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National
ETCS
Implementation Plan

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Contents

Abbreviations

Abbreviation	Description
BMVI	Bundesministerium für Verkehr und digitale Infrastruktur (Federal Ministry for transport and Digital Infrastructure)
Class B system	National train protection system in Germany PZB 90 or LZB
DSTW	Digital interlocking system
EDP	ETCS European Deployment Plan
EBA	Eisenbahn-Bundesamt (Federal Railway Office)
EIU	Railway Infrastructure Undertaking
ERTMS	European Rail Traffic Management System
ESTW	Electronic interlocking system
ETCS	European Train Control System
EVC	European Vital Computer (ETCS computer in the vehicle)
EVU	Railway Undertaking
GSM-R	Global System for Mobile Communications – Rail(way)
GVR	Güterverkehrsräume (Goods Transport Areas)
Indusi	(intermittent) inductive train protection system
LZB	Linienförmige Zugbeeinflussung (Continuous train control system)
NIP	National Implementation Plan
NTC	National Train Control
OBU	On-Board Unit
PZB 90	Punktförmige Zugbeeinflussung (Intermittent train control system)
RSTW	Relay interlocking system
STM	Specific Transmission Module, nomenclature Baseline 2.3.0d
TEN-T	Trans-European Network for Transport
TSI	Technical Specification for Interoperability (EU-Regulation)
ZZS	Subsystems “Train control, train protection and signalling”

1 Technical framework conditions and migration planning

This chapter provides a summary of the initial situation and the current work status of the ETCS migration planning in Germany

1.1 Existing Class B systems

It is stipulated in the *Eisenbahnbau- und Betriebsordnung* (Ordinance on the Construction and Operation of Railways, “EBO”) that lines[1] on which speeds of over 80 km/h are permitted must be equipped with a train control system by means of which a train can be automatically brought to a halt and any unauthorised approach to signals at danger can be monitored. In addition, lines on which a number of trains travel at the same time and passenger trains travel, or on which speeds of over 50 km/h are permitted must be equipped with a train control system by means of which a train can be brought to a halt automatically. The two of these constitute the field of application of the Class B system PZB [Intermittent Train Control] 90.

For speeds above 160 km/h, Section 15(3) of the EBO requires a system by which the train can be controlled. This is the main area of application of continuous train control (LZB).

1.1.1 PZB 90

Since the 1990s, PZB 90 has been the train control system used on most lines in Germany and it is based on the various Indusi designs that have been used since as long ago as the 1930s. Not only can a train be automatically brought to a halt with PZB 90, but also unauthorised approaches to signals at danger are monitored – as is required by Section 15(2) of the EBO.

The transmission of data takes place inductively via what are known as ‘track magnets’. Here, frequencies of 500 Hz, 1 000 Hz and 2 000 Hz are used, with the consequence that three different pieces of information can be transmitted from the line to the traction unit.

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[1] Exceptions for cross-border lines and transit lines are governed by Section 3a of the EBO.

Since the necessary energy is induced by the vehicle in the line magnets, no energy supply to the magnets on the line side is necessary. The intermittent transmission generally occurs at distant signals (1000 Hz), at main signals (2000 Hz) and, in most cases, approx. 150 m – 250 m in advance of main signals (500 Hz). The magnets are activated on the basis of the signal aspect. As far as the vehicles are concerned, a distinction is made between three different monitoring programs (O/M/U), which are to be selected on the basis of the braking capacity of the train. When a traction unit drives over an active magnet (1000 Hz and 500 Hz), different speed monitoring functions are activated depending on the program. If a signal is passed at danger, the 2000 Hz control effects immediate emergency braking.

From the distant signal (1000 Hz) onwards, the speed is monitored over a distance of 1250 m, and the traction unit driver can release himself from this no earlier than after 700 m (if he is able to recognise without any doubt the infilled signal aspect, “optical infill”). To monitor approaches to signals at danger, PZB 90 has had the restrictive mode added to it in comparison with previous Indusi designs. After a halt has been identified (or at least 15 seconds of travel at a speed below a defined switching speed), more restrictive speed monitoring functions are activated on the traction unit.

1.1.2 LZB

Continuous Train Control (LZB) transmits data continuously and bidirectionally. With LZB, a train can be automatically brought to a halt and can additionally be controlled. LZB consists of a line cable that is laid in the form of a loop in the track and an LZB radio block centre. Data telegrams are transmitted from the vehicle to the radio block centre and vice versa, via the line cable.

The on-board computer determines the position of the vehicle by odometry, and the crossover points of the line cable that are provided at regular intervals serve the purpose of automatic position correction in this context. Furthermore, data of the train (maximum speed, train length, braking capacity, etc.) are entered into the on-board computer before the beginning of a journey by the traction unit driver. The traction unit continuously transmits these data to the LZB radio block centre. All of the unchangeable data of the line (permissible speeds, inclines, etc.) are stored in the radio block centre. The changeable data (routes entered, permissible speeds on the basis of the signal aspect, etc.) are taken from the interlocking systems via an interface.

The radio block centre calculates a braking curve for each specific train prior to each reduction of speed or halt on the basis of the information transmitted. On the basis of this braking curve, the reference variables of setpoint speed, distance from destination and target speed are determined and are transmitted to the train. The on-board computer on the vehicle displays these reference variables to the traction unit driver and monitors their compliance.

In order to increase performance, LZB CE I was developed. CE stands for the abbreviation CIR-ELKE (Computer Integrated Railroading – Erhöhung der Leistungsfähigkeit im Kernnetz [Increasing of performance on the main network]). Its use on the newly built Cologne-Rhine/Main line with an operational maximum speed of 300 km/h required further supplementations which were realised in LZB CE II.

1.2 Characteristics and comparison of the existing systems and ETCS

This section deals with the safety of the train control systems used. In particular, the scenarios covered are briefly discussed and weaknesses are highlighted.

1.2.1 PZB 90

The inductive train protection system Indusi, as the system from which PZB 90 originated, was developed in order to lessen the consequences of signals at danger being ignored. The system triggers emergency braking when the main signal at danger is passed, but monitoring must already begin at the distant signal, such that enough braking distance up to the main signal is still available. At the distant signal, the traction unit driver must activate a vigilance button and the subsequent reduction in speed that is required is monitored by monitoring functions prescribed by the system (on the basis of space and time). In the event of emergency braking on account of a maximum speed being exceeded, it cannot be ensured that the train can be stopped in advance of the target signal. Therefore, after the target signal a further overlap up to the danger point is required.

The overlap is cancelled after the train has halted, with the consequence that it is then no longer protected. Upon a signal at danger being approached, despite the emergency braking at the 2000 Hz magnet, the new danger point can be overshot and the train may endanger another train journey. Therefore, in PZB 90 the monitoring curves were reduced and a restrictive mode was introduced. This restrictive mode is switched to after a halt and is intended to prevent any approach to signals at danger by means of suitable speed monitoring functions. However, to this end the stopping places (identified by stop signs) and the laying of the 500 Hz magnets (of which there may be a number) must be coordinated with one another. The stop signs then identify a “safe” stopping place for trains that are setting off.

