International Transport Forum

How governments can bring low-emission trucks to our roads – and fast

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The "Decarbonising Transport: Driving Implementation Actions" project is part of the ITF's wider Decarbonising Transport (DT) initiative. The DT initiative is a key instrument to help governments and industry translate climate ambitions into actions. It currently unites more than 70 governments, organisations, institutions, foundations and companies. More information on the DT Initiative is available at https://www.itf-oecd.org/decarbonising-transport.

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Now or never

Given the urgency of the climate crisis, governments cannot let technological uncertainty be a barrier to action.

Assess the likelihood

Governments need to carefully assess the likelihoods with which different technologies will deliver effective climate action. They must promote the most likely technologies, even with uncertainty.

Bet on batteries

Battery-electric vehicles currently have the highest likelihood of successfully decarbonising road transport.

Policy makers should decide and support a limited number of technologies to decarbonise road freight. In doing so, they should focus on the most promising technologies with the greatest likelihood of success, which are also those most likely to lead to improved economic and industrial competitiveness.

Battery-electric trucks (BEV) for goods transport with stationary charging have the highest technology readiness levels and the greatest likelihood of being deployed quickly.

Carbon budgets are rapidly reducing, meaning policy makers only have little time to decide which technologies to support.

To make decisions in an uncertain technological context, governments should support technologies based on likelihoods. This would empower policy makers with the confidence to financially support a limited number of promising technologies and avoid being accused of "picking winners".

The relative likelihood of BEVs meeting policy goals is unlikely to change in the short term since other technologies will see limited adoption that would rapidly improve their chances or change the understanding of their major drawbacks. Battery-electric trucks currently enjoy higher market acceptance than other technologies due to the parallel roll-out of electric passenger cars and because several decarbonisation technologies could benefit from the infrastructure for battery-electric vehicles.

The investment required for introducing battery-electric trucks at scale will be considerable. However, it can be relatively incremental, starting with short-haul and urban operations, where BEVs have a high likelihood of success, and then scaling up over time to more challenging applications such as long-haul heavy-goods transport.

The rapid deployment of BEVs in short-haul applications will help to understand any technical limitations they may have in more challenging use cases and help to determine whether complementary technologies are needed, such as biofuels or hydrogen, which are unlikely to be suitable for the mass market.

Top recommendations

Do not allow technological uncertainty to delay action

Postponing investment decisions due to technological uncertainty could cost more in environmental damages than acting proactively to support technologies that already have a high likelihood of success.

Decide and provide

Policy makers should support only a limited number of promising solutions to guide the market and avoid diluting funds.

Support for battery-electric vehicles is a low-regret policy

Electric truck technologies have the greatest potential to be low-carbon and cost-competitive.

Invest in charging infrastructure with care, but without delay

Deploying depot chargers and strengthening grids pre-emptively of demand are essential.

How to tackle road freight emissions

Moving away from conventional diesel trucks is essential to decarbonise the road freight sector and reduce air pollution.

Why governments should promote truck decarbonisation technologies

Technology neutrality versus "decide and provide"

Heavy-duty vehicles account for 24% of global transport greenhouse gas (GHG) emissions and demand for road freight is expected to double by 2050.

Reaching goals for net-zero emissions by 2050 requires that zero-carbon trucks account for 100% of sales by around 2040, at the latest, to replace all older vehicles by 2050.

This, in turn, requires the recharging and refuelling infrastructure for zero-carbon technologies to be built this decade to begin sales of zero-carbon trucks as soon as possible, Figure 1 (page 9).

Achieving these milestones requires active intervention by governments to overcome market barriers and accelerate adoption.

Several technologies can play a role in decarbonising road freight. Each of them faces uncertainties regarding their effectiveness and viability.

Policies should avoid picking winners and potentially close the door for other technologies. Successful policies will identify the desired outcome and remain neutral about the technologies that achieve it.

Why governments should promote truck decarbonisation technologies

The transition to zero-emission vehicles is underway for passenger cars and light-duty vehicles. For trucks it is lagging behind.

New low-carbon technologies to reduce carbon emissions in the road freight sector are at the early stages of market commercialisation. To meet climate goals, more must be done to deploy them more quickly.

In the long term, zero-emission trucks are more sustainable and also less costly than today's conventional trucks (ITF, 2022). However, governments need to help the market overcome a number of market barriers. Trucking companies are often small and operate in highly competitive markets. New zero-emission trucks currently cost two to three times more than conventional diesel vehicles, putting them out of reach for most hauliers.

Zero-emission trucks could become cost-competitive on a total cost of ownership basis within the decade, but only if production volumes increase enough to generate economies of scale and reduce costs (ITF, 2022).

Policy packages needed

Doing so will require initial financial support from governments. Zero-emission trucks have to compete with conventional diesel vehicles whose environmental costs are not adequately reflected in their operating costs.

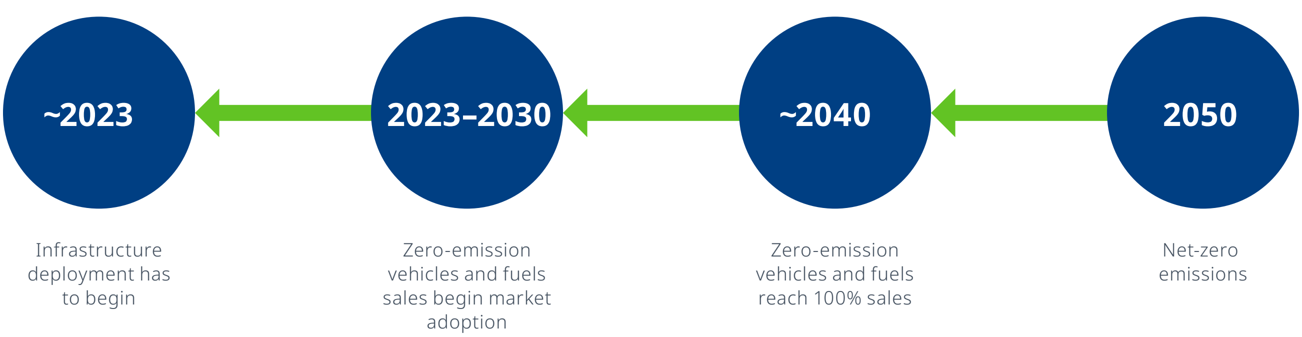
Moreover, the slow uptake of low-emissions trucks results in low demand for the recharging and refuelling infrastructure that is necessary to accompany the growth of the electric vehicle fleet but must be highly utilised to be financially viable.

