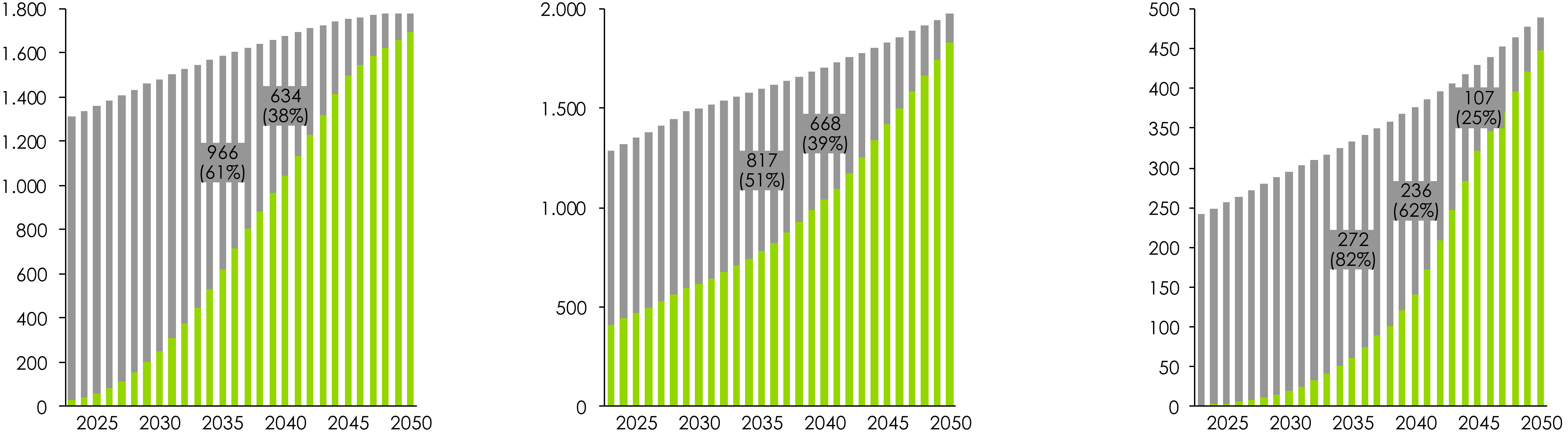
Electrification is the key productivity lever

The world’s car parc continues to grow to 2050, with increased electrification

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

🟫 ICE ■ ZEV[2]

Fossil fuels in Transition report:
Accelerated but Clearly Feasible (ACF) scenario



Passenger vehicles

Two-Three-wheelers

Commercial vehicles[3,4]

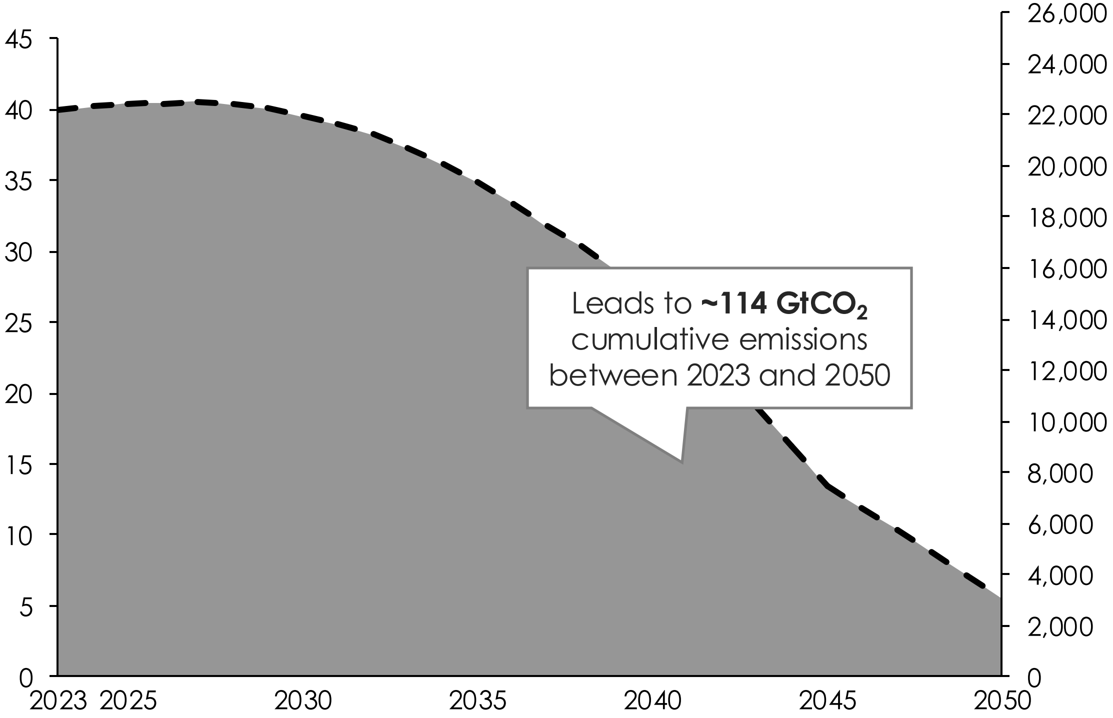
Note: 1. Accelerated but Clearly Feasible; 2. Zero-emission vehicles; 3. Commercial vehicles include light, medium and heavy commercial vehicles; 4. Commercial vehicles include both Electric Vehicles and Fuel-cell Electric Vehicles

Sources: Systemiq analysis for the ETC; ETC (2023), *Fossil Fuels in Transition: Committing to the phase-down of all fossil fuels*

In the ACF scenario, cumulative CO_2 emissions are projected to reach approximately 128 $GtCO_2$, primarily due to the use of combustion engines

Oil demand for road transport

mb/d (LHS); TWh (RHS)

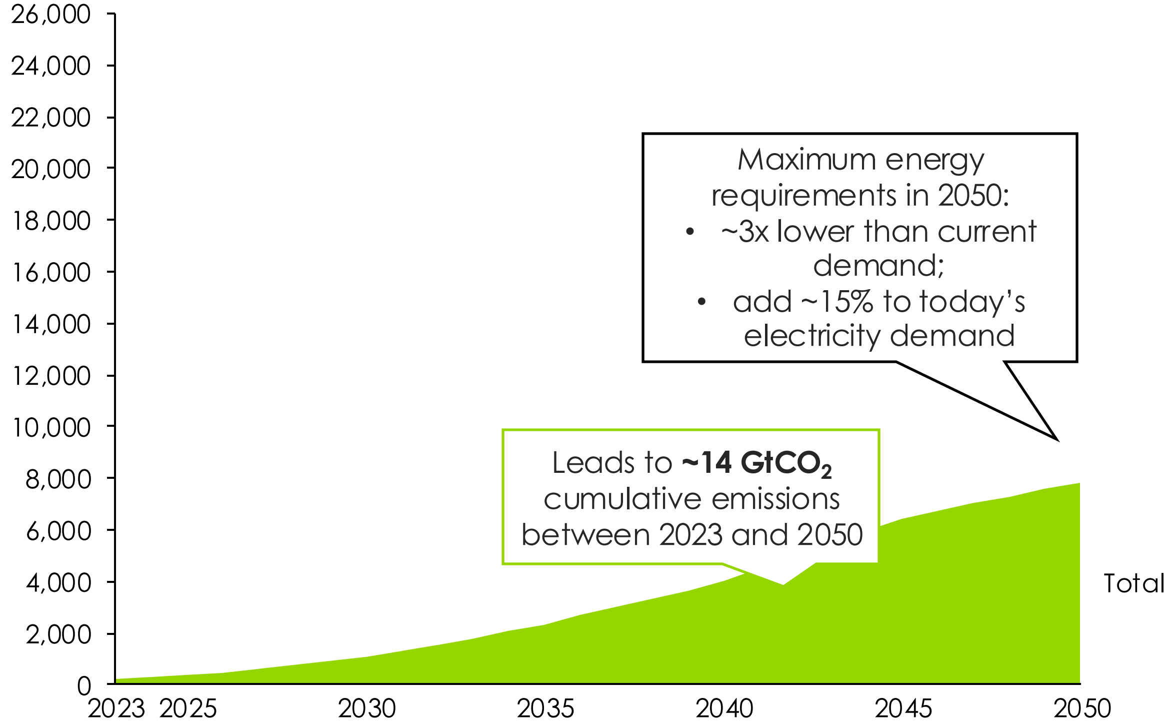


Leads to **~114 $GtCO_2$** cumulative emissions between 2023 and 2050

Oil demand

Electricity demand for road transport

TWh



Maximum energy requirements in 2050:

