The Race Beyond Diesel

The Cost Realities of Zero-Emission Trucking

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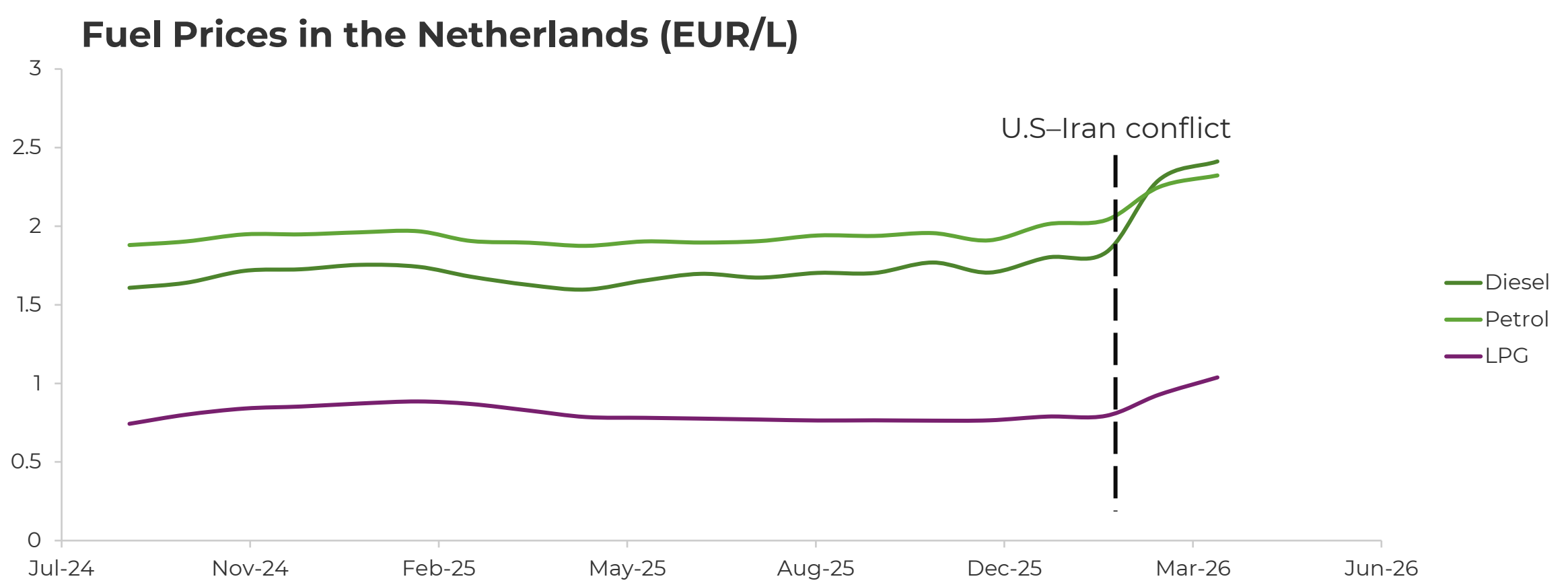
Freight transportation is under growing pressure to decarbonize

~5% of global CO_2 emissions come from heavy-duty trucks.

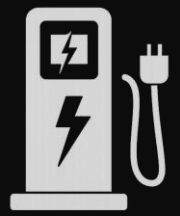
Freight volumes continue to rise across major markets.

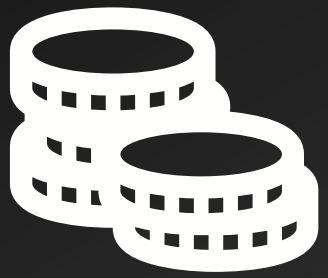
Global policy support is increasing

Fuel prices are increasingly volatile



Multiple zero-emissions pathways are emerging





Which zero-emission trucking pathways will achieve parity with diesel first?

