Regulating Electric Road Systems in Europe - How can a deployment of ERS be facilitated?

A discussion paper from the CollERS2 project

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Introduction

Despite rising electric vehicle sales, road transport is still dominated by fossil fuels usage. Transport is responsible for about one quarter of global energy related greenhouse gas (GHG) emissions, with the largest share of the transport GHG emissions comes from road transport at about 72 % (International Energy Agency, 2021). Fortunately, technologies enabling low carbon road transport are already becoming commercially available or are under development. These technologies include the direct use of electricity in battery electric and plug-in hybrid trucks (BET and PHET) with stationary or dynamic charging via so-called Electric Road Systems (ERS), Fuel Cell Electric Trucks (FCET), biofuels and synthetic renewable fuels. These options are in different stages of technological maturity, commercialization, and development for heavy duty vehicles (HDV). The role of each option, or more likely of reasonable combinations, in a future sustainable road transport system is still under debate (International Energy Agency, 2021; Kluschke, Gnann, Plötz, & Wietschel, 2019).

This discussion paper is the result of an international collaboration on ERS research, the CollERS2 project (please visit: https://electric-road-systems.eu/). It summarizes key results of the second workshop held in March 2022. This paper thus has a focus on regulation and standardization of ERS. The aims are to achieve legal and technical interoperability and to facilitate a rollout of ERS in Europe. An earlier discussion paper focused on technological assessment of the core options.

The paper starts with an overview of ongoing processes in the EU. “Fit for 55” gives the framework for the policy objectives. A key issue related to ERS is when and how it is best included in the alternative fuels infrastructure regulation (AFIR). The paper concludes with a suggestion for a way forward.

“Fit for 55” sets the scene

The “Fit for 55” package aims to implement the EU's climate targets for 2030 and proposes measures to reduce EU’s net emissions by at least 55 % compared to 1990 levels. It also sets the direction for the long-term goal of climate neutrality by 2050. As part of these objectives, the European Commission (henceforth also “the Commission”) promotes market growth of zero- and low- emissions vehicles. It seeks to ensure that citizens have access to adequate infrastructures to

charge these vehicles for short as well as long journeys. In addition, from 2026 road transport will be covered by the emissions trading system, setting a price on pollution, stimulating cleaner fuel use and re-investment in clean technologies.

The proposal of an alternative fuels infrastructure regulation (AFIR) is the latest policy suggestion by the European Commission for a regulation on charging infrastructure for alternative fuels. See Figure 1 for context and Table 1 for a brief overview. The AFIR aims to repeal the current directive on the deployment of alternative fuels infrastructure (AFID 2014).[1] The AFID explicitly positioned biofuels as the most important type of alternative fuel source that "can also contribute to a substantial reduction in overall CO_2 emissions if they are produced sustainably" for all forms of transport (recital 21). The AFIR proposal, on the other side, assumes that heavy road freight transport will be operated fully electrically and including hydrogen in the future. LNG will also be used as a bridging technology for a transitional phase.