- ~3x lower than current demand;
- add ~15% to today's electricity demand

Leads to **~14 $GtCO_2$** cumulative emissions between 2023 and 2050

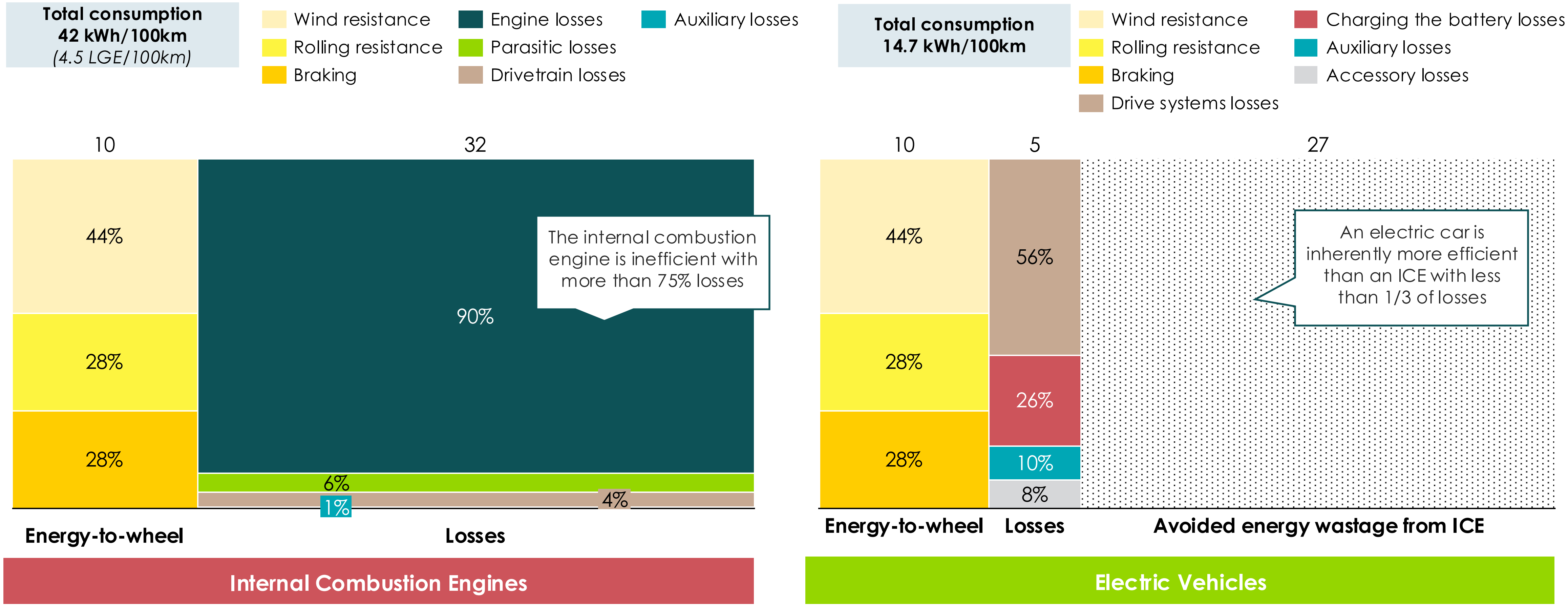
Electricity demand

Note: **ACF** = Accelerated but Clearly Feasible, Energy productivity assumptions are already baked in: efficiency improvements of new ICE vehicles of 0.7% p.a. and of new Evs of 1.6% p.a.. Other vehicles, such as those used in construction or mining are not included. 2-3-wheelers and buses are not included. We consider that the combustion of a barrel of oil equivalent results ~405 kg CO_2Source: 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*, ETC (2023), *Fossil Fuels in Transition: Committing to the phase-down of all fossil fuels*

Today, when comparing equivalent models, Electric Vehicles are 3x as efficient as Internal Combustion Engines

Comparison of Hyundai Kona and electric Hyundai Kona 2024 energy efficiency

kWh/100km and %



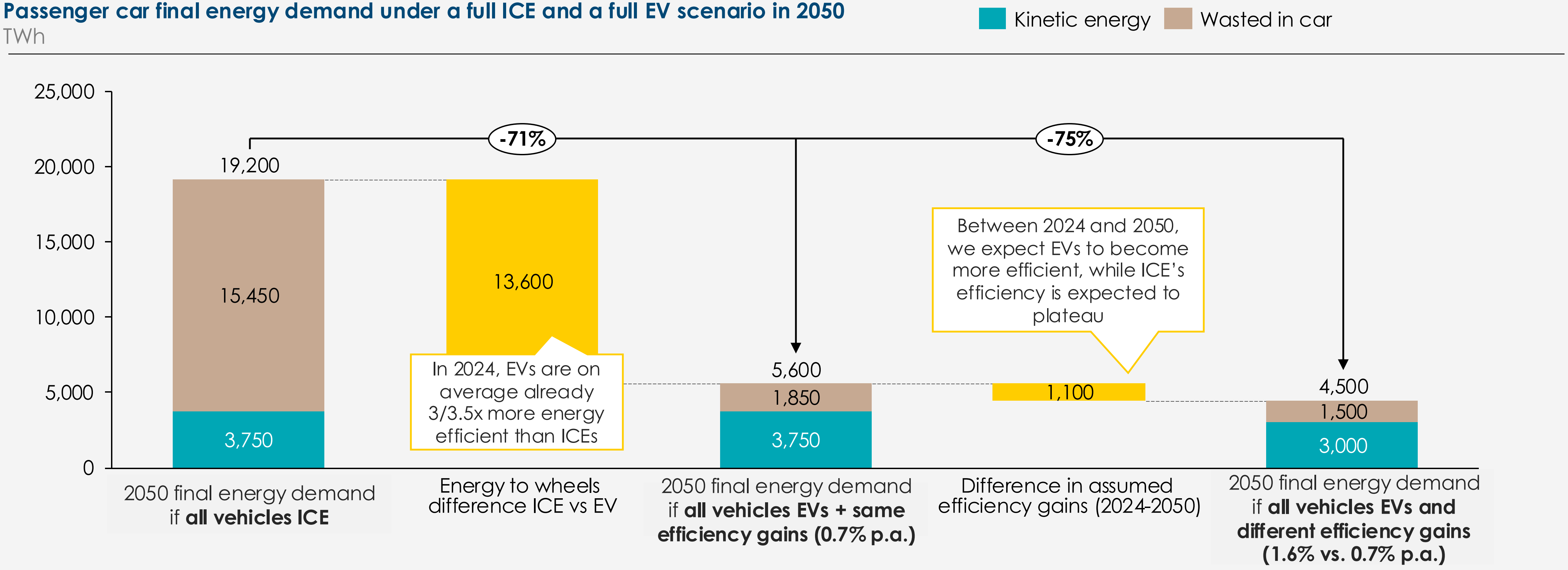
The internal combustion engine is inefficient with more than 75% losses

An electric car is inherently more efficient than an ICE with less than 1/3 of losses

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*

Passenger cars: electrification could reduce final energy demand by 75%

Passenger car final energy demand under a full ICE and a full EV scenario in 2050
TWh