In the event that the signals are ignored, PZB 90 is intended to warn a traction unit driver and also to trigger automatic braking automatically. It is from the outset not designed for cases where signals are deliberately not obeyed. For this reason, cases can also be envisaged in which PZB 90 cannot bring the train to a halt in time before the danger point. A further disadvantage is that magnets which are non-operational or have been removed cannot be systematically identified (no failure disclosure) and thus cannot trigger any function on the traction unit either.

The train control system PZB 90 does not enable any technical infill of the speed monitoring functions. If, for example, a 1000 Hz control measure has taken place at an expect-halt distant signal, the speed function monitored by the traction unit must be shut down even if the main signal has in the meantime switched to a proceed aspect. The system offers no possibility of switching this monitoring function off again “from outside”. The traction unit driver can, however, release himself from the monitoring manually (optical infill). However, this is possible and permitted only 700 m after the 1000 Hz control measure, provided that the traction unit driver is able to recognise the infilled signal aspect without any doubt.

As described above, after a halt PZB 90 switches into the restrictive mode. Then, lower monitoring speeds apply both for the 1000 Hz and the 500 Hz control measures. Although it is possible to release oneself from the 1000 Hz control measure under the conditions stated above, this is not possible for the 500 Hz control measure. If the train has approached an exit signal at danger in the station and has additionally passed a 500 Hz magnet in advance of the stopping place, the vehicle is situated within the restrictive 500

Hz monitoring. This means that the traction unit driver has to comply with a restriction of the speed to 25 km/h up to a point 250 m after the 500 Hz control measure, even if the exit signal indicates a higher speed aspect. A release from the 500 Hz control measure is generally not possible.

The two examples show that under certain circumstances PZB 90 speed monitoring curves are more restrictive than is necessary. Since no technical infill is provided for the enhancements of PZB 90 in comparison with its predecessor (Indusi) do result in greater safety, but this is possibly at the price of operational disadvantages.

The manufacturers have to date not discontinued PZB 90. On account of its comparatively simple design and functionality, it is to be expected that it will still be available for a long time to come, as long as demand continues to exist.

1.2.2 LZB

LZB was originally developed for travel at speeds higher than 160 km/h. With the last stage of development of LZB CE-II, the electronic visibility was increased to 13 000 m and the maximum possible speed to 350 km/h. However, LZB additionally offers the option to increase the capacity of the lines as well. The transmission of data occurs continuously via the line cable laid in the track and continuous monitoring of the dynamic speed profile is available on the traction unit. Both the on-board devices and the radio block centre consist of multi-channel, secure computer systems.

A technical malfunction of the system (for example interruption of the data supply) is recognised and results in braking of the train. If the journey cannot be resumed with LZB, PZB 90 is used as a fallback.

A key disadvantage of LZB is the costs occasioned by the line cable laid in the track. The LZB radio block centre has to be connected to the feed-in points for the line cable loops, which can be a maximum of 12.7 km long. Likewise, the LZB radio block centre requires a connection to all interlocking systems in its area which transmit the necessary information about the routes and signal aspects via interface circuits. The system is no longer being developed by industry and it has already been discontinued. Replacement parts and maintenance are likely still to be available until 2030.

On account of the train-specific calculation of the braking curves as a function of the line data, LZB offers complete and continuous speed monitoring over the whole of the extent of the line. It therefore has an advantage in terms of safety over PZB 90.

1.2.3 ETCS Level 1 LS

In the LS operating mode, the traction unit driver is monitored only in the background. Here, there is no full monitoring over the whole of the line, but rather data is transmitted only for partial monitoring (e.g. between distant and main signal). ETCS offers the possibility to update, and thus also infill, speed profiles once they have been transmitted. This technical infill can be transmitted intermittently to the traction unit by means of infill balises.

During operation, at ETCS Level 1 a release speed is required. If a train had to halt in advance of a signal at danger, for example, the train could, on account of its movement authority (MA) which only permits travel as far as in advance of the signal at danger, in the case of a signal infill, not travel over the balise at the signal so as to obtain a new MA there. The result of this is that a train can travel at a speed below the release speed and is, where applicable, stopped only at the signal at danger.

Under PZB 90, the distant signal distance can be increased from the standard value 1000 m to 1500 m if, for example, the exit distant signal from a station is combined with the entry signal at a location together on a mast. A distant signal distance of more than 1000 m can result in a further advantage for ETCS Level 1. In PZB 90, the braking curve monitoring begins immediately after the 1000 Hz control measure at the distant signal, even though the theoretically possible point at which braking starts is only substantially later. When ETCS Level 1 is used, the point at which braking starts can be determined as a function of train and line parameters[2] and thus can also be not until substantially after the distant signal.

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[2] However, only the vehicle parameters vary on the basis of the standard project engineering provided.

1.2.4 ETCS Level 2

In ETCS Level 2, the speed of the traction unit is continuously monitored on the whole of the line. All of the data of the line relevant for the train journey are transmitted via GSM-R, with the consequence that the EVC on the traction unit can calculate a dynamic speed profile which then enables the full monitoring of the train at all times. Since continuous data transmission occurs at each point of the line, an infill of the MA can be transmitted to the train at any time as soon as the signal has been set to proceed. Passing a fixed balise location, as in the case of ETCS Level 1, is not necessary for an infill. Furthermore, in ETCS Level 2 the release speed can be set at 0 km/h – though this entails operational disadvantages.

ETCS Level 2 can be configured in such a way that a higher capacity of the line arises than in the case of PZB 90 or ETCS Level 1 LS. An increase in capacity is achieved in particular by means of increasing the number of signal blocks along a line section – this is not possible in the case of conventional trackside signalling. Depending on the specific situation, the monitoring curves determined on the basis of the trains also make a positive contribution to the capacity. LZB and ETCS Level 2 do not have any major differences with regard to capacity.

1.2.5 Comparison of the systems

The two train control systems PZB 90 and ETCS Level 1 LS use intermittent transmission media and a monitoring of the speed that is only partly continuous. Trains can be brought to a halt automatically, and also any approach to signals at danger without authority can be monitored by both systems. Thus, both systems can be used in Germany for speeds of up to 160 km/h pursuant to the EBO. ETCS Level 1 LS is parameterised in Germany in such a manner that at least the same safety level of PZB 90 is achieved. In capacity terms, too, there are no major differences between the two systems. In certain situations, advantages in relation to the quality of operation under ETCS Level 1 LS vis-à-vis PZB 90 can arise on account of the “sliding” braking parameters and as a consequence of sensibly placed infill balises[3].

[3] To date not part of the standard project engineering.

With LZB and ETCS Level 2, the speed of the trains can be monitored continuously on the whole of the line. Because of the continuous data transmission, it is possible to control the trains. When the specification and the process requirements contained therein are fulfilled, ETCS Level 2 achieves the highest safety level (SIL4). This can be regarded as being comparable with LZB. In comparison with PZB 90, the use of ETCS Level 2 (in combination with any adjustments to the interlocking system logic) leads to an appreciable increase in the safety and capacity. In comparison with LZB CIR ELKE II, ETCS Level 2 permits a comparable capacity.

