Electric road systems would enable quicker decarbonization by correcting incentives

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Current status of EU road transport decarbonization

EU CO_2 emissions by source

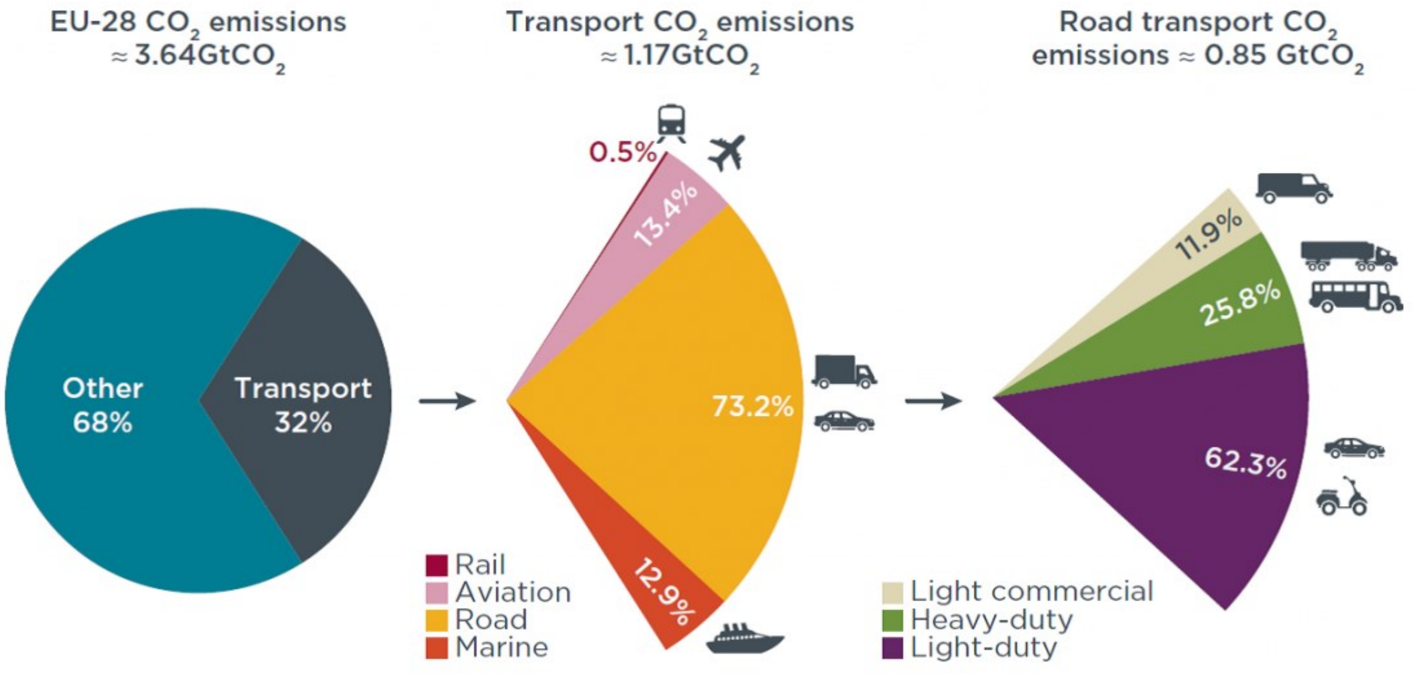
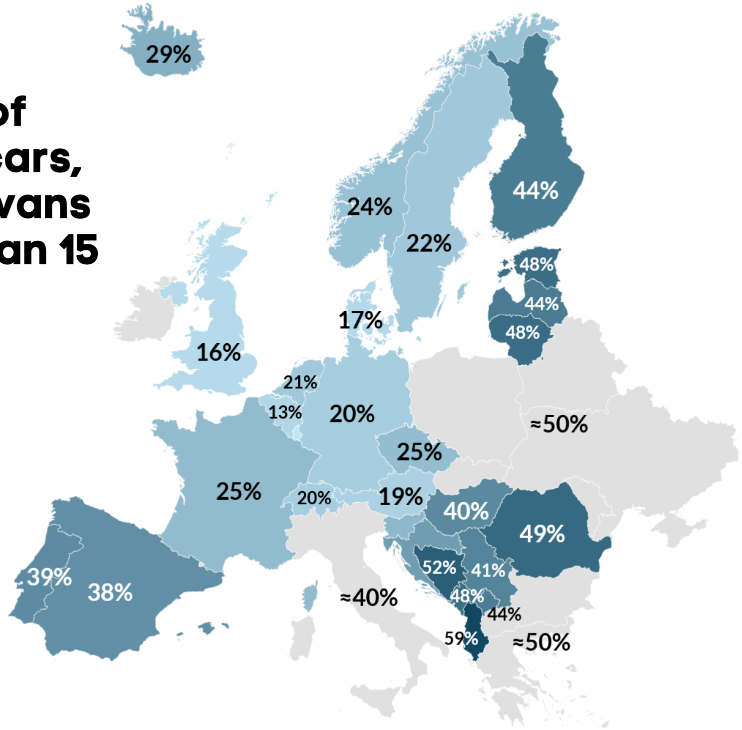


Figure 2. Distribution of total ETS and non-ETS direct CO_2 emissions in the European Union in 2015.[8]
$GtCO_2$: gigatonnes of carbon dioxide

source

The EU vehicle fleet

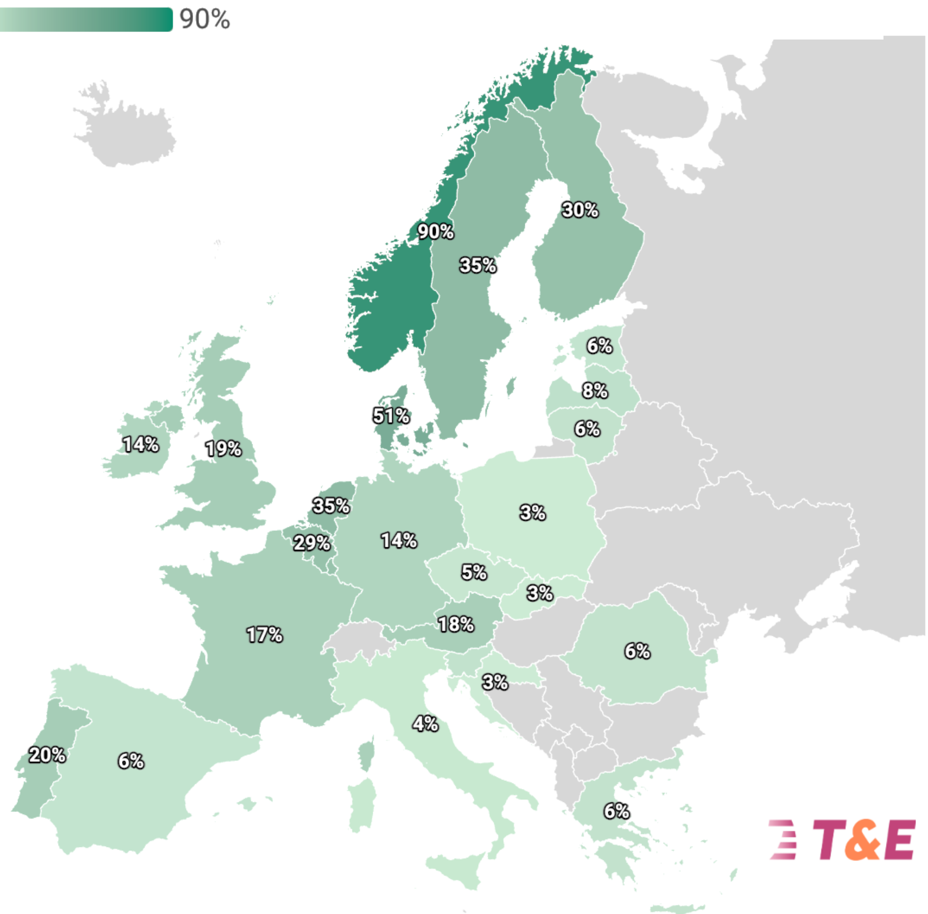
30-35% of European cars, trucks and vans are older than 15 years



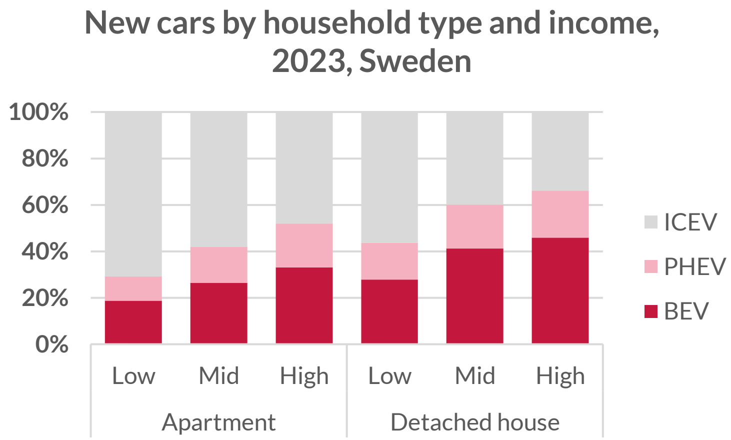
- **Today** (2024):
  ICE in 86% of new cars, 99% of trucks
- **Targets**:
  100% ZEV car sales by 2035,
  90% ZEV truck sales by 2040
- ZEV sales share targets only affect inflow (primary markets)
- Secondary vehicle markets lack agency to decarbonize road transport

