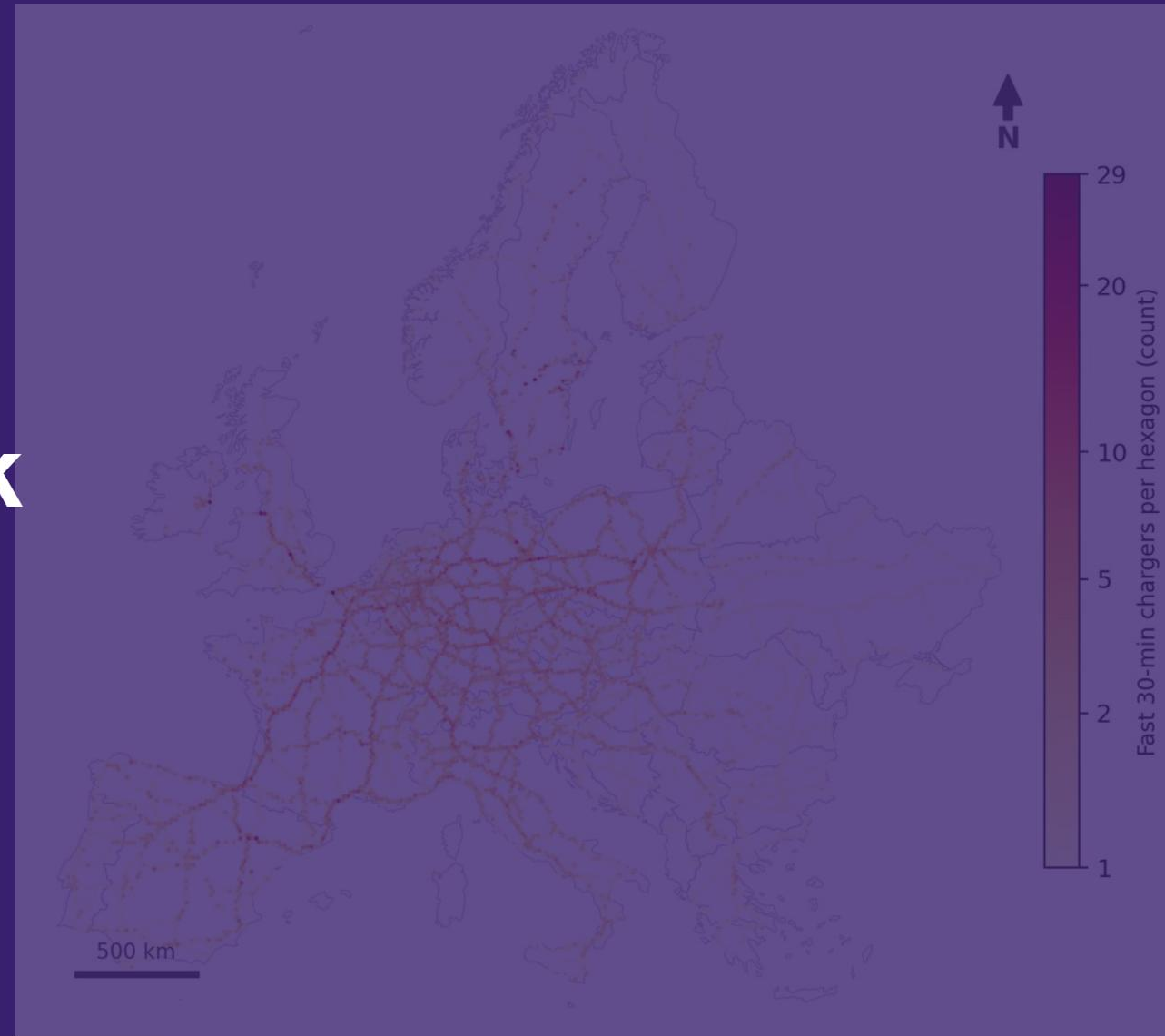


What Europe's truck charging network will cost



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Agenda

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|-----------|--------------------------------------|---|
| 01 | Related previous work | The network being priced, and the design choices that set its size. |
| 02 | From charging points to euros | Five cost streams, two scenarios, one method. |
| 03 | What the network costs | About nine billion euros a year, and where that money goes. |
| 04 | Which choices move the money | Waiting time, technology, the daily peak. |
| 05 | What it means for policy | Where a planner should spend attention. |

THOR: where trucks stop, and what they need

A model of Europe's long-haul freight, built to answer one question: if these trucks were electric, where would they charge?