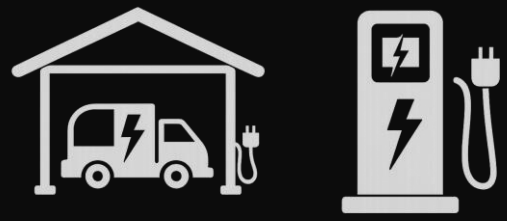
What to expect

01 | **Total-cost-of-ownership modeling**

02 | Tipping point results

03 | Outlook

We consider several technologies and regions



Key variables

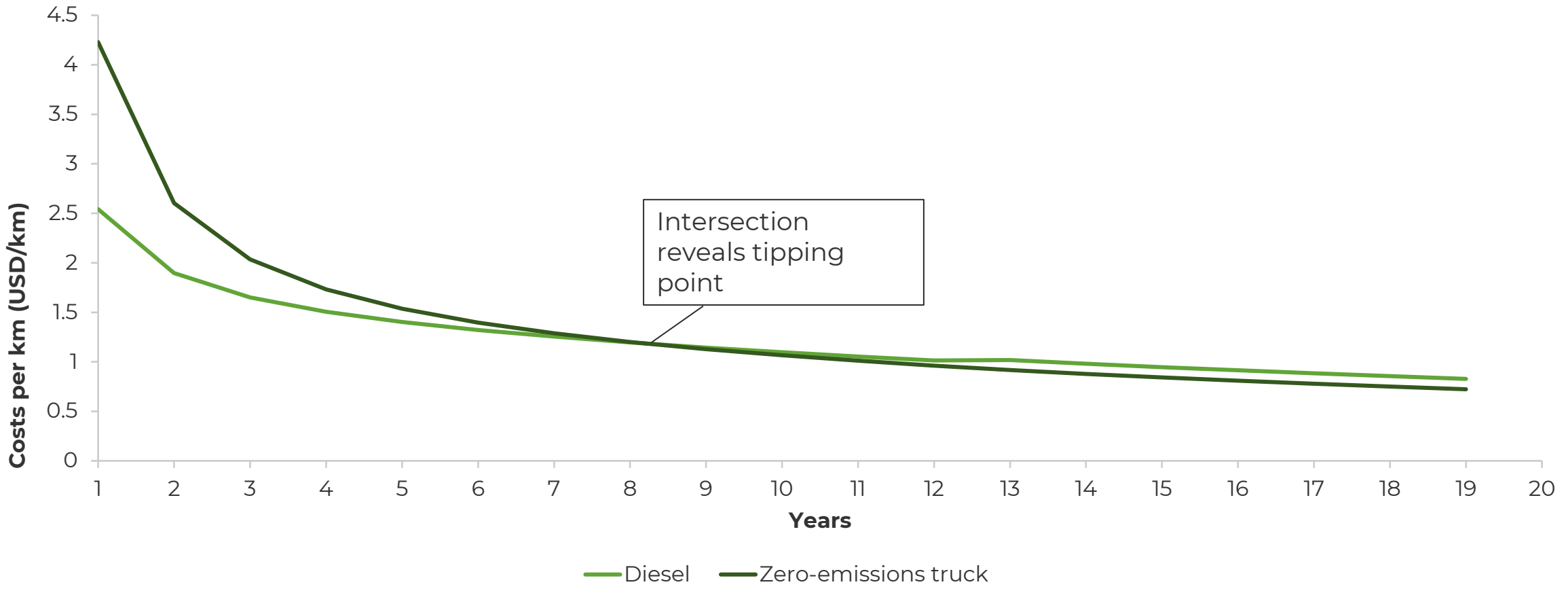
Truck data
(capex, opex)

Energy prices
(diesel, electricity, hydrogen)

Driving-time
regulations

Vehicle
utilization

We calculate tipping points using cost-per-kilometer values



What to expect

01 | Total-cost-of-ownership modeling

02 | **Tipping point results**

03 | Outlook

Battery-electric trucks achieve parity earlier than hydrogen trucks

- **Electricity prices** are the primary determinant of competitiveness.
- **Hydrogen economics** limit fuel-cell truck competitiveness.
- **Higher vehicle utilization** accelerates parity timelines for battery-electric trucks.