Current inflow of new vehicles

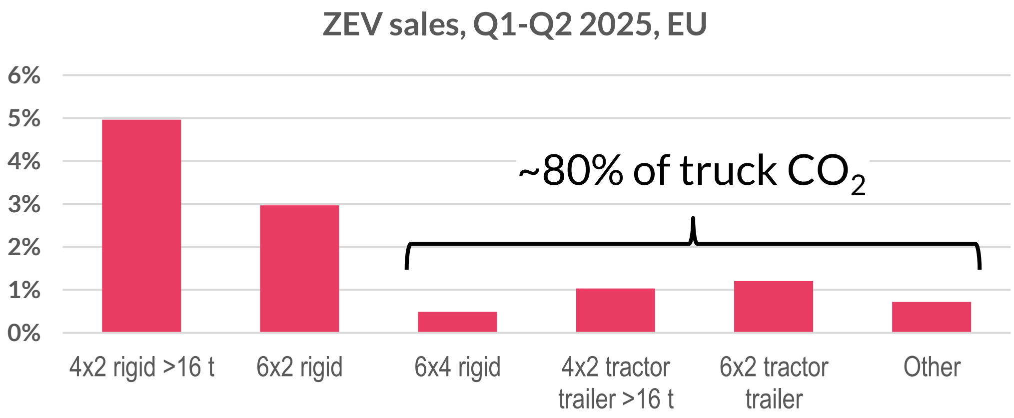
Electric Vehicle new registrations in 2024 (%)



Cars: good income, private parking



Trucks: local operations



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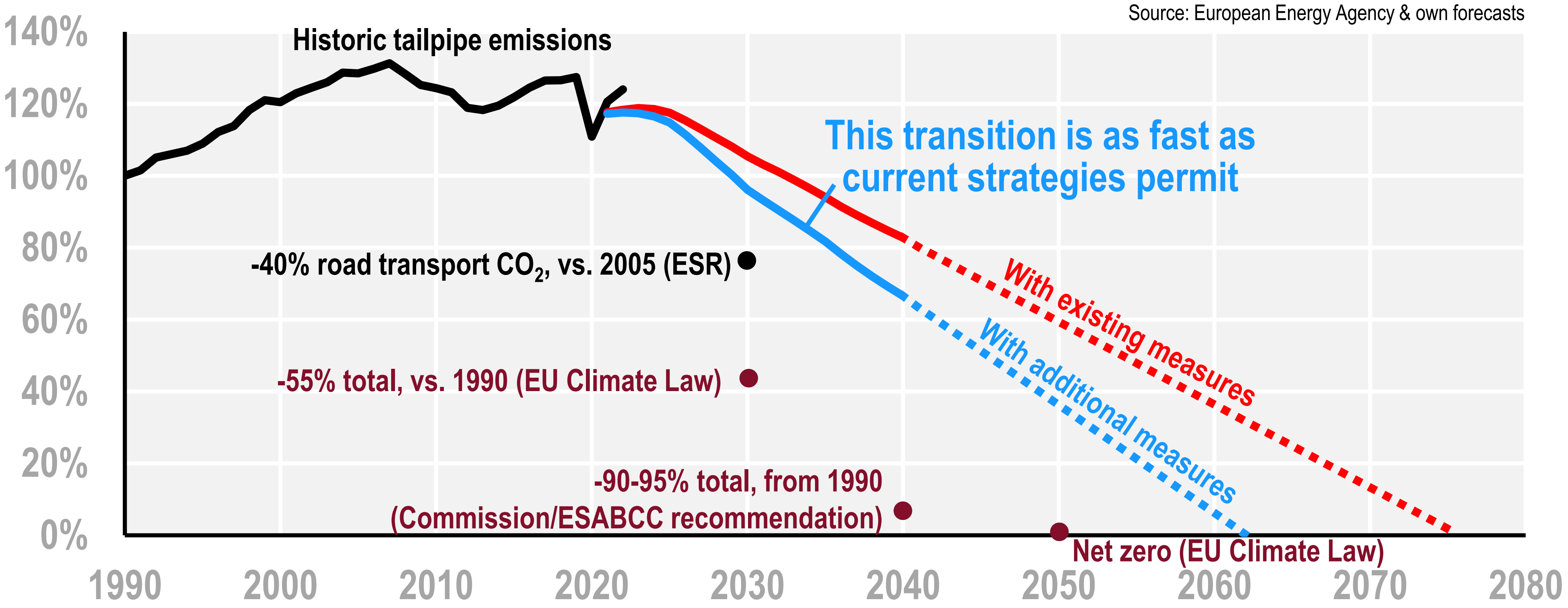
EU Tailpipe CO_2 Emissions



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During 2025–2035, Europe will invest ~€3 trillion in ~60 million new ICE cars, to burn €600 billion in fossil fuels and emit 2 Gt of CO_2

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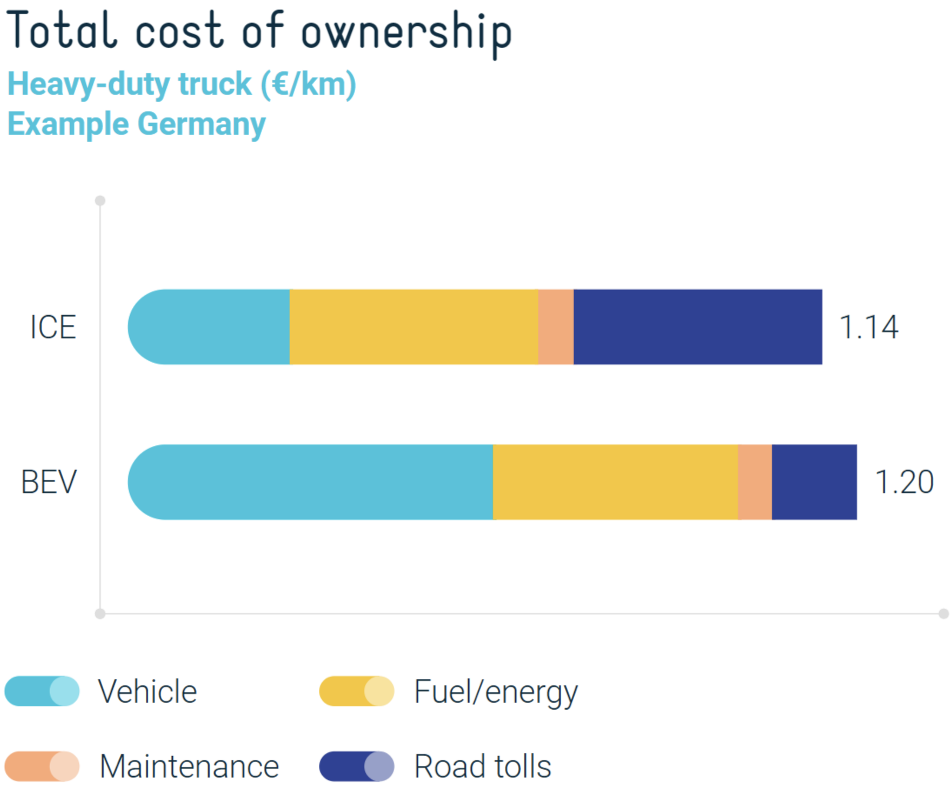
Current stakeholder incentives prevent quicker decarbonization

Vehicle buyers

- Only new-vehicle buyers ***can*** decarbonize
- BEV TCO < ICEV TCO is only possible with home/depot charging
- Private charging requires capital, private parking and grid connection
- Commercial BEVs are unattractive when productive time and cargo capacity are lower
- Trillions of euros in ICEV assets will be owned mainly by the least affluent. Early scrappage is unrealistic.

→ **Fossil fuel penalties are only acceptable for those who can avoid them**



Source: McKinsey / ACEA (Oct 2025)

Charge point operators

- Costs scale with peak power. Profit is maximized by managing demand.
- Overexpansion reduces utilization rates
- Current electrical grid limits site selection

→ Control prices and don’t expand too quickly

Electrical grid operators

- Grids are complex and permits to expand take time. Cannot expand everywhere at once.
- Grid cost per user depends on asset utilization and risk. Will new chargers stay for 30-50 years?

