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Models for the development of electric road systems in Europe

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Content

1. Executive summary

In the European Climate Law presented this year, the EU has set itself the task of becoming climate-neutral by 2050 in line with the Paris climate goals. Given that heavy goods vehicles account for around 25% of total CO_2 emissions from road transport, climate neutrality depends in large part on rapid decarbonisation of this sector. Since alternative fuels such as hydrogen or synthetic fuels are currently still characterised by low efficiency, and battery-only solutions in heavy goods transport are associated with considerable battery weight and correspondingly long charging times, solutions aiming to achieve the greenhouse gas savings required by 2030 must include electric road systems (ERS). This comprises three possible approaches: overhead contact line infrastructure systems, conductor rail systems and induction systems.

Projects involving induction coils on the road have in many instances been affected by technical problems, so this technology does not appear to be operational, at least in the medium term. Pilot projects on conductor rail systems as well as, especially, overhead infrastructure systems, are, however, already at an advanced stage of development. The development of overhead infrastructure systems is particularly noteworthy here, as it is cost-efficient, dynamic and has already been deployed in numerous pilot projects in Germany and abroad. Thus, it has also been assigned the highest Technology Readiness Level (TRL) of the three systems introduced. Moreover, it is ahead of conductor rail systems in terms of technological maturity. If the necessary regulations are implemented at the European and national level and the subsequent planning and construction take place rapidly, heavy goods traffic can be thoroughly decarbonised by 2030 without additional burdens on transport companies and at manageable cost for state-owned operating companies.

In principle, there are three possible scenarios for the deployment of ERS at EU level: Establishment of a few interoperable ERS as a result of national stand-alone or bilateral agreements between individual member states (1), a Europe-wide interoperable system (2) and a compatible system (3). While the unilateral approach or an agreement between selected Member States foreseen in scenarios 1 and 3 already offers a high potential for decarbonisation, it risks producing a number of isolated solutions based on different, possibly non-interoperable technical systems. This would be likely to lead to higher economic costs and lower reductions in greenhouse gas emissions. Scenario 2, on the other hand, outlines an EU-wide, standardised, interoperable solution with a single metering and billing system, which would enable mobility providers to sell electrical power to ERS users in a competitive market across the continent. The participating transport companies would thus be able to choose the most favourable electricity prices, the best service and the tariff models that best suit them on the market. At the same time, they would only have to deal with a single company for all their contracts and invoicing (Single Point of Contact) related both to supplying electric vehicles with power and paying road tolls, as the mobility provider would offer European Electronic Toll Services (EETS). Such standardisation would simplify technical procedures while also being most cost-effective. This position paper therefore designates scenario 2 as its preferred solution.

2. Overview of electric road systems and their market readiness

2.1. The need for a European guiding vision for the development of electric road systems

The European Climate Law, presented by the European Commission on 4 March 2020, "sets the binding target of achieving climate neutrality in the Union by 2050 in order to meet the long-term temperature objective stated in Article 2 of the Paris Convention".[1] The European Commission had earlier declared that, "to achieve climate neutrality, transport emissions must be reduced by 90% by 2050. All modes of transport (road, rail, air and sea) will have to contribute to this reduction".[2] Moreover, the Commission has stated that it "will assess how the Union's legislation to meet the Union's 2030 target needs to be modified to achieve emission reductions of between 50% and 55% compared to 1990 levels" by the middle of 2021.[3] Concrete reduction targets for transport-related emissions by 2030 will soon be set and will be very ambitious. The Climate Change Act is due to be adopted in the second half of 2021.

Regulation 2019/1242 of the European Parliament and of the Council of 20 June 2019 (CO_2 emission standards for new heavy duty vehicles) recalls that "CO_2 emissions from heavy goods vehicles (HGVs), including lorries and buses, account for about 6% of total CO_2 emissions and about 25% of CO_2 emissions from road transport in the Union".[4] The Regulation further underlines that, until it was adopted, "Union law did not contain any targets for the reduction of CO_2 emissions from heavy duty vehicles and therefore concrete measures for such vehicles are needed without delay".[5]

When comparing propulsion technologies, electric vehicle variants show the highest greenhouse gas reduction potential for the commercial vehicle sector up to 2030.[6] The AFI Directive (2014/94/EU) points out that "electricity has the potential to increase the energy efficiency of road vehicles and to contribute to a reduction of CO_2 emissions from transport. It is an energy source which is indispensable for the use of electric vehicles [...] and contributes to improving air quality and reducing noise in urban and suburban areas and other densely populated areas".[7]

The AFI Directive (2014/94/EU) recommends charging points oriented towards the needs of passenger cars as infrastructure for the energetic supply of electric vehicles. This strategy is particularly convincing for electrically powered passenger cars because they can be used to provide adequate range with a high degree of flexibility as soon as a sufficient number of charging points is available. However, the Directive does not foresee a model for the electrification of HGVs. As in the case of cars, normal charging points will become important for the energy supply of HGVs where HGVs are parked for long periods of time, e.g. at depots or car parks with overnight accommodation for drivers. Fast-charging points designed to meet the specific needs of HGVs can also play a role in places with a medium duration of stay (e.g. rest areas with catering facilities where drivers take breaks).

In most transport tasks, heavy goods transport is operationally optimised to cover long distances every day without further stops. The prescribed driving and rest periods for drivers (VO 561/2006/EC), for example, already require meticulous route and pause planning, which must not be complicated by additional stops for charging. Batteries, on the other hand, which usually manage to cover common HGV ranges, weigh a lot and reduce the payload, with ad-

1 European Commission (2020): Proposal for a regulation of the European parliament and of the council establishing the framework for achieving climate neutrality and amending Regulation (EU) 2018/1999 (European Climate Law), p.16. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52020PC0080&from=EN.

2 European Commission (2019): Communication from the Commission. The European Green Deal. Available at: https://ec.europa.eu/info/sites/info/files/european-green-deal-communication_en.pdf.

3 European Commission (2020).

4 European Parliament and Council (2019): Regulation (EU) 2019/1242: p. 2. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019R1242&from=EN.

5 Ibid.

6 Hacker et al. (2020): StratON. Bewertung und Einführungsstrategien für oberleitungsgebundene schwere Nutzfahrzeuge. Final report, p. 84.

7 European Parliament and Council (2014): Directive (EU) 2014/94. p.4. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014L0094.

verse effects on energy and cost efficiency. This problem can be solved by supplementing stationary charging points with electrical road systems (ERS).

ERS are defined as systems that enable dynamic power transfer from external energy supply along the road to a vehicle in motion. Overhead contact line infrastructure systems, conductor rail systems and inductive power transmission systems are all possible candidates for continuous power supply systems in this model.[8] Dynamic power supply enables an unlimited range within the corresponding electric infrastructure network, eliminating the need to interrupt travel for the stationary recharging of energy storage devices. Batteries in vehicles or alternative propulsion systems are only required for trips outside the electric infrastructure network. The size of the battery can therefore be optimised according to various efficiency aspects or supplemented by an alternative propulsion system (possibly hybrid), depending on the specific needs of the transport companies. For purely electric vehicles, ERS applications require much smaller batteries than applications with only stationary charging possibilities, allowing considerable cost and weight savings in heavy-duty transport.[9]

Europe needs a guiding vision for electric mobility for heavy goods transport, in which ERS play a central role, supplemented by tailored stationary charging facilities in all places where longer stays are planned anyway. ERS are the quickest, most economic, most energy-efficient and most cost-effective option (in terms of both user costs and economic costs) for achieving the European emission targets.[10] Supplemented by the targeted establishment of charging points, they also ensure the highest flexibility for route and break planning by transport companies. This position paper aims to show that they can also meet the high requirements of the trans-European transport networks for European interoperability (cf. Art. 170 et seq. TFEU) and that a fragmentation of the internal market due to an uncoordinated market introduction of alternative fuels (cf. Directive 2014/94/EU, recital 10) can be prevented by the timely inclusion of ERS in the AFI Directive (2014/94/EU).

2.2. The goal of this IKEM working paper

When it comes to the construction of electric road systems, one frequently voiced fear is that, in a worst-case scenario, the EU, UK, Norway, Switzerland and neighbouring countries could see a diversity of ERS emerge, while some countries set up no ERS at all. In such an uncoordinated scenario, ERS lorries crossing borders would encounter significant restrictions, forcing the decarbonisation of international heavy goods traffic to rely more on liquid or gaseous fuels. Furthermore, a heterogeneous implementation would be difficult to reconcile with the idea of a European internal market and trans-European networks. This IKEM working paper deals with these issues in three scenarios. It describes a number of scenarios that aim to implement the idea of trans-European transport networks in the area of the ERS through varying degrees of harmonisation and different European regulatory approaches.