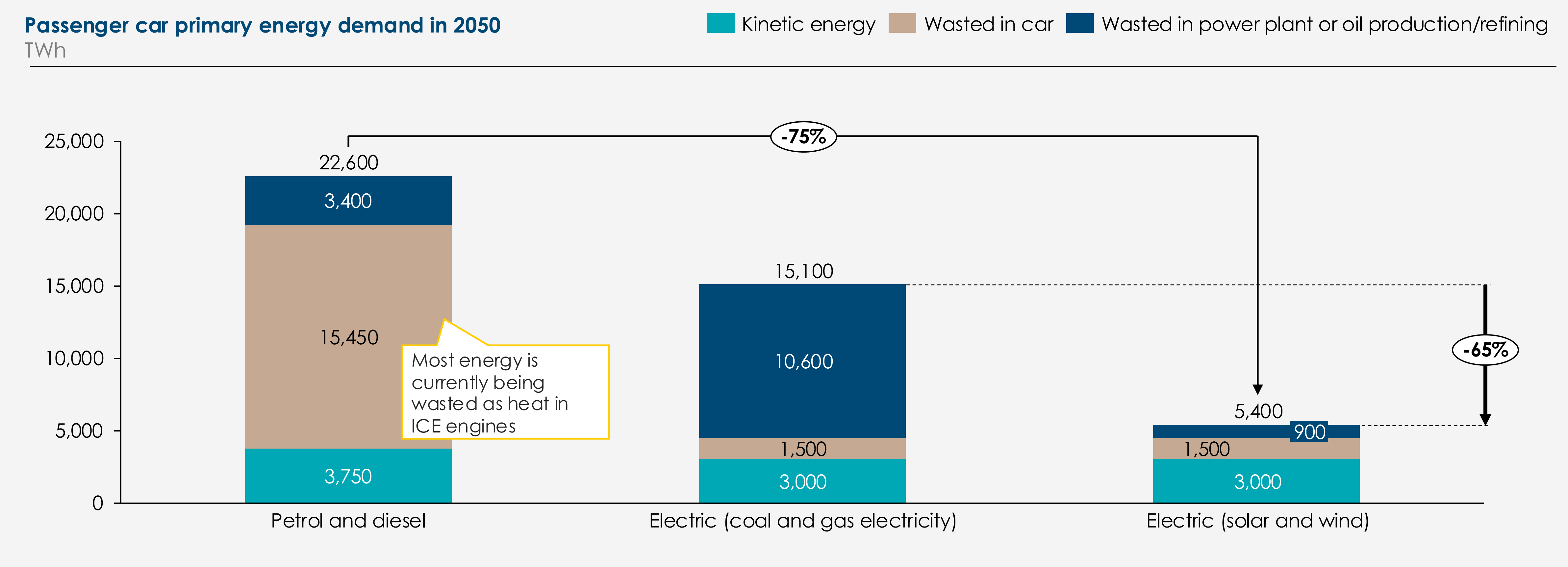


In 2024, EVs are on average already 3/3.5x more energy efficient than ICEs

Between 2024 and 2050, we expect EVs to become more efficient, while ICE's efficiency is expected to plateau

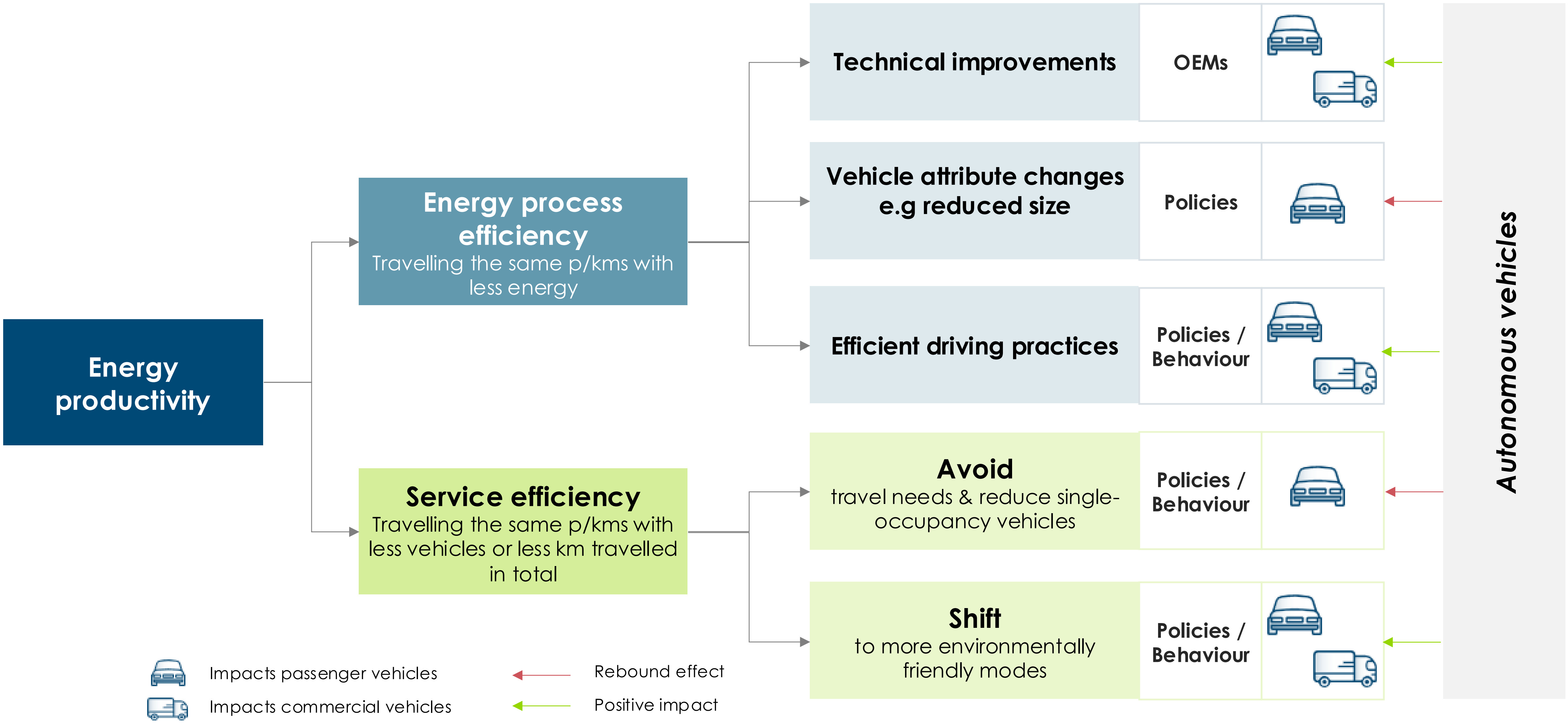
Notes: For Final Energy Demand, demand for transport of ~30,500bn km in 2050, with a fleet of 1.8Bn vehicles; In 2024, new EVs consume on average 20 kWh/100km, and new ICEs 7.4 Lge/100km. We consider efficiency improvements of 1.6% p.a. for EVs and 0.7% p.a. for ICEs, respectively reaching 12.9 kWh/100km 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.

Passenger cars: electrification 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.

Key productivity levers beyond electrification



Energy productivity

Energy process efficiency
Travelling the same p/kms with less energy

Technical improvements — OEMs

Vehicle attribute changes e.g reduced size — Policies

Efficient driving practices — Policies / Behaviour

Service efficiency
Travelling the same p/kms with less vehicles or less km travelled in total

Avoid travel needs & reduce single-occupancy vehicles — Policies / Behaviour

Shift to more environmentally friendly modes — Policies / Behaviour

Autonomous vehicles

🚗 Impacts passenger vehicles
🚚 Impacts commercial vehicles

← Rebound effect
← Positive impact

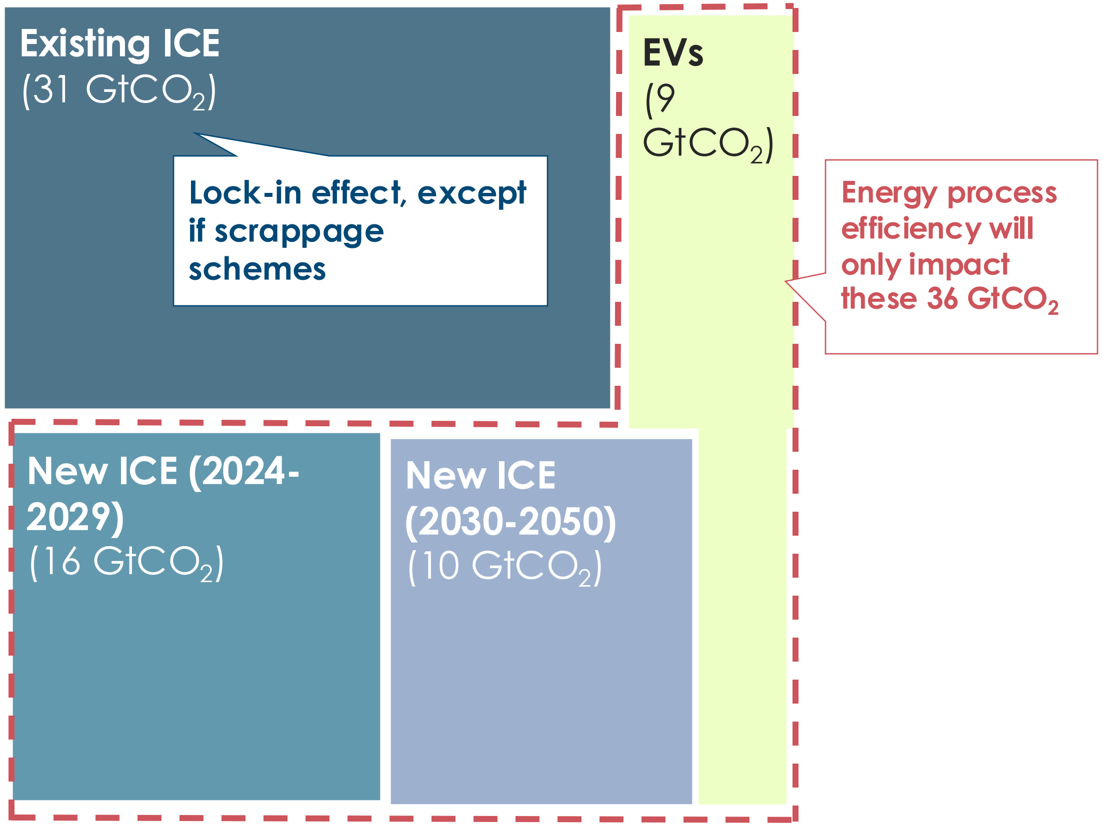
Note: OEM stands for Original equipment manufacturer
Source: Systemiq analysis for the ETC.