Lines can be equipped with the systems in parallel. For instance, the LZB lines are also equipped with PZB 90, which can then serve as a fallback. Lines can also be equipped with the Class B systems and ETCS in parallel. With the exception of transition areas, equipping a line with ETCS Level 2 and ETCS Level 1 LS in parallel is ruled out under current project engineering guidelines.

In the table below, elementary characteristics of the four systems under consideration are compared. The assessments relating to safety and capacity therein are on the basis of a Europe-wide comparison in qualitative terms.

Characteristic	PZB 90	LZB	ETCS L1 LS	ETCS L2
Safety	Average	High	Average	High
Capacity	Average	High	Average	High
Data transmission	Unidirectional, intermittent	Bidirectional, continuous	Unidirectional, intermittent	Bidirectional, continuous
Compatible with interlocking system forms	Mechanical	-	Mechanical	-
	Electromechanical	-	Electromechanical	-
	Relay interlocking system - RSTW	RSTW	RSTW	(RSTW)
	Electronic interlocking system - ESTW	ESTW	ESTW	ESTW
	Digital interlocking system - DSTW	(DSTW)	DSTW	DSTW
Signalling	Trackside	Driver’s cab	Trackside	Driver’s cab

v > 160 km/h	No	Yes	No	Yes
Discontinued by manufacturer for	-	Around 2030	-	-

Table 1 Elementary characteristics of the four train protection systems

1.3 ETCS planning and implementation process

The National Implementation Plan for ETCS (NIP) is produced jointly by the German Federal Ministry of Transport and Digital Infrastructure (BMVI) and DB Netz AG, with the involvement of further stakeholders (e.g. railway undertakings, federations). This occurs in a number of steps:

- High Level Meetings with the European Commission, DB Netz AG and the BMVI, including decision to install two sets of equipment on the infrastructure side so as not to place an excessive burden on railway undertakings
- Production of the NIP with consultations with the sector/federations
- Involvement of external expertise
- Feasibility study involving the sector/federations by the end of 2018 considering an expedited ETCS expansion beyond the present NIP

The responsibilities of the BMVI are primarily:

- To constitute an interface between the European Commission and DB Netz AG with the objective of establishing as much consistency as possible between the requirements of EU law and the implementation plans
- To ensure adequate financing for the installation of ETCS by making funds available

In 2017, the determination of the principles for they laying down of a national implementation strategy for a period from today up to 2033 was commissioned by the BMVI within the framework of a research project. The key aspects of the research project are:

- Collation of information about existing train protection systems

- Creation of a technical and financial migration strategy, in particular with:
    - Coordination of line and vehicle equipment
    - Cost/benefit analysis for introduction
- Establishment of an indicative schedule for equipping individual lines and vehicles

On the basis of these foundations, the present National Implementation Plan (in accordance with Chapter 7.4.4 of the Annex to EU Regulation 2016/919) came into being, and it is being carried forward as the project progresses further. A decision on the switching off of the Class B systems on the network areas in question is not being made in the context of the project. The final results will be available in 2018. Chapter 2 describes the installations of ETCS equipment that are planned up to 2023 as well as elementary input variables into the aforementioned research project.

2 Implementation of ETCS in Germany

Currently, in relation to the implementation and introduction of ETCS, Germany is focussing firstly on the freight transport sector's need for a cross-border rail system that is as interoperable as possible (see in this regard also the comments and maps in the "European Deployment Plan" as per Commission Implementing Regulation (EU) 2017/6 of 5 January 2017 (EDP)). Secondly, in accordance with the requirements of Commission Regulation (EU) 2016/919 of 27 May 2016, it is equipping railway infrastructure projects, the projects financially supported from European funds, with ETCS. The upshot of this is that, alongside the project "Verkehrsprojekt Deutsche Einheit Nr. 8 [Transport Project German Unity No 8]" (VDE 8, upgrading of the Nuremberg – Erfurt – Leipzig/Halle – Berlin main line) that is ongoing and is in part already in operation, it is the German part of the "Rhine-Alpine" corridor (in the context of the "corridor A" project), as the busiest railway transport corridor within Germany, that is the primary one to be equipped with ETCS. In addition, further lines and border crossings will be equipped pursuant to the statements in Commission Implementing Regulation (EU) 2017/6 of 5 January 2017 (EDP). The lengths of line listed and the ETCS levels in the tables in this chapter (cf. Tables 3, 4 and 5) are taken from the EDP, the collective financing agreement for ETCS installation for Corridor A F21 Q0767 of 10.08.2015 and the agreement amending the collective financing agreement for ETCS installation for Corridor A F21 Q0767 of 15.12.2016.

2.1 Present scope of ETCS and that planned by 2023

An overview of existing and anticipated installations of ETCS in Germany that is separated into phases is set out below.

2.1.1 Lines that have already been equipped and are in testing/operation

As of October 2017, ETCS is in operation or operational testing on the following lines in Germany (cf. Table 2):

Section of line	**Length of line**	**ETCS**	**Particular features**
Leipzig Messe Hp - Gröbers	20.0 km	Level 2 2.3.0 d	Combined system, PZB/LZB still in operation
Gröbers/Halle-Ammendorf – Erfurt Main Station	100.8 km	Level 2 2.3.0 d	
Erfurt Main Station – Unterleiterbach including connection to Coburg	112.0 km	Level 2 2.3.0 d	New line is in operational testing
Unterleiterbach – Zapfendorf	3.0 km	Level 2 2.3.0 d	Combined system, PZB is also in operation on two of four tracks
Konstanz – border	2.6 km	Level 1 LS 3.4.0	Separate financing
Thayngen Gr [border] - Singen	9.4 km	Level 1 LS 3.4.0	Lines adjoining border with Switzerland Separate financing in coordination with the equipping of the other German lines on Swiss territory (in particular Thayngen-Schaffhausen (excl.) and Schaffhausen (excl.)-Erzingen)
Basel hub	4.6 km	Level 1 LS 3.4.0	in operational testing
Total	**252.4 km**		

Table 2 Lines already equipped with ETCS as of October 2017 (source: Line database of DB Netz AG)

Figure 1 shows the lines already equipped with ETCS as of October 2017.