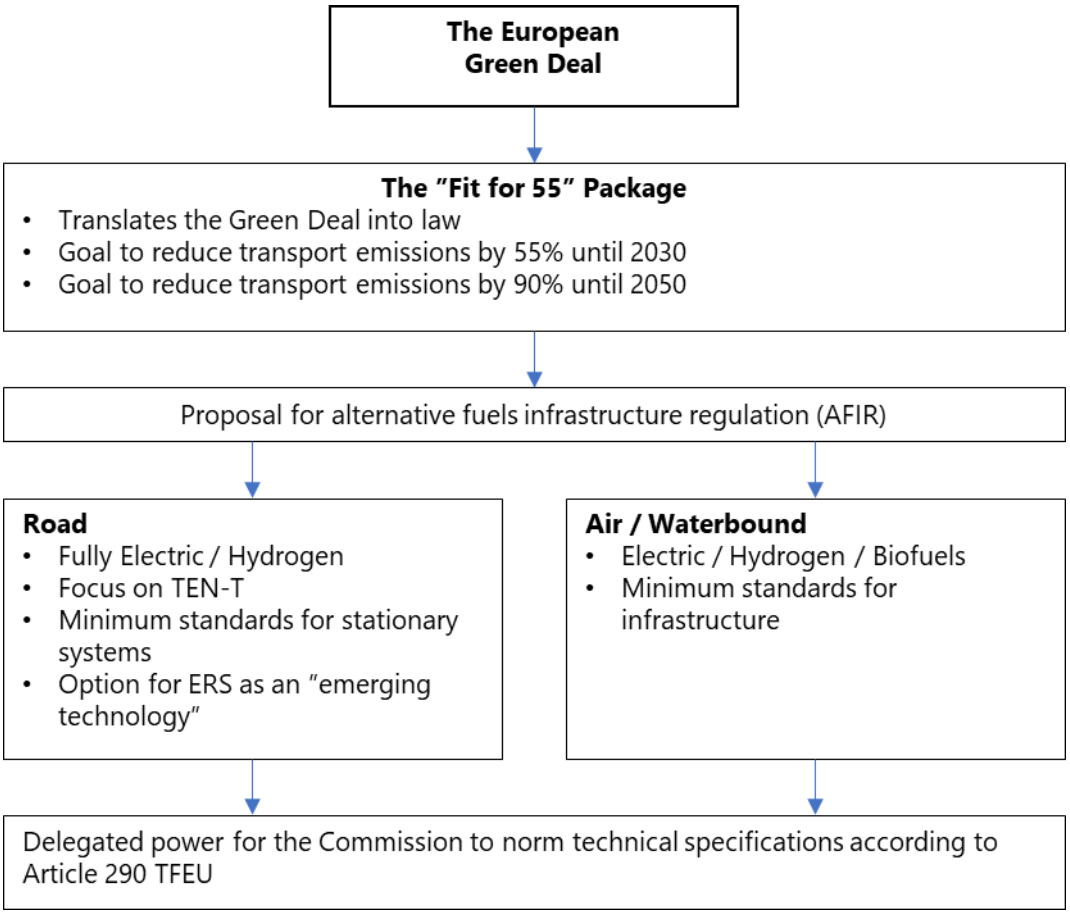

Figure 1: The AFIR within the Fit for 55 package

The use of biofuels or synthetic fuels will be restricted to air and water bound transport modes. The AFIR aims to ensure the availability and usability of a dense, widespread, alternative fuels infrastructural network throughout the EU. The intention is to provide an infrastructure that allows for full interoperability and interconnectivity for electric vehicles, across all transport types and in all Member States. If the Commission's proposal is approved, it will affect the development of ERS

[1] (The European Parliament and the Council, 2014)

in terms of technical competition and harmonization. As of March 2022, the European Parliamentary Research Service claimed that the next step for AFIR was the Committee vote on the proposal.[2] The classification of ERS as an "emerging technology" may be too restrictive as a dynamic charging infrastructure could serve as the backbone in a full electric transport network. This would possibly contribute to significantly reduce the requirements of battery sizes in all vehicle classes and the density of stationary charging networks.

Interoperability issues

When introducing new or alternative fuel infrastructures within the EU there are several issues to consider. One of them is that EU has the ambition to have an interconnected trans-European transport network (TEN-T) with a high level of interoperability (art. 170 TFEU)[3]. For transport firms to be able to operate across borders, there must be a certain level of interoperability. *Interoperability* is defined as: *"…the ability, including all the regulatory, technical and operational conditions, of the infrastructure in a transport mode to allow safe and uninterrupted traffic flows which achieve the required levels of performance for that infrastructure or mode"*.[4]

Actions by the EU in this area should promote interconnectivity and interoperability of national networks as well as access to such networks (art. 170 No. 2 TFEU). Interconnectivity refers to the availability of transport systems between countries. The general requirement in TFEU is further explained in, for example, the AFID, which seeks to proactively avoid a fragmentation of the internal market due to uncoordinated market introductions of alternative fuels (recital 10) (The European Parliament and the Council, 2014).

Standards are crucial for interoperability and functioning markets. They specify characteristics or performance levels of products, processes, services, or systems. Actions regarding technical standardization of ERS have already been started by CENELEC, who are the responsible European standardization body on electricity charging infrastructures and vehicle interfaces. Details and references on the emerging TS (Technical Specifications) are given in a later chapter of this paper.

A further interoperability issue is how Member States shall finance the construction, operation, maintenance, and development of ERS. This problem is addressed in the revised Eurovignette Directive[5] (see Table 1 for a brief overview of this and other laws). In recital 45 the Commission emphasizes the need to allow Member States to finance installations for energy and fuel to low- and zero-emission vehicles. The Eurovignette Directive should not prevent Member States from charging the use of such facilities for financing purposes. For this reason, art. 9(1) is amended: "*Member States should not be prevented from applying, on a non-discriminatory basis, charges specifically designed to finance the construction, operation, maintenance, and development of installations, embedded in, or deployed along or over roads, providing energy to low- and zero-emission vehicles in motion and levied on such vehicles.*"

For Member States that do not apply any tolls and user charges on road users, this new legislation opens the possibility of introducing special charges for the use of ERS. In contrast, Member States that have already implemented tolls and user charges do not need this opening.

[2] (European Parliamentary Research Service , 2022)

[3] TFEU – Treaty of the Functioning of the European Union (TFEU, 2008)

[4] See the TEN-T Regulation art. 3(o) (The European Parliament and the Council, 2013).

[5] (Directive 1999/62/EC last amended by Directive (EU) 2022/362 on 24.2.2022)

In Germany, researchers[6] and the planning authorities involved in the ERS pilot projects (test tracks) FESH[7], ELISA[8] and eWayBW[9] have so far agreed on the premise that overhead power supply systems on motorways, including the supply lines from the substation onwards, can only be safely constructed and operated as part of the road. If the overhead line infrastructure is considered part of the road, it would equally be owned by the federal government and planned, constructed, operated, maintained, financed, and managed as part of the road by the competent authorities. Therefore, it would be financed as part of the road by means of the road toll for HDV. The Eurovignette Directive does not specify what precise infrastructures constitute a road. Hence, there is no legal argument against inclusion of ERS infrastructures in the calculation on which the toll is based. However, legal certainty for this type of infrastructure financing, and in particular for the allocation of individual cost components (such as power loss between grid and vehicle, power consumption etc) as operating costs of the motorway, can only be achieved through clarification in the Eurovignette Directive. Since ERS were not considered when the Directive was enacted, it would also be desirable for greater legal certainty to clarify that it is legitimate to include this infrastructure in the infrastructure costs. This further clarification is missing in the revised version of last year.

