



CASE STUDY

ANALYSES OF DIESEL USE FOR MINE HAUL AND TRANSPORT OPERATIONS

FORTESCUE METALS GROUPS LTD • DOWNER EDI MINING PTY LTD • LEIGHTON CONTRACTORS PTY LIMITED

Diesel is a significant energy source for the mining industry. It is used for material transport processes such as the hauling of ore and overburden. Trucks and trains constitute one of the key diesel-using activities.

The understanding of the energy efficiency of a haul truck or locomotive should not be limited to the analysis of vehicle-specific parameters. Mining companies can often find greater benefits by expanding the analysis to include many other factors that affect the amount of energy used across an entire fleet, including road gradient and elevation.

The rigorous approach required by the Energy Efficiency Opportunities (EEO) Program enables a corporation to determine the energy savings from projects and the cost of implementing these projects. A systematic and thorough approach focuses efforts on the most energy intensive processes, the key energy and material flows in the process and where opportunities for increased efficiency are likely to lie.

As EEO takes a data-driven approach to identifying energy-savings opportunities by collecting and analysing energy use and production data (including the factors impacting on both), it can enable companies to view common processes from new perspectives and identify additional opportunities.

This Case Study aims to provide mining companies with examples of comprehensive

analyses of diesel use in mining operations used by **Fortescue Metals Group Ltd, Downer EDI Mining Pty Ltd** and **Leighton Contractors Pty Limited**. It provides several examples of analytical techniques that have been used in the mining sector to develop a rigorous understanding of energy and material flows, and enable the identification of energy savings for haul truck operations and rail operations.

This Case Study demonstrates analyses of diesel use in trucks by trending energy data over time, development of models and simulations, use of indicators, and benchmarking, including theoretical benchmarking. It also shows how an Energy-Mass Balance (EMB) has been applied to rail operations. All of these processes can be used by companies to understand energy use, manage energy performance, improve business decision making and identify potential energy efficiency opportunities.

DIESEL USE IN MINING OPERATIONS

As of 2008–09, 40 reporting EEO companies in the mining sector consumed 308 PJ of energy of which 52.5 PJ was diesel (17%) for haulage and electricity generation. These EEO mining companies had identified 3 PJ (or 6%) worth of savings directly related to diesel use. These companies adopted 66% of these identified savings in diesel use.

TRUCK OPERATIONS IN MINING

Trucks are used to haul overburden and ore from the pit to a dump site, stockpile or to the next stage of a mining process. Their use is scheduled in conjunction with other machinery, such as excavators, loaders and diggers, according to the site layout and production capacity.



Photo courtesy of Downer EDI Mining Pty Ltd

Trucks use a significant amount of diesel, and are expensive to purchase and maintain. Operating procedures influence energy use and maintenance costs. Truck velocity, especially cornering speeds, braking patterns and road surface characteristics can affect tyre wear and replacement costs.

In open cut mining, many parameters can affect the efficiency of the fleet, such as:

- Mine plan and mine layout
- Speed, payload and cycle time
- Tyre wear and rolling resistance
- Age and maintenance of the vehicles
- Dump site design
- Idle time
- Engine operating parameters and transmission shift patterns

Fortescue Metals Group, Downer EDI Mining, and Leighton Contractors, have each developed a thorough analytical method to investigate energy use in their haul truck operations.

RESULTS AT A GLANCE

Fortescue Metals Group identified and quantified the energy costs associated with stopping haul trucks unnecessarily, which equated to 361 kL (13,935 GJ)¹ of diesel per annum for the Caterpillar 777 fleet and 407 kL (15,710 GJ) of diesel per annum for the Terex 3700 AC fleet for a single stop sign per payload cycle.

Fortescue also found additional savings through a change to the engine control unit of the haul trucks. Modelling showed a 2.3% reduction in fuel consumption, with an increase in cycle time of 1.8%, resulting in a fleet-wide fuel savings of 232 kL (8,955 GJ) of diesel per annum.

In rail operations, Fortescue found that the installation of an automatic start-stop system would reduce idle time, with savings estimated at 675 kL (26,055 GJ) of diesel per annum. Numerical modelling also found that savings of between 300 kL (11,580 GJ) to 500 kL (19,300 GJ) of diesel could be achieved by reducing the speed of trains to reduce waiting times at crossing points.

Downer EDI Mining developed performance indicators that use an 'equivalent flat haul' calculation to account for elevation changes on a specific mine route. The indicators provide a more consistent measure of true energy performance, enabling the company to track energy intensity over time. The Commodore open-cut coal mine in South East Queensland has been used as the pilot site for energy-efficiency improvements at DEDIM. The energy intensity of the Commodore mine has improved by 18.2% over five years.

Leighton Contractors developed a Best Truck Ratio model to evaluate and benchmark the efficiency of fleet operations across a single site and multiple operations, where the nature of the work undertaken varied greatly.

This model provides an indication of how efficient their fleet is in comparison with what is practically and realistically possible. It is providing a rigorous analytical tool which Leighton is using to support decision making processes.

¹ All fuel conversions reference the Department of Climate Change and Energy Efficiency, *National Greenhouse Accounts (NGA) Factors*, July 2010.

ENERGY ANALYSIS OF TRUCK OPERATIONS

DATA COLLECTION AND MEASUREMENT

There are several data sources that can be used as inputs to an energy efficiency analysis of haul trucks.

Mining companies typically maintain records of total diesel use across the mining fleet. In some cases the fuel consumption of individual trucks is measured by recording the amount of fuel that is filled into each vehicle, while other operations simply measure total fuel dispensed to the fleet. Fortescue was able to acquire data for fuel deliveries to each haul truck from their fuel management system, and those of their contractors. These accounting systems are necessary for compliance with Australia's diesel fuel rebate legislation. Diesel using EEO corporations can leverage these record-keeping systems to address some of the Key Requirements of the EEO Assessment Framework.

Many mining vehicles have onboard data collection capabilities. Fortescue's fleet of Caterpillar 777 trucks used the onboard Vital Information Management System (VIMS) to capture information from sensors and controllers throughout the vehicle, enabling detailed analysis of vehicle performance and engine operating conditions.

Fortescue worked closely with Caterpillar to develop a detailed understanding of relevant VIMS parameters. For many of the values recorded, it was important to understand how the VIMS system determined when each mode of the payload cycle started and stopped.

In addition to the quantitative data available from fuel and vehicle systems, Fortescue found it useful to also gather qualitative information. Many factors affect the energy efficiency of the trucks, such as: the diversity of routes; truck utilisation patterns (which can increase the complexity of the analysis); historic information on mine development; site production; and other contextual details that enable a more comprehensive understanding of fuel records and truck utilisation data.

FORTESCUE METALS GROUP

The Fortescue Metals Group Ltd is a rapidly-growing iron ore company operating in Western Australia. Fortescue's Chichester operations consist of the Cloudbreak and Christmas Creek sites, which are currently mining at the rate of 55 million tonnes per annum. With further planned expansions at the Solomon deposits, Fortescue's production is planned to increase to 155 million tonnes per annum by 2013. When the assessment was undertaken, Fortescue was predominantly using Caterpillar 777 and Terex 3700 haul trucks in these sites, some of which were owned and operated by mining contractors.