Energy process efficiency could play a role for both ICEs and EVs

Illustrating the stock turnover effect: passenger car emissions in ACF scenario without new ICE efficiency improvements

Projected CO_2 emissions under the ACF scenario without efficiency gains, Gt CO_2

ICE (57 $GtCO_2$) + **EVs** (9 $GtCO_2$) = 66 $GtCO_2$



Existing ICE (31 $GtCO_2$)

Lock-in effect, except if scrappage schemes

EVs (9 $GtCO_2$)

Energy process efficiency will only impact these 36 $GtCO_2$

New ICE (2024-2029) (16 $GtCO_2$)

New ICE (2030-2050) (10 $GtCO_2$)

Cars on the road typically last around 18 years:

- vehicles retiring from the global vehicle stock in 2024 were therefore typically new vehicles from 2006;
- a retiring 2006 ICE consumes approximately 37% more fuel than a new 2024 ICE.[24]

The **most important driver** of past improvements in vehicle energy efficiency has **therefore been the gradual replacement of old vehicles with new more efficient ones**.

And this effect would **continue to drive significant improvements in average ICE fleet efficiency over the next 18 years.**

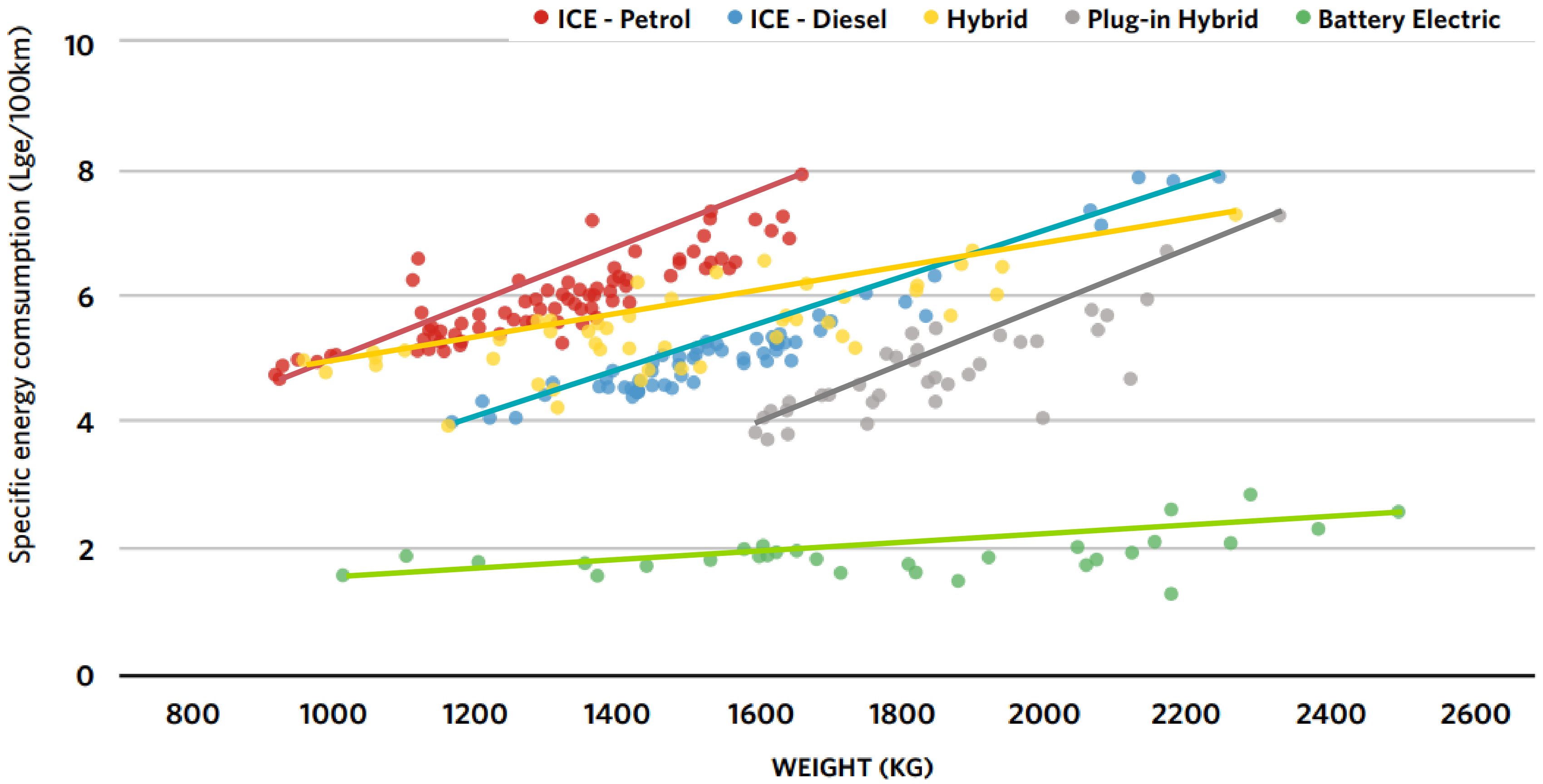
Note: ICE means Internal Combustion Engine Vehicles, EV means Electric Vehicles. We consider that the combustion of a barrel of oil equivalent results ~405 kg CO_2.
Source: Systemiq analysis for the ETC; ETC (2023), *Fossil Fuels in Transition: Committing to the phase-down of all fossil fuels*

Energy process efficiency – key things that matter

	Drive unit improvements	Tyre rolling resistance	Weight	Speed
ICEs	Main efficiency gain is hybridisation (= electrification)	Benefits both vehicles proportionately.	ICE SUVs generally weight more than BEV SUVs.	Reducing high speeds improves efficiency, particularly for EVs which are more inefficient at higher speeds.
EVs	Scope for 20% improvement in efficiency		Bigger range = bigger weight, but inherent EV efficiency and regenerative breaking limits impact.	

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

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:

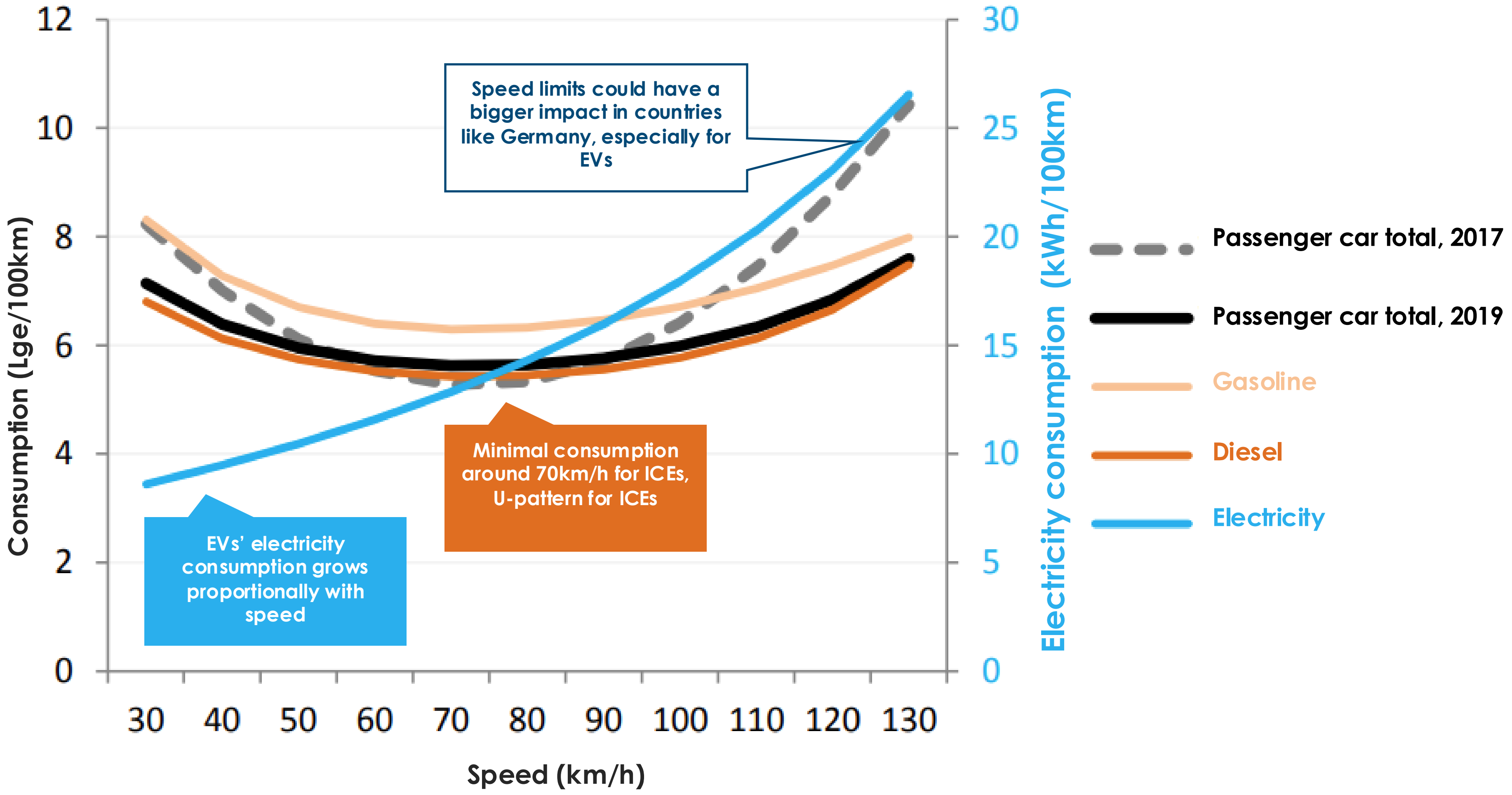
1. **EVs are inherently more efficient**, bigger vehicles therefore lose less energy
2. **Regenerative braking benefits larger EVs**, offsetting some energy losses in heavier EVs compared to heavier ICEs.