In light of these factors, governments need to develop comprehensive policy packages to promote the adoption of low-carbon road freight vehicles and the infrastructure that supports them. For shaping such packages, consultations with industry stakeholders will be vital.

New zero-emission trucks are out of reach for most hauliers as they currently cost two to three times more than diesel trucks

Figure 1:

How much time is left to make road freight emissions-free?



Technology neutrality versus "decide and provide"

Governments can support only a limited number of promising solutions with public spending.

The technologies that can play a role in decarbonising road freight include battery-electric trucks which use stationary recharging, electric trucks that recharge using electric road systems (ERS), and trucks using swappable batteries. Trucks could also be powered by biofuels, hydrogen or e-fuels.

Each of these technologies has upsides and downsides, with different degrees of certainty about their viability. Governments need to promote the uptake of these technologies, even if not all will see mass-market deployment. To be successful, policies should target a desired outcome and remain neutral about the technologies that achieve it.

The value of technology neutrality

Such technology neutrality helps to avoid closing the door to specific technological pathways. Instead, it lets market forces choose how to meet targets efficiently. Policies that are agnostic about technologies tend to be more resilient to technological change.

Technology neutrality is particularly relevant for performance-based targets such as carbon dioxide (CO_2) emissions standards, which set a target value of the CO_2 emission intensity (gCO_2/km) for vehicle fleets to meet. Technology neutrality also helps in fundamental scientific research with the development of new technologies from initial concept to early-stage testing.

Sustainable production of biofuels in a modern bio gas plant

However, strict technology neutrality has limitations when it comes to the commercial deployment of new solutions. Governments could fund all options equally but this would dilute funds, hamper economies of scale and not use infrastructure optimally.

Thus, technology neutrality is a desirable feature of a policy but not a goal in itself (Aisbett, Cheng and Beck, 2021). When government financial support is needed but funds are limited, only some technologies can be funded. Inevitably, governments will then need to prioritise funds and spend them on the most promising projects.

Decide and provide

A number of countries have taken a decide and provide approach to decarbonise heavy-duty road freight. To maximise the effectiveness of public spending, they support only a limited number of promising solutions.

This also streamlines efforts by setting a long-term direction on which technologies are thought to most likely meet policy objectives. These governments have created policy initiatives that actively promote low-carbon trucks through financial support and binding regulations for specific technologies and the associated infrastructure.

- The European Union's Alternative Fuel Infrastructure Regulation (AFIR) (Council of the European Union, 2023) sets mandatory requirements for building electric charging and hydrogen refueling infrastructure along the roads of the Trans-European Transport Network (TEN-T). Other technologies, such as ERS, are not prioritised.

- In the United States, the Inflation Reduction Act (IRA) made funding available for the construction of charging points and hydrogen refueling stations. The IRA also includes tax credits for hydrogen production and funding for grants for BEVs and fuel-cell electric vehicles (FCEVs), as well as a modest budget for advanced biofuels (US Congress, 2022).

- The California Air Resources Board's (CARB) Advanced Clean Trucks regulations promote zero-emission vehicles (BEVs and hydrogen FCEVs) (CARB, 2021).

- France (Vinci, 2023), Germany (BMDV, 2020), Sweden (Ullström, 2021) and the United Kingdom (UK DfT, 2021) are all reportedly considering ERS solutions in addition to BEVs and hydrogen trucks.

The recent announcement by the Swedish transport ministry to scrap the planned public procurement process for an electric road suggest support for ERS may be waning, however (Trafikverket, 2023).

Technology neutrality is a desirable feature of a policy but not a goal in itself

Basing policy decisions on the likelihood of technologies' success

Many technological solutions for decarbonising road freight are possible in principle, but not all are also probable. Some are only feasible under specific assumptions that would require ambitious or even implausible changes.
In order to prioritise effectively, governments need to compare and evaluate technologies in an impartial and transparent manner.

The best way to do this is to consider the *likelihood* with which emerging technologies will successfully deliver on a policy goal. Armed with a robust assessment of their potential to deliver successes, governments should define a minimum *likelihood threshold*. Above this likelihood threshold, evidence for the viability of a technology and its effectiveness in supporting the policy objective justifies support for scaling it up.

Once there is increasing evidence that certain technologies will not reach the likelihood requirements, governments should phase out support for their mass-market deployment or redirect support towards the technology with a higher likelihood.

Four criteria are particularly important for determining the likelihood of a technology to effectively decarbonise road freight: the maturity of the technology, the potential to become cost-competitive, the potential to be sustainable and low-carbon, and the potential for quick deployment. These are covered in detail in the following four sections.

How mature are different truck decarbonisation technologies?

Can truck decarbonisation technologies become cost-competitive?

Which truck decarbonisation technology is most sustainable?

Which truck decarbonisation technologies can be rolled out quickly?

How mature are different truck decarbonisation technologies?

Biofuels currently have the highest market adoption, followed by battery-electric vehicles.

Technologies take time to progress and mature. This maturity can be expressed in terms of technology readiness levels (TRL), a concept initially developed by NASA that has recently been adapted by the International Energy Agency (IEA) to reflect the development of energy technologies (IEA, 2023b).

Technologies progress in eleven TRLs from initial concept (TRL 1) to reaching proof of final stability (TRL 11). The different levels are set out in Table 1 (page 13).

Time to progress

Increasing maturity and experience help to refine assessments about the viability of different technologies. Technical hurdles encountered during testing may render some options infeasible.

Technologies at early stages of readiness will take significant time to progress to more mature levels: additional technical standards must be developed, large-scale pilot projects set up, and market risk reduced to mobilise private funding and launch production at an industrial scale.

The TRLs of the leading technologies to decarbonise heavy-duty road freight are shown in Table 2 (page 19). Biofuels currently have the highest market adoption, followed by battery-electric vehicles. Induction and rail electric road system technologies have the lowest level of technological maturity. Hydrogen trucks need to prove they can be refuelled in similar time spans as diesel trucks in around ten minutes.

Slow flow rates

Of the roughly one thousand hydrogen refuelling stations operating globally today (IEA, 2022a), most are designed for light-duty passenger vehicles or buses and operate with flow rates approximately ten times lower than that needed for hydrogen trucks (Martineau, 2022). The IEA currently classifies high-flow-rate hydrogen refuelling systems at TRL 4 (IEA, 2022a).

