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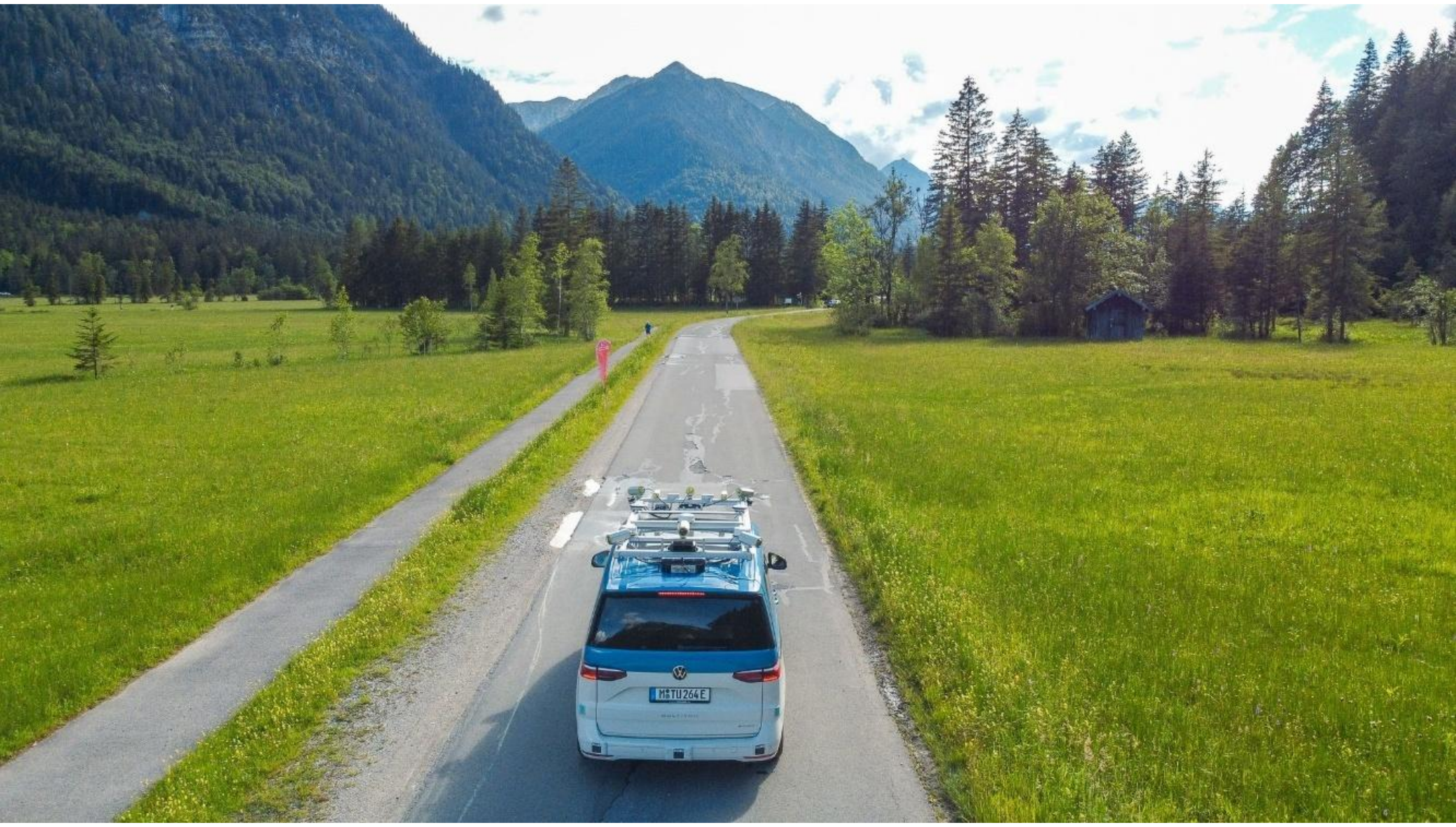

Sector Study on Smart & Sustainable Road Mobility in Germany

FINAL REPORT

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We would like to thank everyone involved in this study for their interviews & collaboration!

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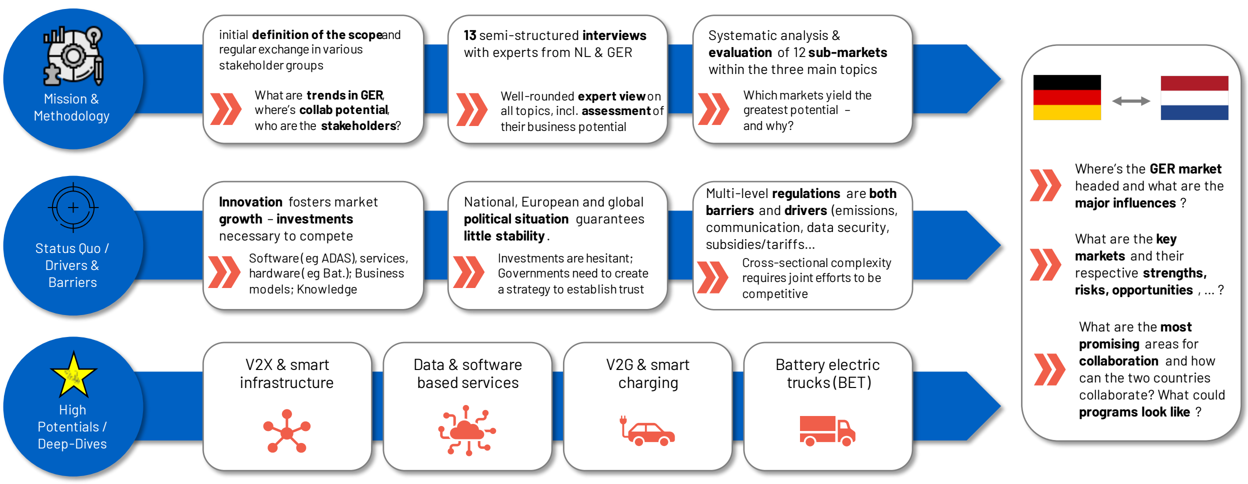
Executive Summary

This study serves as a basis for the development of strategic funding programs for Dutch companies on the German market for smart and sustainable mobility. Therefore, we set out to identify key drivers and developments as well as strengths, risks and opportunities on both the Dutch and the German side. This way, we identify the most promising areas for collaboration and derive recommendations on the design of funding programs. The study is supported by 13 interviews with experts from both countries (industry, research, government). The sector is divided into 12 sub-markets which we analyze systematically and, based on the assessment, four deep-dive topics are selected: V2X & smart infrastructure, Data & software-based service, V2G & smart charging, and battery electric trucks (BET). In the submarket of **V2X & smart infrastructure**, Dutch stakeholders have an opportunity in shaping European and German V2X communication standards by promoting secure data management, partnerships for pilot projects, and expanding test environments, but must proceed cautiously due to limited interest from some automotive OEMs. The expertise in mobility **data and software-based services** of Dutch stakeholders can help German cities adopt data-driven solutions through cross-border knowledge transfer and common standards, but Dutch companies must define a clear USP to compete with strong German digital providers. **V2G & smart charging** is a market that yields both great potential and great complexity. This is mainly because it couples the energy and mobility sector. Furthermore, it requires international collaboration on a European level. However, it is without competition: the parallel ramp-ups of BEV and renewables require such significant and costly changes to the grid on all levels, that not leveraging the potential of millions of BEV on the road is unthinkable. The challenge mainly lies in creating a regulatory and business environment that fosters benefits for all stakeholders. Most heavy commercial vehicles sold by the end of the decade will be **electric**. With the battery being the key component, gaining market shares is important for Germany and the Netherlands. Due to technological advances, which enable increased driving ranges and, thus, enable electric trucking in the first place, there are still opportunities to strengthen the market position. The most promising way to achieve this in an economically efficient manner is fostering research collaborations, which are crucial in the build-up of knowledge.



1. Introduction

The purpose of this study is to analyze market opportunities for Dutch companies, scientific institutions and policymakers in the context of Germany's changing mobility sector. It looks at crucial areas such as; smart mobility, green propulsion and digitalization of transport. Based on both the opportunities and limitations of the Dutch industry in the German market, this study offers recommendations for investment and positioning. The findings are meant to assist Dutch stakeholders in identifying opportunities to leverage their knowledge and technology to support and profit from Germany's shifting mobility scene.

1.1 Vision and mission of Smart and Sustainable Road Mobility in Germany

Germany, as a global leader in the automotive and transportation sector, is at a pivotal moment in its journey toward sustainable road mobility. With increasing urbanization, climate change concerns, and technological advancements, the country envisions a future where mobility is efficient, low-emission, and seamlessly integrated. The goal is to create a transportation system that not only meets the demands of a growing population but also aligns with environmental and economic sustainability.

To achieve this vision, two key missions are at the forefront of Germany's sustainable road mobility strategy: **digitizing and connecting mobility** as well as **transforming propulsion systems for motorized individual transport** in both passenger cars and heavy-duty vehicles. The first mission focuses on leveraging digital technologies to optimize traffic flow, enhance connectivity, and enable intelligent mobility solutions. The second mission addresses the shift from fossil-fuel-based propulsion systems to low- and zero-emission alternatives, such as battery-electric and hydrogen-powered vehicles, ensuring that both individual and commercial transport contribute to a greener future. Figure 1 shows an overview of the topics considered within this study.

These missions, driven by innovation and policy support, are essential for reducing emissions, improving efficiency, and maintaining Germany's mobility industry in the global transition. The following sections will explore how digitalization, connectivity, and clean propulsion technologies are shaping the future of road mobility in Germany.

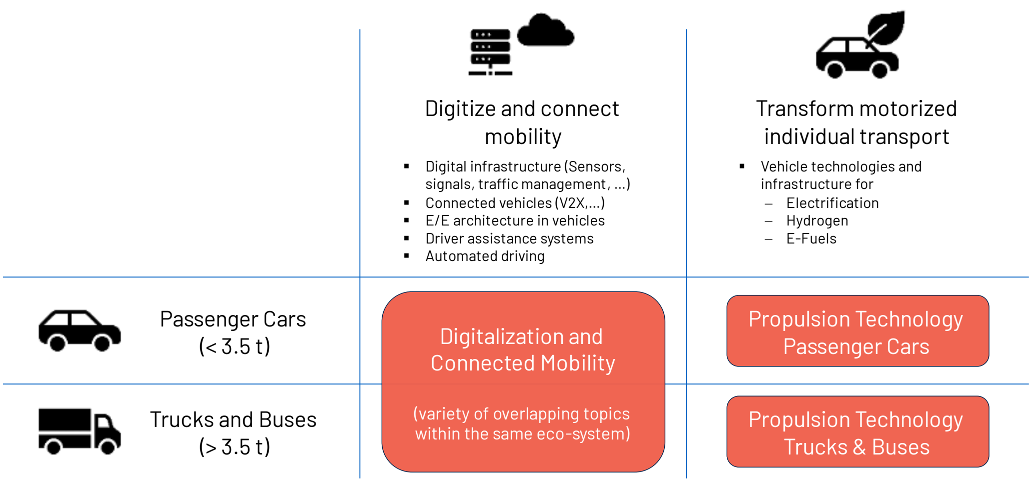


Figure 1: topics of the study

1.2 Methodology

This study follows a structured approach (see Figure 2) to assess market opportunities for Dutch companies, scientific institutions, and policymakers in Germany's mobility sector. The methodology combines expert insights, market research, and trend analysis to provide a comprehensive understanding of emerging opportunities and challenges.

To identify key trends and market dynamics, expert interviews and workshops are conducted, allowing for the scouting of hot topics and emerging developments. The market is then categorized into relevant submarkets, followed by extensive research to evaluate technological and business opportunities. A systematic rating process is applied to assess different technologies, services, and market segments, leading to the selection of key "Deep Dive" topics for further exploration.

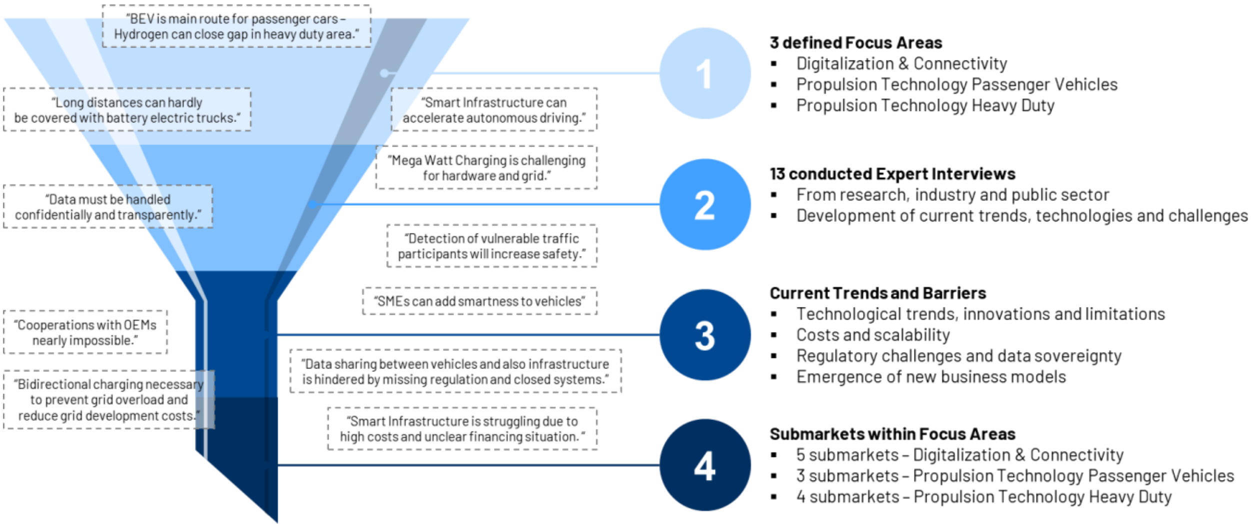


Figure 2: General study approach

The study is structured into three main work packages:

- **WP 1.1: Vision and Mission** – Defining the overarching goals and strategic direction for sustainable mobility.
- **WP 2.1: Influencing Factors and Boundary Conditions** – Analyzing external factors such as policy, economic trends, and technological advancements shaping the mobility landscape.
- **WP 2.2: Market and Potential Analysis** – Evaluating current and future market opportunities for Dutch stakeholders in Germany.
- **WP 3.1: Deep Dive Analysis** – Conducting an in-depth exploration of selected topics, focusing on high-potential areas for investment and collaboration.

By integrating expert perspectives, structured market assessment, and deep-dive evaluations, this study provides actionable recommendations for Dutch companies and institutions aiming to navigate and capitalize on Germany's mobility market.

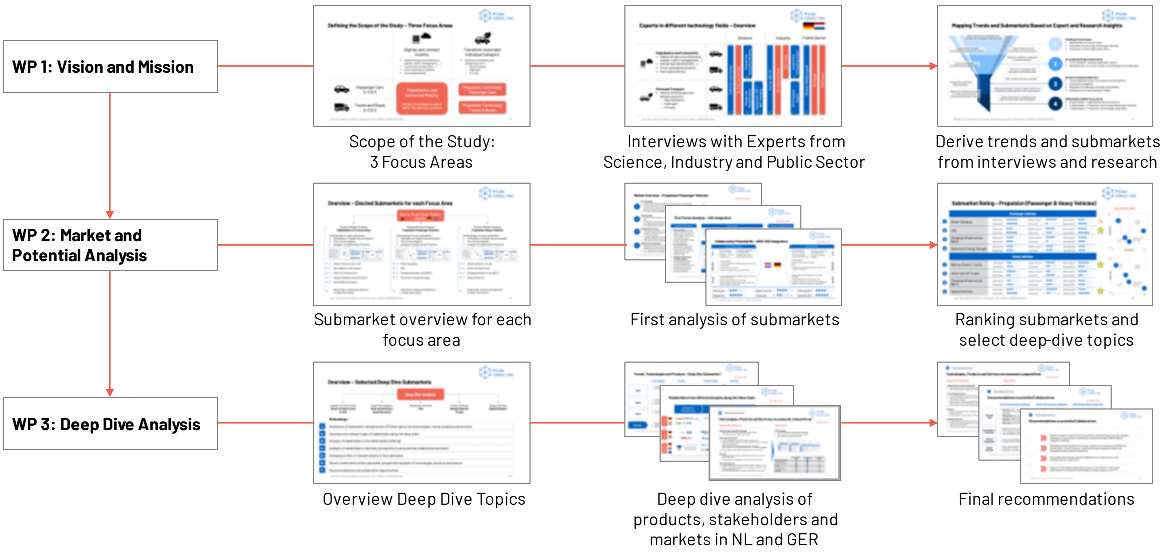


Figure 3: overview of the studies work packages

As part of this study, 13 in-depth interviews were conducted with experts from science, industry, and the public sector to gain insights into the digitization and transformation of propulsion systems in the automotive sector (see Figure 4).. The German interviewees included leading researchers from institutions such as TUM, specialists in connected mobility, electrification, and vehicle-to-grid (V2G) charging, as well as experienced industry professionals, including a former OEM vice president, an OEM supplier expert, an automotive consulting specialist, and a mobility expert from the Bavarian Ministry of Transport. On the Dutch side, the interviews featured an automotive professor, industry specialists, the CEO of V-tron, and experts from RAI and RVO. These discussions provided valuable perspectives on market trends, technological developments, policy frameworks, and business opportunities, forming the foundation for the study's strategic recommendations.

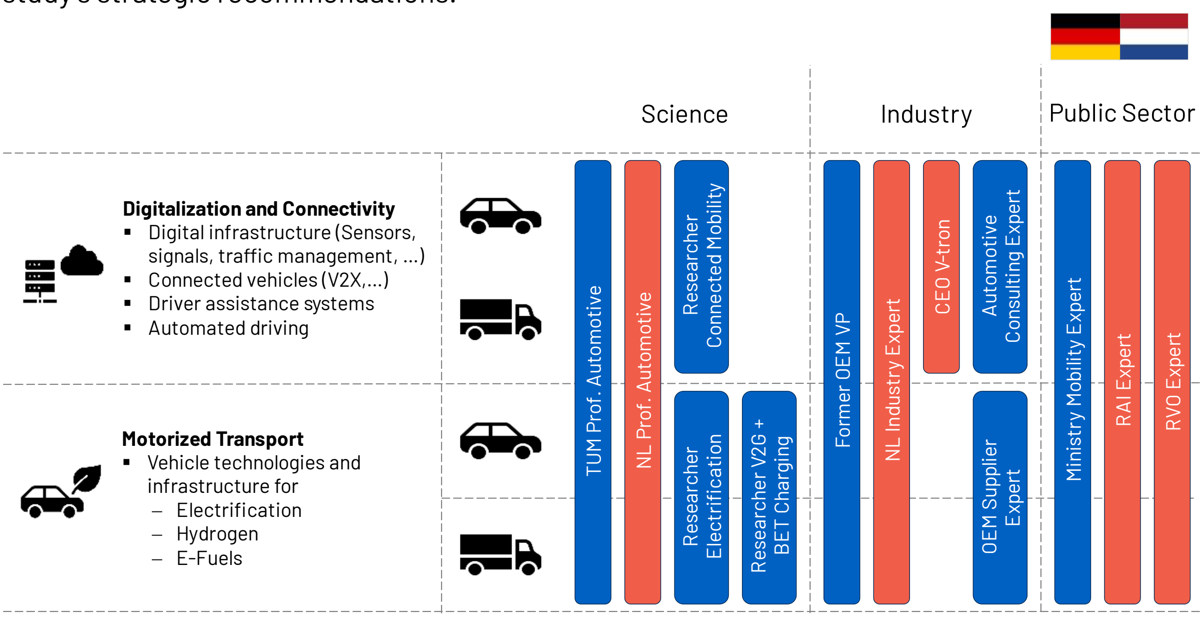


Figure 4: overview of interview partners from Germany and the Netherlands for the analyzed topics

2 Sector Analysis

The transformation of road mobility is mainly driven by advancements in digitalization, connectivity, and the shift toward sustainable propulsion systems. This chapter provides a detailed analysis of key sectors and their respective submarkets, evaluating their potential for growth, competitiveness, and collaboration opportunities between Germany and the Netherlands. The analysis is structured into three main sectors (see Figure 5):

1. **Digitalization & Connectivity** – Covering smart infrastructure and V2X communication, as well as technologies enabling autonomous driving. Key submarkets include software-defined vehicles (SDVs), E/E architecture, data- and software-based services, and new mobility services.

2. **Propulsion for Passenger Vehicles** – Focusing on the transition to electrified propulsion systems, with submarkets such as smart charging, vehicle-to-grid (V2G) solutions, and charging infrastructure for battery electric vehicles (BEVs).

3. **Propulsion for Heavy Vehicles** – Addressing the decarbonization of freight transport through battery electric trucks (BETs), hydrogen and fuel cell trucks, charging infrastructure, and digital solutions for optimizing heavy-duty transport operations.

In addition to these core sectors, the study also considers the **niche market of electrification for construction machinery**, recognizing its growing importance in reducing emissions and increasing efficiency in the construction industry.

For each submarket, a structured approach is applied, including an **estimation of market size and growth**, a **Five Forces Analysis** to assess competitiveness, and an **examination of collaboration potential between Germany and the Netherlands**. This methodology ensures a comprehensive understanding of market dynamics and strategic opportunities for Dutch stakeholders in Germany's evolving mobility landscape.

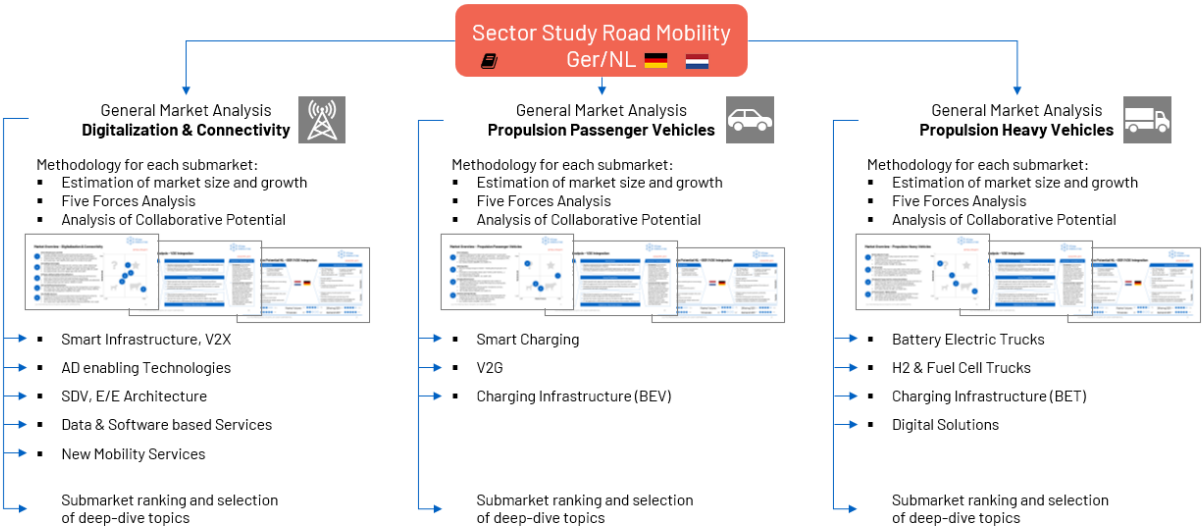


Figure 5: approach for the sector study on three major topics

2.1 Digitalization and Connectivity

Sector Overview – Trends & Drivers

The Digitalization and Connected Mobility sector encompasses a wide range of technologies that enhance vehicle intelligence, enable seamless communication with the environment, and optimize mobility services through software and data. Within the vehicle itself, innovations such as software-defined vehicles (SDVs), advanced driver assistance systems (ADAS), autonomous driving, teleoperation, and cutting-edge sensor technologies (Lidar, Radar, Cameras) are transforming mobility. Enhanced human-machine interfaces, infotainment systems, and battery management further improve user experience and vehicle efficiency. In terms of communication with the environment, technologies like vehicle-to-infrastructure (V2I), vehicle-to-vehicle (V2V) for platooning, vehicle-to-network (V2N) for cloud-based services and over-the-air updates enable a more connected and efficient transport ecosystem. Additionally, urban vehicle access regulation and solutions for vulnerable traffic participants contribute to safer and more sustainable urban mobility. Finally, in the domain of software and data, innovations such as fleet management, Mobility-as-a-Service (MaaS), Vehicle-as-a-Service (VaaS), smart parking, route planning, data management, predictive maintenance, and micro-mobility solutions are revolutionizing transportation by increasing efficiency, reducing costs, and enabling new business models in the mobility sector.

Connected vehicles

The connected vehicle ecosystem is undergoing a major transformation, driven by a shift from hardware-based functionality to software-driven solutions. This transition is enabled by software-defined vehicles (SDVs), over-the-air (OTA) updates for vehicle lifecycle management, and the continuous advancement of advanced driver assistance systems (ADAS). As consumer expectations evolve, connectivity is becoming an essential foundation for these innovations, shaping the future of mobility.

Recent developments highlight the rapid growth of connected vehicles (see Figure 6). The share of connected cars is expected to rise from 5% to 37%, significantly increasing the volume of real-time data available for mobility services. The value of software per vehicle is projected to grow from €820 to €2,375, reflecting the rising importance of software in vehicle functionality. Additionally, the automotive software market is expected to triple over the next decade, creating new business opportunities in data-driven services. Data analytics is becoming a key enabler for these services, supporting predictive maintenance, fleet management, and personalized user experiences. However, despite this potential, OEMs and Tier 1 suppliers remain hesitant to open their systems due to cost pressures, limiting interoperability and cross-industry collaboration.

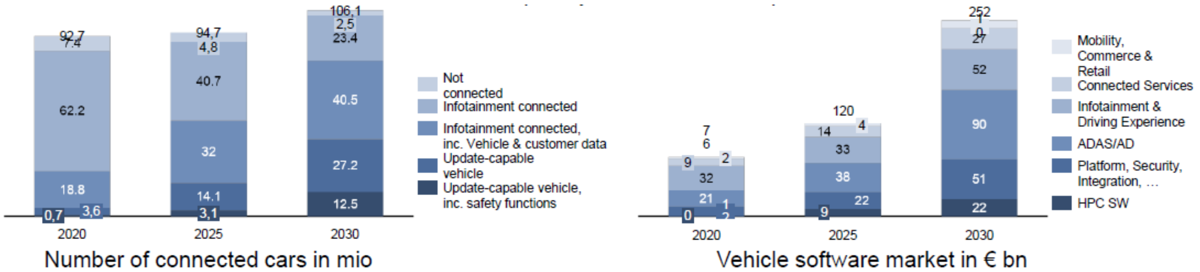


Figure 6: number of connected cars and vehicle software market size

The challenges in this transformation are significant. Regulatory frameworks are tightening, adding complexity to compliance and data governance. At the same time, cost pressures are rising, pushing manufacturers to find a balance between innovation and efficiency. Unclear responsibilities in the ecosystem — for example, determining accountability for software failures—further complicate the landscape. Additionally, ADAS and other assistance systems remain mostly closed, making integration between different suppliers difficult. As one expert noted, "Tier 1 suppliers don't want to open their systems to make OEMs dependent on them," while another emphasized that "OEMs want their own ADAS systems for brand recognition and differentiation." This competitive dynamic hinders standardization efforts and slows down the development of seamless, interoperable connected vehicle solutions.

Despite these challenges, the transition toward software-driven mobility is inevitable. Companies that successfully navigate cost pressures, regulatory changes, and collaboration hurdles will be best positioned to capitalize on the growing market for connected and intelligent vehicle solutions.

Connected infrastructure

The development of connected infrastructure is becoming increasingly important as cities grow and traffic density rises. The integration of connectivity between vehicles and infrastructure (V2I) enables real-time data collection and sharing, improving traffic management, safety, and efficiency. A key trend is the detection of unmotorized road users, such as pedestrians and cyclists, helping to reduce accidents involving vulnerable traffic participants. While ADAS systems continue to evolve, full autonomous driving remains rather a hype than a near-term reality, largely due to infrastructure and regulatory limitations. Nevertheless, smart infrastructure is critical for improving mobility in expanding urban environments, supporting safer and more efficient transportation networks.

Recent developments show that sensors such as cameras and LiDAR are increasingly used in vehicles for ADAS, but their usage is often limited to specific driving scenarios. The cost of these sensors is decreasing due to large-scale production, making them more accessible. However, a more efficient approach is to integrate sensors into the infrastructure itself, where they can be used continuously to improve traffic flow, safety, and comfort. As one expert noted, "Smart infrastructure has a better overview in complex situations," making it particularly valuable in dense urban areas. Additionally, V2I technology can accelerate autonomous driving by a factor of three, particularly in challenging traffic scenarios. Some experts suggest that OEMs could play a role in developing smart infrastructure, similar to their involvement in charging station deployment. Furthermore, infrastructure-based sensors can reduce the reliance on expensive in-vehicle sensors, ultimately lowering vehicle costs, as highlighted by another expert: "Smart infrastructure and V2I can reduce necessary sensors in vehicles and thus vehicle costs."

Despite its potential, connected infrastructure faces several challenges. High investment costs for technology and infrastructure upgrades remain a significant hurdle. Additionally, missing regulations regarding data ownership and system responsibilities create legal uncertainties—"Who is responsible if ADAS systems with V2I fail, the infrastructure or the vehicle?" one expert questioned. The lack of clear business models also slows adoption, as it remains unclear who should finance and maintain the infrastructure. Furthermore, standardized communication is not yet established, as different manufacturers and use cases require varying communication protocols—for example, short-range communication for V2I and long-range communication for public transport (PT). This fragmentation complicates large-scale deployment and interoperability.