For orientation purposes, the paper first gives a brief overview of the existing technologies and their market maturity.

2.3. Technologies enabling a dynamic electricity supply of long-distance goods transport on the road

Electric road systems consist of four subsystems: (1) the electricity supply via (a) an upstream electricity supply network and (b) the ERS infrastructure, including operation and energy management, (2) the road on which they are mounted and as part of which, according to the predominant expert opinion, they are to be considered, (3) the electric vehicles with Current collector through which they are supplied with electricity directly from the infrastructure and (4) a background system comprising in particular a user

8 Gustavsson, Hacker and Helms (2019): Overview of ERS concepts and complementary technologies, p. 5.

9 Kühnel, Hacker and Görz (2018): Oberleitungs-Lkw im Kontext weiterer Antriebs- und Energieversorgungsoptionen für den Straßengüterfernverkehr, p. 20.

10 Ainalis, Thorne and Cebon (2020): Decarbonising the UK's Long-Haul Road Freight at Minimum Economic Cost, p. 22.

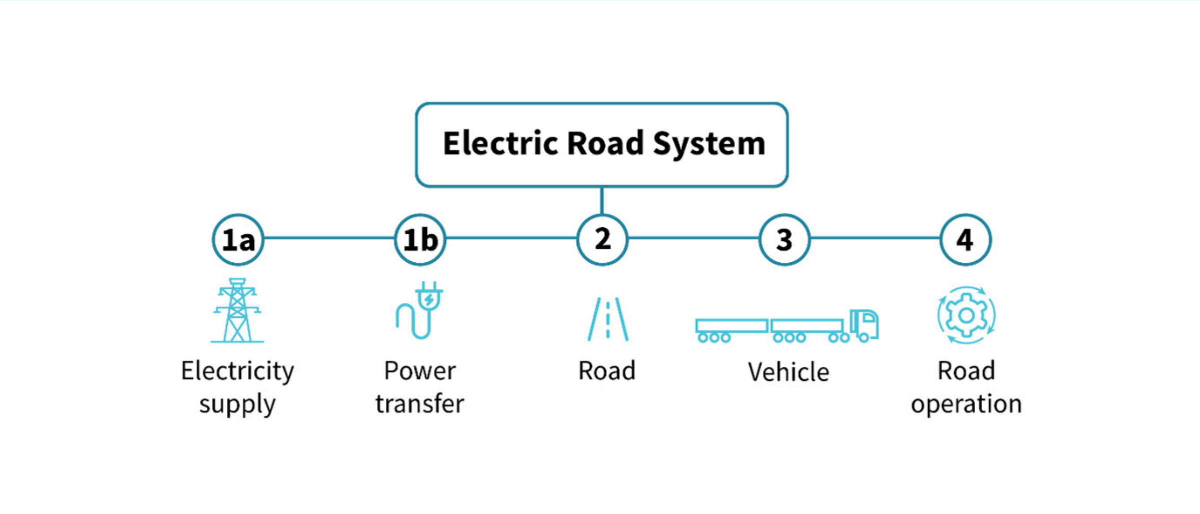

Figure 1: Electric Road System (Source: own representation).

authorisation system (from vehicle identification via access management to legal enforcement against misuse) and a data management system that covers all the functions required for operational management, user authorisation system, billing and invoicing.[11]

The technical integration of ERS into the already existing subsystems of electricity supply and road entails challenges which only marginally affect European interoperability and therefore need not be dealt with in greater depth here. European standards in the form of technical specifications are currently being developed for lorries with electric propulsion (e-lorries) and Current collector systems. The drivers of this development are the ERS infrastructure and the automotive/supplier industry, which would like to produce uniform series vehicles for the international market, including the segment of e-lorries for ERS, regardless of the type of power supply.

On the one hand, this creates the challenge of having to design ERS and stationary charging points in a way that would enable them to supply standardised electric lorries in equal measure. At the same time, it has the advantage of providing European and even international interoperability for an important subsystem without additional coordination effort on the part of European policy-makers. International vehicle approval law (Homologation, in particular the ECE standards) will have to be updated with regard to the new electric vehicle systems so that interoperable electric lorries can soon be produced in series for ERS as well. This position paper therefore calls for a European guiding vision for the ERS infrastructure and parts of the background system and outlines three scenarios with different levels of regulation.

In the current state of the art, there are three basic technological approaches for ERS power supply infrastructure for which serious efforts to achieve market maturity are being made (figure 2). They make use of overhead contact lines, conductor rails in the road and induction coils in the road, respectively.[12]

2.4. Classification of the technology and market maturity

2.4.1. Overhead contact line system

An overhead contact line system has been under development by Siemens Mobility GmbH under the name eHighway since 2010. This technology was developed on the basis of comparable overhead contact line systems and the corresponding technical standards in the railway sector, and can

11 Gustavsson, Hacker and Helms (2019).

12 cf. Gustavsson, Hacker and Helms (2019): S. 8; Suul and Guidi (2018): Technology for dynamic on-road power transfer to electric vehicles, Overview and electro-technical evaluation of the state-of-the-art for conductive and inductive power transfer technologies, p. 12 and Wietschel et al. (2017): Machbarkeitsstudie zur Ermittlung der Potentiale des Hybrid-Oberleitungs-Lkw, p. 82.

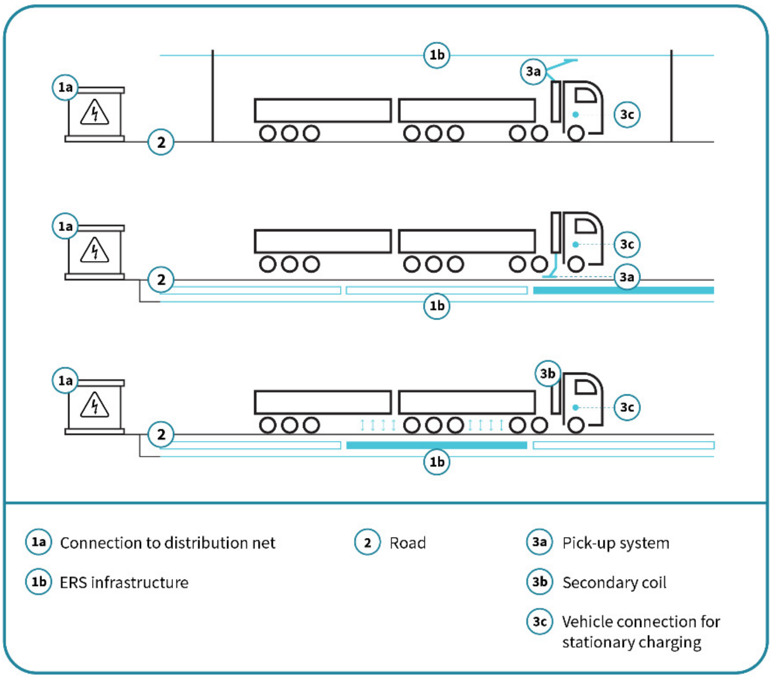

Figure 2: Three Technological Approaches for ERS Infrastructure (Source: own representation).

be used reliably at speeds of up to 90 km/h. Adjustments were mainly made with regard to the pantograph, which, as with trolley buses, represents the electromechanical interface to the vehicle and must therefore provide the return current. In addition, a technical and optical integration of the ERS infrastructure into the motorway area was carried out.[13] The integration of the current collection technology into the electric vehicle system was carried out by Scania AB.

