Proceedings of the 10th International Conference on Civil Structural and Transportation Engineering (ICCSTE 2025)
July 18, 2025 - July 20, 2025 | Imperial College London Conference Center, London, United Kingdom
Paper No. 121
DOI: 10.11159/iccste25..121

Sustainable Drivetrain Concepts in Earth-moving Machinery: A Systematic Market and Literature Research

Adrian Josef Huber[1], Eva Maria Dondl[1], Johannes Fottner[1]
[1]Technical University of Munich – Chair of Materials Handling, Material Flow, Logistics
Boltzmannstraße 15, 85748 Garching, Germany
adrian.huber@tum.de; eva.dondl@tum.de, j.fottner@tum.de

Abstract **-** Mitigating climate change and reducing carbon emissions across all industries represents one of the most significant challenges of the 21st century. The earth-moving machinery industry has been largely overlooked in research initiatives aimed at reducing greenhouse gas emissions. The majority of earth-moving machinery is currently powered by fossil diesel, and it is not yet evident which sustainable fuel will emerge as a viable alternative. The objective of this study is to identify sustainable drivetrain concepts that can be employed to operate earth-moving machinery in a variety of applications. A market analysis of five major earth-moving machine manufacturers focusing on the drivetrains of various machine categories is conducted. The results indicate that only one in 20 products offered in Europe is equipped with a sustainable drivetrain, while the current overall market share remains at approximately one percent. For existing vehicles, HVO100 and e-fuels represent promising alternatives. For new machines, in addition to electrification through battery-electric or cable-connected drivetrains, hydrogen combustion engines exhibit high potential, particularly in addressing the partial lack of electrical infrastructure on construction sites. A diversification of drivetrains in the earth-moving machinery sector will likely occur, presenting challenges for both manufacturers and contractors.

Keywords**:** sustainable drivetrains, earth-moving machinery, construction equipment, sustainability, civil engineering

1. Introduction

As stated by the Intergovernmental Panel on Climate Change, a committee of the United Nations Environment Programme, anthropogenic greenhouse gas emissions are the leading cause of climate change [1], [2]. The continued increase in global carbon emissions highlights the need for researchers to focus their attention on the reduction of emissions in the construction machinery industry [3]. Mobile machinery accounts for 1.3% of total greenhouse gas emissions, a figure that is comparable to that of shipping and aviation [4]. In Europe, the construction machinery's use of fossil diesel is responsible for the emission of 100 million tons of carbon dioxide annually [5], [6]. Compared to other industries, for earth-moving machinery, there is still no clear roadmap as to which carbon-neutral drivetrain concept is viable for various construction scenarios and tasks. Especially the challenge of operating machinery on uneven ground, in dusty environments, with a high variance of power demand, and limited access to charging infrastructure inhibits the transition.

Given the considerable diversity in construction machinery, the focus of this paper is on earth-moving machinery [5]. According to the standards set forth in DIN EN ISO 6165:2022, an earth-moving machine is defined as a 'self-propelled or towed basic machine [...] on wheels [...], tracks or stabilizers, which may have attachments [...] and/or working equipment [...], primarily designed for digging, loading, transporting, drilling, spreading, compacting or milling earth, rock and other materials [7]. In contrast with the prevailing view, König [5] excludes compaction equipment from the category of earth-moving machinery in his comprehensive study, 'Machines in Construction Operations'. This study follows König's assertion and excludes compaction equipment from its scope.

2. Market Analysis

2.1. Procedure

A situation analysis following the methodology proposed by Grimm [8], is conducted to determine the current state of drivetrain concepts. Firstly, it is first necessary to define the market in question [8]. The focus lies on the European market and the number of major manufacturers is limited to five. It is not feasible to conduct an exhaustive analysis of all potential manufacturers within the confines of this study as it would likely have yielded minimal to no additional insights. The turnover, defined as the number of units sold multiplied by the price per unit, is selected as the most suitable parameter for determining the relevance of each manufacture [9]. Using turnover instead of the number of units sold is important, as it also accounts for the size of the machine, which in turn affects engine power and correlates closely with carbon emissions. As European sales figures for earthmoving machinery are not publicly available for every manufacturer, global sales figures for 2022 were used.