Electricity prices are the primary determinant of competitiveness

Energy price scenarios

Electricity

Low

Medium

High

Diesel

Preconflict

Postconflict

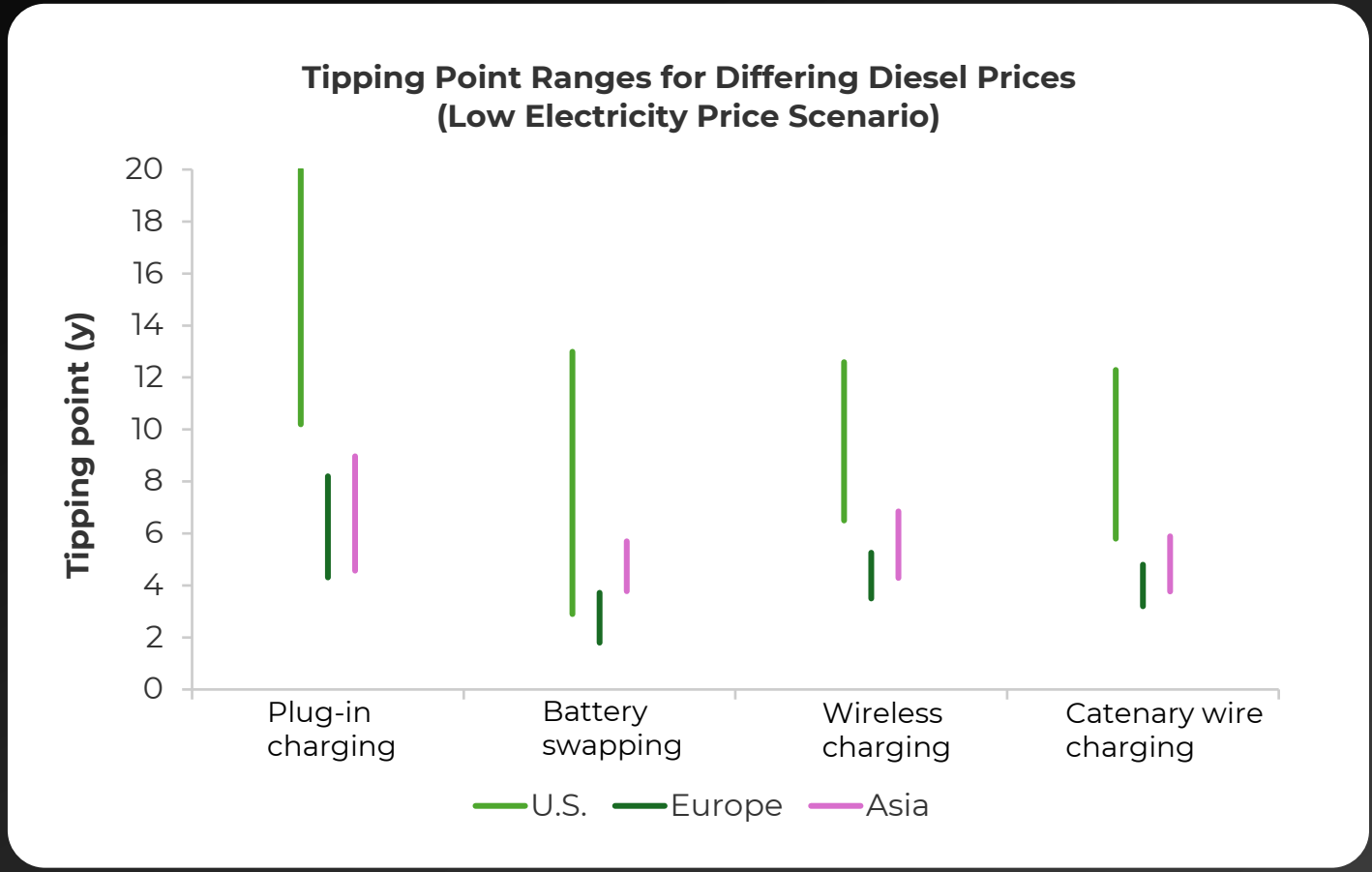
Low electricity prices enable battery-electric competitiveness

Battery swapping reaches parity the fastest.