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

Relationship between speed and energy consumption for passenger vehicles

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



Speed limits could have a bigger impact in countries like Germany, especially for EVs

Minimal consumption around 70km/h for ICEs, U-pattern for ICEs

EVs' electricity consumption grows proportionally with speed

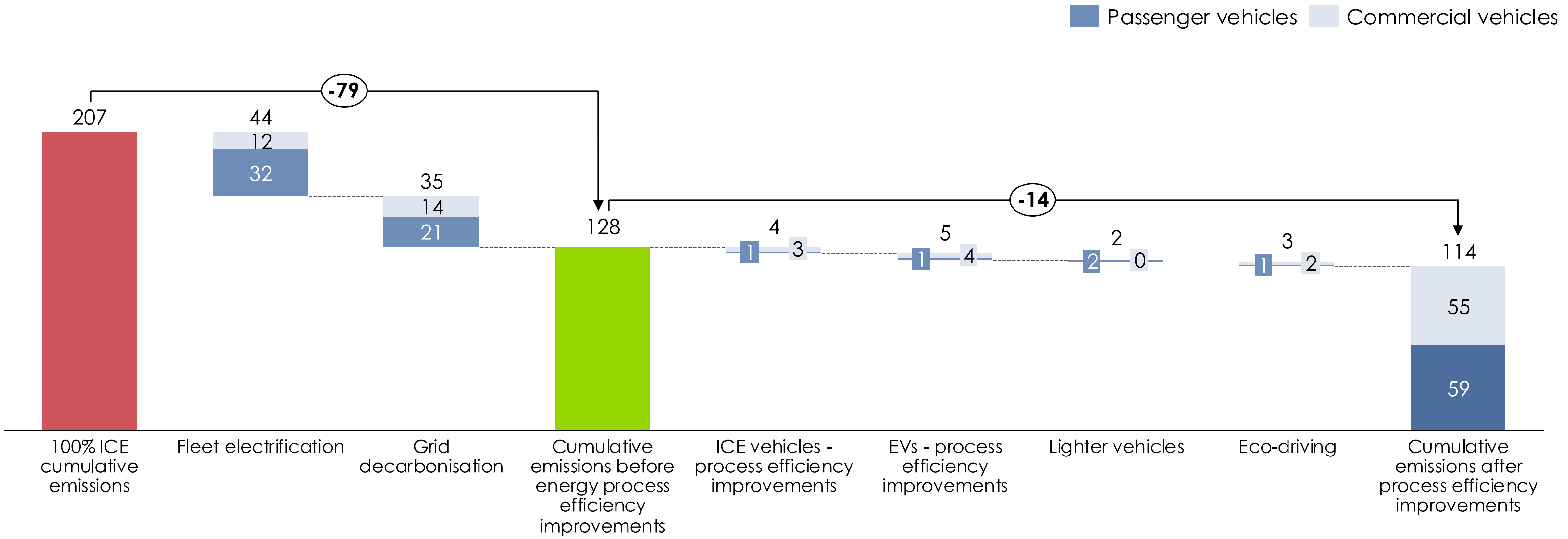
Notes: Lge: liter of gasoline equivalent

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*

Combining electrification and energy process efficiency levers could reduce road sector emissions from 207 $GtCO_2$ to 114 $GtCO_2$

Projected cumulative CO_2 emissions between 2023 and 2050 in a full ICE scenario vs with energy productivity levers

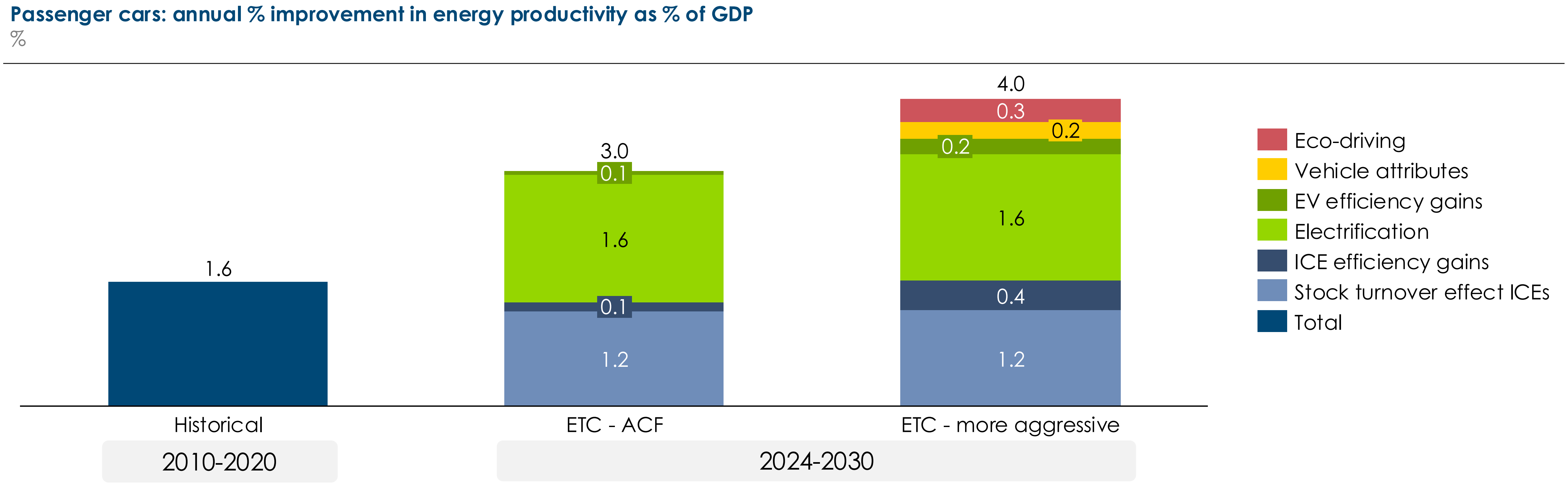
$GtCO_2$



Note: All ICE means Internal Combustion Engine Vehicles, EV means Electric Vehicles. We consider that the combustion of a barrel of oil equivalent results ~405 kg CO_2.

Source: Systemiq analysis for the ETC; ETC (2023), *Fossil Fuels in Transition: Committing to the phase-down of all fossil fuels*

Passenger car energy productivity could improve by 3-4% annually



- New ICE efficiency improvements: 0.7% p.a.
- New EV efficiency improvements : 1.6% p.a.