The world's leading manufacturers of construction machinery, in descending order of sales volume, are Caterpillar, Komatsu, XCMG, John Deere, Sany, Volvo Construction Equipment, Liebherr, and Hitachi Construction Machinery [10]. However, John Deere only offers two product categories of earth-moving machinery, and thus is not considered further in the following analysis [11]. XCMG and Sany are primarily active in the Chinese market and have relatively low sales figures in Europe. However, due to a lack of transparency regarding their business figures, it is not possible to provide further substantiation of this assumption. Accordingly, the market analysis concentrates on Caterpillar, Komatsu, Volvo CE, Liebherr, and Hitachi CM. Furthermore, only products that explicitly comply with the current European emissions standard Stage V and are sold in Europe are analysed. Key figures include the machines' engine power, operating weight, predominant drivetrain system, and application scenario [8].

2.2. Results from Market Analysis

Analysing a total of over 500 product data sheets revealed that a mere 5% of the earthmoving equipment currently available within the European market employs a carbon-neutral drivetrain. The most common are battery-electric vehicles (BEV) and cable-connected electric vehicles (CCEV). Also, it should be noted that some engines have already been approved for use with the alternative fuel HVO100 [12]. The decision to use HVO100 is contingent upon the user. HVO100 remains considerably less accessible and more costly than fossil diesel [13]. Across all categories, irrespective of size, 3.5% of wheel loaders and 7% of excavators are equipped with sustainable drivetrains. In the case of certain product categories, such as articulated dump trucks and backhoe loaders, only diesel-powered products are available. Products within the machine class of hydraulic cable excavators are offered exclusively as CCEV.

3. Classification of Earth-moving Machinery

The multifaceted responsibilities of earth-moving machinery result in the existence of an extensive range of machines. In contrast to the prevailing practice in other industries, a universal approach to powering earth-moving machinery sustainably is, therefore, untenable. Prior to further analysis, it is necessary to classify earth-moving machinery into distinct categories based on key characteristics. In addition to the characteristics of the equipment itself, the employment location and duration of use play an essential role. The existing infrastructure is of particular importance, as the equipment is generally lacking in mobility. A distinction is thus drawn between sites with and without electrical infrastructure.

It is not possible to determine typical operation times to a reasonable degree of accuracy within the context of this analysis, given the paucity of publicly accessible data. To address the research question, there is thus a distinction between two general categories of operation: short operations, which last for a maximum of three hours per 24 hours, and long operations, which last for a maximum of eight hours per 24 hours. In all operational scenarios, it is assumed that the uninterrupted operating time will be at most six hours. This assumption is based on the stipulations of EU labour legislation, which requires employees to take a break after six hours of work [14].

Furthermore, equipment locomotion patterns influence drivetrain feasibility. The following subdivisions are established:

- Short locomotion patterns: during the entirety of one operation cycle, the machine covers only short distances (less than 50 m)
- Medium locomotion patterns: During operation, the machine covers medium distances (between 50 m and 1 km) with a high variance and alternating locomotion patterns.
- Long locomotion patterns: during operation, the machine covers long distances (over 1 km) and/or at high speed (greater than 10 km/h).

Table 1 presents an overview of select equipment and its most relevant characteristics. The characteristics are based on the analysis of 162 product data sheets from Caterpillar, 127 from Komatsu, 81 from Liebherr, 76 from Volvo CM, and 56 from Hitachi CM, resulting in an overall sample size of 502. The findings were condensed significantly to create a concise categorization of the most essential categories.