ERS definition in the AFIR

Another step forward taken by the proposed AFIR is the explicit inclusion of ERS as "an emerging technological development", which must be accounted for (COM (2021) 559 final p. 25, (53)). In the preparation of proposal of AFIR, ERS were "*discarded*" as a policy measure as they were "*not yet sufficiently mature and uptake of vehicles uncertain*". Still, the proposal recognised ERS as an alternative fuel infrastructure. Article. 3 (17) in the AFIR states that "'*electric road system means a physical installation along a road that allows for the transfer of electricity to an electric vehicle while the vehicle is in motion*". But apart from that, no direct mentioning of ERS can be found in the regulation itself. Further definitions of ERS for dynamic overhead and ground level power supply and standardisation efforts are found in the annex.

Accordingly, the guideline presumes that the energy supply for these direct electric vehicles is initially based on a stationary charging infrastructure for recharging battery electric vehicles ('recharging points'). Thus, the respective articles of the AFIR, which deal with the recharging infrastructure dedicated to light-duty vehicles (art. 3), heavy-duty vehicles (art. 4) and with respect to the operators (art. 5), makes clear specifications only for recharging points. If ERS are to be regarded as an integral solution for a battery electric road haulage system, this could best be achieved by including ERS in these articles of the AFIR especially regarding the TEN-T.

Nevertheless, Annex I in the AFIR proposal indicates that a progress report according to art. 14(1) on the level of achievement of the national objectives reported for the deployment of ERS (if applicable) must be submitted by the Member States to the Commission for the first time by 1 January 2027 and every two years thereafter. Even more important, Annex II explicitly requires the European standardization bodies to develop common technical specifications including inductive dynamic wireless recharging for heavy-duty vehicles (1.11), ERS for dynamic overhead power supply via a pantograph for heavy-duty vehicles (1.14.) and for dynamic ground level power supply through conductive rails for passenger cars, light-duty vehicles, and heavy-duty vehicles (1.15.). These

[6] (Boltze, Lehmann, Riegelruth, Sommer, & Wauri, 2021; Hartwig M. , 2020)
[7] FESH – Feldversuch eHighway an der BAB A1 in Schleswig-Holstein, https://www.ehighway-sh.de/de/
[8] ELISA - eHighway Hessen, https://ehighway.hessen.de/projekt
[9] eWayBW, https://ewaybw.de/

should be adopted under the AFIR by delegated acts. This can be understood as an indication that requirements for stationary charging infrastructures can already be set to facilitate market uptake. Nevertheless, a wider implementation towards a full electric scenario may, as mentioned before, need to rely on or be backed up by infrastructures for dynamic charging, i.e. ERS power supplies.

Rolling out of ERS

When the "ideal" EU ERS approach is discussed, the basic idea is that all ERS users should be able to drive electric vehicles through a sequence of EU Member States, for example from Rome to Stockholm, with a largely uniform payment system and only one contact with one single service provider (Hartwig, Bußmann-Welsch, & Lehmann, 2020).

The creation of a single European transport area and objectives of the development of the trans-European network are discussed in art. 4 of the TEN-T Regulation (The European Parliament and the Council, 2013). EU-law requires that the Commission supports this agenda by coordinating policy frameworks and by providing long-term predictability for public and private investments in trans-national matters. The proposal for replacing the AFID with the AFIR that accepts ERS as alternative full infrastructure and leads the way to a European standardisation is a step in this direction. Furthermore, the proposal for a revised TEN-T Regulation[10] undertakes to mandate the Member States to ensure that an "alternative fuels infrastructure is deployed on the road network in full compliance with the requirements of Regulation (EU)".

AFIR and TEN-Tare two regulation proposals in conjunction with the European efforts to establish common standards and quantity requirements in the AFIR for certain alternative fuel infrastructure. All together this is a strong tool to promote the connectivity and interoperability of a European transport area where cross-border transport with different alternative drives is feasible.

However, for the expansion of publicly accessible recharging points for heavy trucks, the AFIR draft sets specific targets in art. 4.2 for the provision by Member States only of stationary publicly accessible recharging points dedicated to heavy-duty vehicles along the trans-European networks. These stipulations, both differentiated between the TEN-T core and the TEN-T comprehensive network and completion dates of 31 December 2025 and 31 December 2030, concern

- the density of the network (maximum distance of recharging points) by 2025 and 2030
- the power output of each recharging points

Primarily European CEF funds (Connecting Europe Facility) as the CEF Transport Blending Facility from 2019 were used in the course of the former AFID, which brings the total CEF contribution for alternative fuels in excess of € 6.8 billion.[11] However, with a financial framework totalling some € 25 billion for the trans-European network for all modes of transport and all measures by 2027, against the challenges of implementing ERS on a TEN-T core network of more than 20,000 km, such funding can only set incentives for national initiatives.