Overall, connected infrastructure presents a major opportunity to enhance mobility, improve safety, and support future autonomous driving. However, overcoming regulatory barriers, investment challenges, and standardization issues will be crucial for its widespread implementation. Collaboration between governments, OEMs, and technology providers will be essential to realize the full potential of connected infrastructure.

New Mobility Services

The transformation of mobility services is largely driven by electrification, digitalization, and changing consumer preferences. However, the adoption of battery electric vehicles (BEVs) in shared and subscription-based models faces challenges due to the high depreciation of used BEVs—mainly caused by battery aging and rapid technological advancements. This uncertainty holds back potential buyers but increases the importance of vehicle lifecycle management, where features like over-the-air (OTA) updates and software-as-a-service (SaaS) extend vehicle usability.

Urbanization is another major driver. Growing cities with high population densities require mobility solutions with low land consumption and minimal emissions, making shared mobility and subscription models increasingly attractive. Shared mobility enhances vehicle utilization rates, while subscriptions can generate new profit potential for automakers and mobility providers. As one expert highlighted, "Leasing and subscription models become more popular," reflecting the shift toward flexible ownership alternatives. Notably, major OEMs like Volkswagen are adjusting their strategies accordingly—one expert noted, "VW wants to keep 80% of new electric vehicles in company ownership," signaling a preference for long-term fleet management over direct sales.

The global shared mobility market is set to grow significantly, increasing from $258 billion in 2023 to $401 billion by 2030, though it will still account for less than 5% of the total mobility market. In Europe, shared mobility is expected to grow from $50 billion to $70 billion in the same period, with ride-hailing and taxis holding the largest share of the market. However, ride-hailing costs in Europe, and especially Germany, remain very high, limiting accessibility and mass adoption.

One of the fastest-growing segments is car subscription services. Europe leads in this space, with expected growth from $900 million in 2020 to $15 billion by 2030. Meanwhile, Mobility-as-a-Service (MaaS) in Germany has stagnated due to high operational obstacles, though it is projected to grow after 2035 with the introduction of autonomous driving. In contrast, Vehicle-as-a-Service (VaaS) is already experiencing strong growth in Germany, largely fueled by the increasing popularity of subscription models over traditional ownership.

Despite promising growth, several challenges hinder the widespread adoption of new mobility services. The success of MaaS depends on better integration of multi-modal transport options to create a seamless urban mobility ecosystem. However, high costs remain a major barrier, as driver expenses significantly impact pricing. As one expert noted, "Ride-hailing costs in Europe and especially Germany are very high," making affordability a key issue. The long-term viability of MaaS relies on cost reductions through autonomous driving, which is not expected to make a large impact until after 2035.

Additionally, while shared mobility and subscription models are growing, long-distance travel still depends heavily on private car ownership, as current shared mobility offerings are primarily optimized for urban environments. Overcoming this limitation requires both behavioral changes among consumers and the development of reliable, long-range shared mobility solutions.

Identified sub-markets

In the broad field of digitization and connectivity we identified five submarkets:

- **1 - Smart Infrastructure and V2X** technologies play a crucial role in enabling intelligent transport systems (ITS) and vehicle-to-everything (V2X) communication through cellular and WiFi-based networks. However, high initial costs and a lack of standards and regulations present significant implementation challenges. The V2X market is estimated at $160 million, with a strong 35% CAGR, while ITS is projected to reach $1–2 billion with a growth rate of 8–14% CAGR.
- **2 - Autonomous Driving (AD) enabling technologies**—including cameras, radar, LiDAR, and digital maps—are increasingly integrated into vehicles, driven by the demand for ADAS, autonomous driving, and enhanced safety features. The LiDAR market is expected to grow to $550 million (20% CAGR), while cameras for ADAS are projected to reach $8 billion (12% CAGR). The digital maps market is also expanding rapidly, with an estimated $2 billion volume and 30% CAGR.
- **3 - Software-Defined Vehicle (SDV) and new E/E** (electrical/electronic) architectures are shifting vehicle design from distributed to zonal architectures, reducing the number of electronic compute units (ECUs) and decoupling hardware from software. As a result, global OEM revenues from software are expected to rise from $87 billion (2023) to $248 billion (2030). The overall software and E/E market is estimated at $300 billion, with a 6% CAGR.
- **4 - Data and software-based services** are transforming mobility, offering cybersecurity, fleet management, smart parking, and predictive maintenance. The cybersecurity market is forecasted to grow to $186 million (22% CAGR), smart parking to $513 million (21% CAGR), and fleet management to $900 million (7% CAGR).
- **5 - New Mobility Services** such as Vehicle-as-a-Service (VaaS) and carsharing are gaining traction, particularly in Europe, where subscription models (6–12 months) are becoming increasingly popular. However, OEMs are emerging as strong competitors for new players, with companies like VW AutoAbo offering their own subscription services. The VaaS market is estimated at $600 million (25% CAGR), while the carsharing market is valued at $870 million (2.6% CAGR).

Figure 7 shows the qualitative ranking of the potential market growth and market volume of these five submarkets.

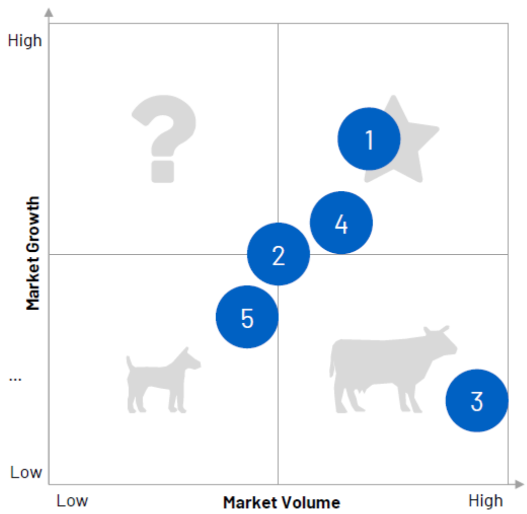


Figure 7: qualitative ranking of the potential market growth and market volume of the Digitalization and Connectivity sector submarkets

Submarket Analyses

Five Forces analysis for smart infrastructure and V2X:

Suppliers & Dependencies

- Sensor and camera manufacturers deliver essential technologies for smart infrastructure (e.g. LiDAR, cameras)
- Manufacturers of C-V2X chips (e.g. Qualcomm)
- Traffic management system manufacturers (e.g. Yunex) deliver ITS
- Network operators and telecommunication companies provide and develop 5G networks (necessary for C-V2X implementation)
- Telecommunication companies that collect and share data of mobile phones to enable V2P
- Platform and service providers
- Software providers

New Entrants

- Expensive development and lack of coherent standard hinders entrants
- Missing regulation regarding data collection and processing leads to unclear responsibilities and hinders development of successful business models
- High initial investments for smart infrastructure

Buyers

- OEMs and suppliers that want to increase connectivity and add new services to cars, especially ADAS/AD,
- Cities and municipalities that install smart infrastructure and want to collect data and increase safety
- Data analytics companies with business models based on vehicle data
- End customers who want to use ADAS, connected services and other services

Substitutes

- V2V: Smart and connected vehicles that are not dependent on infrastructure
- No holistic traffic optimization and no integration of pedestrians
- Public transport (especially railway) needs less sensors than individual motorized vehicles

Internal Competition

- Due to increasing traffic in cities, smart infrastructure becomes more important to use existing infrastructure more efficient
- Closed systems complicate sharing and processing of data
- Established companies dominate market

Collaborative potential for smart infrastructure and V2X:

		
Quick Facts	• Pilot projects: Smartwayz.NL: 10-year mobility program, €1,6B volume; DITM: digital infrastructure • Experience with digitalized infrastructure • NXP V2X offers wifi-based V2X technology	• Pilot projects: Smart test track with V2I/I2G based on ITS-G5 (WIFI) installed in Hamburg • V2XV-technology: W favors wifi-based standard, BWM/Daimler cellular based standard
Stakeholders	• Providers of Smart Mobility Platforms • Specialized suppliers along the value chain (e.g. sensors, cameras) • Telecommunication companies and network operators	• Cities/ municipalities: want to reduce traffic congestions and pollution, meanwhile increasing safety and available space to public trough better use of infrastructure • OEM/Tier 1 suppliers want to connect their cars to accelerate ADAS/AD and increase safety and comfort
Potentials	• The Netherlands are leading in traffic management, traffic lights and information signs are already connected • NL can export expertise from various smart traffic projects • Pilot Project in Amsterdam (Smart Flow), Experience in on-street parking services (Amsterdam, Egis)	• Need of new legal frameworks for data handling • Traffic management not widely employed

Offering NL	weak ●●●○○ strong		Market Volume	small ●●●●○ large		Offering GER	weak ●●●●○ strong	
Demand NL	low ●●●●● high		Timescale	Short-term ●●●●○ Long-term		Demand GER	low ●●●●● high	

Five Forces analysis for AD enabling technologies:

Suppliers & Dependencies	• Sensor, camera and chip manufacturers collaborate together and with OEMs/suppliers (e.g. Qualcomm, Veoneer) • Reliance on high quality parts leads to small number of suppliers being able to compete • German suppliers have still big market share within ADAS system market, Chinese players are rising • Network operators and mobile service providers • Network operators (5G grid development)
New Entrants	• Development is a highly complex task and requires high investments and knowledge, technology should be low priced, scalable and flexible • Market entry is difficult for small players – cooperations with OEMs/Tier-1 suppliers for critical parts difficult, niche ADAS domains more realistic
Buyers	• OEMs that want to equip their vehicles with ADAS systems • Suppliers that need components for their ADAS systems • Customers who want vehicles with ADAS/AD and are willing to pay premium prices
Substitutes	• Individual technologies can be replaced by others, but the interaction of different technologies is essential to develop redundant and secure systems • "Smart technology" could move from vehicles to infrastructure with V2X, but this is rather a complement than a substitute
Internal Competition	• ADAS technology is crucial, most OEMs are dependent on suppliers and chip manufacturers and therefore often have R&D collaborations • Europe has numerous established players with expertise of AD

Collaborative potential for AD enabling technologies:

		
Quick Facts	• "Experimenteerwet zelfrijdende auto" (law governing the experimental use of self-driving vehicles) • 5G Coverage: 100%	• Est. German ADAS market size: $2,2B, 11,7% CAGR (6,6% of global market) • Numerous established suppliers with expertise in ADAS • 5G coverage: 98%
Stakeholders	• Truck manufacturers: implementing and testing of AD technologies • Leading suppliers within fields of chips, radar (NXP) and maps (TomTom, HERE)	• German suppliers successfully develop and integrate ADAS systems • Specialized technology companies
Potentials	• Digital Maps: Dutch companies are market leaders • Sensorfusion: improving sensor edge data processing (Innatera, NXP)	• Creation and update of digital maps

Offering NL	weak ●●●○○ strong		Market Volume	small ●●●○○ large		Offering GER	weak ●●●●○ strong	
Demand NL	low ●●●○○ high		Timescale	Short-term ●●○○○ Long-term		Demand GER	low ●●●●● high	

Five Forces analysis for Software-defined-vehicle, E/E architecture:

Suppliers & Dependencies

- Sensor manufacturers: provide technology at the edge ("eyes of the car") and first data processing steps ("sensor bridge")
- Chip manufacturers: total number of compute units in cars may decrease, fewer but more powerful ECUs, mainly domain and zonal compute units
- Besides the powertrain transformation, the software and E/E architecture transformation in the automotive sector represents a major challenge for large established OEMs in Europe

New Entrants

- E/E architecture is core element of modern vehicles, development requires high investments and knowledge and is linked close to OEMs
- New Chinese and American OEMs (BYD, Tesla, etc.) take the technological lead in software-defined-vehicles; they introduced centralized architectures earlier

Buyers

- OEMs and suppliers want to develop vehicles and systems with Over-the-Air (OTA)-capable architectures
- OEMs and retailers want to create revenue out of OTA updates and additional functions
- Customers want to add functionality to their vehicles and keep them up to date, even after purchase
- Customers experience new and partly better software solutions from foreign OEMs

Substitutes

- Demand for updatable functions requires connected vehicles
- Current E/E architectures do not scale in terms of updateability, customizability and connectivity – possible development speed is a limitation

Internal Competition

- OEMs collaborate closely with suppliers for their E/E architectures
- German OEMs invest high amounts to build up own competences (e.g. VW invests 2.5 Bn € per year into CARIAD, VW's software company)

Collaborative potential for Software-defined-vehicle, E/E architecture:

		
Quick Facts	• Zonal E/E architectures cut vehicle wiring costs and complexity • Transformation of German automotive software market poses chances for NL suppliers with innovative solutions	• German suppliers and OEMs transform E/E architecture towards zonal architectures (fewer, more powerful ECUs) • Importance and value creating shifts from hardware to software – hardware must follow software
Stakeholders	• Some NL suppliers and small companies work in the SDV E/E architecture field, however rather as a technology supplier or service provider than a system integrator • NXP offer network solutions	• OEM and suppliers that develop E/E architectures • Often suppliers are part manufacturer as well as system integrators • OEMs that invest high amounts in own software companies
Potentials	• Expertise and knowledge can be transferred • Cyber security: in-vehicle security trough securing ECUs • Cooperation with Tier 1 and Tier 2 suppliers in Germany	• E/E Architectures need stable, uniform interfaces and uniform definitions to keep complexity manageable • German OEMs and Suppliers need to adapt automotive software and E/E quickly to new standards in order to keep up with foreign competition

Offering NL	weak ●●○○○ strong	Market Volume	small ●●●●● large
Demand NL	low ●●●○○ high	Timescale	Short-term ●●○○○ Long-term
Offering GER	weak ●●●●○ strong	Demand GER	low ●●●●● high

Five Forces analysis for Data and Software based Services:

Suppliers & Dependencies

- OEMs offer cars and collect the data the car – usually they own the data and limit data access for third parties – trend towards factory built in data tracking devices
- Suppliers: develop services that add value, e.g. in form of value to the car
- Tech infrastructure and platforms providers: offer cloud platform, few big players
- Manufacturers / providers of data loggers: can track data and provide analyses

New Entrants

- Many ways to enter this market field in different positions in the value chain (e.g. as software platform provider, service provider, retailer, municipality)
- Lacking data ownership makes it difficult for new players to enter the market
- Common standards would simplify entry for smaller players in niche fields

Buyers

- OEMs are interested in increasing the vehicle lifetime value and customer retention - therefore interested in services with a valid business model
- Fleet operators that profit from data: e.g. increase utilization of existing fleet, maximize value of vehicle
- Municipalities that want to use mobility data to improve traffic flow and congestion
- Customers: can profit from smart data and software based services – on an individual level (OTA, car gets smarter) and a societal level (e.g. traffic can be guided more efficiently)

Substitutes

- Shared Mobility services: data ownership lies with MaaS providers, collaboration with third parties and municipalities more probable
- Third party applications on user devices are often free to use, no integration in the vehicles necessary

Internal Competition

- Data ownership usually lies with OEMs since vehicles generate data
- OEMs compete with software and tech companies (Google, Apple)

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Collaborative potential for Data and Software based Services:

		
Quick Facts	• 9,4 Mio cars, among highest vehicle densities in Europe • Est. software market size: €9,2Bn • Est. automotive IoT market size: $2Bn, 8% CAGR	• ~50 Mio cars (around 20% connected) • Est. market (size, CAGR): auto. cyber security: $186Mn (2023, 22%); smart parking market: $513Mn (2021, 21%); fleet management market: $900Mn (2022, 7%)
Stakeholders	• Suppliers • Software developers, App developers, platform providers • Traffic companies • Ministries, regulatory authorities	• OEMs and system integrators that collect data trough their vehicles and systems • Startups that offer services / software • Companies within software developers and data analytics • Cities / municipalities: want to reduce traffic congestions and pollution, meanwhile increasing available public space
Potentials	• Developing products, software and services, exporting knowledge • Transfer of knowledge from pilot projects (e.g. Smart Flow in Amsterdam) and experience (e.g. on-street parking services in Amsterdam, Egis)	• Expertise in Telematics and Fleet Management • Smart Parking: currently focus on parking space management, holistic approaches could improve traffic and reduce congestion

Offering NL	weak ●●●●○ strong		Market Volume	small ●●●●○ large		Offering GER	weak ●●●●○ strong	
Demand NL	low ●●●●● high		Timescale	Short-term ●●○○○ Long-term		Demand GER	low ●●●●● high	

Five Forces analysis for New Mobility Services:

Suppliers & Dependencies

- OEMs: provide cars for mobility services
- Retailers: despite the shift towards online sales, retailers remain an important connection between service provider and customer
- Technology providers: shift towards online-sales require software and digital platforms, e.g. for payments
- Maintenance / Service companies: offer services that are connected to new mobility services
- Financing partners: shift from vehicle-ownership to vehicle-usership and subscription-based monetarization requires financing solutions

New Entrants

- OEMs and Startups are entering the market, digital platforms facilitate entry, high required capital investment for fleet is high barrier
- Rental services have expanded their services towards subscription (e.g. Sixt +)
- Peer-to-Peer carsharing platforms

Buyers

- Companies that want to offer their employees flexible and more sustainable mobility solutions
- Customers that want to have a more flexible or sustainable mobility solution than buying or leasing a car
- Different services and offers are already available for customers, high price sensitivity due to different price structure with no upfront initial costs

Substitutes

- Mobility-as-a-Service (especially ride-hailing) offers flexible rides and could be cheaper with autonomous driving and ride-sharing in the future (e.g. MOIA)
- Conventional car leasing (>24 m) and car rental (days to weeks)
- Public transport and traditional car ownership

Internal Competition

- OEMs, car rental services, MaaS providers and startups are fighting for market share
- Competitors usually have slightly different business models to differentiate themselves from each other (e.g. financing model, rental period)

Collaborative potential for New Mobility Services:

		
Quick Facts	• 74% of households own cars, number rather increasing • Almost 1 mio car-sharers in NL in 2021, driven by C2C	• 26% of Germans interested in subscription models (2019) • 2030: 1 mio potential subscriptions, covering 10% of market • VW does not want to sell cars any more after 2025
Stakeholders	• Platform / SaaS Providers • Carsharing providers • Specialized suppliers (e.g. telemetry systems, key systems) • Service providers, e.g. charging stations, payment system	• German OEMs, Startups and rental service providers • Financing Partners, Assurance companies • Customers who appreciate flexibility
Potentials	• Peer-to-Peer Carsharing is popular and successful in NL	• Fleet Management and leasing services for businesses • Expanded subscription model offers • Combination of different mobility solution • Peer-to-Peer Carsharing-Services not popular yet • Experience in carsharing pilot project (ComfficientShare)

Offering NL	weak ●●●○○ strong	Market Volume	small ●●○○○ large	Offering GER	weak ●●●●○ strong
Demand NL	low ●●●●○ high	Timescale	Short-term ●○○○○ Long-term	Demand GER	low ●●●●○ high

2.2 Propulsion Passenger Vehicles

Passenger vehicles manufacturing is one of Europe's, and especially Germanys, flagship industries. With close to 800.000 jobs directly in the industry itself and an annual turnover of more than half a billion Euro, its economic contribution is significant. Traditionally, the Netherlands are one of the most important supplier nations, and a relevant market. Technological advances, regulatory affairs, and geopolitical developments have caused major changes in recent years and will continue to do so in the future. In the following section, we outline the most relevant trends and drivers in the German sector for passenger vehicles, with a focus on propulsion technologies.

Sector Overview – Trends & Drivers

The discussion on regulation regarding alternative propulsion technology has dominated the agendas both on European and national levels, including Germany. Despite some efforts toward "technological openness", the German government has made a rather clear decision in favor of BEV. H2 and FCEV are unlikely to play a relevant role in passenger vehicles as infrastructure buildup is focused on charging stations instead of a hydrogen distribution network. The interviewees of this study uniformly agree that they perceive the decision to be taken and that their respective companies will focus on BEV to meet the CO2 targets. The latest ramp-up goal for BEV by the government was to achieve 15 million registrations in 2030. Both optimistic and neutral estimates forecast those targets to be clearly missed, as Figure 8 shows. Looking at daily registrations of BEV, the neutral estimates even seem far too optimistic. Meeting the 2030 target would require more than 6.000 new registrations of BEV per day – the 2024 average was less than 1.000 BEV per day. An intuitive explanation for those sobering numbers may be a lack of charging infrastructure. However, the sheer number of available chargers exceeds the theoretical analyses and does not pose a barrier to EV adoption. The perceived availability, paired with uncertainty regarding future developments, may still be a perceived hurdle for potential BEV customers. 25 % of current BEV users consider the provision of improved charging infrastructure a crucial factor for buying another EV. This is backed up by studies who conclude that a massive increase in charging infrastructure may boost BEV sales by 300.000 units by 2030. While this number is relevant, other factors have a stronger influence on the market's development. This includes retaliatory tariffs. While it is currently unclear how the transatlantic trading relationship will develop, the EU has introduced tariffs due to suspected subsidies, distortive of competition, on Chinese BEV. Those were reciprocated by China. Currently, around 35 % of sales and profit of German OEM are generated in China. The country also controls up to 60 % of raw materials and components needed to manufacture a BEV. The experts interviewed acknowledge the dependency on China, especially regarding battery technology. They consider it crucial to not further decouple Europe from other markets but

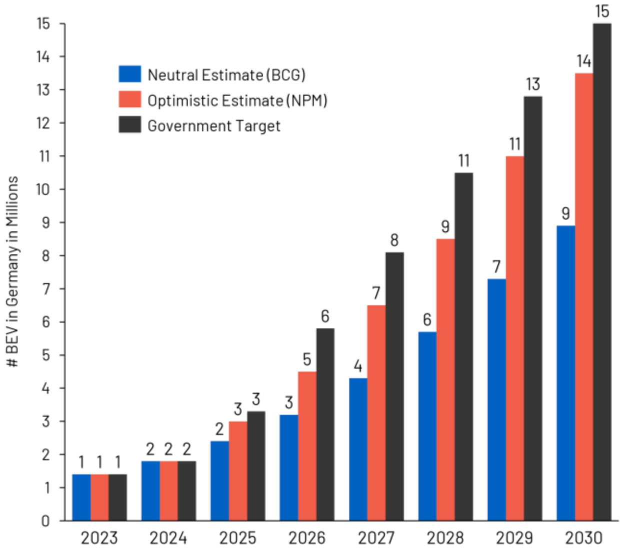

Figure 8: governmental target and forecasted numbers on the number of BEV in Germany

collaborate with and learn from them. While the share of Chinese vehicles registered in Germany currently is insignificant, it is expected to grow in the short-term future as depicted in Figure 9. This will result in a Chinese market share of up to 15 % in 2030, pushing German OEMs back to 47 %. As those BEV are subject to tariffs, negative effects on the market and overall are forecasted. The increase in prices and the deceleration of technological development due to reduced competition will result in 0,6 € Mn. less vehicles sold. The departure of Chinese manufacturers from the German market will furthermore lead to another 0,7 € Mn. less vehicles sold. The biggest opportunity to increase BEV market penetration in Germany until 2030, however, lies in regulatory measures like incentives and quotas. Those should aim at leveling the TCO of BEV and ICEV and may include quotas on company vehicles, CO2-based taxation, or a combined reform of energy- and vehicle taxation. Especially company cars, which currently only comprise 11 % of BEV, pose a viable approach to disseminate electric vehicles. This could lead to a fast development of the used vehicle market and make electric mobility more affordable for private customers. While the last government ended incentives on BEV, the parties likely involved in the new one announced a reintroduction of subsidies for local makes. Additionally, electricity for BEV may be subsidized. Some interview partners from the industry see ICEV bans critically as they may affect PHEV, which they consider relevant for long distance or high mileage traveling.

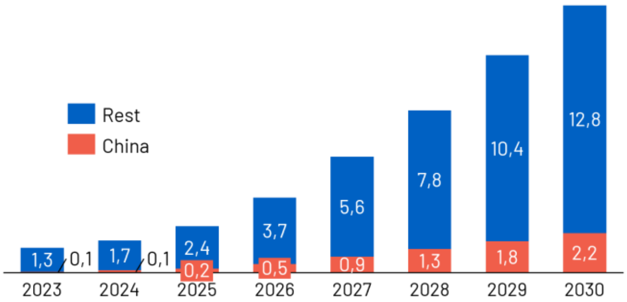

Figure 9: expected market shares of China in the German passenger vehicle market

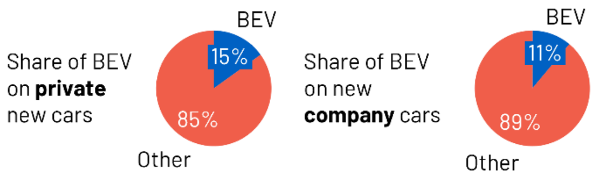

Figure 10: shares of BEV on private and company cars

Identified sub-markets

In the vast field of propulsion technologies for passenger vehicles, we identify three key sub-markets, which are comparatively visualized in Figure 11:

- **1 - Smart Charging:** while it comprises various functionalities and applications, it mainly means the economic optimization of charging events without compromising operability. According to the specific application (private, public, commercial, ... sites), different features can be included, such as: cost minimization, charged energy maximization, increase of consumption of PV, employee billing, shared CIS on joint property, and others. The market volume is estimated at €800Mn and the CAGR at 14 %.
- **2 - V2G Integration:** BEV can be understood as energy storage on wheels, meaning they can power local grids, other EV, buildings or even send electricity back to the grid. There are multiple opportunities for cost optimization (e.g. peak shaving) and even revenue generation by trading different products on the energy markets and, thus, offering services to the grid. The direct market has a volume of around € 180Mn at a CAGR of 25 %, but this does not include extensive effects on the whole electricity system, both locally and nationally.
- **3 - Charging Infrastructure:** the BEV ramp-up requires corresponding infrastructure. As BEV are not yet the predominant form of propulsion and a significant uptake is necessary to meet regulatory goals, the infrastructure market is expected to grow further. Different types of chargers (AC, DC, HPC, inductive) for different applications will be needed. While some standardization is in place, there is still movement regarding technical requirements and norms, for example regarding V2G use-cases. The marked volume is around € 412 Mn. with a CAGR of 9 %.

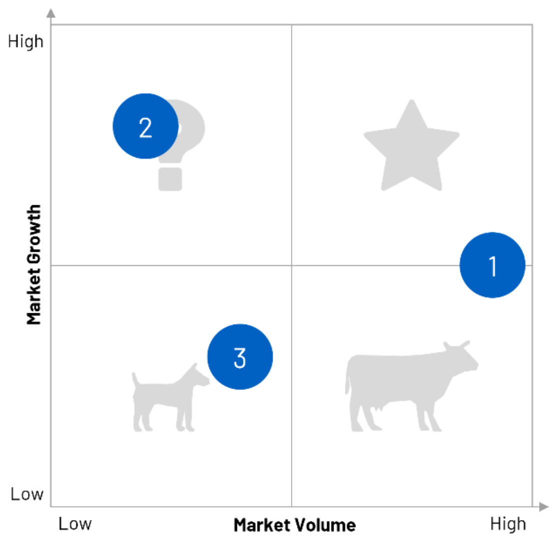

Figure 11: BCG Matrix of the three selected sub-markets for the passenger vehicle market

Submarket Analyses

Five Forces Analysis for the Smart Charging market:

Suppliers & Dependencies

- As software is the main product, the market is relatively robust to supply chain issues, and the hardware suppliers' leverage is limited
- However, there is some reliance on charging infrastructure manufacturers. Especially technicians installing novel solutions are scarce.
- Energy suppliers must accept the proposed installation and enable new/extended grid connections
- Due to the rapid evolution of the market, skilled workforce like software developers and engineers is sought after
- Regulation and standardization from different sectors is relevant (energy, vehicles, etc.)

New Entrants

- Energy suppliers, which are large corporations with economic strength, are widening their portfolio and entering the smart charging market. As they approve of installations, they have significant market power.
- Suppliers from the smart home sector possess knowledge in integrating e.g. PV, energy storage, heating, … and rely on an existing network of vendors, technicians, and resellers

Buyers

- Private households retrofitting existing electrical installations to facilitate EV charging. High complexity and bad scalability due to individuality of each site.
- Commercial customers with various use-cases, e.g.: housing development, fleet operators, CIS as convenience factor for customers

Substitutes

- Instead of optimizing the charging, stationary energy storage may be used to increase available power at any time
- Solutions driven by the BEV or housing technology sector may lead the market instead of opening up for new players

Internal Competition

- Many providers of technologically simple products but few with sophisticated, cutting-edge technology
- CIS reselling and installation as by-product of energy suppliers
- As long-term customer support is necessary, market exit is undesirable

Collaborative Potential Smart Charging

		
Quick Facts	• 3 GW load peak through EV in 2030 • Peaks can be reduced by 10-15 % by SC • € 0,9 Bn grid investment expected 2025-30	• 120.625 installed chargers as of 2024 • 1,4 Million BEV • 2,9 % BEV rate in national fleet
Stakeholders	• Energy suppliers • One-stop-shop offers (planning, hardware, installation, energy mgmt.) • Suppliers of sub-components	• All political levels; need to meet decarbonization targets • Private & commercial customers
Potentials	• Use experience w. congested grid & ops. of private CIS • Knowledge transfer as short-term revenue stream	• Partnering with OEMs who need to decarbonize fleets • Demand for one-stop-shop to facilitate necessary fast ramp-up

Offering NL	weak	●●●●●	strong	Market Volume	small	●●●○○	large	Offering GER	weak	●●●○○	strong
Demand NL	low	●●●●●	high	Timescale	Short-term	●○○○○	Long-term	Demand GER	low	●●●●○	high

Five Forces Analysis for the Vehicle-2-X (Grid/Home/Vehicle/…) market:

Suppliers & Dependencies

- Energy utilities are large corporations with market power. Potential benefits through avoidance of costly measures to deal with congested and overloaded systems. They can use their power to lead standardization and regulation.
- Vehicle OEMs need to make use of potential TCO decrease and increased customer value of the vehicle. First to market potential still relevant.
- CIS and software suppliers are driving the developments and are an intermediary between automotive and energy sectors. High potential for economic success.