01

Trace each route

Every origin-to-destination freight flow is driven over the real road network, a point every ten kilometres.

**02**

Apply the driving rules

European law along the route: a 45-minute break after 4.5 hours at the wheel, a 9-hour rest after nine.

**03**

Sort the stops

A break needs power quickly. A rest has all night. Two different machines.

**04**

Attach the energy

Distance driven and speed give the energy each truck draws at each stop.

**05**

Group by place

Stops are summed onto equal-area cells. 6,283 of them carry break demand, and each is sized as its own queue.



The result is not one number for Europe. It is a charging requirement for every location, built from the trips that actually pass through it and the time a driver is allowed to drive.

THOR is a trip-based model of heavy-goods traffic across Europe, developed at Chalmers. It runs for the year **2030**, using national forecasts of how many trucks will be electric by then.

A charging area is a queue

Three quantities describe it, and each of them becomes a cost later in this talk.

TRUCKS ARRIVE



λ — trucks per hour, from the freight flows.
Nobody books a slot, so they arrive independently.

THEY WAIT



W_q — the wait for a free point. Held to five minutes here, and paid for as a driver's time.

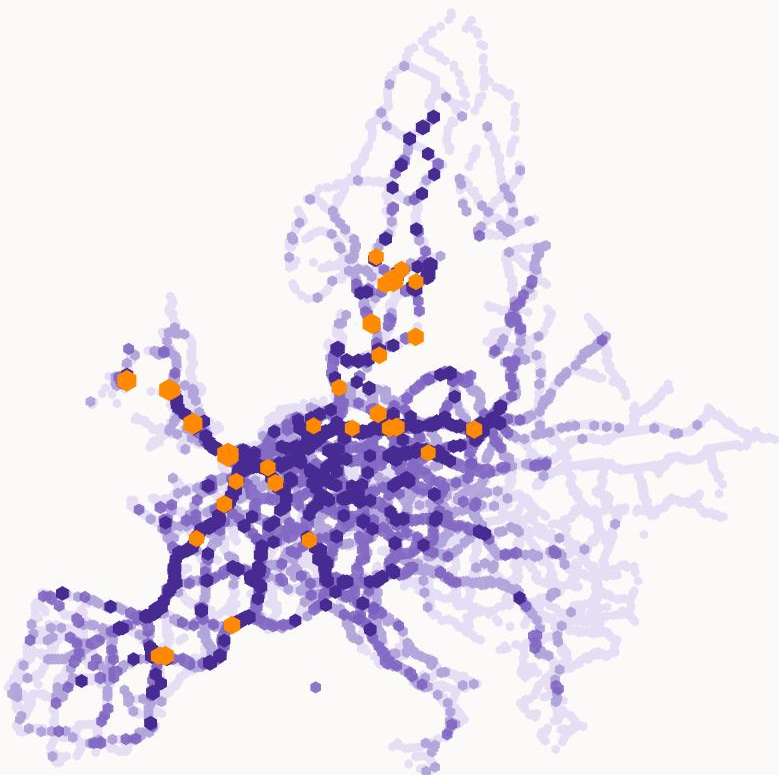
THEY CHARGE



c points — each one a machine that is bought, given ground to stand on, and fed electricity.

The charging network

Every location sized so that a driver waits no more than five minutes.



- 1 charging point
- 2 points
- 3 to 4 points
- 5 to 9 points
- 10 or more — the corridor hubs

TWO KINDS OF STOP, SO TWO KINDS OF CHARGER

 **11,878** megawatt charging points
for the 45-minute break — about 1,100 kW

 **29,882** overnight charging points
for the 9-hour rest — above 100 kW

6,283 demand areas, each sized as its own queue

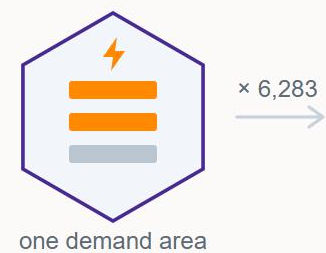
36 countries, from Portugal to Finland

A demand area is a hexagon of about 240 square kilometres, roughly 17 by 19 km. Every one of them is sized on its own, and the network is what they add up to.

Five design choices, and what each one does

The number of chargers is not a fact. It has to do with the quality of service and demand variability within the charging areas.