ANALYSIS AND OPPORTUNITY IDENTIFICATION

The data drawn from real-time truck data, fuel records, knowledge of the mine plan and production cycles, enabled the development of models and simulations which allowed Fortescue to examine the energy use and productivity of existing practices, and explore how changes would affect the efficiency of fleet operations.

TRUCK OPERATING MODE

Fortescue examined the range of fuel consumption rates, trip distances, vehicle speeds, and other parameters to understand energy use in different modes of operation.

The time spent during each mode of operation is presented in Figure 1. There are five modes defined within a single payload cycle, namely:

- Travelling while empty
- Loading
- Stopped while loaded
- Travelling while loaded
- Stopped while empty

The vertical axis of the graph in Figure 4 illustrates the amount of time spent in each operating mode, and indicates that the greatest amount of time is spent stopped while empty.

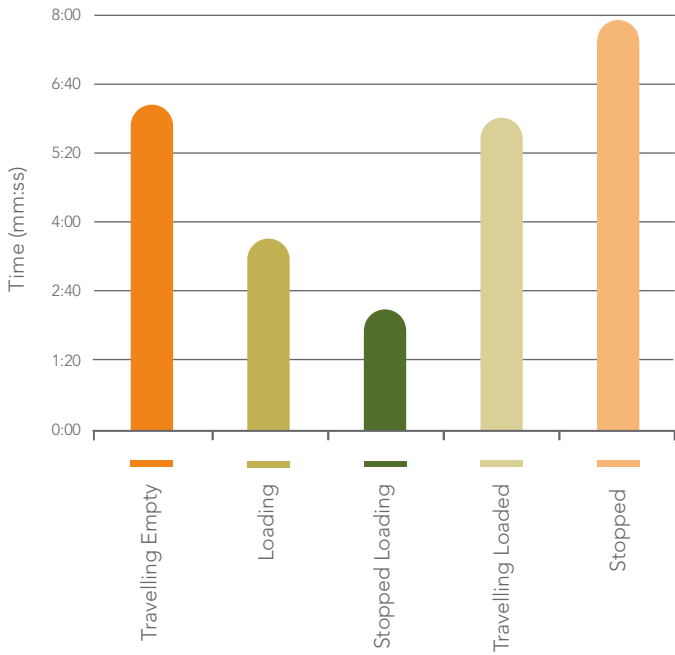


Figure 1: Example of Caterpillar 777F operating modes within a payload cycle

This information, combined with the fuel consumption rate (litres per hour) during each mode of operation, provided a deeper understanding of baseline energy use and the relationship between fuel use and productivity. The model allowed Fortescue to estimate the results of changes to cycle times, payload, and number of trucks.

The analysis of the different modes of operation in the payload cycle allowed Fortescue to identify and evaluate the value of reducing the time stopped when empty and optimising truck cycles and scheduling.

THE COST OF STOPPING A TRUCK

The Fortescue fleet includes Caterpillar and Terex haul trucks. Fortescue worked with both manufacturers to model the fuel cost associated with stopping and then accelerating a loaded truck as compared to the truck continuing along at a constant speed.

The speed and fuel use for the two modelled scenarios is illustrated in Figure 2. The blue traces in Figure 2 indicate the speed (kph) and fuel use (L) for the vehicle travelling the specified distance without stopping, while the red traces indicate the speed and fuel use for a vehicle that stops once while travelling the specified distance. The difference between the two scenarios provided the estimated fuel savings that could be achieved through the elimination of one stop per cycle.

When extrapolated across the entire fleet, Fortescue estimated that removing an unnecessary stop sign from each truck cycle could reduce fuel consumption by 361 kL (13,935 GJ) per annum across the Cat 777F fleet, and 407 kL (15,710 GJ) per annum across the Terex 3700 fleet.

This knowledge can be integrated into mine plan costing and design processes to improve energy efficiency along with reductions in maintenance costs.

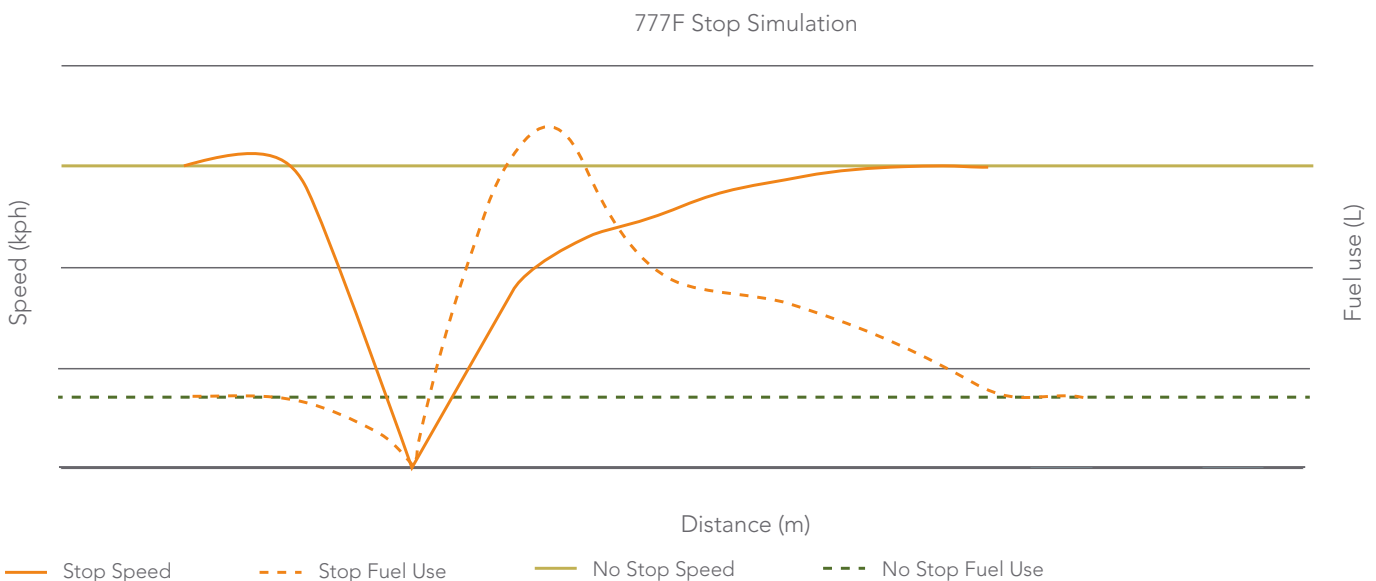


Figure 2: Caterpillar 777F Stop Simulation

ENGINE CONTROL UNIT MODELLING

Haul trucks are equipped with an Engine Control Unit (ECU) that uses an engine map to control the relationship between power, torque and engine speed. On the Caterpillar 777F haul trucks used by Fortescue, an 'economy mode' is available which reduces the power of the vehicle by approximately 4.5% for gears 2 and above. A reduction in power reduces the fuel consumption of the engine, but may also result in a reduction in productivity.

The Caterpillar 777F trucks owned by Fortescue were delivered with the economy mode available as an option within the ECU. A technician was able to set the ECU for economy mode using a diagnostic computer. Other Caterpillar 777D trucks operating at the site, which are owned by contractors, did not have the economy mode option available and would require the ECU to be re-programmed to implement the change.