After the successful completion of system tests on roads in California and Sweden, the 2018 system was assigned a TRL 7.[14] In May 2019, an overhead contact line system in both directions was put into operation on a five-kilometre section of the A5 motorway near Frankfurt in Hesse, on which test operations with vehicles from various haulage companies will continue until 2022.[15] In December 2019, a comparable test installation of 2 x 5 km on the A1 between Reinfeld and Lübeck entered operation.[16] A further test operation will start on the B462 in Baden-Württemberg on a route of 2 x 4 km between the cities of Kuppenheim and Gernsbach-Obertsrot, probably at the beginning of 2021. Thanks to the largely trouble-free regular operation of the pilot projects, it can now be assumed that a TRL 8 (designating an actual system that has been completed and qualified through testing and demonstration) will be achieved. As no further technical obstacles are expected, and with a likely completion of the projects in 2021 or 2022, a TRL 9 (an actual system tested by successful mission operation) can be achieved by that time.[17]

13 Suul/ Guidi: Technology for dynamic on-road power transfer to electric vehicles, 2018, p. 12.
14 Ibid.: p. 14.
15 Hessen Mobil (n.d.): ELISA – Elektrifizierter, innovativer Schwerverkehr auf Autobahnen. Available at: https://ehighway.hessen.de/ELISA.
16 eHighway.SH (n.d.): Feldversuch eHighway Schleswig-Holstein. Available at: https://www.ehighway-sh.de/de/projektbeschreibung.html.
17 Suul and Guidi (2018): p. 15 ff.

Apart from general aesthetic objections to overhead contact lines on highly frequented highways and solvable challenges in their maintenance and electrical protection[18], the main criticism of the overhead contact line system is that it only allows traction power supply to vehicles of a certain minimum size: pantographs reaching up to the required height are probably still possible in certain cases for vehicles with a permissible total weight of 7.5 tonnes, but are excluded for smaller vehicles.[19] However, as the electrification of passenger cars and local freight transport can be carried out by means of stationary charging solutions for almost all applications, the use of ERS in heavy goods transport as proposed here is no disadvantageous restriction.

In the monitoring of these projects, international standards from the railway sector will be updated and applied directly or analogously. Accompanying projects to determine economic and climate action potential, the technical and legal adaptation to the motorway sector, the updating of standards, and the development of solutions for necessary measurements as well as billing and invoicing, have been running since 2011 and have presented viable solutions for all essential areas.[20]

2.4.2. Conductor line system

Another way of supplying electricity to road vehicles while they are in motion is by means of conductor rail systems: different companies have adopted a range of approaches in this domain. Although the development of these systems can to some extent be based on existing railway technology, this would still require considerable adaptations for installations on the road. For example, in the absence of rails, precautions must be taken to compensate for vehicle movements in the track, whereas for overhead contact lines the wider contact surface on the pantograph gives vehicles more lateral play in the track.

The French group Alstom is building on the technology it developed for trams. This has already been used in the Swedish project 'Slide-in Electric Road Systems'; after tests were completed, the system developed in this project could be assigned as TRL 4 at least.[21] The companies Elways and Elonroad developed systems without links to existing traction power supply systems in public transport applications. In 2016, Elways's system was able to achieve at least TRL 4.[22] In addition, further development up to TRL 7 was expected by 2018.[23] The eRoad Arlanda project, in which Elways is further developing the technology, features an e-lorry operating on a 10-kilometre section between Arlanda and Rosersberg. For the project, two kilometres of the total route were equipped with conductor rails from October 2017 onwards.[24] Elonroad's system, which is comparable to that of Elways and whose rails protrude around five centimetres from the ground, achieved TRL 3 in a laboratory environment on a test track in Lund, Sweden. In addition, the technology could be classified as at least TRL 4 on a 2017 test track.[25] The standardisation of the vehicle-infrastructure interface has also begun, but faces the challenge that different system approaches are partially incompatible from a mechatronic point of view and must be described with different specifications.

2.4.3. Inductive systems

The use of inductive systems enables contact-free power transmission between vehicle and infrastructure by means of magnetic fields. The required infrastructure is not visible aboveground, as the power is transmitted by primary coils located under the surface of the road to secondary coils within the vehicle via moving magnetic fields.

The first significant development steps in this field were taken in South Korea. The Korea Advanced Institute of

18 Nicolaides, Cebon and Miles (2017): Prospects for Electrification of Road Freight, p. 8.

19 Ibid.

20 Hacker et al. (2020); Hartwig, Schneider und Bußmann-Welsch (forthcoming): AMELIE - RED. Abrechnungssysteme und -methoden für elektrisch betriebene Lkw sowie deren interoperable Infrastrukturen im europäischen Kontext and Jöhrens et al. (2020): Roadmap OH-Lkw: Einführungsszenarien 2020-2030.

21 Suul and Guidi (2018): p. 18.

22 Ibid.: p. 24.

23 Ibid.

24 eRoadArlanda (n.a.): About the project. Available at: https://eroadarlanda.com/about-the-project/.

25 Suul and Guidi (2018): p. 27.

Science and Technology (KAIST) has worked on the 'Online Electric Vehicle' (OLEV) project, which made it possible to charge buses and trams while driving, since 2013. The induction charging technology was used in 2013 on two buses on a 24-kilometre route between Gumi railway station and In-Dong district. The charging panels were used for 5-15% of the total route.[26] Today, the technology is considered a failure in South Korea because its commercialisation failed.[27] The tests in the scheduled operation in Berlin were also discontinued in 2019.[28] Instead, Berlin is relying on stationary, conductive energy transmissions using pantographs.[29] TRL 5 and 6 could therefore not be exceeded for inductive energy transmission to buses.

The Canadian manufacturer Bombardier has been developing technologies for inductive power transmission since 2010, but mainly for stationary charging of trams and buses. At sites in Germany (Berlin, Braunschweig and Mannheim) and Sweden (Södertälje), Bombardier's PRIMOVE E-buses are used and recharged along the route using charging stations at regular stops.[30] The technology can also be used for dynamic charging, which has been tested by Bombardier on a tram section of Line 3 in Augsburg.[31] A project which took place in Mannheim from 2013 to 2018 used Bombardier's PRIMOVE technology, with two electric buses inductively charged while travelling. However, the project was discontinued in 2018 without being extended, as workshop visits became more frequent, the battery charging facilities were too short and the technical installations on the line were too complex.[32] This project also faced problems similar to those in South Korea.

The Smartroad Gotland project currently underway in Gotland, Sweden, for which ElectReon AB is providing the technology involves the electrification of 1.6 kilometres (800 metres in two directions) on a four-kilometre line. The first tests with lorries and a bus are planned for 2020.[33] The further project period, which lasts until 2022, will show whether the technology used in the project can reach or exceed TRL 5 and 6. There are also pilot projects in various other countries for charging electric vehicles while driving[34] and China in particular seems to be trying to set standards for the inductive charging of electric vehicles.[35]

However, no concrete pilot projects for the use of charging e-lorries on a motorway while driving (i.e. at a speed above 90 km/h) or plans to this effect by the companies mentioned above could be identified. In 2018, for example, the trade press attested that stationary inductive charging of electric vehicles was "still in its infancy".[36] No inductive charging solution with a power transfer rate of over 50 kW is commercially available. This is significantly lower than the power transfer rate required for road transport – even with 100% coverage of the road surface, some 140 kW of power are required. While this problem at least seems solvable with the installation of several secondary coils on a lorry,[37] such

26 PHYS (2013): Wireless Online Electric Vehicle, OLEV, runs inner city roads. Available at: https://phys.org/news/2013-08-wireless-online-electric-vehicle-olev.html.

27 The Korea Times (2019): ICT minister nominee accused of wasting research money. Available at: https://www.koreatimes.co.kr/www/tech/2019/04/325_265924.html.

28 Urban Transport Magazine (2019): Berlin: E-Bus Test mit Induktionsladung eingestellt. Available at: https://www.urban-transport-magazine.com/berlin-e-bus-test-mit-induktionsladung-eingestellt/.

29 Tagesspiegel (2020): BVG elektrifiziert die Linie 200. Available at: https://www.tagesspiegel.de/berlin/geladen-wird-der-bus-per-pantograf-bvg-elektrifiziert-die-linie-200/26133720.html.

30 Bombardier (2017): Bombardier's PRIMOVE E-Bus Fleet in Braunschweig Proves the Power of E-Mobility. Available at: https://rail.bombardier.com/en/newsroom/press-releases.html/bombardier/news/2017/bt-20171215-bombardiers-primove-e-bus-fleet-in-braunschweig-prov/en.

31 B4B Wirtschaftsleben Schwaben (2012): Straßenbahnen ohne Oberleitung werden Realität. Available at: https://www.b4bschwaben.de/b4b-nachrichten/augsburg_artikel,-strassenbahnen-ohne-oberleitung-werden-realitaet-bombardier-_arid,116490.html.