→ Expand grid, but by priority and with caution

Vehicle OEMs

- Legacy vehicle platforms
- No control over battery supply chain
- Must respond to market demand
- Face fines if ZEV sales shares are too low
- Strong EU lobby power

→ Lobby against fines, for subsidies & heavier ZEVs

Policy makers

- Policy is limited by voter acceptance and techno-economic feasibility
- Most carrots and sticks inherently favor new vehicle buyers. Equity is low.
- Subsidies are affordable only where marginal abatement costs are low (or scale is limited)

→ Targets are unenforceable

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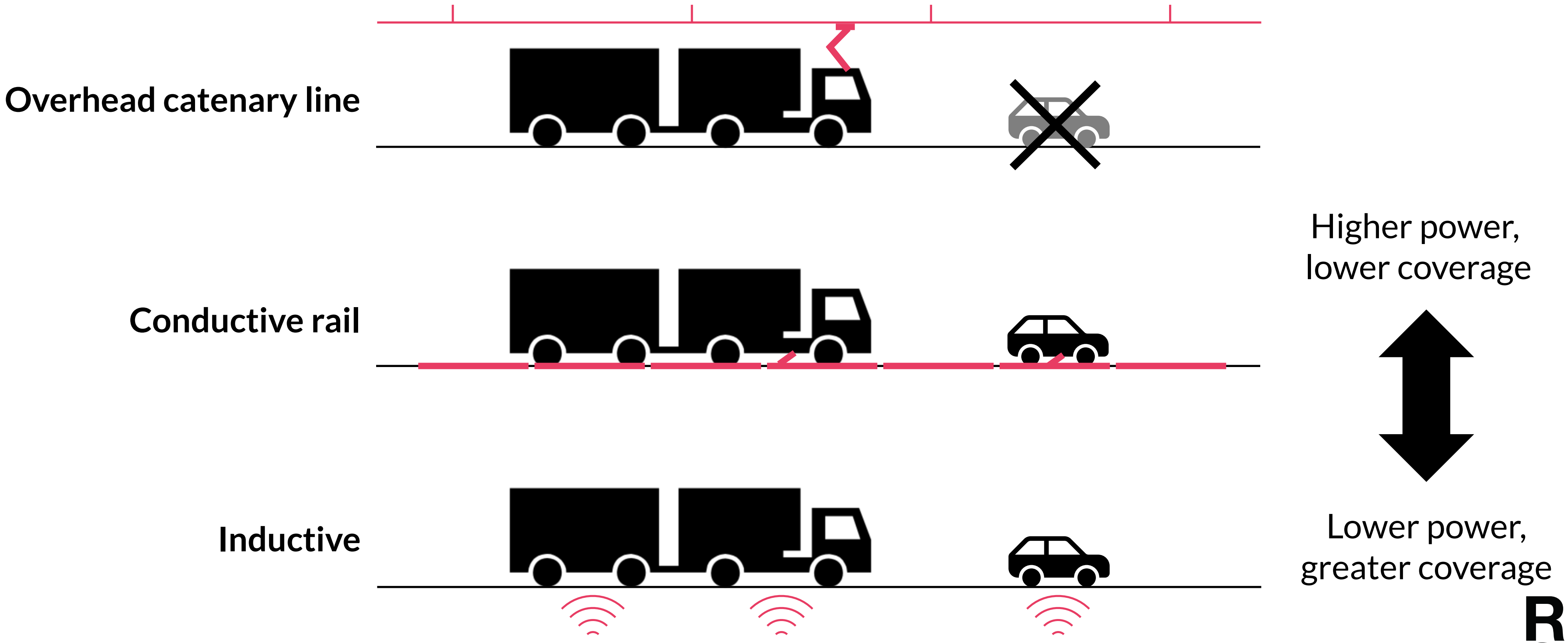
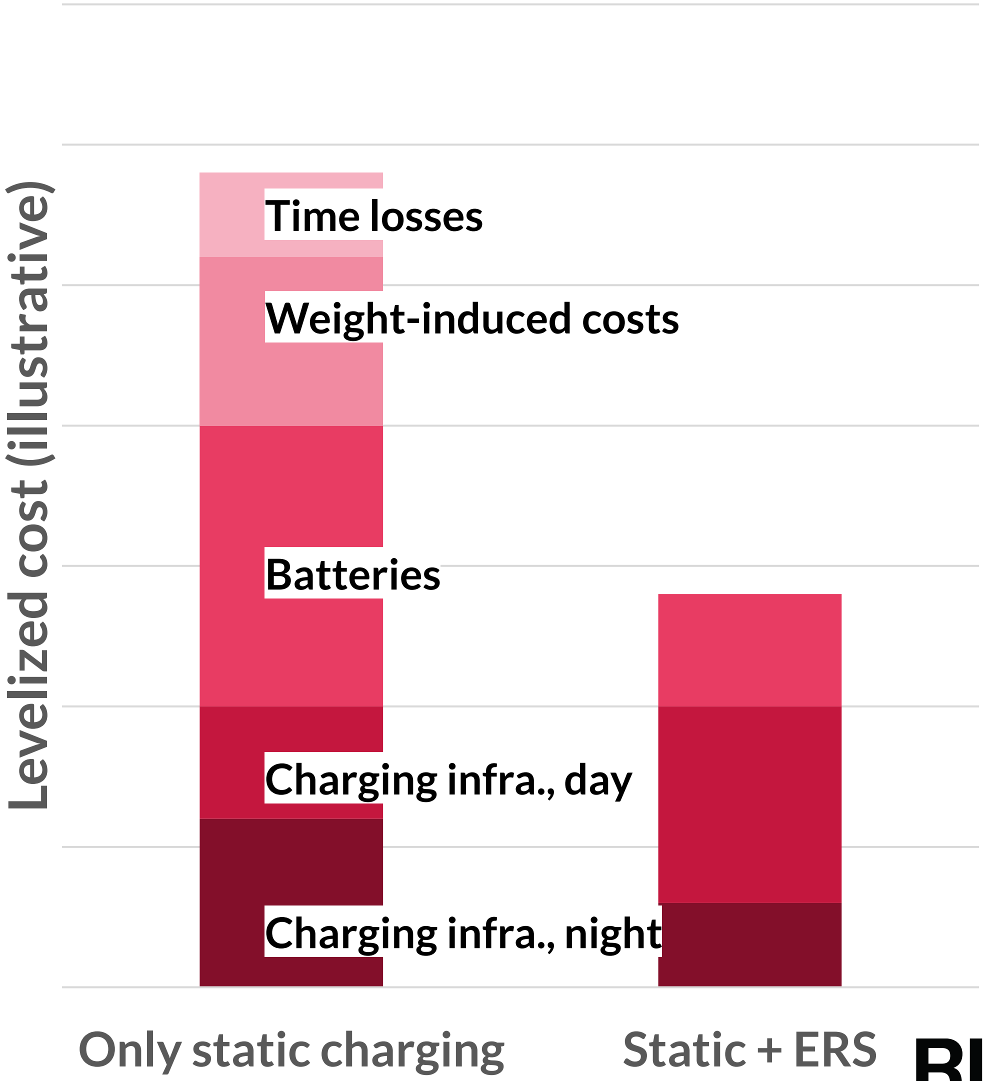
ERS aligns incentives to decarbonize

What are Electric Road Systems (ERS)?

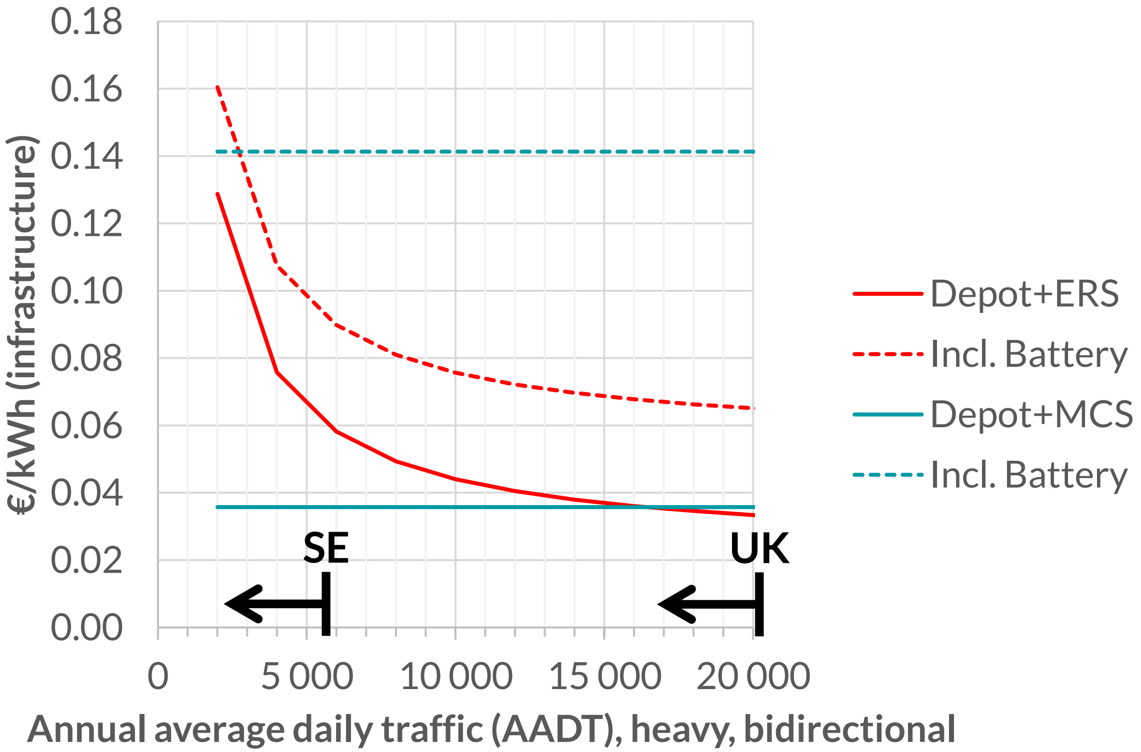


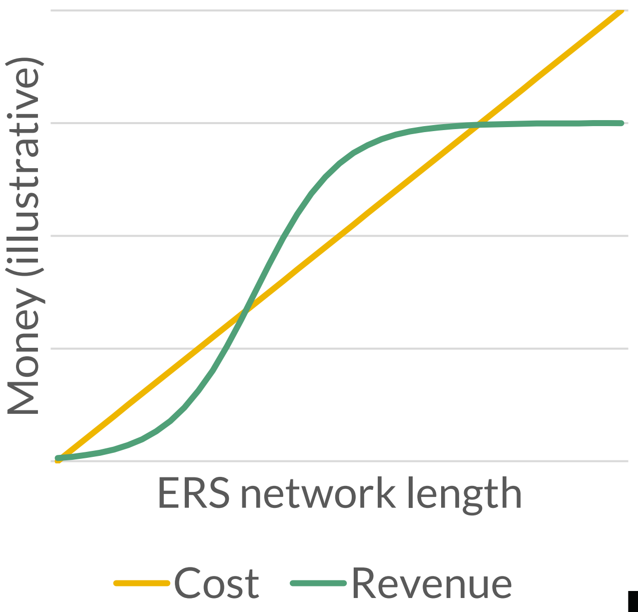
Costs that change with ERS in the mix (for <100% of vehicles)