To help make a decision on whether to employ economy mode on the Cat 777F fleet, Fortescue required an understanding of current energy

use and performance, and the fuel savings and productivity impact of a change to economy mode.

Caterpillar provided Fortescue with model simulations for four sample haul loads. The model calculated the cycle time (minutes) and fuel use (litres diesel per hour) for both 'standard' and 'economy' modes.

The modelling showed that a 2.3% average reduction in fuel use could be achieved across the four sample routes, with an increase in cycle time of 1.8%. When extrapolated across the fleet of Cat 777F trucks, the savings were estimated to be 232 kL (8,955 GJ) per annum. It should be noted that Fortescue's operations are relatively flat and this potential opportunity may be less applicable to deeper mining operations².

² Note: This depends on existing energy use profiles and factors impacting on operations.



Photo courtesy of Fortescue Metals Group

KEY PERFORMANCE INDICATORS FOR MINE FLEET APPLICATIONS

PURPOSE OF KEY PERFORMANCE INDICATORS (KPIs)

Many industries use Key Performance Indicators (KPIs) to evaluate the performance of a business activity. A properly designed KPI will provide managers with a discrete quantitative indicator of the status of one or more important business parameters. The KPI can be assessed continuously or periodically, and can be tracked to monitor changes in performance over time.

One indicator currently used by the mining industry is fuel consumption expressed as litres per bank cubic metre³ (litres/BCM). This indicator is easy to calculate, but does not take into account the differences between mine sites or changes within individual mines (such as haul routes and distances; increasing dump heights; pit or underground depths). Given the significant contribution of these factors to mine efficiency, litres/BCM is potentially a very limited performance indicator and does not capture the effects of other variables. It can also be misleading to suggest that a haul fleet's efficiency is decreasing due to an increase in litres/BCM. Similarly, a comparison of the litres/BCM for different mines is potentially meaningless given that a mine with a lower litres/BCM value may actually have less efficient operations and haulage equipment than a mine with a higher litre/BCM value.

Companies should determine the key performance indicators that enable an adequate analysis and management of energy use. In practice this may require a set of indicators to be developed. To effectively track energy performance, companies will need to develop a framework that adequately considers the variables affecting operations to provide a fair or normalised picture of the operation's energy use and enable potential efficiency improvements to be identified.

3 A bank cubic metre (BCM) represents the contents of a cubic metre of rock in place, before it is drilled and blasted.

DOWNER EDI MINING

Downer EDI Mining Pty Ltd (DEDIM), a division of the Downer Group, provides contract mining and mine services at 45 sites in Australia. In 2009–10 DEDIM employed almost 3,000 people and moved over 121 million bank cubic metres (BCM) of overburden and product on mine sites.

DEDIM is a major provider of integrated contract mining services for both open-cut and underground mining operations. Besides operating and managing mines, key services include exploration drilling, blasting, crushing, tyre management and rehabilitation. Coal, gold and iron ore are the main commodities currently mined by DEDIM.

Energy use (as reported under the EEO program) for which the DEDIM business unit was deemed to have operational control in the 2009–10 financial year was 0.27 PJ, with the main energy sources being diesel fuel and biodiesel B20 – a blend of 20% biodiesel and 80% petroleum diesel. The majority of energy is used in mobile fleet and equipment on mine sites to transport minerals and waste.

DEDIM'S APPROACH

To capture the effects of several variables in a single analysis, DEDIM developed its own energy and greenhouse gas (GHG) performance measure – the Downer Energy and Emissions Measure (DEEM). This enables the company to measure and improve its fuel and energy efficiency. It also measures the reductions in GHG emissions of its mining operations. The DEEM considers the sources and destinations of material mined, together with the mass and volume of material moved and the fuel used to move the material. DEDIM uses two separate indicators; one for haulage and another for excavators and equipment.

Indicator for haulage: The GJ/tonne-km indicator applies to haulage-related equipment, such as haul trucks, road trains, water trucks, scrapers and graders.

Indicator for excavators and equipment: The GJ/tonne material moved indicator applies to excavation-related equipment, such as excavators, dozers, loaders and surface miners. Ancillary equipment, such as lighting plants, generators and pumps, are also considered in the non-haul indicator, as these are considered to be essential equipment for the operation.

CALCULATION OF THE DEEM

The simplified process for calculating the DEEM is presented in Figure 3. The base data that is used to calculate the DEEM is the total fuel consumed and the BCM moved. This is converted to the common measure of litres of diesel per tonne moved (L/tonne). The L/tonne measure is then adjusted for equipment fuel use, distance travelled and change in elevation to normalise the effect of changes in the material movement task, resulting in a fuel efficiency factor measured in L/tonne-

kilometre. As a final step, the fuel efficiency factor is converted to units of energy (GJ) and greenhouse gas emissions (tonnes CO₂-e).

EQUIVALENT FLAT HAUL

The 'equivalent flat haul' (EFH) parameter was defined to describe the characteristics of the haul route travelled. The EFH is a calculated parameter that accounts for both the distance from the source to the destination, and the elevation change from the source to the destination. The EFH normalises the elevation change and distance travelled, which enables a comparison of the energy consumed and tonnage moved for a mining activity.

For a given material movement task, illustrated in Figure 4, the DEEM accounts for the energy required to move the material, the tonnage moved, and the EFH.



Figure 3: Summary of the DEEM calculation process

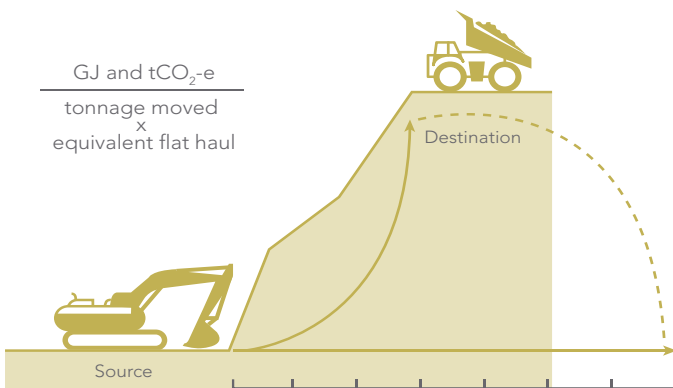


Figure 4: Illustration of Equivalent Flat Haul

APPLICATION OF THE DEEM

The DEEM compares and links the weekly to monthly haul and non-haul energy performance to on-site operational activities, decisions and conditions. Performance data can be analysed and compared for a mine site to identify trends and factors that have either positively or negatively influenced energy efficiency. The DEEM can reveal many factors that have a direct or indirect influence on energy efficiency, such as changes in equipment size, the performance of different operators, the influence of production schedules or volumes on fleet efficiency, the effect of rainfall on road conditions, and many other factors. The DEEM's variation can be accurately correlated with and explained in terms of these and other quantifiable factors. These factors and their influences are then taken into consideration in future planning and operational decision-making.

While the DEEM is a useful energy tool for performance tracking and reporting, it is also more useful for informing business improvement decisions than a simple indicator such as litres/BCM. DEDIM applies this approach to identify where factors contributing to efficiency improvements at one mine and/or mine type may be measured and implemented at another. Typical solutions include applying different mining methods, mine planning and design changes, haul road changes (length, gradients, design and materials), changing equipment operator behaviour, mining plant selection, and fuel types.