32 heise online (2018): Induktives Laden: Mannheim will keine weiteren Primove-Elektrobusse. Available at: https://www.heise.de/newsticker/meldung/Induktives-Laden-Mannheim-will-keine-weiteren-Primove-Elektrobusse-4060084.html.

33 Smartroad Gotland (n.a.): FAQ Smartroad Gotland. Available at: https://www.smartroadgotland.com/faq.

34 aio (2018a): Elektroauto laden: Künftig lädt das E-Auto während der Fahrt. Available at: https://aiomag.de/unendliche-reich-weiten-elektroautos-waehrend-der-fahrt-laden-8840.

35 Elektroauto-News (2020): China veröffentlicht Standard für induktives Laden von E-Fahrzeugen. Available at: https://www.elektroauto-news.net/2020/china-standard-induktives-laden-elektrofahrzeugen.

36 aio (2018b): Kabellos aufladen: Ist das die Zukunft für Elektroautos? Available at: https://aiomag.de/kabellos-aufladen-ist-das-die-zukunft-fuer-elektroautos-7121.

37 Nicolaides, Cebon and Miles (2017): p. 8.

an installation would entail a reconstruction of the outer lane at some cost as well as an unclear amount of follow-up expenses for maintenance.[38] The solution would probably be unsuitable for asphalt roads, as these are prone to cracks in the area of recessed equipment.[39] Consequently, no publication on ERS mentions a TRL for this technology in this application area. It can be assumed that, at high speeds on the motorway, and the additional challenges that arise from this (vibration, impossibility to track vehicles exactly, etc.), an implementation is impossible in the current state of the art.

An additional problem during the operation could be that the systems have to be installed in the roadway, which would entail high additional costs for installation and maintenance. There are no known plans to standardise a technology for dynamic charging of lorries while driving on motorways. The ability to supply different classes of vehicles (cars and lorries) is sometimes cited as an advantage,[40] but this is only partly valid, since high efficiency and reliability require the coil systems to be adapted to different speeds, dimensions and performance requirements of the vehicles.[41]

2.5. Status quo of the system structure without coordinated regulation

2.5.1. Construction and operation of ERS on European motorways

ERS are road-related systems that are inseparably linked to the road structure and must fit into the security architecture of these roads when they are built and operated on motorways. There are hardly any European standards for the equipment and security architecture of trans-European transport routes in road traffic. However, the pilot projects on ERS in Germany and Sweden have shown that it is possible to integrate ERS infrastructure into the road area in each case in accordance with national planning law and that this can be linked to both specific standards for ERS infrastructure from the railway sector and planning processes for road infrastructure.

Due to the high degree of automation of all the solutions under development, the use of the ERS infrastructure is likely to require only minor adaptations of road traffic rules in all Member States to exclude technically unsuitable vehicles from use, which is a prerequisite for smooth integration into the road space. The user authorisation systems, from vehicle identification to access management and enforcement against misuse, will either be integrated into the system in such a way that they do not require any further adaptation of the legal framework, or (in the case of enforcement) will have to adapt to national conditions. National differences in this area and the need for regulation in individual cases do not place European interoperability in question. Standards for the approval of vehicles with suitable current collector systems and the associated electric vehicle system should be developed or harmonised at the European level to accompany the market launch and ensure that the electric vehicle systems are designed uniformly so that the same vehicles can be supplied with electricity both via stationary charging stations and via different ERS, i.e. only the current collectors would have to be adapted if necessary.

Three basic decisions concerning the planning, establishment and operation of ERS should be taken uniformly at European level in order to ensure their interoperability and with regard to stationary charging points:

– ERS should be defined at the European level as an "infrastructure for alternative fuels" (AFI-RL 2014/94/EU) similarly to charging points. However, they should not be put on an equal footing with them, but regulated independently.
– ERS should be defined at the European level in such a way that they are not part of the distribution grid and, like charging points, must be operated separately from it.
– ERS should have a Europe-wide definition as part of the road and as such be included in the infrastructure costs Directive RL 1999/62/EC. Detailed regulatory proposals for the implementation of the preferred scenario (scenario 2) are presented in conjunction with the scenario.

38 Ibid.: p. 9.
39 Ibid.
40 Nicolaides, Cebon and Miles (2017): p. 9 and Ainalis, Thorne und Cebon (2020): p. 7.
41 cf. PIARC (2018): Electric Road Systems: A Solution for the Future? Appendices, p. 155.

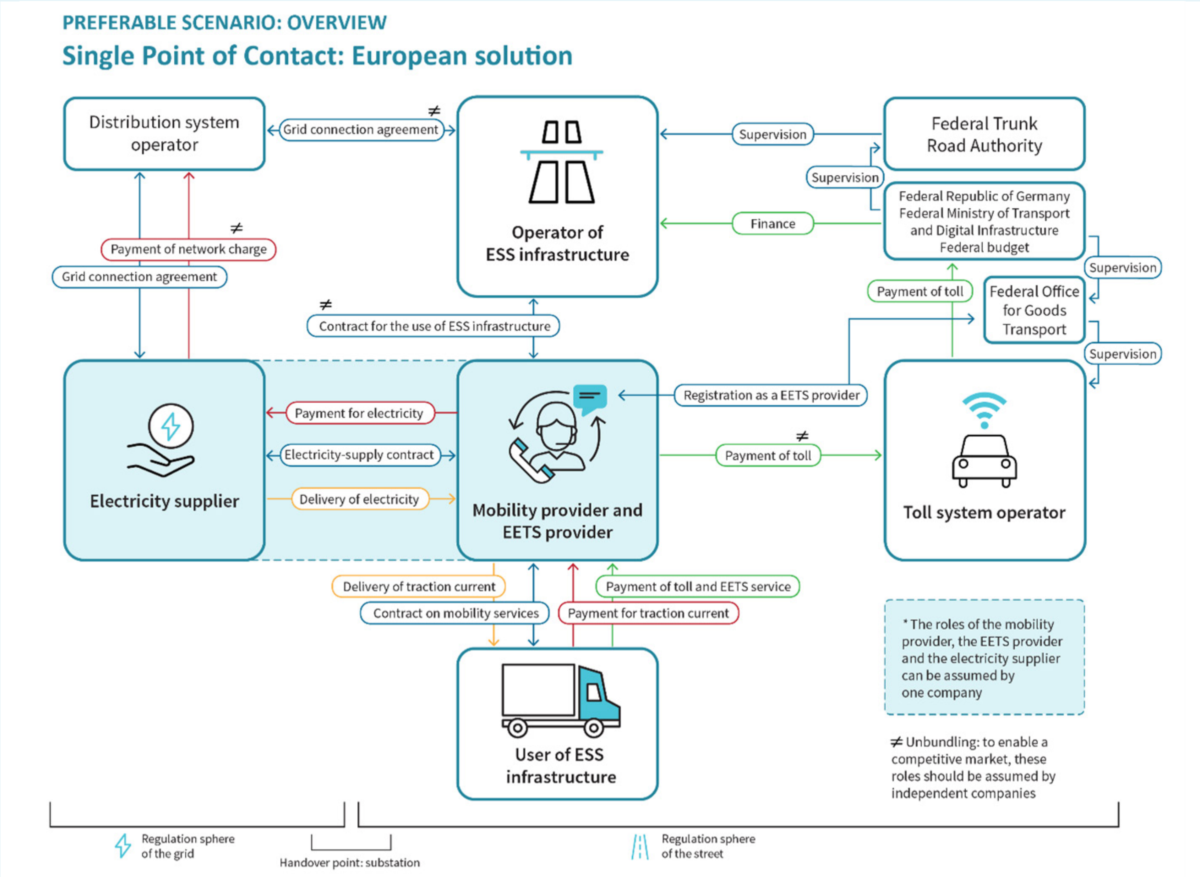

Figure 3: Single Point of Contact: European Solution (Source: own representation).

2.5.2. Financing and billing for electric road systems

Furthermore, an interoperable European financing and accounting system for ERS must be created. A guiding vision of how such a system could look using the example of the German legal framework is presented in the IKEM working paper 'Preferential model for the financing and billing of electrical road systems' (forthcoming). The following graphic overview shows that, with extensive links to existing European regulation in the area of infrastructure costs, the internal energy market and the European Electronic Toll Service (EETS), a market model would be possible in which trans-European, interoperable traffic could be connected to an ERS while a competitive market for mobility providers could be created in which they can offer the best price, the best service and the best tariff model for electrical power combined with EETS. The European framework Regulation means that many of these considerations are largely transferable to the other Member States and guided by the need to find an approach for the establishment and operation of ERS in Germany that would enable interoperable operation within the European framework.

