Electric drives offer energy-efficient tamping

Real operating data recorded over a long period have demonstrated the energy-saving potential of Plasser & Theurer's electric drive technology, as well as reducing exhaust emissions

Thomas Radler, **Lukas Hofmann**, **Christian Koczwara** and **Markus Buchner**
Plasser & Theurer*

Sustainability and energy efficiency are clear priorities for the railway construction and maintenance sector. Many railway operators and infrastructure managers have set a target of becoming climate-neutral by 2040, in line with wider national commitments[1-3]. This in turn is driving a requirement to provide automated machine-specific verification of greenhouse gas emissions. And in some cases, that obligation is coming into force much sooner — it will apply in Sweden from this year, for example[4].

Fortunately, the track machine sector has been undergoing its own revolution, with the introduction of hybrid and all-electric drive concepts. Plasser & Theurer presented its first electrically powered tamping machine back in 2015, and over the past decade data has been collected to evaluate the operational performance and environmental impact of these new drives. It is now possible to harness that data to analyse the potential benefits of 'electrified' track maintenance machines.

Electrification options

With the introduction of the E³ tamping machine, it became possible to draw energy from the overhead contact line, to power both the travel to site and the working processes. The technology has since been further optimised, to the point where all rotary motion (traction and work-unit drives) can be powered electrically.

69%
of energy costs saved by all-electric operation compared with diesel

Electrically driven universal tamping machines that take power from the overhead line are now being used in several countries (Fig 1). Most still have a diesel-electric power pack for use when overhead power is not available. To further reduce the use of diesel engines, the next logical step was the development of battery powered machines. Last year, for example, Austrian Federal Railways started taking delivery of 56 zero-emission battery-electric-diesel maintenance vehicles (RG 7.23 p16).

Drive concepts

To assess the benefits of an electric drive, we compared the energy consumption of two modern continuous-action universal tamping machines — a Unimat

* **Thomas Radler** is a Data Science & Analytics specialist at Plasser & Theurer's Digital Services Department in Linz, where **Lukas Hofmann** is Team Lead. **Christian Koczwara** is R&D Scientist in the company's Research & Simulation Department, and **Markus Jürgen Buchner** is Senior International Product Manager for the MDZ product portfolio.

Fig 1. Electrically driven tamping machine with integrated ballast profiling and dynamic track stabilisation.

09-8x4/4S Dynamic and a Unimat 09-8x4/4S Dynamic E^3 (Fig 2). These are equipped with identical two-sleeper tamping units and Dynamic Track Stabilisers. Essentially, the only difference lies in the drive concept. The Unimat 09-8x4/4S has a conventional diesel engine and pump distribution gearbox. The traction drive for working travel is hydrostatic, while hydraulic eccentric drives power the vibratory movements.

By contrast, the E^3 tamping machine has a hybrid drive (Fig 3). It can be powered all-electrically from the overhead line or as a diesel-electric using the onboard power pack. The traction drive and all rotating work units are driven electrically. One clear advantage is that the amount of hydraulic oil required can be reduced significantly — usually by around two-thirds.

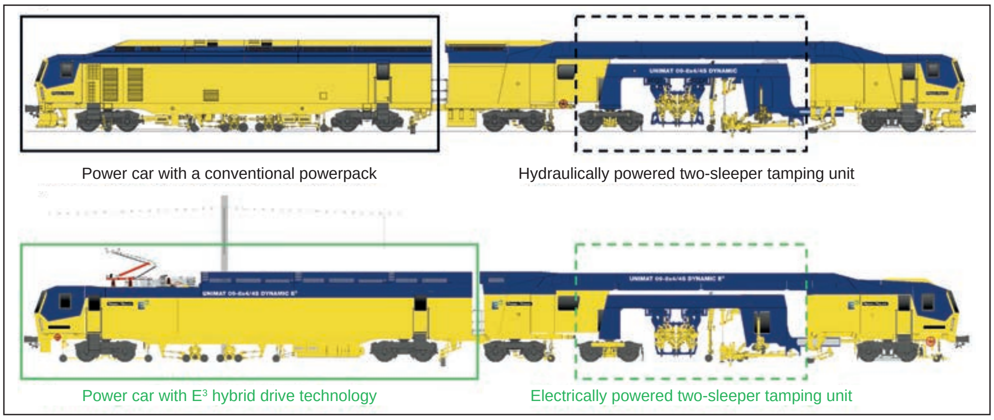
A hybrid drive means that the operating strategy can be optimised for every application. On non-electrified lines, or when the overhead line is switched off for maintenance, the energy required to operate the machine is provided by the diesel engine. This ensures independence and flexibility, but the machine operators still benefit from reduced fuel consumption thanks to the more efficient electric drives. This in turn means lower CO_2 emissions.