DEDIM's Technical Services Department and its mining project engineers developed, trialled and implemented the DEEM to ensure its applicability across all projects and sites. Given their leading

role in mine planning, design and operations, the project engineers' involvement ensured that the DEEM is credible, accurate and transparent.

The project engineers also have ownership of the DEEM, and are responsible for calculating and reporting the monthly DEEM performance of their respective projects. This process enables and encourages DEDIM's mine project managers to test and understand the energy performance implications of their decisions and, hence, to include energy-efficiency considerations in their day-to-day decision-making.

MINE COMPARISONS

The graphs presented in Figure 5 and Figure 6 compare the annual performance, on a monthly basis of three mines, each mining a different commodity. The haulage-related indicator in Figure 5 illustrates that haulage on Mine 1 is more energy-intensive than on Mines 2 and 3, while Figure 6 illustrates that excavation on Mine 1 is less energy-intensive than on Mines 2 and 3.

Several factors can influence the energy intensity measured by the DEEM across different sites:

- Rock hardness and fragmentation. Sites with hard rock are often more energy-intensive to excavate.
- Density of the material being excavated and hauled.
- Material moved through blasting, and work required by dozers and loaders to shift material into haul trucks.
- Fleet selection, including size of equipment in use at the site, as fewer numbers of larger equipment can result in greater energy efficiency and productivity.
- Mine planning integrating energy efficiency, including haul slope optimisation, haul road and dump configuration and optimisation can reduce the energy intensity.
- Energy-efficiency measures deployed that include a cumulative suite of improvements for DEDIM, including operator training, automation of lighting plants and idle time minimisation.

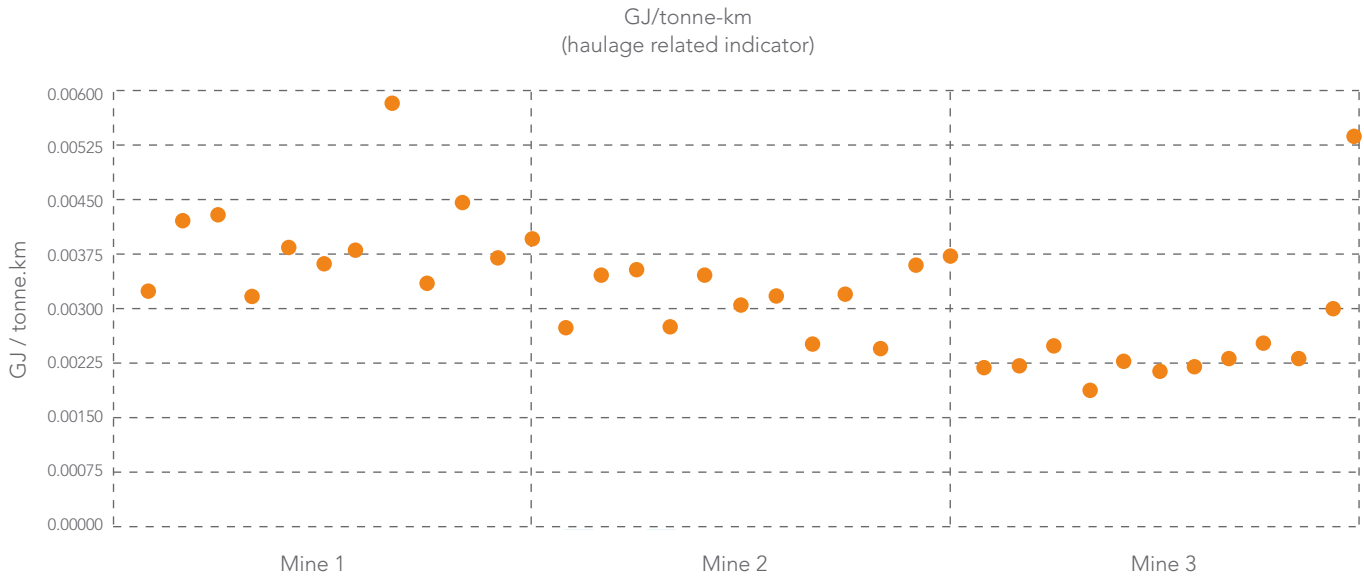


Figure 5: Comparison of monthly haul energy use for three sample mines

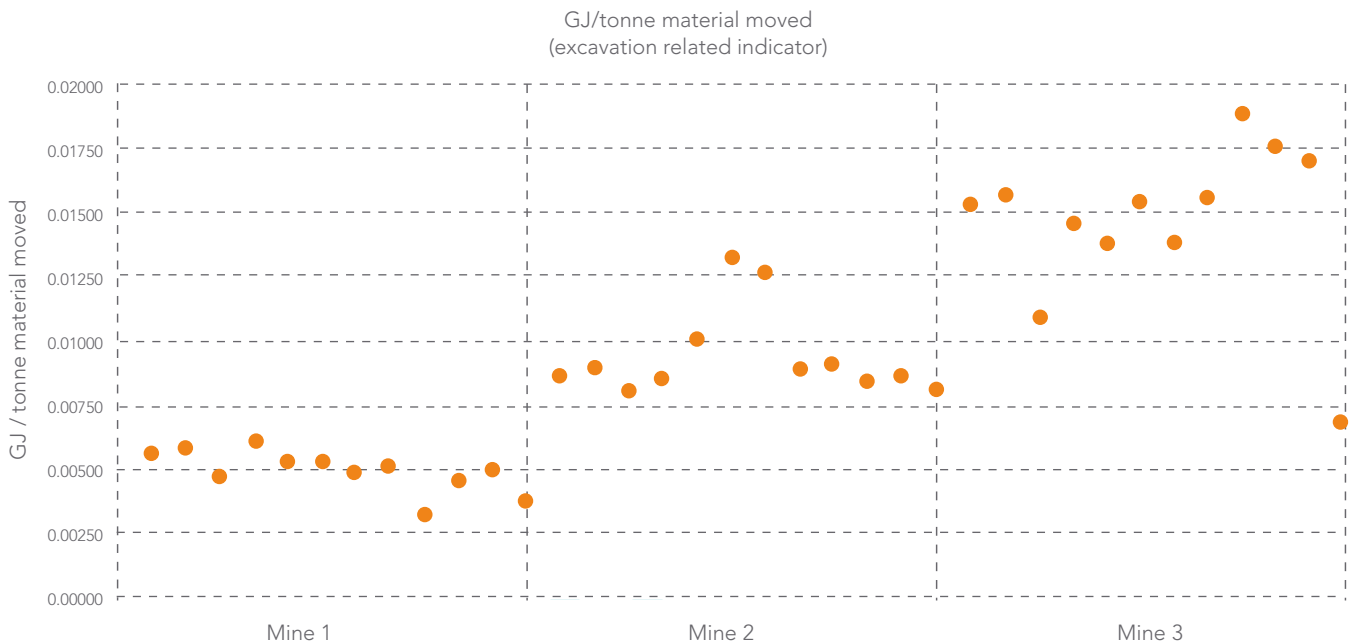


Figure 6: Comparison of monthly excavation energy use for three sample mines

TRACKING ENERGY PERFORMANCE OVER TIME

The trend presented in Figure 7 demonstrates the link between monthly energy performance and mining activities for an open cut coal mine. Trending of the energy indicators is more useful than simply trending monthly energy use. Fuel use could increase or decrease due to changes in production activity or other factors that can obscure energy-efficiency insights. The use of key performance indicators, such as the DEEM, can prompt managers to enquire into the observed changes in energy efficiency over time, and deeper

analysis can reveal insights into the factors that drive energy efficiency on the site.