The Commission also considers it necessary to define an appropriate governance framework and to define the roles of the various actors in the vehicle-to-grid communication ecosystem. If this part of the proposal is approved, the Commission will be able to harmonize the establishment of the

[10] Proposal for a Regulation n Union guidelines for the development of the trans-European transport network, Strasbourg, 14.12.2021, COM (2021) 812 final, 2021/0420(COD.)

[11] EVALUATION of Directive 2014/94/EU of the European Parliament and of the Council on the deployment of alternative fuels infrastructure, p.10

ERS infrastructure. If the Commission would be given the opportunity to advance delegated acts on standardization, the degree of technological maturity would most likely be strengthened and sufficient maturity be achieved within a shorter period than otherwise feasible (Hartwig, Bußmann-Welsch, & Lehmann, 2020). It cannot be ruled out that standardization might lead to several alternatives (for the same or different vehicle classes), and this may result in semi-interoperability where different parts of the EU choose different ERS technologies. Even if this scenario becomes reality, the consequences of a heterogeneous implementation (compared to a homogenous scenario) across the Union would be limited (Hartwig, Bußmann-Welsch, & Lehmann, 2020).

Moreover, pragmatic best matches of stationary and dynamic charging infrastructures can evolve for different vehicle classes without the ultimate pressure to present a completely unified solution. The advantage of such an approach is twofold. Firstly, assumptions for total electric power demands and grid connections can already start independently from the final shares of static or dynamic charging. Secondly, Member States would be encouraged to mature favoured technologies for the same or different vehicle classes that could than fit to an integrated full electric scenario for all vehicle classes.

Table 1 gives an overview over the directives and legislations that are discussed in this chapter and will be of importance for a market ramp-up of ERS.

Table 1: Summary of EU legislation

Law	Description
TEN-T regulation (EU) No 1315/2013 (The European Parliament and the Council, 2013)	The TEN-T regulation identifies a trans-European transport network for the different sectors of transportation of strategic importance and establishes guidelines and priorities for the development of the core network by the Member States. The regulation is in the process of being revised. Among other things, the proposed revised regulation mandates the Member States regarding the core and comprehensive network of road transport infrastructure to ensure that an "alternative fuels infrastructure is deployed on the road network in full compliance with the requirements of Regulation (EU)". So far that does not apply to ERS, but it could be the gateway for a roll-out on the TEN-T road network if the alternative full infrastructure regulation is adjusted accordingly.
ITS-directive 2010/40/EU	The ITS-directive presents a framework for the deployment of Intelligent Transport Systems in the field of road transport and for interfaces with other modes of transport. It contains definitions of e.g., compatibility, interoperability and standard, that might be of future importance for ITS for the administration of ERS (user authorization system) and billing the users for electricity.
Alternative fuels infrastructure directive (AFID) 2014/94/EU (Directive 2014/94/EU of the European Parliament and of the Council, 2014)	The AFID is the main policy instrument for the EU to implement alternative fuels infrastructures. The process to replace the directive with a regulation is ongoing. The proposal for the regulation contains definitions of ERS in general and for "inductive dynamic wireless recharging for heavy-duty vehicles", "dynamic overhead power supply via a pantograph for heavy-duty vehicles" and for "dynamic ground level power supply through conductive rails for passenger

	cars, light-duty vehicles and heavy-duty vehicles" and promotes the standardization of such systems. For some alternative fuel infrastructure, the AFIR-proposal mandates the Member States to ensure a minimum coverage of publicly accessible such infrastructure in their territory. If in the future a European roll-out of ERS in Europe is desired, the AFIR would be the place to regulate such a roll out, especially because it is referred to in the TEN-T regulation for the mandatory equipment of the core road network.
Eurovignette directive 1999/62/EG (Directive 1999/62/EC of the European Parliament and of the Council , 2015) Amended by Directive (EU) 2022/362	The Eurovignette directive regulates charging of heavy goods vehicles for the use of certain infrastructures. Until the amendment of the directive via Directive (EU) 2022/362 the Member States were authorized to charge HDVs on motorways and similar roads the distance they travelled (toll) or in proportion to the time that the infrastructure is used (user charge). Since the amendment of the directive, the Member States with user charges have to replace them with distance-based tolls within the next years. The directive is of importance for all Member States that plan to charge for ERS as part of the roads via road toll. For Member States that don't have road tolls, the old directive 1999/62/EG posed a problem because it excluded other road charges than the one regulated in the directive. The new art.9(1) solves this problem (see above).
Internal electricity market directive (EU) 2019/944 of the European Parliament and of the Council , 2019	Establishes common rules for the generation, transmission, distribution, energy storage and supply of electricity, together with consumer protection provisions, with a view to creating truly integrated competitive, consumer-centred, flexible, fair, and transparent electricity markets in the Union (art. 1). It also regulates the "integration of electromobility into the electricity network" (art. 33). So far this concerns stationary recharging points only. If the integration of ERS into the electricity networks is to be regulated in the future, some changes in the Internal electricity market directive might be advised, based on the market model for the operation of ERS preferred by the EU.
Measuring instruments directive 2014/32/EU of the European Parliament and of the Council, 2014	Directive 2014/32/EU (MID) defines essential requirements for electricity meters. Meters with special requirements might be needed on ERS vehicles. Such meters are under development for the systems with overhead power supply at the moment. European interoperability might require the future regulation of such measuring instruments in the directive.
EETS directive (EU) 2019/520 of the European Parliament and of the Council, 2019	The EETS directive regulates the interoperability of European electronic road toll systems (EETS) and is facilitating cross-border exchange of information on the failure to pay road fees in the Union. An interoperable system for paying the electricity supplied via the system is required if ERS are established in Europe. The EETS regulation could be a model for regulation to be transferred to a European mobility provider service, so that users only must rely on one service provider to obtain electricity supply all over Europe from different electricity providers in different ERS. The joint regulation of both providers in one directive is not necessary in this respect, but at least a possibility.