Similarly, megawatt charging systems for trucks are currently in demonstration stages at TRL 6 or 7, while 350 kilowatt systems are at TRL 8 (IEA, 2022a).

Table 1:

Technology Readiness Levels (TRL)

1	Initial concept
2	Formulating an application for the concept
3	Validating the concept
4	Early prototype
5	Large prototype
6	Full prototype at scale
7	Pre-commercial demonstration
8	First-of-a-kind commercial demonstration
9	Commercial operation in relevant environment
10	Integration needed at scale
11	Proof of final stability

Can truck decarbonisation technologies become cost-competitive?

New technologies should be compared based on their potential long-term financial competitiveness without public subsidies.

Technologies should be assessed using a range of scenarios rather than only optimistic forecasts.

A recent analysis for Europe (ITF, 2022) found that battery electric vehicles are likely to be cost-competitive on a total-cost-of-ownership basis before 2025 for smaller vehicles and around 2035 or earlier for larger vehicles if there are financial incentives, Figure 2 (page 15).

Similarly, electric road systems using catenaries were also estimated to be financially cost-competitive if governments help to ease the burden of relatively long payback periods for the necessary infrastructure construction.

Not enough techno-economic assessments exist for other direct electrification solutions, such as rail and induction-based electric road systems or the battery swapping options which are seeing large-scale trials in China (Liu and Danilovic, 2021).

Ambitious assumptions

Conversely, hydrogen fuel cell vehicles (FCEV) have a much lower likelihood of reaching cost-competitiveness in the mass market in Europe (ITF, 2022). They could only outcompete other options in the long term if ambitious assumptions about low hydrogen prices came true.

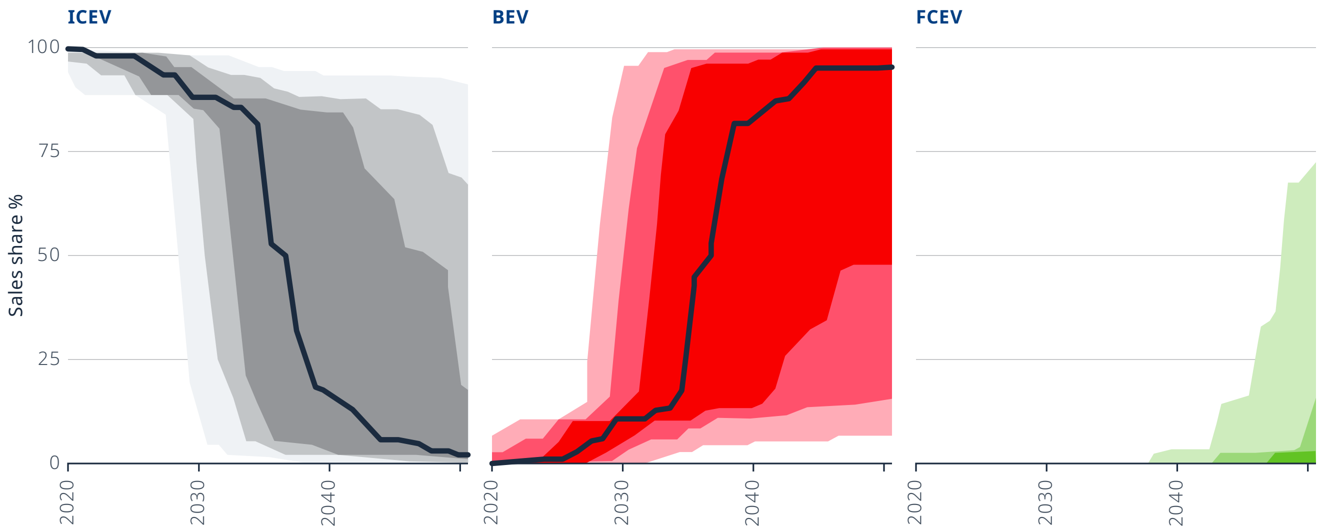
Similar analyses have shown that BEVs outcompete FCEVs in the United States (ICCT, 2023b). The efficiency of hydrogen ICEVs is slightly lower than that of FCEVs, which may make their operating costs marginally higher than those of FCEVs.

However, this advantage of ICEVs will vary with drive cycle and operational requirements. Additionally, the fact that ICEVs require lower-purity hydrogen than FCEVs may help them become relatively cost-competitive once their purchase price has fallen significantly. Figure 2 (page 15) illustrates how market shares for the technologies with the lowest total cost of ownership could develop over the coming decades.

Between 2019 and 2022, biodiesel was consistently more expensive than conventional diesel. In the United States, biodiesel costs 55% more; in Europe it was 27% more expensive than diesel (IEA, 2022b). The most significant cost factor for biodiesel is the cost of feedstocks, but the prospect of significantly reducing their cost in future is marginal (Cazzola et al., 2023).

Figure 2:

What are the potential sales shares of lowest total-cost-of-ownership technology?



Source: (ITF, 2022). ICEV= Internal combustion engine vehicle, BEV= Battery-electric vehicle, FCEV= Fuel cell electric vehicle.

Black lines denote the median scenario, shading denotes 50th, 75th and 95th confidence intervals of the scenarios explored.

Biomethane costs vary by region but were more than double that of fossil natural gas in Europe and North America in 2020. While there are some opportunities to reduce this cost gap by increasing the scale of biomethane production, road transport will still be competing with other difficult-to-decarbonise sectors such as shipping, aviation and heavy industry for the available supply. The result could be increasing prices and limited availability (IEA, 2020; Cazzola et al., 2023).

Niche use-cases

Synthetically produced diesel, or diesel e-fuel, is likely to remain significantly more costly than conventional diesel fuels and unlikely to see mass-market adoption in the road sector (ITF, 2023b).

Recent analyses conclude that electric trucks are more likely to be cost-competitive for the mass market than other solutions, see Table 2 (page 19). Some niche use-cases may exist for which electrification may not be optimal and which will require other decarbonisation solutions. These include long-range and intensive-use applications or potentially in the construction sector. Some unknowns remain on the cost-competitiveness of battery swapping and alternative ERS solutions.

Which truck decarbonisation technology is most sustainable?

The emissions of different propulsion technologies over the entire vehicle life cycle are an important determinant of how likely innovations are to help meet CO_2-reduction goals.

A comparison of the global average GHG emissions performance of different technologies showed that the carbon intensity of new electric trucks over their lifetime is 40% lower than for conventional diesel trucks (ITF, 2021; Basma et al., 2023).