- Smaller batteries with in-motion charging
- ERS costs much more than MCS-chargers! (yes, more day-time charging)
- Less overnight charging with smaller batteries
- Some combination of:
  - Lower axle weight = less road wear
  - More cargo capacity = fewer vehicles
- More productive time

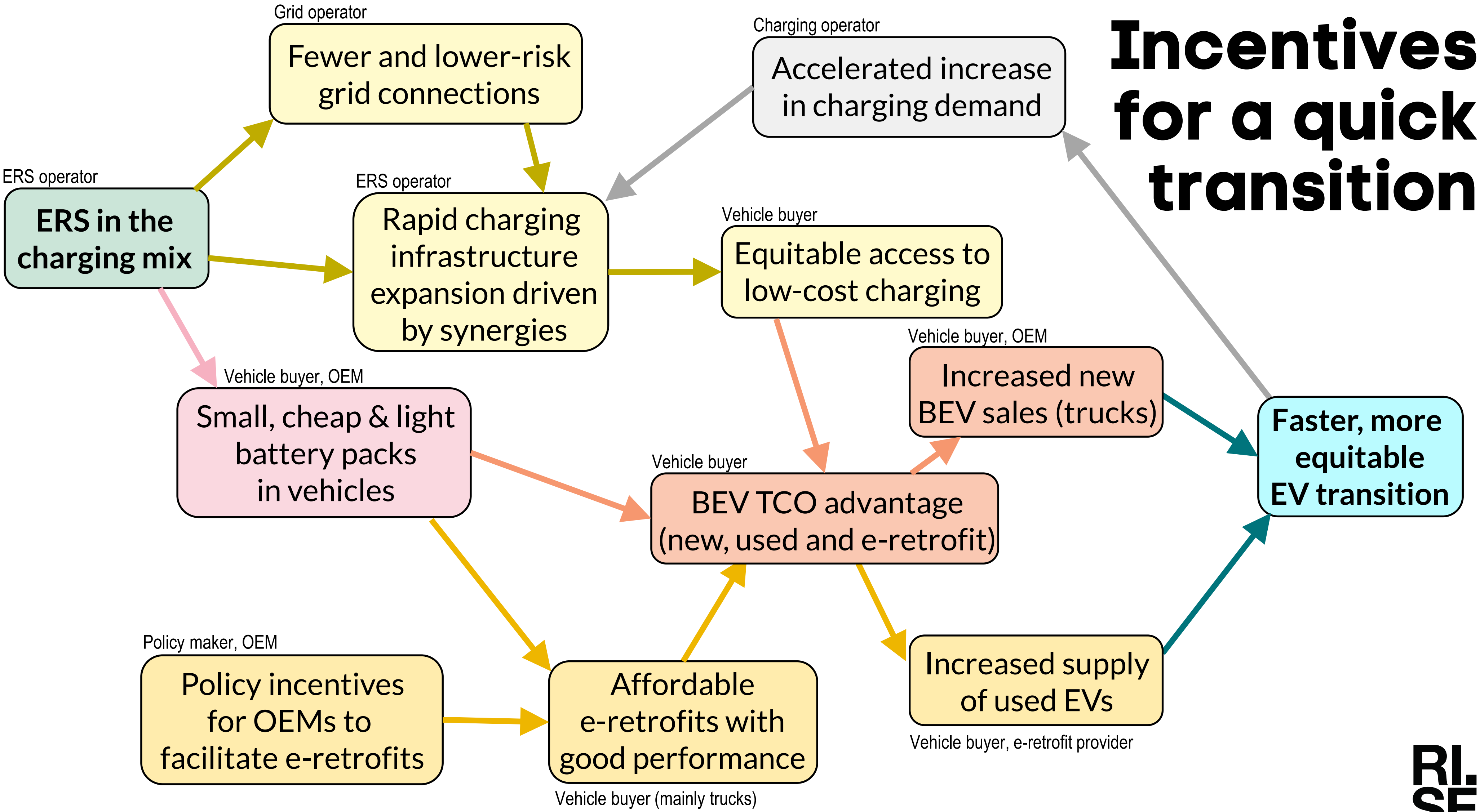


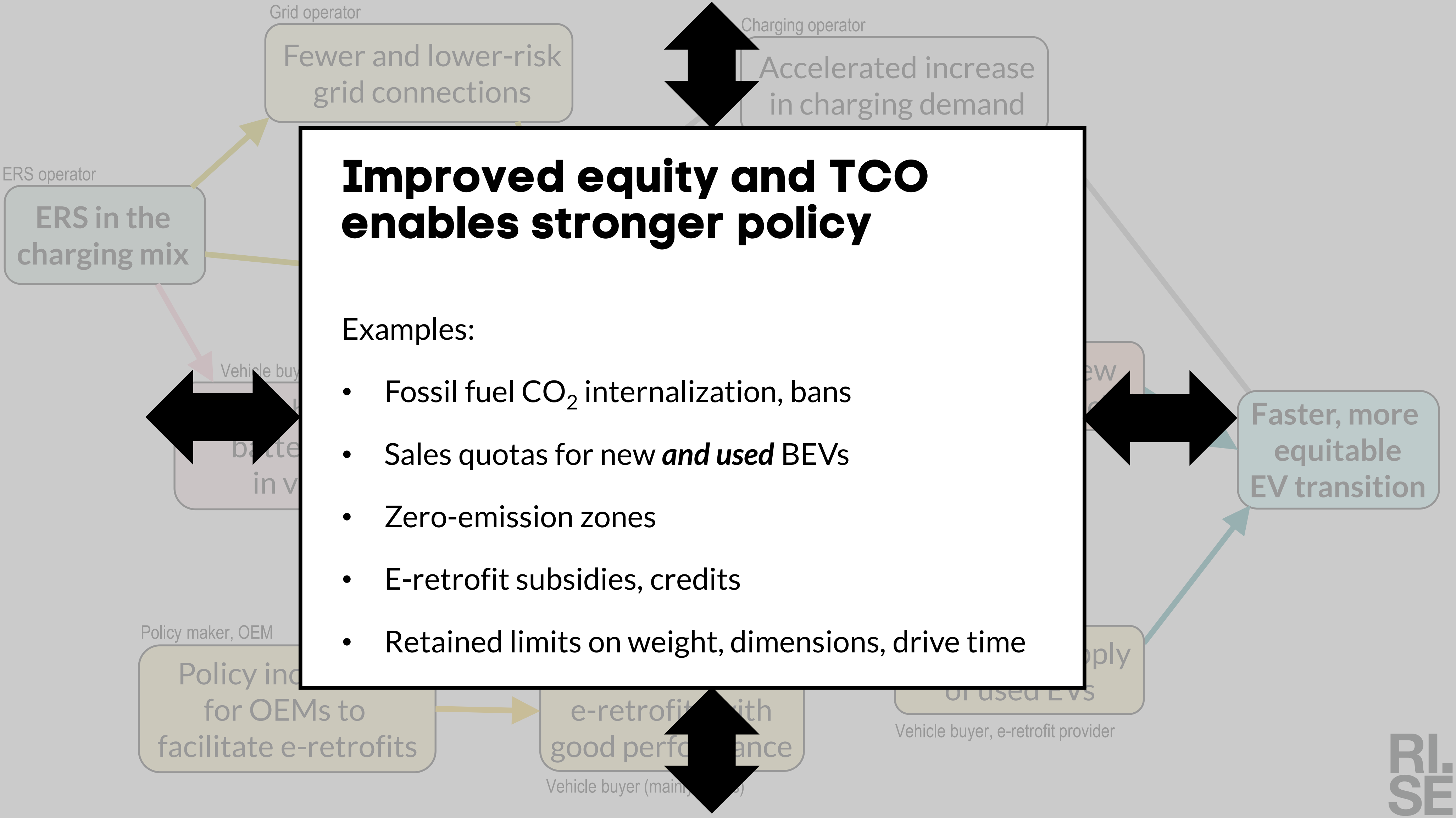
ERS makes economic sense where traffic is dense enough