Such machines can be operated in a way that is almost carbon neutral. And if the more efficient operation using power from the overhead line can be combined with a comparatively favourable price for traction current, the operating costs will be even lower.

Reduced noise emissions

The European Union classifies ambient noise as one of Europe's main environmental problems (Directive 2002/49/EC), recognising that noise emissions have a negative impact on the environment and can also affect health. So the rail sector has been under pressure to make its own contribution to noise reduction. That is not limited to transport operations, but also applies to infrastructure construction and maintenance.

Several studies have demonstrated that electrically powered tamping machines are significantly quieter in operation than their diesel-powered counterparts[5,6]. In electric mode, the noise emission level was reduced by 19 dB(A), thanks to the elimination of noise from the diesel powerpack. That reduction was measured at a distance of 7·5 m from the track, in line with current standards. In the immediate vicinity, just 1 m from the machine, the reduction was more than 20 dB(A)[7].



Top: Fig 2. Two continuous-action tamping machines were used for the analysis: the diesel-hydraulic Unimat 09-8x4/4S Dynamic (top) and the electrically driven Unimat 09-8x4/4S Dynamic E^3.

Table I: Comparison between tamping operations using different drive technologies

	Diesel-hydraulic	Diesel-electric	Savings %
Tamping km evaluated	175	36	
Diesel consumption *l/km*	113	81	
CO_2 emissions *kg/km*	298	214	28
Energy costs *€/km*	169	122	

Data acquisition

The following analyses are based on data recorded by the Plasser Datamatic tool. This uses a railway-certified Machine Data Connector — an IIoT Edge Device, which is fully integrated into the machine control system to avoid any risk of interference.

Encrypted data are transmitted securely in real time using a mobile broadband connection, and made available via the web-based Machine Condition Observer platform.

The system is used to support a range of fleet management and other optional services; for example, automatically generating customised reports of machine performance every week or every shift. Thanks to the customisation function, data can be reported as interactive plots or individual map views as well as in table form.

A sample report showing energy consumption and emission data for a typical universal tamper can be found at **www.plassertheurer.com/performance-and-emissions-report**.

Analysis methodology

To enable a fair comparison between the E^3 and diesel-powered technologies, two machines with a matching configuration were selected. From the outset, care was taken to ensure that both machines were operating in the same geographical area, to minimise the impact of different infrastructure or working specifications.

Sections of comparable machine operation were then extracted from the aggregate data. Specifically, the analysis was limited to plain-line track tamping with one tamping cycle per sleeper, with the dynamic stabiliser being used proportionately in an approximately equal manner. As a first step, the working speeds were limited to a narrow range, but to highlight the general applicability of the results the evaluation has been extended to a wider range of working speeds.

A distinction was made between diesel-electric and all-electric operation of the E^3 hybrid drive. This shows that considerable advantages can be achieved by moving to diesel-electric operation, even if a pure electric option is not available.

Analysis results

Diesel-electric: We first compared a conventional diesel-hydraulic drive with the E^3 operating in diesel-electric mode. To achieve statistically meaningful results, the evaluation was conducted over a sufficiently large number of tamping kilometres (Table I).