Their carbon intensity is even lower when using the lower-carbon electricity mixes. These are already available in the European Union and the United States, and are likely to improve over time as the share of renewable energy increases.

This is likely the case for all direct electrification solutions including battery swapping and electric road systems. The infrastructure for the latter requires additional material inputs such as copper and aluminium but can also help

An electric truck at a recharging station (Artist's impression)

to save battery materials. Electric road systems using catenaries are only for heavy-duty vehicles, but induction and rail solutions could also power light-duty vehicles.

Sources of hydrogen

The GHG emissions intensity of hydrogen vehicles depends largely on the source of hydrogen. Today, almost all hydrogen is produced with fossil fuels and for industrial purposes (IEA, 2022a). Using it for trucks will only yield marginal emissions reductions compared with conventional diesel (ITF, 2021; O'Connell et al., 2023).

Hydrogen produced with renewable electricity can effectively reduce emissions. However, supply will be scarce in the short-term and remain highly uncertain in the long-term (Odenweller et al., 2022). Regardless of the availability of renewable hydrogen, direct electrification solutions will always offer superior energy efficiency (ITF, 2021).

The carbon intensity of e-fuels hinges on the source of hydrogen and whether the carbon used is captured from industrial sources or from the atmosphere (ITF, 2023b). However, the process of making e-fuels requires even more (still scarce) renewable energy to produce the required hydrogen than using hydrogen directly as a fuel.

Varying emission intensities

E-fuels are therefore unlikely to be low-carbon should they replace conventional diesel to a significant degree (ITF, 2023b). The e-fuels that become available should be prioritised for transport modes with few other technological alternatives, such as aviation.

The GHG emissions intensity of biodiesels varies significantly with the type of feedstock used for production. Waste feedstocks, such as used cooking oils, can offer emissions savings but may cause indirect emissions through replacement effects of feedstocks (Malins, 2023).

However, their availability is limited. As with e-fuels, biofuels should primarily help decarbonise transport modes with few other decarbonisation options. Alternative biodiesel feedstocks risk triggering significant emissions from indirect land-use change (Cazzola et al., 2023).

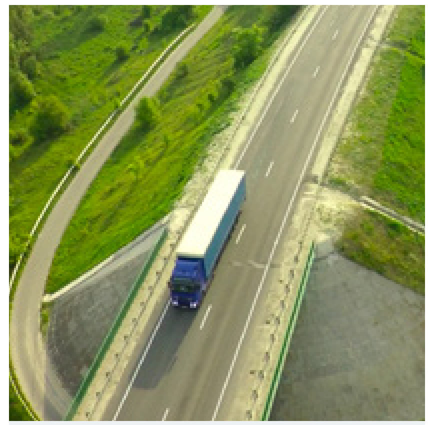
The carbon intensity of new electric trucks is 40% lower than for diesel trucks

Which truck decarbonisation technologies can be rolled out quickly?

Those that can adapt to existing infrastructure and other technologies will have an advantage.

To meet 2050 net-zero targets, any new decarbonisation technologies for road freight need to become available to hauliers well before 2040. The speed at which emerging technologies can be rolled out and scaled up must therefore be a key factor in assessing their relative merits.

It will likely take at least a decade to build the recharging and refuelling infrastructure and create the production capacity for new fuels at an industrial scale. Those that can adapt to existing infrastructure and technology in other sectors will have an advantage over those with, for example, limited sustainable feedstock supplies.



The speed at which emerging technologies can be rolled out must be a key factor in assessing their relative merits

Satisfying charging demand

Electric trucks with stationary charging can benefit from the current rush to create charging networks for the rapidly growing number of passenger cars. Existing electricity grids already transport energy over long distances to areas of charging demand. That said, a high-powered chargers may need grid connections over 30 megawatts, requiring additional investment and considerable lead times.

In Europe, additional grid strengthening could take up to ten years (BMDV, 2022). However, with pre-emptive planning that anticipates demand and streamlined permission procedures a shorter timeframe should be possible. A lack of critical materials could affect battery production in the medium term, but the supply of raw materials is expanding rapidly and close to reaching demand levels for current decarbonisation goals by 2030 (IEA, 2023a).

Conversely, no significant infrastructure exists to transport hydrogen for vehicle refuelling. Similarly, low-carbon hydrogen production is almost inexistent; it will need considerable time to reach significant production levels.

Fuel production bottlenecks

Even if renewable hydrogen production were scaled up at the same rate as the past, rapid deployment of wind and solar power, it would still represent less than 1% of final energy consumption in 2030 for the EU and 2035 for the world. Even by 2040, renewable hydrogen production would likely reach only 3% to 11% of final energy consumption in the EU and 1% to 3% globally (Odenweller et al., 2022).

Additionally, the road freight sector would be in direct competition with other sectors for the limited supply of renewable hydrogen. So even if hydrogen could be deployed at a faster pace than wind and solar, it would nonetheless face significant challenges.

E-fuel production will face similar challenges to an even greater extent due to their higher energy requirements for low-carbon fuel production (ITF, 2023b).

The limited availability of sustainable biofuel feedstocks will hold up the widespread use of biodiesel and biomethane (Cazzola et al., 2023).

Sweden and Germany have tested electric road systems using catenaries since 2016 and 2019 (F3 Centre, 2021). In theory, such systems could be built reasonably quickly. Average rates of electrification of overhead wires in the rail sector suggest that an ERS could be built in less than ten years and cover 40% to 60% of vehicle travel on main roads (ITF, 2021).

Electric road systems

With substantially smaller batteries than comparable BEVs, trucks for ERS could have lower purchase costs, reducing the investment barriers for small trucking companies. However, discussions on financing ERS via toll systems and ensuring broad alignment in the road transport sector are in early stages, making the rapid creation of ERS infrastructure doubtful.

Catenary ERS solutions could play a role if other solutions for long-haul trips are not feasible or in regions that introduce new technologies for road freight later than elsewhere. Induction and rail ERS technologies would face similar barriers. They are also at lower TRLs (see Table 2) and have not been tested in real-world operations, making their timely deployment unlikely.

Table 2:

What is the likelihood of emerging low-carbon technologies meeting net-zero policy goals?