DESIGN CHOICE	RANGE TESTED	EFFECT ON POINTS		
Waiting-time target	3 to 30 minutes	+8% to -18%	The strongest factor a regulator can simply set.	DECIDE FIRST
Session duration	60 to 15 minutes	+55% to -29%	Technology moves it more than policy does.	LIMITED BY POLICY
Arrival variability	1 to 3	0% to +18%	Clustered arrivals only ever cost more.	A ONE-SIDED RISK
Daily peak factor	1.0 to 2.0	0% to +12%	The daily average leaves the afternoon short.	A ONE-SIDED RISK
Utilisation cap	0.50 to 0.99	+14% to 0%	Above 0.90 it changes nothing.	SETTLED

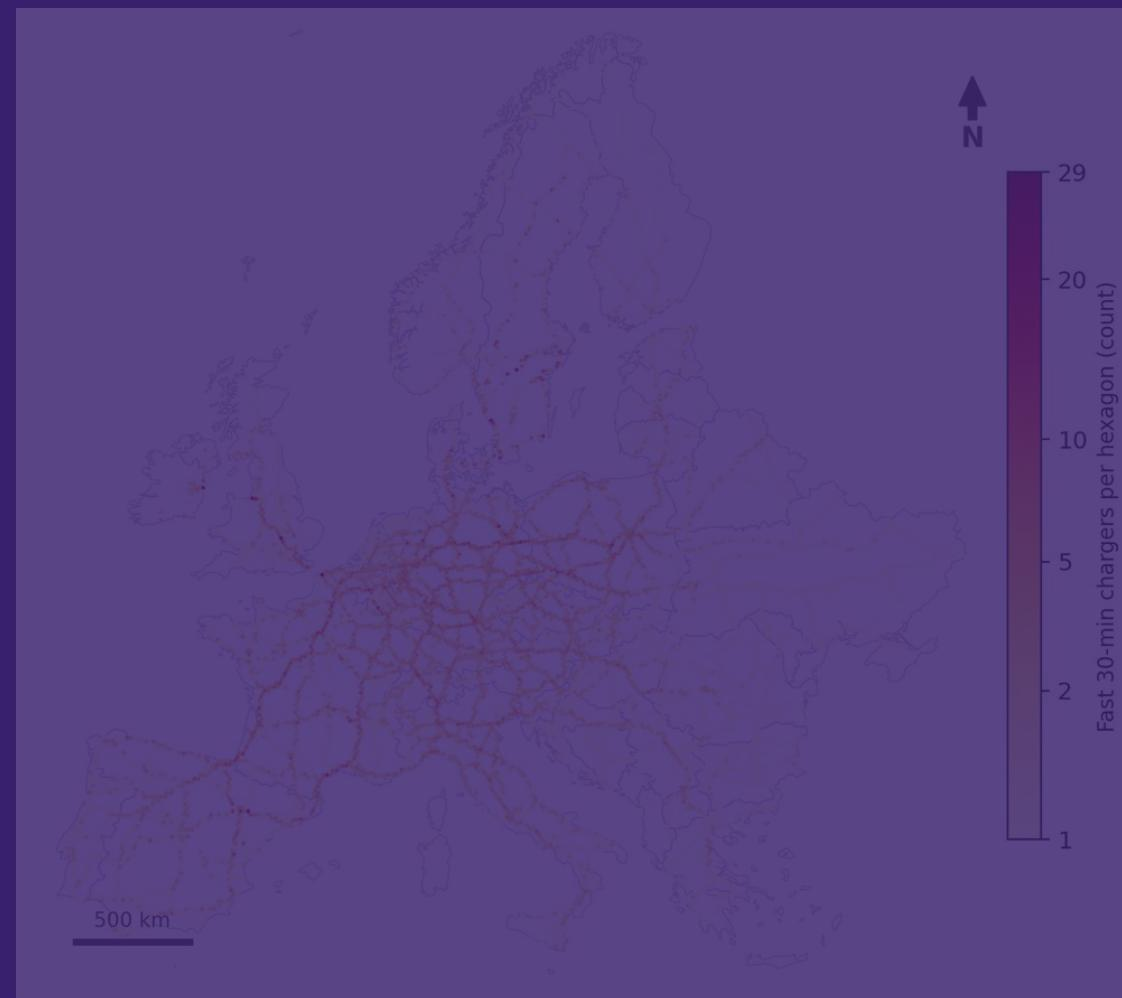


Every one of these five is applied inside one demand area. Holding the charging points that serve the trucks passing through it, and each one is sized as its own queue. Change any factor above and the number of charging points changes in all 6,283 of them.