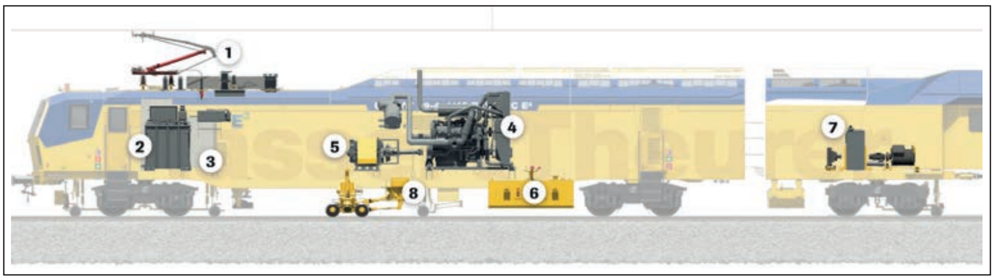


Fig 3. Schematic of the E^3 drive technology. 1 Pantograph, 2 Transformer, 3 Inverter, 4 Diesel Engine, 5 Generator, 6 Fuel tank, 7 Hydraulic Power Pack, 8 Dynamic Track Stabiliser.

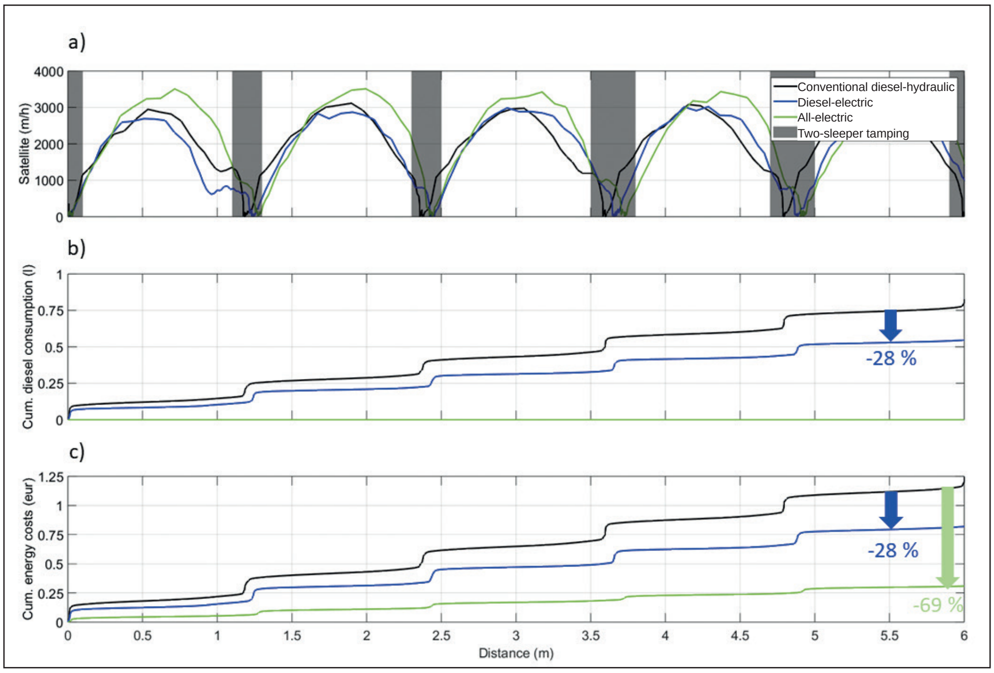


Fig 4. Cumulative diesel consumption and energy costs over a distance of 6 m for a representative section of satellite speed.

Diesel consumption was calculated based on the instantaneous consumption from the engine control unit, which is recorded via Plasser Datamatic. CO_2 emissions were then calculated from this as a 'tank-to-wheel' value, using a factor of 2·64 kg/l in line with ISO 14083[8]. The price of diesel was assumed to be €1·50 per litre.

Savings of 28% in diesel consumption were identified, thanks to the improved efficiency of the electric drive. The values may differ for other machine configurations, but in general the electric drive allows the diesel engine to be run at a lower rotational speed, which can be even more beneficial for older powerpacks.

All-electric: In all-electric operation, the energy drawn from the overhead line is measured via the machine control system and recorded using the Plasser Datamatic.

The power consumption for the tamping operation under the described conditions was 261 kWh/km. Using an electricity price of €0·20/kWh gives an energy cost of around €52/km for all-electric operation. That represents a 69% saving compared to the diesel-hydraulic drive.