Technology	Maturity	Cost-competitive	Sustainable low-carbon	Fast deployment
Short haul battery-electric truck (with stationary charging)	**TRL 9**	Likely	Likely	Likely
Long haul battery-electric truck (with stationary charging)	Vehicle: **TRL 8/9**	Likely	Likely	Possible
	<350kW chargers: **TRL 8**			
	>1MW chargers: **TRL 6/7**			
Battery-electric truck (with battery swapping)	**TRL 8/9**	Unknown	Likely	Unknown
Hydrogen fuel-cell electric truck	Vehicle: **TRL 8/9**	Challenges	Short-term challenges	Challenges
	HFR refuelling: **TRL 4**		Long-term possible	
Hydrogen internal combustion engine truck	Vehicle: **TRL 6**	Challenges	Short-term challenges	Challenges
	HFR refuelling: **TRL 4**		Long-term possible	
Electric Road System truck (with catenary)	**TRL 8**	Possible	Likely	Challenges
Electric Road System truck (with induction/rail)	**TRL 4/5**	Unknown	Likely	Unlikely
Biodiesel/ biomethane truck	**TRL 9/10**	Challenges	Challenges	Challenges
Diesel e-fuel truck	**TRL 6**	Unlikely	Unlikely	Unlikely

TRL = Technology Readiness Level, HFR = High-flow-rate, Biodiesel is a broad category, including both Fatty Acid Methyl Esters (FAME) and Hydrotreated Vegetable Oil (HVO). TRLs adapted from (IEA, 2023b).

When to act and how to act: Factors to consider

Once they have determined the relative likelihood of different technologies meeting policy goals, governments face the question of when to act and use public funds to accelerate adoption.

This invariably involves a balancing act between working quickly under uncertainty to try to meet objectives and waiting until the prospects for individual technologies become clearer. Five factors need consideration:

Will the potential of emerging technologies to decarbonise road freight change relative to each other?

How big is the risk of choosing an uncompetitive technology and funding underused assets?

How much will scaling up low-carbon solutions cost and how long will they need support?

Which solutions are favoured by markets and other governments?

How much time is left to make a decision on technology?

A decision about support could be delayed until greater certainty is established if a technology's likelihood of achieving policy goals markedly improves within a short period of time, for example because a large pilot project is underway.

Conversely, a decision should not be postponed if the relative likelihood of technologies' success is unlikely to change, for instance if one technology is likely to be the single available solution due to technical constraint.

Will the potential of emerging technologies to decarbonise road freight change relative to each other?

How big is the risk of choosing an uncompetitive technology and funding underused assets?

How much will scaling up low-carbon solutions cost and how long will they need support?

Which solutions are favoured by markets and other governments?

How much time is left to make a decision on the preferred technology?

Will the potential of emerging technologies to decarbonise road freight change relative to each other?

Battery-electric vehicles are best-placed to deliver results, other systems may come to play a role where experiences with BEVs show limitations.

Battery-electric vehicles, particularly BEVs for short-haul applications, are being introduced much faster than other zero-emission technologies. They currently have the highest likelihood of scaling up quickly, see Table 2 (page 19).

In combination with early approval of megawatt charging standards this will quickly lead to a better understanding of BEV technologies and of any limitations that could require complementary technologies.

Learning from experience

Learnings from the experience with BEVs over the short term will help to better inform the likelihood of them meeting policy goals. Similarly, continued deployment of battery swapping technologies in China may help clarify their economic viability and better define their relative likelihood of success.

However, the remaining technologies are unlikely to see significant market deployment in the next five years. Their likelihood of meeting policy goals depends largely on a better understanding of the limitations of BEVs with stationary charging.

Therefore, promoting the rapid uptake of BEVs for short-haul applications appears to be a low-regret policy that can help to accelerate the decarbonisation of road freight and offer a better understanding of the use cases that require different approaches.

An electric truck equipped with an overhead pantograph drives on an “eHighway” test route in Germany

How big is the risk of choosing an uncompetitive technology and funding underused assets?

Governments must balance reducing the risks of lock-in and stranded assets with the disadvantages of postponing choices.

When governments incentivise one technology over another, they may create barriers to alternative solutions, should circumstances change. This risks locking in a technology, which, if underutilised, could become an uneconomic, stranded asset. This challenge is common, and often unavoidable, for governments seeking the best solution among technological options. This risk can be mitigated by setting a higher likelihood threshold for support.

Building any type of refuelling and recharging infrastructure for trucks can result in some degree of lock-in. However, some infrastructure can benefit multiple technologies. For example, all electric technologies could benefit from grid upgrades along main roads.

A question of demand

If electric road systems were built, they would probably be used since they could offer a low total cost of ownership, suggesting a relatively low risk of creating stranded assets (Rogstadius, 2022). That said, an ERS network of significant size would have to be completed to incentivise operators to buy large numbers of ERS vehicles.

Existing short test sections of catenary electric roads have not been highly utilised due to their small scale. Substantial financial support for hauliers' investments from governments would be necessary to ensure the rapid and widespread utilisation of an ERS.

In light of the competition from cheaper electric options it is unclear how much demand there will be for hydrogen refuelling infrastructure. This currently makes it challenging to invest without significant government support. However, some synergies for hydrogen production and use could materialise given its potential role in heavy industry and ports.

Converting infrastructure

Many biofuels can be blended with fossil fuels and use existing refuelling infrastructure. This can help to reduce the risk of creating stranded assets in the short term.

Some existing biofuel production facilities could be converted to produce alternative fuels for sectors such as aviation and shipping – this could also help to reduce the risk of building obsolete infrastructure. However, in the longer-term, biofuels will have to move away from blends with fossil fuels to provide their full decarbonisation potential.

Promoting investment into depot chargers is also a low-regret policy that is relatively unlikely to lead to significant stranded assets

Aerial view of a logistics park with warehouse, loading hub and semi trucks with cargo trailers

Several decarbonisation technologies will likely depend on charging trucks in their depots. This will likely be among the cheapest ways to source energy for electric trucks, because charging can be relatively low-power (ITF, 2022).

Depot charging could also be important for hydrogen vehicles. It will likely be cheaper to charge a battery for short distances and use hydrogen for longer journeys. This means promoting investment into depot chargers is also a low-regret policy that is relatively unlikely to lead to significant stranded assets.

How much will scaling up low-carbon solutions cost and how long will they need support?

Expanding charging networks incrementally limits the need for massive upfront investment into infrastructure.

The larger the investment needed to accelerate the uptake of a new technology, the more governments must scrutinise decisions to intervene in the market. This is especially the case where longer-term policy support is envisaged.