New Entrants

- The high complexity, both technological and especially regulatory, favor established companies – the market entry is hard for small and/or independent endeavors
- OEMs and energy utilities with strong financial background may enter the market as supplementary product to their core product

Buyers

- Consumers are interested in decreasing the TCO of their BEV and utilizing smart energy solutions in their facilities. Due to uncertainty in energy prices and politics, it is likely to stay a niche instead of a must have for a few more years
- Commercial fleet operators like courier services, freight forwarders, etc. will use V2X to power their sites and, most importantly, cut costs.

Substitutes

- Stationary energy storage and smart charging may slow down the uptake, depending on political decisions, availability, and pricing
- V2G has relatively low investment costs compared to SES, but with more vehicle batteries becoming ready for 2nd life the SES prices may drop

Internal Competition

- Industry must keep up with BEV market growth – vehicle owners unwilling to invest twice. They either use V2X from day one or will wait at least some years
- OEMs being forced into BEV market may lead to price erosion
- Strategic partnerships between the sectors are necessary to avoid parallel sub-optimal developments

Collaborative Potential Vehicle-2-X (Grid/Home/Vehicle/…)

		
Quick Facts	• Est. energy capacity in BEV: ~27GWh • Potential revenues through V2G: 7-13 % of TCO • Congestion mgmt. cost 2023: €278Mn • Restriction & reactive power contracts more common	• Est. energy capacity in BEV: ~80 GWh • 79 % of home + BEV owners interested in V2G • Congestion mgmt. cost 2023: €2,1Bn • Increasing redispatch volumes
Stakeholders	• Energy suppliers avoiding costly measures • Offerings monetizing the car battery being parked • Commercial fleet operators • Hardware/component suppliers	• OEMs decreasing TCO • Freight forwarders • Smart energy providers • Govt. increasing the attractiveness of GER for industry
Potentials	• Use potential of small energy market with fewer DSOs • Develop EU-level policies • Strengthening role as electricity exporter and leader in renewables	• Mitigating urgency in grid expansion • Monetize existing assets and decrease TCO • Synergetic integration of sectors

Offering NL	weak ●●●●○ strong	Market Volume	small ●●●○○ large	Offering GER	weak ●●●○○ strong
Demand NL	low ●●●●● high	Timescale	Short-term ●●●●○ Long-term	Demand GER	low ●●●●● high

Five Forces Analysis for the Charging Infrastructure market:

Suppliers & Dependencies

- Dependence on installation cost & complexity. Large-scale rollouts are nearly impossible to estimate in time and cost.
- Dependency on utilities to support installation, especially fast-charging infrastructure.
- Highly regulated: most use-cases possess specific regulations. Specializing in selected categories suggested.
- High up-front investment necessitates superior quality, little/no downtimes and flawless customer support.
- Global supply-chains through hardware-heaviness
- For public chargers, the CPO is crucial to attract users and provide seamless integration

New Entrants

- Competitive market, hard to enter due to technological complexity
- Large corporations (utilities, OEMs) forced to enter leads to contortion
- Mainly attractive if one of the assets exists (technology, grid, e. production, ...)

Buyers

- Municipalities setting up both public chargers and often running local energy suppliers, thus selling to consumers
- Home- and BEV-owners looking for convenient, affordable, and future-proof solutions to charge. Technological readiness is crucial.
- Utilities aiming to provide a one-stop-shop solution for their existing and new customers.

Substitutes

- No direct substitute, rather a question of market volume through e.g. uptake of e-mobility and/or grid congestion
- Causes high degree of competitivity

Internal Competition

- Regional utilities (ENBW, E.ON, ...)
- Established infrastructure providers (Shell, Siemens, BayWa, Tesla)
- Suppliers/Manufacturers
- Charge Point Operators

Collaborative Potential Charging Infrastructure

		
Quick Facts	• Chargers: 144.453 • BEV: ~450k • EV-rate: ~5% • Underdeveloped DC network • EV rate new reg.: ~50% • Installed Charging power: ~2,7 GW • Average power: 19 kW	• Chargers: 120.625 • BEV: ~1,4 Mn. • EV-rate: 2,9% • EV rate new reg.: ~16,5% • Installed Charging power: ~5,6 GW • Average power: 46 kW
Stakeholders	• Charging infrastructure manufacturers • Component suppliers • Engineering service providers	• Energy utilities • Municipalities • Private consumers • OEMs • Smart-charging companies
Potentials	• Establish strategic connections to OEMs • Adapt to regulations of a high potential market • Development of new technologies • Leading position in European regulations	• Provide one-stop-shop offerings • Deal with complexity of required CIS build-up • Reliable solutions for private customers • Strategic partnerships

Offering NL	weak ●●●●○ strong	Market Volume	small ●●●○○ large
Demand NL	low ●●●○○ high	Timescale	Short-term ●○○○○ Long-term
Offering GER	weak ●●●●○ strong	Demand GER	low ●●●○○ high

2.3 Propulsion Heavy Vehicles

Propulsion in heavy vehicles is of great importance to Europe's transport and logistics sector and plays an important roly in trade and supply chains. Germany is a leader in the production of heavy vehicles, while the Netherlands is a prime example of a manufacturer in itself and also a key supplier to and market for that sector. The economic value generated is substantial, thanks to technological advances, regulatory changes, and changing market dynamics. Access to recent advances in battery electric and fuel cell propulsions, the growing importance of efficiency in energy consumption, and, furthermore, electric-charging infrastructure is among the key influences in the industry. Lasting problems such as continuous planning stability, a dependency on raw materials, and the economic viability of new technologies still continue to shape the field. The next section will deal with the key trends and drivers which will define the future of heavy vehicle propulsion in Germany.

Sector Overview – Trends & Drivers

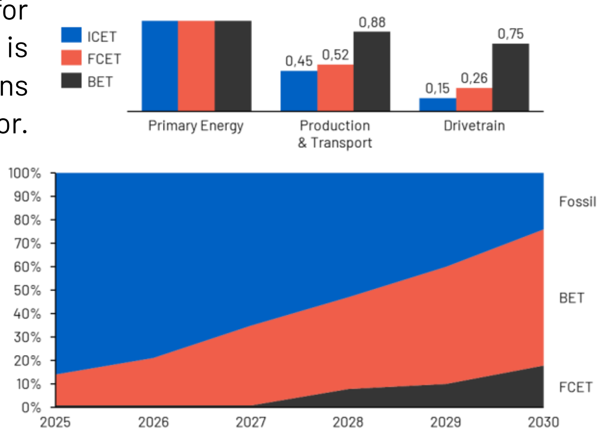

Figure 12: Drivetrain efficiency and market shares until 2030 for ICET, FCET and BET

Contrary to passenger vehicles, decisions for heavy vehicles are mainly taken objectively. TCO is the key driver. Furthermore, strict EU regulations require a stepwise decarbonization of the sector. In 2030, emissions must be cut by 47 % and in 2040 by 90 %. Considering the usual development and planning cycles in the automotive sector, this means the according vehicles to meet these targets must be decided upon now. In the recent past, German OEMs have presented some of the most promising BET on the market. As Figure 12 shows, battery electric trucks (BET) possess the best wheel-to-wheel efficiency. 75 % of the primary energy sources' amount of available energy are translated to movement with only 12 % lost in production and transport. Internal combustion engine trucks (ICET) and fuel cell electric trucks show significantly worse performance with 15 and 26 % of the initial energy being used to move the truck, ultimately. Despite being the most efficient, the TCO advantage of BET is volatile. The main drivers are battery cost and charging price, as Figure 13 shows. Variations in charging price of as little as 5 Cent per kWh can lead to a TCO disadvantage for the BET compared to a classic diesel truck. As it is currently unclear which electricity tariffs will be charged for on-route charging, there's a significant amount of planning instability involved. Same goes for battery prices – if the cost per kWh (battery size of a bet is between 200 and 600 kWh) varies by few percentage points, the ICET may be the more profitable option for fleet operators. General economic developments, regulation and subsidies, charging infrastructure build up, collaboration with the electricity market etc. are all relevant factors which may delay the tipping point. Cell

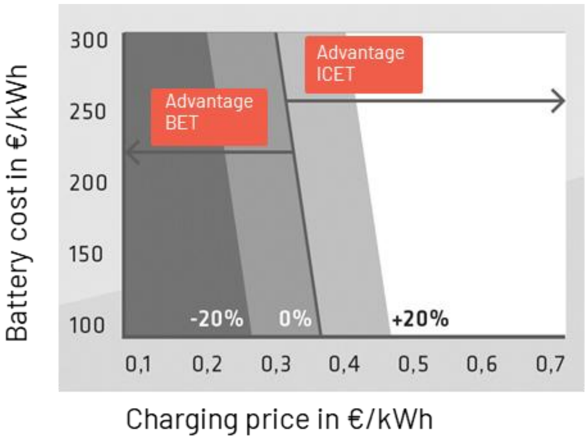

Figure 13: dependecy of chargin price and battery cost for TCO advantage between BET and ICET

Figure 14: comparison of cell technologies for different BET use cases

technology is the decisive factor from a technological point of view. A BET battery is required to last 5000 charging cycles, power the truck for up to 1000 km on a single charge, possess a high energy density (a battery can weigh up to 5 tons and consumes important load capacity), and, while guaranteeing these factors, should be priced competitively (the battery may cost around 50k €). Developments in cell chemistry, cell to pack manufacturing and powertrain efficiency can aid in achieving these goals. Together, they can help to increase driving range from 600 to 900 km. Furthermore, various cell technologies are still under development: LFP, LMFP, and NMC all yield specific strengths and weaknesses. To meet the specific requirements of different use-cases (distribution, line haul, long haul), the most suitable technology to meet the TCO goals can be chosen as shown in Figure 14. Finally, to operate BET, charging infrastructure is needed both in the operators depots and along the trans-European transport network (TEN-T). From initial planning to implementation of a megawatt charging site, a duration of 2 to 10 years must be expected depending on the grid level of the connection (medium voltage level 2 years, HV/HV transformer 10,3 years average duration in Germany, as shown in Figure 15). To achieve coherence in the activities of the different stakeholders, governmental pushes are necessary. BET-specific dispatching software or sharing of private CIS can aid in the implementation. Studies suggest that operators lack information, knowledge and experience and, thus, are hesitant in investing.

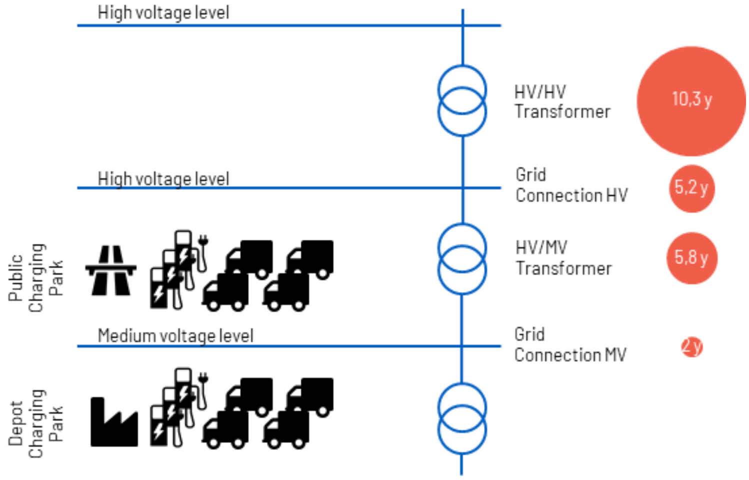

Figure 15: average duration of implementation of grid connections on different grid levels for BET charging infrastructure

Identified sub-markets

In the field of propulsion technology for heavy vehicles, we identify four submarkets for further analysis, as shown in Figure 16:

- **1 – Battery electric trucks:** With the strict EU emissions regulations, Battery Electric Trucks (BET) will seize the largest share in the market from about 2029 onward. Some of the key enablers for adoption include technological progress in batteries, charging infrastructure, and supporting services. However, for success in deployment, an integrated ecosystem is required, demanding synchronized interchanges in infrastructure and operations. The market volume for the same has been pegged at $1.3 billion, showing a CAGR of 15%.

- **2 – H2 and fuel cell:** It is predicted that the hydrogen fuel cell technology will grab a 10% market share by 2040 for specific applications. Germany, for example, is putting money into hydrogen fuel trucks, yet overall adoption is still unclear due to infrastructure and cost issues. Adoption on an industry-wide level will largely depend on particular sector demands. Market volume is capped at $250 million, and the anticipated CAGR is 8%.

- **3 - Charging for heavy commercial vehicles:** The development of charging infrastructure for both private and commercial users is crucial for widespread BET adoption. High-power charging (HPC) solutions for trucks will likely be concentrated along key transport corridors, including highways. Cost sensitivity is expected to play a significant role in deployment decisions, particularly regarding hardware, electricity prices, and site locations. The estimated market volume is $1.4 billion, with a projected CAGR of 26%.

- **4 – Software based/digital solutions:** Digitalization in heavy vehicle logistics includes applications such as fleet management, route optimization, real-time monitoring, and charging infrastructure planning. Increasing demand for regulatory compliance and certification is expected to drive the adoption of digital tools. New business models may emerge as a result of these technological advancements. The estimated market volume is $3.78 billion, with a projected CAGR of 9%.

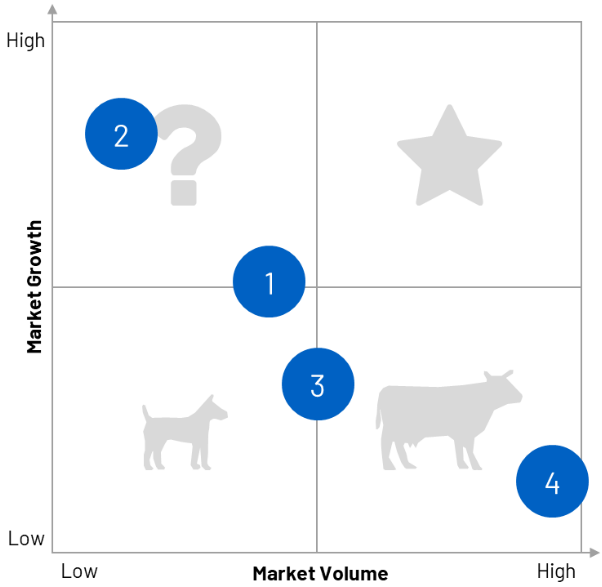

Figure 16: BCG Matrix for propulsion heavy vehicles submarkets

Submarket Analyses

Five Forces Analysis for the BET market:

Suppliers & Dependencies

- Battery supply (materials and production) is dominated by China.
- German OEMs leverage their expertise in vehicle development to secure market share.
- Key components such as battery management, cooling, and drivetrains gain importance as efficiency improves.
- Dependence on high-quality parts leads to a limited number of suppliers, making standard parts less attractive due to weak negotiating positions. Specialized suppliers have a stronger market position.

New Entrants

- Entering the market requires significant capital investment due to high production volumes and slim profit margins, posing a high risk for SMEs.
- Niche and highly specialized solutions may appeal to OEMs.
- Public funding for collaborative efforts could support SME participation.

Buyers

- Logistics companies (many small and medium-sized carriers) exhibit high price sensitivity and rely on multi-year service contracts. Fleet expansion depends on private and public charging infrastructure. Leasing models could enhance adoption.
- E-commerce and delivery fleets, often operated by large logistics groups, also demonstrate high price sensitivity but are expected to drive large-scale adoption.

Substitutes

- Internal combustion engine trucks (ICET) are being phased out due to EU regulations.
- Hydrogen and fuel cell (H2) technology is emerging but remains limited to niche applications.

Internal Competition

- Market growth is strong, but most opportunities are reserved for established OEMs.
- SMEs face challenges due to long-term contractual obligations and stringent requirements.
- Economic crises and market disruptions may lead to order cancellations or delays.

Collaborative Potential BET

		
Quick Facts	• Approximately 5% of Dutch truck exports are to Germany. • The Netherlands has a high commitment to green transport, aiming for a 45% reduction in transport-related emissions, with a 23% increase in alternative drive solutions. • Battery Electric Truck (BET) market demand is forecasted to rise significantly, with market penetration expected to grow from 4% to 31%.	• Germany accounts for approximately 50 billion ton-km (around 70% of national transport volume). • 38.5% of commercial vehicles in Germany are registered for freight transport, contributing to 47% of total emissions. • Germany represents over 70% of EU truck sales. • Policy-driven electrification goals have led to a 140% increase in electric truck registrations since 1990.
Stakeholders	• OEMs: Primarily DAF & VDL. • Component and system suppliers. • Software developers specializing in fleet management, planning, and operational efficiency of BET charging networks.	• OEMs: Major manufacturers such as Daimler and MAN. • Tier 1-2 suppliers. • Charging network operators.
Potentials	• Strong export position in electric buses and specialized truck applications. • Expertise in truck-specific battery packs and powertrain components. • Advanced knowledge in charging infrastructure and energy management, including power distribution and electric grid integration.	• Long-term partnerships in joint vehicle and component development. • Reducing production complexity and cost through integrated component solutions. • Infrastructure expansion to support the transition to BET technology.

Offering NL weak ●●○○○ strong	Market Volume small ●●●●○ large	Offering GER weak ●●●●● strong
Demand NL low ●●●○○ high	Timescale Short-term ●●●●○ Long-term	Demand GER low ●●●●○ high

Five Forces Analysis for the H2 & Fuel Cell market:

Suppliers & Dependencies

- Hydrogen production and availability are critical for market adoption. While distribution infrastructure is planned, it has not yet been fully realized in the context of road mobility. Once implemented, supplier dependency will decrease.
- Limited availability of fuel cell hardware and technology suppliers.
- Hydrogen engines exhibit a high level of technological readiness.
- Industrial applications of hydrogen allow for shared usage, providing synergy in niche sectors.

New Entrants

- Entering the hydrogen and fuel cell vehicle market requires significant capital investment due to high complexity and hardware dependencies.
- New entrants must rely on infrastructure development, which is often outside their control and depends on governmental support.

Buyers

- Freight and heavy industries depend on OEMs' hydrogen vehicle offerings but remain highly cost-sensitive.
- From an OEM perspective, developing and supporting two competing technologies (H2 and battery-electric) requires major capital investment, making broad-scale adoption uncertain.
- Environmental regulations will play a significant role in influencing purchasing decisions.
- Government initiatives, including subsidies and infrastructure development, will impact buyer confidence and adoption rates.

Substitutes

- The majority of the heavy-duty vehicle market is expected to shift toward battery-electric vehicles (BEVs).
- Diesel and e-fuels may serve as alternative solutions, particularly in niche applications where BEVs are not viable.

Internal Competition

- Established OEMs such as Daimler, MAN, and DAF maintain a strong presence in both Germany and the Netherlands, shaping market competition.
- Smaller companies play a role in niche applications, particularly in construction and specialized freight sectors.
- Strategic alliances for research and development, as well as infrastructure expansion, are crucial for market competitiveness.
- As hydrogen infrastructure scales up, competition among providers and technology suppliers will increase.

Collaborative Potential H2 & Fuel Cell

		
Quick Facts	• Hydrogen price: 10–14 €/kg, cost parity requires 5 €/kg. • €125 million in subsidies for fueling infrastructure and vehicles. • Currently 17 hydrogen refueling stations in operation.	• Hydrogen price: 6–14 €/kg, cost parity requires 5 €/kg. • Total investment of €62 billion in hydrogen infrastructure (including €800 million for H2 refueling stations). • 106 hydrogen refueling stations currently in operation. • German OEMs (e.g., Daimler Truck) subsidized with €24 million, aiming to deploy 100 hydrogen trucks by 2026. • Multiple government-subsidized projects supporting hydrogen adoption.
Stakeholders	• Hydrogen suppliers. • OEMs involved in hydrogen & fuel cell / zero-emission truck (ZET) markets. • Suppliers of fuel cell drivetrains and components. • Notable companies: Zepp.Solutions, BAM.	• Hydrogen infrastructure developers and suppliers. • Leading OEMs in the hydrogen truck segment. • Notable companies: Mörtlbauer, Liebherr.
Potentials	• Leverage synergies with port infrastructure for hydrogen distribution. • Strategic advantage in green hydrogen production due to geographic location near the sea.	• Development of hydrogen infrastructure to establish Germany as the EU leader in mass hydrogen transit. • Regulatory framework positioning hydrogen as an energy carrier instead of industrial gas. • Integration with TEN-E and TEN-T frameworks for trans-European energy and transport networks.

Offering NL	weak ●●●●○ strong	Market Volume	small ●○○○○ large	Offering GER	weak ●●●○○ strong
Demand NL	low ●●○○○ high	Timescale	Short-term ●●●●○ Long-term	Demand GER	low ●●○○○ high

Five Forces Analysis for the heavy vehicles charging market:

Suppliers & Dependencies

- Battery electric truck (BET) OEMs: Batteries and charging capabilities, as well as compatibility with different charging systems, are critical for BET adoption.
- Electricity suppliers: Grid connection and electricity tariffs significantly impact market viability. Current EU regulations play a crucial role in shaping supplier strategies.
- Charging hardware providers: Regulatory pressure affects infrastructure deployment, with challenges in power availability, communication, and technology standardization.

New Entrants

- Market conditions are favorable due to increasing investments, but entering the charging infrastructure sector requires significant expertise and technological know-how.
- Large players (OEMs, utilities, hardware manufacturers) are likely to dominate due to regulatory requirements, making it harder for smaller entrants.
- Government policies and regulatory pressure may push existing businesses to adapt but could also limit profitability and innovation for new market participants.

Buyers

- Freight operators and logistics companies: Highly price-sensitive and reliant on public infrastructure for fleet operations. The limited range of available products linked to BET adoption may pose financial challenges.
- Government entities: Actively fostering the local and EU economy by implementing regulations and subsidies, though investments in infrastructure remain slow.
- OEMs: Struggling with high investment costs, potentially requiring them to push for infrastructure development to increase adoption

Substitutes

- BET is expected to dominate distribution and hub-to-hub traffic, but long-haul applications may still face competition from hydrogen fuel cell (H2 FC) trucks.
- Privatized, fragmented charging networks could replace optimal large-scale charging infrastructure, leading to inefficiencies in the market.

Internal Competition

- Key differentiation factors include network size, charging speed, geographic coverage, and service quality, necessitating partnerships and collaboration between key industry players.
- Large OEMs and utilities may face financial strain, affecting their business models if forced to invest heavily in securing core infrastructure.
- The market is likely to experience competition between holistic, well-integrated solutions and more fragmented, privately managed charging networks.

Collaborative Potential heavy vehicles charging

		
Quick Facts	• Over 5,200 fast-charging points installed across the country, but no specific national target for truck charging. • 3,500 km of highways supporting freight transport. • Approximately 146 million ton-km of freight transported by road annually.	• National target: 350 fast-charging sites covering 6% of highways, with 1,800 MCS (Megawatt Charging System) and 2,400 CCS chargers. • Extensive 13,192 km highway network, with close to 2,000 charging stations currently available. • Policy framework: "Durchleitungsmodell" – mandating or promoting public chargers at depots and truck stops.
Stakeholders	• Fleet (hub) operators and grid operators. • Charge point operators (CPOs) and e-mobility service providers (EMSPs). • Turnkey solution providers and hardware manufacturers. • Large industrial sites and port authorities.	• Fleet (hub) operators and grid operators. • BET OEMs supporting high-power charging infrastructure. • CPOs and EMSPs driving network expansion. • Turnkey solution providers and hardware manufacturers.
Potentials	• Strengthen the leading role in charging hardware and standardization. • Support electric road freight transport by focusing on important European transit hubs. • Develop expertise in depot electrification, enabling efficient charging infrastructure for logistics and freight depots.	• Electrified depots can provide financially and operationally optimal solutions for fleet operators. • Support transit corridors through new business models, such as integrating HPC (high-power charging) and HPC-P/C (public/private commercial charging infrastructure). • Help avoid grid congestion by implementing smart grid and energy storage solutions. • Promote BET sales by ensuring a reliable and widespread charging network

Offering NL	weak ●●○○○ strong	Market Volume	small ●●●○○ large	Offering GER	weak ●●●○○ strong
Demand NL	low ●●●●○ high	Timescale	Short-term ●○○○○ Long-term	Demand GER	low ●●●●○ high

Five Forces Analysis for the heavy vehicle software market:

Suppliers & Dependencies

- Digital solutions primarily focus on software development, with minimal dependence on hardware. Solutions are typically cloud-based and scalable.
- Diverse supplier landscape, depending on the software focus area:
- Planning & cost calculations: Specialized consultants with industry-specific expertise.
- Location and energy/charging management software: Integration with smart energy solutions.
- Remote/home-based charging solutions: Energy sector involvement.
- Fleet and logistics disposition software: Optimized for BET fleet operators.

New Entrants

- Favorable market conditions for SMEs, as there are no dominant industry leaders yet.
- High scalability of digital products, reducing capital intensity for new entrants.
- Niche opportunities exist due to cost sensitivity in the market, enabling specialized solutions tailored to fleet operators.

Buyers

- Large number of road freight forwarders in both Germany and the Netherlands, providing a broad customer base.
- High price sensitivity in the transport sector affects software adoption rates.
- Charging infrastructure operators require digital solutions to amortize high investment costs through optimization.
- Service area operators focus on customer retention and energy management through software solutions.
- Distribution grid operators seek software tools to support network stability and optimize energy resale strategies.

Substitutes

- No direct substitute exists for planning and operational software in electrified transport.
- Manual or legacy systems may still be in use but lack efficiency and scalability.

Internal Competition

- Large utilities and energy distribution companies (DSOs) may expand into specialized software markets.
- The wide scope of digital solutions creates numerous business opportunities across different fields.
- The "winner takes all" effect in digital platforms (e.g., fleet management, route optimization) may lead to price wars and business model erosion.

Collaborative Potential heavy vehicles software based solutions

		
Quick Facts	• 48 billion ton-km of freight transported in 2023. • 7 Distribution System Operators (DSOs) managing energy distribution. • Approximately 2,350 freight forwarders operating in the market. • Around 200 service areas along Dutch motorways.	• 300 billion ton-km of freight transported in 2023. • Around 14,000 freight forwarders operating in the logistics sector. • ~170 public CPOs managing charging networks. • 883 DSOs handling power distribution and grid services. • Nearly 2,000 service areas along German highways.
Stakeholders	• Charge Point Operators (CPOs) managing public and private charging infrastructure. • Fleet operators and freight carriers optimizing logistics efficiency. • Utilities and grid operators offering pre-bookable tariff-based charging solutions.	• Vehicle manufacturers offering integrated software solutions to enable BET adoption. • Fleet operators and freight carriers requiring advanced digital solutions for fleet and energy management. • Utilities and energy companies seeking predictable pricing models and revenue streams from electric truck charging.
Potentials	• Support electric trucking by enabling efficient charging along TEN-T corridors. • Crucial role for port logistics, ensuring optimized electrified transport hubs. • Increase utilization of private charging infrastructure for fleet operators. • Improve grid stability through scheduled charging, reducing peak load issues.	• Enhance the attractiveness of electric trucks through improved access to charging services. • Reduce Total Cost of Ownership (TCO) by enabling optimized energy contracts and charging strategies. • Streamline operational transitions in the trucking industry through advanced planning, disposition, and routing software.

Offering NL	weak	●●●○○	strong	Market Volume	small	●●●○○	large	Offering GER	weak	●●○○○	strong
Demand NL	low	●●●○○	high	Timescale	Short-term	●●●○○	Long-term	Demand GER	low	●●●○○	high

2.4 Niche Markets and products

The following chapter focuses on one specific niche market: **electrical construction site machinery**. The transition to environmentally friendly technologies in the construction machinery sector is being significantly influenced by growing environmental and regulatory pressures aimed at reducing noise and air pollution. Government incentives are further accelerating this shift by promoting the adoption of eco-friendly solutions. In construction environments, particularly in confined spaces like tunnels and urban sites, reducing noise and emissions is crucial, not only for regulatory compliance but also for minimizing ventilation costs. As a result, the total cost of ownership (TCO) for electric construction machinery is becoming increasingly competitive due to their lower operating expenses and the decreasing costs of electrical machines themselves.

However, this transition is not without its challenges. The initial investment required for electric construction machinery remains higher compared to traditional diesel-powered alternatives, even though TCO often proves to be a more important factor over time. Effective thermal management is another significant challenge, particularly in the development of larger machines equipped with substantial battery capacities. In these cases, fuel cells are being considered as a potentially more efficient and sustainable solution.

Despite these obstacles, there are promising opportunities for growth and innovation in the sector. The modularity of battery packs allows for greater flexibility, enabling construction machinery to be customized according to specific tasks and operational needs. This adaptability not only enhances efficiency but also supports a smoother and more strategic integration of electric machines into a wide range of construction applications. By capitalizing on these opportunities, the construction industry can move closer to achieving its sustainability goals while maintaining performance and cost-effectiveness.