Higher diesel prices significantly accelerate parity.

The U.S. remains the most challenging market due to lower diesel prices.

Depot charging provides the strongest near-term pathway.

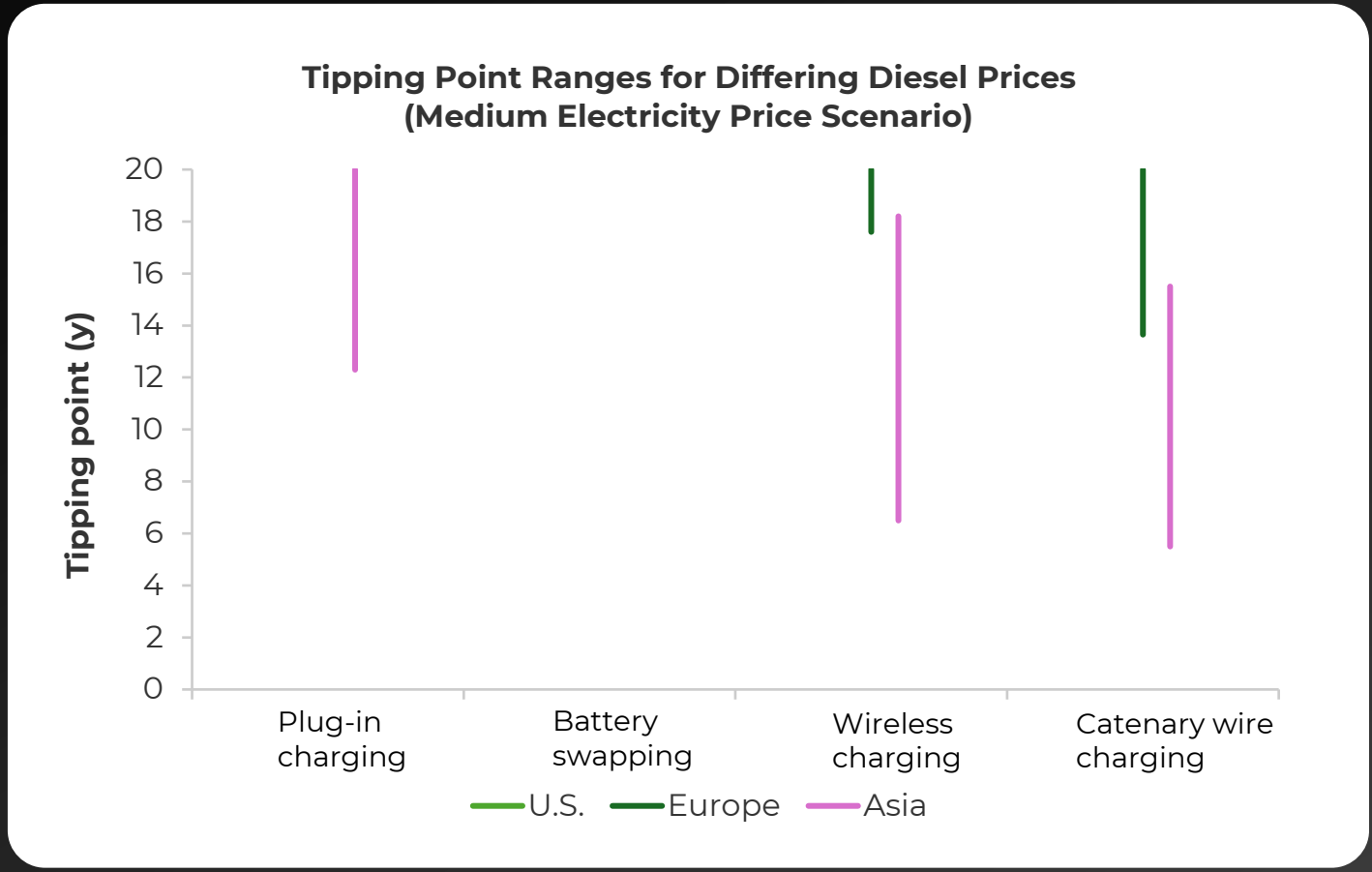


Rising electricity prices narrow viable electrification pathways