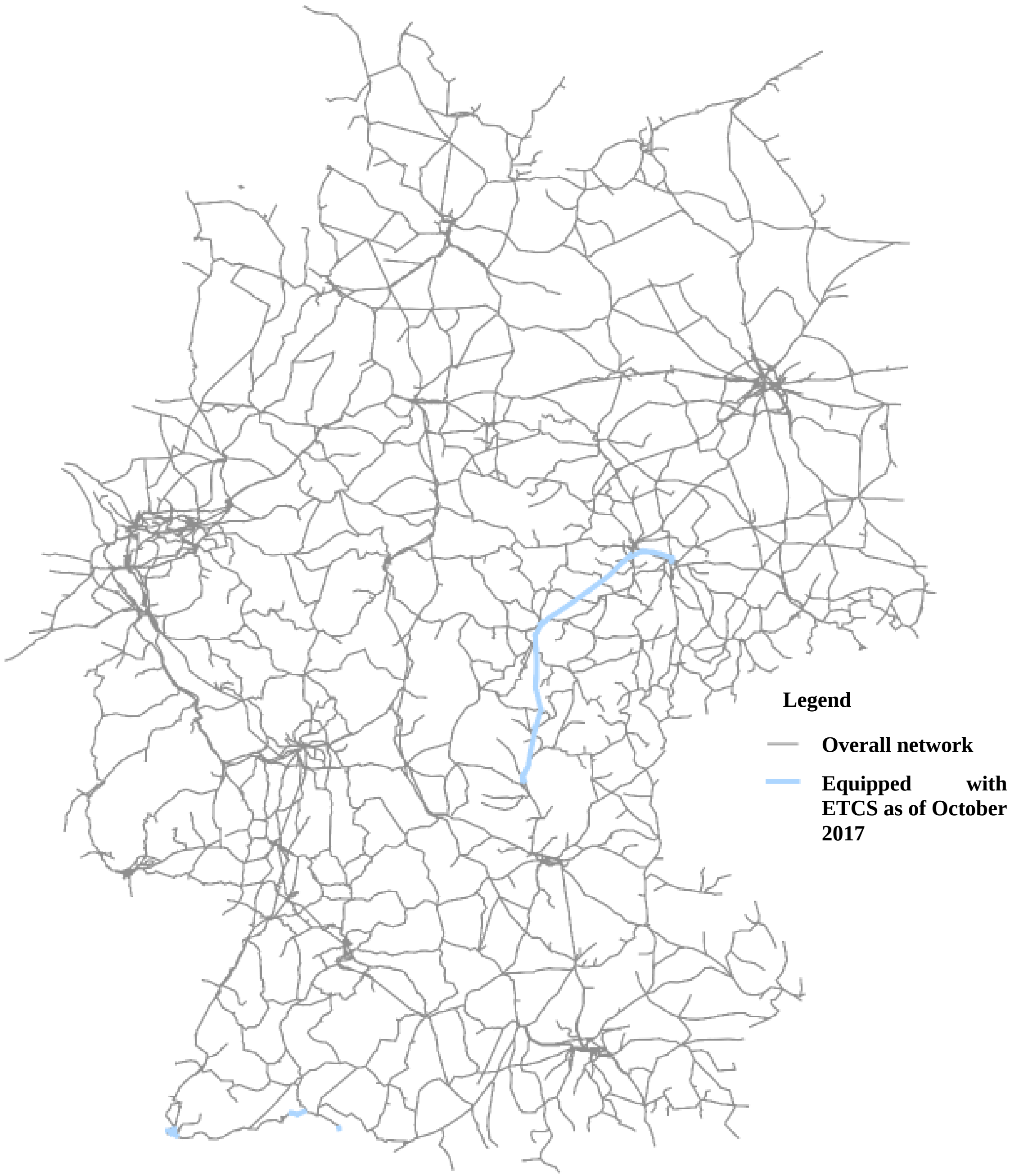

Figure 1 Map showing an overview of the lines already equipped with ETCS as of October 2017

2.1.2 Lines planned to have ETCS by 2023

By 2023, the Eisenach-Erfurt connection will be equipped with ETCS as part of the VDE 8 project. The northern section of the Paris – Eastern France – South-West Germany project (POS Nord) will also be completed by 2023. On the German side, it is intended that the upgrade to the line between Saarbrücken and Ludwigshafen, which is just under 128 km long, will be equipped with ETCS.

In addition, it is planned that by 2023 “Corridor A” (part of the “Rhine-Alpine” corridor (RALP)) and the most important border crossings will be fully equipped with ETCS so as to provide integrated, interoperable navigability for (transit) freight transport. In this context, it is intended to install ETCS Level 1 LS or Level 2 on a section-by-section basis. ETCS Level 2 is to be used on those sections which provide for speeds over 160 km/h or in respect of which the performance requirements stipulate this or if it is at least as economical to equip the section with ETCS Level 2 as with ETCS Level 1 LS.

The installation of ETCS in the Corridor A project means that it is installed in large parts of the “Rhine-Alpine” corridor. At the same time, various terminals are connected to the corridor. The connections to the terminals are generally equipped with ETCS L1 LS. At the same time as the corridor is equipped with ETCS, it is also intended for further lines adjoining borders to be equipped with ETCS. Furthermore, the associated financing agreement provides for planning work in respect of further sections of line which are not referred to here.

The outstanding measures are scheduled to be completed by 2023 at the latest.

Section of line	**Length of line**	**ETCS**	**Particular features**
Oberhausen Main Station – Tiefenbroich branch	45.6 km	Level 1 LS 3.4.0	Corridor A
Ratingen West Rwf – Leverkusen-Schlebusch	47.8 km	Level 1 LS 3.4.0	Corridor A, possibly also L2 in parts
Branch Berliner Straße – Cologne – Bad Honnef	63.5 km	Level 1 LS 3.4.0	Corridor A, possibly also L2 in parts
Unkel – Neuwied	27.2 km	Level 2 3.4.0	Corridor A
Neuwied – Niederlahnstein	22.6 km	Level 1 LS 3.4.0	Corridor A
Oberlahnstein – Loreley	37.0 km	Level 2 3.4.0	Corridor A
Kaub – Wiesbaden-Biebrich	45.4 km	Level 2	Corridor A

		3.4.0	
Wiesbaden Biebrich – Darmstadt Main Station	37.4 km	Level 1 LS 3.4.0	Corridor A
Darmstadt Main Station – Heppenheim	28.3 km	Level 2 3.4.0	Corridor A
Rheinhausen – Krefeld-Linn	51.5 km	Level 1 LS 3.4.0	
Krefeld-Linn – Neuss	21.0 km	Level 1 LS 3.4.0	
Neuss – Cologne-Gremberg/Eifeltor	45.6 km	Level 1 LS 3.4.0	
Cologne Kalk – Troisdorf	17.6 km	Level 1 LS 3.4.0	Corridor A
Cologne West – Mainz-Bischofsheim	246.1 km	Level 1 LS 3.4.0	Line on the left bank of the Rhine
Karlsruhe Hagsfeld – Brunnenstück/Dammerstock	11.0 km	Level 1 LS 3.4.0	Running of purely ETCS trains in the event of deviations in normal operation and the corresponding limitations in terms of the availability of the whole corridor
Offenburg Goods Station	4.5 km	Level 2 3.4.0	For change of traction unit staff
"Loop" Weil – Basel Bad Shunting Yard	2.6 km	Level 1 LS 3.4.0	Facilitating operations in international transportation
Connection to Oberhausen West	34.1 km	Level 1 LS 3.4.0	
Connection to Ruhrort Hafen		Level 1 LS 3.4.0	
Connection to Rheinhausen / Duisburg-Wanheim		Level 1 LS 3.4.0	
Mannheim Shunting Yard – Ludwigshafen BASF	47.6 km	Level 1 LS 3.4.0	
Laudenbach – Südliche Bergstraße	16.8 km	Level 2 3.4.0	Corridor A
Mannheim-Friedrichsfeld –	27.9 km	Level 1 LS	Corridor A