PART TWO · THE MONEY

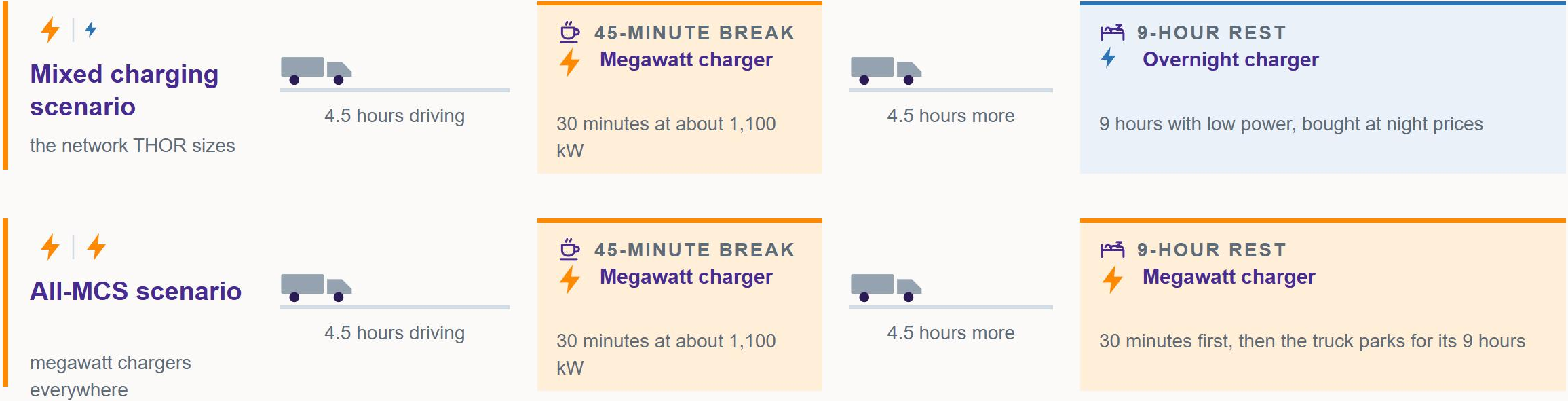
What does it cost?

Five cost streams, added up for the whole of Europe, then re-run for every design choice and for a second technology scenario.



Two ways to charge the same truck

The driving day is identical in both. Only the machine standing at each stop changes — and that one choice moves every cost on the next slide.



WHAT THAT CHANGES — THE FIVE COSTS PRICED ON THE NEXT SLIDE

	Charger hardware	Electricity	Driver waiting	Driver session	Land
Mixed	two kinds of machine	rest energy bought at night	a queue at the break, another at the rest	none	lanes plus overnight parking
All-MCS	one kind, and fewer of them	all of it bought by day	one shared queue	30 minutes out of the working day	charging lanes only

METHOD

From charging points to euros

Every design choice changes the network, and every network carries the same five annual costs. Add them up and a design question becomes a money question.

	Charger hardware IC	Charger hardware, spread over ten years. €300k per megawatt point, €80k per overnight point.	 Operator
	Electricity EC	Energy delivered, priced per country and split by time of day.	 Logistics
	Driver waiting WTC	Time a driver spends queueing, valued at a country-specific hourly rate.	 Logistics
	Driver session STC	Charging time that would otherwise have been rest time. Zero in the Mixed charging scenario; positive only when an overnight rest is replaced by megawatt charging.	 Logistics
	Land LC	Ground occupied, charged as the rent it gives up, at a researched land price for each country.	 Operator

TWO NETWORKS COMPARED

Mixed charging scenario

Megawatt points for the 45-minute break, slower overnight points for the 9-hour rest. Each stop uses the charger that suits it.