Exemplary companies in the Netherlands:

- Eleo: Battery Packs for Off-Highways EVs
- Dens: Battery, Fuel Cell
- Sherpa: electric mini loaders
- Spierings Mobiles Cranes: electric cranes

Exemplary companies in Germany:

- Reverion: container-based storage system, power-to-gas
- Wirtgem Group: small electric machines for construction sites
- Wacker-Neuson and Liebherr: loaders, rollers, excavators
- German suppliers develop electric systems for construction, e.g. ZF

Case Study: Emission-Free Construction Sites in Germany

In an initiative to advance sustainable construction practices, a German grid operator, in collaboration with Liebherr and Wacker-Neuson, has launched a series of tests focusing on emission-free construction sites. This project involves close cooperation with German municipalities and aims to demonstrate the feasibility and benefits of using fully electric and hybrid construction machinery in urban environments.

The application areas for this initiative are diverse and strategically chosen. In residential neighborhoods, the use of emission-free machines significantly reduces noise and air pollution, enhancing the quality of life for residents. Moreover, the ability to operate during night shifts presents a substantial advantage, particularly in light of Germany's stringent noise regulations, which typically permit construction work only between 7 AM and 8 PM. Additionally, cities and municipalities with strict emission constraints offer an ideal setting for testing these advanced machines, showcasing their capability to meet rigorous environmental standards.

Both Liebherr and Wacker-Neuson bring extensive expertise and a comprehensive portfolio of full electric and hybrid construction machinery to the project. A key technology being tested is the Lido Power Port (LPO) by Liebherr, a battery-based stand-alone power source designed to support electric construction machines at off-grid sites. This solution addresses one of the critical challenges of electrification in construction—providing reliable power in remote or infrastructure-limited areas.

The overarching goal of the grid operator is ambitious yet clear: to ensure that all future construction sites associated with the sustainable power grid will exclusively utilize full electric construction machinery. This case study not only highlights the technical and operational feasibility of such an approach but also serves as a blueprint for other regions aiming to reduce emissions and noise pollution in urban development projects.

Dutch-German Collaboration Potential on Electric Construction Machinery

The transition to electric construction machinery presents a promising opportunity for collaboration between the Netherlands and Germany, leveraging the unique strengths of both countries. The Netherlands has established itself as a leader in battery pack production and stationary power solutions, supported by a dynamic ecosystem of small original equipment manufacturers (OEMs). Meanwhile, Germany's strengths lie in its numerous large OEMs, a wide network of both large and small suppliers, and a growing capability to develop in-house solutions for electric powertrains and battery systems.

Dutch companies have the potential to significantly contribute to the German market by exporting high-quality battery packs and stationary power solutions. These products can complement the capabilities of German OEMs, enhancing the performance and sustainability of electric construction machinery. For instance, Dutch expertise in modular and scalable battery systems could address the growing demand for flexible power solutions in Germany's construction sector.

However, this collaboration faces challenges. A key competitive pressure for Dutch companies is the presence of large German OEMs that often prefer to use their own in-house power and battery solutions. Additionally, Germany's expanding domestic battery pack production, exemplified by companies like Akasol—now part of BorgWarner—poses a direct competition to Dutch battery exports. To overcome these challenges, Dutch companies could focus on niche markets, offer tailored solutions, or pursue strategic partnerships with German suppliers and OEMs.

By aligning their complementary strengths and addressing competitive challenges, the Netherlands and Germany have the potential to build a robust cross-border ecosystem for electric construction machinery. This collaboration could accelerate the adoption of sustainable technologies in the construction industry across Europe.

2.5 Overall Ratings and Selection of High Potentials

Figure 17 and Figure 18 show an overview of the market sectors and their submarkets. The rating for market volume and growth as well as the offering and demand level in the Netherlands and Germany for those technology give an indication of the selected high potential topics for collaboration between both countries.

	Digitalization & Connectivity	Offering NL	Demand NL	Market Volume	Timescale	Offering GER	Demand GER	
1	Smart Infrastructure, V2X	●●●○○	●●●●●	●●●●○	●●●●○	●●●●○	●●●●●	★
2	AD enabling Technologies	●●●○○	●●●○○	●●●○○	●●○○○	●●●●○	●●●●●	
3	SDV E/E Architecture	●●○○○	●●●○○	●●●●●	●●○○○	●●●●○	●●●●●	
4	Data and Software based Services	●●●●○	●●●●●	●●●●○	●●○○○	●●●●○	●●●●●	★
5	New Mobility Services	●●●○○	●●●○○	●●○○○	●○○○○	●●●●○	●●●○○	

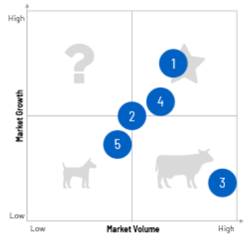

Figure 17: overview and rating of submarkets in the field of digitalization & connectivity

For the market sector digitalization and connectivity, two submarkets smart infrastructure and data and software-based services were selected for the deep dives. In the propulsion sector smart charging and V2G as well as battery electric trucks were selected for deep dives (indicated by the stars in Figure 17 and Figure 18).

	Passenger vehicles	Offering NL	Demand NL	Market Volume	Timescale	Offering GER	Demand GER	
1	Smart Charging	●●●●●	●●●●●	●●●○○	●○○○○	●●●○○	●●●●○	★ (1–2)
2	V2G	●●●●○	●●●●●	●●●○○	●●●●○	●●●○○	●●●●●	
3	Charging Infrastructure (BEV)	●●●●○	●●●○○	●●●○○	●○○○○	●●●●○	●●●○○	
	Heavy vehicles							
1	Battery Electric Trucks	●●○○○	●●●○○	●●●●○	●●●●○	●●●●●	●●●●○	★
2	H2 & Fuel Cell Trucks	●●●●○	●●○○○	●○○○○	●●●●○	●●●○○	●●○○○	
3	Charging Infrastructure (BET)	●●○○○	●●●●○	●●●○○	●○○○○	●●●○○	●●●●○	
4	Digital Solutions	●●●○○	●●●○○	●●●○○	●●●○○	●●○○○	●●●○○	

Figure 18 overview and rating of submarkets in the field of passenger and heavy vehicles

3 High Potentials / Deep Dive Analysis

This deep dive analysis aims to explore four key areas that are shaping the future of transportation: Smart Infrastructure & V2X (Vehicle-to-Everything), Data and Software-based Services, Battery Electric Trucks, and V2G (Vehicle-to-Grid) & Smart Charging. Each of these topics represents a crucial component of the evolving ecosystem of sustainable and intelligent mobility solutions.

To provide a comprehensive understanding of these areas, a structured methodology has been adopted (see Figure 19). The analysis for each topic begins with a breakdown of the submarket, categorizing related aspects into technologies, trends, products, and services. This approach ensures a clear and detailed view of the landscape, highlighting both current developments and emerging opportunities.

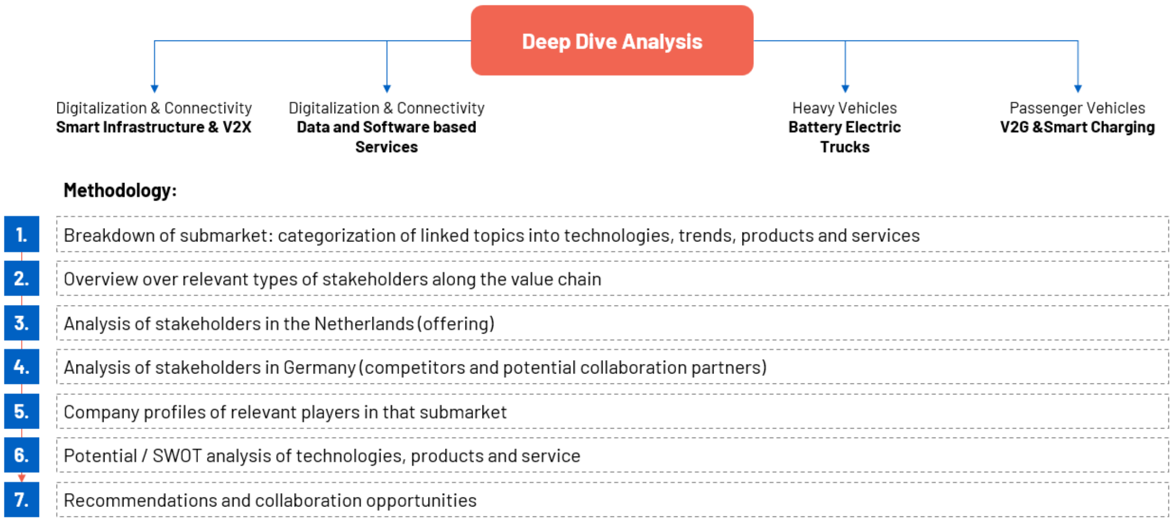

Figure 19: overview of the applied methodology of the deep-dive analysis

Following this, the report offers an overview of relevant types of stakeholders across the value chain, identifying key players involved in technology development, manufacturing, and service provision. This is further refined through an in-depth analysis of stakeholders in the Netherlands, focusing on their offerings, innovations, and market presence. A parallel analysis of stakeholders in Germany is conducted to identify competitors as well as potential collaboration partners, providing a comparative perspective on the market dynamics in both countries.

Additionally, the analysis includes company profiles of relevant players within each submarket, presenting insights into their strategies, product portfolios, and competitive positioning. To assess the market potential, a SWOT analysis of key technologies, products, and services is provided, outlining strengths, weaknesses, opportunities, and threats.

The report concludes with recommendations and collaboration opportunities, identifying strategic pathways for Dutch and German stakeholders to leverage synergies, address challenges, and accelerate the deployment of sustainable and smart mobility solutions. This comprehensive approach aims to serve as a strategic guide for industry players seeking to navigate the evolving landscape of electric and smart transportation.

3.1 Deep Dive 1: Smart Infrastructure and V2X

Infrastructure plays a pivotal role in shaping the future of road mobility. To meet the demands of increased connectivity, safety, and efficiency, traditional infrastructure must evolve into smart, digital systems. "Smart infrastructure can accelerate autonomous driving" by leveraging advanced technologies to enable real-time data exchange and adaptive traffic management, paving the way for a more seamless and sustainable mobility ecosystem. A key component of this transformation is V2X (Vehicle-to-Everything) communication, which facilitates interaction between vehicles, infrastructure, pedestrians, and other road users. Although "V2X market so far very limited", its potential benefits are significant. In particular, V2I (Vehicle-to-Infrastructure) communication has been highlighted by experts for its ability to "improve safety, comfort, and costs", making it a crucial element of smart infrastructure. By enabling vehicles to "talk" to traffic signals, road signs, and other infrastructure elements, V2I can optimize traffic flows and enhance road safety.

However, challenges remain. For instance, experts argue that "V2V (Vehicle-to-Vehicle) will not work as most cars are not able to participate", indicating that a widespread adoption of V2V may not be feasible in the near term. Instead, focusing on V2I and other V2X applications may offer a more practical pathway to advancing smart infrastructure capabilities. Additionally, there is a growing recognition of the need to consider all road users in this transformation. The "big trend: detection of transport modes that are not motorized" emphasizes the importance of inclusive solutions that enhance safety for cyclists, pedestrians, and other non-motorized road users. Together, smart infrastructure and V2X form the foundation of intelligent mobility, driving innovation at the intersection of technology, transportation, and urban planning. By addressing current challenges and focusing on the most impactful applications, these technologies can significantly advance the goals of safer, smarter, and more efficient road networks.

Key Insights:

- **Comfort and Safety Improvements**: Smart infrastructure can significantly enhance comfort and safety for all road users, and even accelerate autonomous driving, but the high cost of equipment and the lack of profitability in achieving broad coverage pose challenges.
- **V2X Standardization Challenges:** Europe has not yet adopted a unified V2X communication standard, mostly hybrid communication approaches are pursued (DRSC vs C-V2X).
- **Data Ownership and Exchange Complexity:** Managing data ownership and facilitating data exchange remains a significant hurdle. Current regulatory frameworks do not provide a solid foundation for viable business models, making it difficult for stakeholders to monetize or share data effectively while ensuring compliance with privacy and security requirements.

The Deep Dive is divided into thematic blocks of communication (communication standards and units), infrastructure (hardware, sensors, C-ITS, ATMS) and others (detection of vulnerable road users, integration of mobile devices).

Communication Standards:

The development of V2X (Vehicle-to-Everything) communication standards is critical for the future of connected mobility, yet it remains a point of contention and divergence in Europe. A notable attempt to standardize the technology occurred in 2019 when the European Commission proposed a directive to adopt DSRC (Dedicated Short-Range Communication, Wifi-based) as the official standard. This proposal faced significant resistance from industry stakeholders advocating for C-V2X (Cellular-V2X), ultimately leading to the directive's rejection. The debate highlighted the need for a more flexible approach to V2X communication.

Currently, there is a shift toward hybrid V2X communication systems, integrating both DSRC and C-V2X technologies to leverage their respective advantages. DSRC, based on Wi-Fi-like protocols, excels in scenarios requiring low-latency communication over short distances, making it ideal for high-density urban areas or safety-critical applications such as collision warnings. In contrast, C-V2X, supported by cellular networks, offers greater range and better performance in areas with lower vehicle density, such as highways or rural regions.

The V2X market is supported by a range of critical hardware products, including:

- Modems and Modules: Core components that enable connectivity between vehicles and infrastructure.

- Chips: Embedded in V2X devices to handle data processing and communication protocols.
- Roadside Units (RSUs): Installed along roadways to facilitate communication with vehicles and relay information to the cloud.
- Onboard Units (OBUs): Vehicle-mounted devices that serve as the interface between the vehicle and external systems.

Case Study: Smart Infrastructure and V2X – The MCube Project "Testkreuzung"

The MCube project "Testkreuzung" has launched a permanent V2X test field in Taufkirchen, south of Munich, dedicated to advancing automated and connected driving. This initiative has established a specialized test intersection that is not compliant with regular road traffic regulations, allowing for a controlled environment to explore the potential of smart infrastructure and V2X communication. The intersection is equipped with traffic surfaces, traffic lights, sensors, and V2X communication infrastructure to facilitate real-time data exchange between vehicles and the surrounding environment. The project, in collaboration with partners such as TUM, Hochschule Augsburg, TÜV Süd, EasyMile, and others, has utilized TUM's automated vehicle fleet (AVF) alongside vehicles from other project partners. One of the primary goals is to improve safety and efficiency in the interactions between vulnerable road users—such as pedestrians and cyclists—and automated vehicles, including autonomous shuttles in public transport. By focusing on networking and communication between vehicles and infrastructure, the project aims to enhance traffic flow and safety.

In addition to advancing vehicle-to-infrastructure (V2I) and vehicle-to-vehicle (V2V) communications, the project has collaborated with TÜV Süd to develop certification processes that could standardize safety protocols for automated and connected driving systems. The focus on high-traffic areas aligns with expert opinions suggesting that "focus on main routes could be profitable" but "only in places with high traffic density". Furthermore, the project emphasizes the critical role of data and cybersecurity in smart infrastructure, echoing expert insights that "smart infrastructure is strongly connected with data and cybersecurity". Ensuring secure and reliable data transmission is essential for protecting both the infrastructure and the users who rely on it.

Through its targeted approach, the MCube project not only demonstrates the practical applications of V2X technology but also sets the stage for broader deployment on major routes where traffic density justifies the investment. This case study highlights the potential of smart infrastructure to significantly enhance safety, efficiency, and security in the evolving landscape of automated and connected driving.

Case Study: Honda and SoftBank's Connected Mobility Initiative

Honda and SoftBank have partnered to enhance next-generation mobility and reduce traffic accidents by leveraging LTE/5G networks to connect vehicles, traffic infrastructure, and pedestrians. This initiative addresses the high rate of accidents involving pedestrians and motorcyclists, who make up nearly 70% of traffic accidents in Japan. A key focus is on predicting the behavior of both connected and non-connected vehicles during the transition to fully connected systems. SoftBank developed a system that aggregates data from vehicles and roadside sensors to predict risks and notify drivers in real-time using Cellular V2X technology.

Tests on the Shin-Tomei Expressway demonstrated the system's ability to prevent accidents, such as by predicting unpredictable lane changes by motorcycles. Risk algorithms and 4G LTE/5G communications enable timely warnings to drivers, enhancing safety. By addressing challenges like data synchronization and communication delays, the project aims to scale connected systems across road networks, creating a safer driving environment and reducing accidents significantly.

Stakeholders

The following Figures give an overview of the stakeholder landscape in Germany and the Netherlands within the smart infrastructure and V2X market. Figure 20 divides exemplary stakeholders between industry, research and regulatory instances as well as component manufacturers, system integrators and OEMs.

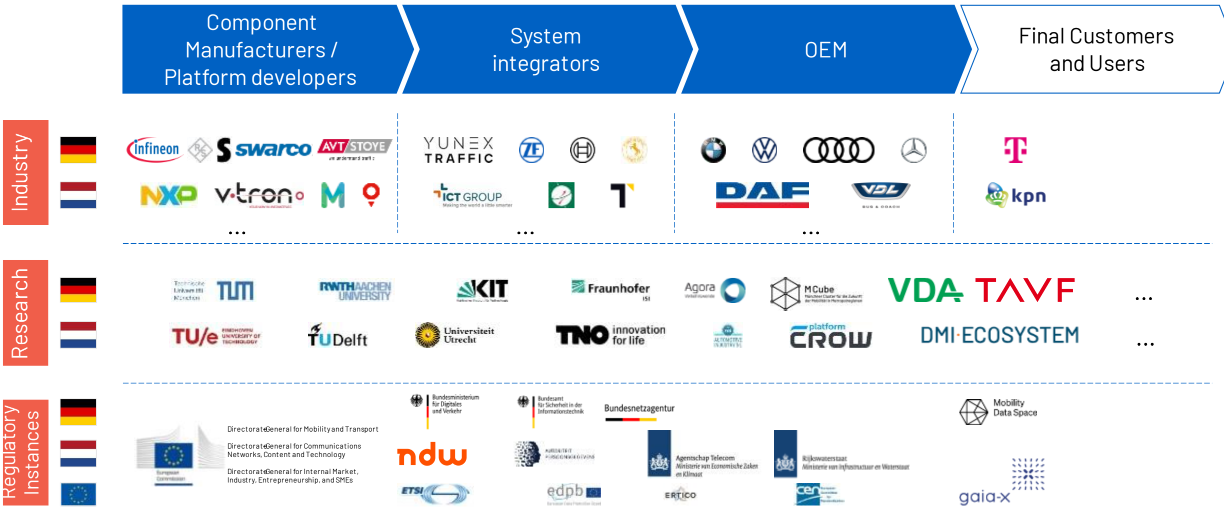

Figure 20: stakeholder landscape Smart Infrastructure and V2X

Figure 21 and Figure 22 provide an overview of the geographic distribution of different stakeholder types in the Netherlands and in Germany.

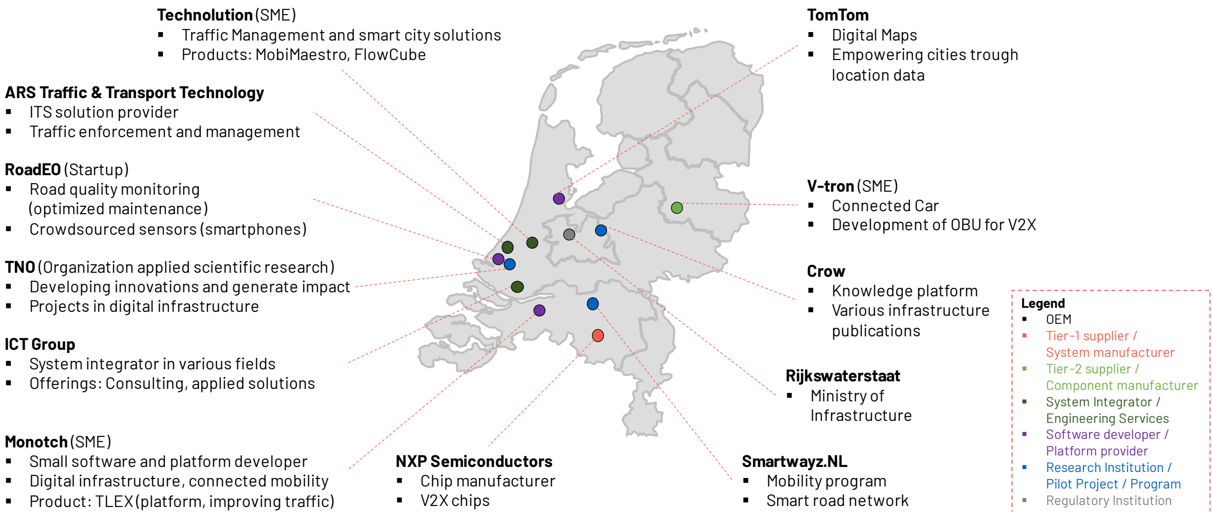

Figure 21: geographic distribution of different stakeholder types in the Netherlands

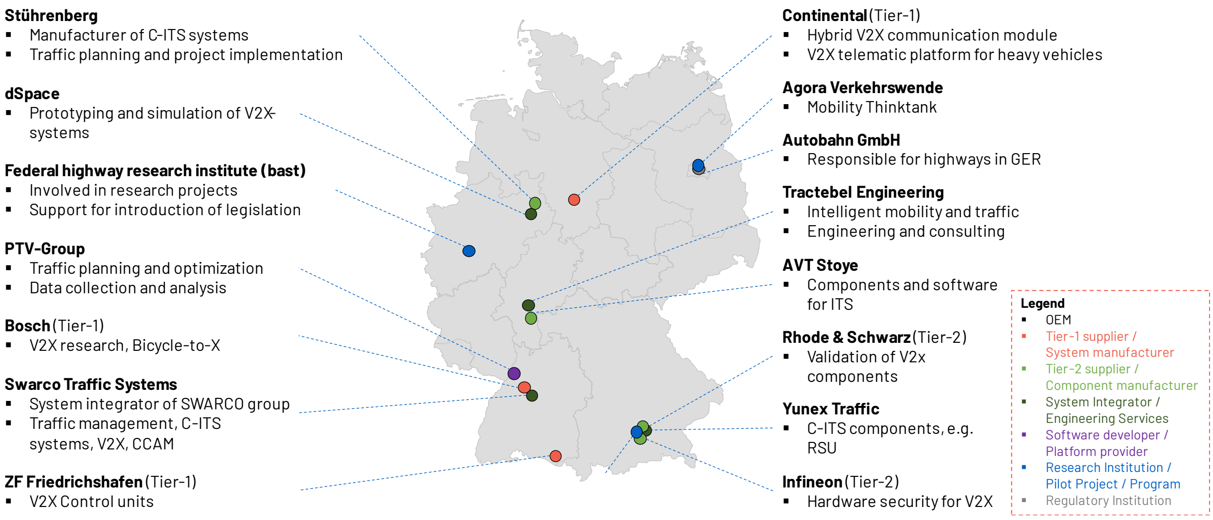

Figure 22: geographic distribution of different stakeholder types in Germany.

Selected companies were highlighted with fact sheets that give detailed information on the products and economic activities as well as collaboration potential:

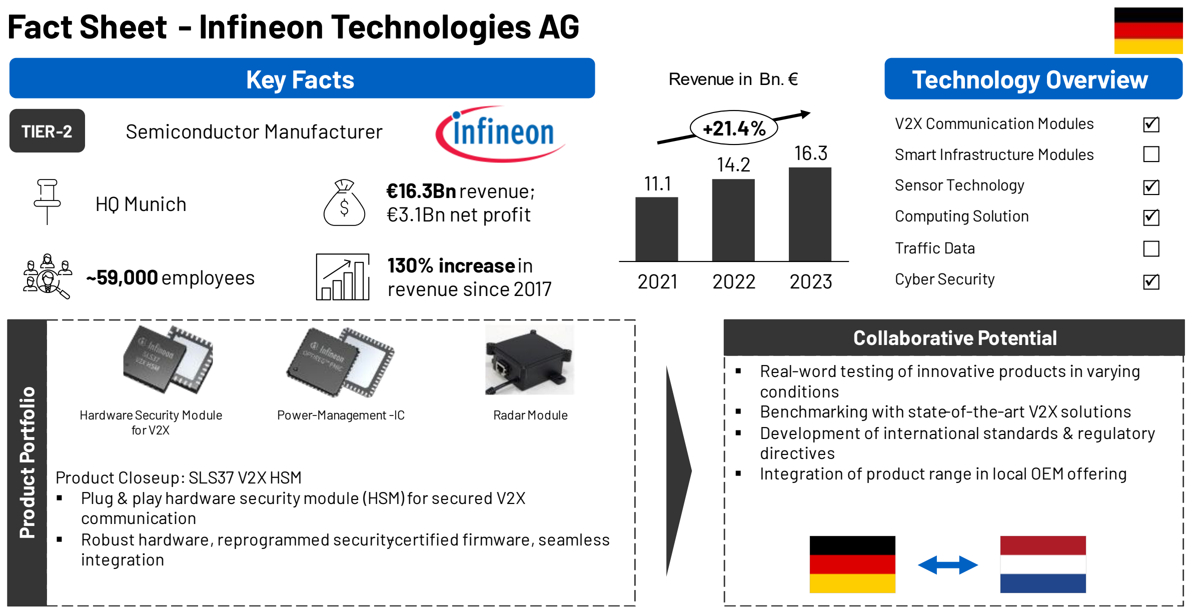

Figure 23: Fact Sheet – Infineon Technologies AG

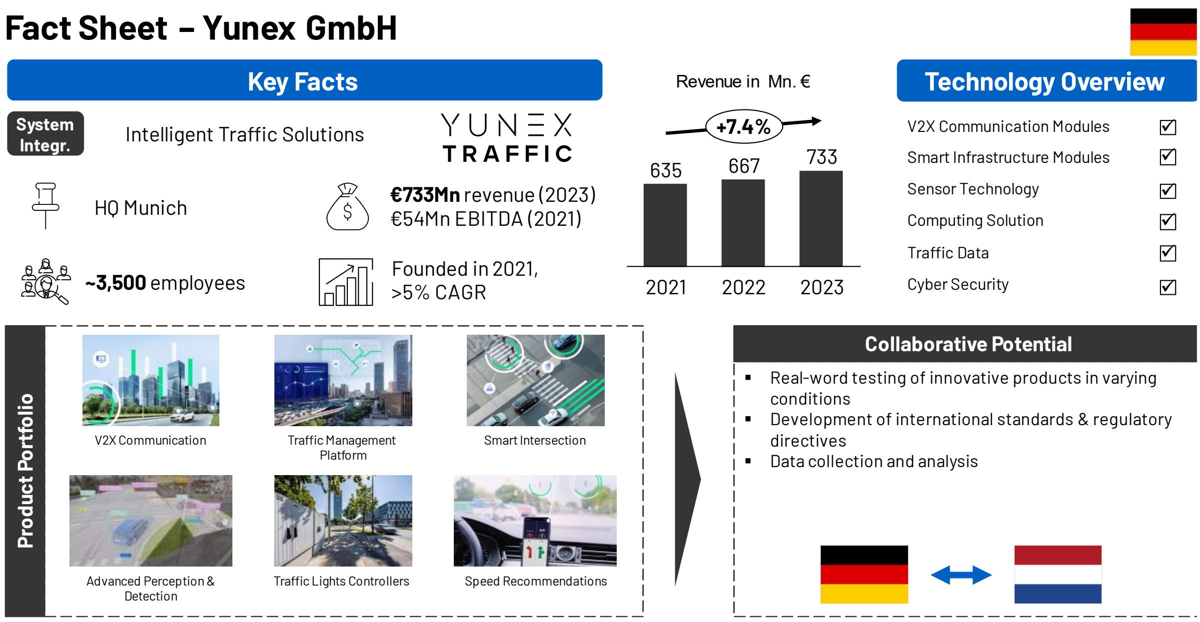

Figure 24: Fact Sheet – Yunex GmbH

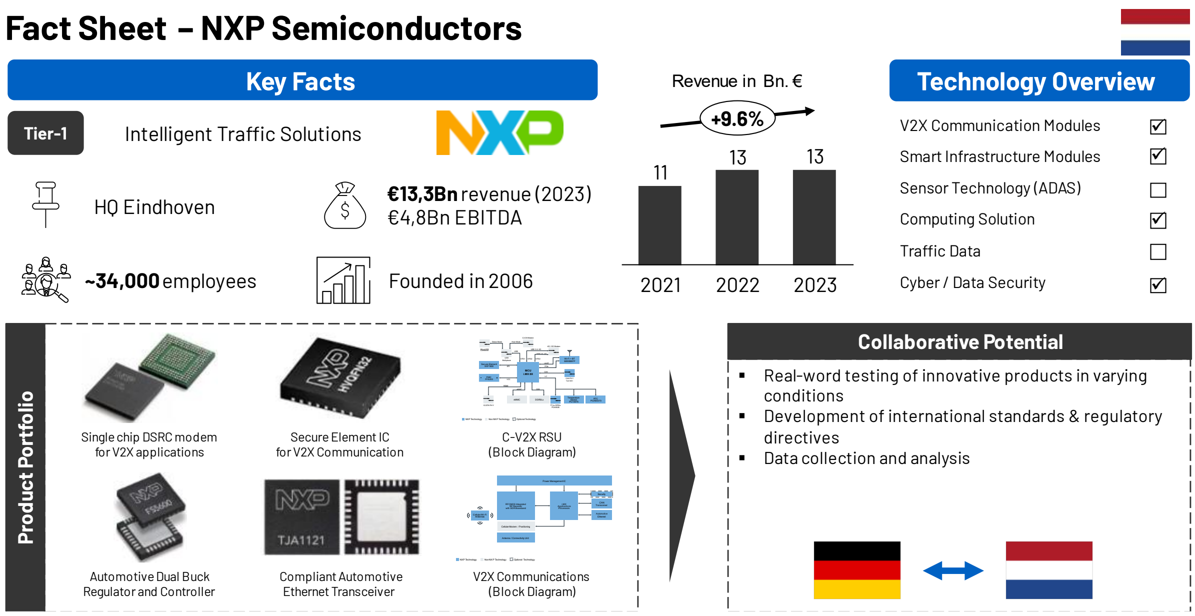

Figure 25: Fact Sheet – NXP Semiconductors

SWOT Analysis – V2X Communication Standards (Figure 26):

	Strengths ▪ V2X market is increasing strongly ▪ Leading suppliers and system integrators in NL and GER develop innovative products	**Weaknesses** ▪ No leading SOC manufacturers for C-V2X modules ▪ Expertise in DSRC V2X communication chips (NXP)
Opportunities ▪ V2X has different important communication forms (V2V, V2I, V2P, …) ▪ Solutions for various vehicles	S-O Strategies ▪ Frequently equipped hybrid communication modules are versatile and offer best-suited communication technology in every situation	W-O Strategies ▪ Tier-2 suppliers develop and manufacture "assistance chips" ▪ Leading system integrators can also implement C-V2X chips in their products
Threats ▪ Strong dependencies on C-V2X chip manufacturers ▪ Risk that manufacturers outside of the EU dominate the V2X-module	S-T Strategies ▪ Hybrid communication is researched and available ▪ Hybrid modules may not be attractive for foreign markets and could be more expensive	W-T Strategies ▪ No leading C-V2X chip manufacturers in Europe, Qualcomm leading global market

- GER and NL companies are among the leaders in V2X communication, hybrid communication offers flexibility and adabtability
- No clear EU decision / direction on technology choice, most other countries bet on C-V2X

Figure 26: SWOT Analysis – V2X Communication Standards

V2X (Vehicle-to-Everything) communication is emerging as a key technology for connected vehicles, making it essential to avoid dependencies that could hinder its deployment. Establishing clear standards and guidelines is crucial to ensuring seamless implementation across Europe. Collaborations between various stakeholders play a vital role in preventing technological backlogs and enabling large-scale test projects that accelerate development. The primary customers for V2X solutions include infrastructure development companies, cities, and some OEMs. In the short term (next 5 years), the focus will be on practical projects that demonstrate the viability of C-V2X (Cellular V2X) technology. Key stakeholders in this process are research institutes for small-scale testing, traffic solution companies, Tier-1/2 suppliers for module development, and telecommunication providers offering 5G expertise. The collaboration will focus on research and knowledge transfer, as well as developing comprehensive guidelines and standards for V2X deployment. The expected outcome of these projects is a deeper understanding of C-V2X technology and a clear roadmap for V2X communication in the EU, setting the stage for widespread adoption and improved safety in connected mobility.

