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WHITE PAPER

# Improving transport efficiency

Advances and opportunities  
to accelerate sustainable transport





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# Transporting more people and freight with less energy

Transportation is an essential and integral part of our lives, and the world is looking for ways to reduce emissions and eliminate the use of fossil fuels. Therefore, we require cleaner and more sustainable modes of transport.

## Rail transport and efficiency

When we think of efficient methods of transport, our first thoughts are often about electric or hybrid cars and trucks and only rarely about mass transportation. Electric trains have been in use for well over 100 years and they are one of the most efficient modes of transport available. Even when trains are powered by fossil fuels, they are still significantly more efficient than cars and trucks. In fact, only 3% of the world's energy is consumed by railways even though they account for 9% of the world's passenger transport and 7% of freight transport.<sup>1</sup>

Railways are highly energy efficient for several reasons, the most important of which are their large carrying capacity of both passengers and freight, the high efficiency of the traction chain, and the very low rolling resistance of steel wheels on steel tracks. On average, trains are nearly 12 times more energy efficient than cars per passenger kilometer and 8 times more efficient than trucks per tonne of freight.<sup>2</sup>



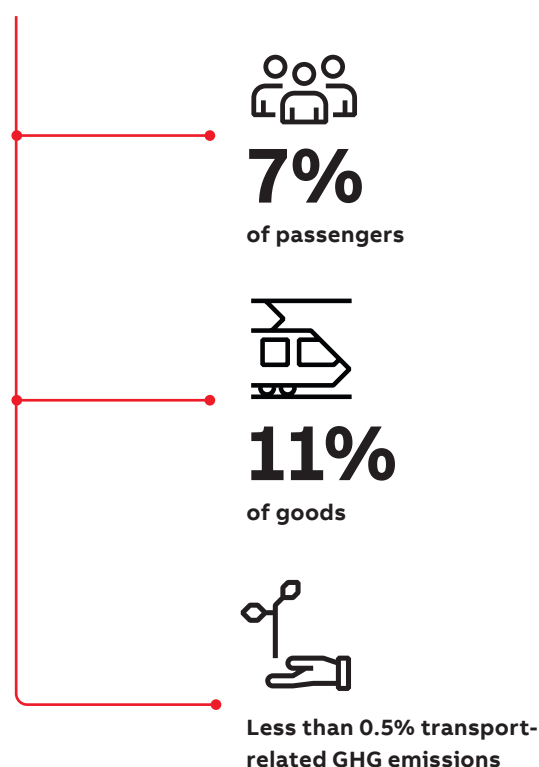
Technology developments have ensured that railways have steadily reduced their greenhouse gas emissions while improving their energy efficiency.<sup>3</sup> Because of this, rail is currently being promoted and developed in many areas of the world. Urban transit and high-speed rail infrastructure have expanded rapidly over the past decade in addition to the further development of commuter and inter-regional services, laying the foundation for a convenient and environmentally friendly transport system within and between cities.

2021 is “The European Year of Rail” and with this initiative the EU aims to highlight the benefits of rail as a sustainable, smart and safe means of transport. Currently, the EU is calling for massive investments in energy efficiency as it aims to decarbonize transport as well as support the shift to rail and increase its share of both passenger and freight transport.<sup>3</sup>

The importance of rail as a sustainable and efficient means of transport is not restricted to one particular geographical region. For example, the development of metro and high speed rail is proceeding at an astonishing pace in China, with over 41,000 km of high-speed rail tracks built in the last 10 years.<sup>2</sup> Other large economies like India are also rapidly electrifying their railway network and set to triple the length of its metro network within the next few years. In Russia, \$84 billion is expected to be invested in railways by 2026, while in the USA some \$621 billion will be spent over the next eight years in improving infrastructure, including rail systems. Rail is therefore an integral part of both infrastructure and sustainable transition planning all over the world with increased investments in both new and existing rail networks.

#### 2021 is the European Year of Rail.<sup>4</sup>

In the EU, rail accounts for:



#### Opportunities for improvement

Rail, as described above, is a clean and efficient mode of transport when compared to others but that does not mean that there is no scope for further improvement. The question, then, is how can we improve the efficiency of rail transport and in particular that of the rolling stock?