That said, the costs of not rolling out infrastructure needed for decarbonising road transport are high. Every year, the greenhouse gas emitted by 100 000 trucks (the equivalent to half of Hungary's truck fleet) causes approximately USD 2 billion in environmental damages (assuming damages of USD 185 per tonne of emitted CO_2 (Rennert, Errickson and Prest, 2022)).

In comparison, installing charging infrastructure for this number of electric trucks would cost in the order of USD 4-5 billion. This means postponing investment decisions by two years could cost more than building all the required charging infrastructure.

Potential synergies

From an investment perspective, stationary charge points for trucks have the advantage that they can be deployed incrementally by successively adding charge points and strengthening grids locally as demand increases. A parallel deployment of chargers for passenger cars offers potential for synergies.

Both can reduce the scale of upfront investments and help to accelerate the electrification of road freight. Initially, depot charging and limited public charging infrastructure will suffice to kick-start the use of battery-electric trucks.

Electric road systems and hydrogen refuelling infrastructure need a large publicly accessible network to unlock vehicle uptake. An incremental deployment of ERS or hydrogen refuelling infrastructure could potentially begin with for vehicle fleets operating in ports, open pit mines or for industrial clusters.

However, the initial investment required for ERS and hydrogen technologies will always be relatively large, making it more difficult for governments to provide public funding at the required scale.

Postponing investment decisions by two years could cost more than building all the required charging infrastructure

Which solutions are favoured by markets and other governments?

Governments can do much to improve co-ordination between stakeholders and help them plan ambitiously.

Co-operation will accelerate the adoption of low-carbon truck technologies. The road transport industry and all stakeholders should be involved, because diverging views and competing interests in a context marked by uncertainty can hamper governments from intervening effectively. Governments may be tempted to postpone decisions until stakeholders are aligned; in the meantime powerful lobbies might promote less-than-optimal solutions.

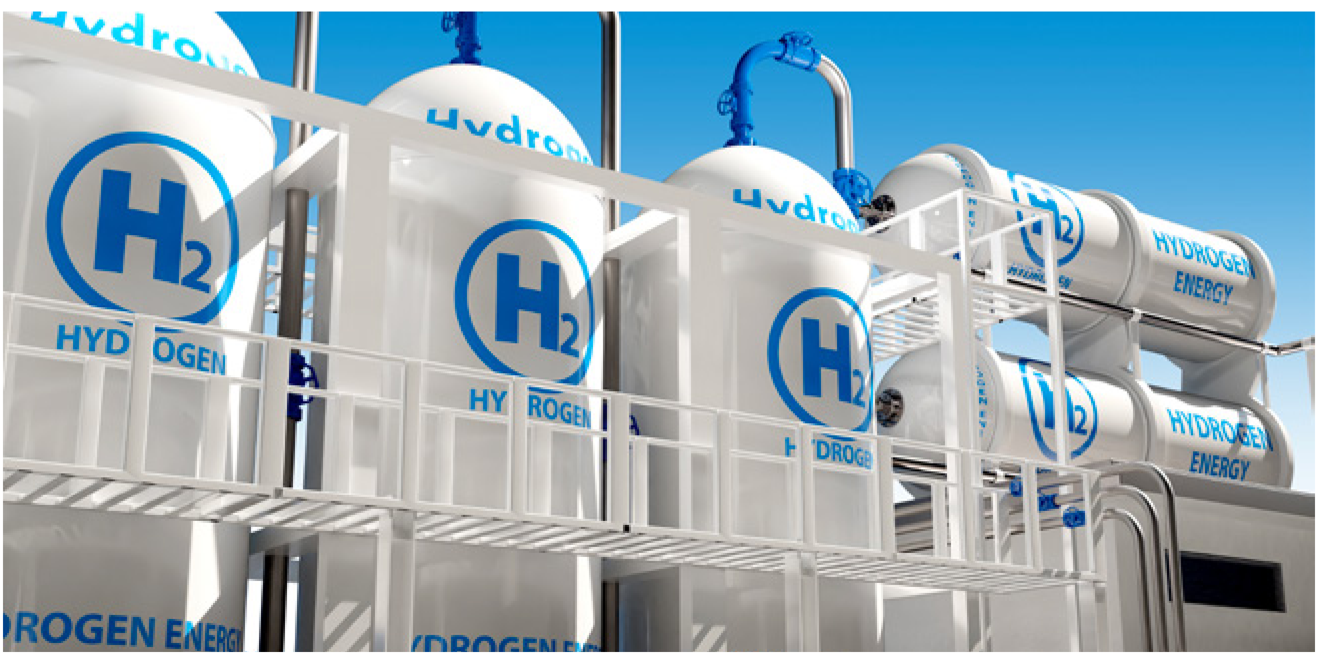
Improving knowledge sharing and long-term co-ordination between operators and utilities is an important area. Many utilities are still evaluating whether there will be additional electricity demand from zero-emission trucks. Many hauliers already expect electric trucks to play a major role in decarbonising their operations but have no visibility of whether the complementary grid infrastructure will meet their needs.

Public-private planning

Joint cross-sector, private-public planning for the upcoming electricity demand for trucks is therefore vital. One result could be an agreement to over-specify grid infrastructure in anticipation of vehicle electrification.

Governments also need to collaborate with other countries and jurisdictions to ensure coherent approaches and interoperability. At the same time, the economic opportunities from being an early adopter of decarbonisation technology and an accelerated green industrial policy can be reasons to act quickly and “go it alone” despite technological uncertainty.

Artist’s impression of hydrogen storage tanks



How much time is left to make a decision on the preferred technology?

Not much.

Delaying the transition to net zero emissions to gain more evidence about the most viable technologies may be worse than committing to certain emerging technologies today even if they may not satisfy all success criteria in the long run. Back-casting techniques can be a useful way to highlight the limited time available and define a moment when a decision must be taken.

To reduce the lead time for deploying truck charging infrastructure, governments can work to simplify permitting procedures. On an international level, templates and guidelines for land access typically differ significantly between countries and could be standardised. Sharing best practices and promoting open data exchange between regions and countries can also accelerate adoption.

A successful example of international co-operation is the European Commission's Sustainable Transport Forum, which brings European policymakers together with leading companies to plan and evaluate legislation (European Commission, 2023).

Reinforce grids, prepare sites

To help future-proof existing infrastructure, governments can reinforce electricity grids along motorways and in areas where high demand for electric charging demand is probable. Sites can already be prepared to accommodate high-power charging in future, for example by mandating that empty tubing for future power cables be installed underneath roads.