As can be seen in Table 1 especially the AFIR and TEN-T regulation are of vital importance for the implementation of ERS. Their links and possible future amendments are illustrated in Figure 3 (see page 13) and should be read in conjunction with the conclusion remarks.

Payment systems

In art. 5 of the proposed AFIR, a slight harmonization between payment systems is suggested for the charging infrastructure. The Commission proposes that operators of publicly available charging stations shall be free to purchase electricity from any Union electricity supplier. Operators should allow end users to charge their electric vehicles on an ad-hoc basis with a payment instrument commonly used in the Union. For charging points with a power output exceeding 50 kW, operators shall accept electronic payment through terminals and devices used for payment services. A minimum requirement is the use of devices such as payment card readers and devices with contactless functionality.

When operators offer automatic authentication at their publicly available charging points, they must ensure that end users have the choice not to use this authentication, but to either recharge their vehicle on an ad-hoc basis or to use another contract-based charging solution offered at the charging point. Operators shall also clearly display the ad-hoc price and all its components at all publicly accessible recharging stations. As a minimum requirement, the following price components shall be clearly displayed, if applicable, at the recharging station: price per session, price per minute, and price per kWh.

Although no such harmonization is proposed for ERS payment systems so far, art. 5 in the AFIR clarifies that alternative fuel infrastructure needs a certain level of harmonization on this aspect to be interoperable. While the technological development of ERS has come quite far, the discussion of a feasible system for paying and billing for the electricity supplied via ERS and the actors to be regulated for such a system is not finished and yet to be decided. A decision still to be made is whether an operator should buy the electricity from the electricity suppliers or whether a mobility provider should have an intermediate role here (Hartwig, Bußmann-Welsch, & Lehmann, 2020). This is an ongoing discussion within European and national regulation organs.

Standardization of electric road systems

The CollERS 1 report *Connecting Countries by Electric Roads: Methodology for Feasibility Analysis of a Transnational ERS Corridor* concluded that there were no published standards or draft dedicated to ERS, neither on a Swedish, German, or European, nor on a global standardization level (Jöhrens, et al., 2021). Since then, several activities on ERS standardization have been initiated on both the EU and on a global level, which is described below.

Since 2020, the Technical Committee CLC/TC 9X (on Electrical and electronic applications for railways) has been working on the development of two important deliverables on the topic of ERS. Two working groups have been dedicated to the matter of ERS-standards:

1) **CLC/TC 9X/WG 27** – Current collection systems – Technical criteria for the interaction between pantograph and overhead contact lines on electrified roads.
2) **CLC/TC 9X/WG 30**[12] – Current collectors[13] for ground-level feeding system on road vehicles in operation.

The working groups are currently developing two Technical Specifications (TS):

[12] WG 30 address only vehicle with current collector but is not applicable to vehicles with dynamic or static inductive charging systems

[13] A current collector is an equipment fitted to a vehicle and intended to collect current from a contact wire or conductor rail.

i) **CLC/TS 50712** – Current collection systems – Technical criteria for the interaction between pantograph and overhead lines on electrified roads

ii) **CLC/TS 50717** – Technical Requirements for Current Collectors for ground-level feeding system on road vehicles in operation

Both working groups (WG 27 and WG 30) feature international experts and are supervised within CENELEC TC9X structure. Publication of the TS is estimated to occur around December 2022. In addition to TC 9X, TC 69X develop European standards related to electrical systems for road vehicles. However, TC 69X is primarily following up the work for international standards conducted by IEC in TC 69 (elaborated below) to avoid double work.