One way is to specify higher energy efficiency requirements, which are possible with technologies already available today, while procuring new rolling stock. For new investments, train operators should choose the most efficient traction systems available – this is especially important in the investment phase because energy consumption accounts for a significant part of the life cycle costs of a train. Therefore, investing in energy efficient rolling stock not only accelerates the transition to sustainable mobility but also reduces the total cost of ownership for the operator.

Existing rolling stock which have not reached their end of life can have their energy efficiency improved by upgrading to more efficient traction systems, by adding on-board energy storage systems, or reducing auxiliary power consumption with intelligent load management and more energy efficient propulsion and auxiliaries.

In addition, implementing eco-driving assistance systems can also reduce energy consumption.<sup>5</sup>

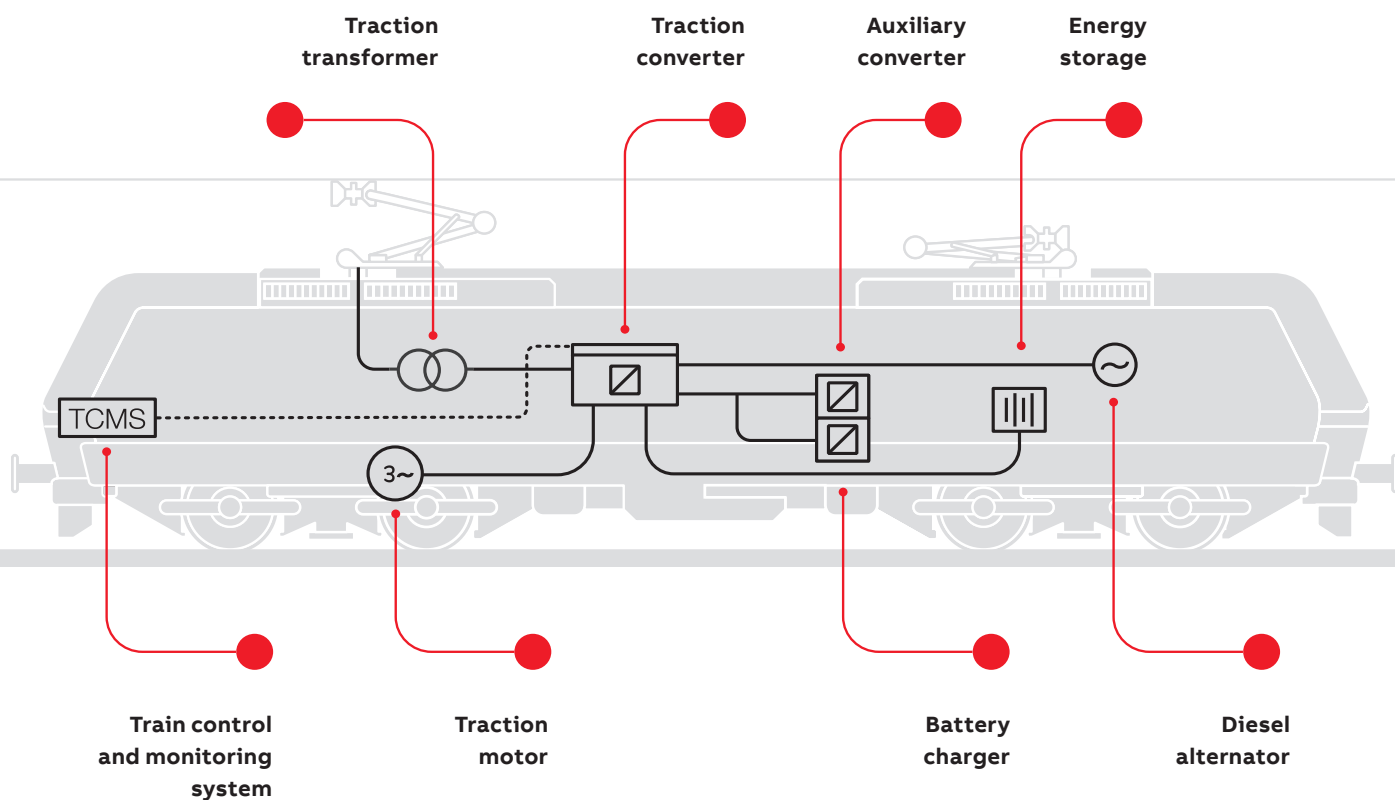
Let's take a look at some of the technologies available to improve the efficiency of rail vehicles.