Table 1. Overview of Select Earthmoving Equipment with Relevant Characteristics

Equipment Category	Typical Operating Weight [t]	Typical Engine Power Output [kW]	Locomotion Pattern	Typical Duration of Operation [h]
Hydraulic Excavator - Mobile	9 - 28	50 - 160	medium	6
Hydraulic Excavator - Crawler	9 - 100	55 - 300	short	6
Compact Excavator	1-10	5,5 - 55	short	6
Hydraulic Cable Excavator	800 - 1400	540 - 1350	short	6
Small to Medium Wheel Loader	2,5 - 20	35 – 150	long	6
Medium to Large Wheel Loader	15 -250	150 - 1300	long	6
Dump Truck (articulated steering)	22 - 55	200 - 500	long	6
Dump Truck (rigid frame)	30 - 370	260 - 2600	long	6
Bulldozer	7 - 50	50 - 300	long	6
Backhoe Loader	7 - 10	50 - 82	long	6
Grader	12 - 34	90 - 227	long	6

4. Evaluation and Allocation of Drivetrain Concepts

The following criteria were considered in the selection of potentially viable sustainable drivetrains:

- Emissions during operation and production of the power source
- Use of critical raw materials
- Infrastructural requirements
- Charging & refueling time
- Weight of the entire drivetrain
- Overall energy efficiency
- Technology maturity level
- Possibility of retrofitting machinery
- Restrictions in mobility

Fuel cell electric vehicles (FCEVs), battery electric vehicles (BEVs), cable-connected electric vehicles (CCEVs), hydrogen combustion engines (HICE), as well as e-fuels and HVO100, meet the criteria.

4.1. Evaluation of Existing Machines

Given the lengthy product lifecycles of construction machinery, it is neither economically nor environmentally feasible to immediately replace all existing machines. HVO100 and e-fuels are compatible with existing diesel engines and have similar everyday use properties, enabling a straightforward transition [15]. The combustion of HVO100 or e-fuels produces emission values that are comparable to those of fossil diesel, but both require carbon dioxide that is already present in the atmosphere during production, resulting in a closed cycle and only negligible new carbon emissions [15], [16]. HVO100 is currently available for purchase in numerous European countries [17]. However, the current supply is insufficient to meet the needs of all existing vehicles [15], [17]. E-fuels are often regarded as a more sustainable alternative, but data indicate that the quantities are not sufficient in the near future [15].

4.2. Evaluation of New Machines

In contrast to legacy machinery, newly produced earth-moving machinery offers a broader array of viable alternatives. In terms of overall efficiency and technological readiness level, (TRL), BEV and CCEV are most advantageous [18], [19], [20]. The latter option offers the advantage of minimal complexity and investment costs [18]. Given that these are accompanied by a limitation regarding the range of locomotion, they are only realizable for a relatively small quantity of machinery in select application scenarios [21]. Both drivetrain concepts necessitate the presence of adequate infrastructure on-site, particularly grid connection. For the BEV, it is also necessary to ensure that the machine's power demand is proportional to its operating weight.

As BEVs allow for greater flexibility in various construction scenarios and infrastructural prerequisites, they are, at least for smaller, mobile machinery, more favorably received by the market than CCEVs. A combination of BEV and CCEV is a combination particularly well-suited for wheeled excavators with medium power requirements. In cases where infrastructural prerequisites, process-related locomotion patterns, and power demands are incompatible with electrified machines, fuel cells can be utilized for power generation. Fuel cells are generally susceptible to damage from polluted air and vibrations, which are prevalent on construction sites [23], [24]. Furthermore, high peak energy demands are challenging to meet. Nevertheless, fuel cells can be employed as stationary energy provision, especially as up to power outputs of 350 kW, fuel cells prove advantageous compared to HICEs [24]. While some OEMs are currently engaged in the prototyping phase for HICEs in mobile machines, FCEVs remain below the TRL five threshold.

In comparison to e-fuels, hydrogen-powered equipment necessitates the implementation of considerably more intricate refueling methodologies [25]. HICE and FCEV both require a considerable amount of energy to refuel, due to the necessity of compressing the hydrogen. At this time, it is not yet evident which drivetrain systems will ultimately prevail in the context of mobile earth-moving machinery applications. Ultimately, the debate might come down to the question of whether hydrogen or e-fuels can be offered on-site at a lower price point. Figure 1 illustrates a possible allocation of drivetrain concepts in construction sites with and without grid connection. Furthermore, the analysis is divided into two categories: market-ready solutions (TRL nine) and future solutions (TRL five and below). In the areas delineated by a striped pattern, for equipment with short locomotion patterns, CCEVs are feasible. The graphic does not differentiate between individual equipment categories but rather divides earthmoving machinery as a whole by power and operating weight.