There are many factors that influence energy use on a mine, and many indicators are required to track changes in energy use. The DEEM example illustrates how using appropriate indicators that normalise for key sources of variability can help to give a better indication of true energy performance. Examination of indicators over time can provide a useful basis for business decisions and may help to identify opportunities to improve energy performance.

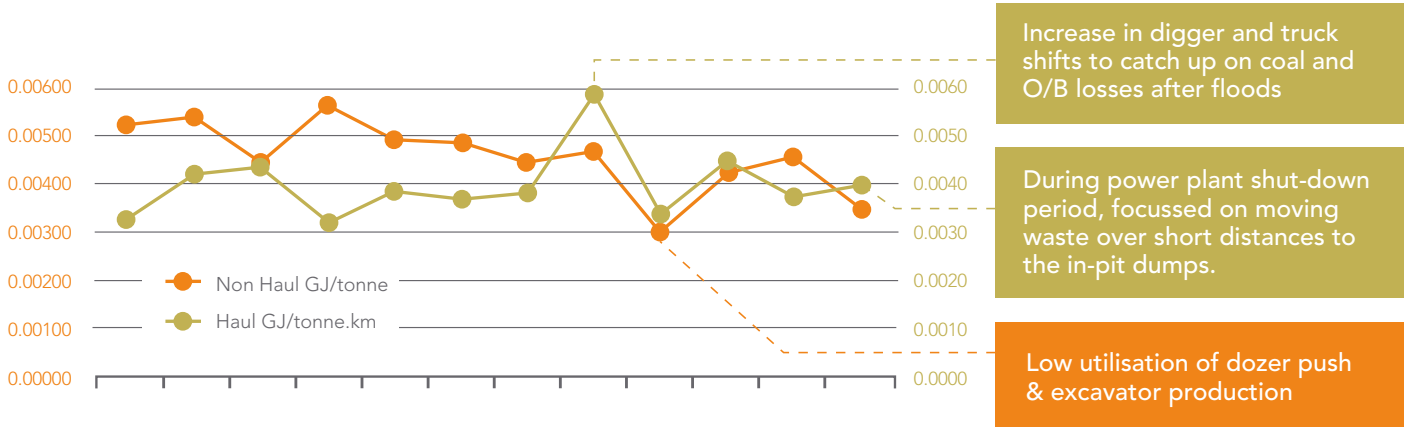


Figure 7: Trend of monthly performance

It is beneficial for mining companies to be able to compare their performance against a consistent set of indicators. By calculating the DEEM for multiple sites, DEDIM is able to draw comparisons and insights across different activities and operations.

DEDIM has used the DEEM to set annual targets for reducing energy intensity, and to track project and company performance against the target. The Commodore open-cut coal mine in South East Queensland has been used as the pilot site

for energy-efficiency improvements at DEDIM. The energy intensity of the Commodore mine has improved by 18.2% over five years. DEDIM has used the DEEM to measure an 8% reduction in energy intensity for 2009/10, against a company-wide target of 3%. With the confidence gained from past performance, and a continued-improvement program pipeline identified for 2010–11, DEDIM has set an energy-intensity reduction target of a further 2%.



Photo courtesy of Downer EDI Mining Pty Ltd

BENCHMARKING TRUCK OPERATIONS

PURPOSE OF BENCHMARKING, INCLUDING THEORETICAL BENCHMARKING

Benchmarking provides a means to measure and identify best-practices within a single organisation, or across multiple organisations.

There are many variables that can affect haul truck energy efficiency. Simplistic performance indicators, such as litres of diesel per tonne moved, are often too blunt to provide useful insights into the factors that drive efficiency because they do not account for factors such as the distance travelled, the payload per cycle, or other characteristics of an individual hauling task.

Calculations of theoretical energy efficiency may not reflect the level of performance that can realistically be achieved but can be a useful tool to track improvements in energy efficiency. The development of relevant theoretical benchmarks provide organisations with a practical energy efficiency measurement tool that quantifies best practice, and highlights areas where improvements can be made.

BEST TRUCK RATIO

After gathering real-time haul cycle data, GPS data, and mine site information, Leighton Contractors developed a series of mass and energy equations which were designed to compare actual truck performance against the theoretical best performance. This technique essentially calculates the best theoretical performance a haul truck is capable of in order to move a mass of material from one location to another based on vehicle and site characteristics. The actual performance can be compared to the theoretical energy use for a specific truck, resulting in the 'Best Truck Ratio' (BTR).

$$\text{BTR} = \frac{\text{Actual energy use}}{\text{Theoretical best truck energy use}}$$

For a defined material movement task via a specific haul path, the BTR is the ratio of the actual energy consumed to perform the task over the best-practice benchmark energy consumption.

LEIGHTON CONTRACTORS

With operations in 19 coal, iron ore, gold and manganese mines in Australia and New Zealand, Leighton Contractors Pty Ltd is one of Australia's largest contract mining providers. With one of the largest mobile equipment fleets in the country, the Leighton fleet moves in excess of 240 million cubic metres per annum. Leighton Contractors operates at both brown-field sites and green-field start-ups. The Leighton fleet includes over 300 large haul trucks, as well as many other types of mobile plant and equipment.

For example, if a haul truck achieves a BTR of 2.0 that indicates that the actual fuel consumption was twice that of the best-practice benchmark.

APPLICATION OF THE BTR

The BTR allows Leighton to compare the performance of their operations between sites, trucks, operators, and other parameters. More specifically, haul trucks can be compared on every cycle of a particular day and site. As this is a ratio of actual performance against the best possible performance for a particular haul cycle it gives a much more accurate indication of the energy efficiency of the operation than alternative performance indicators such as litres/tonne moved.

One example is payload optimisation, presented in Figure 8. For a fixed task of 20 million tonnes moved, Figure 8 illustrates four payload scenarios and the corresponding BTR. The third scenario, a payload of 154.25 tonnes, is identified as the optimal scenario with a BTR of 2.22. The other three scenarios score a higher BTR, and would result in greater fuel use to achieve the same material movement outcome. For each scenario the fuel consumption in litres is stated below the BTR, and for the three non-optimal scenarios the values in red text indicate the additional fuel required to move the same amount of material via the same path at a higher BTR. In effect, setting the payload at the optimal 154.25 tonnes per cycle would result

Payload

Results

– based on 20 million tonnes moved

Payload 126.21	Payload 140.22	Payload 154.25	Payload 168.28
Best Truck Ratio: 2.55	Best Truck Ratio: 2.37	Best Truck Ratio: 2.22	Best Truck Ratio: 2.41
Litres: 3,873,587	Litres: 3,599,800	Litres: 3,369,789	Litres: 3,632,128
+504,798	+230,011		+262,339

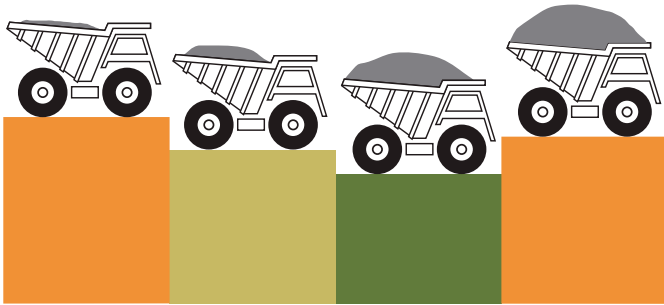


Figure 8: Optimising payload using the Leighton Contractors Best Truck Ratio

in the consumption of 3,369,789 litres to move 20 million tonnes. If the payload were increased to 168.28 tonnes then 3,632,128 litres would be required (an additional 262,339 litres).