SWOT Analysis – Smart Intersections and Highways (Figure 27):

	Strengths	**Weaknesses**
	▪ Smart Infrastructure market is growing strongly ▪ German and Dutch Companies cover whole value chain for smart infrastructure projects	▪ Missing Regulation regarding data privacy and handling currently offers hardly any incentives for business models
Opportunities ▪ C-ITS can improve traffic flow, safety and comfort for all traffic participants ▪ Detect different modes of transport / traffic participants	S-O Strategies ▪ Hybrid V2X allows high compatibility with all road users, short and long term ▪ Smart Infrastructure can accelerate Autonomous Driving	W-O Strategies ▪ A European solution should be pursued (e.g. gaia-x project) ▪ Commonly developed European Framework as the foundation for new business models
Threats ▪ Lack of standardization and interoperability ▪ Initial costs for infrastructure is very high and operation infrastructure is not profitable	S-T Strategies ▪ Data privacy gets even more important ▪ Openness to share data required ▪ Cyber Security	W-T Strategies ▪ Working ecosystem must successfully work together – broad coverage required to see benefits of smart infrastructure ▪ Establish certain financing

- Technological implementation already possible, but complicated by lack of standards and missing inadequate regulation
- Focus on main routes and whole pilot areas

Figure 27: SWOT Analysis – Smart Intersections and Highways

Smart intersections and highways are essential for improving traffic flow and safety while accelerating the adoption of autonomous driving (AD) technologies. The strategic goal is to enhance efficiency and reduce congestion through intelligent traffic management systems. Collaborations between stakeholders are crucial to lowering the initial costs of infrastructure deployment and ensuring a smooth transition to smart mobility solutions. The primary customers for these solutions are cities and municipalities seeking to optimize traffic conditions over the long term (next 10–15 years). Key stakeholders include system integrators for infrastructure development, cities and municipalities for planning and regulation, and digital solution providers for mapping and navigation services. Collaboration will focus on developing common guidelines and implementing cross-border projects to promote seamless integration of smart traffic systems. The expected outcome is to enhance interoperability between infrastructure elements through standardization and to launch functional pilot areas that demonstrate the potential of smart intersections and highways in real-world scenarios.

SWOT Analysis – Vulnerable Road Users and Mobile Device Integration (Figure 28):

	Strengths ▪ Detection of unmotorized traffic participants already possible – experience trough big field testing and research	**Weaknesses** ▪ Missing Regulation regarding data privacy and handling currently offers hardly any incentives for business models
Opportunities ▪ Smartphones and wearables are widely used and offer detection at low investment cost	S-O Strategies ▪ "Talking Traffic" project with over 12.000 users makes optimal use of existing facilities and standards, information is offered via smartphone navigation	W-O Strategies ▪ A European solution should be pursued (e.g. gaia-x project) ▪ Commonly developed European Framework as the foundation for new business models
Threats ▪ Multiple data sources increase complexity and costs ▪ Dependency from mobile devices may increases + unnecessary participation for some people	S-T Strategies ▪ Detection possible by different methods: vehicles, infrastructure, smart roads, handheld devices and wearables	W-T Strategies ▪ Different stakeholders involved in data collection and sharing process – they pursue different, mostly self-serving goals, which makes cooperation difficult

- Detection of unmotorized traffic participants (bikes, pedestrians) increases safety and reduces accidents
- Regulation needed to generate incentives for collaborative data sharing and business models

Figure 28. Vulnerable Road Users and Mobile Device Integration

V2P (Vehicle-to-Pedestrian) technology plays a crucial role in reducing traffic accidents and enhancing the safety of vulnerable road users (VRUs), such as pedestrians and cyclists. The strategic goal is to leverage mobile devices to detect VRUs and provide real-time traffic warnings. Achieving cross-border functionality and standards requires extensive collaboration among stakeholders. The main customers for these solutions include phone manufacturers, network providers, and cities aiming to improve urban mobility safety. In the short term (next 5 years), projects will focus on integrating mobile devices with smart infrastructure. Key stakeholders are system integrators for connecting infrastructure to mobile devices, telecommunication providers for ensuring X-to-network communication, and software developers for creating specialized smartphone apps. Collaboration efforts will emphasize developing data privacy guidelines and establishing EU-wide standards for seamless integration. The expected outcome is a smartphone app capable of detecting VRUs and providing timely traffic warnings, along with a standardized interface that enables effective communication between mobile devices, infrastructure, and vehicles.

3.2 Deep Dive 2: Data and Software based Services

In the evolving landscape of road mobility, data and software-based services have become pivotal in enhancing efficiency, sustainability, and user experience. The integration of diverse data sources—ranging from commercial vehicle fleets (telemetry and GPS) and public transport data (including occupancy, delays, and fleet sizes) to mobile phone GPS data, private vehicle telemetry, and information from public infrastructure sensors—offers unprecedented opportunities for innovation. These data streams power a broad spectrum of applications, including traffic flow management, fleet management, sharing services, navigation apps, and in-vehicle services like infotainment and smart parking. Moreover, they are essential for research, consulting, and regulatory functions such as toll and fee management.

However, the effective use of data in road mobility is contingent upon addressing critical challenges such as data ownership, regulation, and cybersecurity. As highlighted by industry experts, the absence of clear regulatory frameworks not only hampers data-driven business models but also raises concerns about data privacy and security. The assertion that "missing regulation leads to missing business models" underscores the need for comprehensive policies that balance innovation with protection. Additionally, the call for "conscious data handling" emphasizes the importance of ethical and transparent practices in data collection, processing, and sharing.

In this chapter, we will explore how data and software-based services are transforming road mobility in Germany, the regulatory and security challenges involved, and the pathways to leveraging data responsibly and effectively for a smarter and more sustainable transport ecosystem.

Technologies, Trends, Products and Services

Data and software-based services are being driven by advanced *technologies* such as 5G, GPS, and vehicle BUS-systems, which enable seamless communication and data exchange between vehicles and infrastructure. Traffic cameras, various sensors, smartphone sensors, and the concept of Software-defined vehicles further expand data collection capabilities. Additionally, Digital and HD maps, Big Data analytics, and secure data handling practices are crucial for processing and protecting vast amounts of information. Effective management of this data relies on robust database systems that support real-time decision-making.

Emerging *trends* highlight the growing importance of fleet management and the integration of GPS tracking directly at the factory level. The synergy between 5G and HD maps is accelerating advancements in autonomous driving. However, there is a shift in perception where customers and their data are increasingly seen as products. This evolution underscores the urgent need for clear regulations on data ownership, protection, and cybersecurity to build trust and facilitate new business models. As experts point out, "Data must be handled confidentially and transparently (e.g., labels & certificates)" to ensure user trust and compliance.

In terms of *products*, the landscape is populated with telemetry units, cameras, LIDAR, radar, and other sensors, alongside consumer-facing tools like smartphones, digital maps, navigation systems, infotainment apps, and fleet management software. These products serve as the building blocks for a variety of data-driven services.

Key *services* in this domain include cloud computing, big data analytics, database management, and telematics services. Other essential services are sharing platforms, consulting, regulatory design, traffic flow optimization, parking management, and cybersecurity. The ability to process and analyze large-scale data in real-time is central to these offerings.

Despite the promising landscape, the lack of regulation for data ownership and protection is a significant barrier to unlocking new services and business models. Nonetheless, mobility data is becoming a vital asset for service providers, enabling more efficient traffic management and comprehensive mobility systems as data sources continue to expand. Addressing regulatory gaps and ensuring confidential and transparent data handling will be crucial for the sustainable growth of smart road mobility.

Case Study: Data ecosystem and platforms across the EU

Figure 29 gives an overview of the data ecosystems and platforms within the EU. The European Union is actively fostering new mobility data ecosystems to advance its digital and green transformation goals. A key focus is on unlocking mobility data, which is crucial for smarter transport solutions, reducing environmental impact, and enabling innovations such as AI-driven services. To facilitate this, the EU has introduced policies and frameworks like the Data Act and Data Governance Act, which promote secure, fair, and accessible data sharing across different sectors. These regulations aim to build trust and establish a balanced data economy.

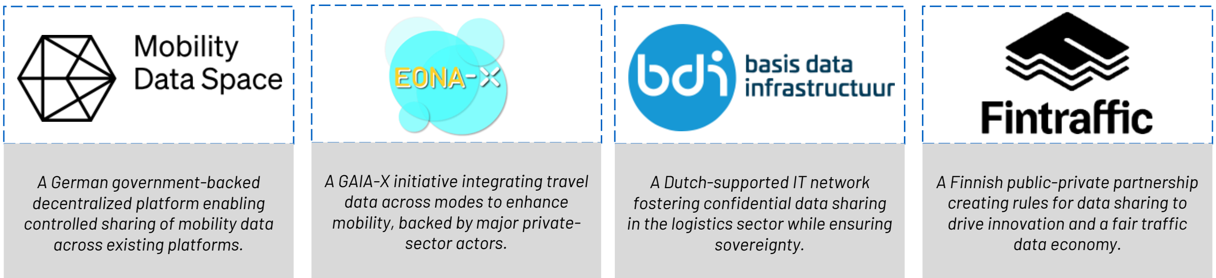

Figure 29: Overview of data ecosystems and platforms within the EU

A central initiative in this strategy is the European Mobility Data Space (EMDS), designed to unify fragmented transport data and enhance interoperability. The EMDS supports innovation while safeguarding data sovereignty and ensuring that data remains under the control of its rightful owners. The EU is also backing several initiatives and funding programs such as ITS, NAPCORE, and other EU-funded projects. These efforts aim to accelerate the digitalization of urban mobility, improve cross-border logistics integration, and develop advanced mobility solutions.

Additionally, cross-sector collaboration plays a crucial role, with interoperable data spaces extending to energy, tourism, and other industries. This approach is supported by shared standards and open-source tools to ensure seamless data exchange. However, as experts emphasize, “Harmonizing regulation on the European level is important” to overcome national disparities and unlock the full potential of a unified mobility data ecosystem. Standardized regulations would facilitate smoother data sharing, drive innovation, and support sustainable mobility across Europe.

Case Study: Digital Mobility Platforms – Growing Market with high data dependency

Digital mobility platforms are transforming how both private and commercial customers access and manage transport services, but their focus and functionality differ significantly between these user groups.

Private Customers: Mobility-as-a-Service (MaaS):

For private users, digital mobility platforms aim to simplify and unify access to various transport options. These platforms integrate micromobility services (like e-scooters), public transport, ride-hailing, and sharing providers into a single app. Typically developed and offered by public transport providers, they provide a seamless alternative to juggling multiple accounts and apps for different services. This approach not only enhances convenience but also encourages multimodal transport solutions, reducing dependency on private car ownership.

Commercial Customers: Business-Centric Solutions

In contrast, platforms for commercial customers focus on optimizing operations and maximizing efficiency across several sectors:

- Automotive: Digital platforms support infotainment integration, predictive maintenance, vehicle-as-a-service models, and app-based car functions. They enable new subscription models and enhance the in-car experience for users.
- Sharing and On-Demand Services: These platforms utilize tracking devices, map-matching, dispatching algorithms, and fleet planning software to streamline operations and improve service reliability.
- Public Transport: For transit operators, platforms offer route planning software, databases, tracking systems, and data analytics to develop new strategies and enhance service efficiency.
- Cities: Urban authorities use smart city dashboards, planning tools, sensor data databases, and traffic management platforms to monitor and optimize urban mobility, making cities more sustainable and responsive.

For private customers, the focus is on convenience and integration of multiple transport modes into a single user-friendly interface. For commercial customers, the emphasis is on operational efficiency, data-driven decision-making, and service optimization through specialized software and analytics tools. This distinction highlights how digital mobility platforms are tailored to meet the unique needs of each user group, driving both user satisfaction and business efficiency in smart road mobility.

Stakeholders

The following Figures give an overview of the stakeholder landscape in Germany and the Netherlands within the smart infrastructure and V2X market. Figure 30 divides exemplary stakeholders between industry, research and regulatory instances as well as component manufacturers, system integrators and OEMs.

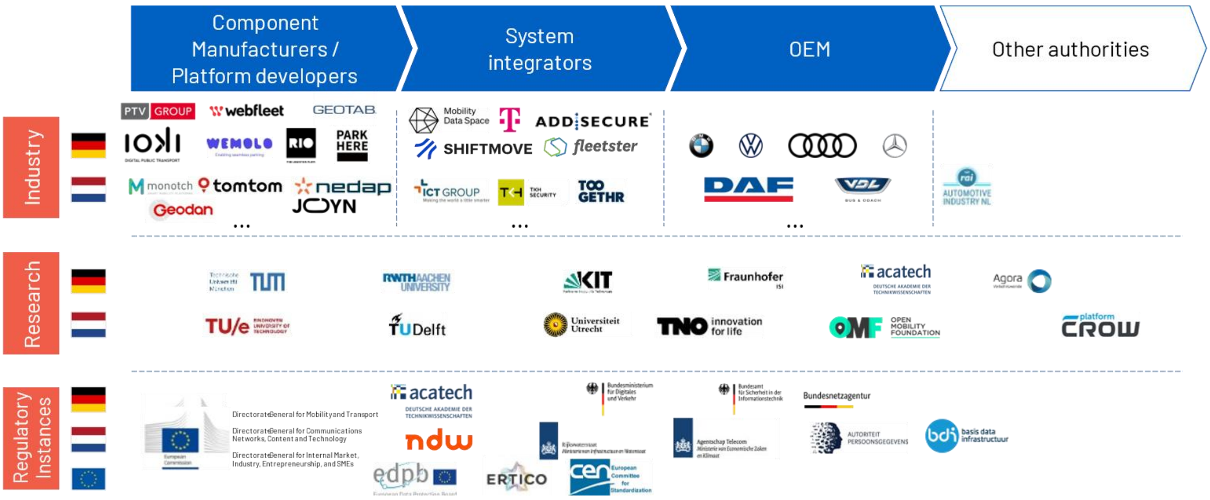

Figure 30: Overview of Stakeholders for Data and Software based Services

Figure 31 and Figure 32 provide an overview of the geographic distribution of different stakeholder types in the Netherlands and in Germany.

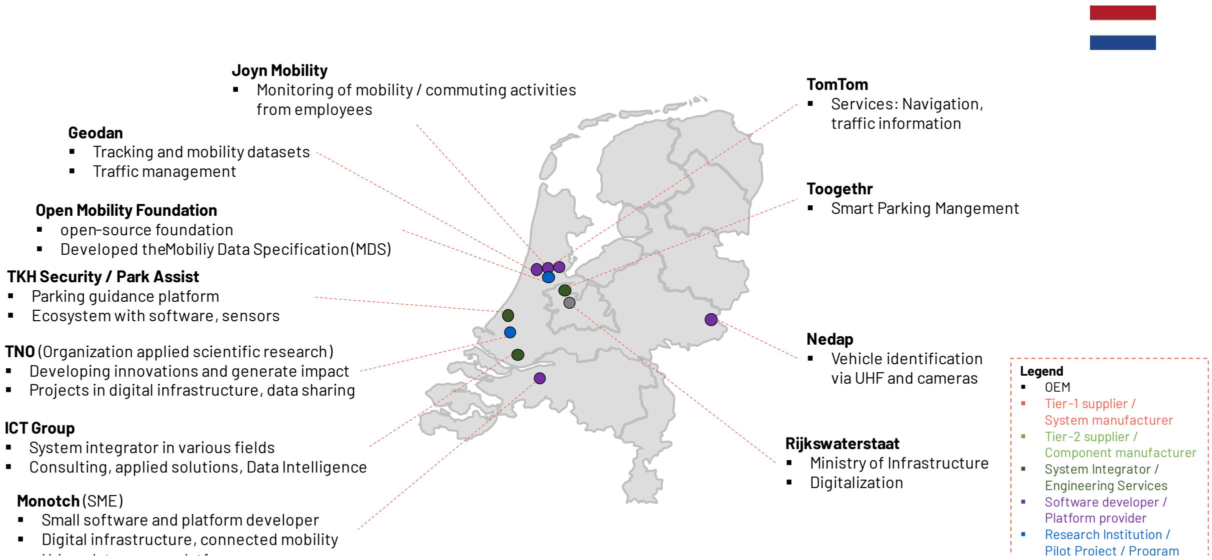

Figure 31: Geographic distribution of stakeholders in the Netherlands

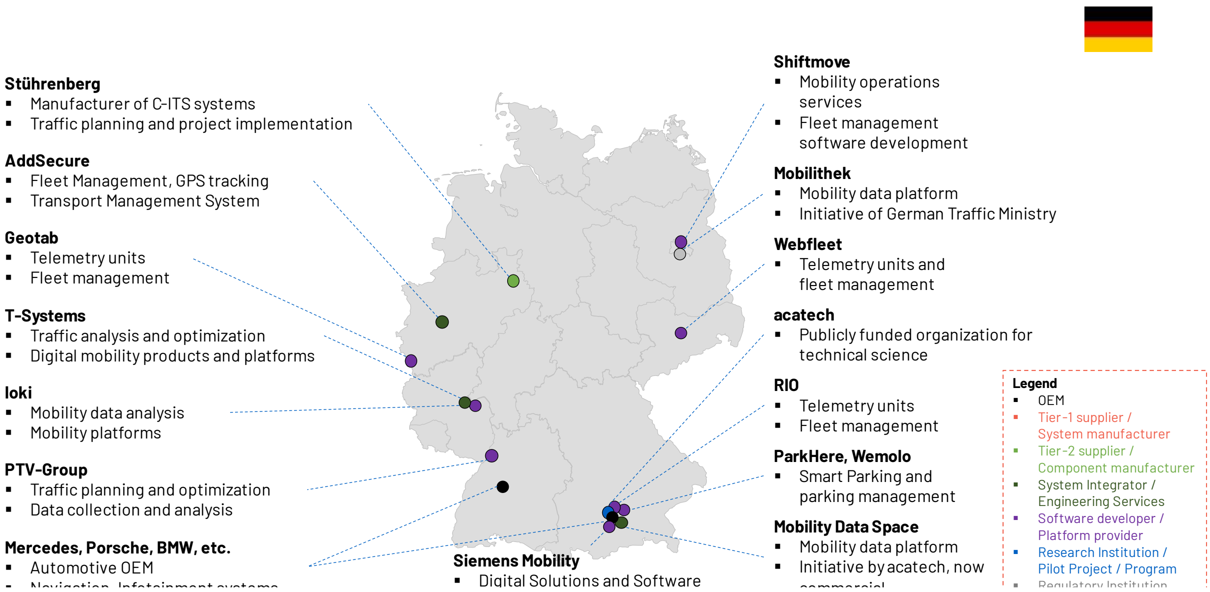

Figure 32: Geographic distribution of stakeholders in Germany

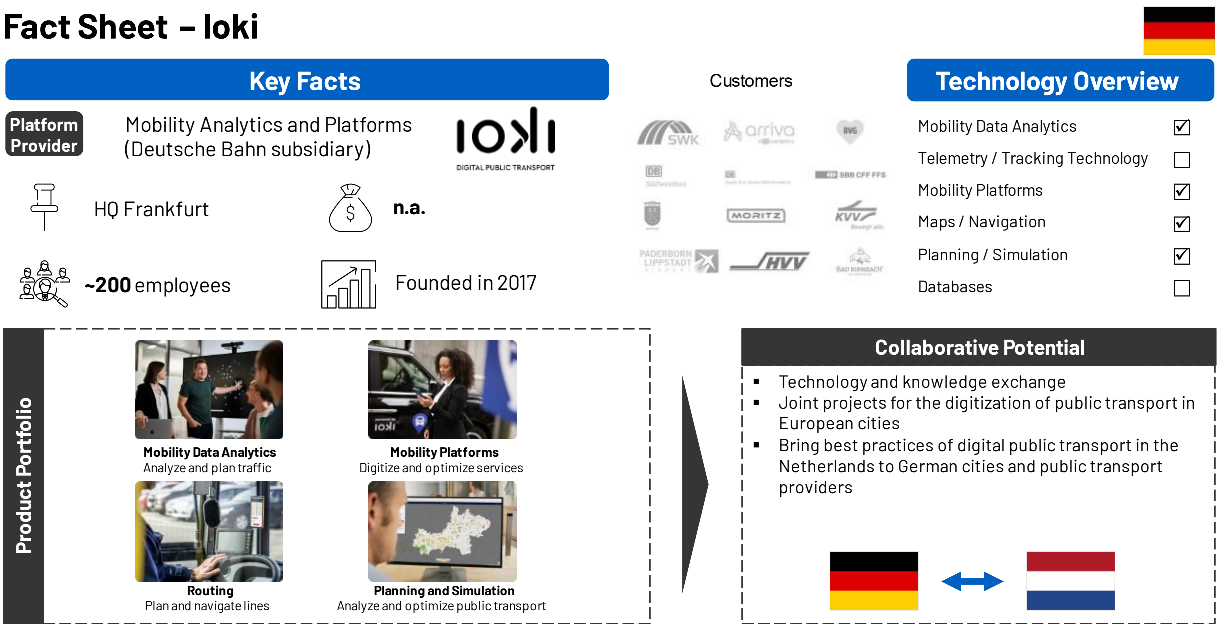

Figure 33: Fact Sheet - Ioki

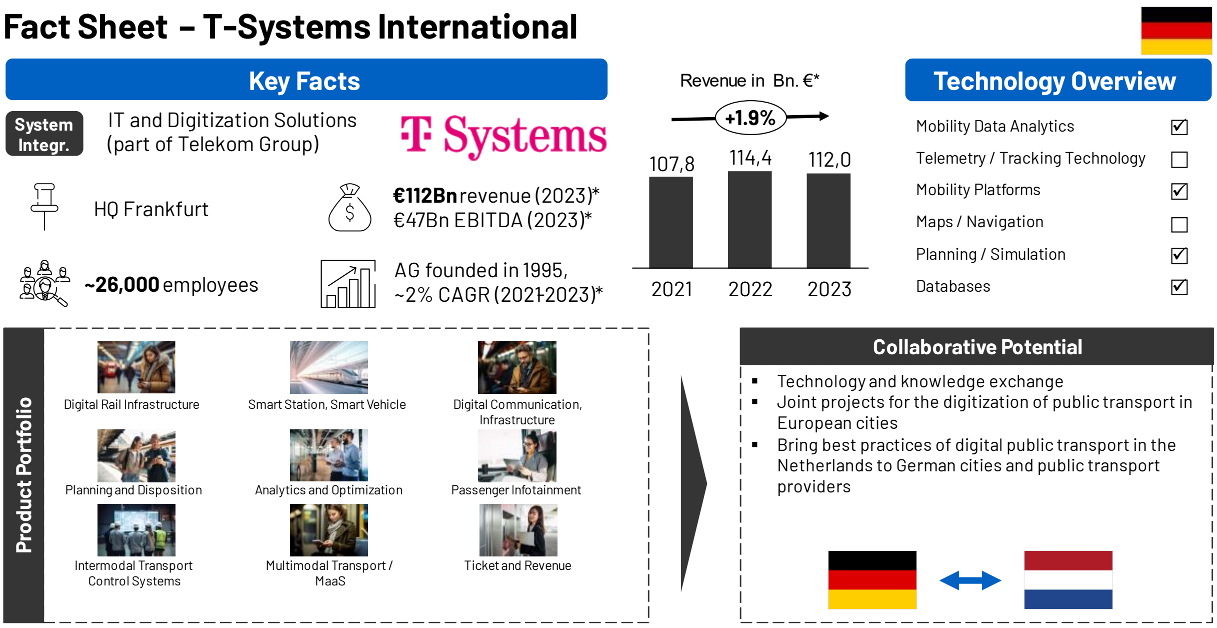

Figure 34: Fact Sheet – T-Systems International

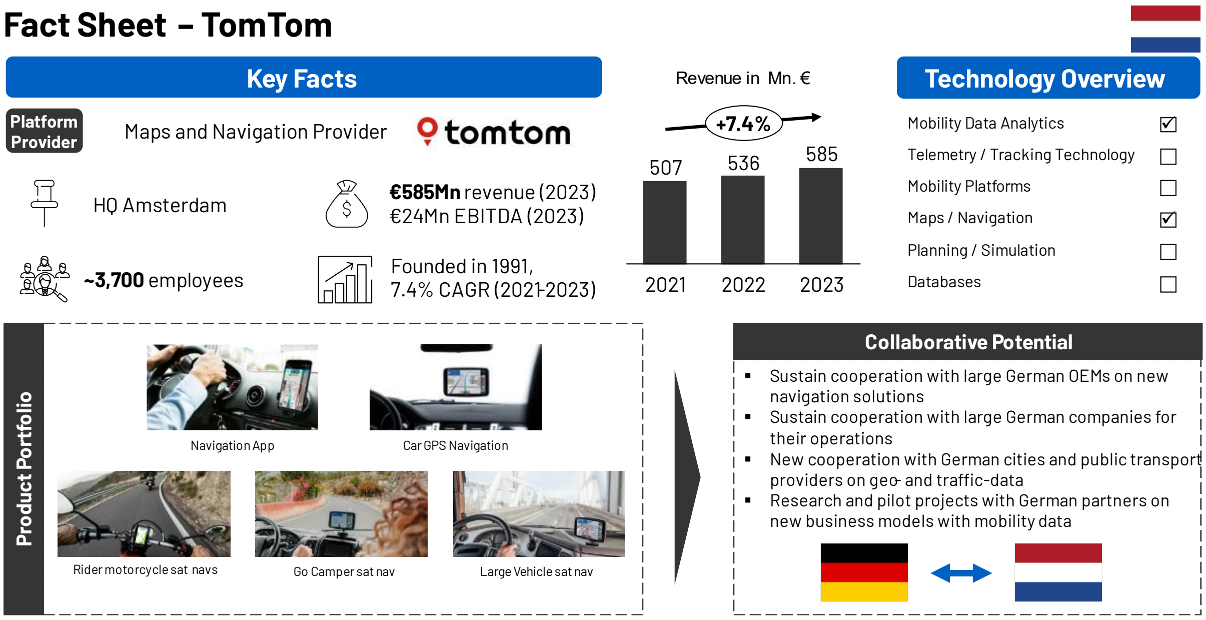

Figure 35: Fact Sheet - TomTom

SWOT Analysis – Traffic Data Management:

	Strengths ▪ Vehicles, phones and infrastructure can collect real-time data and can share data with other vehicles and infrastructure	**Weaknesses** ▪ Mostly depending on political decisions ▪ Exchanging data from two different owners is difficult
Opportunities ▪ Improve traffic flows ▪ Reduce traffic emissions ▪ Plan and steer traffic ▪ Increase overall sustainability	S-O Strategies ▪ Use fleet data to improve traffic flows by implementing different measures (informative, economical, regulative)	W-O Strategies ▪ Development of European standards for data exchange ▪ Data-based and objective decision-making processes help political decision makers
Threats ▪ Cyber Attacks ▪ Citizens criticize traffic management measures / new regulations	S-T Strategies ▪ Include cyber security measures in traffic management ▪ Data- / science-based communication with citizens (scientific quality indicators)	W-T Strategies ▪ Develop guidelines for protection of personal data ▪ Good planning with simulation software ▪ Testing with smaller groups

- Real-time data of vehicles and infrastructure can improve the flow and sustainability of traffic systems significantly
- Data-based and objective planning processes and communication can help decision makers and citizens

Figure 36: SWOT Analysis – Traffic Data Management

The strategic goal of traffic data management is to improve traffic flow and reduce emissions. This is achieved by incorporating more data sources through collaborations among cities, municipalities, and public transport providers. In the short term (next 5 years), the focus is on enhancing these capabilities. Key stakeholders include component manufacturers (for telemetry units and smart sensors), software, simulation, and database developers (who provide the necessary platforms), and OEMs and rental services (who supply data). The form of cooperation involves business relations, sales, new business models, and the development of guidelines and standards. The expected outcomes are increased traffic management sales between the Netherlands and Germany and improved traffic conditions across European cities.