Incentives for a quick transition





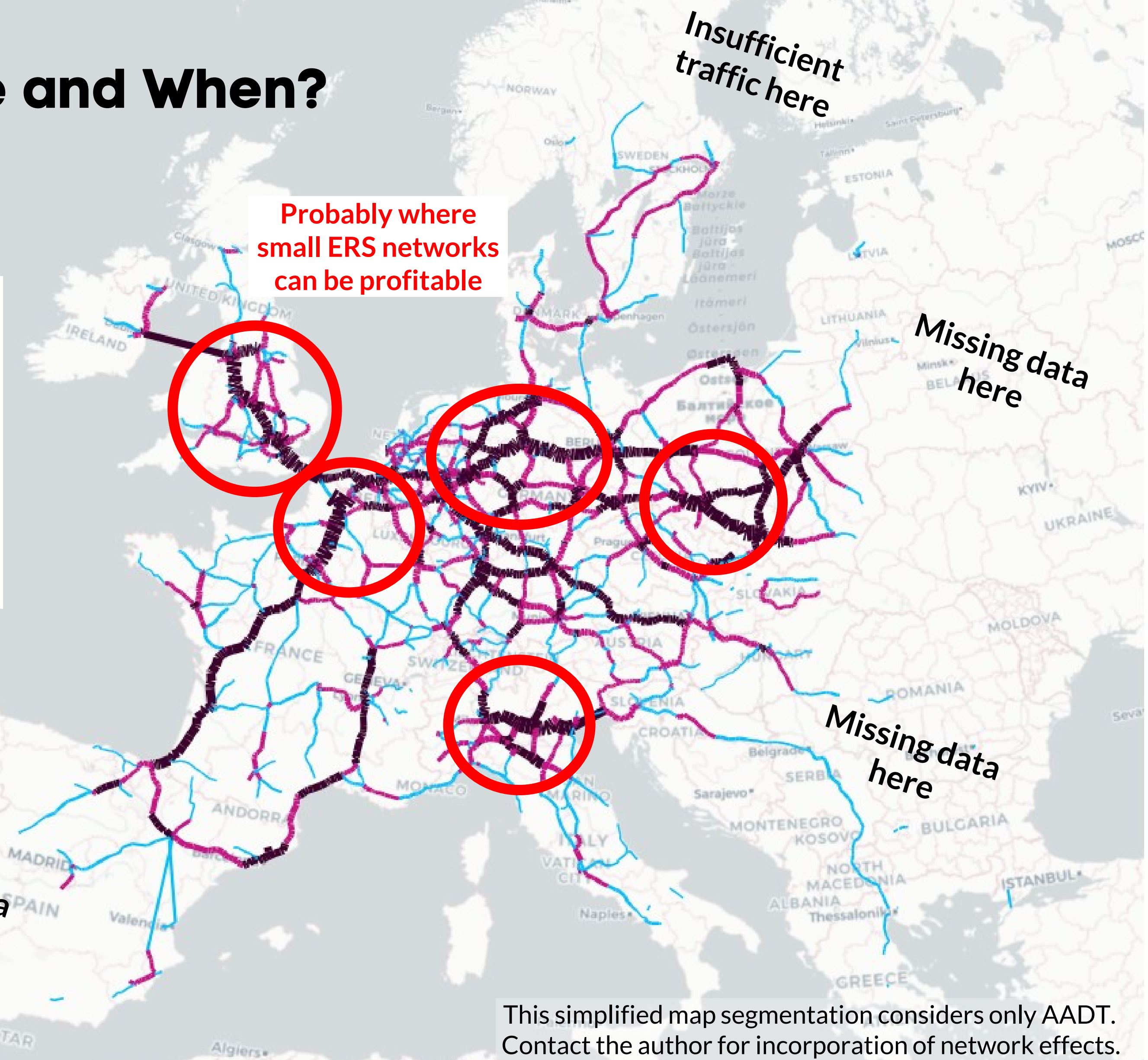
Improved equity and TCO enables stronger policy

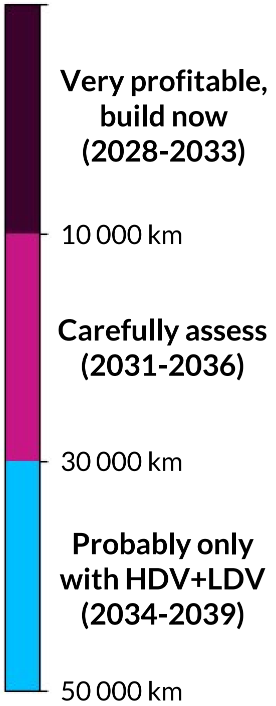
Examples:

- Fossil fuel CO_2 internalization, bans
- Sales quotas for new ***and used*** BEVs
- Zero-emission zones
- E-retrofit subsidies, credits
- Retained limits on weight, dimensions, drive time

ERS – Where and When?

ERS ROI calculator





This simplified map segmentation considers only AADT.
Contact the author for incorporation of network effects.

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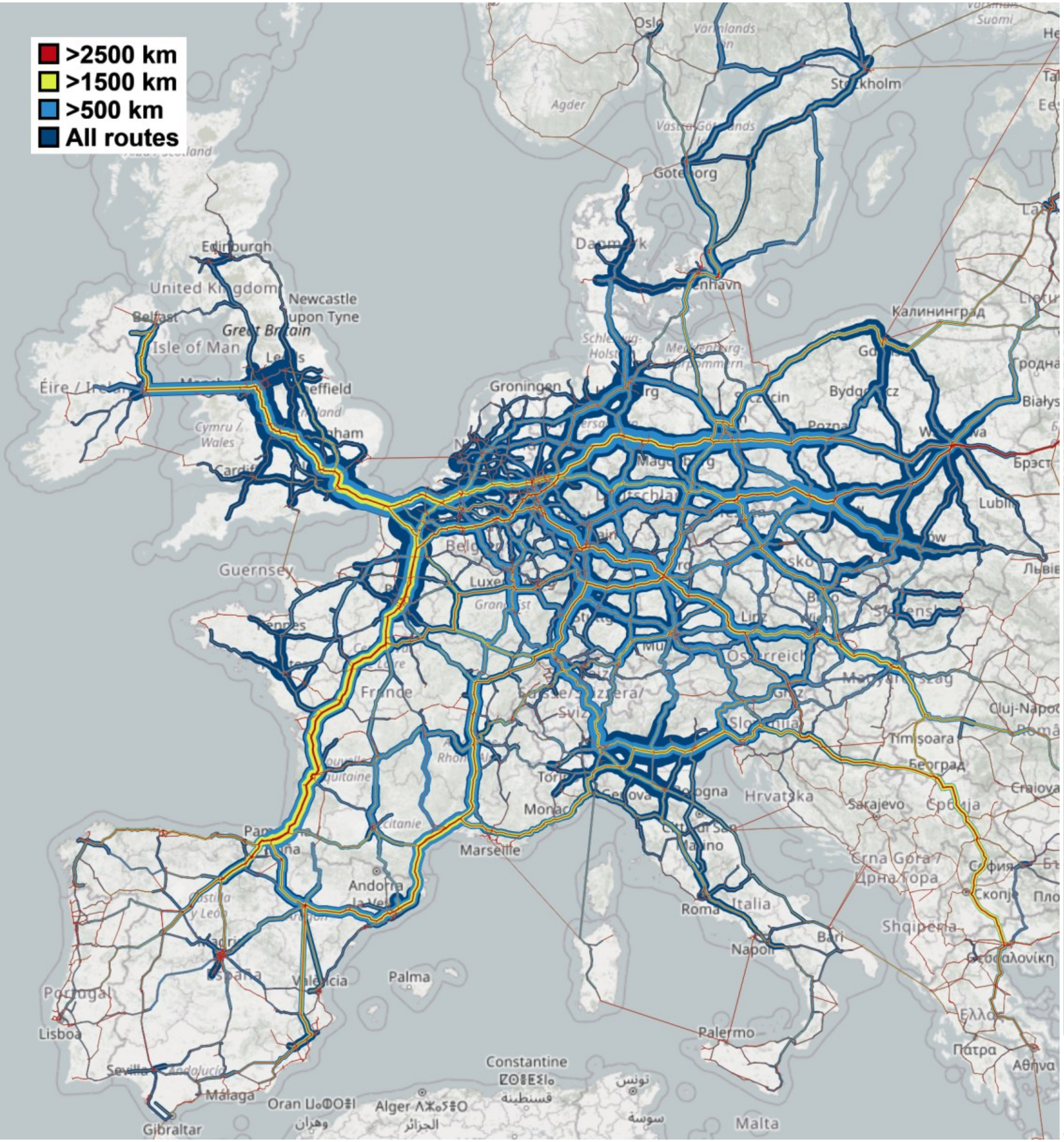
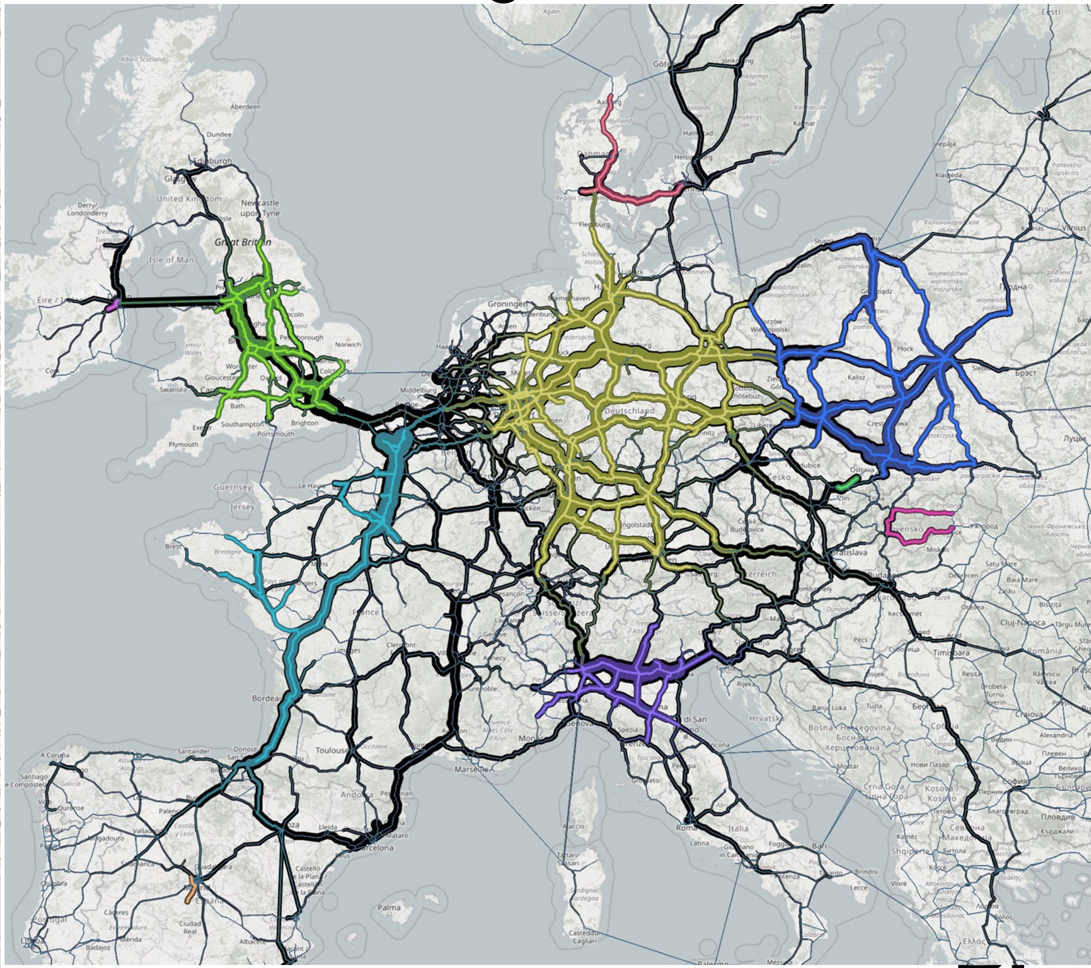
National no-regret ERS networks