In parallel, the European Commission has submitted a standardization request to CEN-CENELEC, in support of the proposed AFIR, to develop a series of standards related to ERS.[14] The request deals with the demand to develop European standards containing technical specifications on ERS with unified solutions for the following technologies:

I. Inductive dynamic wireless recharging for light duty vehicles (deadline end of 2025)

II. Inductive dynamic wireless recharging for heavy duty vehicles (deadline end of 2025)

III. Dynamic overhead power supply via a pantograph for heavy duty vehicles (deadline end of 2023)

IV. Dynamic ground level power supply through conductive rails for passenger cars, light duty vehicles and heavy-duty vehicles (deadline end of 2024)

CEN-CENELEC predict that they will propose the two TS (i. e. TS 50712 and TS 50717) prepared by the TC 9X as elements to respond to the above request. Furthermore, they have communicated to the Commission that these two TS will contribute, at least in some respects, to the request. CEN-CENELEC will continue the discussion both with the Commission and internally within the TC 9X working group. Hence, further development will take place in the coming months. A schematic summary of the activities is illustrated in Figure 2 below.

[14] See C(2022) 1710 final

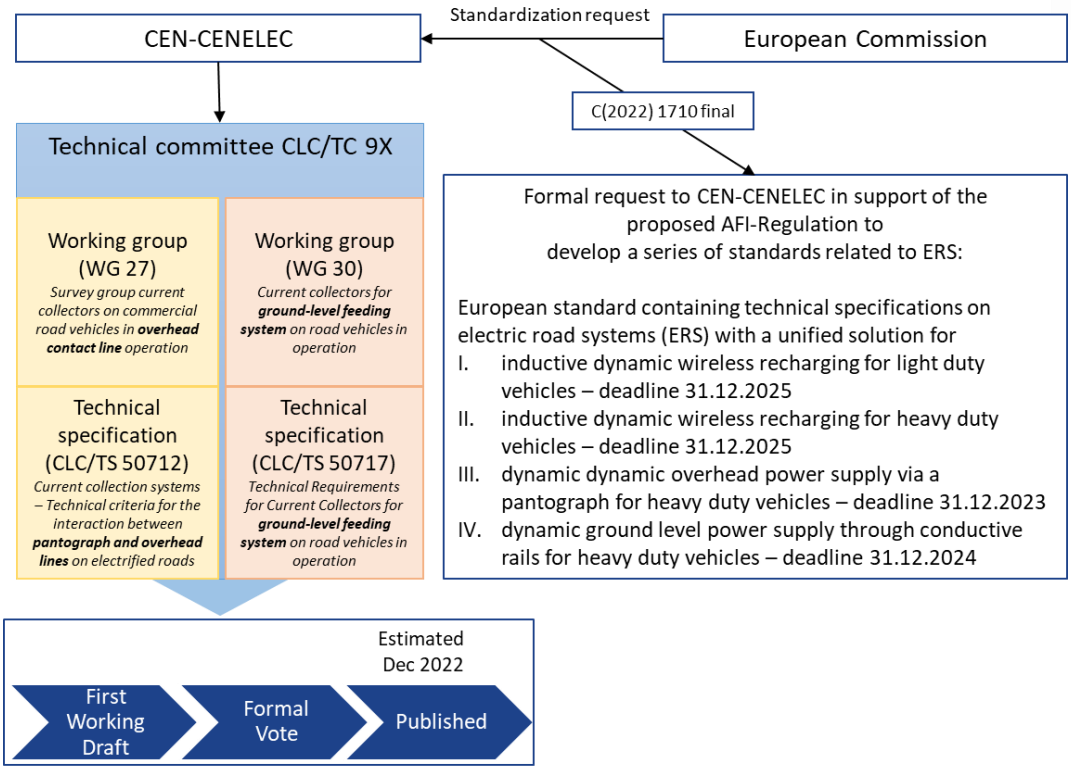

Figure 2: Schematic illustration on activities on standardisation of ERS at CEN-CENELEC

WG 27 (working towards TS 50712) already proposes a unified electro-mechanical interface for the connection between overhead contact lines to the current collectors. This unification has not been reached yet in the work of WG 30 (heading for TS 50717), which presents three possible interfaces (Type A-C) for the ground conductor rails to current collector interface. To fulfil the EC standardization request, further steps will need to be taken for this technology until end of 2024.

The European Technical Committees (TC 9X and TC 69X) also work closely with the International Electrotechnical Commission (IEC) and each time a new project starts at TC 9X, the project is by default put under parallel work. In the IEC there is a technical committee, TC 69, which, as mentioned above, is relevant for the context of ERS as it covers electrical power/energy transfer systems for electrically propelled road vehicles and industrial trucks.

The scope of the TC is to prepare publications for this specific area, including the transfer of power/energy from conductive power/energy wireless power/energy transfer, and battery swap. The different publications can cover (International Electrotechnical Committee, 2022):

- General requirements (e.g., safety, EMC, construction, testing)
- Functional requirements (e.g., charging modes)
- Communication between the EV and the EV supply equipment
- Electrical power/energy transfer between EV and supply network (G2V and V2G)
- Management of the corresponding infrastructures in view of offering the associated value-added services.

In the above, EV include passenger cars and buses, two and three-wheel and light four-wheel vehicles, trucks and goods vehicles, trailers, and special and industrial trucks. Trains, trams, and trolleybuses are not included. Out of the 44 involved countries, 30 of them are participating countries and 14 observer countries. Both Sweden and Germany are participating countries.