In practice, it may not be feasible to operate at the optimal payload calculated through the BTR. For example, the calculated optimal payload may be outside the rated payload of the truck, or an increase to a higher optimal payload may have a negative influence on other factors such as rolling resistance. The results and insights that emerge from the BTR analysis must be evaluated in the context of other operational considerations.

Truck Model

Results

– based on 20 million tonnes moved

785C	789C	793C
Best Truck Ratio: 2.37	Best Truck Ratio: 2.41	Best Truck Ratio: 2.54
Litres: 3,599,800	Litres: 3,665,445 +65,645	Litres: 3,849,260 +249,460

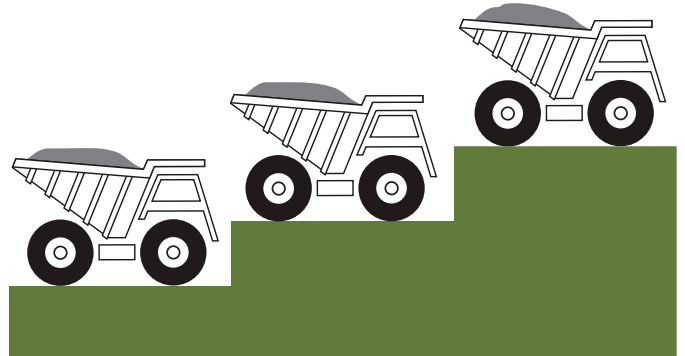


Figure 9: Optimising truck selection using the Leighton Contractors Best Truck Ratio

The BTR can also be used for performance analysis to inform vehicle selection and purchase decisions. Figure 9 illustrates the application of BTR to evaluate three different truck models. The 785C achieves the lowest BTR and the lowest corresponding fuel consumption, however it is also the smallest of the three models. Analysis using the BTR must account for the larger number of cycles that would be required for a smaller truck to fulfil the fixed transport task of 20 million tonnes moved.



Photo courtesy of Leighton Contractors Pty Limited

Grade

Results

– based on 20 million tonnes moved

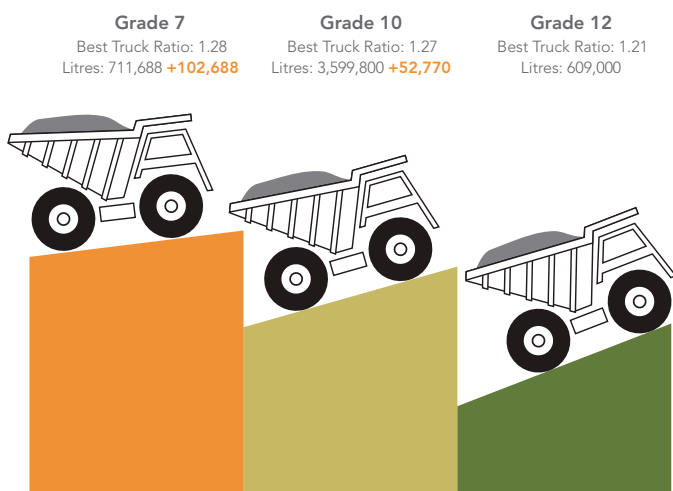


Figure 10: Optimising road grade using the Leighton Contractors Best Truck Ratio

Similarly, the BTR can be used to evaluate the effect of a mine route's slope, or grade, on the energy efficiency of the transport task. The illustration in Figure 10 shows three different scenarios that were evaluated to determine the optimal road grade. Haul trucks travel slower on a steeper grade. Based on a fixed transport task of 20 million tonnes moved, the analysis shows that the highest BTR is achieved for a Grade 12 road. The BTR indicates that a lower road grade will increase the amount of fuel required to achieve the material movement task. A steeper grade will improve the energy performance of the haul trucks however it will also reduce the speed of the haul trucks. Managers can use the BTR to help determine the optimal haul road design.

Rolling Resistance

Results

– based on 20 million tonnes moved

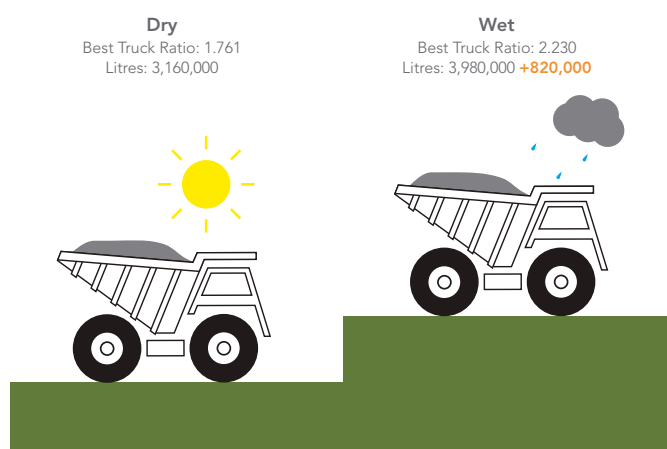


Figure 11: Comparing rolling resistance using the Leighton Contractors Best Truck Ratio

One of the factors that can affect the fuel consumption of haul trucks is the type and condition of the haul road. Figure 11 illustrates the use of the BTR to analyse how road condition can change the rolling resistance of the haul trucks. A dry and hard-packed haul road keeps fuel costs and tyre wear to a minimum. Wet conditions can increase the rolling resistance experienced by the vehicle. To move 20 million tonnes over a specific path, the BTR indicates that a wet haul road will result in the consumption of an additional 820,000 litres of diesel. This analysis can help fleet managers to determine the optimum use of haul trucks in wet conditions, and can inform decisions on road design and maintenance.

The energy use of haul fleets is affected by a wide range of variables. The BTR is used by Leighton Contractors to provide a baseline indication of energy use for a given operation at a mine site, and to examine a wide range of parameters effecting fleet energy use. The BTR is a rigorous analytical tool which provides very high-quality efficiency information into decision-making processes.

TRAIN OPERATIONS

FORTESCUE'S ENERGY ANALYSIS OF FREIGHT TRAINS FOR MINERAL TRANSPORT

Many of Australia's mining operations are located a substantial distance from the nearest port. Rail transport is often used to transport bulk materials, such as iron and coal, from the mine site to a port for export.

In the case of most iron ore mining operations in the north-west of Western Australia, mining companies have built and own the railways which they use to transport product from the mine-site to the port.

Fortescue built its railway line from the Cloudbreak site to the ship-loading facility at Port Hedland, a journey of approximately 250km. The trains consist of two locomotives pulling 240 open-top wagons which have a full-load mass of approximately 40,000 tonnes. The locomotives have a power output of 4,400 HP (3,280 kW) each, generated by diesel engines coupled with electric traction motors. Energy use for rail operations accounts for approximately 9% of Fortescue's energy use.