Hockenheim		3.4.0	
Waghäusel – Karlsruhe Goods Station	29.9 km	Level 2 3.4.0	Corridor A
Branch Brunnenstück – Rastatt	45.4 km	Level 1 LS 3.4.0	Corridor A
Baden-Baden – Steinbach	7.2 km	Level 2 3.4.0	Corridor A
Steinbach – Haltingen	155.1 km	Level 2 3.4.0	Corridor A
Connection to Terminal Duisburg-Ruhrort Harbour	20.5 km	Level 1 LS 3.4.0	Access lines from Oberhausen West Goods Station, Mathilde branch and Ruhrtal branch
Connection to Gremberg Shunting Yard	10.0 km	Level 1 LS 3.4.0	Access lines from Gremberg North and South and Cologne Kalk Goods Station
Connection to Mannheim Shunting Yard	20.0 km	Level 1 LS 3.4.0	Access lines from Mannheim-Friedrichsfeld, Ziehbrunnen branch and Schwetzingen station
Belgian Border – Aachen West	8.0 km	Level 1 LS 3.4.0	Line adjoining border Corridor F, Rhine-Alpine Corridor, North-Sea-Baltic Corridor
Belgian Border – Aachen Main Station	8.0 km	Level 2 3.4.0	Line adjoining border Corridor F, Rhine-Alpine Corridor, North-Sea-Baltic Corridor
Passau border crossing – Passau Goods Station	3.0 km	Level 1 LS 3.4.0	Line adjoining border Rhine-Danube Corridor, Scan-Med Corridor
Danish border – Flensburg (points)	9.0 km	Level 1 LS 3.4.0	Line adjoining border Scan-Med Corridor
Closure of gap POS Nord – Corridor A	21.0 km	Level 1 LS 3.4.0	Line adjoining border TEN Atlantic Corridor
Polish border – Frankfurt (Oder)	5.0 km	Level 1 LS 3.4.0	Line adjoining border North-Sea-Baltic Corridor, Corridor F
Frankfurt (Oder) –Erkner	66.0 km	Level 2 3.4.0	Line adjoining border North-Sea-Baltic Corridor, Corridor F

Czech border – Schirnding	3.0 km	Level 1 LS 3.4.0	Line adjoining border Rhine-Danube Corridor
Dutch border – Viersen – Krefeld / Cologne-Ehrenfeld	100.0 km	Level 1 LS or Level 2 3.4.0	Line adjoining border Rhine-Alpine Corridor
Knappenrode - Horka	52.0 km	Level 1 LS 3.4.0	Line adjoining border Poland Separate financing
Erfurt Main Station - Eisenach	57.0 km	Level 2 2.3.0 d	Measure fixedly determined Combined system, PZB still available and in operation
Rostock – Nassenheide incl. connection to Rostock harbour	190.6 km	Level 1 LS 3.4.0	Separate financing
POS Nord	126.0 km	Level 1 LS or Level 2 3.4.0	Measure fixedly determined
Total	**1817.8 km**		

Table 3 Lines planned to have ETCS by 2023

The following map showing an overview of the lines that are expected to have been equipped with ETCS by 2023 is produced on the basis of Tables 2 and 3.

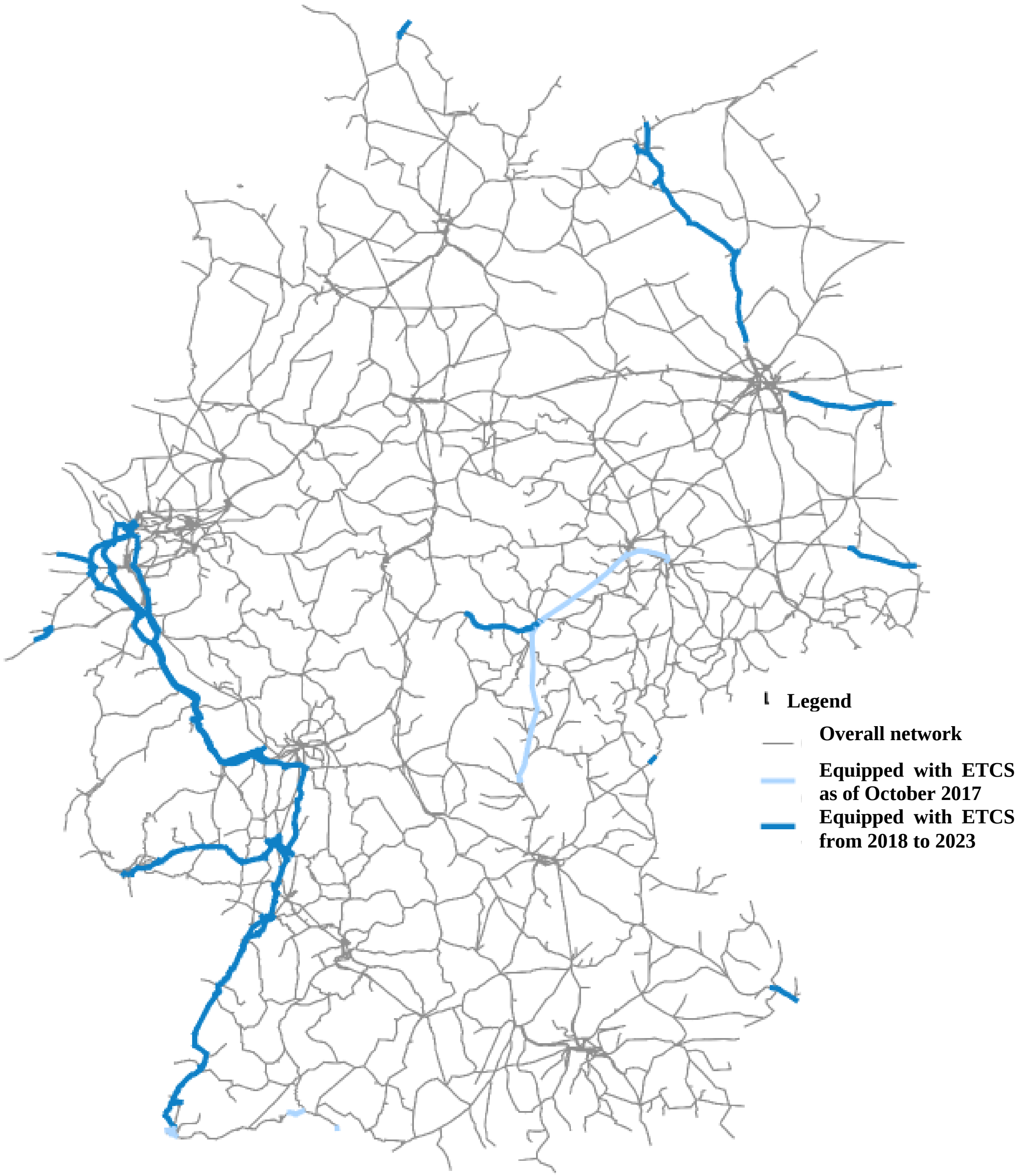

Figure 2 Map showing an overview of lines planned to be equipped with ETCS by 2023

2.1.3 Outlook on the projects prioritised for the future

In addition to the Project Corridor A, the following sections of line are to be equipped with ETCS as a priority. The intended completion dates are after 2023 and in some cases are also dependent on the implementation of other infrastructure projects, planning approval procedures, costs developments and availability of funds.