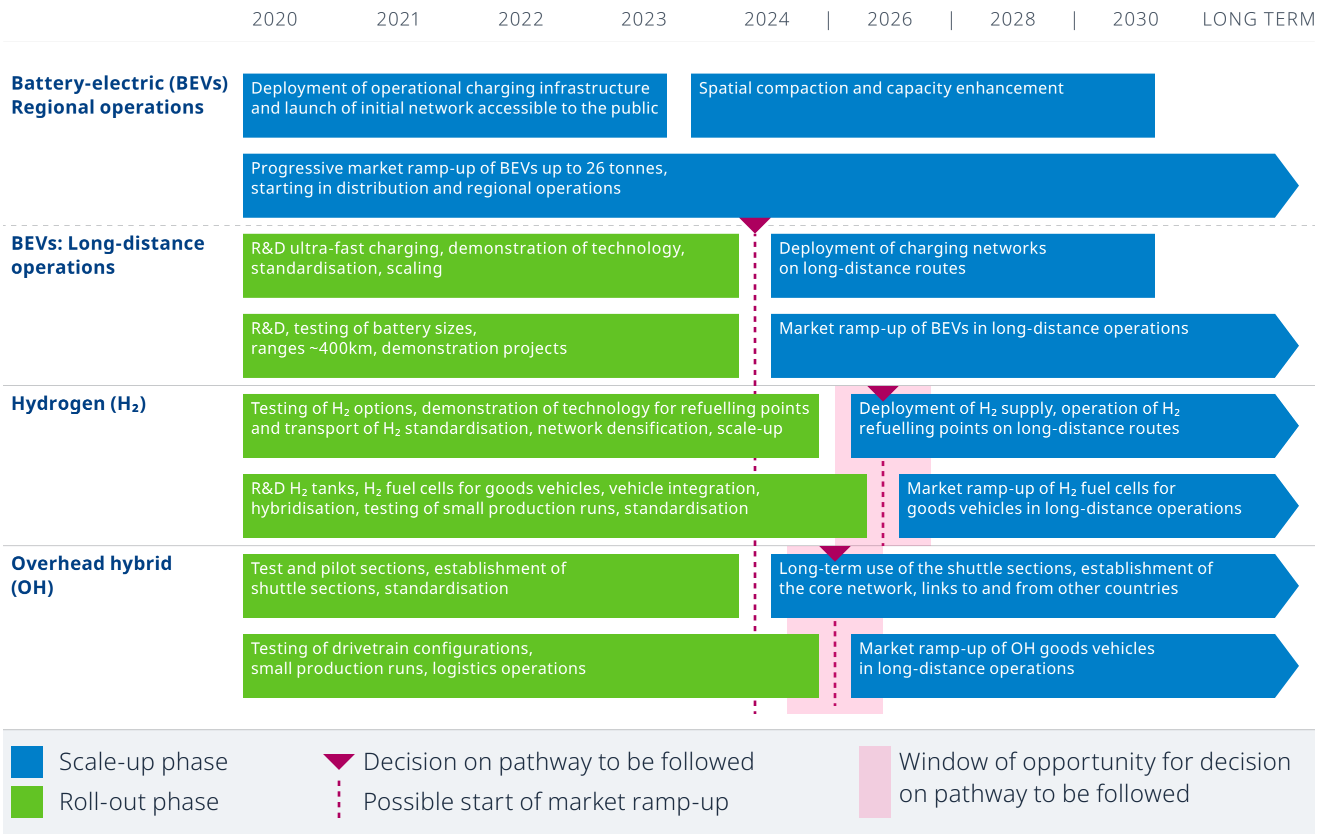
This could be particularly effective in regions where significant new transport infrastructure is planned, as is the case in many emerging economies, since the marginal costs of incorporating elements in preparation for a low-carbon future are relatively low.

Clearly communicating about the need to make rapid decisions about technologies despite all uncertainties helps to reduce political risks and clear the way for action. A good example for such a strategy is Germany's approach, see Case study 1 (page 27).

Sites can already be prepared to accommodate high-power charging in future, for example by mandating that empty tubing for future power cables be installed underneath roads

Figure 3:

Germany's Drivetrain Technologies Road Map



Based on Working Group 1 of Germany's National Platform on the Future of Mobility

Case study 1

How Germany prepares decisions on zero-emission truck technologies

The German government has set a goal of zero emissions for one-third of road freight transport by 2030. To achieve that objective, it has developed a roadmap to assess the pathways for different technologies and evaluate their relative potential. The Drivetrain Technologies Road Map is split into two main phases: a scale-up phase until the mid-2020s and a later roll-out phase, see Figure 3 (page 27).

The scale-up phase uses pilot projects for long-haul battery-electric vehicles, hydrogen vehicles and electric road systems with overhead catenaries to understand the advantages and disadvantages of each technology by the mid-2020s. The results of the pilot projects will determine whether to proceed with a roll-out phase with deployment at scale will follow for any of the technologies. Battery-electric vehicles for regional operations are considered to be in the roll-out phase already.

Expert task forces follow each technology to understand critical issues for the roll-out phase. These include interactions with the electricity grid, European integration and security issues. The aim is to develop the necessary technical experience during the scale-up phase so that the task forces can draft a roadmap for the roll-out.

References

Aisbett, E., W. Cheng and F. Beck (2021), "Green Industrial Policy and Technology Neutrality: Odd Couple or Unholy Marriage?", Australian National University ZCEAP Working Papers, No. 01/21, https://iceds.anu.edu.au/research/research-initiatives/zero-carbon-energy-asia-pacific-initiative/publications.

Basma , H. et al. (2023), "Total cost of ownership of alternative powertrain technologies for Class 8 long-haul trucks in the United States", White paper, International Council on Clean Transportation, https://theicct.org/publication/tco-alt-powertrain-long-haul-trucks-us-apr23.

BMDV (2022), "Einfach laden an Rastanlagen: Auslegung des Netzanschlusses für E-Lkw-Lade-Hubs" [Easy charging at rest areas: Design of the network connection for electric truck charging hubs], Bundesministerium für Digitales und Verkehr, Berlin, https://nationale-leitstelle.de/wp-content/uploads/2022/09/Leitstelle_LKW-Netzstudie.pdf.

BMDV (2020), "An Overall Approach to Climate-friendly Commerical Vehicles", Bundesministerium für Digitales und Verkehr, Berlin, https://bmdv.bund.de/SharedDocs/EN/publications/overall-approach-climate-friendly-commercial-vehicles.