- New ICE efficiency improvements: 2.5% p.a.
- New EV efficiency improvements : 6% p.a. until 2035
- Ban on vehicles above 1,8 tons
- 20km/h speed limit on highways

Notes: 1. Past improvements were driven by an increase in the share of electric vehicles in fleets, continued improvements in engine technology and the introduction of hybrid powertrains.
Sources: Systemiq analysis for the ETC; ETC (2023), *Fossil Fuels in Transition: Committing to the phase-down of all fossil fuels*

Service efficiency potential could be large, but uncertain

Big European cities are enforcing measures to reduce demand for polluting ICEs and incentivise modal shift towards cleaner transport modes

Oslo: Planning to establish a **ZEZ in the city center** area, overlapping with the car-free zone

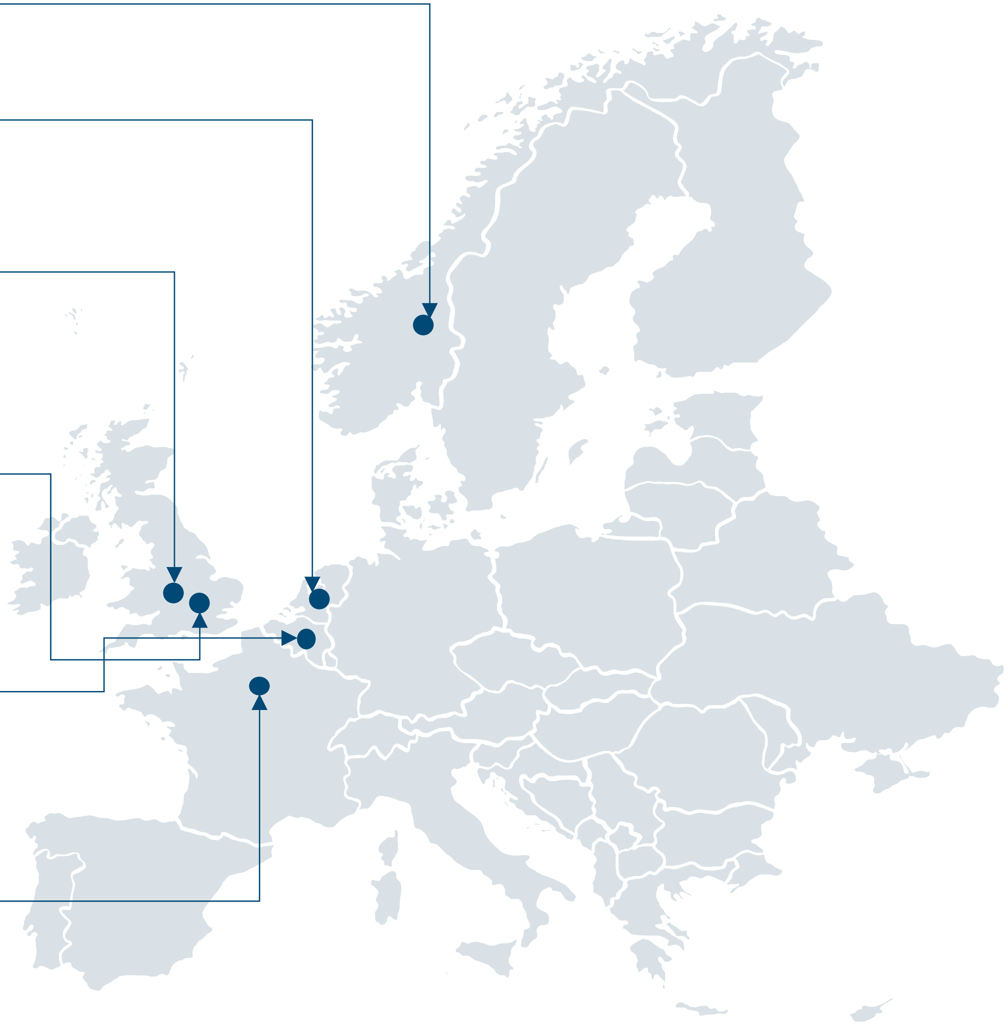
Amsterdam:
- Remove **>10,000 parking spaces** by 2025
- **Bicycle Plan of €54 million** between 2017 and 2022

Oxford:
- Reduce **car trips by a quarter by 2030** and achieve **net-zero transport by 2040**
- City plans to install **more ZEZ enforcement cameras**

London:
- In 2017, the mayor introduced a **£42 million taxi delicensing scheme to scrap older diesel taxis** for zero-emission capable vehicles.
- With the planned expansion of the ULEZ, the city introduced a **new £110 million vehicle-scrappage scheme**

Brussels:
- Good Move plan aims to **reduce private car use by 24% in Brussel**
- Bruxell’Air scheme offers a **bonus for scrapping a car** in exchange **for active modes**, **public transport or car sharing**

Paris:
- Recently allocated **€250 million for 180 km of new cycling roads** and over **130,000 new bicycle parking spaces**
- Government offers up **to €4,000 to low-income households in the LEZ for swapping their old ICE for e-bikes**

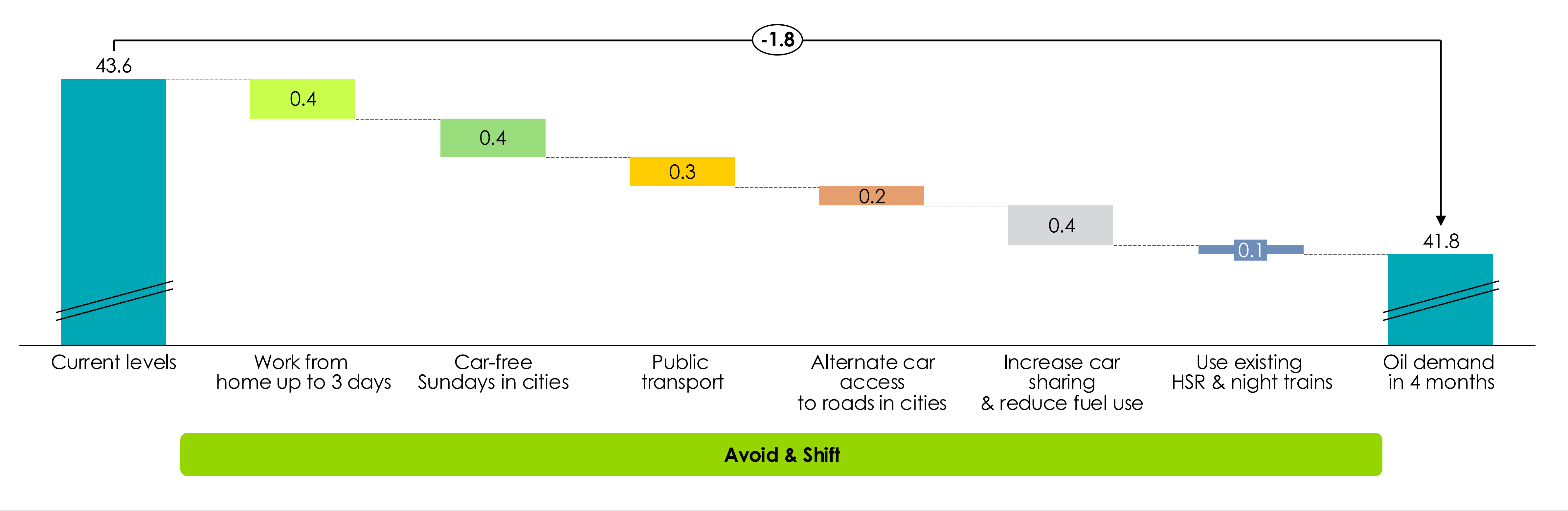


Notes: LEZ = Low Emission Zones, ZEZ: Zero Emission Zones
Sources: Systemiq analysis for the ETC; The ICCT (2023), *Planning and implementation of low- and zero-emission zones in cities*

Avoid & shift levers could displace ~1.8 mb/d overnight according to the IEA

Oil demand reductions in advanced economies within four months in the IEA's 10-Point Plan*, 2022