4.3. Analysis of Select Construction Site Ecosystems

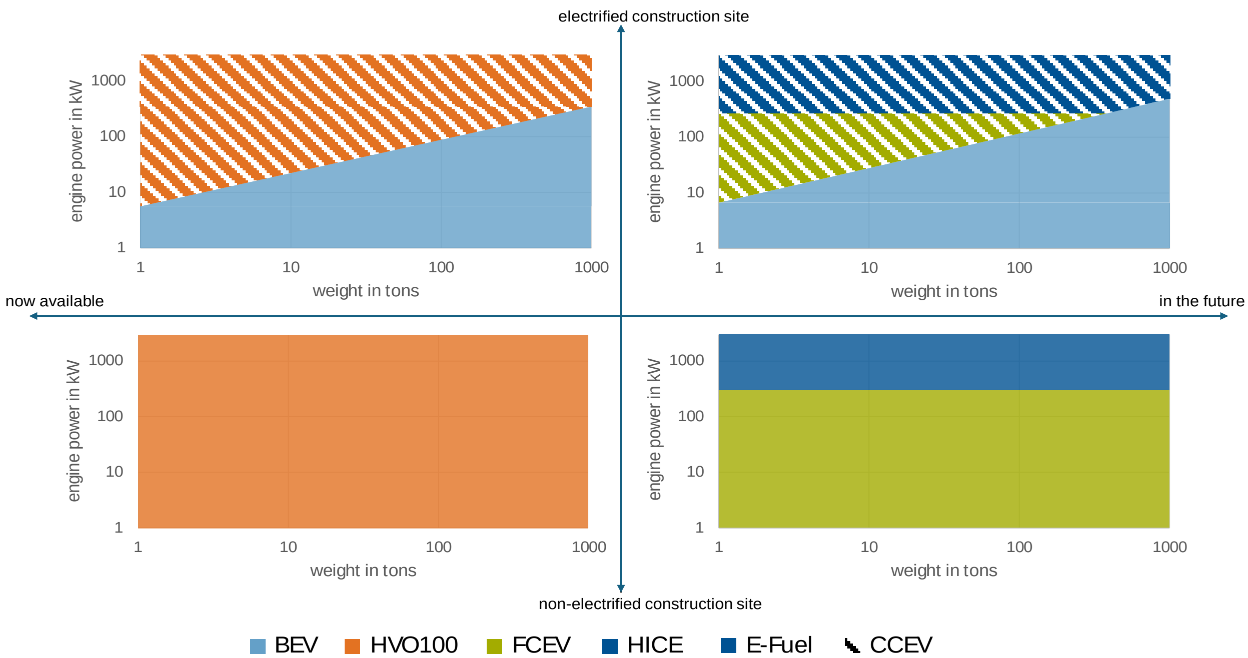

Fig. 1 Allocation of the drivetrain depending on power supply, engine power, and operating weight

As a novel approach to the investigation of sustainable drivetrain feasibility for earthmoving machinery, different construction site ecosystems and application scenarios are considered in the following. It is uncommon for earth-moving machinery to operate in isolation during a construction process. In the majority of cases, the equipment performs one step in a chain of construction processes, working in conjunction with a variety of other machinery within the context of broader construction site ecosystems. The composition of drivetrain types on a given construction site is, hence, of great consequence. With respect to their influence on sustainable drivetrain feasibility, three distinct construction site scenarios are analysed. Firstly, applications of earth-moving equipment in gardening and landscaping, which entail low power requirements and exhibit short process times, are evaluated. Furthermore, these activities frequently occur in locations with established electrical infrastructure. BEVs and CCEVs represent a highly promising alternative to conventional machinery as in most cases, a grid connection is already in place. Industrial applications, on the other hand, use more powerful equipment with industry-specific operating times and cycles. In the case of brief operating periods, the transition to BEV can be initiated easily, for the equipment is always operated within the same location. For industry applications where extensive locomotion and continuous operation are required, other drivetrain concepts may become feasible. The currently available

HVO100 solution will most likely be replaced by HICE or e-fuels. The diversification of energy supply and drivetrain concepts will become apparent in the long term.