Many battery-electric pathways no longer reach parity within the vehicle lifetime.

Only catenary and wireless charging remain competitive in most regions.

Higher diesel prices in Europe and Asia partially offset rising electricity costs.



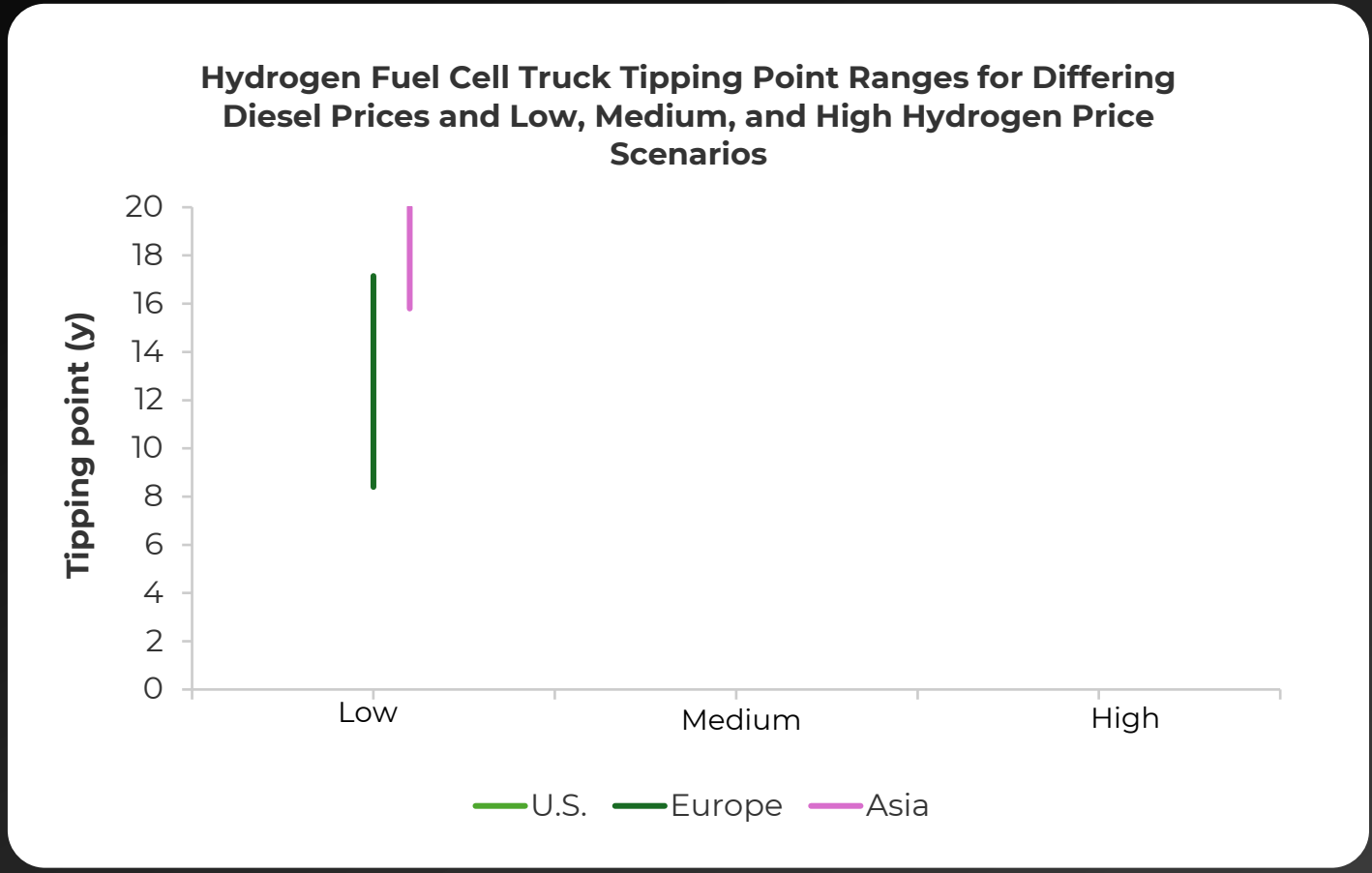
Hydrogen economics limit fuel-cell truck competitiveness