3. ERS as part of the trans-European transport networks: three scenarios for European regulation

As described above, there are three basic technological approaches that provide possible solutions for supplying ERS lorries with power while driving, and they are at different levels of market maturity. Against this background, it is conceivable that European countries could opt for different systems in different forms, which are not interoperable or are even incompatible with each other, especially since there is currently no legal obligation for states to comply with existing or future standards. This basic assumption will be examined in a chapter on standardisation and its effect in Europe preceding the scenarios.

As described above, there is urgent need for action to decarbonise heavy goods transport by 2030. The overview shows that, by that date, only the overhead contact line system and (provided that the remaining technical hurdles are overcome) a maximum of one or two conductor rail systems will probably reach a degree of technological and market maturity that will allow operational setup and operation within the required time frame. Below, it is shown that standardisation strengthens the trend towards one or a few technology variants. However, due to the relatively low complexity of the technologies and their already advanced standardisation, it should be possible for many different companies – especially those with previous experience in the railway sector – to make ERS or subsystems of it available. Therefore, the tendering for the construction and operation of the systems is expected to involve a highly competitive processIn this way, the invitation to tender for the construction and operation of the systems can also be extended in a competitive process. Thus, there are three possible scenarios for regulation:

- Scenario 1: One Member State leads the way with a system while further states follow based on bilateral agreements
- Scenario 2: A Europe-wide interoperable ERS
- Scenario 3: A few compatible systems are introduced in Europe

While this paper finds that scenario 2 is preferable from the point of view of the European internal market and the trans-European transport networks, even in scenarios 1 and 3, it is possible to establish and operate ERS in a way that is efficient and compatible with European objectives from the outset.

3.1. The effect of standardisation

Instruments such as technical standards and standardisation are essential to ensuring interoperability and compatibility. Although norms and standards are voluntary rather than legally binding, they represent safety standards. They are important in the approval process and serve to concretise legal regulations. They also serve industrial policy objectives. In the scenarios described here, norms and standards can contribute to ensuring interoperability and compatibility and enable technology transfer and the opening of markets for ERS. Usually, standards are developed by economic and social actors on their own behalf, but also embedded in the legislative framework – as reflected, for instance, in the role of DIN, which is contracted as the central standards organisation at the national level in Germany.[42]

Theses:

- A standardisation process for two ERS (overhead contact line and conductor rail) is currently underway. A standardisation process will also be initiated in the future for a small single-digit number of systems.

- If an EU state decides to set up and operate an ERS, it will most likely choose a system that is the subject of a standardisation process and actively participate in this standardisation.

- If two EU states decide to set up and operate an ERS according to the same standard (scenario 1), these systems will be technically interoperable in terms of pow-

42 Federal Government of Germany (2009): Normungspolitisches Konzept der Bundesregierung, p. 2. Available at: https://www.bmwi.de/Redaktion/DE/Downloads/M-O/normungspolitisches-konzept-der-bundesregierung.pdf?__blob=publicationFile&v=3.

er transmission from the infrastructure to the vehicle. In this case, only the interoperability of a financing and billing system would have to be legally regulated.

– This would entail that only a very limited variety of ERS could be simultaneously created in parallel in Europe. In the worst case, initially only one state or several non-neighbouring states could set up and operate ERS on their own (scenario 3), or 'islands' with different ERS could be created, in which one group of states opts for one system and another group of states for another system. Interoperability would be ensured within these islands, but might be impossible between them (scenario 1).

– Standardisation should also be carried out on ERS that are not fully interoperable in order to at least ensure compatibility (scenario 3).

3.2. Scenario 1: One Member State leads the way and bilateral approaches

In this scenario, one Member State takes the lead alone by setting up an ERS without neighbouring countries following. Two Member States could also make a bilateral agreement, or a group of Member States could agree to establish an ERS together or join the Member State that originally led the way.

The assumption of this scenario is that Germany will build an overhead contact line infrastructure for electric lorries with pantographs. While no decision on technology has yet been made in Germany, this is based on the fact that, both in concrete pilot and research projects on ERS on motorways for heavy goods traffic and in political discussions, overhead contact lines have been the only technology considered, whereas other Member States such as Sweden have taken a broader approach and attempted to test as many different technological approaches as possible in pilot projects.

The studies considered below conclude that the establishment of an overhead contact line system in Germany, even if solely implemented nationally, makes sense for achieving climate policy goals, and even from an economic point of view. It would also be legally feasible.

3.2.1. A national ERS already represents a sensible alternative to conventional propulsion systems

The Roadmap OH-Lkw study[43] and the SWOT analysis[44] from the same project use the overhead contact line system as an example to show that, at least in Germany, a purely national ERS already represents a sensible alternative to propulsion drive systems. It must be taken into account that the contribution of ERS lorries to CO_2 reductions depends on the extent to which the technology is accepted on the market, to which degree the infrastructure is expanded, and the share of ERS lorries in traffic. In the Ifeu's potential analysis, the CO_2 reduction potential on a fully developed and utilised overhead contact line network was estimated to be about 10.5 Mt/year in 2030.[45]

The Roadmap OH-LKW study assumes a suitable core network on which the overhead contact line system will be built. This will result in an estimated reduction of 9.2 Mt of CO_2 in 2030 and, taking into account ERS lorries suitable exclusively for commuter traffic (electrification in both directions), a reduction of 3.6 Mt in 2030.[46] Even if the overhead contact line were to be installed in Germany only, ERS lorries driving across borders could still achieve an electric traction share that could make their operation as ERS lorries economically viable.[47]

The study assumed a spatial restriction to traffic within Germany. This is due to the consideration that, although a significant amount of the share of road freight in Germany is cross-border traffic, there are also obstacles to cross-border expansion due to unresolved issues in the area of standardisation and interoperability. As a result, the study is based on

43 Jöhrens et al. (2020).

44 Jöhrens et al. (2017): Roadmap OH-Lkw: SWOT-Analyse.

45 Jöhrens et al. (2018): Roadmap OH-Lkw: Potentialanalyse 2020-2030, p. 32.

46 Jöhrens et al. (2020): p. 13.

47 Ibid.: p. 14.

a German-only base network of about 3,200 km. Traffic is not assumed to take place exclusively on this basic network, but is assumed to not be connected to an overhead contact line outside the network.[48] The development of the electricity mix in Germany and the share of renewable energies in it will be of crucial importance for the estimated CO_2 emissions. In the field of energy generation, Fraunhofer ISI expects a 45% reduction in greenhouse gas emissions compared to the reference year 1990,[49] which would be necessary to implement the goals of the EU Renewable Energy Directive[50] and the EU Energy Efficiency Directive.[51] [52]

The study 'StratON – Evaluation and Implementation Strategies for Overhead Contact Line Heavy Goods Vehicles'[53] also comes to the conclusion that even an ERS (here: overhead contact lines) installed only in Germany has high potential for reducing greenhouse gas emissions from road freight transport.[54] This is based on the electrification of a basic network of 4,300 km, which by the year 2030 will already make it possible to reduce emissions by 3-6 or 2-4 Mt. Thus, a significant climate advantage can be achieved compared to diesel lorries, even if the German power mix is not yet 100% renewable.[55]

3.2.2. Construction, operation and financing of the ERS infrastructure and a billing system can be designed in compliance with European law

In its final report,[56] the AMELIE project examines the legal feasibility of the construction, operation, financing and accounting of ERS. Among other things, the project examines the national approach of a Member State using the example of European and German law:

– Financing and billing of the ERS infrastructure can be made permissible under European law within the framework of a purely national structure in one Member State by including it in tolls (in other Member States possibly other types of road user charges), although a minimum level of European regulation seems to make sense for later applicability in other Member States.

– State financing of the ERS infrastructure and subsidies for lorry operators can be designed in conformity with European law during the market launch phase.

– A competitive market for mobility providers can be created for the sale of electrical power using governmentally provided ERS infrastructure. The electrical power would thus be offered by the private sector in competition.

– The national approach can be designed with regard to all aspects of construction and operation in such a way that it does not violate any European regulation governing trans-European networks. The prerequisite for this is that the company can use the ERS regardless of its location or focus of activity. Nor should access to the use of the roads that are part of the European transport networks be subject to additional hurdles that do not exist for nationals. In this case, the national approach is also compatible with all other principles of European law.