All-MCS

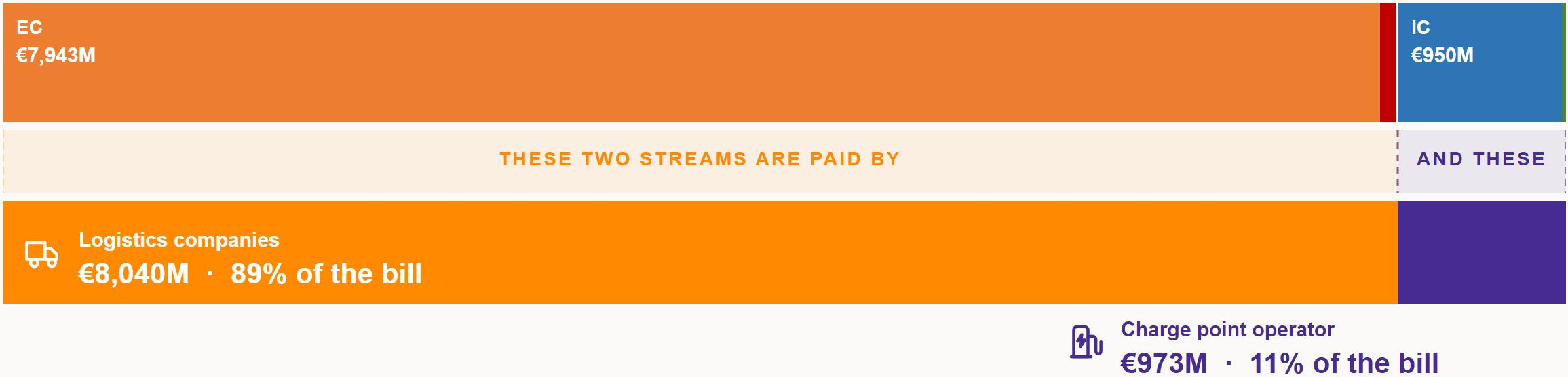
Megawatt points for every stop, break and rest together in one shared queue. Fewer machines, but they are the expensive kind and they are used at the wrong time of day.

Both are sized with the same queueing model and priced with the same five streams, so the difference between them is a design result, not an assumption.

The 2030 network costs about €9 billion a year

The Mixed charging scenario. The striking part is not the total, but how little of it is the chargers.