Transport accounts for  $\frac{1}{4}$  of the EU's greenhouse gas emissions.<sup>6</sup>



## More efficient traction systems

In general, railway vehicles either operate with electricity (AC or DC supply) sourced via an overhead catenary or 3rd rail or are powered by on-board diesel engines. On an electric train, the traction system includes a traction transformer (only in vehicles with AC supply), traction converter, and traction motors. In diesel electric trains, the traction system is composed of alternators, traction converters and traction motors. Irrespective of the power supply system, the technology used in the traction system will have a significant effect on energy efficiency.



### Improving traction chain efficiency

The traction converter converts the electrical supply from the power source into a variable voltage and variable frequency output according to the needs of the train. The choice of traction converter is therefore key to reducing the energy consumption of all other components in the traction chain.

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ABB's BORDLINE® traction converters can reduce the energy consumption of a commuter train by up to 20%.<sup>7</sup>

The traction chain based on ABB's multi-level traction converter is among the most efficient on the market. ABB's BORDLINE® Compact Converters utilize the latest generation of Insulated-gate Bipolar Transistors (IGBT). This, together with the multi-level topology and high switching frequency and Best Efficiency Control (BEC) allows total optimization of the traction transformer and motors and significantly reduces the losses in the traction chain apart from other accrued benefits like the lowering of audible noise and reduced mechanical stress of the drive train. A typical commuter train can reduce its energy consumption by up to 20% which not only lowers the environment impact but also the operating costs.<sup>8</sup>

### Hybrid drivetrains

While electricity is commonly used to power trains, a significant proportion still use diesel power where overhead powerlines are not available. For example, in Europe, although almost 100% of urban rail networks are electrified, only 60% of the mainline networks are. Because these lines carry a low density of traffic, it is often economically unviable to electrify them and, for this reason, it is unlikely that they will be electrified in the near future.

The on-board energy storage system can be used to store the energy regenerated during braking. The stored energy can then be re-used to provide motive power support to the vehicle during the acceleration phase and also to feed on-board auxiliary loads at station stops, obviating the need to operate the diesel engine and thereby reducing local emissions. The use of on-board energy storage also allows the downsizing of the diesel engine, and the possibility of operating it more often at optimal efficiency, due to the energy storage system acting as the buffer storage providing peak power.

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Using a hybrid system, a 2-car diesel-electric hybrid train can reduce its energy consumption by **up to 15 to 20%**.<sup>8</sup>



Hybridisation of diesel-electric drive trains indeed helps to reduce the environmental impact but does not eliminate the need for fossil fuels entirely. Therefore, two other alternatives have emerged and are gaining significant traction in the railway market:

- a. trains equipped with hydrogen fuel cells in combination with batteries
- b. electric trains equipped with on-board batteries to enable catenary free operation.

ABB is already serving both those approaches with traction converters and traction batteries which are particularly optimized for such hybrid technologies.

#### **Batteries for mass transportation**

Energy storage systems are becoming an integral part of electric vehicles in both road and rail transport, and they will play a key role in the transition towards energy efficient mobility. The increasing prevalence of these technologies will help to de-carbonize transport and deliver many other benefits, including better operational flexibility and lower total cost of ownership.

The requirements for the batteries used in public transport vehicles are quite different from those used in electric cars. The batteries used in mass transportation applications like

railways, trolley buses and electric buses must have high power charging capabilities, endure continuous use and withstand higher charging cycles multiple times. This is because, while passenger cars are typically used for less than a few hours per day, on average, public transport vehicles are in use 16 to 18 hours a day. Further, they must meet safety requirements taking into consideration the number of passengers carried and the infrastructure on which they are deployed (such as operating in tunnels and on bridges).