SWOT Analysis – Fleet Management Telematics:

	Strengths ▪ Use of fleet management services are increasing rapidly ▪ Increased installations of telemetry units in vehicle fleets	**Weaknesses** ▪ Exchanging data from two different owners is difficult ▪ Currently no helpful standard or regulation on European level
Opportunities ▪ More efficient use of cars and large vehicle fleets, ▪ Reduction in CO2 and increased transparency	S-O Strategies ▪ Vehicle manufacturers consider subscription models on fleet data insights ▪ Data analytic solutions are needed	W-O Strategies ▪ Development of suitable European standards and interfaces for data exchange ▪ New business models possible with helpful new regulation
Threats ▪ Cyber Attacks ▪ Vehicle data can contain confidential and sensible personal data	S-T Strategies ▪ Include cyber security measures in fleet management ▪ Develop guidelines for protection of personal data	W-T Strategies ▪ Proprietary solutions make data exchange difficult ▪ Positive effects of fleet management most beneficial when whole fleet is involved

- Question of Data Ownership and sustainable data management must be addressed
- Common standards for data tracking improve interoperability between systems and make digital solution accessible / secure

Figure 37: SWOT Analysis – Fleet Management / Telematics

The strategic goal of fleet management is to improve efficiency and reduce costs. This is supported by collaborations aimed at establishing common standards for data exchange. Key customers include rental services, MaaS providers, leasing companies, businesses with fleets, OEMs, and public transport providers, with a focus on short-term projects over the next 5 years. Stakeholders involve OEMs (offering factory-installed GPS tracking), fleet management service providers (supplying software and platforms), and regulatory institutions (setting standards and rules). The form of cooperation includes business relations, sales, new business models, and the development of guidelines and standards. The anticipated outcome is the creation of new recurring income streams for fleet and vehicle operators through subscription models that monetize data sharing with customers.

M Cube CONSULTING

SWOT Analysis – Smart Parking Solutions:

	Strengths ▪ Various Dutch and German smart parking companies ▪ Automated on-street parking services already implemented	**Weaknesses** ▪ No holistic parking approaches available ▪ "Microlevel view" helps individual road users, but does not solve larger traffic problems
Opportunities ▪ High potential in reducing congestions and emissions ▪ Efficient use of space in dense-populated urban areas	S-O Strategies ▪ Holistic implementation of smart parking solutions in larger urban areas ▪ Convince decision makers to implement new solutions	W-O Strategies ▪ Increasing urbanization and lack of space increase the demand for intelligent parking solutions ▪ Choose holistic solution for smart parking in urban areas
Threats ▪ Cost for infrastructure is high ▪ Dependencies from mobile devices may increase ▪ Citizen's critic on pricing	S-T Strategies ▪ New regulation frameworks need to implemented in Germany to introduce new parking mgt. ▪ Crowd sourcing of data could reduce costs	W-T Strategies ▪ For holistic approaches, traffic data needs to be exchanged between vehicles, infrastructure and solution providers

- Data exchange / availability and high cost for infrastructure make implementation of holistic parking solutions difficult
- Currently no valid business model that incentivizes global parking optimization

Figure 38: SWOT Analysis – Smart Parking Solutions

The strategic goal of smart parking is to reduce urban traffic, as up to 30% of city traffic is caused by drivers searching for parking. Collaborations aim to expand existing solutions into holistic systems that optimize traffic flows. Key customers are cities and parking lot providers, with a focus on short-term projects over the next 5 years. Stakeholders include component manufacturers (providing sensors), smart parking solution providers, cities and municipalities, and conventional parking service providers. The form of cooperation involves business relations, sales, new business models, and the development of guidelines and standards. The expected outcomes are a reduction in parking search traffic and a decrease in land use dedicated to parking within cities.

3.3 Deep Dive 3: V2G Integration

The increasing electrification of transportation presents both an opportunity and a challenge for energy systems. Smart Charging and Vehicle-to-Grid (V2G) solutions are emerging as essential tools to optimize energy consumption, balance grid loads, and integrate renewable energy sources more effectively. By enabling bidirectional power flow between electric vehicles (EVs) and the grid, these technologies can enhance energy efficiency, reduce infrastructure strain, and create new revenue opportunities. As more electric vehicles enter the market, unmanaged charging could cause severe grid congestion and spikes in electricity demand, requiring costly grid reinforcements. Smart Charging addresses this by dynamically adjusting charging schedules to align with energy availability, minimizing peak loads and optimizing self-consumption. Meanwhile, V2G allows vehicles to act as distributed storage units, feeding power back into the grid during peak demand periods. This approach enhances grid stability and increases the flexibility of energy networks, particularly as the share of variable renewable energy sources (RES) grows. However, while the technological readiness of Smart Charging and V2G is high, their large-scale deployment faces regulatory, economic, and technical barriers. Tariffs accounting for grid-friendly charging are not in place yet, and double taxation in Germany makes the case less attractive, highlighting the need for policy support and financial incentives. Moreover, standardization remains a key hurdle, as different regions and stakeholders are still working to align communication protocols, grid integration methods, and business models. Despite these challenges, the potential benefits are significant. Well-integrated Smart Charging and V2G systems could reduce the need for grid expansion, enable profitable energy trading, and support the transition to a more decentralized and resilient energy system. The following sections will explore key technologies, trends, and business models that are shaping the future of Smart Charging and V2G.

Key Technologies Enabling Smart Charging & V2G:

- ISO 15118 – A key standard enabling bidirectional charging and secure data exchange.
- Bidirectional Chargers – Allow vehicles to both draw power from and supply power to the grid.
- Energy Management Systems (EMS) – Software platforms that optimize energy flows, manage grid interactions, and balance demand.
- Smart Meter Gateways – Facilitate dynamic energy pricing, enabling time-based charging adjustments.

Market Trends:

- Growing demand for congestion mitigation, driven by increasing EV penetration.
- Rising interest in local microgrids, with EVs acting as decentralized energy storage units.
- New business models emerging in energy trading, allowing fleet operators and private users to sell stored electricity back to the grid.

Smart Charging and V2G represent a critical evolution in energy and mobility integration, offering grid stabilization, cost savings, and new revenue opportunities. However, the transition will require strong collaboration between policymakers, utilities, fleet operators, and vehicle manufacturers. Key Takeaways:

- Economic & Grid Benefits: Optimized charging reduces infrastructure strain and creates new revenue models through energy trading.
- Regulatory & Standardization Gaps: Tariff structures and taxation policies must evolve to make bidirectional charging economically viable.

- Scalability Through Phased Implementation: A stepwise approach allows Smart Charging & V2G to be introduced gradually, ensuring infrastructure keeps pace with technological advancements.
- Despite regulatory and financial hurdles, the long-term potential of Smart Charging & V2G is undeniable. As energy and mobility continue to converge, these technologies will be essential in shaping a more flexible, efficient, and sustainable energy system.

Definition: V2G levels & Business Cases

The definitions and interdependencies on the road from simple charging to complex cases of BiDi charging can be confusing. Therefore, Figure 39 offers an explanation on the five levels towards full integration and the respective business cases.

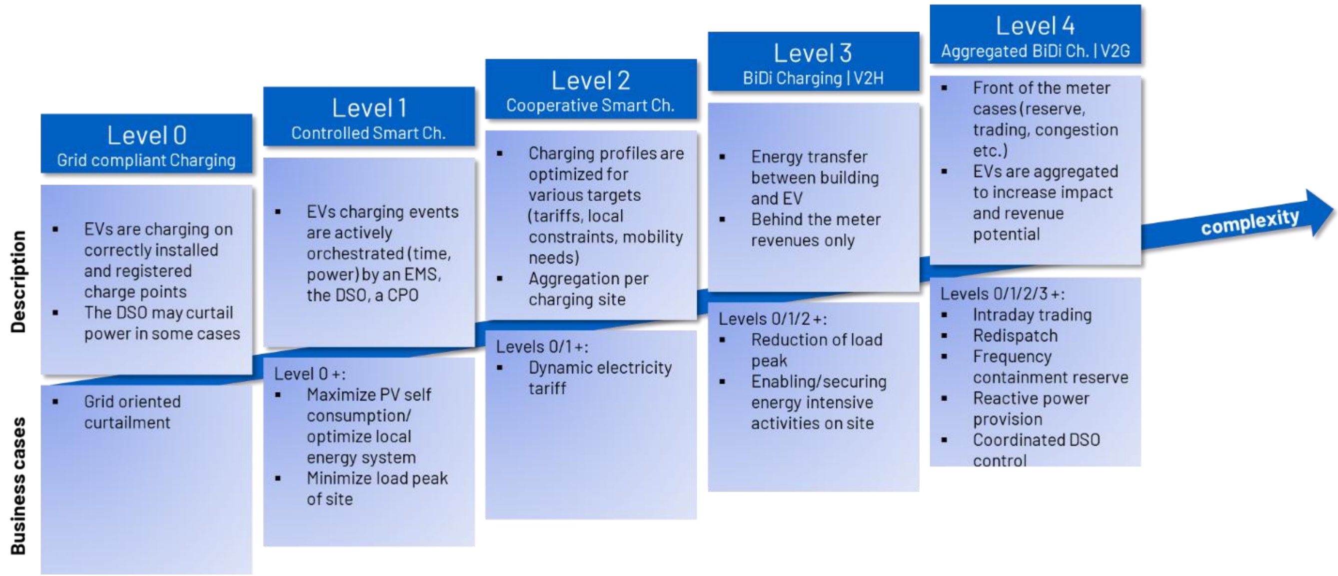

Figure 39: V2G & Smart Charging levels definition

Case Study: Potential of Smart Charging and V2G to reduce load peaks

Fleet electrification introduces significant challenges in terms of grid load management. Without intervention, high power demand from simultaneous charging events can overload local grids, requiring costly infrastructure upgrades. A simulation based on historic fleet data reveals how Smart Charging and V2G can mitigate these issues as shown in Figure 40:

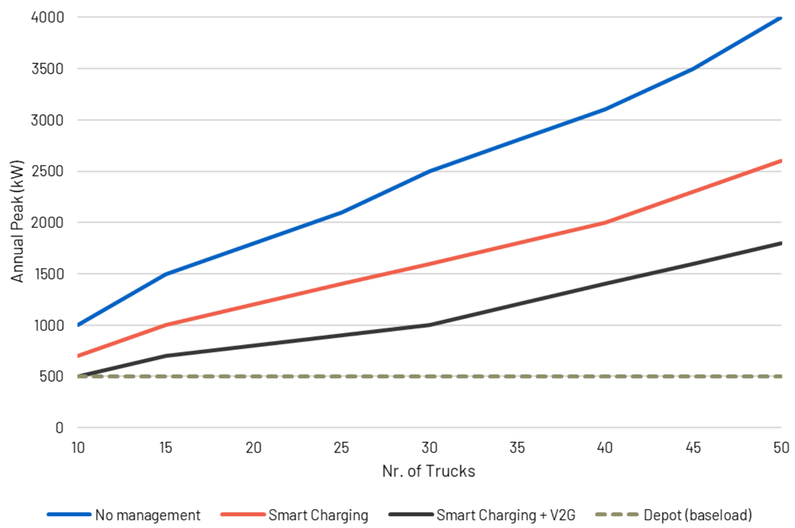

Figure 40: simulation results on the effectiveness of Smart Charging & VG on the annual load peak at a depot

- Smart distribution of available power and shifting of charging events significantly lowers the peak, reducing energy costs and grid strain.

- Through V2B and V2V, the maximum needed power can be reduced further, distributing demand more evenly across the day.
- Peak load reduction decreases both the cost for fleet operators and the overall burden on the grid, making fleet electrification more economically viable.

By leveraging Smart Charging and V2G, fleet operators can reduce operational expenses, participate in energy trading markets, and contribute to grid stability. However, success depends on regulatory alignment, pricing models that reward grid-friendly behavior, and technical integration with energy networks.

Stakeholder Overview

The ecosystem for Smart Charging and V2G is shaped by a diverse network of stakeholders spanning industry, research institutions, and regulatory bodies. This landscape includes component manufacturers and platform developers, such as Schaltbau, Mennekes, and Heliox, which provide the foundational hardware and software required for charging infrastructure. System integrators, including Allego and Last Mile Solutions, play a crucial role in ensuring seamless interoperability between energy providers, charging networks, and vehicles.
On the OEM and Tier 1 level, companies like VDL and Ionity contribute to vehicle-side and high-power charging solutions, while final customers and users—such as fleet operators and municipalities—drive real-world implementation and adoption. Research institutions such as TUM, Fraunhofer IEE, and TU Delft support the sector with technical innovation, feasibility studies, and pilot projects, bridging the gap between development and commercialization.

The regulatory framework is shaped by national and EU-level institutions, including KfW, dena, and the European Commission, which provide financial incentives, standardization efforts, and policy direction to facilitate the large-scale deployment of Smart Charging and V2G solutions. This interconnected ecosystem highlights the need for collaboration across all levels, from technology providers to policymakers, to ensure a sustainable and scalable transition toward electrified transport and grid integration.

Figure 41: stakeholders of the Smart Charging & V2G ecosystem

Geographic Location of exemplary Stakeholders in Germany and the Netherlands

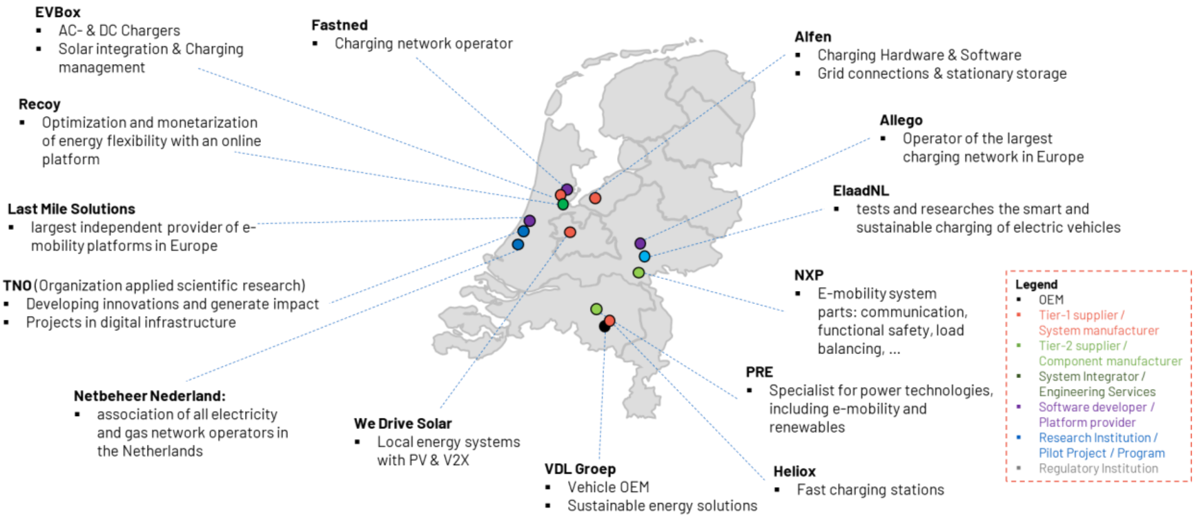

Figure 42: Location of V2G Stakeholders in the Netherlands

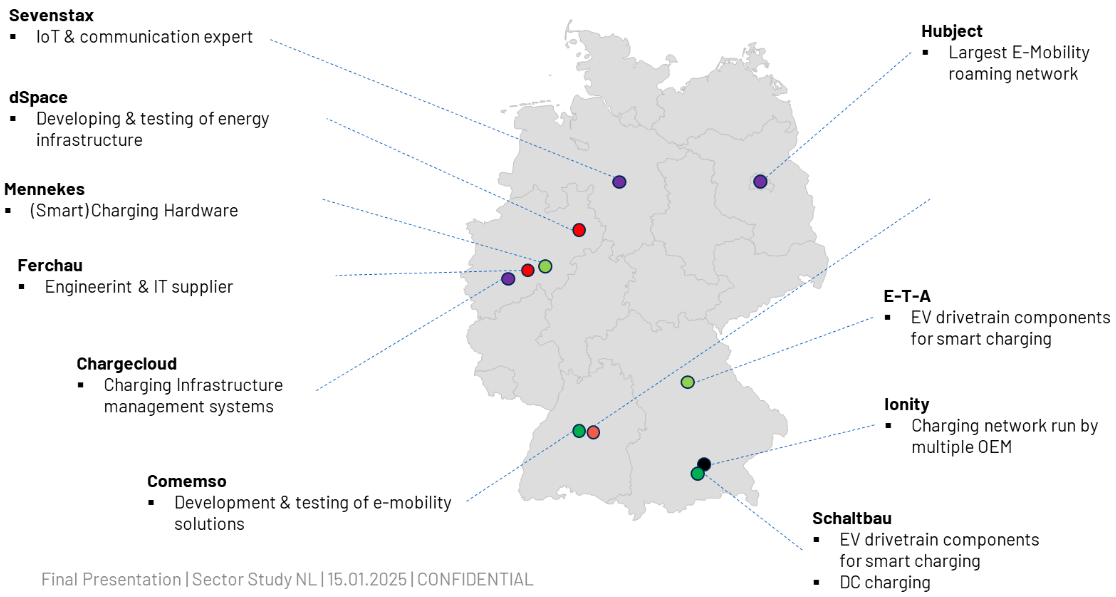

Figure 43: Location of V2G Stakeholders in Germany

Exemplary Company Fact Sheets

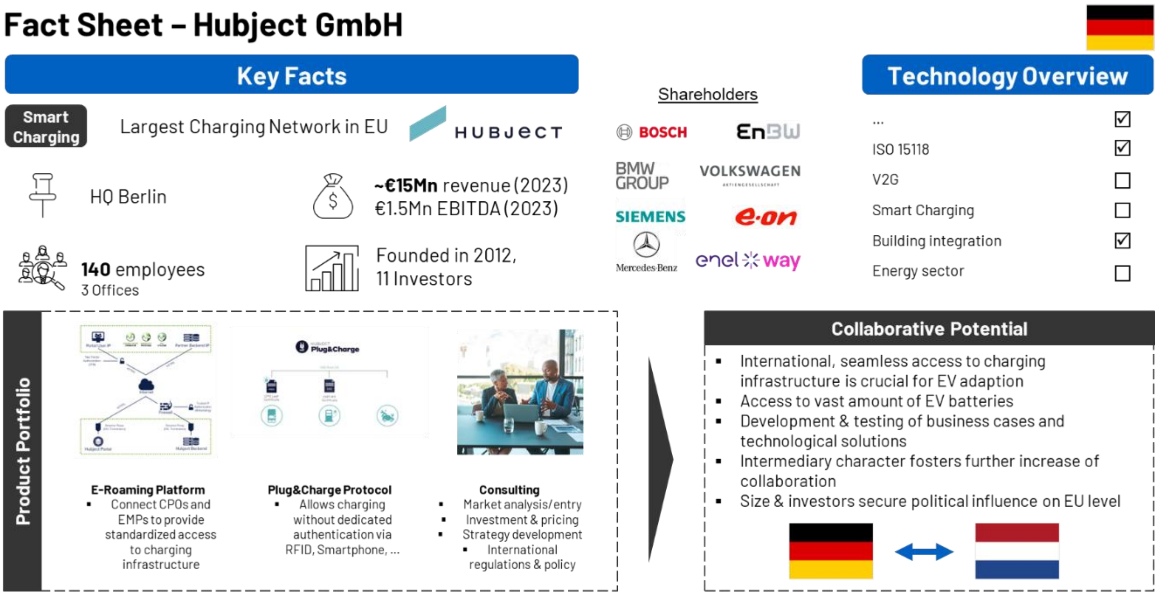

Figure 44: Fact Sheet – Hubject GmbH

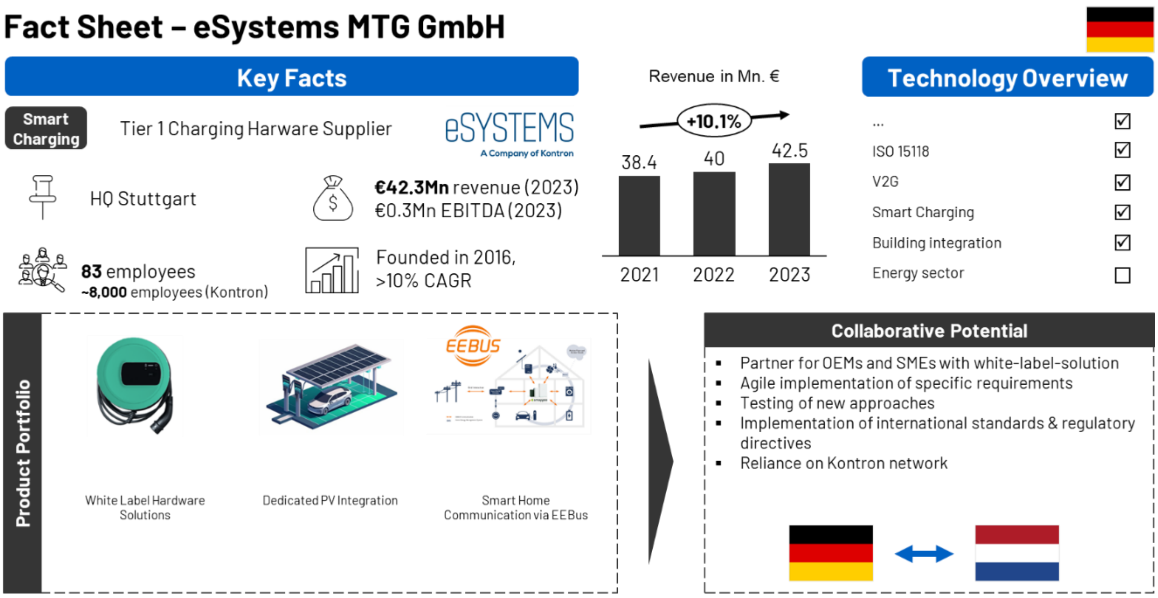

Figure 45: Fact Sheet – eSystems MTG GmbH

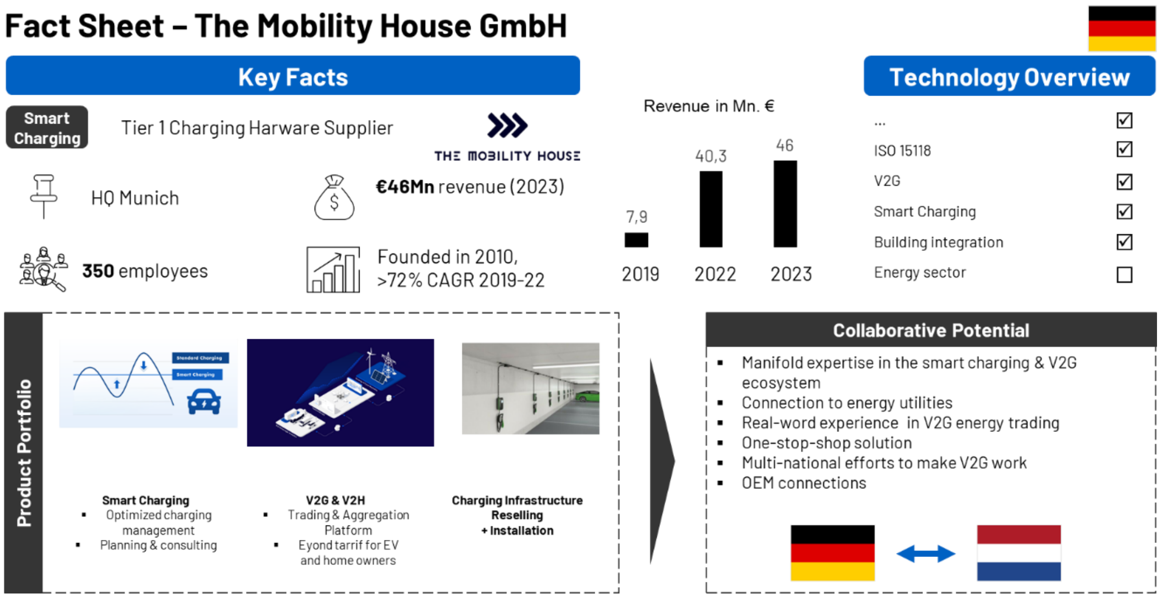

Figure 46: Fact Sheet – The Mobility House GmbH

SWOT Analysis V2G & Smart Charging

	Strengths ▪ NL European leader in CIS ▪ Cross-border grid utilities ▪ Existing successful col-laborations & research projects	**Weaknesses** ▪ International (EU) standardization laborious but necessary for breakthrough ▪ Highly fragmented market
Opportunities ▪ Shift to renewables is inevitable and requires sector-coupling ▪ EVs have mid- to long-term political support; sales are taking up	**S-O Strategies** ▪ Holistic implementation of smart parking solutions in larger urban areas ▪ Convince decision makers to implement new solutions	**W-O Strategies** ▪ Provide integrated one-stop-shop solutions for energy mgmt. ▪ Use well-organized OEM network to push standards
Threats ▪ Aggressive competition of CIN EV manufacturers ▪ Changes to grid slow & costly ▪ General financial instability	**S-T Strategies** ▪ Collaboration between OEMs and grid operators to develop solutions for the EU market and optimize sector coupling	**W-T Strategies** ▪ Develop EU standards in close collaboration ▪ Use shared pain-points of stakeholders to achieve solutions

- V2X & SM have the potential to simultaneously generate revenue and savings. Due to complexity, it needs a strategic plan & guidance
- Close collaboration between regulatory instances, OEMs and grid operators is crucial to achieve a long-term solution

Figure 47: SWOT V2G & Smart Charging

The successful deployment of Vehicle-to-Everything (V2X) and Smart Charging requires a well-structured strategic approach, as it operates at the intersection of mobility, energy, and digital infrastructure. The SWOT analysis highlights key internal and external factors influencing the market, providing insights into the strengths, weaknesses, opportunities, and threats shaping its development.

Strengths - Europe has established itself as a global leader in smart energy solutions, particularly in the cross-border grid utility sector. The region benefits from an active research ecosystem, with multiple successful collaborations and pilot projects already in place. These initiatives provide a strong foundation for further innovation and policy development, ensuring that V2X and Smart Charging solutions align with both mobility and energy sector needs.

Weaknesses - Despite the technological advancements, V2X standardization remains a significant challenge, particularly at the international (IEC) level. The absence of a unified regulatory framework complicates interoperability between different systems and slows down widespread adoption. Additionally, the market remains highly fragmented, with diverse stakeholders—ranging from utilities and grid operators to OEMs and tech providers — each pursuing their own strategies, making it difficult to create a cohesive and scalable implementation plan.

Opportunities - The increasing shift toward renewable energy sources creates an urgent need for sector coupling strategies that integrate transport, energy, and digital infrastructure. V2X technology can play a pivotal role in grid stabilization, helping balance electricity supply and demand as variable renewables such as wind and solar gain market share. Additionally, EV sales are projected to grow rapidly, particularly in long-term fleet electrification, increasing the demand for smart charging and energy flexibility solutions.

Threats - However, the competitive landscape remains challenging, with strong competition from Chinese and North American manufacturers in both hardware and software solutions. Policy uncertainty is another risk: changes to grid regulations or slow policy adaptation could hinder investment and innovation in Smart Charging and V2X. Furthermore, global financial instability could slow down funding for infrastructure deployment, making large-scale rollouts more difficult without strong public-private collaboration.

Strategic Approaches for Market Growth

S-O Strategies (Leveraging Strengths to Seize Opportunities)
To capitalize on Europe's leadership in grid utilities and research collaboration, scaling smart charging pilots in major urban areas can accelerate adoption. Convincing policy makers and utilities to support Smart Charging & V2G as part of larger infrastructure investments will be key to ensuring long-term financial viability.

W-O Strategies (Overcoming Weaknesses to Seize Opportunities)
A major focus should be on developing integrated, one-stop solutions that simplify the transition for fleet operators and energy managers. Collaboration between grid operators and charging networks is essential to ensure that Smart Charging becomes an integral part of energy system planning, rather than an isolated solution.