The analysis conducted by Fortescue on their train operations consisted of an operational analysis and an energy balance on the entire train, including locomotives and wagons. The energy balance on the train took into account the rolling resistance and the aerodynamic resistance as well as the losses in the prime mover and associated transmission equipment.

DATA COLLECTION AND ANALYSIS

Fortescue has two data systems which can be used for analysis: a tracker which monitors the position and the time spent in each part of the cycle of the wagons; and a recorder on the locomotives. Several position and locomotive operating parameters were gathered from Fortescue's train monitoring systems, including:

- Train cycle time
- Engine characteristics including:
 - Throttle position
 - Speed
 - Break position

- Kilometre post (a record of the train's position along the track from the mine)

- Track survey data
- Train weight and total weight transported
- Standard fuel consumption data for each throttle position
- Total fuel consumption

This data supported a number of analyses which provided an understanding of baseline energy use. This generated some immediate insights. The train cycle time data (from the system monitoring the wagons) and the throttle position data (from the locomotive system) showed the proportion of time spent in different phases of the cycle. The time spent in each phase of the cycle, expressed as a percentage of total cycle time, is presented in Figure 12.

Fortescue calculated the fuel use in each phase of the cycle by multiplying the average cycle time for the wagons and the estimated fuel consumption rate associated with the throttle position which was recorded for each part of the cycle.

The locomotive's internal data system collects information on the throttle position of each locomotive. This data showed that up to 74% of the locomotive's time was spent with the throttle in the idle position. The amount of fuel used at idle was estimated at 7% of total fuel usage. Fortescue was in the process of ramping up operations at the time that the analysis was undertaken, and whilst the high proportion idle time was clearly an issue, it was not reflective of their steady state operation.

Another important observation from the cycle time and locomotive throttle analysis was that the most fuel-intensive part of the cycle is actually the empty run from the port to the mine. As illustrated in Figure 12, the Empty Run accounts for 53.8% of the total cycle fuel use because it is uphill and into the prevailing wind. In contrast, the Loaded Run is downhill and aided by gravity. Note that Figure 12 applies only to the recorded cycle time and excludes unrecorded time at the shunting yard.

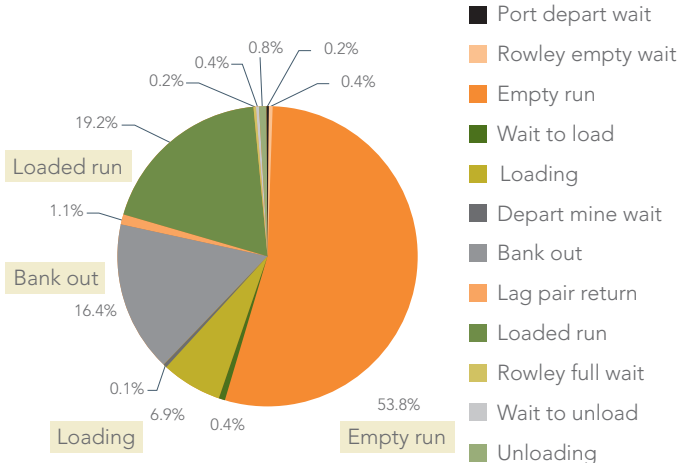


Figure 12: Locomotive fuel use distribution

ENERGY-MASS BALANCE (EMB)

Fortescue performed an EMB analysis on the high fuel-consuming return run of the train. The elements of the EMB are shown in Figure 13. Several energy saving opportunities were identified as a result of the fuel analysis and energy-mass balance process. Two opportunities selected for detailed analysis were auto-stop-start technology and reducing empty train speed.

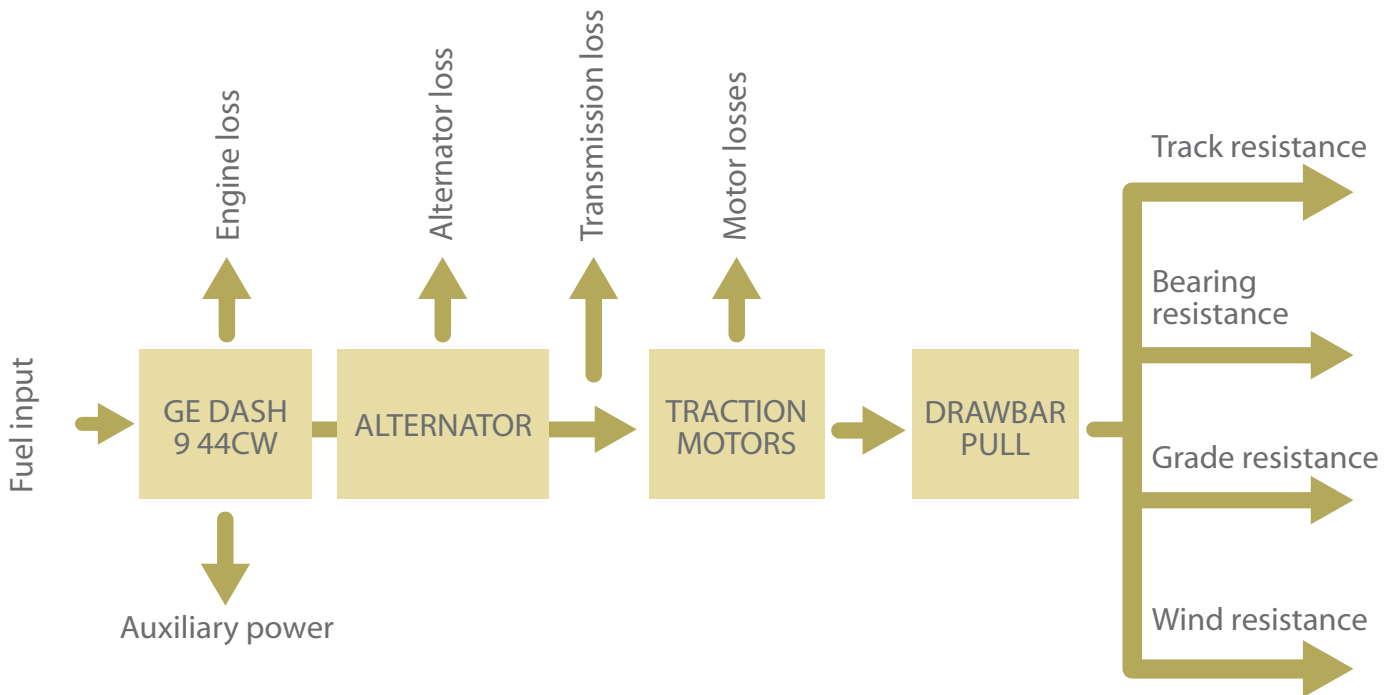


Figure 13: Train energy flows for energy-mass balance analysis

1. AUTO-STOP-START TECHNOLOGY

The automatic engine stop start (AESS) system is a proprietary technology provided by the locomotive manufacturer, General Electric, which shuts down the engine if it has been idling for more than 10 minutes and meets some additional conditions such as sufficient battery charge and brake pressure. If a number of conditions are met while the engine is shut-down then it will automatically re-start.