Mb/d



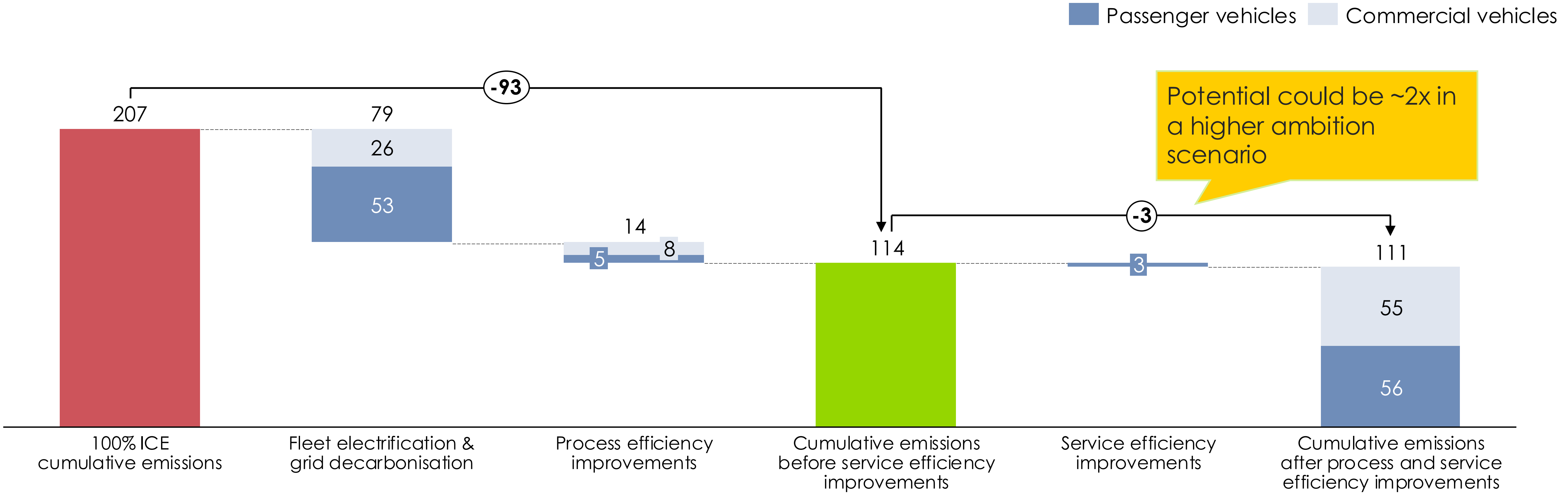
Notes: HSR = high-speed rails. *In the face of the emerging global energy crisis triggered by Russia's invasion of Ukraine, the IEA's 10-Point Plan to Cut Oil Use proposes 10 actions that can be taken to reduce oil demand with immediate impact – and provides recommendations for how those actions can help pave the way to putting oil demand onto a more sustainable path in the longer term. Only 6 points related to avoid & shift in passenger road transport are highlighted.

Sources: Systemiq analysis for the ETC; IEA (2022), *A 10-Point Plan to Cut Oil Use*

Combining electrification, energy process and service efficiency levers could reduce road sector emissions from 207 $GtCO_2$ to 111 $GtCO_2$

Projected cumulative CO_2 emissions between 2023 and 2050 in a full ICE scenario vs with energy productivity levers

$GtCO_2$



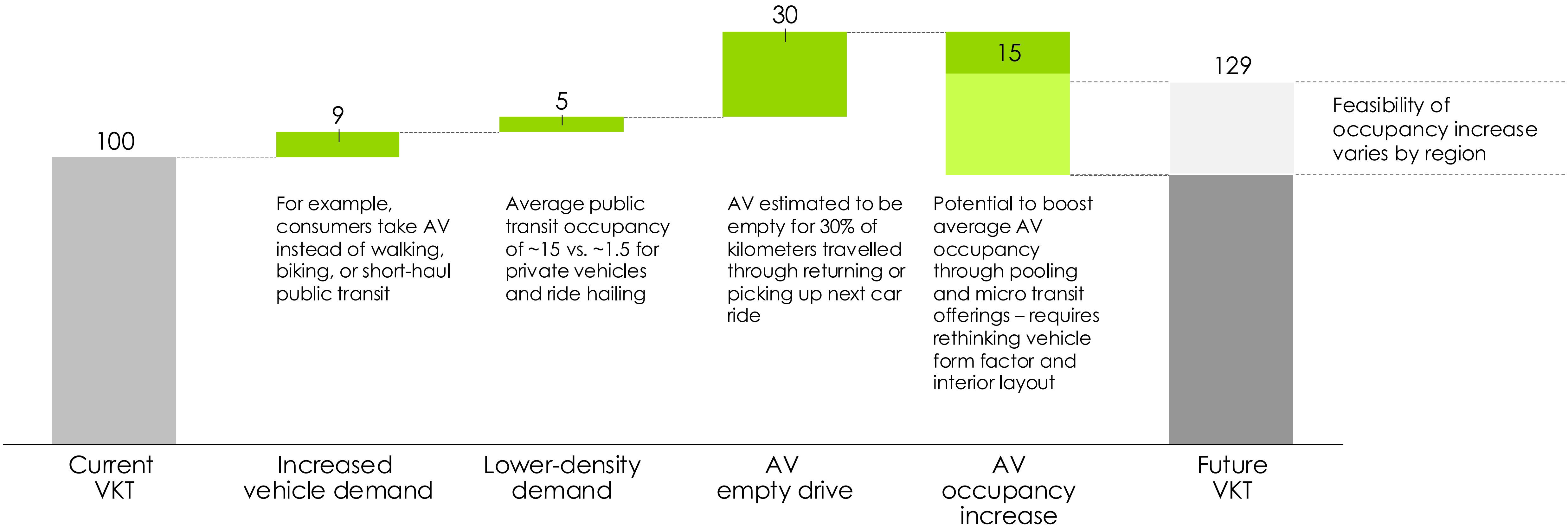
Potential could be ~2x in a higher ambition scenario

Note: All ICE means Internal Combustion Engine Vehicles, EV means Electric Vehicles. We consider that the combustion of a barrel of oil equivalent results ~405 kg CO_2.
Source: Systemiq analysis for the ETC; ETC (2023), *Fossil Fuels in Transition: Committing to the phase-down of all fossil fuels*

Autonomous vehicles- an ambivalent effect

Ambivalent impact of autonomous vehicles on total passenger car demand

Illustrative effects of autonomous vehicles on vehicle kilometers travelled (VKT)



For example, consumers take AV instead of walking, biking, or short-haul public transit

Average public transit occupancy of ~15 vs. ~1.5 for private vehicles and ride hailing

AV estimated to be empty for 30% of kilometers travelled through returning or picking up next car ride

Potential to boost average AV occupancy through pooling and micro transit offerings – requires rethinking vehicle form factor and interior layout

Feasibility of occupancy increase varies by region

Notes: AV refers to autonomous vehicles; pooling refers to rides shared with other passengers; vkt refers to vehicle kilometers traveled.
Sources: Systemiq analysis for the ETC; BCG analysis (2022)

For commercial road transport, rise of autonomous vehicles could lead to increased efficiency

Energy process efficiency

- **Vehicle attributes**: Removing human-centric features and optimising vehicle design for autonomous operation can reduce weight and improve aerodynamics (e.g. truck cabin redesigned).
- **Limiting highway speeds**: More consistent driving at optimal speeds reduces fuel consumption by maintaining lower speeds without the pressure of limited driving hours .
- **Eco-driving:** Autonomous trucks can consistently apply optimal driving techniques, such as efficient acceleration, braking, and coasting, to save fuel.

Service efficiency

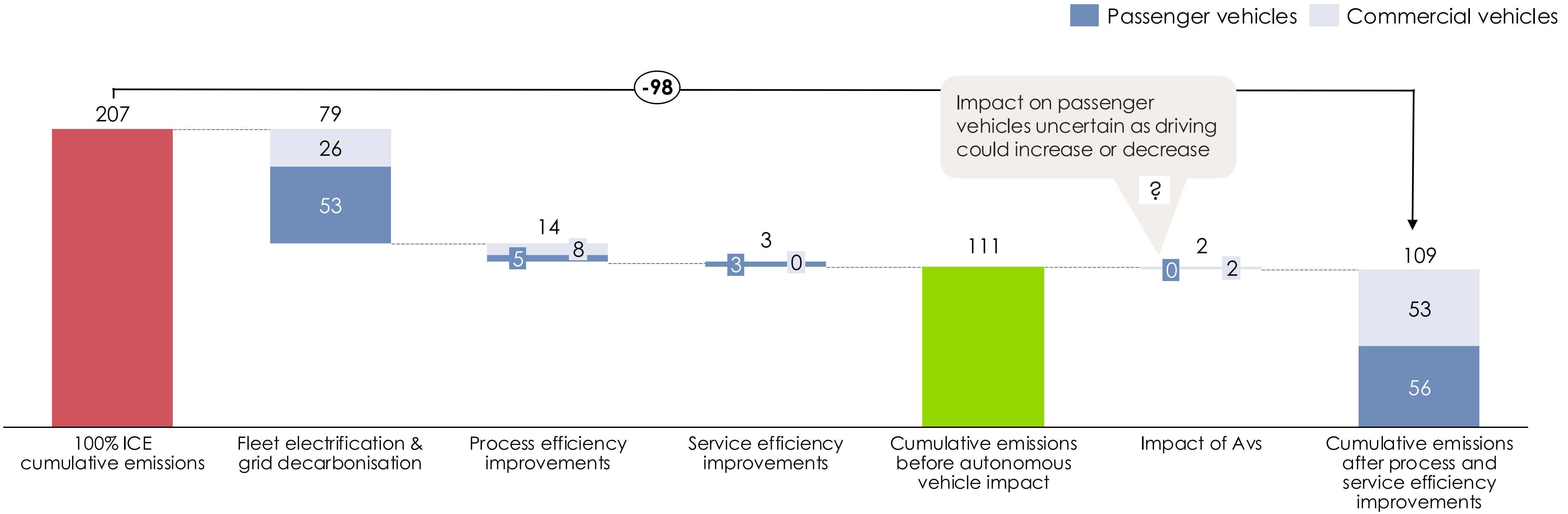
- **Reducing idling:** Eliminating driver rest breaks cuts down on idle time and fuel wastage.
- **Deadhead reduction:** By optimising logistics, autonomous trucks can minimise empty “deadhead” miles (currently ~15% of truck mileage in the U.S), reducing overall fuel use.
- **Off-peak driving:** Autonomous trucks can operate nearly 24/7, significantly increasing vehicle utilisation and reducing operational costs by shifting to low congestion times.