S-T Strategies (Using Strengths to Mitigate Threats)
By strengthening partnerships between OEMs, charging infrastructure providers, and utilities, the European market can maintain competitiveness against non-EU manufacturers. Aligning smart energy solutions with fleet electrification efforts will help optimize energy costs and improve business models, ensuring that V2X adoption is driven by both regulatory incentives and market-based demand.

W-T Strategies (Addressing Weaknesses to Reduce Threats)
To avoid regulatory uncertainty delaying progress, EU-wide standardization efforts must be prioritized to ensure smooth interoperability between different V2X solutions. Additionally, a clear division of responsibilities among key stakeholders—including policy makers, utilities, and OEMs—is crucial to achieving a scalable and sustainable rollout of Smart Charging infrastructure.

Conclusion - V2X and Smart Charging present a unique opportunity to generate both financial and environmental benefits by enabling efficient energy management and reducing infrastructure costs. However, due to the complexity of the ecosystem, a strategic implementation plan is essential. Collaboration between regulatory bodies, grid operators, and vehicle manufacturers is key to overcoming existing challenges and unlocking the full potential of Smart Charging & V2X in Europe.

3.4 Deep Dive 4: Battery Electric Trucks

The transition to Battery Electric Trucks (BETs) is gaining traction as industries seek low emission, energy-efficient, and economic alternatives for freight transport. As global regulations tighten, zero-emission logistics solutions are becoming increasingly critical, with BETs emerging as a key technology pathway. Advances in battery technology, megawatt charging infrastructure, and digital fleet management are shaping the future of electric heavy-duty transport. However, challenges related to infrastructure deployment, battery cost, energy density, and total cost of ownership (TCO) remain key barriers to widespread adoption. BET offer significant advantages by integrating renewable energy sources, reducing dependence on fossil fuels, and improving overall energy efficiency. However, fleet operators face major logistical challenges, including charging downtime, range limitations, and operational efficiency. Solutions such as depot-based smart charging, megawatt charging, and vehicle-to-grid (V2G) technologies can help optimize energy use while minimizing costs. Grid-friendly charging strategies allow BETs to act as energy storage assets, improving grid stability and enhancing fleet profitability through energy trading opportunities. Despite these benefits, technological uncertainty persists, particularly in battery chemistry and energy storage systems. Unlike passenger EVs, where lithium-ion batteries dominate, BET applications require a broader range of battery technologies, tailored to specific operational demands, cost constraints, and energy requirements. The industry is still evaluating which battery chemistry is most suitable for different transport applications, particularly for long-haul trucking where energy density is a critical factor. Fleet operators, policymakers, and OEMs must work together to develop a scalable and economically viable BET ecosystem. Strategic investment in charging infrastructure, standardization efforts, and long-term battery development will determine the pace of BET adoption in the coming years.

Key Takeaways:

- Charging & Infrastructure: The electrification of freight transport requires a mix of depot-based, en-route, and megawatt charging solutions. Strategic charging network expansion is critical to ensuring BET feasibility for both regional and long-haul applications.
- Battery Development: There is no single dominant battery chemistry for BETs. The choice of battery depends on vehicle range, cost structures, energy density, and charging speed. Fleet electrification strategies must consider multiple battery chemistries tailored to different use cases.
- Regulatory & Market Readiness: BET adoption is influenced by policy incentives, carbon pricing, and electricity grid integration. Government support, particularly in charging infrastructure subsidies and energy taxation, will play a decisive role in fleet electrification.
- Long-Term Scalability: The BET market requires standardized charging solutions, vehicle-to-grid (V2G) integration, and advancements in battery technologies to ensure a future-proof and cost-effective transition to electric trucking.

Case Study: Battery Cell Development

One of the most critical aspects of BET deployment is the selection of optimal battery technology. Unlike passenger EVs, where lithium-ion (NMC/NCA) dominates, the BET market is more diverse and application-specific. The choice of battery chemistry directly impacts vehicle range, cost, weight, and durability, making a one-size-fits-all approach impractical.

Figure 48 illustrates the suitability of different battery chemistries—Sodium-Ion, LFP (Lithium Iron Phosphate), LMFP (Lithium Manganese Iron Phosphate), and NMC/NCA (Nickel Manganese

Cobalt/Nickel Cobalt Aluminum) — for various applications, from urban distribution to long-haul trucking.

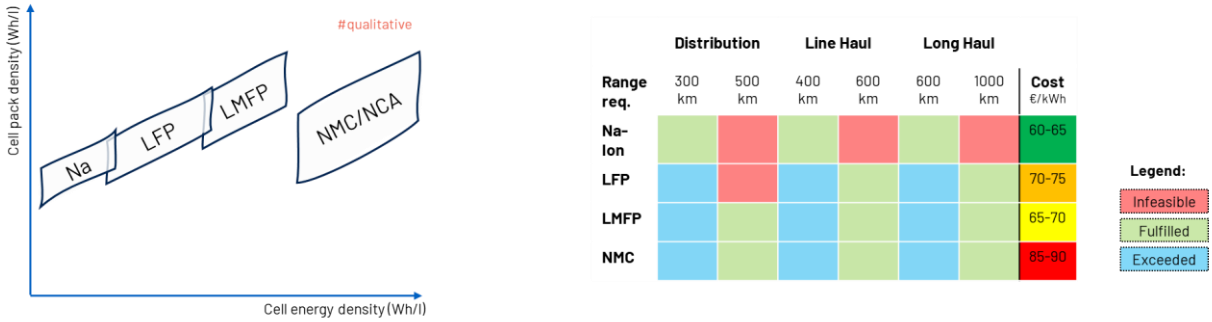

Figure 48: overview of cell technologies and application areas

Key Insights from the Analysis:

- No single battery chemistry dominates—selection depends on the specific operational requirements of a fleet.
- Sodium-Ion (Na-Ion): A cost-effective option for short-range applications, though its energy density is limited.
- LFP (Lithium Iron Phosphate): Well-suited for medium-range trucks, offering lower costs and safety advantages but lower energy density than NMC.
- LMFP (Lithium Manganese Iron Phosphate): A promising alternative combining the safety of LFP with improved energy density—still under development.
- NMC/NCA (Nickel-based chemistries): Best for long-haul transport, providing high energy density but at a higher cost and potential sustainability concerns due to raw material dependencies.

This case study highlights the industry's shift towards a diversified battery portfolio, where multiple chemistries coexist to serve different truck segments. Fleet operators and OEMs must align battery strategies with specific duty cycles, cost structures, and charging infrastructure investments to ensure long-term BET adoption.

Case Study: Cell manufacturing in Germany

Germany has positioned itself as a key battery production hub in Europe, attracting major international and domestic players that are investing in next-generation energy storage solutions (Figure 49). The country's strong automotive industry, skilled workforce, and government-backed incentives have led to the development of several large-scale gigafactories, serving both local and European markets. One of the most ambitious projects is Volkswagen's PowerCo facility in Salzgitter, which is transitioning from internal combustion engine (ICE) production to battery manufacturing. With an expected annual capacity of 20-40 GWh and 1,500 jobs created, the plant is a critical component of Germany's long-term electrification strategy. Similarly, CATL, the world's largest EV battery producer, has established its European headquarters in Arnstadt, with plans to scale production to 100 GWh per year. While European and Chinese manufacturers dominate the sector, Swedish company Northvolt is also expanding its footprint in Germany, with a $4.5 billion investment into a 60 GWh capacity plant specializing in lithium-ion and sodium-ion cells. The future of Northvolt though remains uncertain. At the same time, Porsche's acquisition of Cellforce highlights a trend of OEMs investing directly in battery production, ensuring supply chain security for high-performance applications. However, the battery manufacturing sector is not without challenges. Svolt's planned 16 GWh factory in Brandenburg was canceled in mid-2024, citing political and regulatory uncertainty as key reasons. Similarly, ACC's Kaiserslautern facility—

originally a promising EU-backed initiative—has halted operations due to unclear cell technology decisions. These cases demonstrate that while Germany remains a top destination for battery investments, stability in regulatory frameworks and policy support will be essential for long-term growth.
Overall, Germany's battery production ecosystem is rapidly evolving, with significant mutual interests between Germany and the Netherlands. The close collaboration between OEMs, technology providers, and policymakers will be crucial in ensuring Europe's leadership in battery innovation and sustainable transport solutions.

Figure 49: Major battery production facilities in Germany

Stakeholder Overview

The transition to Battery Electric Trucks (BETs) and Smart Charging solutions requires a diverse set of stakeholders along the value chain, each contributing expertise in technology development, system integration, manufacturing, and policy-making, as visualized in Figure 50. At the core of the industry are component manufacturers and platform developers, such as Schäffler, Leoni, ITK, and Heliox, which provide key technologies for energy storage, drivetrains, and charging solutions. These companies are complemented by system integrators, including SBRS, ChargeBIG, and GreenFlux, who focus on ensuring seamless compatibility between energy providers, vehicles, and grid infrastructure. OEMs such as Daimler Truck, MAN, DAF, and VDL play a pivotal role in bringing electric trucks to market, integrating battery and charging technologies into scalable vehicle platforms. Meanwhile, logistics companies like Kuehne+Nagel, DB Schenker, and HSF Logistics represent the final customers and users, whose fleet electrification strategies will determine the real-world deployment and economic feasibility of BETs. Research institutions, including Fraunhofer IEE, TNO, TU Delft, and TUM, provide technical innovation, feasibility studies, and pilot project support, bridging the gap between development and large-scale adoption. Regulatory agencies such as KfW, dena (German Energy Agency), Rijksdienst voor Ondernemend Nederland, and NOW GmbH are responsible for setting policies, funding infrastructure projects, and ensuring market stability. This interconnected ecosystem highlights the importance of collaboration across industry, research, and policy-making to drive technological advancement, regulatory alignment, and successful market adoption of electric trucks and smart charging infrastructure.

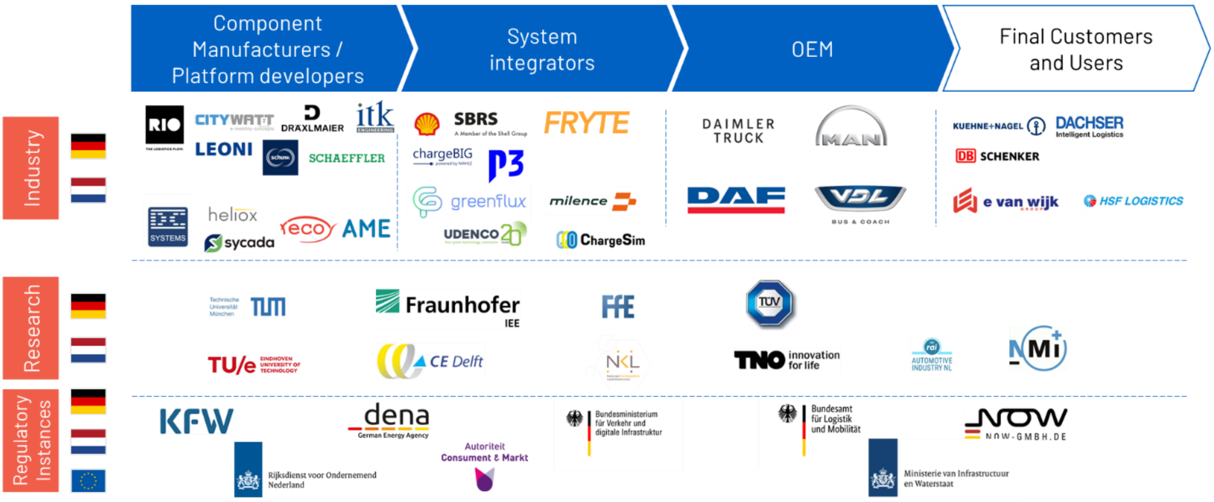

Figure 50: stakeholders along the value chain for truck electrification

Geographic Location of exemplary Stakeholders in Germany and the Netherlands

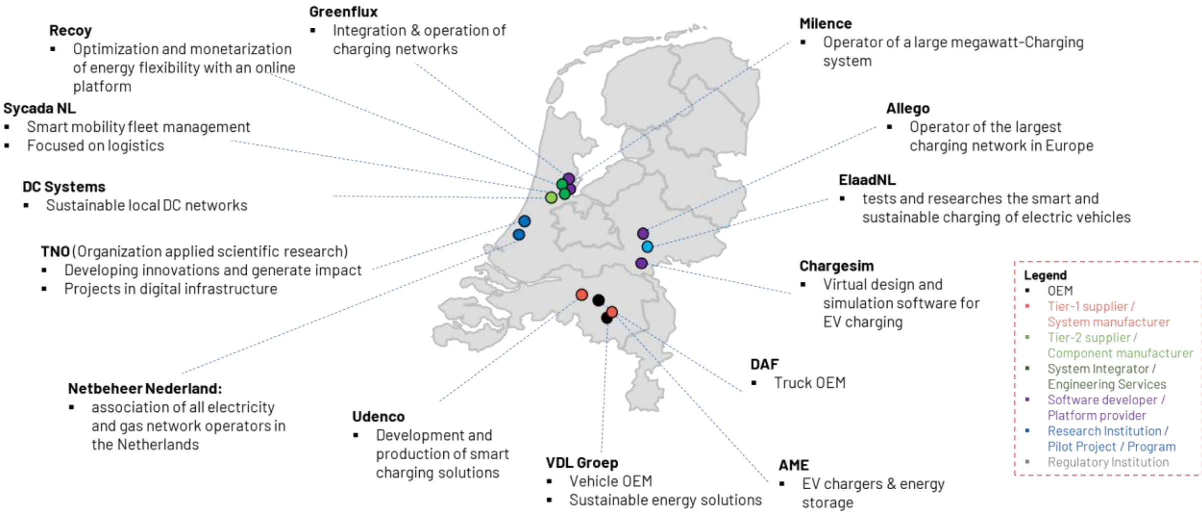

Figure 51: Location of BET Stakeholder in the Netherlands

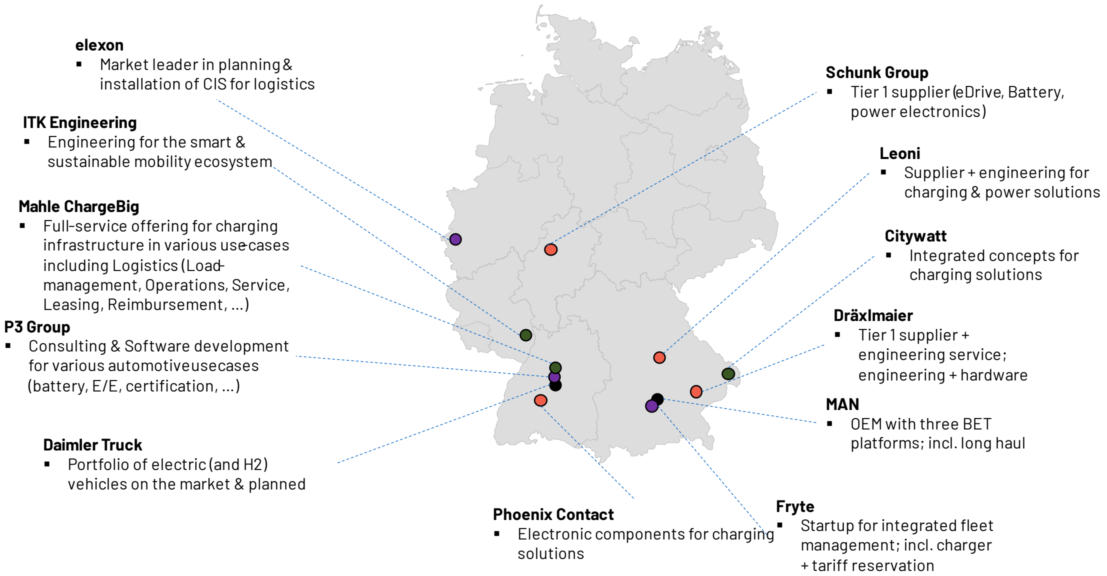

Figure 52: Location of BET Stakeholder in Germany

Exemplary Company Fact Sheets

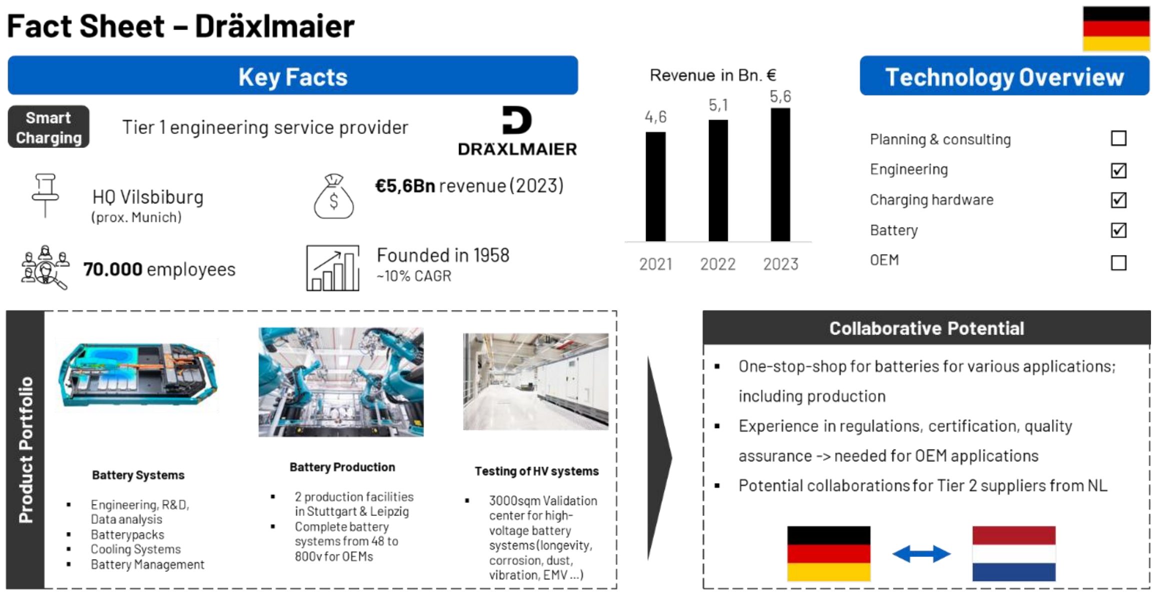

Figure 53: Fact Sheet - Dräxlmaier

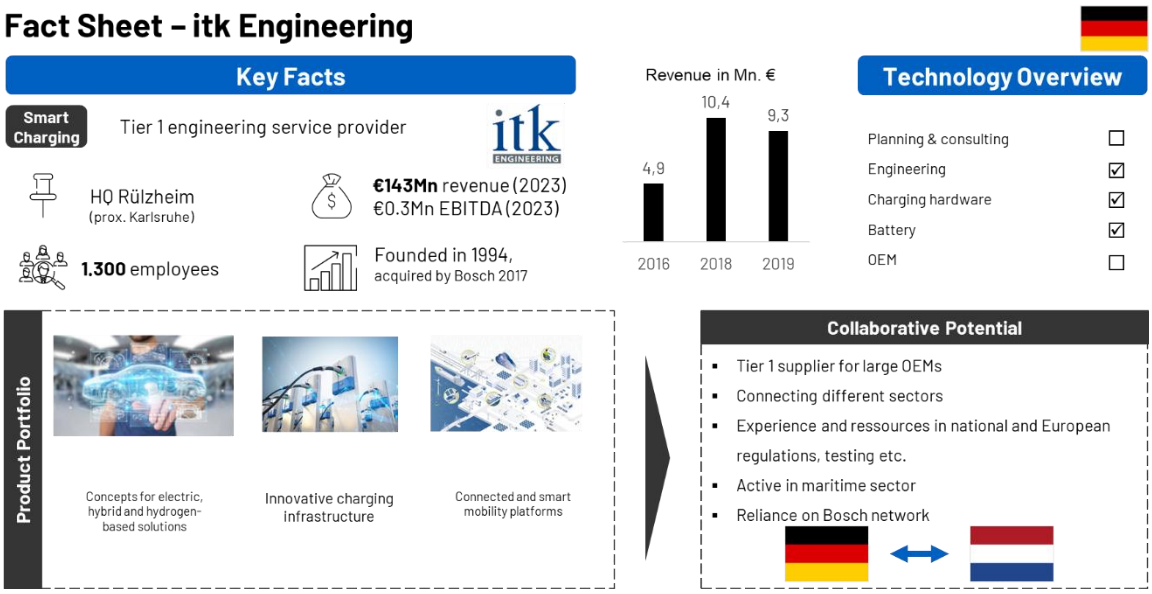

Figure 54: Fact Sheet – itk Engineering

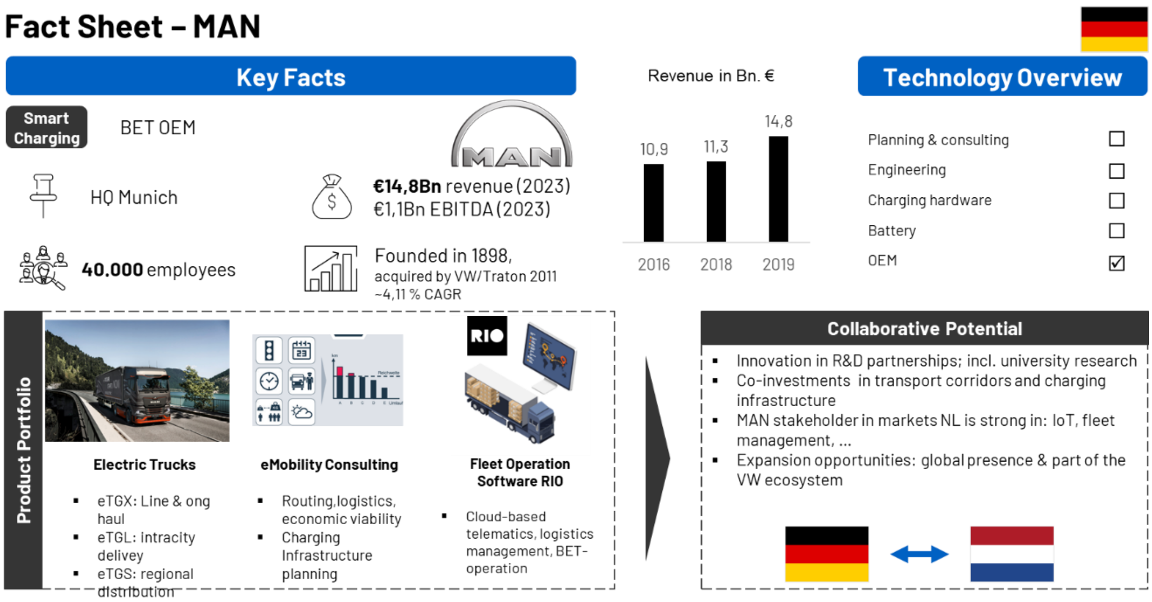

Figure 55: Fact Sheet - MAN

SWOT Analysis Truck Electrification

The transition to Battery Electric Trucks (BETs) and electrified logistics is driven by technological advancements, regulatory alignment, and corporate sustainability goals. However, widespread adoption faces infrastructure limitations, high initial costs, and range constraints, necessitating strategic planning to address market challenges.

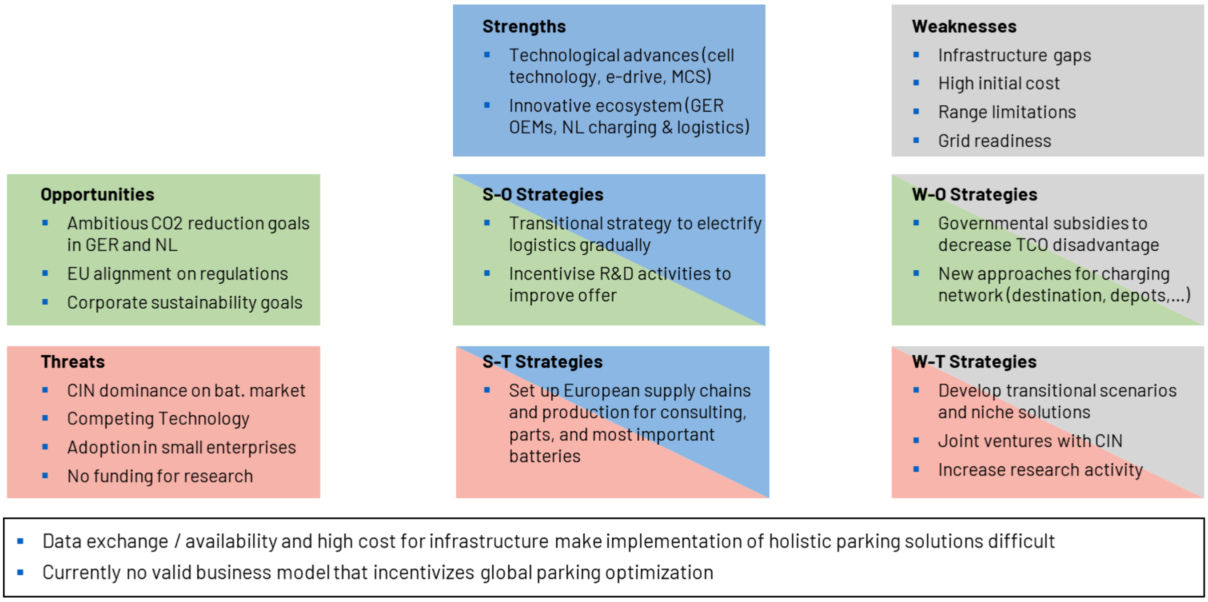

Figure 56: SWOT Analysis Truck Electrification

Strengths - Europe's technological leadership in battery cell development, megawatt charging systems (MCS), and electric drivetrains create a solid foundation for BET adoption. Additionally, Germany's strong OEM ecosystem and the Netherlands' expertise in charging infrastructure and logistics provide a collaborative advantage for advancing truck electrification.
Weaknesses - Despite these strengths, gaps in charging infrastructure, high capital expenditure, and limited grid readiness pose significant hurdles. The total cost of ownership (TCO) for electric trucks remains higher than diesel counterparts, particularly in long-haul applications, making government incentives and innovative business models essential.
Opportunities - Regulatory drivers, including EU-wide CO_2 reduction targets and sustainability commitments by major corporations, provide a clear policy direction for the expansion of electric trucking. Standardization of charging networks and regulatory alignment across Germany and the Netherlands will further support market adoption.
Threats - The dominance of Chinese battery manufacturers (CIN) in the global supply chain, along with competing technologies such as hydrogen fuel cells, poses a risk to European battery independence. Limited adoption by small and medium-sized enterprises (SMEs) and insufficient R&D funding may slow the transition, reinforcing the need for strong industrial policies and investment in local supply chains.

Strategic Approaches for Truck Electrification

S-O Strategies (Leveraging Strengths to Seize Opportunities) - Implement a transitional strategy for the electrification of logistics fleets, allowing gradual fleet conversion while ensuring operational efficiency. Incentivize R&D initiatives to improve battery performance, cost efficiency, and integration with existing freight operations.
W-O Strategies (Overcoming Weaknesses to Seize Opportunities) - Introduce government subsidies to reduce the total cost of ownership (TCO) disadvantage, making electric trucks more attractive to fleet operators. Develop new charging infrastructure models, including dedicated depot charging and en-route megawatt charging, to improve operational reliability.
S-T Strategies (Using Strengths to Mitigate Threats) - Strengthen European supply chains for battery production, consulting services, and essential truck components, reducing reliance on non-EU suppliers. Encourage industry collaboration between OEMs, logistics companies, and energy providers to create integrated electrification strategies.

W-T Strategies (Addressing Weaknesses to Reduce Threats) - Develop transitional market solutions, such as hybrid fleets or modular electrification approaches, to ease the transition for SMEs. Establish joint ventures with Chinese battery suppliers (CIN) where necessary, while investing in European battery independence. Increase research funding to address infrastructure bottlenecks, range limitations, and grid integration challenges.

Conclusion

Truck electrification presents a complex but necessary transformation in the logistics sector, requiring technological innovation, policy alignment, and investment in infrastructure. A multi-stakeholder approach, involving OEMs, energy providers, logistics companies, and regulators, is critical to overcoming current barriers and positioning Europe as a leader in electric freight transport.

4 Recommendations

4.1 Overall recommendations

The following recommendations focus on the activities and potential collaborations within the four deep dive topics.

Smart Infrastructure and V2X:

The development of smart infrastructure and V2X communication is crucial for the future of connected mobility. V2X technology enables vehicles to communicate with each other and their surroundings, reducing dependencies and preventing technological backlogs. Large-scale test projects are necessary to refine this technology, with infrastructure developers, cities, and some OEMs playing key roles in its deployment. Research institutes, traffic solution providers, and telecommunication companies will contribute by conducting small-scale testing and providing 5G expertise. Establishing guidelines and standards will facilitate a better understanding of Cellular V2X (C-V2X) and help shape a European roadmap for V2X communication.
Smart intersections and highways represent another vital component in optimizing traffic flow and enhancing safety. By integrating digital mapping and infrastructure development, cities and municipalities can improve traffic management and accelerate the adoption of autonomous driving. Since these projects require long-term investments of 10 to 15 years, collaborations between system integrators, municipalities, and digital solution providers are essential. Standardization will improve interoperability between infrastructure elements, enabling smoother cross-border projects and implementation of functional pilot areas.
Vulnerable road users (VRUs) and mobile device integration offer significant potential for improving traffic safety. The increasing trend of detecting pedestrians and cyclists through vehicle-to-pedestrian (V2P) communication reduces accident risks. However, cross-border functionality and standards must be established to ensure widespread adoption. Collaboration between phone manufacturers, network providers, and cities will be essential to create standardized interfaces between mobile devices, infrastructure, and vehicles. This also necessitates the development of data privacy guidelines and EU-wide standards to ensure secure and effective communication.
To move forward, the strength of hybrid V2X communication should be leveraged to create a unified European roadmap, connecting industry stakeholders and regulatory bodies. Regulatory frameworks must address the secure collection, processing, and utilization of mobility data, requiring collaboration between industry, national, and European authorities. Despite its potential, business opportunities for V2X remain limited, necessitating pilot projects in urban areas to test real-world applications and identify sustainable business models. European collaboration projects in Cooperative Intelligent Transport Systems (C-ITS) can serve as large-scale test environments for V2X technology. However, the limited interest of automotive OEMs poses a risk, as many will only engage with V2X when regulations mandate it. Given that full adoption across all vehicles is unlikely in the next 10 to 15 years, strategic planning and phased implementation will be crucial in overcoming these challenges.