annual cost of the Mixed charging scenario, €9,012M in total

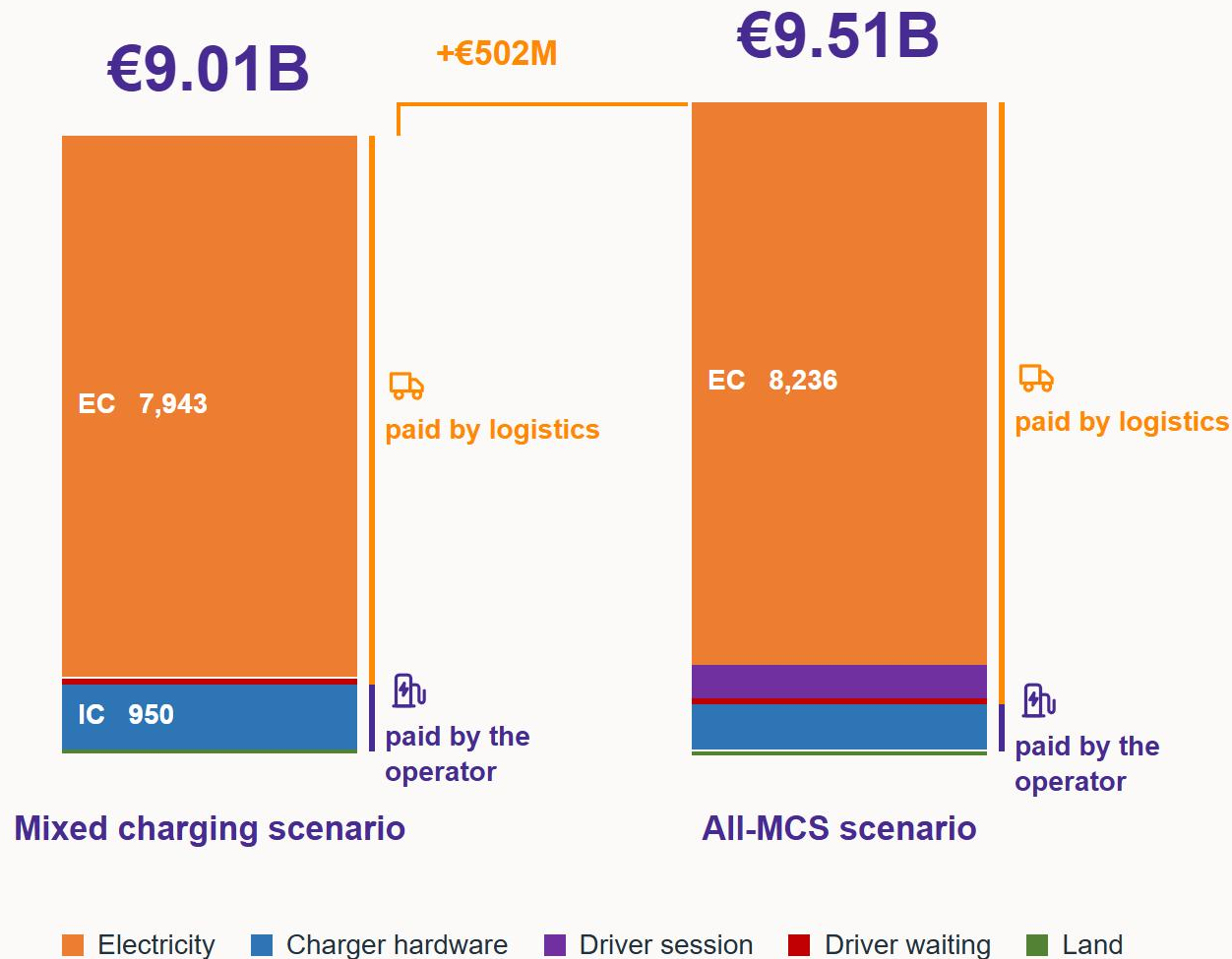


Nine tenths of the bill lands on logistics, and almost all of that is electricity.

A ten per cent tariff cut is worth more than every charger in Europe.

Two ways to build it, priced the same way

Same trucks, same stops, same service standard. Only the choice of charger differs.



COMPARED WITH THE MIXED CHARGING SCENARIO

All-MCS needs fewer chargers. One shared queue instead of two, so the operator spends €277M a year less on machines.

All-MCS buys its energy by day. Overnight charging moves into daytime prices, so logistics pays €293M a year more.

All-MCS takes half an hour from the working day. A truck must charge before its rest can start, so logistics pays €494M a year more.

Every cost lands on one of two parties

The Mixed charging scenario again, with the same five streams sorted by who writes the cheque. The band at the bottom of each column is what changes for that party if the network is built all-megawatt instead.

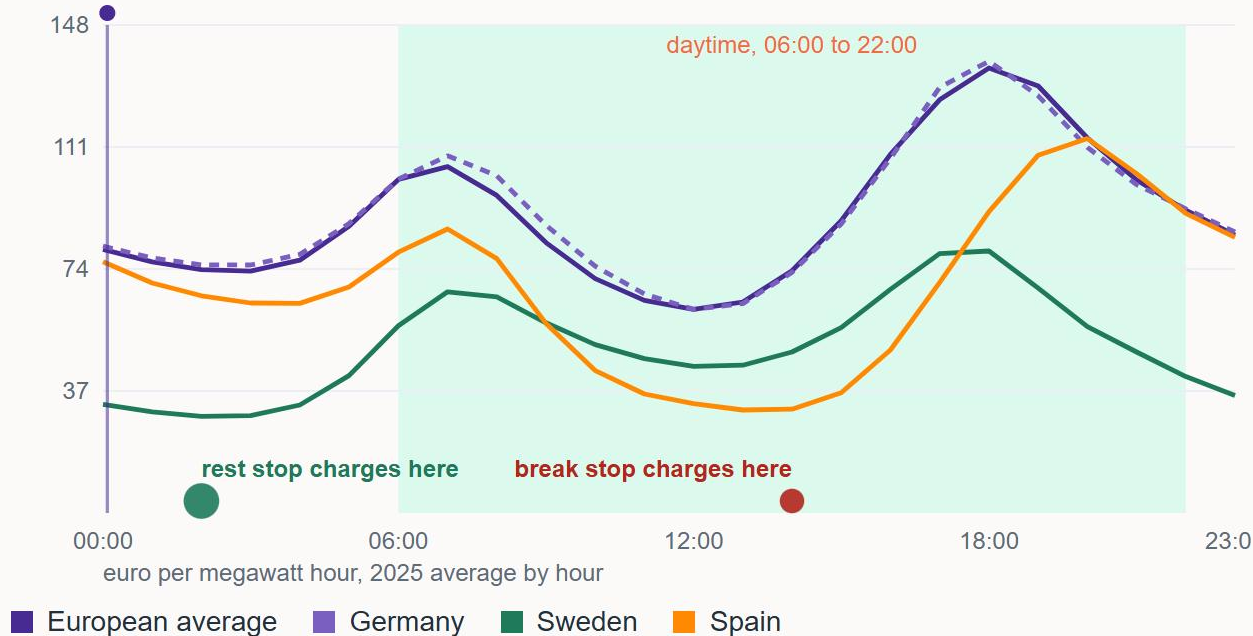
	The charge point operator	€973M
	Charger hardware The machines, spread over ten years	€950M
	Land The ground they stand on	€23M
BETTER UNDER ALL-MCS Fewer machines: one shared queue instead of two.		-€292M