Looking at the scopes of the involved TCs it is quite clear that collaboration is needed and should be strengthened. This pertains not just to the TCs on national, CEN-CENELEC and IEC level, but also to the regulative bodies involved in technical specifications, such as UNECE and departments of the Commission. Possible fields of further normative actions related to ERS are the consideration of on-board meters for heavy duty vehicles in ERS in the revision of the Measuring instruments directive (2014/32/EU) to enable cross-border billing systems based on uniform measurement data. Moreover, the current collectors for HDVs for overhead or ground power supplies should be incorporated into the European vehicle approval legislation.

To address and focus the corresponding standardization activities the corresponding German national standardization body DKE (Deutsche Kommission Elektrotechnik) set-up a dedicated Working Group "Arbeitskreis" AK.351.1.13 – ERS as joint working group of the Railway Technology committee (K.351) and the Electric Road Vehicles committee (K.353). The next standardization project of this AK will be a specification of the current collector to vehicle drive system interfaces including safety and EMC considerations. The group involves experts from both domains. The establishment of such joint working groups in national and international standardisation bodies can be considered a viable means to promote interoperability and interconnectivity.

German and Swedish experiences with the European legal framework

In Sweden as well as in Germany, pilot/demonstration projects have managed to implement ERS on different types of roads. European legislation has not been an obstacle to the implementation of these pilots as road legislation and planning are predominantly governed by national legislation. Possible future points of contact with the European law - such as the integration of ERS into the electricity grids financing, and billing - have not been addressed on a scale big enough to demand a European solution.

As was to be expected by the analysis of the European legislation in relation to ERS from both Swedish and German perspective, the degree to which both Member States would be affected by the legislation for a potential roll-up of ERS is in part uniform but differs in some areas where their road systems have different prerequisites. What stands out most is the different perspective on the Eurovignette directive: Sweden has neither tolls nor user charges imposed on the national roads (with two exceptions for direct infrastructure financing, as well as the Öresund fixed link).

Under the opening of the new art. 9(1a) D 1999/62/EG (Eurovignette directive), Sweden is free to develop a system of charging for ERS-infrastructure not bound by the directive. Germany has implemented a (distance based) road toll for HDV on its motorways and research now discusses how to implement the financing of ERS for dynamic overhead power supply via this toll. Therefore, the further development of the Eurovignette directive is important for the implementation of ERS in Germany and other Member States with such systems for road charging already implemented. From the perspective of both countries, it will be important how the European Union proceeds to support different approaches for Member States that have such systems for road charging and for Member States that don't have and don't plan to have such a system. Both systems should be interoperable, too, but have different requirements.

Suggestions for ways forward

The proposed AFIR is an important step for greening road haulage and creating a seamless trans-European road network for electric vehicles. However, ERS is not the focus of AFIR; it is only referred to as an emerging technology and the AFIR does not require the Member States to ensure a "minimum coverage" with ERS like for other alternative fuel infrastructure. Referring to ERS as an emerging technology might be too defensive, and hydrogen (which is not referred to as an emerging technology), for example, does not have significantly higher TRL levels. However, an advantage of the solution suggested by the AFIR proposal relying on stationary recharging infrastructure along the TEN-T corridors is that this network expansion can be incremental and selective, and that it will induce immediate local benefits in every single case.

Doubts remain whether all HDV can travel fully electric in all profiles powered by stationary charging only. In this respect, the EU specification for this network expansion (similar to the introduction of new control and safety technologies in the railway sector on a corridor basis) makes sense only as an initial step. Nevertheless, also for ERS, an orientation along the TEN-T corridors would certainly be helpful and necessary. ERS could then be supplemented by TEN-T planning and financing tools regarding a core network. In this case, the solution for ERS will rather be to first concentrate on one of the core network corridors (e.g. Scandinavian-Mediterranean Corridor). The choice of corridor will be addressed in the third CollERS workshop and in the third discussion paper that is planned to be published in the autumn of 2022. Hence, this paper does not elaborate further on this issue.

For the moment, EU legislation provides a legal framework for providing a Europe wide alternative fuels infrastructure for small vehicles. With regards to heavy-duty vehicles, Member States are working on different tracks not hindered by EU law in doing so. Moreover, with the amended Eurovignette Directive, Member States will be able to use additional user tolls for financing.

At present, the time is not fully ripe for a European framework for the role out of a single alternative fuels system for heavy-duty vehicles. Nonetheless, the Commission has started working on the goal of directly and indirectly electrifying this transport sector as well and sees ERS as "an emerging technological development" in this context. It is welcomed that the proposed AFIR includes a definition of ERS and competences for the standardisation of ground level and overhead technologies. Furthermore, this approach encourages actors to establish synergetic combinations of stationary and dynamic charging for different vehicle classes in a fully electric road traffic system.