- ⇒ Build on strength in hybrid V2X communication and lead the way toward a European roadmap on communication standards by connecting industry stakeholders & regulatory instances
- ⇒ Develop & propose regulations for secure collection, processing and utilization of mobility data – Connect industry, national & European regulatory bodies, and independent data protection authorities

⇒ Limited business opportunities yet: Set up pilot areas through research collaborations focused on real-world implementation in urban areas to develop better business models

⇒ Support for (European) collaboration projects in the field of C-ITS as a test environment for testing V2X technologies on a large scale (e.g. ECo-AT)

⇒ Risk: Be aware of limited interest of automotive OEMs in the V2X technology; some will only be active in this with according regulation; not all vehicles will be equipped with the technology within the next 10-15 years

Data and Software based Services:

As urban mobility evolves, data and software-based services play a crucial role in optimizing traffic flow, improving fleet management, and addressing parking challenges. Strategic collaborations between stakeholders in the Netherlands and Germany can drive innovation, enable smarter mobility solutions, and enhance efficiency. Traffic congestion and emissions remain pressing urban issues, requiring improved data-driven traffic management systems. By integrating multiple data sources, such as telemetry units and smart infrastructure sensors, cities and municipalities can gain better insights into traffic patterns and optimize their transport networks. Partnerships between software developers, OEMs, and public transport providers are essential in this endeavor. The exchange of mobility data across borders, particularly between the Netherlands and Germany, offers the potential to enhance traffic management efficiency and reduce congestion within European cities.
Fleet management solutions can significantly reduce operational costs and improve efficiency for rental services, leasing companies, and public transport providers. Establishing common data exchange standards through collaborative efforts between OEMs, software providers, and regulatory bodies is critical. The integration of GPS tracking and fleet management platforms enables better real-time monitoring and predictive maintenance. A shift toward subscription-based revenue models could also provide fleet operators with recurring income, encouraging further investment in digital solutions. Parking-related congestion contributes significantly to urban traffic problems, with up to 30% of traffic in cities attributed to the search for parking spaces. Expanding existing smart parking solutions into comprehensive, city-wide systems can reduce unnecessary traffic and optimize land use. Collaborations between sensor manufacturers, parking service providers, and municipalities will be crucial in implementing such solutions. Successful integration of these systems can lead to more efficient use of urban space, alleviating both environmental and logistical burdens.
The Netherlands and Germany present unique opportunities for collaboration in mobility innovation. By connecting Dutch technology providers with traditional transport companies in Germany, pilot projects can facilitate the transition to new digital solutions. Start-ups and established firms can mutually benefit from knowledge-sharing initiatives, allowing them to develop best practices and common guidelines. Furthermore, working towards European-wide standards for data exchange, ownership, and security will strengthen regulatory frameworks and ensure data-driven mobility solutions are scalable and sustainable. However, competition in the German market for digital mobility services is intense, requiring Dutch companies and start-ups to differentiate themselves through unique selling propositions and highly innovative solutions. By focusing on expertise in mobility data utilization and demonstrating proven success in traffic optimization, Dutch firms can establish a foothold in the German market.

- ⇒ Support the collaboration between NL solution providers and conventional transport providers and cities in Germany; start with pilot projects to let conventional companies adapt to new technologies
- ⇒ Initiate know-how transfer between small players / start-ups and established larger companies in Germany and Netherlands; both sites benefit from new innovations and potentially decide on common guidelines
- ⇒ Work on joint efforts for the development of European standards for data exchange, data ownership and data security on the political / regulative level; include experts from research and industry
- ⇒ NL companies should provide best practices for improved traffic solutions by utilizing mobility data to get access to German market
- ⇒ Risk: Large competition on German side for digital solution providers; NL companies / start-ups need to find their USP and offer highly innovative solutions

V2G and Smart Charging:

As electric vehicle adoption accelerates, bidirectional charging and vehicle-to-grid (V2G) technology will play a crucial role in ensuring grid stability and optimizing renewable energy integration. With increasing dependence on renewables, the ability to use EVs as flexible energy storage units is essential. However, widespread implementation requires EU-wide regulatory alignment to foster investment and encourage standardization. Key stakeholders, including utilities, grid operators, software developers, and government institutions, must collaborate to define business models, product requirements, and feasibility assessments. Short-term efforts will focus on showcasing technological readiness and developing common standards, while long-term projects will be essential to create a European roadmap for future energy supply. By securing long-term investment in V2G and leading policy development, stakeholders can mitigate grid congestion, reduce curtailment, and ensure a stable energy transition.

In parallel, smart charging solutions are an immediate necessity to support the rapid scaling of electric vehicles. The Netherlands, with its extensive experience in real-world charging infrastructure, can provide valuable insights, while partnerships with German manufacturers, suppliers, and technology providers can drive further advancements. Smart charging requires collaboration between charging hardware providers, energy system integrators, and utilities to ensure a seamless user experience through optimized tariffs and interoperability. Short-term implementation projects should focus on challenging showcases to gain practical experience, refine cost estimates, and validate large-scale benefits.

For both V2G and smart charging, strategic alignment between mobility, housing, and energy sectors is crucial. Intersectional collaboration can help overcome regulatory hurdles and unlock the full potential of integrated energy and transport systems. However, fragmentation in the market poses a risk—without holistic solutions, benefits will be too limited to drive widespread adoption. The challenge lies in balancing innovation with regulation while ensuring that all stakeholders, from EV owners to utilities and policymakers, align toward a common vision. Only through coordinated efforts can Europe establish a resilient, future-proof energy ecosystem that fully leverages the potential of electric mobility.

- ⇒ Build on strength in the EV market. NL has a leading role in EV charging infrastructure, GER has multiple OEMs and strong suppliers.

- ⇒ Develop strategies that will secure long-term benefits for utilities, OEMs, EV- & home-owners. Derive policy recommendations and leverage strong EU position.
- ⇒ Support the short-term implementation and demonstrate technological readiness while investigating future use- and business cases
- ⇒ Intersectional collaboration is crucial to overcome regulatory hurdles and leverage the full potential which lies in coupling mobility, housing, and energy.
- ⇒ Risk: market may become too fragmented in order to realize the potential benefits. Only holistic solutions benefit the stakeholders; otherwise, benefit is too little.

Truck Electrification:

The electrification of heavy-duty transport is a crucial step in reducing CO_2 emissions, with long-haul trucking alone accounting for a significant share of traffic-related emissions, particularly in Germany. Battery electric trucks (BET) are at the core of this transition, and their widespread adoption depends on advances in battery technology, charging infrastructure, and operational integration. While China currently leads global battery production, the EU—particularly the Netherlands and Germany—holds a strong position in this sector, with Dutch expertise in charging solutions playing a key role. Collaboration across the supply chain, including cell manufacturers, electronics suppliers, OEMs, and governmental institutions, is necessary to ensure a competitive European market. Short-term projects will focus on developing charging infrastructure, while long-term efforts must address the establishment of a European roadmap for battery production and energy management.

Beyond technological advancements, the success of BET depends on a well-coordinated approach to fleet management, route planning, and charging infrastructure. The financial burden of installing charging networks remains a challenge, and uncertainty regarding long-term regulatory support may slow adoption. Establishing interoperability standards and ensuring forward compatibility can help mitigate concerns among freight companies. Additionally, integrating software solutions for fleet optimization, tariff roaming, and energy management will be critical to ensuring that BET operates efficiently within existing logistics frameworks. Given the Netherlands' extensive experience with charging networks, collaboration with German manufacturers and infrastructure providers can accelerate deployment and improve operational efficiency.

However, research funding in Germany has seen significant cuts, making joint projects between OEMs, universities, and technology providers even more essential. Without sustained investment in R&D, the transition to battery-electric trucking risks losing momentum. Policymakers must provide consistent regulatory support to build trust within the industry and encourage further investment. A fragmented or unstable subsidy landscape could undermine adoption, slowing the transition instead of accelerating it. A coherent strategy, balancing technological innovation with clear policy direction, is necessary to ensure that BET becomes a viable and competitive solution for the heavy-duty transport sector in Europe.

- ⇒ The battery (+ bat. management) is the most expensive part of BET – technological advances yield the possibility to regain market shares. R&D and funding necessary!
- ⇒ Charging infrastructure is crucial. While it's technically feasible, the large upfront investment causes hesitation. Standards guaranteeing the forward compatibility may ease the doubts. Knowledge exchange for freight companies, too.

⇒ BET need an integrated approach to work. Fleet optimization, charging, route planning with tariff roaming etc. will be significant markets.

⇒ Funding for research activity in GER was massively cut. Use well-established collaborations between OEMs and universities to set up joint projects

⇒ Risks: there must be a coherent strategy in place in order for BET to succeed. If governments change the course for subsidies, trust will be lost – slowing down the transition.

4.2 Funding Programs

The Dutch Embassy in Germany and Dutch Ministry of Economic Affairs are planning funding programs to accelerate collaborations between Dutch and German industry in the field of sustainable road mobility. The following section highlights the recommended activities in three different areas: sales, innovation and regulation. Figure 57 summarizes the potential of sales, innovation and regulation activities within the four selected deep dives.

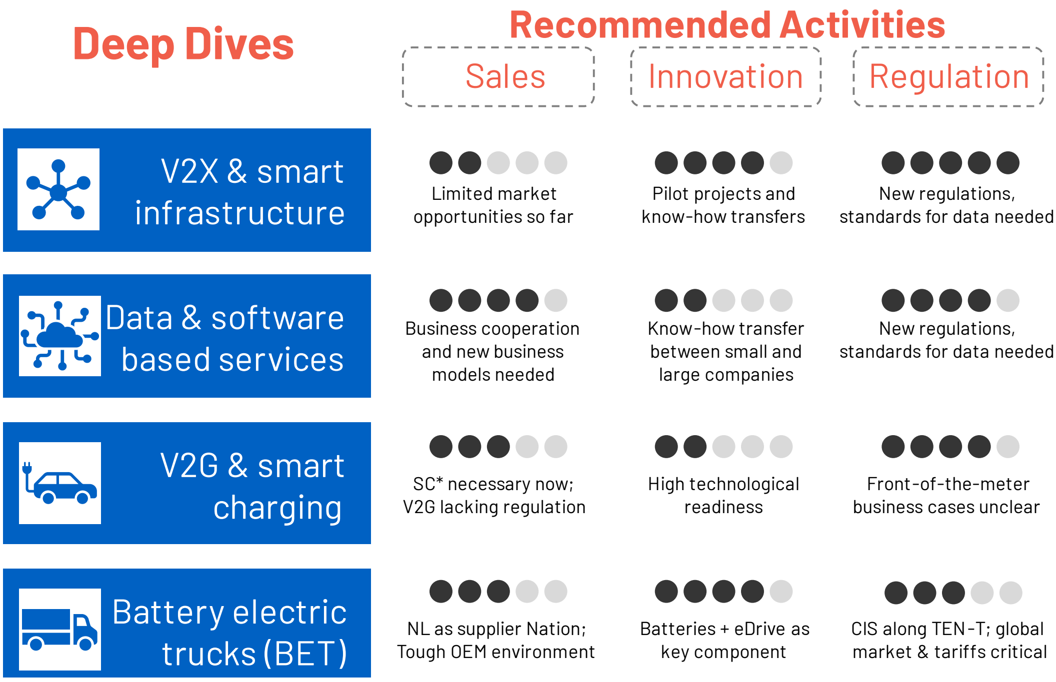

Figure 57: summary of recommended activities for the four deep-dive topics

For **V2X and smart charging** it is recommended to support regulatory, research and pilot projects. Sales activities will increase in the long term after innovation and regulation activities have been successfully promoted.

Sales activities for existing business models of **data and software-based services** should be supported. At the same time new regulation could enable new business models and potential collaborations between Germany and the Netherlands.

Subsidization of planning and installation of **V2G and smart charging** is highly recommended. Also, cross-sector and multinational networking should be facilitated.

Research is still very important for **battery electric trucks** (BET) to maintain knowledge and competitiveness on global level as well as a good OEM network. For the Dutch – German collaboration, BET is more favorable than passenger EV market due to less volatility and higher predictability.

5 Outlook and Conclusion

The transformation of Germany's mobility sector presents significant opportunities for Dutch companies, scientific institutions, and policymakers. As the country moves towards smart and sustainable road mobility, the integration of smart infrastructure, digital services, vehicle electrification, and advanced charging solutions will be pivotal. This study highlights the potential for Dutch stakeholders to leverage their expertise in EV infrastructure, data management, and smart mobility solutions to enter and expand in the German market. Strategic collaborations and pilot projects will play a crucial role in addressing challenges related to standardization, regulatory alignment, and market fragmentation.

The shift towards hybrid V2X communication offers an avenue for Dutch stakeholders to lead in developing a European roadmap for communication standards. Establishing regulations for secure data management and forming partnerships for pilot projects will be essential. However, a cautious approach is required given the limited interest of some automotive OEMs in V2X technologies. Expanding test environments like C-ITS can showcase the benefits and drive broader adoption.

The Dutch expertise in mobility data management positions them well to support German cities and transport providers in transitioning to data-driven solutions. Encouraging know-how transfer between start-ups and established companies across borders can accelerate innovation. The focus should be on establishing common standards for data exchange, ownership, and security to enhance interoperability. However, intense competition from German digital solution providers necessitates a clear USP for Dutch companies.

The Netherlands' leadership in EV charging infrastructure provides a strong foundation for partnerships with German OEMs and utility providers. Developing holistic solutions that integrate mobility, housing, and energy sectors can maximize benefits and address potential market fragmentation. Intersectional collaborations are vital to overcome regulatory challenges and demonstrate the technological readiness of V2G solutions. A coordinated EU approach can further support this transition.

The path to electrifying heavy-duty transport in Germany depends heavily on advances in battery technology and the deployment of a robust charging infrastructure. Dutch companies can contribute by facilitating knowledge exchange and participating in joint research projects. The emphasis should be on standardization to ensure forward compatibility and build confidence among fleet operators. A comprehensive strategy, supported by consistent policies and funding, will be essential for the success of BET.

Germany's mobility transformation offers a substantial opportunity for Dutch stakeholders to expand their influence by leveraging strengths in EV infrastructure, data services, and smart mobility solutions. Establishing EU-wide standards and enhancing cross-border collaborations will be crucial for overcoming regulatory barriers and ensuring the interoperability of new technologies. By focusing on pilot projects, research collaborations, and standardization efforts, Dutch companies can position themselves as key players in shaping the future of smart and sustainable road mobility in Germany.

Appendix

Interviews with German Experts:

1. Large German Automotive Consulting Company (Manager)
2. Large German Automotive Supplier (C-level office)
3. German Truck Electrification Researcher
4. Former VP of German OEM
5. German Researcher Connected Mobility and automated Traffic
6. German Automotive Professor (TUM)
7. Former Deputy Head of Division Mobility in Bavarian State Ministry of Housing, Building and Transport
8. German Researcher Battery Electric Truck Charging and Grid Integration

Interviews with Dutch Experts:

9. CEO of Dutch Connected Car Company
10. Manager of Dutch Interest Organization (RAI)
11. Dutch Automotive / Mobility Professor
12. Transportation Expert (Dutch Ministry - RVO)
13. Former Director of Dutch Interest Organization (RAI)

Documentation of the interviews:

1. <u>Large German Automotive Consulting Company (Manager)</u>

- Trends in digital technologies: Software-defined-vehicle, Automation, Connectivity, Level 2+, Infotainment, AI for vehicles
- Due to missing regulation OEMs focus on Level 2+ Automation and do not go higher than Level 3
- Connectivity: mostly cloud and mobile phone connection as well as Over-the-Air Updates for E/E components; V2X very limited
- Generative AI applications in infotainment; neural networks in controllers, ADAS and thermal management

2. <u>Large German Automotive Supplier (C-level office)</u>

- Propulsion systems: main focus electrification, for high loads H2-engine (mining, off-road), for high range H2-cell
- Trends
- Inductive Charging: especially for autonomous vehicles and premium customers
- V2G: hardware charging components and IT / Grid connection software needed
- Thermal management for BEV: highly integrated systems, new cooling systems for e-components
- Strategy: Focus in products instead of wide range in products

3. <u>German Truck Electrification Researcher</u>

- Main focus on BEV to comply with future regulations
- H2 applications only niche
- Range will be long enough with BEV due to mandatory breaks of driver and megawatt charging infrastructure
- Battery main driver for costs of the vehicle; other e-components very similar between light- and heavy-duty
- Mega-watt charging more challenging for the hardware; different charger plug, power electronics, etc. needed
- Main trend in truck electrification: software outside the vehicle
- Planning and cost calculation tools for transport companies
- Location and energy- / charging management software
- Software for reservation of charging infrastructure for trucks
- Integration of disposition software with e-truck charging software
- Milence: big player in the charging infrastructure market

4. Former VP of German OEM

- Electrification is main route for private cars
- PHEV can be an alternative for long distances, but ICE ban 2035 would also affect PHEV
- Electrification is extremely challenging for long distance trucks
- Electric trucks works well until 200km, no problem for busses and urban trucks
- Long distances can hardly be covered with electric trucks since charging network is not there yet and power demand is high
- Charging Infrastructure (highway DC-Charing and truck MW-Charging) must be designed for high demand peaks
- High investment necessary to supply power demand reliably with green electricity and avoid waiting time
- Truck Megawatt charging parks need about 25 MW of power in peak times, grid needs to be reinforced for this power
- 100% electric mobility is hard to achieve, PHEV and Hydrogen can support in transition phase
- Hydrogen can support the electrification transition
- Especially for trucks and for long distance private vehicles as range extender
- Can be used in other sectors/ industries – how big are interfaces with the mobility sector?
- Battery production is heavily dependent on China
- Low value creation in Europe, high dependence on raw material as well as production technology
- Reduce raw material dependency and increase resilience in materials and technologies
- Europe must not decouple itself from other markets (e.g. China, USA) but learn from them

5. German Researcher Connected Mobility and automated Traffic

- 2 Main Trends in the field of connected infrastructure:
- Connectivity between Vehicles and Infrastructure: collect and share data
- Detection of other transport modes that are not motorized: vulnerable traffic participants (bikes, pedestrians)
- Challenges:
- Investment costs: technology is expensive, broad coverage not profitable
- Different Communication forms: short range used in cars (compatible with traffic lights, but not with PT), PT uses long range
- Missing regulation: cities provide infrastructure, cars don't share data with infrastructure, no business model yet
- Longevity of infrastructure hardware leads to slow decisions (interesting for new projects)
- Market development of sensors are driven by the broad use in cars:
- Cameras are cheap and mature (problems: accuracy, data privacy), Lidar has advantages (problems: cost, research needed)
- Infrastructure uses same sensors, but algorithms need to be trained
- Vision: smart infrastructure communicates with cars
- Focus on main routes (profitability)
- Regulation needed, openness for startup to collect and use data
- Smart Infrastructure can accelerate autonomous driving (factor 3), especially in complex situations with different road users

6. <u>German Automotive Professor (TUM)</u>

- General:
- Cooperation with OEMs nearly impossible. High quality standards, high risks, high volume = capital-intensive. And they want Tier1-suppliers to take responsibility, no small companies. -> SME should aim for suppliers, not OEM directly
- Prefer services (engineering, consulting, ...) over production as it yields higher flexibility and chances of success at lower risks
- Difficulties with Chinese suppliers (esp. Software): re-engineering could be interesting field
- AD probably a field for the big players. Hard to get into that market.
- EV: difficult for SME due to large suppliers being forced to focus on EV market
- Redesign of mobility systems: customers are municipalities
- Joint research is important to establish collaboration -> include in calls
- Connectivity & Digitalization:
- Decision: V2V or V2I? V2V will not work as most cars is not able to participate.
- Smart infrastructure: what's the use and who pays for it? Investment too large for public and OEMs won't pay because they don't earn enough. (see Japan)
- Nice-to-have in passenger sector, probably must-have in heavy vehicles
- Propulsion Technologies:
- EV without competition in passenger sector, also for heavy vehicles basically no future because the EV market will grow.
- H2 Only stationary usage -> maybe interesting for ports.
- Bi-directional charging mandatory to avoid grid overloads -> joint efforts to get EU regulations desireable
- HPC charging needed for long distance trucking -> grid connections needed. Large market!

7. <u>Former Deputy Head of Division Mobility in Bavarian State Ministry of Housing, Building and Transport</u>

- Electrification is not an easy political issue, transport transition is not popular
- Communication is difficult, since costs are increasing with transition to electric vehicles
- Politic should communicate that alternatives (H2, E-Fuels) are even more expensive than battery electric
- Politic is afraid of taking decisions and not capable to decide – industry needs reliability
- Regulatory and Politics:
- Politic don't take decision, 2 groups: soften climate targets vs clear and consistent regulatory
- Current trend in potential governments: soften climate targets
- Autonomous driving: hot topic for logistics and public transport, not emotionally loaded
- BET charging infrastructure: gas stations shall install charging station every x km, chicken-egg-problem: incentives/subsidies or law?
- Smart Infrastructure:
- Sensors in the car are in most cases more useful than in the infrastructure ▯ V2V sufficient on highways
- Sensors in infrastructure only for nodes and places with high traffic density of many different modes
- Rule of thumb: for short distances ▯ infrastructure, for long distances ▯ vehicles
- Data: who has data ownership? ▯ current developments show that regulations and changes are possible (e.g.: Deutschland Ticket)
- "If price is favorable, the customer is the product with his data " - data is part of the business model
- Exchanging data from 2 different owners is difficult

8. <u>German Researcher Battery Electric Truck Charging and Grid Integration</u>
- Today available grid connection at most transport company hubs is not sufficient for BET fleet (often not even for single truck)
- Bidirectional Charging for BET is an additional business model creating revenue during standstill ("Secondary Use Cases")
- Dependent on power and capacity of battery
- Primary use case shall not be affected negatively
- Separation in "Behind-the-Meter" (BTM) and "Front-of-the-Meter" (FTM):
- BTM: on client side, no regulatory, bidirectional charging station and smart control is sufficient
- FTM: technical implementation possible trough aggregation of multiple vehicles and sites (virtual power plant)
- Regulatory complex (double grid charges, taxation for mobile energy storages, benefits for stationary storages)

- Is energy coming from vehicles to grid "green energy"? Usually "grey energy"
- Different markets offer different products and have different entry requirements (FTM):
- Balancing power markets: min. 1 MW available power (MCS or aggregating of HPC chargers)
- Spot market, trading (Day-ahead, Intraday): trading in 0.1 MWh multiples -> results in minimum fleet size in order to participate
- BEV and BET can push fossil power plants out of market, no competition among the vehicles at first, demand for grid services increases due to increasing (fluctuating) renewable energy generation
- Calculations on possible revenue dependent on base scenario (just charging, smart charging behind-the-meter)
- Ranges from 600-800 €/y for electric vehicles and 12-15.000 €/y for trucks

9. <u>CEO of Dutch Connected Car Company</u>

- ADAS and V2I are main trends for private vehicles, autonomous driving is rather a hype
- ADAS is a trend, but needs more R&D, current systems often have flaws
- Communication between vehicles and infrastructure can improve safety and comfort as well as reduce costs
- Assisted vehicles have many expensive components onboard due to legal situation, however utilization of systems is low
- ADAS key components: cameras in combination with Lidar
- Technology installed in the infrastructure instead of onboard installation is more scalable would increase utilization and reduce costs for private cars (ADAS components are a relevant share of total car costs)
- For trucks this is not a concern – teleoperation in combination with L3 autonomous driving and platooning could increase utilization while full autonomous driving is not possible yet)
- Key question: who takes the responsibility?
- Data must be handled confidentially and transparently (e.g. labels and certificates for security)
- Companies should cooperate with cities and municipalities (e.g. european Innovation Partnerships, EIP)
- Traffic management system players focus on devices and infrastructure, space for new players who deal with data
- Can OEMs fill that space and provide intelligent infrastructure (comparable with charging infrastructure)

10. <u>Manager of Dutch Interest Organization (RAI)</u>

- NL is a supplier nation within the mobility sector with strong dependencies to GER and has many small flexible companies
- NL has a Focus on digitalization and the mobility environment as a whole
- Digital traffic management and connected infrastructure: hard to export
- NL companies are mainly not integrators, but rather in the beginning of the chain (Tier 3)
- OEM within truck field: DAF (Paccar), VDL, research on H2-combustion engine
- High tech companies: Philips spinoffs; semiconductors: ASML, NXT
- Navigation: Tom Tom
- Charging Hubs + bidirectional charging have business potential in GER, problems: congestion in electricity grid, grid connection
- BEV is main route for passenger car, mixed with H2 in heavy duty area (TCO are driver for technology decision)
- Cell makers invest in German
- Challenges:
- Geo-political situation (i.e. Chinese software ban)
- Grid expansion to avoid congestion is necessary, H2 infrastructure would be important for the use of H2 trucks

11. <u>Dutch Automotive / Mobility Professor</u>

- Smart Mobility / Responsible Mobility: (Very broad knowledge in topics of mobility)
- Digitization / Connectivity more important for passenger cars
- Even though Tesla and Waymo make great progress, technology for AD not quite there yet
- Technology for AD not smart enough, European way is better, because it considers collaborative part
- Overall mobility system should be considered for AD to decrease emissions, congestions and other externalities
- Important: User acceptance and ethics for AD: how to avoid trolly problems? How to sustain livable spaces?

- More work on collaborative actions needed: more communication between infrastructure and vehicle
- The right information better than just any form of data: conscious data handling
- Smart infrastructure is struggling due to the financing situation, government is mostly paying for smart systems, but they could also benefit due to savings in maintenance, etc.
- Telecommunication companies see business case in data exchange
- Large Companies have biggest influence rather than SME
- SME: sensor and algorithm development: "Adding smartness to the vehicle"
- For trucks AD is needed faster
- Zero emission technology:
- There is not only one solution for trucks because of different use cases
- SMEs can produce very customized products in smaller quantities for truck sector
- SMEs can bring smartness to the passenger cars with software (battery management systems, etc.)
- Combination of Smart+Electrified+AI is needed for planning of future scenarios of electric and smart vehicles
- Data security very important, EU regulations needed for easy data transfer within Europe
- China dependency: Software from China should not be trusted; BEV market is also struggling due to rare resources
- All hands on deck are needed

12. <u>Transportation Expert (Dutch Ministry - RVO)</u>

- Relevance of Chips is increasing
- Number of chips increases from around 1.000 to 4.000 per car, chips are used in cars and infrastructure
- Architecture is changing, high demand for software, sensors and (cyber) security
- Digital Maps: Cars need maps and software, just using google maps won't be enough, HD Maps deliver important information for ADAS/AD
- Centralized Computing, Edge Computing, Cloud Computing
- Computing, analyses and decisions should be possible in the car to accelerate reaction time and avoid additional data transfer (Edge Computing)
- Legal Challenges:
- Systems are often closed and do not allow sharing and collecting data, OEMs do not have interest in sharing data
- Who owns the data? Are companies willing to share the data? Responsibilities unclear
- NL has expertise in the field of Smart Charging
- NL company developed "gold standard" communication protocol, bidirectional charging pilot projects in collaboration with energy operators
- Unclear role for OEMs in bidirectional charging can be a hurdle since they want to earn money, but their battery can wear off
- China is battery supplier, but Europe can deliver battery management (chips, software)
- New field: tracing critical materials; smart information about batteries
- NL is supplier for lightweight and composite materials: could be interesting for truck market (niche topic)

13. <u>Former RAI Director</u>

- Charging Infrastructure for BET is not ready yet and not fast enough for BET rollout (OEMs are ready)
- Grid development is not fast enough
- High speed charging network along highways is important
- Digital infrastructure should be connected to heavy duty charging, digital standards should be established for charging solutions
- Focus of NL currently physical part and hardware, NL can offer a lot
- Experience from infrastructure for passenger cars can be used for heavy duty, service is also important in addition to hardware
- Hydrogen-propulsion will be important to close gap to carbon neutral transport since electrification can not cover 100%
- Hydrogen infrastructure could be problem
- Collaboration between stakeholders important for infrastructure development and energy transition
- Includes energy and logistic sectors, organization difficult, strategic discussion should be early in process
- Government is mostly responsible for transition and investments into infrastructure
- Smart Infrastructure and V2G: Europe has a lot of infrastructure due to high population density, but industry is lacking momentum in Europe

- 50% of traffic lights in NL are already smart, NL has a lot of practical experience
- No business model yet, especially big companies do not recognize new business models yet (main industry is not vehicle industry anymore)
- Harmonizing regulation on European level is important, German-Dutch cooperations could be forerunners
- Smart infrastructure is strongly connected with data and cyber security, harmonization for data use (also for business purposes) is needed in EU
- Battery technology: numerous Dutch companies, re-use and recycling of material

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