Section of line	Length of line	ETCS	Particular features
Emmerich - Oberhausen	69.1 km	Level 2	Separate requirements plan financing (ABS 46/2), therefore not in the “Project Corridor A”
Emmerich Gr [border] – Emmerich station	11.8 km	Level 2	Combined system, PZB/LZB still in operation
Erlangen – Eltersdorf	3.8 km	Level 2	Combined system, PZB/LZB still in operation
Rastatt South – Offenburg	44.1 km	Level 2	Continued use of the previous goods-train paths by purely ETCS trains also
Karlsruhe Main Station	42 km	Level 2	Redirection lines in the Karlsruhe area
Goods train bypass Freiburg	11.1 km	Level 1 LS	Continued use of the previous goods-train paths by purely ETCS trains also
Dammerstock branch – Bashaide branch (Rastatt tunnel)	10.9 km	Level 2	
Katzenberg tunnel	9.4 km	Level 2	Fitting of ETCS with DB’s own funds
Total	**202.2 km**		

Table 4 Projects prioritised for the future (after 2023)

The following map showing an overview of the lines with ETCS which are envisaged by 2023 and prioritised after 2023 is produced on the basis of Tables 2, 3 and 4.

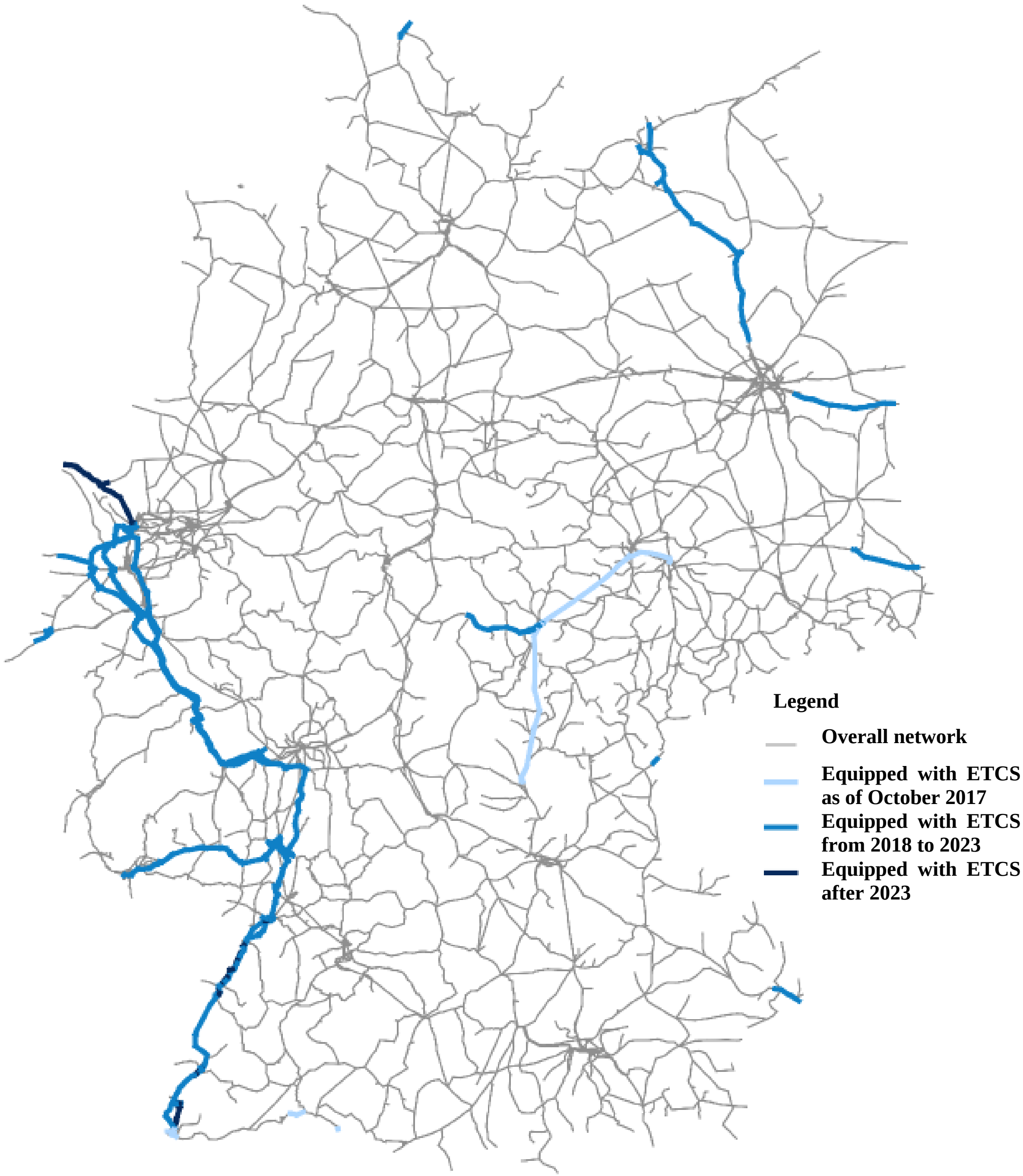

Figure 3 Map showing an overview of the projects prioritised for the future (after 2023)

2.1.4 Summary

In summary, the implementation of the installation of ETCS is taking place as follows:

Fitting of ETCS	**Length of line**	**ETCS**
In existence in 2017	252.4 km	Majority Level 2
Lines with ETCS planned for 2023	1817.8 km	Level 1 LS or Level 2
Projects prioritised for the future (after 2023)	202.2 km	Level 1 LS or Level 2
Total	**2272.4 km**	

Table 5 Summary of the cases in which ETCS is already installed in 2017, is planned by 2023 and projects prioritised for the future (after 2023)

Figure 4 is a map showing an overview of where ETCS has already been installed in 2017, where it is planned by 2023 and projects prioritised for the future (after 2023). The forms of ETCS which are intended to be implemented are differentiated in terms of their colour.