In road and highway construction, utilization of electrified equipment is challenging, as the electric power supply is often inadequate. Also, the hydrogen infrastructure remains underdeveloped, rendering the use of HVO100 the sole viable option in the short term. For future machines, e-fuels and HICE represent the most viable alternative from an economic, ecological, and processual standpoint. As infrastructural circumstances evolve, the utilization of electricity may become more prevalent, with e-fuels and hydrogen contributing to the diversification of energy sources. Equipment in road construction will most likely become electrified to the extent of a battery capacity of up to around 100 kWh. Table 2 summarizes the findings and showcases machine park compositions in current and future road construction scenarios.

Table 2. Earth-moving Equipment and Alternative Drivetrain Concepts in Road Construction

Equipment Category	Typical operating weight [t]	Typical Engine Power output [kW]	Current Drivetrain	Future Drivetrain (no grid connection)	Future Drivetrain (grid connection)
Mobile Excavator	9 - 28	50 - 160	HVO100	HICE or E-Fuels	BEV & CCEV
Crawler Excavator	9 - 25	55 - 120	HVO100	HICE or E-Fuels	BEV
Crawler Excavator	21 - 100	121 - 300	HVO100	HICE or E-Fuels	BEV & CCEV
Small Wheel Loaders	10 - 20	35 – 150	HVO100	HICE or E-Fuels	BEV
Large Wheel Loaders	15 - 53	144 - 300	HVO100	HICE or E-Fuels	HICE or E-Fuels
Dump Trucks (articulated)	22 - 55	200 - 470	HVO100	HICE or E-Fuels	HICE or E-Fuels
Heavy-duty Dump Trucks	30 - 370	260 - 2600	HVO100	HICE or E-Fuels	HICE or E-Fuels
Bulldozer	3 - 50	50 - 300	HVO100	HICE or E-Fuels	HICE or E-Fuels
Grader	3 - 50	50 - 300	HVO100	HICE or E-Fuels	HICE or E-Fuels

5. Discussion

5.1 Discussion of Results

Presently, HVO100 is the sole means of ensuring a more sustainable construction process across a multitude of construction applications, machine types, and legacy machines. The HICE, as an alternative to HVO100, is currently in the process of being implemented in machines that are nearing series production [25]. The probable diversification of drivetrain types across equipment in the future, in addition to the potential for divergence across construction site ecosystems, presents a significant challenge for both manufacturers and contractors. For manufacturers, the expansion of the portfolio necessitates investment in expertise, supplier network, and production system. For smaller manufacturers with a limited product range, an effective strategy for developing a more sustainable product portfolio is to conduct a detailed analysis of their individual customers, their construction processes, and the optimal drivetrain concept to achieve the construction task. If similar requirements across equipment types exist, the transition to a unified sustainable drive system can streamline complexity and reduce investments.

The provision of sufficient energy for a diverse range of machinery with fluctuations in machine park composition and varying energy demands is a significant challenge for contractors. It remains to be seen whether the additional expense of supplying diverse energy sources and maintaining different drivetrain concepts is offset by the benefit of being able to select the most efficient and optimal drivetrain configuration for each individual machine and application. Construction companies with a limited machine portfolio may find it more feasible to specialize in one drivetrain concept. Nevertheless, they may find themselves constrained in their ability to accept contracts for construction sites that lack the necessary infrastructure. Conversely, failure to invest in sustainable machinery may preclude contractors from certain projects.

The extent to which drivetrain diversification will materialize in the long term is, according to the current state of research, uncertain. The distribution between HICE, HVO100, and e-fuels is a particularly contentious issue. It is unlikely that HICEs and e-fuels will coexist within construction sites in the long term. It is similarly unclear whether the FCEV can be integrated into construction site ecosystems. In the presence of suitable framework conditions (no grid connection, clean air, low vibration, low impacts, and minimal peak power demand), the FCEV represents an efficient alternative.