To meet these demands, ABB has developed the BORDLINE® Energy Storage System (ESS), a powerful new lithium-ion battery technology. BORDLINE® ESS is already used in a wide variety of rail and road vehicles ranging from diesel hybrid multiple units, light rail vehicles, electric multiple units and trolleybuses.





### Trolleybuses

Just like rail vehicles, trolleybuses are usually powered by overhead lines. And, also like rail vehicles, this limits their range to routes that have an overhead power network. As a result, cities often use diesel buses to serve routes that don't have overhead electrical infrastructure. Thanks to advances in battery technology, the range of a trolleybus can now be expanded beyond the limits of the overhead power network. This reduces pollution, noise, emissions, network investment and energy use.

#### CUSTOMER CASE



### The benefits of on-board energy storage

The city of Zurich recently replaced their diesel buses on route 83 with eight electric trolleybuses equipped with ABB traction converters, electric motors, and battery technology. The trolleybuses use overhead lines where possible and they use the batteries to power them wherever the overhead lines are unavailable. The batteries are charged by the overhead lines during normal use. The battery system also allows 100% regenerative braking which reduces energy use by about 15% compared to a conventional trolleybus. Altogether, the switch from diesel to electric vehicles saves over 200,000 liters of diesel and 540 tonnes of CO<sub>2</sub> emissions a year.

### Retrofits

In existing rail networks, the rolling stock can be several decades old. Even if the traction systems in these trains are still in working order, there has been huge progress in power electronics and control techniques since they were commissioned. This means that retrofitting older trains with state of the art components not only extends their operational life but also significantly improves their efficiency and reliability, and reduces both operating and maintenance costs. Depending on their condition and age, one or more of the components in the traction chain (for example the traction converter) can be upgraded to improve performance, or new systems such as ESS can be added.

#### CUSTOMER CASE



### Modernizing SBB locomotives

As part of a project to modernize the Swiss Federal Railways (SBB) rail fleet, ABB has retrofitted 119 locomotives with modern traction converters and control systems. The retrofit work includes removing the older and less efficient GTO (gate turn-off thyristor) converters and replacing them with more efficient and flexible IGBT converters. The improvements are expected to deliver savings of around 27 GWh/year, which is equivalent to the consumption of 6,750 Swiss households.<sup>7</sup>

# Conclusion

## Continuing the journey to better efficiency

Electric trains have been in use for over 100 years, and technology has come a long way since then. Today, we have much more powerful and efficient traction equipment, which can further lower the environmental impact of railway rolling stock and other vehicles used for mass transportation. At the moment, change and improvement in the transport sector is strongly driven by both urbanization and by targets and regulations which aim for sustainable, low-carbon solutions. In addition, advances in technology are also likely to transform the industry further.

Globally, the railway industry is working hard to meet efficiency and emissions targets, and the technology to deliver significant improvements is already here. Although we have come a long way, improving the efficiency of our transport systems is a journey that must continue.

(1) <https://www.iea.org/reports/rail>

(2) IEA, The Future of Rail, Opportunities for energy and the environment, [https://iea.blob.core.windows.net/assets/fb7dc9e4-d5ff-4a22-ac07-ef3ca73ac680/The\\_Future\\_of\\_Rail.pdf](https://iea.blob.core.windows.net/assets/fb7dc9e4-d5ff-4a22-ac07-ef3ca73ac680/The_Future_of_Rail.pdf)

(3) EU sustainability factsheet, <https://www.unife.org/wp-content/uploads/2021/04/Sustainability-Factsheet-February.pdf>

(4) EU press release, The journey begins – 2021 is the European Year of Rail!, [https://ec.europa.eu/commission/presscorner/detail/en/IP\\_20\\_2528](https://ec.europa.eu/commission/presscorner/detail/en/IP_20_2528)

(5) <https://uic.org/sustainability/energy-efficiency-and-co2-emissions/>

(6) EU sustainable transport page, [https://ec.europa.eu/transport/themes/sustainable\\_en](https://ec.europa.eu/transport/themes/sustainable_en)

(7) Based on ABB calculations

(8) Based on ABB calculations and measurements





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**ABB Motion**

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