source

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Steps towards a pan-European ERS network

- ERS must count towards AFIR targets
- Economies of scale and scope imply sequential concessions starting from profitable beachheads
- De-facto standards set by market seem more likely than political agreements
- De-risk ERS investments through market correcting policy/fee structures (see paper)
- Overbuild solar PV for cheap day-time electricity

Post-decarbonization benefits

- Road wear, cargo capacity, productive time, flexibility, robustness, geopolitical exposure

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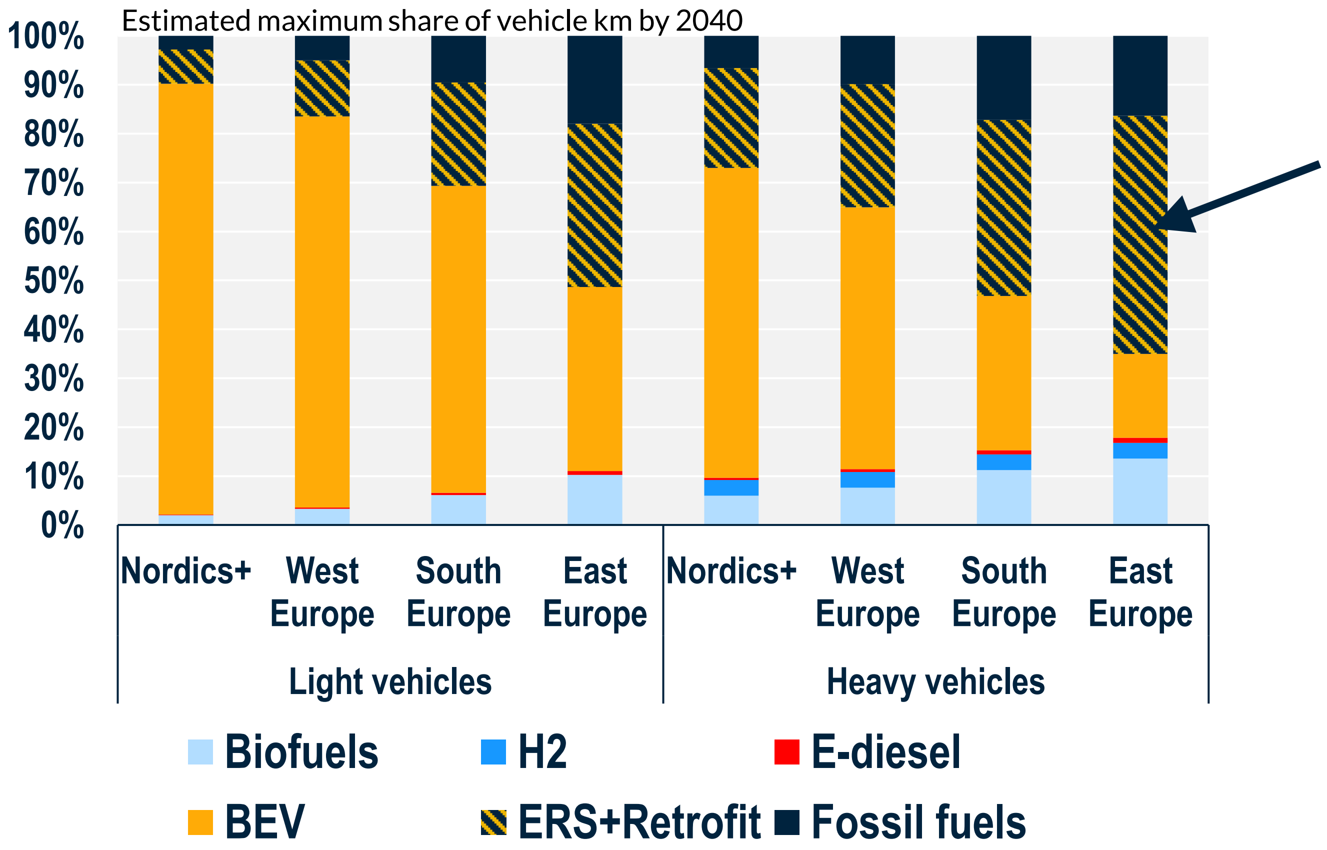
ERS Reduces CO_2 Emissions
(mainly if ERS enables e-retrofits)

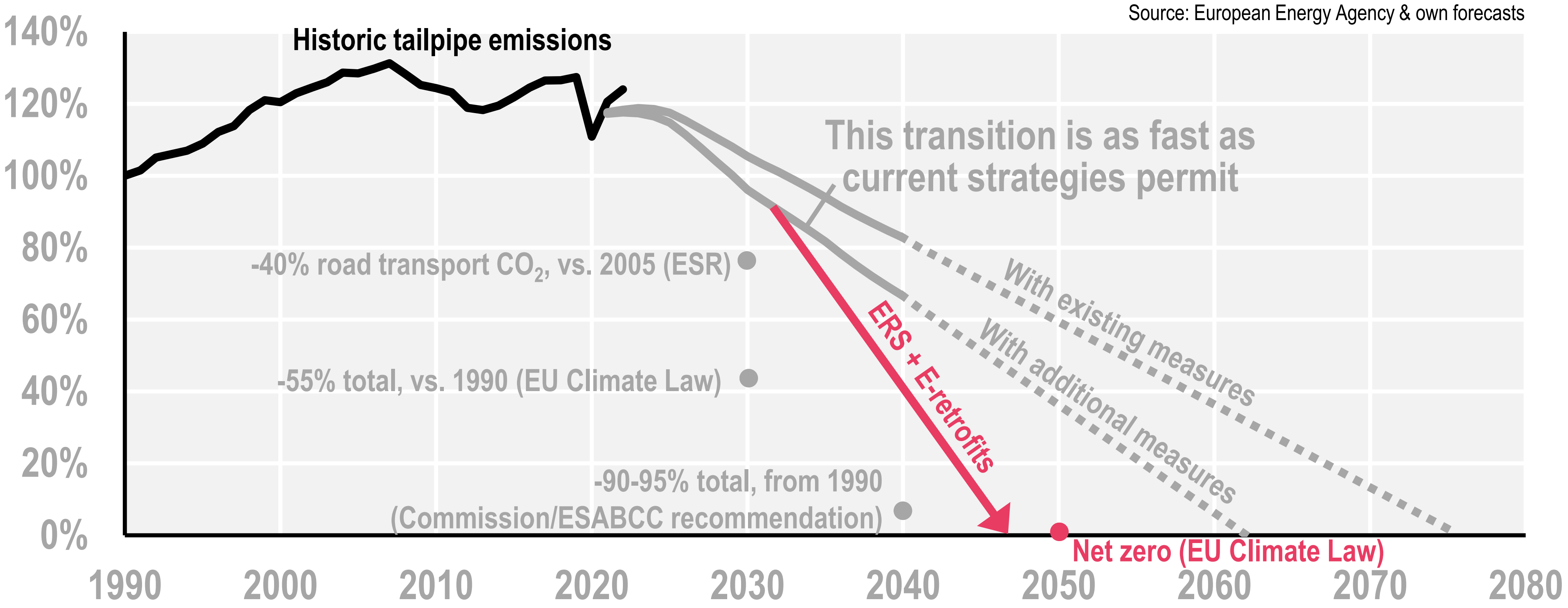


ERS may accelerate BET sales, but only if construction starts now

Small batteries being cost-optimal
+ reduced charging costs
+ continuous power delivery
= Better ROI for e-retrofits

source

EU Tailpipe CO_2 Emissions



Cumulative post-2020 road transport GHG emissions still 2-5x more than the EU's global fair share!

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Recap

- Industry and voter resistance to EU decarbonization policy today is rational and expected.
- Incentives could be corrected by a pan-European ERS network:
  - ERS investors want to scale quickly.
  - BEV TCO is improved by small batteries and cheap charging.
  - Good TCO, range and performance improves e-retrofit appeal.
  - E-retrofits and more new e-truck sales accelerate decarbonization.
  - Truck benefits are clear, car benefits are externalized.
  - Aligned incentives allow more ambitious and equitable decarbonization policy.