All-electric operation can be considered to be emission-free at the point of use. Overall CO_2 emissions will of course vary, depending on the power generation mix. But in Austria 100% of traction energy is now drawn from renewable sources[9].

It is important to note that for this analysis, energy use at the worksite was analysed — this comparison does not take into account CO_2 emissions from energy production, which is why the diesel operation in Table I was assessed on the basis of tank-to-wheel rather than well-to-wheel.

Based on these assumptions, all-electric operation can save 69% of energy costs and 100% of the CO_2 emissions. A similar analysis can easily be undertaken for other conditions, particularly in regard to local electricity and diesel prices.

Energy savings compared

In addition to the statistical analysis, it is possible to show the energy savings visually using a short section of plain line. Fig 4 shows five consecutive single tamping cycles (with a two-sleeper tamping unit) for each configuration or operating mode analysed over a 6 m section of track. The speed and path of the tamping satellite were determined using a rotary encoder, and the curves show that both machines conducted their work at a similar speed.

The diesel consumption curve clearly shows the efficiency of the diesel-electric drive over the diesel-hydraulic version. Reductions in energy use of around 28% were achieved, giving a matching cost saving. Analysis of the all-electric drive showed the greater saving of 69%, confirming the results of our statistical analysis.

The same methodology has also been applied across a wider range of working speeds. Fig 5 shows that the relative numbers hold true almost irrespective of working speed. The reduction in specific energy costs with increasing working speed is notable, although the graphs have been truncated where the available data did not allow statistically valid conclusions.

This analysis only examined the energy efficiency of the actual tamping operations. However, there is potential for savings in other operating conditions. In conventional tamping machines, for example, up to 30% of diesel engine operating time is spent idling, whereas an all-electric operation would be much more efficient. This percentage may be even higher for other infrastructure machines, such as the Catenary Crafter overhead line inspection maintenance vehicles. And in addition to the energy savings, there are also benefits from lower maintenance and servicing costs.

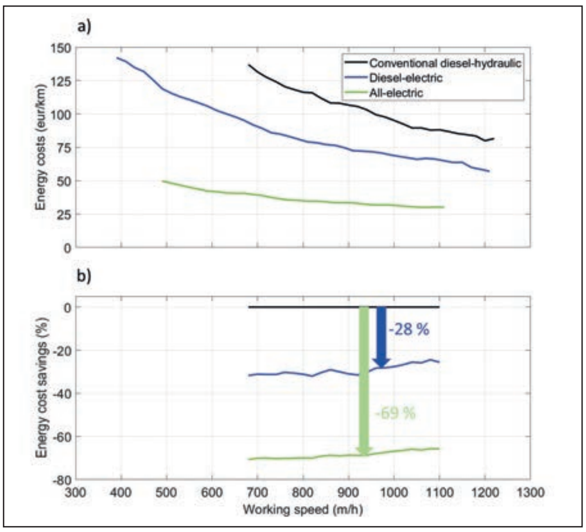


Fig 5. Switching from diesel to electric drives offers a significant reduction in energy costs at all working speeds.

References

1. Deutsche Bahn AG, Investor Relations and Sustainable Finance report 2023
2. South Western Railway, *Journey to a net zero future: Our roadmap to 2040*
3. DB AG, *Die Deutsche Bahn wird 2040 klimaneutral*
4. Löfberg A. Krav på digital miljörapportering. Lilleström, 2023
5. Auer F, Pumberger A and Jodlbauer G. Lärmreduktion Stopfen – schall-technische Vergleichsmessung, *Eisenbahn Ingenieur* 3/2019
6. Achs G and Floss S. Schalltechnische Untersuchung bei unterschiedlichen Antriebsarten von Stopfmaschinen, *ETR* 10/2023
7. Antony B, Auer F, Jodlbauer G and Pumberger A. Maschinenlärm lässt sich verringern, *ZEVrail* 11/2019
8. ISO 14083 (2023): Quantification and reporting of greenhouse gas emissions arising from transport chain operations
9. ÖBB-Infrastruktur AG, *100 Prozent grüner Bahnstrom*