	Logistics companies	€8,040M
	Electricity The energy, bought through the charging price	€7,943M
	Driver waiting Time a driver spends waiting for a free point	€97M
	Driver session Charging time taken out of the working day	€0M
WORSE UNDER ALL-MCS Daytime energy prices, and half an hour out of the working day.		+€794M

RESULT 4 · WHEN THE ENERGY IS BOUGHT

The hour of the day sets the price

Measured 2025 prices, averaged by hour. Breaks charge in the shaded hours; rests do not.



The average hides what matters. Germany is flat, the Nordics are far cheaper at night, Iberia runs the other way.

DAYTIME PRICE DIVIDED BY NIGHT-TIME PRICE

Finland	2.04	nights are close to free
Sweden	1.71	hydro and wind, cheap after dark
Germany	1.18	tracks the European average
France	1.17	close behind Germany
Spain	0.90	solar makes the daytime cheaper

1.00 means day and night cost the same

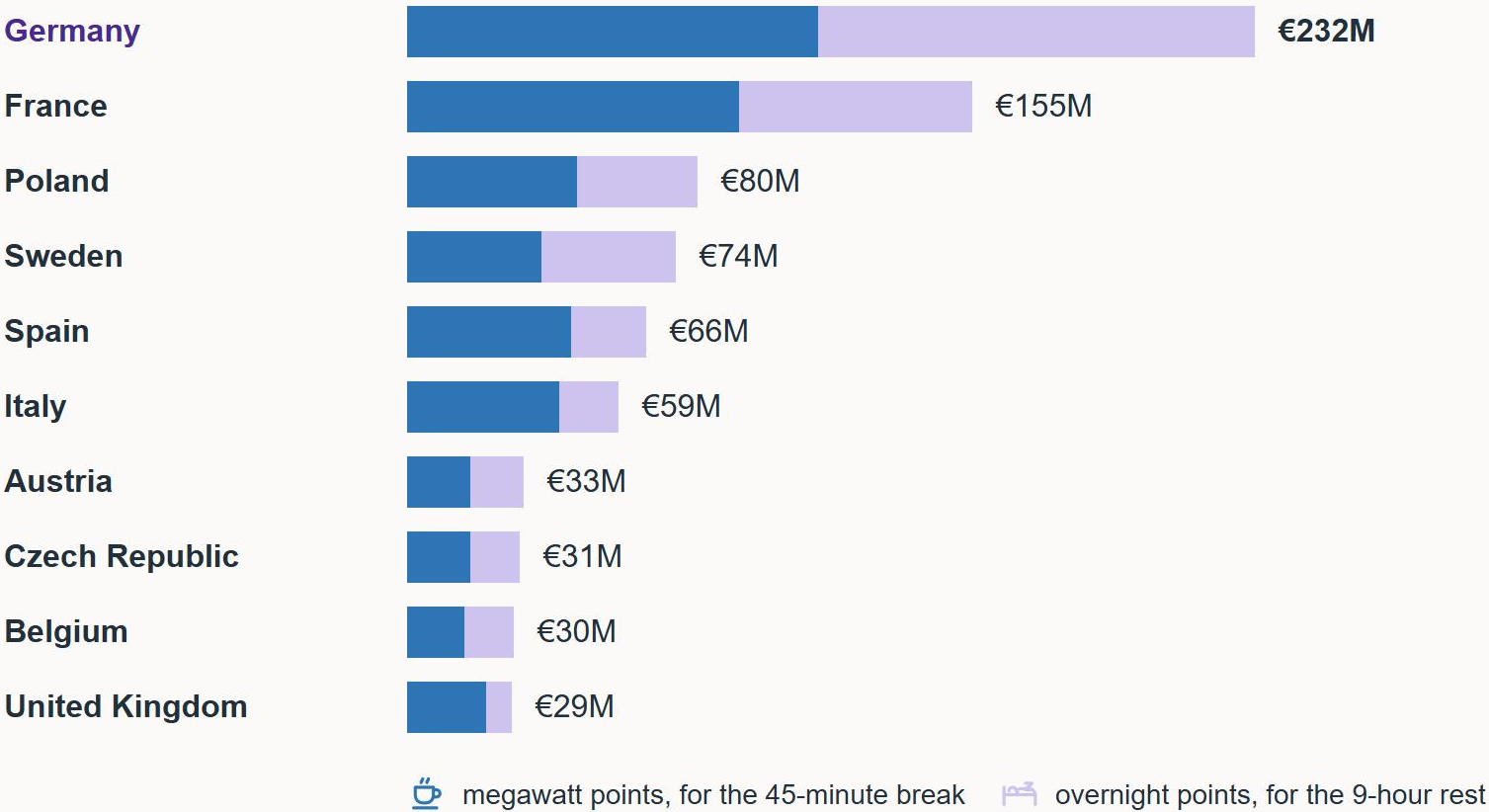
WHY IT MATTERS HERE

Break charging happens in the expensive hours and overnight charging in the cheap ones. Moving rest charging into the daytime pays the daytime price for energy that could have been bought at night: **€293M a year** across Europe. Solar is closing the gap, and in Iberia it has already reversed it.

Source: 2025 day-ahead prices, 21 bidding zones. The day and night ratio is applied only to the wholesale part of the bill (55%); network charges follow a fixed split and taxes stay flat.

Six countries carry two thirds of the hardware

The money follows the freight corridors, not the population.



READING THIS

Germany alone is about a fifth of the European hardware bill, and most of that is overnight points rather than megawatt chargers, because most stops are rests.

These are transit countries. Much of the demand they host neither starts nor ends there, which is a question about who pays.

Charger hardware is about a ninth of the annual cost of the network.

Computed from the per-country charging-point counts at €300k per megawatt point and €80k per overnight point, annualised at 15.95% a year. Equipment only.

The wait you promise barely changes the bill

Between three and thirty minutes the total cost moves by less than three per cent.

extra cost per year, against the cheapest setting

3 minutes

a tighter promise



+€9M a year

buys chargers that are rarely used

5 minutes

the convention today



cheapest

the cheapest of the three

30 minutes

a looser promise



+€205M a year

spends drivers' time instead

So the waiting-time standard is a decision about service, not about money. Five minutes is already the cheapest of the three, which means the promise we make to drivers costs almost nothing to keep.