Contact

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List of publications

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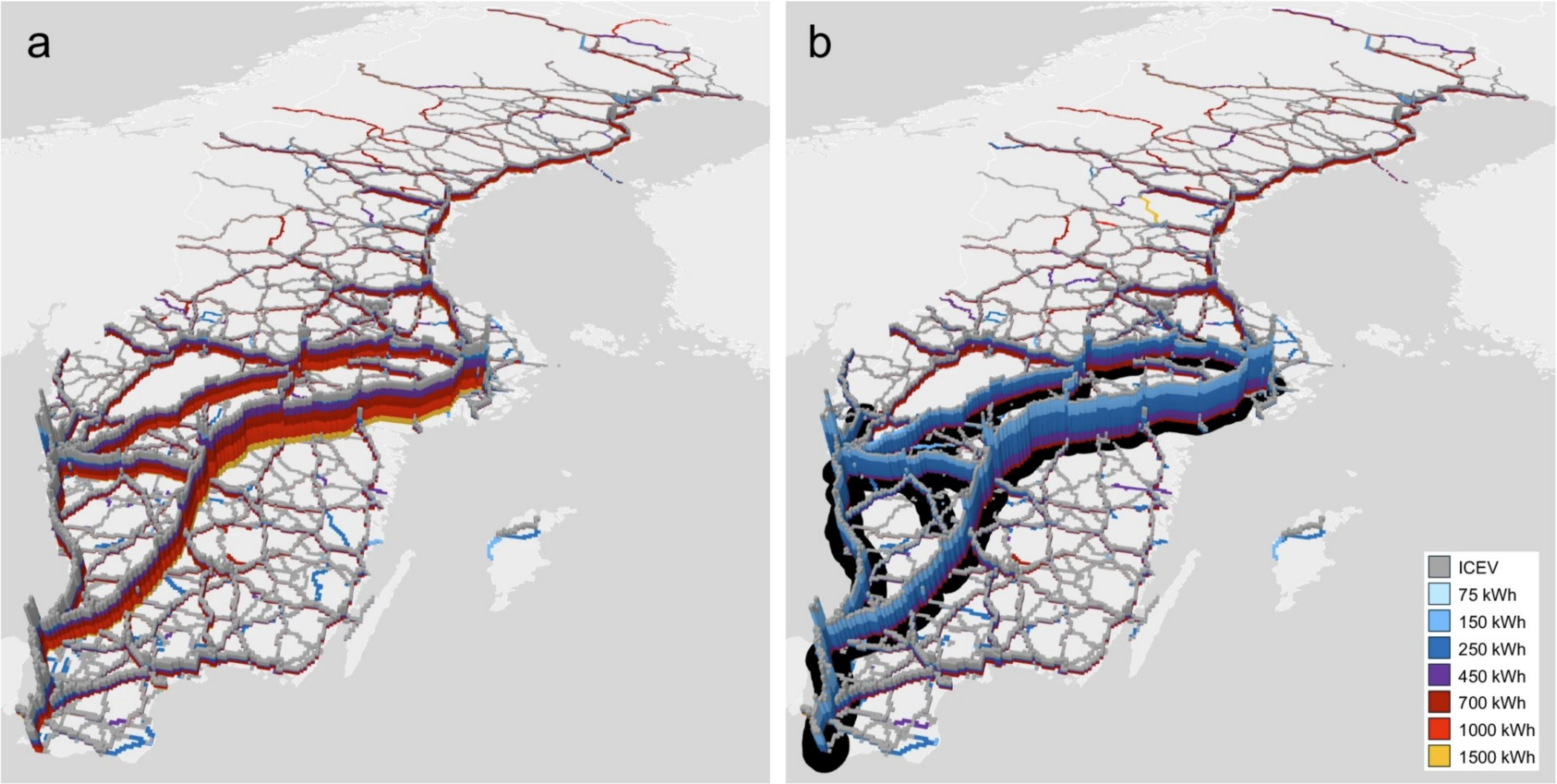
Extra slides

Fig. 3: Electric road system (ERS) impact on cost-minimizing battery capacity per truck.

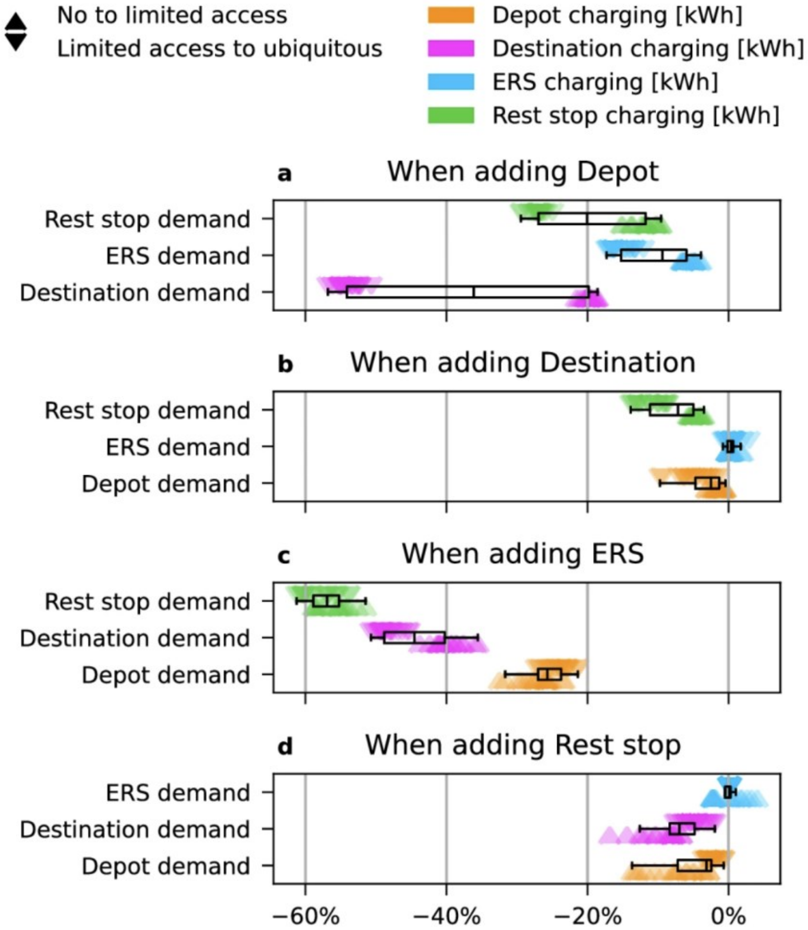
From: Correcting market failure for no-regret electric road investments under uncertainty



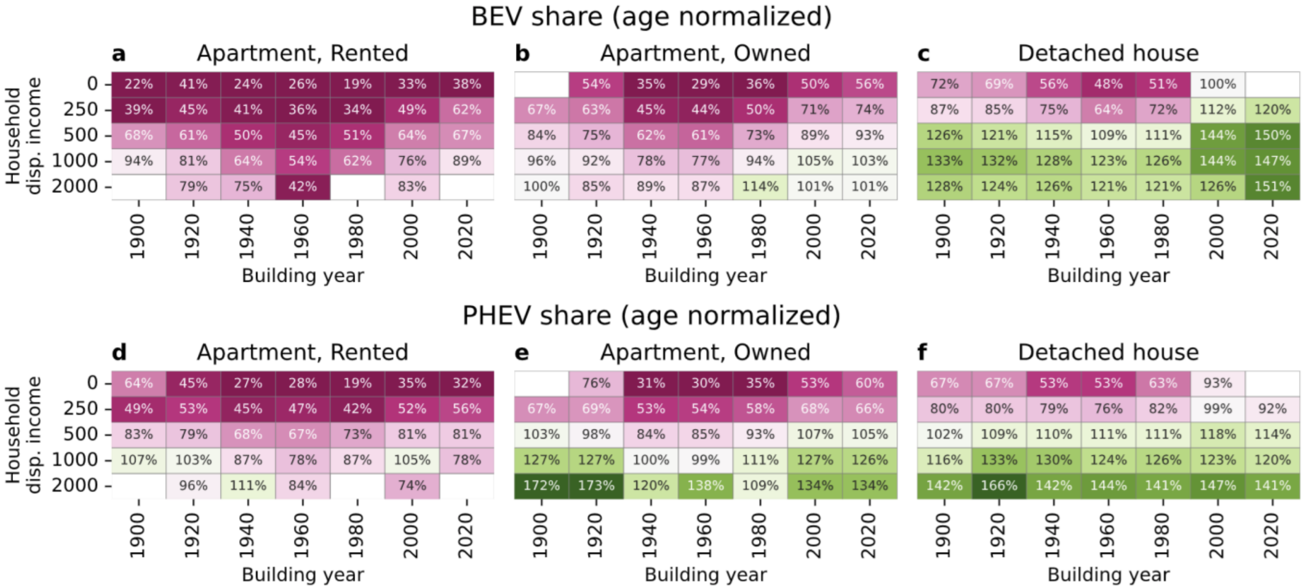
Access to ERS reduces the cost-minimizing usable battery capacity per vehicle by ~70% in this scenario. The effect size depends on location along the road network, year, ERS network scope, static charging infrastructure, and global model parameters. The maps show the Neutral scenario in 2035, **a** without ERS; and **b** with policy-supported ERS on a 2000 km road network. Black indicates where ERS is available; other charging infrastructure is present but not shown. Bar height indicates traffic volume (vehicles per day), and color indicates the share of that traffic from vehicles equipped with different usable battery capacities (75–1500 kWh, light blue–orange). Country shapes from geoBoundaries[39], licensed under CC BY 4.0.