5.2 Limitations

A comprehensive analysis of the economic framework would necessitate the examination of internal data from a diverse range of companies and has, therefore, been neglected. Nevertheless, it is imperative for companies to operate within the parameters of the market and to achieve profitability. It is thus probable that contractors will continue to rely predominantly on fossil diesel rather than the more expensive HVO100. In the absence of regulatory measures, contractors and manufacturers are currently unable to profit economically from the transition to sustainable drivetrains.

A significant limitation of this study is that it exclusively examines the European market for earth-moving machinery. In other markets, particularly in developing countries, the construction industry frequently utilizes previously owned machinery from developed countries in second-life applications, thereby extending the product life cycle even further. Infrastructural conditions, particularly in remote areas, are frequently inadequate. Nevertheless, the findings of this study are not contingent on particular European emission standards or other external factors and can be applied to different countries and regions.

6. Summary and Contribution

This paper concludes with a listing of the most significant findings and novel contributions that have emerged from the analysis:

- All types of earth-moving equipment, both existing and new, can be operated more sustainably.
- In the short term, the demand for alternative fuels, particularly HVO100, will rise in response to legislative mandates requiring contractors to adopt more sustainable operational practices.
- In construction sites where a grid connection is in place, operations be likely performed using a combination of battery-electric vehicles (BEV) and cable-connected vehicles (CCEV)
- The prospective diversification of drivetrains presents a set of challenges for both manufacturers and contractors. It is not yet evident which type of internal combustion engine will gain the greatest market share. Ultimately, economic viability will likely supersede technical considerations.
- Despite the advent of alternative energy sources, internal combustion engines remain a vital component of the earthmoving machinery industry.

References

[1] Intergovernmental Panel On Climate Change (Ipcc), Ed., "Emissions Trends and Drivers," in *Climate Change 2022 - Mitigation of Climate Change*, 1st ed., Cambridge University Press, 2023, pp. 215–294. doi: 10.1017/9781009157926.004.

[2] U. Nations, "Causes and Effects of Climate Change," United Nations. Accessed: Jan. 07, 2025. [Online]. Available: https://www.un.org/en/climatechange/causes-and-effects-climate-change

[3] "Global CO2 emissions by year 1940-2024 | Statista." Accessed: Jan. 07, 2025. [Online]. Available: https://www.statista.com/statistics/276629/global-co2-emissions/

[4] A. Roy, B. Y. McCabe, S. Saxe, and I. D. Posen, "Review of factors affecting earthworks greenhouse gas emissions and fuel use," *Renew. Sustain. Energy Rev.*, vol. 194, p. 114290, Apr. 2024, doi: 10.1016/j.rser.2024.114290.

[5] H. König, *Maschinen im Baubetrieb: Grundlagen und Anwendung*. in Leitfaden des Baubetriebs und der Bauwirtschaft. Wiesbaden: Springer Fachmedien, 2014. doi: 10.1007/978-3-658-03289-0.

[6] B. Europa, "Norwegian cities lead the way in reaching zero-emissions in construction sites," Bellona.org. Accessed: Jan. 07, 2025. [Online]. Available: https://bellona.org/news/zecs/2021-03-norwegian-cities-lead-the-way-in-reaching-zero-emissions-in-construction-sites

[7] "ISO 6165:2022(en), Earth-moving machinery — Basic types — Identification and vocabulary." Accessed: Jan. 07, 2025. [Online]. Available: https://www.iso.org/obp/ui/en/#iso:std:iso:6165:ed-7:v1:en

[8] R. Grimm, M. Schuller, and R. Wilhelmer, *Portfoliomanagement in Unternehmen: Leitfaden für Manager und Investoren*. Wiesbaden: Springer Fachmedien, 2014. doi: 10.1007/978-3-658-00260-2.

[9] S. M. Abbasi and K. W. Hollman, "Turnover: The Real Bottom Line," *Public Pers. Manag.*, vol. 29, no. 3, pp. 333–342, Sep. 2000, doi: 10.1177/009102600002900303.