CARB (2021), "Advanced Clean Trucks Fact Sheet", California Air Resources Board, https://ww2.arb.ca.gov/resources/fact-sheets/advanced-clean-trucks-fact-sheet.

Cazzola, P. et al. (2023), "Research for TRAN Committee: Assessment of the potential of sustainable fuels in transport", European Parliament Think Tank, www.europarl.europa.eu/thinktank/en/document/IPOL_STU(2023)733103.

Council of the European Union (2023), "Alternative fuels infrastructure: Council adopts new law for more recharging and refuelling stations across Europe", Press release, 25 July 2023, www.consilium.europa.eu/en/press/press-releases/2023/07/25/alternative-fuels-infrastructure-council-adopts-new-law-for-more-recharging-and-refuelling-stations-across-europe.

European Commission (2023), "Sustainable Transport Forum", Directorate-General for Mobility and Transport, https://transport.ec.europa.eu/transport-themes/clean-transport/sustainable-transport-forum-stf_en.

F3 Centre (2021), "Electric Road Systems Fact Sheet", https://f3centre.se/en/fact-sheets/electric-road-systems-ers.

IEA (2023a), "Critical Minerals Market Review 2023", International Energy Agency, Paris, www.iea.org/reports/critical-minerals-market-review-2023.

IEA (2023b), "ETP Clean Energy Technology Guide", International Energy Agency, Paris, www.iea.org/data-and-statistics/data-tools/etp-clean-energy-technology-guide.

IEA (2022a), "Global Hydrogen Review 2022", International Energy Agency, Paris, www.iea.org/reports/global-hydrogen-review-2022.

IEA (2022b), "Biodiesel and diesel prices, 2019 to April 2022", International Energy Agency, Paris, www.iea.org/data-and-statistics/charts/biodiesel-and-diesel-prices-2019-to-april-2022.

IEA (2020), "Outlook for biogas and biomethane", International Energy Agency, Paris, www.iea.org/reports/outlook-for-biogas-and-biomethane-prospects-for-organic-growth.

ITF (2023a), *ITF Transport Outlook 2023*, OECD Publishing, Paris, https://doi.org/10.1787/b6cc9ad5-en.

ITF (2023b), "The Potential of E-fuels to Decarbonise Ships and Aircraft", International Transport Forum Policy Papers, No. 111, OECD Publishing, Paris, https://doi.org/10.1787/3d96e0d9-en.

ITF (2022), "Decarbonising Europe's Trucks: How to Minimise Cost Uncertainty", International Transport Forum Policy Papers, No. 107, OECD Publishing, Paris, https://doi.org/10.1787/ab17c66b-en.

ITF (2021), "Cleaner Vehicles: Achieving a resilient technology transition", International Transport Forum Policy Papers, No. 90, OECD Publishing, Paris, https://doi.org/10.1787/08cb5e7e-en.

Liu, J.L. and M. Danilovic (2021), “Electrification of the transportation system in China. Exploring battery swapping for heavy trucks in China 1.0”, Sweden-China Bridge Collaborative Academic Platform for the Electrification of Transportation Systems, www.diva-portal.org/smash/record.jsf?pid=diva2%3A1630337&dswid=8980.

Malins , C. (2023), “Fat of the land: The impact of biofuel demand on the European market for rendered animal fats”, Cerulogy, www.cerulogy.com/the-fat-of-the-land.

Martineau , R. (8 June 2022), “Fast flow future for heavy-duty hydrogen trucks”, National Renewable Energy Laboratory, www.nrel.gov/news/program/2022/fast-flow-future-heavy-duty-hydrogen-trucks.html.

O’Connell , A. et al. (2023), “A comparison of the life-cycle greenhouse gas emissions of european heavy-duty vehicles and fuels”, White paper, International Council on Clean Transportation, https://theicct.org/publication/lca-ghg-emissions-hdv-fuels-europe-feb23.

Odenweller, A. et al. (2022), “Probabilistic feasibility space of scaling up green hydrogen supply”, Nature Energy, Vol. 7, pp. 854-65, https://doi.org/10.1038/s41560-022-01097-4.

Rennert, K., F. Errickson and B.C. Prest (2022), “Comprehensive evidence implies a higher social cost of CO2”, *Nature*, Vol. 610, pp. 687-92, https://doi.org/10.1038/s41586-022-05224-9.

Rogstadius, J. (23 November 2022), “Interaction effects between battery electric trucks, electric road systems and static charging infrastructure”, LinkedIn Pulse, https://www.linkedin.com/pulse/interaction-effects-between-battery-electric-trucks-road-rogstadius.

Trafikverket (28 August 2023), “Vi avbryter upphandlingen för Sveriges forsta permanenta elvag” [We are canceling the procurement for Sweden’s first permanent electric road], Swedish Transport Administration, www.trafikverket.se/vara-projekt/projekt-i-orebro-lan/sveriges-forsta-permanenta-elvag/nyheter-for-sveriges-forsta-permanenta-elvag/2023/vi-avbryter-upphandlingen-for-sverige-forsta-permanenta-elvag.

UK DfT (2021), “Zero emission road freight trials funding winners”, UK Department for Transport, www.gov.uk/government/publications/zero-emission-road-freight-trials-funding-winners.

Ullström , R. (2021), “Electrification of the state road network”, Swedish Transport Administration, https://bransch.trafikverket.se/contentassets/4f5faad7102c4b57b9ce6bbe78ea0176/eng-elektrifiering-av-det-statliga-vagnatet-leverantorsdag-20210923_till-webben.pdf.

US Congress (2022), *Inflation Reduction Act*, H.R.5376, www.congress.gov/bill/117th-congress/house-bill/5376/text.

Vinci (2023), « Sur l’A10, les poids lourds électriques pourront bientôt se recharger en roulant » [On the A10, electric heavy goods vehicles will soon be able to recharge while driving], www.vinci-autoroutes.com/fr/actualites/environnement/a10-experimentation-recharge-poids-lourds-electrique.

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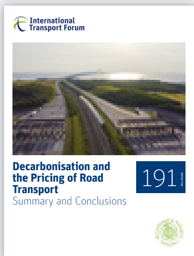

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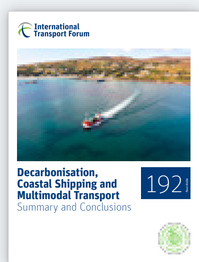

Decarbonisation, Coastal Shipping and Multimodal Transport
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