Starting with the laid out minimum requirements for stationary charging infrastructures, the next few years can be a good opportunity to integrate a unified ERS topology or combinations thereof in electrified corridors, presumably for different vehicle classes. These experiences can then support a Europe wide infrastructure roll-out of ERS. This paper shows that this roll-out could be orchestrated with existing instruments and incremental amendments of those instruments. With the AFIR a minimum infrastructure could be provided. This could be supplemented by TEN-T planning and financing tools regarding a core network. Furthermore, the financing of ERS via distance-based HGV tolls is possible, but still fraught with legal uncertainties. The amended Eurovignette directive allows for additional tools but does not present a clear pattern which costs of the ERS-infrastructure can be charged via existing tolls regulated by the directive. Figure 3 gives an overview on the links of AFIR and TEN-T regulation and further Directives to be considered for a full covering of ERS.

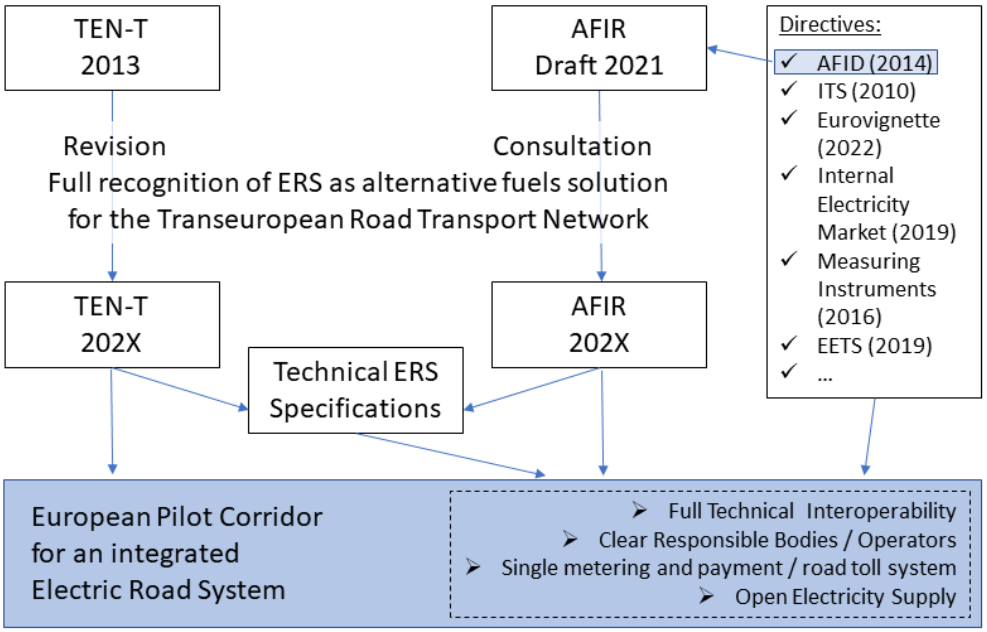

Figure 3: Overview of the link between the AFIR and TEN-T proposals. These regulations and the directives listed to the right are introduced more elaborately in Table 1

A challenging part of these regulatory preparations concern the organising and functioning of the system. On the edge of street-bound infrastructure and the electricity systems, new actors will probably be needed to provide a smooth billing system, which should comprise tolls and energy services. The AFIR, supplemented by amendments of the Internal Electricity Market Directive and the Measuring Instruments Directive, could be the basis for this. The Commission could and should prepare a regulatory framework for this to avoid a loss of time in case that it decides on an infrastructure roll-out.

Summing up, the authors want to draw the following conclusions and give hints regarding possible ways forward:

- As we did not discover any prohibitive regulative issues there is no need to decelerate or hinder any developments in the emerging technologies and their possible combinations.
- It remains to see whether an "ideal" EU ERS scenario (where all ERS users can drive electric vehicles through a sequence of EU Member States, for example from Rome to Stockholm, with a largely uniform payment system and only one contract) will be the chosen way forward. However, regulations should facilitate all technique scenarios. "One contract" does not imply one single infrastructure operator (that would imply risk for monopolistic behaviour); it implies that the customer only interacts via one interface.
- AFIR and TEN-T core network are the right instruments to be used for ERS deployments for long haul trucks. While a European obligatory roll-out of ERS for the TEN-T core network via amendment of the AFIR and TEN-T-directive would be beneficial but might still need further discussion, the time is ripe to choose at least one corridor to pilot an integrated system of dynamic and stationary charging with an interoperable cross-border ERS.

- Support standardization activities and seek to unify the ground-level supply in a similar way the overhead solution already has been. This will also facilitate competition between ERS suppliers.
- Obstacles in the European law to promote a national roll-out with available financing instruments should be removed. The most important steps in this direction would be
    - clarifying the inclusion of cost items of the ERS-infrastructure in the Eurovignette directive (D 2022/362/EU). In this way, financing through fees would be possible.
    - including on-board-meters for ERS-HDV in the Measuring instruments directive 2014/32/EU to enable cross-border billing systems based on uniform measurement data
    - including pantographs for HDVs (overhead and ground) into the European vehicle approval legislation to enable uniform safety standards for this essential vehicle equipment for ERS
- Despite actual shares of dynamic and stationary charging still being uncertain, power grid infrastructure improvements and network connections are indispensable. This improvement should be prepared before the actual shares are known. Further research activities on regulatory issues are needed on these aspects.

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