[10]“Construction equipment manufacturers: world equipment sales 2023 | Statista.” Accessed: Jan. 07, 2025. [Online]. Available: https://www.statista.com/statistics/280343/leading-construction-machinery-manufacturers-worldwide-based-on-sales/
[11]“Construction Equipment | John Deere US.” Accessed: Jan. 07, 2025. [Online]. Available: https://www.deere.com/en/construction/
[12]W. Härle and R. Geyer, “HVO fuel for Liebherr machines.” Accessed: Jan. 07, 2025. [Online]. Available: https://www.liebherr.com/en-de/group/products/solutions/hvo-at-liebherr/hvo-at-liebherr-3704753
[13]G. Lorenzi, P. Baptista, B. Venezia, C. Silva, and M. Santarelli, “Use of waste vegetable oil for hydrotreated vegetable oil production with high-temperature electrolysis as hydrogen source,” *Fuel*, vol. 278, p. 117991, Oct. 2020, doi: 10.1016/j.fuel.2020.117991.
[14]“Working hours in EU: What are the minimum standards?,” Your Europe. Accessed: Jan. 07, 2025. [Online]. Available: https://europa.eu/youreurope/business/human-resources/working-hours-holiday-leave/working-hours/index_en.htm
[15]A. Odenweller and F. Ueckerdt, “Probabilistic feasibility space of scaling up green hydrogen supply,” 2022. Accessed: Jan. 07, 2025. [Online]. Available: https://www.semanticscholar.org/paper/Probabilistic-feasibility-space-of-scaling-up-green-Odenweller-Ueckerdt/8edeeb02c4a98043f853455be22993b9123ccc98
[16]F. Ueckerdt, C. Bauer, A. Dirnaichner, J. Everall, R. Sacchi, and G. Luderer, “Potential and risks of hydrogen-based e-fuels in climate change mitigation,” *Nat. Clim. Change*, vol. 11, no. 5, pp. 384–393, May 2021, doi: 10.1038/s41558-021-01032-7.
[17]“EU biodiesel production 2023 | Statista.” Accessed: Jan. 07, 2025. [Online]. Available: https://www.statista.com/statistics/1485234/eu-biodiesel-production/
[18]I. Stadler and M. Sterner, Eds., *Energiespeicher: Bedarf, Technologien, Integration*, 2. korrigierte und ergänzte Auflage. Berlin: Springer Vieweg, 2017.
[19]M. Doppelbauer, *Grundlagen der Elektromobilität: Technik, Praxis, Energie und Umwelt*, 1st ed. 2020. in Springer eBook Collection. Wiesbaden: Springer Fachmedien Wiesbaden, 2020. doi: 10.1007/978-3-658-29730-5.
[20]R. Korthauer, *Handbuch Lithium-Ionen-Batterien*, 1st ed. Berlin, Heidelberg: Springer Berlin / Heidelberg, 2013.
[21]A. Villaumé, “Two new local zero emission excavators from Liebherr: R 976-E and R 980 SME-E electric crawler excavators - Liebherr.” Accessed: Jan. 07, 2025. [Online]. Available: https://www.liebherr.com/en-de/n/two-new-local-zero-emission-excavators-from-liebherr-r-976-e-and-r-980-sme-e-electric-crawler-excavators-26263-3704916
[22]“Energiespeicher - Bedarf, Technologien, Integration | SpringerLink.” Accessed: Jan. 07, 2025. [Online]. Available: https://link.springer.com/book/10.1007/978-3-662-48893-5
[23]M. Ziegler, “Seine hohe Energiedichte spricht für den Wasserstoff,” *MTZ - Mot. Z.*, vol. 84, no. 2–3, pp. 24–27, Feb. 2023, doi: 10.1007/s35146-022-1437-y.
[24]M. Schrank, V. Langer, and B. Jacobsen, “Metastudie zu Wasserstoffverbrennungsmotor veröffentlicht.” Accessed: Jan. 07, 2025. [Online]. Available: https://www.now-gmbh.de/aktuelles/pressemitteilungen/metastudie-zu-wasserstoffverbrennungsmotor-veroeffentlicht/
[25]H2 Mobility, “Wasserstofftanken im Schwerlastverkehr.” Accessed: Jan. 07, 2025. [Online]. Available: https://h2-mobility.de/wasserstoffbetankung-im-schwerlastverkehr/