Both of the costs that decide it fall on logistics

Neither arrives as an invoice, which is why a hardware comparison misses them.

 **+€494M**

The driver's own time

Charging for thirty minutes before a nine-hour rest is not rest. It comes out of the working day.

 **+€293M**

Energy bought within busy hours

Night energy is cheap energy. Charging the rest stops by day buys the same kilowatt hours at the daytime price.

Together €788M a year, against a hardware saving of €277M that the operator keeps.

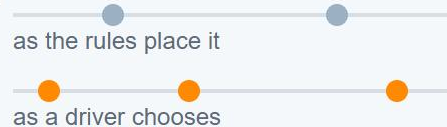
Count only the machines and you reach the opposite conclusion, and you bill the wrong party.

Four things this model cannot yet answer

Each one is a number in this talk that is, for now, a single assumption.

When drivers actually charge

Every truck charges where the driving rules put it. Real drivers top up early, skip a stop, or wait for a cheaper hour.



→ moves where the demand lands

What the electricity really costs

One retail price per country. A real bill also charges for the peak power a site draws, which one point and a hub of eight pay very differently.



→ moves the €7.9B energy bill

Which technology, and where

Megawatt and overnight charging are treated as two fixed choices. They are really a mix that can differ by location, corridor and hour.



→ moves the €502M between scenarios

Whether the network holds up

A surge, a closed corridor, a site out of service or a cold snap all push traffic somewhere it was not sized for.



→ changes whether it works at all

The first three change what the network costs. The fourth changes whether it works.

CONCLUSIONS

Four things to take away

From the five-stream cost model, applied to the same 2030 network part one sized.

1

Electricity is the system

€7,943M a year, 88% of the total, about eight times the charger bill. A ten per cent tariff cut is worth more than every charger in Europe.

2

Megawatt charging belongs at the break, not the rest

Using it everywhere costs €502M a year more, because of daytime energy and the driver's own time, not because of the machines.

3

Nine tenths of the bill lands on logistics

The operator carries €973M of chargers and land. Logistics carries €8,040M of energy and drivers' time. Any policy aimed at the cost of this network has to reach the party that actually pays it.

4

Five minutes is already right

Between three and thirty minutes the total moves by under three per cent, with the minimum at the convention in use today. Spend the argument elsewhere.

THANK YOU

Questions

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