Hydrogen trucks remain limited by high fuel costs

Parity is limited to low-cost hydrogen scenarios in Europe and Asia.

High hydrogen fuel costs remain the primary barrier to competitiveness.

Battery-electric pathways remain the more competitive option.



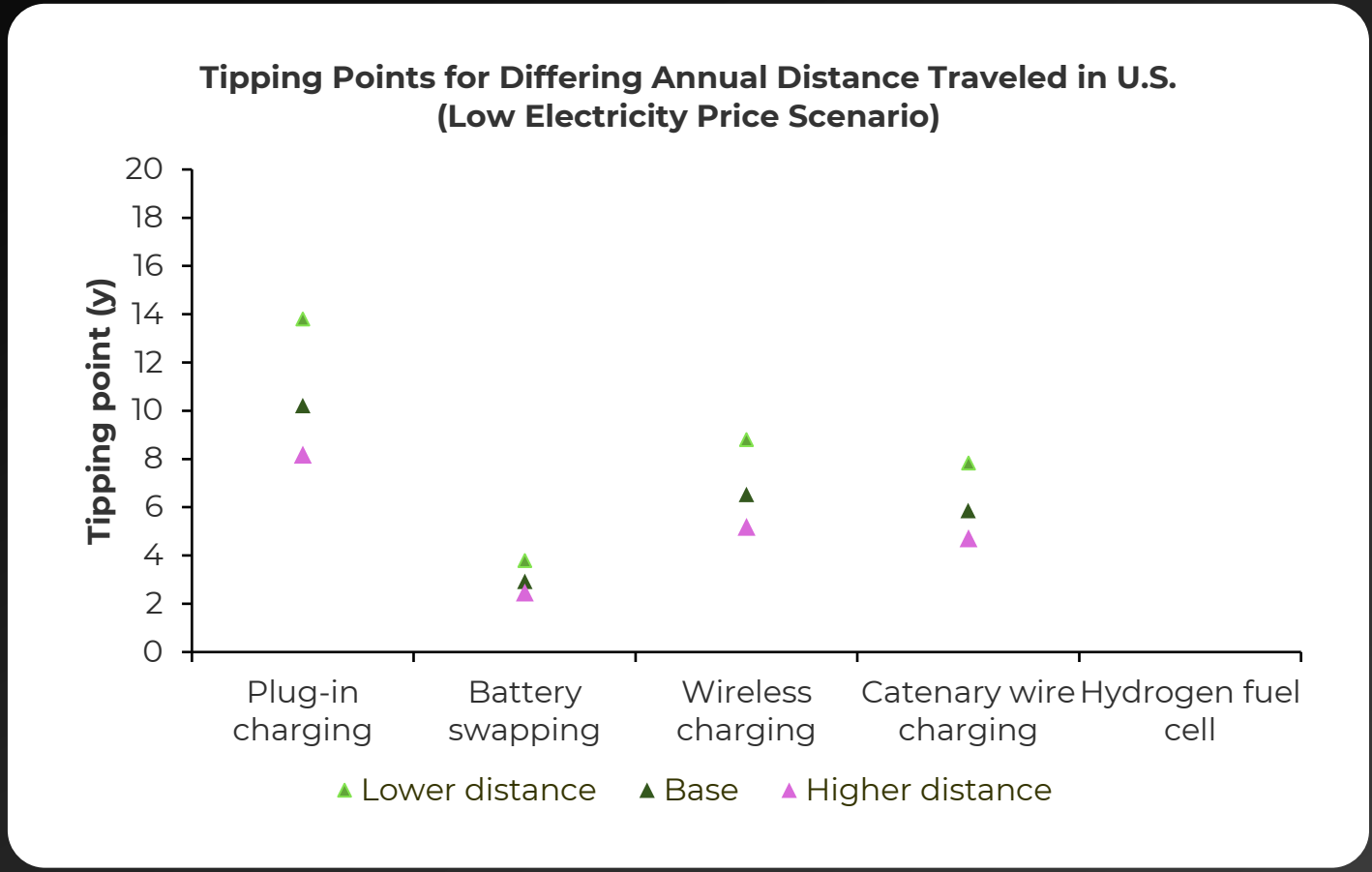
Higher vehicle utilization accelerates parity timelines for battery-electric trucks