Proportionate toll collection for ERS, which not all fee debtors can use:

The ERS infrastructure can already be interpreted as part of the road under the current law. European law does not rule out this classification: Art. 17 TEN-T Regulation (1315/2013/

48 Ibid.: p. 21f.

49 Fraunhofer ISI and Öko-Institut (2016): Climate Protection Scenario 2050. 2. Final report.

50 European Parliament and Council (2009): Directive 2009/28/EC. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009L0028.

51 European Parliament and Council (2009): Directive 2018/2002. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L2002&from=EN.

52 Jöhrens et al. (2020): p. 27.

53 Hacker et al. (2020).

54 Ibid.: p. 19.

55 Ibid.: p. 16 f.

56 Hartwig, Schneider and Bußmann-Welsch (forthcoming)

EU) does not explicitly define ERS as road transport infrastructure within the framework of trans-European networks, but it does not exclude it either. Authorities approving the infrastructure development in the three pilot projects in Germany therefore classified the ERS infrastructure as part of the road. For better legal certainty, this should be clarified by the national legislator of the respective Member State. At the European level, an explicit inclusion in Art. 17 TEN-T Regulation (1315/2013/EU) would provide clarity as well.

If the ERS infrastructure is part of the road, its costs can easily be included in the road costs and passed on via tolls (or other road charges in other Member States) to all users of the federal trunk roads according to the originator and polluter pays principle. According to national charging legislation, it is unproblematic, at least in Germany, if some users are charged a fee to use a state facility (here: road use). This also applies if they cannot use parts of the facility (here: lorries without pantographs cannot use the ERS as part of the road, but they can use the rest of the road). In this case, the fee can be justified by the fact that it has an incitation effect (here: emission reduction) and that additional external costs are charged via the fee (here: ERS infrastructure as a countermeasure for the emissions of the lorries and imposing it according to the polluter-pays principle). In addition, each user can, by making the appropriate investment, make use of the advantages of the facility of which he or she has been deprived so far (here: any person can buy an ERS lorry and use the ERS). The imposition of costs thus also has an incitement effect, as it creates a strong incentive for each transport company to convert its fleet to ERS lorries and thus to benefit from the ERS, which the company co-finances through the toll anyway.

Disproportionate impact on EU foreigners/state aid law:

Any Member State which wishes to introduce an ERS on its own must take pains to examine whether the disproportionate impact on EU foreigners – having them finance infrastructure that they cannot always use in a cost-effective way – can be justified under European law. It would be contrary to European law, for example, if the users of ERS lorries were to receive further support through discounts on vehicle tax (only for vehicles registered in the Member State). An environmental bonus for the purchase of ERS lorries or discounts on energy costs (giving away electricity) could also be problematic in this context (depending on the design).

Such support measures (depending on their design) would be compatible with European law only if they would benefit all ERS users regardless of their place of business. To this end, a comparison can be made in particular with regard to the rulings and the discussion about the car toll in Germany. For the financing and operation of the ERS and the encouragement of users, it is crucial to ensure in every respect that it is designed in a non-discriminatory manner and is under no circumstances linked to the headquarters of the transport company. However, all types of cost sharing or support can be linked to the degree of use of the ERS (e.g. according to time, kilometres travelled or electrical power used in kWh), as this is independent of the company headquarters. The fact that companies based in the Member State are often able to achieve a higher level of utility because of their domestic activities should not be objected to as discrimination.

Trans-European grids, single European market and fundamental freedoms:

One of the EU's main goals is to establish a single market comprising an area without internal borders in which the free movement of goods, persons, services and capital is ensured in accordance with the provisions of the Treaties. This includes, among other things, establishing and developing trans-European transport infrastructure and, within the framework of a system of open and competitive markets, promoting the interconnection and interoperability of national networks and access to them.

The introduction of a user charge for ERS, which serves to finance it and which all heavy goods vehicles (including diesel) must pay when using the trunk road, does not violate the prohibitions of discrimination in Art. 34 TFEU (freedom of movement of goods) or Art. 56 TFEU (freedom to provide services). According to Art. 34 TFEU, "quantitative restrictions on imports and all measures having equivalent effect are prohibited between Member States". A measure having equivalent effect exists in the case of a toll if the user charge is likely to impede the access of products from other Member States to the German market.[57] This is also the case because a toll can potentially and indirectly affect trade flows. The user charge does not target the marketing of goods per se. However, it does increase the transport costs of goods traffic and can thus influence competitiveness, since rising transport costs also affect the prices of the transported goods. Higher transport costs can also impede the exercise of freedom to provide services.[58]

However, distribution-related regulations that restrict or prohibit certain sales modalities cannot hinder trade between Member States and thus do not constitute a "measure having equivalent effect", provided that they do not discriminate (according to the so-called 'Keck formula').[59] The user fee is to be classified as distribution-related, since it affects the transport route and not the product itself. A user charge for lorries would have to be paid by all lorries on the trunk road in the respective Member State, irrespective of the nationality of the owner. There is therefore no overt or covert discrimination (Art. 36 S. 2 TFEU). However, this must not be accompanied by tax relief only for the owners of the Member State in which the ERS is established, as this would in fact constitute covert discrimination.

However, an isolated solution resulting from a national approach certainly contradicts the idea of trans-European transport networks according to Art. 170ff. AEUV and the TEN-T Regulation (1315/2013/EU), since the aim is not only to avoid discrimination in the use of national infrastructures, but also to actively contribute to the development of trans-European, interoperable networks in the fields of transport and energy. This is not justiciable, but it is politically relevant. An isolated solution does not hinder cross-border traffic per se and the purely national implementation, e.g. on a core network, initially only brings advantages for national traffic. What remains to be examined, however, is what measures the EU can take to actively promote the development of interoperable or at least compatible networks, rather than merely enabling national solutions (more on this in the sections on the other two scenarios).

3.2.3. The need for legal adaptation in Europe to enable national approaches

An adaptation of European law is not mandatory for national implementation. However, a lack of relevant European law would be fraught with legal uncertainties and would make it more difficult for Member States who decide to set up an ERS at a later date to connect to it. The detailed regulatory proposals in scenario 2 should be considered in this regard.

3.2.4. Bilateral approach

It is conceivable that two Member States form a bilateral agreement, or a group of Member States make a bilateral or multilateral agreement on the establishment of an ERS. The scenario is largely comparable to the approach described above, with the advantage that the 'island' for the ERS becomes larger. This would increase the efficiency and climate gains, since the longer distances would allow more lorries to use the ERS. The length depends primarily on the commitment of the Member States, so that the island system of a group of Member States does not necessarily have to be larger than the network of a single Member State that is particularly keen to expand.

The efficiency and climate impact of the system would be closely linked to the length of the core network, both nationally and across Europe: the calculations made for Germany in various studies can be considered here.[60] This structure can also be designed in accordance with European law, with due consideration of remarks on going it alone for the need for adaptation. However, the major disadvantage in this context is that the expansion would not be coordinated by

57 Vgl. auch Becker (2012), in: Schwarze, Becker, Hatje und Schoo: EU-Kommentar, Art. 34 AEUV, Rn. 37ff. Zudem liegt eine Maßnahme gleicher Wirkung vor, wenn sie im Falle der Dienstleitungsfreiheit geeignet ist, den Zugang von Dienstleistungen von aus einem anderen Mitgliedstaat stammenden Dienstleitungserbringern (bzw. -empfängern) zu behindern: Müller-Graff (2018), in: Streinz: EUV/AEUV, Art. 56 AEU, Rn. 70ff.

58 EuGH (1995): Rechtssache C-55/94: https://eur-lex.europa.eu/legal-content/DE/TXT/HTML/?uri=CELEX:61994CJ0055&from=DE.

59 EuGH (1993): Verbundene Rechtssachen C-267/91 und 268/91: https://eur-lex.europa.eu/legal-content/DE/TXT/HTML/?uri=CELEX:61991CJ0267&from=DE.

60 Jöhrens et al. (2020): p. 13.

the EU. The larger the 'island' becomes, the more facts on the ground it creates here for later European regulation or standardisation. This does not necessarily have to be a disadvantage as long as the 'islands' are technically interoperable or compatible.