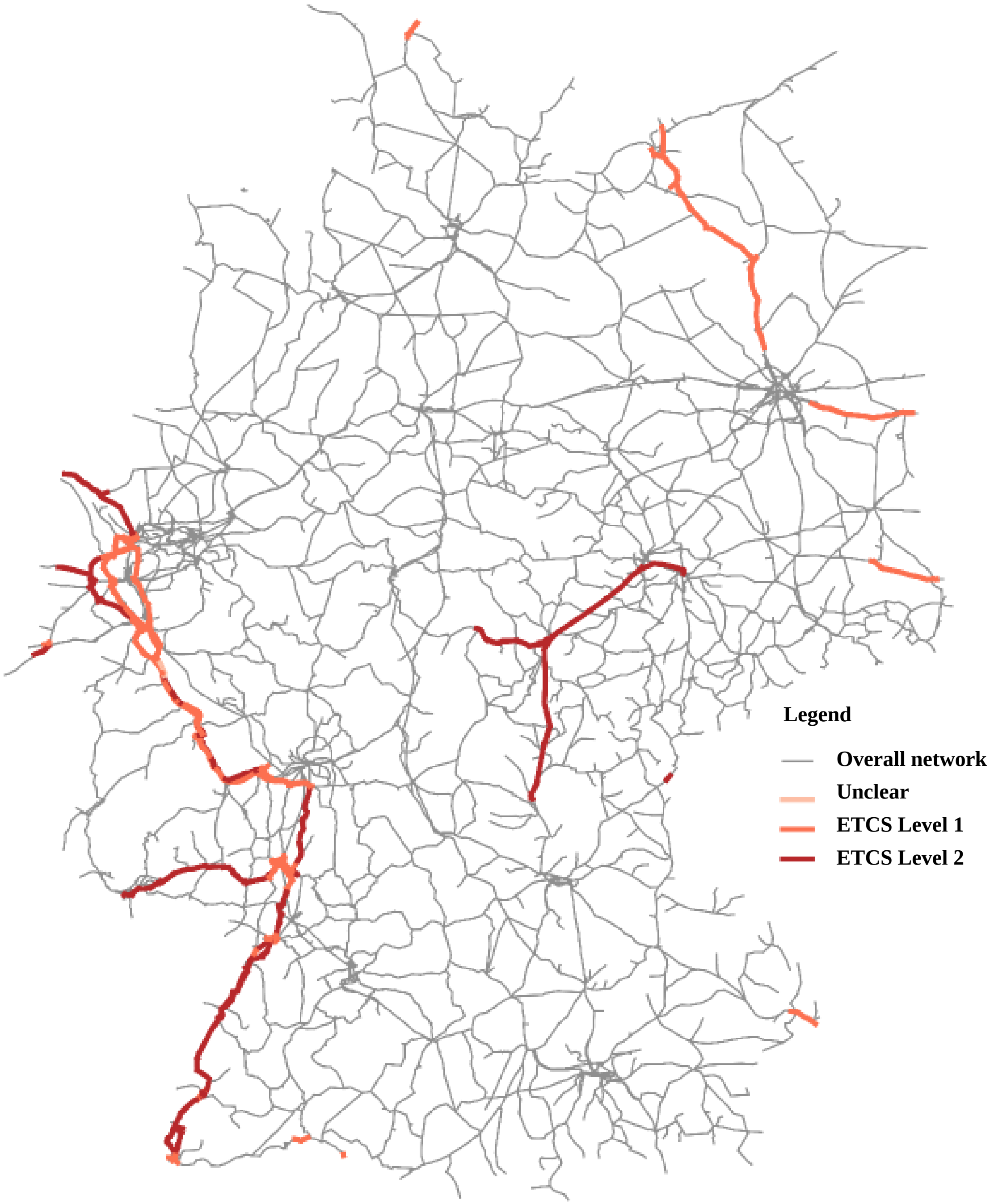

Figure 4 Map showing an overview of where ETCS will be installed by 2023 and of projects prioritised for the future (after 2023) with the respective ETCS Levels that are envisaged (unclear = not yet decided)

2.2 Cost/benefit analysis

For the evaluation of the installation of ETCS up to 2023 and beyond, a dynamic cost/benefit analysis is currently being produced, the input data for which will be agreed with the infrastructure operator DB Netz AG and other players in the German rail sector (federations, etc.). The aim is to use a comparison of scenarios to determine the most economical installation strategy, which at the same time takes into account the commitments in terms of installation and deadlines that have been made to the European Commission and the budgetary requirements of the German federal government. No final results of the evaluation or comparison of scenarios are yet available. However, it is intended to take account of the following benefit and cost components.

2.2.1 Benefit components

The benefit components are prepared with reference to the evaluation of the measures of the Bundesverkehrswegeplan 2030 (Federal Transport Infrastructure Plan 2030). This means that the greatest possible degree of comparability with the other infrastructure projects planned in Germany can be ensured during the evaluation. The benefit components taken into account for the ETCS migration are shown in the table below.

Benefit component	**Effects**	**Indicator**	**Particular features**
Macroeconomic operating costs	Change in time- and performance-dependent operating costs of trains on the basis of reliability, reductions in journey times, excl. route prices	Δ train km & Δ train hours per type of train and year	-
	Change in energy consumption (change in braking and starting-off processes)	Δ kWh/a and Δ litre diesel / a	-
Journey times for individuals	The savings in terms of journey times are used to increase reliability and are taken into account there	-	-

Transportation time loading	The savings in terms of journey times are used to increase reliability and are taken into account there. Exception: goods trains that cross borders have 5% shorter hub stopover times at border stations	Δ nnth/a (net-net tonne hours per year)	-
Reliability	Passenger transport: increase in reliability and reduction in person hours of delays on account of the change of train protection system	Δ Train delay minutes / a for each type of train	-
	Goods transport: increase in reliability and reduction in net hours of delays in terms of tonnes on account of the change of train protection system	Δ % point of delayed tonnes	-
Transport safety	Change in number of events • Involving passing a signal at danger on account of the change to the train protection system • Involving track workers on account of the change to the train protection system	Δ Costs/train km and year	Based on Δ number of fatalities, persons with serious injuries and persons with minor injuries for each type of event
Emissions	Change of operational performance for rail (incl. additional traffic) Taken into account: CO_2, NO_x, PM10	Δ train km/a	-
	Change in energy consumption (change in braking and starting-off processes)	Δ kWh/a and Δ litre diesel/a	-
Lifecycle emissions of greenhouse gases from the infrastructure	Are classed as not being very relevant for the ETCS migration		

Benefit in the case of competing transport providers	Passenger transport: increase in reliability and reduction in person hours of delays on account of the change of train protection system	Δ % point of passengers delayed	Shift from road to rail: taking into account operating costs for cars, emissions and accidents

Table 6: Benefit components of the cost/benefit analysis

A further benefit component is the benefit arising from interoperability, inter alia on international goods transport corridors. Installing the train protection system ETCS with no gaps, for example from Rotterdam to Genoa, means that obstacles in cross-border transportation for railway undertakings are reduced. For instance, goods and persons can travel across borders without any change of traction unit, as a consequence of which any border stoppage times can be reduced. The nature of the quantification of the benefit arising from interoperability and the way in which it is taken into account in the benefit/cost analysis are currently the subject of discussions.