Higher utilization brings tipping points closer

Driving more miles improves the economics of every battery-electric option.

Higher utilization can reduce parity timelines by up to ~6 years.

Hydrogen fuel costs continue to limit competitiveness.



What to expect

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02 | Tipping point results

03 | **Outlook**

“ ”

Many companies are small and medium-sized enterprises with one to 10 trucks…if one truck becomes a liability, you could be out of business.

– European port and logistics stakeholder

Fuel price volatility opens the trucking industry to disruption

Fuel volatility favors electrification.

Integrated freight platforms with vehicles, charging, and energy management are emerging.

Startups can disrupt incumbents.

“ ”

If you look at grid connections, there are more than 800 DSOs in Germany alone, and each has a different process…there is no common visibility of where the capacity is.

– European logistics industry association

“ ”

It takes 12–24 months to get a permit…and not just for the grid connection…you have to go to three or four other authorities…. This slows deployment down.

– European logistics industry association

Infrastructure readiness will determine the pace of electrification

Charging infrastructure and grid interconnections remain the largest barriers to deployment.

Depot charging is the most practical near-term pathway due to lower infrastructure requirements.

Battery swapping, catenary, and wireless charging require significant ecosystem coordination and investment.

“ ”

[Battery electric trucks] can be competitive in specific use-cases but only under tightly controlled conditions: stable routes, high utilization, and access to low-cost charging….

– Global freight transport nonprofit

Predictable freight corridors will drive electric truck adoption

Battery-electric trucks are already approaching cost parity on some routes.

Early adoption will concentrate in fixed, high-utilization freight corridors with depot charging.

Flexible long-haul operations remain more challenging due to charging and routing uncertainty.

Electric truck fleets will evolve into flexible grid assets

Truck depots will become major new electricity loads as fleets electrify.

Managed charging can shift demand to periods of lower electricity prices or higher renewable generation.

Fleets can participate in demand-response and flexibility markets.

Electric truck fleets could need additional investments in larger batteries and energy management systems.

Key Takeaways

1

Electrification will scale where operations are most predictable.

Fixed routes with high utilization improve economics.

2

Infrastructure will determine adoption speed.

Charging deployment and grid capacity remain the primary constraints on scaling electric trucking.

3

Electrification is creating a new freight-energy ecosystem.

Integrated fleet services and flexible charging operations have the potential to disrupt the status quo.

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