This approach even accommodates the European law principle of subsidiarity. The EU has already decided with the OFSP Directive 2014/94/EU to regulate the infrastructure for other alternative fuels on the way to a single European transport area (recital 1), to implement its climate action goals in order to prevent fragmentation of the internal market through an uncoordinated market introduction of alternative fuels (recital 10), and to meet the long-term energy needs of all modes of transport with alternative energies (recital 11). It would therefore only make sense to build up and regulate ERS on this basis in a coordinated European manner and not in national or bilateral standalone measures.

3.3. Scenario 2: A Europe-wide interoperable ERS (preferred scenario)

3.3.1. A European approach is more efficient and corresponds to the idea of trans-European transport networks

There are no studies on a Europe-wide implementation of ERS. However, the results of studies related to Germany suggest that both cost efficiency and the potential for climate action, reduction of air pollutants and noise abatement would increase significantly with a trans-European implementation of the system, since a significant part of long-distance road freight transport in Europe takes place across borders.[61] Given the prospect of a European Green Deal,[62] the preferred scenario should therefore be to develop and operate ERS on a trans-European basis. All ERS users should be able to drive electrically from Lisbon to Tallinn or from Rome to Stockholm with a largely uniform billing system and only one contract with one mobility provider (Single Point of Contact) in all member states and be able to ensure their power supply largely during the journey and via charging points for e-lorries.

Electricity is an alternative fuel according to Art. 2 No. 1 of the OFSP Directive (2014/94/EU). Art. 1 of Directive 2014/94/EU formulates the ambition to create a common framework "for measures to develop an infrastructure for alternative fuels in the Union" and to define "minimum requirements for the construction of alternative fuel infrastructure [...] which are to be implemented by the Member States through their national strategic frameworks, as well as common technical specifications" for the infrastructure and user information requirements in the spirit of the trans-European transport networks. Article 4 TEN-T Regulation states that "the trans-European transport network strengthens the social, economic and territorial cohesion of the Union and contributes to the creation of a single European transport area which is efficient and sustainable, increases user benefits and promotes inclusive growth." This idea would be best served if a single interoperable ERS for heavy goods transport were to be established throughout Europe. This should be developed in coordination with the other alternative fuel infrastructures, in particular in close coordination with the establishment of charging points for heavy goods traffic, in order to optimally complement each other as two compatible systems

3.3.2. Need for legal adaptation in Europe

From the perspective of European regulation, the preferred scenario can be implemented with only a few adjustments to already existing Directives and Regulations. The centrepiece would be an adaptation of the OFSP Directive (2014/94/EU) on the development of infrastructure for alternative fuels, which in its Annex II defines technical specifications with direct reference to a concrete ERS (overhead contact line systems, a specific conductor rail or induction system) and the technical standards applicable to it. Each Member State

61 Eurostat (2017): National and international road transport of goods, 2015. Available at: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=File:National_and_international_road_transport_of_goods,_2015_(%25_based_on_million_tkm_of_laden_transport)_YB17-de.png&oldid=353218.

62 Europäische Kommission (n.a.): Ein europäischer Grüner Deal. Erster klimaneutraler Kontinent werden. Available at: https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_de.

is obliged to include ERS technology in its national strategic framework for the market development of alternative fuels for transport and for the development of the correspon-ding infrastructure in accordance with Art. 3 of Directive 2014/94/EC. The strategic framework must also contain individual and overall national targets for the development of a core network and the length of electrified motorway.

Other framework parameters must comply with all the broad requirements of Art. 3 of Directive 2014/94/EU, which also specifies the support to be provided by the EU. Alternatively, the measures can also be included as a recommendation only. Additionally, for heavy commercial traffic, a leaf can be taken out of the books regulating the rail freight sector, where Regulation (EU) No. 913/2010 specifies that "rules for the establishment and organisation of international freight corridors for competitive rail freight transport shall be established with the aim of creating a European rail network for competitive freight transport" (Art. 1 para. 1).

Determining a technology for Europe would require the Directive procedure to include a technology selection with the participation of the Member States, based on the technology selection that led to the determinations in Annex II OFSP Directive (2014/94/EU). The requirements of technology neutrality (recitals 8, 22 and 64 of Directive 2014/94/EU) would have to be weighed against the requirements of interoperability of the trans-European networks on the basis of an energy-efficient, cost-effective and economical solution. If only one technology turns out to be suitable and sufficiently market-ready, it should be applied on a Europe-wide basis. However, several technologies can also be adopted at once (scenario 3), especially if the establishment of an ERS is regulated as an option rather than an obligation. Further concretisation and adaptation to national conditions, especially with regard to road space, can be left to the national strategic frameworks and planning law of the Member States. All measures can be based on the legal foundations already laid down in the OFSP Directive and the other legal acts mentioned below.

ERS are an independent "infrastructure for alternative fuels"

(Directive 2014/94/EU). They are not a charging point and require their own regulation in the AFI Directive (2014/94/EU) and the Electricity Directive (Directive 2019/944). Directive 2014/94/EU defines charging points uniformly for the whole of European law as "an interface at which only one electric vehicle can be charged [...] at the same time". Charging points are considered as being countable and stationary (see Art. 4 of Directive 2014/94/EU), and ERS are consequently not mentioned in the "national strategic framework for the market development of alternative fuels for transport" (Art. 3 of Directive 2014/94/EU). A direct or analogous application of the regulation on charging points to ERS would not do justice to their special features and was not provided for when the Directives were adopted. Nevertheless, electricity is an alternative fuel within the meaning of Art. 2(1) of Directive 2014/94/EU, for which "a common framework for measures for the development of an alternative fuel infrastructure in the Union [with] minimum requirements for the establishment of an alternative fuel infrastructure" (Art. 1 of Directive 2014/94/EU) must be established. Since the aim of the OFSP Directive (supplemented by the Electricity Directive in this respect) is to provide a common legal framework for the Union for such infrastructure, there is an unplanned regulatory gap which cannot be filled by simply applying the law. Based on the Regulation for charging points, the following tasks for regulation would therefore lie with the EU:

– ERS should be defined as a separate category of infrastructure (Art. 2 of Directive 2014/94/EU)

– Quantitative targets that meet the needs of the transport mode, accompanied by appropriate information and reporting obligations of the Member States for the national strategic frameworks for the development of ERS in a specific timeframe, should be considered for the electricity supply for transport. This should also cover measures that are necessary to ensure that the individual and overall objectives listed in the respective strategic framework are achieved in a timely manner (cf. Art. 3 and 4 of Directive 2014/94/EU and Annex I of Directive 2014/94/EU). In addition, Member States could be more specifically obliged to provide for the development of a core network. Studies carried out for Germany[63] and the United Kingdom[64] have recommended a core network for the development of a specific ERS (namely an overhead contact line system) in relation to specific motorway sections. These correspond to a large extent to the core networks defined in Annex I TEN-T Regulation (1315/2013/EU) Road of the Trans-European Transport Networks, so that a comparison would be useful.

– As for charging points, technical specifications for ERS should be defined (see Annex II of Directive 2014/94/EU) which take up existing standards for ERS, but do not have to codify them. The establishment of a single system (as is already the case in Annex II of Directive 2014/94/EU) only makes sense if, following the technology selection suggested above, only one system proves to be so energy-efficient, cost-effective and economical that there is no alternative to its introduction throughout Europe. Even then, it would be possible to add an opening clause to take future technical developments into account.

– Considerations on quantity requirements and technical specifications should take into account that ERS and stationary charging points for long-distance road freight transport complement each other as infrastructure for alternative fuels to supply electricity to heavy goods vehicles. The technical specifications should ensure the compatibility of infrastructure systems for the stationary and dynamic charging of electric lorries. In addition, the quantity specifications can be coordinated with each other. In the area of an ERS core network, fewer stationary charging points are likely to be required, and they should be concentrated in those places where lorry drivers already plan longer stops based on their current route planning (logistics centres, lorry depots with overnight accommodation, etc.). In contrast, more stationary charging points should be available on the periphery of the core network in order to extend the range of the vehicles.

– It should be ensured at European level that a competitive market for electrical power can be created in ERS and that its users do not have to face a national monopoly operator of the ERS infrastructure as a electrical power supplier. In this case a significantly different regulation from those for charging points would be necessary, as ERS users cannot choose between different infrastructures. The unbundling of distribution grid, ERS and electrical power supply and further necessary regulation to establish a competitive market for mobility providers within the ERS infrastructure should be regulated in Art. 33 of Directive 2019/944 and Art. 4 of Directive 2014/94/EU.