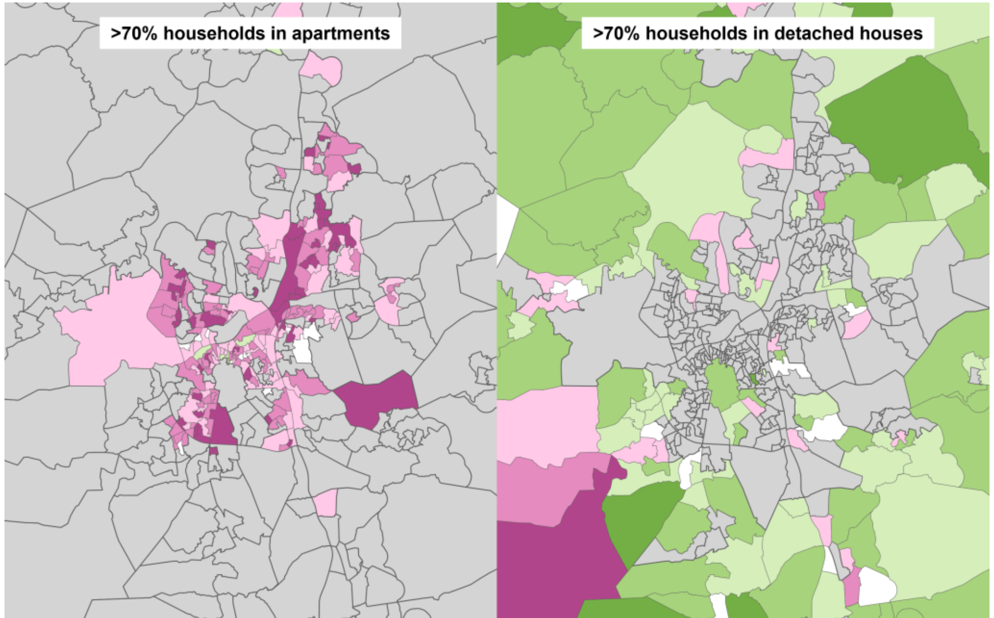
Fig. 6: Substitution and synergy effects.

From: Correcting market failure for no-regret electric road investments under uncertainty

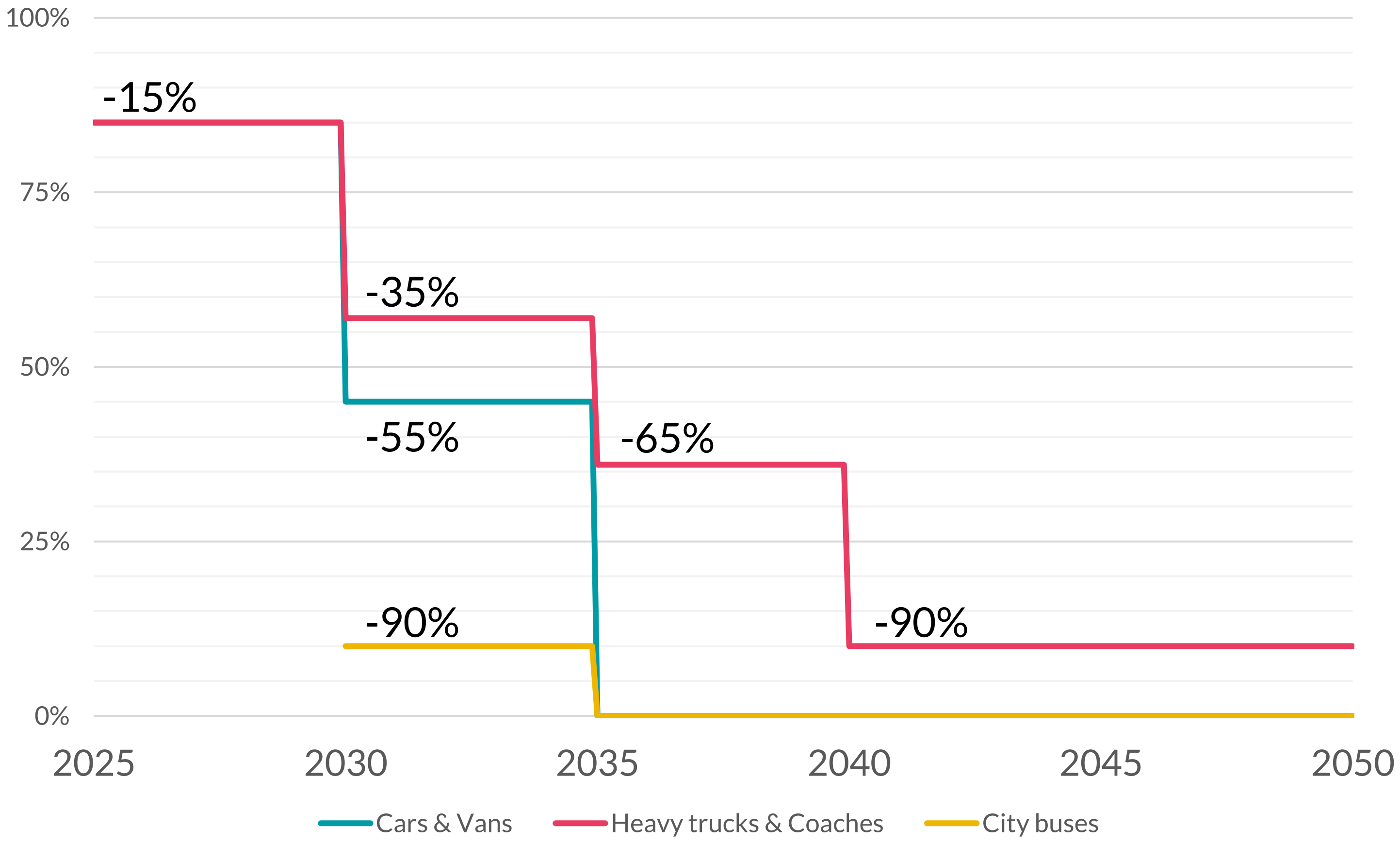


When additional charging infrastructure is introduced into the system, this can compete with or support existing infrastructure. Each marker shows the change in total delivered energy from one step of increase in the availability of another type of infrastructure ($n = 54$ samples per type). See "Experimental design" for details. Adding ERS to the charging mix (subplot **c**) reduces demand for fast charging at rest stops by 50–60% (green), at destinations by 35–50% (magenta), and slower charging at depots by 20–30% (orange). Depot charging is a direct substitute for destination charging (**a**, magenta), though this effect may be overestimated by the representation of traffic as routes between origin-destination pairs. Demand for ERS charging is insensitive to static charging availability (subplots **a**, **b** & **d**, light blue). Boxplots extend from the first quartile to the third quartile of the data, with a line at the median. The whiskers extend from the box to the farthest data point lying within 1.5× the inter-quartile range from the box. Effect sizes vary with global model parameter assumptions, local transport patterns, and local road network conditions.


BEV share (age normalized)
a Apartment, Rented
b Apartment, Owned
c Detached house
Household disp. income
0
250
500
1000
2000
22% 41% 24% 26% 19% 33% 38%
39% 45% 41% 36% 34% 49% 62%
68% 61% 50% 45% 51% 64% 67%
94% 81% 64% 54% 62% 76% 89%
79% 75% 42% 83%
54% 35% 29% 36% 50% 56%
67% 63% 45% 44% 50% 71% 74%
84% 75% 62% 61% 73% 89% 93%
96% 92% 78% 77% 94% 105% 103%
100% 85% 89% 87% 114% 101% 101%
72% 69% 56% 48% 51% 100%
87% 85% 75% 64% 72% 112% 120%
126% 121% 115% 109% 111% 144% 150%
133% 132% 128% 123% 126% 144% 147%
128% 124% 126% 121% 121% 126% 151%
1900 1920 1940 1960 1980 2000 2020
Building year
PHEV share (age normalized)
d Apartment, Rented
e Apartment, Owned
f Detached house
Household disp. income
0
250
500
1000
2000
64% 45% 27% 28% 19% 35% 32%
49% 53% 45% 47% 42% 52% 56%
83% 79% 68% 67% 73% 81% 81%
107% 103% 87% 78% 87% 105% 78%
96% 111% 84% 74%
76% 31% 30% 35% 53% 60%
67% 69% 53% 54% 58% 68% 66%
103% 98% 84% 85% 93% 107% 105%
127% 127% 100% 99% 111% 127% 126%
172% 173% 120% 138% 109% 134% 134%
67% 67% 53% 53% 63% 93%
80% 80% 79% 76% 82% 99% 92%
102% 109% 110% 111% 111% 118% 114%
116% 133% 130% 124% 126% 123% 120%
142% 166% 142% 144% 141% 147% 141%
1900 1920 1940 1960 1980 2000 2020
Building year


>70% households in apartments
>70% households in detached houses

EU emissions quotas
(average CO_2 intensity average for new vehicle sales)



ERS benefits

Short-term

Long-term

- Quicker transition, due to corrected incentives
- In-vehicle battery savings
- Cap on public charging cost
- Increased productive time
- Improved freight robustness and flexibility(?)
- Less geopolitical exposure
- Road wear (or cargo capacity) savings

ERS challenges

- Greater up-front infrastructure investment cost
- Incentives for road operator
- Incentives for use by light-duty vehicles
- Cost of extra lanes for light-duty vehicles
- Winners have weak lobbying power

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