2.2.2 ETCS infrastructure investments

For the investments in equipping the infrastructure of the “Rhine-Alpine” corridor with ETCS and in the border crossings to the Netherlands, Belgium, France, Denmark, Poland, the Czech Republic and Austria, which are not part of the corridor, the collective financing agreement F21Q0767 and the agreement amending it of 2016 specify a value of EUR 314.1 million plus planning costs (prices as at October 2015). They also contain ETCS installations on lines from the border crossings, the closing of gaps in ETCS and the renewal of the Stolberg (Rhineland) and Viersen interlocking systems.

	Millions of euros
ETCS L1 LS (incl. GVR/adjustment measures)	145.6
ETCS L2 (incl. adjustment measures)	104.2
ESTW	64.3
Total	314.1

Table 7 ETCS infrastructure investments for Corridor A and border crossings pursuant to the collective financing agreement between the BMVI, DB Netz AG and DB Energie GmbH (plus planning costs)

The costs apply to construction implementation works such as

- Implementation planning of suppliers and undertakings
- Assembly works
- Adjustments to the electricity supply
- Adjustment to telecommunication systems
- Underground cabling work
- Security works
- Transport closures (e.g. railway crossings)
- Construction area management

According to the financing plan, the investments run over the period from 2013 to 2022. The financing agreement is regularly updated.

2.2.3 Investments in equipping vehicles with ETCS

The present strategy relating to the ETCS migration in Germany starts with a first phase of the infrastructure largely being dually equipped with ETCS and existing systems, with ETCS lines also being able to be used by vehicles having conventional equipment. It is therefore left to the owners of older vehicles to decide for themselves when to change their equipment to ETCS. This migration strategy means that the maintenance costs on the infrastructure side are increased while the incentive to re-equip existing vehicles with ETCS is low. On the other hand, the railway undertakings are not excessively burdened with the costs of converting vehicles. Rather, the migration on the vehicle side can in part occur without conversions, by means of replacement vehicles when older vehicles reach the end of their technical or economic life.

However, it is clear from the research projects and studies relating to the introduction of ETCS that were commissioned by the federal government that a quicker migration, with an earlier switch-off of the national systems, will generate the desired overall economic benefit more quickly. Initial results regarding the quantification of benefits and costs are expected in 2018. In this context, the following points should be considered in particular:

- Supply and installation of the ETCS equipment inc. setting up for GSM-R data transmission
- Necessity of specific transmission modules (STM)
- Testing, approval and commissioning
- Maintenance
- Training of traction unit drivers and maintenance staff
- Management and engineering works of the vehicle owners
- Loss of income for the period during which the vehicles are not available for commercial operations because of the conversion work.

A further important aspect during the migration is the synchronisation between the fitting of the ETCS equipment to the line and to the vehicles so that the investment can produce its benefit promptly. In order to avoid subsidy tourism in the country with the best subsidy conditions, the conversion of the traction units should be subsidised in a standardised manner on a European level.

2.2.4 Operating and maintenance costs

For as long as Corridor A and the border crossings are equipped simultaneously with

ETCS and conventional systems, the costs for ETCS operation and maintenance must be added to the costs for operation and maintenance of the conventional protection systems. On sections of line on which PZB and LZB are currently already operated in parallel, there will be little change in the operating and maintenance costs.

On sections of line which have at some point been completely and exclusively re-equipped with ETCS Level 2 and no longer require any external signals (and at most require more GSM-R stations), the operating and maintenance costs will be lower than with conventional protection systems. Even with a switch to ETCS Level 1 LS, lower operating and maintenance costs can be expected even if external installations still need to be maintained: these are new systems with a high level of reliability, availability and maintainability (“RAM”), which, unlike the outgoing existing systems, are available on the market throughout Europe and have a high degree of standardisation.

Switches to ETCS are also expected to produce costs savings in relation to the operation and maintenance of vehicle equipment, specifically if Class B systems and STM are dispensed with and if the equipment is also able to be standardised in cross-border transportation. The new systems additionally offer better opportunities for remote monitoring and maintenance. On the other hand, cost increases may arise from more frequent software and hardware updates and from potentially shorter lifecycles of the ETCS components in comparison with national systems.

These considerations are currently being studied in greater detail and quantified for the purposes of the cost/benefit analysis.

2.3 Sources of financing and possibilities of subsidies

2.3.1 Funds from federal government

To finance the “Corridor A” project and the associated connections as well as the installation of ETCS on lines adjoining borders (details of the sections of line as described above), the BMVI has entered into a collective financing agreement (F21Q0767 of July/August 2015 and the agreement amending it of December 2016) with the infrastructure operator DB Netz AG. It currently covers costs eligible for subsidy of

EUR 393.1 million and includes the use of EU funds.

This collective financing agreement provides that the aforementioned investments are made in the infrastructure by the infrastructure operator by 2023. On the existing lines, PZB and LZB, as Class B systems, will remain in operation. To date, it is not envisaged that Class B systems will be switched off.

The plan of requirements pursuant to the Bundesschienenwegeausbaugesetz (Federal Railways Upgrading Act) contains a series of further upgrade projects which include ETCS and are to be financed from the budgetary resources available (cf. Section 2.1 in relation to these projects). The federal government may also contribute to the replacement of existing systems with ETCS by way of the Performance and Financing Agreement (LuFV) between the federal government and Deutsche Bahn. Negotiations for an LuFV III for the period after 2019 are currently ongoing.

2.3.2 EU

The EU provides funds for supporting transport projects as part of the Connecting Europe Facility (CEF). The CEF Transport Multi-Annual Work Programme has been allocated EUR 1 billion for the period from 2017 to 2020, of which at most explicitly EUR 100 million can be used for ETCS. The support must be applied for from the EU and is granted in accordance with predetermined priorities. When funds are awarded, the EU assumes up to half of the costs actually incurred in the funding period in respect of the matter that is the subject of the application.

2.3.3 Further possibilities for subsidies

For railways not owned by the federal government, the financing of the installation of ETCS could occur by way of the Gemeindeverkehrsfinanzierungsgesetz (Municipal Transport Financing Act - GVFG) or by way of an amendment to the Schienengüterzfemverkehrsförderungsgesetz (Rail Goods Long-Distance Transport Support Act - SGFFG). For local transport networks, project subsidies from the federal states are possible. In individual cases, the European Investment Bank will also contribute to the costs of re-equipping vehicles.

3 Framework conditions for this national implementation plan

This national implementation plan constitutes the strategy of the BMVI in relation to the introduction of ETCS in Germany as at October 2017. It applies subject to the framework conditions and caveats of EU Regulation 1315/2013. These include in particular Article 1(4), Article 7(2)(c) and Article 39(3) of 1315/2013. As a consequence of these provisions, it can be adapted in the event of corresponding costs developments or availability of funding.