Source: Transport and environment report (2022), *Digitalisation in the mobility system: challenges and opportunities, Annex 3 Autonomous freight transport,* Aurora (2024), *The Sustainability Opportunity of Autonomous Trucking.*

Combining electrification, process energy and service efficiency levers, and autonomous vehicles could reduce road sector emissions from 207 $GtCO_2$ to 109 $GtCO_2$

Projected cumulative CO_2 emissions between 2023 and 2050 in a full ICE scenario vs with energy productivity levers

$GtCO_2$



Impact on passenger vehicles uncertain as driving could increase or decrease

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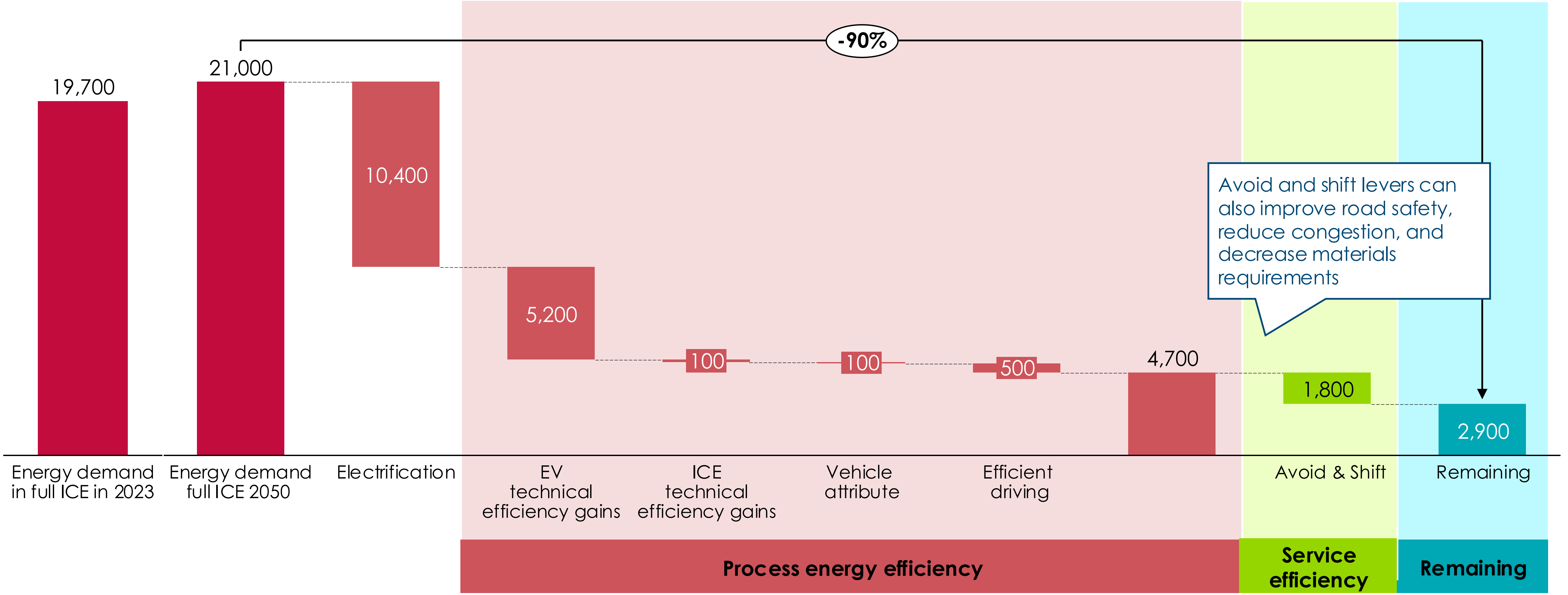
Source: Systemiq analysis for the ETC; ETC (2023), *Fossil Fuels in Transition: Committing to the phase-down of all fossil fuels*

Summary conclusions

Passenger car final energy demand reduction: suite of levers is critical

Passenger car final energy demand in 2050 and impact of energy productivity levers

TWh



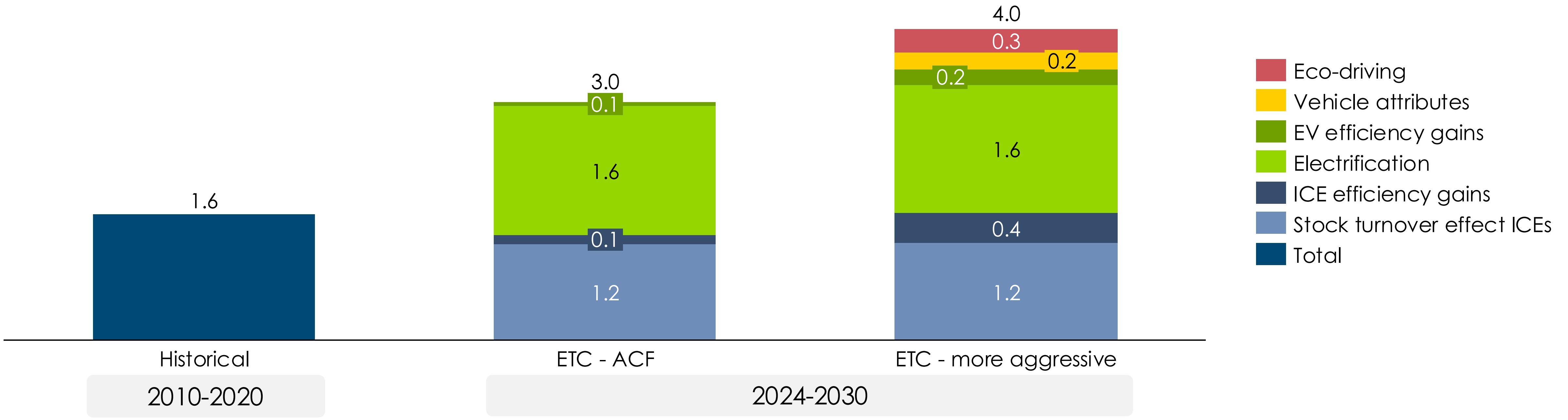
Avoid and shift levers can also improve road safety, reduce congestion, and decrease materials requirements

Note: ICE means Internal Combustion Engine Vehicles, EV means Electric Vehicles. Productivity levers: 20% efficiency gains for ICEs by 2050, 50% efficiency gains for EVs by 2035, 20km/h speed limit reduction on highways and 30km/h speed limit in urban areas, 36% demand reduction by 2050 through Avoid & Shift levers. Final Energy Demand attributed by lever with LMDI (Logarithmic Mean Divisia Index) methodology. For Primary Energy demand, energy efficiency of 85% from fossil fuel extraction to tanker, and for renewables power (e.g., electricity conversion and transmission losses) is taken,
Source: Systemiq analysis for the ETC; ETC (2023), *Fossil Fuels in Transition: Committing to the phase-down of all fossil fuels*

Passenger car energy productivity could improve by 3-4% annually

Passenger cars: annual % improvement in energy productivity as % of GDP

%



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Notes: 1. Past improvements were driven by an increase in the share of electric vehicles in fleets, continued improvements in engine technology and the introduction of hybrid powertrains.

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Key actions for policymakers & industry

- **Fleet electrification and grid decarbonisation** should remain critical priorities for all stakeholders, especially policymakers.

- **Ensure proper vehicle Scrappage:** With the accelerated pace of fleet electrification, ensuring proper old ICE scrappage should also be a key priority for policymakers to prevent these polluting vehicles from ending up in second-hand markets.

- **Process Energy Efficiency:** Energy efficiency improvements can be achieved with ambitious policies.

- **Service Efficiency Policies:** Service efficiency relies on systemic transformation and behavioural changes, requiring all stakeholders to work hand in hand.

- **Autonomous vehicles:** Given the rebound effect associated with autonomous vehicles, it is crucial for regulators and OEMs to prioritise their appropriate applications to ensure climate-positive impacts.