– In addition, it makes sense to define the kilowatt-hour uniformly as the billing unit for electrical power in Art. 4 of Directive 2014/94/EU and to establish uniform specifications for energy measurement and energy data acquisition systems on the vehicles in Annex II of Directive 2014/94/EU in order to ensure European interoperability (compatible with the regulation for the railway sector based on implementing Regulation 2018/868/EU of 13 June 2018 amending Regulation 1301/2014/EU and Regulation 1302/2014/EU)

ERS are not part of the distribution grid and should be operated separately from it like charging points:
Art. 33 of Directive 2019/944 states that charging points may not be part of the distribution grid, but that a facilitated connection to it should be ensured (Art. 1). Distribution grids and charging points should be two separate infrastructures and not operated together (Art. 2). A comparable separation must also apply to ERS, but with a separate regulation that reflects the systemic characteristics of ERS. There is a predominant opinion in the professional public that ERS technology needs a regulation that largely excludes it (like charging points, cf. Section 3 No. 25 EnWG) from the network regulation of Directive 2019/944 and sufficiently takes into account its specific characteristics. However, since ERS are a monopoly infrastructure for the supply of electricity comparable to a distribution grid, regulation must also be based on the objective of "competitive, consumer-oriented,

63 Hacker et al. (2020): S. 112ff.
64 Ainalis, Thorne und Cebon (2020): S. 12f.

fair and transparent electricity markets in the Union [which] serves to ensure affordable and transparent energy prices and costs, a high degree of security of supply and a smooth transition to a sustainable energy system with low CO_2 emissions, while taking advantage of the benefits of an integrated market for consumers" (Art. 1 of Directive 2019/944). Art. 5 of Directive 2019/944 states that "suppliers should also be free to determine the price at which they supply electricity to their customers. Member States should also be required to take appropriate measures to ensure effective competition between suppliers.". This requires a separate market organisation, which is based on the rules for distribution grids, but simplifies them in such a way that the ERS can function smoothly.

ERS are part of the road:

In the professional public and in the practice of the authorities, the view prevails that at least the physical part of an ERS (as distinct from the electrical power grid) is part of the road on which it is built. This ensures its safe integration into the road space in planning and operation. At the same time, it is thus included in road financing, which has already been made subject to European regulation by Directive 1999/62/EC (infrastructure costs Directive). The integration of the ERS into the infrastructure costs directive would have the advantage of a pre-existing European legal framework into which the different road financing systems of the Member States can fit without creating interstate barriers in contradiction to the idea of trans-European transport networks. At the same time, the infrastructure costs would be shared equally by all road users in heavy goods traffic, so that the emitters of harmful greenhouse gas emissions could easily co-finance the infrastructure to reduce them (polluter pays principle).

– Explicit inclusion in the TEN-T Regulation (1315/2013/EU) as part of the road infrastructure (especially Art. 17) and consideration in the set objectives

– Comparison of the scientific proposals for a core network for an ERS infrastructure[65] with the TEN-T core network according to Annex I of Regulation 1315/2013/EU, since the "availability of alternative environmentally friendly fuels" is required on the TEN-T core network according to Art. 39 (2) lit. c of Regulation 1315/2013/EU (there is already a high degree of agreement here)

– Addition of the availability of ERS to Art. 39 para. 2 lit. c of the Regulation 1315/2013/EU

Explicit inclusion of ERS in Annex III No. 2 of the Infrastructure Cost Directive (1999/62/EC) (infrastructure costs) and classification of individual cost items as construction costs, costs for the operation, maintenance and development of the relevant transport infrastructure network, so that unusual costs, especially for road construction and operation, are clearly covered and classified in the same way in all Member States (example: leakage current as part of infrastructure costs).

3.4. Scenario 3: A few compatible systems are introduced in Europe

In the third scenario, a number of neighbouring countries also decide to set up ERS, as in scenario 1. However, the systems are not interoperable, but merely compatible. It would be conceivable that the EU would decide not to define a single technology in Annex II of the OFSP Directive (2014/94/EU), but would either select two or three suitable market-ready technologies or leave the choice entirely to the Member States. Here, too, different ERS may be set up. In the first case the Member States and in the second case the EU would have to ensure that the systems are at least compatible, meaning that they meet each other's requirements and have compatible properties, without necessarily working together seamlessly.

In this scenario, approaches are to be presented to enable cross-border traffic with restrictions compared to scenario 2.

1. Thesis:

Compatibility can be achieved through the partial standardisation of certain parameters, so that a lorry equipped

65 Hacker et al. (2020): S. 112ff. und Ainalis, Thorne und Cebon (2020): S. 12f.

(as required) with a combination of pantograph, ground current collector or secondary coil can use different ERS. Since all lorries capable of dynamic charging should also be capable of stationary charging and are mass-produced yet adapted to different power supply systems, the vehicle can be the core element here. The electric vehicle system should be subject to uniform standards, which are already under development. There is no doubt that equipping a lorry with several power supply systems would entail additional costs, which would reduce the number of applications that allow economical cross-border operation. Since only the current collection system needs to be supplemented, while the lorry's electric system can also be developed according to the same standards, the additional costs would probably be kept within a range that would not jeopardise economic efficiency in many applications. The applications for which the economic viability threshold is exceeded can ultimately be left to the market, if it is clear that the infrastructure can be economically viable in scenario 1 and any additional traffic via a compatibility solution would only increase economic viability through higher user numbers and further reduction in greenhouse gas emissions.

2. Thesis:

If scenario 1 is already economically feasible, all additional traffic would increase economic efficiency by adding user numbers while lowering CO_2 emissions. Against this background, interchangeable systems, marginal traffic with batteries and the extension of the cross-border range by stationary charging systems or by hybrid propulsion would also be beneficial for the overall system.

3. Thesis:

If there are economic applications for compatible vehicles or interchangeable systems, cross-border harmonisation of charging systems would bring equal benefits.

4. Outlook

An interoperable European ERS can be implemented with little regulatory effort, exclusively by adapting existing directives and regulations and based on European competences already used for this purpose. If the necessary regulation at the European and national level and the subsequent planning and construction are implemented quickly, heavy goods traffic can be decarbonised to a very large extent by 2030 without any additional burden on the transport companies and at manageable costs for the state operating companies.

If the ERS infrastructure is built by a road-related monopoly operator, it should serve as a basis for a competitive market for mobility providers so that they can offer ERS users the best prices, best services and best tariff models. There are various options for regulation, so that the EU can decide whether, by way of subsidiarity, it should ultimately only provide the Member States with the basis for a national development of ERS, or (as for stationary charging infrastructure) ensure better interoperability of the trans-European transport networks with clear system and quantity specifications.

The questions left open in this IKEM working paper will be considered in the final report from the AMELIE project, which will be published in early 2021.[66] Research on the best legal design for the ERS structure, the market model for infrastructure construction and electrical power operation, and the financing and billing of the system will be continued in the AMELIE II research project from November 2021. This is planned to include a continuation of the exchange format 'European Networking Group on Electric Road Systems (ERS)', which will be continued in the two subgroups 'Financing and Accounting for ERS' and 'Road Standards and Planning for ERS'. The questions raised in this IKEM working paper will also be further discussed with European research partners.

66 Hartwig, Schneider and Bußmann-Welsch (forthcoming)

Current IKEM Working Papers

Beckers, Thorsten; Gizzi, Florian; Jöhrens, Julius; Liedtke, Gernot:
Zentrale Ausgestaltungsfragen hinsichtlich eines Förderregimes für Oberleitungs-Hybrid- LKW (OH-Lkw) – Eine (institutionen-) ökonomische Analyse.
IKEM Working Paper Nr. 3, 2019.

Beckers, Thorsten; Gizzi, Florian:
Die Bereitstellung von (Basis-)Ladeinfrastruktur für die Elektromobilität im öffentlichen Straßenraum – Eine ökonomische Analyse.
IKEM Working Paper Nr. 2, 2019.

Beckers, Thorsten; Gizzi, Florian; Hermes, Georg; Weiß, Holger:
Die Bereitstellung der Schnellladeinfrastruktur für die Elektromobilität in Deutschland – Eine ökonomisch-juristische Analyse zentraler Fragestellungen und alternativer Organisationsmodelle.
IKEM Working Paper Nr. 1., 2019.

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