Fortescue have installed the auto-stop technology and are currently gathering data from the train manufacturer to determine the effectiveness of the intervention. It is estimated that up to 675 kL (26,055 GJ) of diesel per annum could be saved. The utilisation of the train fleet has significantly increased with Fortescue’s growing production volumes, which has also reduced the amount of time that locomotives spend idling.

2. REDUCING EMPTY TRAIN SPEED

At the time of the analysis, trains were running to and from the port along a single track, with a number of sidings along its length. Fortescue plans to duplicate the rail in 2012–13, which will increase the efficiency of the operations.

Cycle time data collected from the operations showed that empty trains often spend a substantial amount of time waiting at three crossing points along the line. By reducing the speed of the empty train on its return to the mine, the aerodynamic losses on this high fuel-consuming part of the cycle could be reduced.

The analysis needed to take into account the various operational considerations that would result from running the trains at lower speeds. For example, one of the scheduling objectives was to ensure that the returning empty trains did not hinder the laden port-bound trains.

A numerical model was developed and used to estimate the benefits from reducing speed between the three crossing points along the track. This would result in reducing the waiting time at the crossing point as well as reducing the waiting time at the mine.

The analysis showed that a majority of trains were spending time waiting at the crossing points.

The model was then used to estimate a lower speed that would reduce waiting times at the crossing points. This model took into account the proportion of energy loss that had been calculated

in the EMB and used this to estimate the throttle position and therefore the fuel usage.

The output of the model is shown in Figure 14. The blue trace illustrates actual speed recorded during an empty run, along with the throttle position. The green trace illustrates the calculated speed that could have been used to minimise the waiting time at crossing points.

A numerical model output was calculated for three sample runs to estimate the fuel savings that could be achieved. The model calculated the added time that would be required to make the trip at the reduced speed, and the corresponding fuel savings.

The numerical analysis found significant variation across the three Runs. Based on the results of this model, Fortescue estimated that a change in waiting time could save between 300 kL (11,580 GJ) and 500 kL (19,300 GJ) per annum without any loss in productivity.

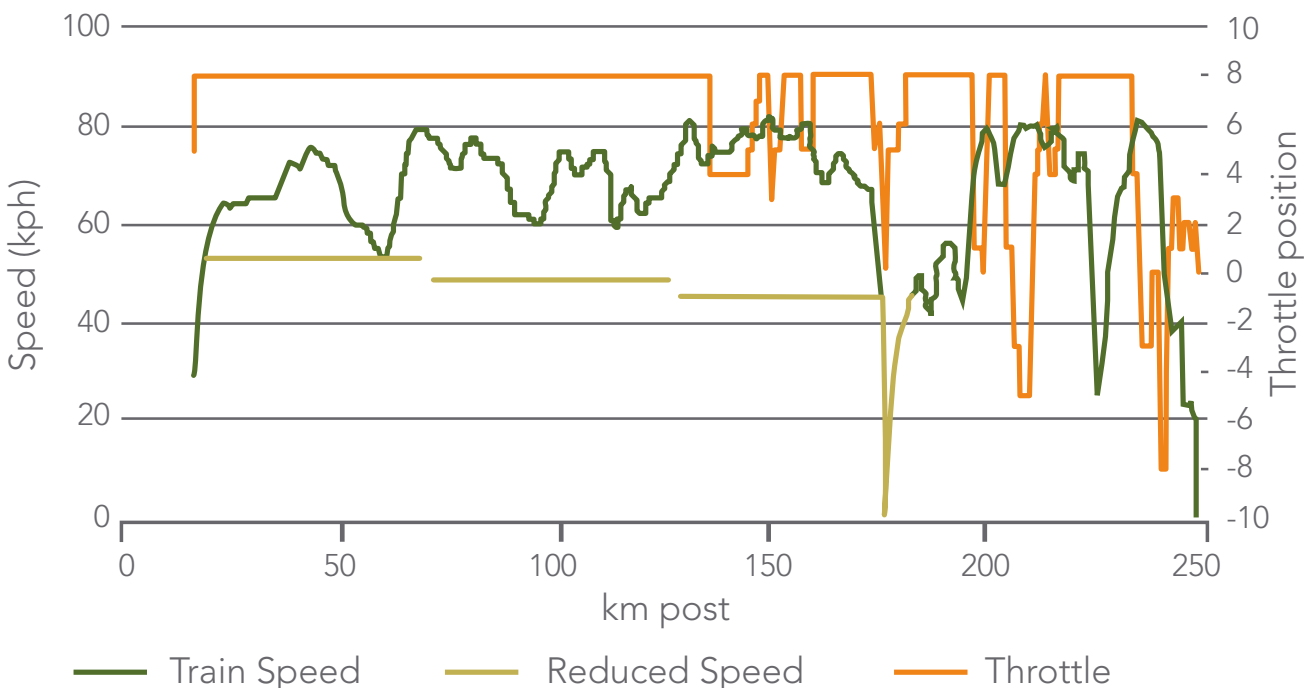


Figure 14: Actual speed and calculated speed for the empty run

LESSONS LEARNT

In undertaking detailed energy analysis and opportunity evaluation of their transport operations, the featured companies in this case study obtained some invaluable insights.

- The analysis of haul trucks and trains can benefit from a broader consideration of the variables affecting energy use and material transport across the entire fleet. An expansion of the scope of analysis to include fleet-wide factors could yield important insights.
 - Several data sources for mineral transport processes are available, however comprehensive knowledge of mine plans and production cycles is often necessary to correctly interpret this data. For haul trucks, the use of GPS data can assist in the identification of opportunities involving route and payload cycles when interpreting real-time vehicle data.
 - Manufacturers of mining equipment typically offer a range of instrumentation options. Many mining vehicles have onboard data collection capabilities that can be used to capture information required for detailed analysis. The selection of a monitoring package that includes a wide range of sensors and on-board real-time data logging provides an important input to the analysis of site and material energy flows. Real-time data can allow more energy efficiency opportunities to be identified, and a more comprehensive evaluation of proposed changes.
 - The energy efficiency of fleet hauling processes is often dominated by factors such as mine planning, production scheduling, pit design, dump design, and significant aspects of the site. The analysis of different modes of operation and the impact of different variables enables companies to identify the need and evaluate the value of modifying haul road design so that trucks can maintain an optimal speed for a greater proportion of the payload cycle.
 - As a deposit is mined, the pit typically gets deeper and material needs to be moved across a greater distance. This can result in more energy being used to achieve the same ore output, so that the operation can appear less efficient over time. Performance indicators need to be carefully designed to account for the increased distance and amount of material moved by haul trucks. These indicators effectively inform business improvement decisions and enable setting targets for the reduction of energy intensity.
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CONCLUSION

The EEO Program requires the use of appropriate energy data collection, measurement and analytical techniques such as the development of suitable key performance indicators and benchmarks. In all featured case studies, the application of rigorous analytical techniques has resulted in a series of useful insights into the key factors that determine the energy efficiency of diesel-using activities.

The haul truck models and simulations developed by Fortescue are being used to improve the efficiency of existing sites, and are being referenced in expansion plans.

The Downer Energy and Efficiency Measure is being used by Downer EDI Mining to track energy efficiency performance within and across several operations, and a better understanding of the key factors that determine energy efficiency has been obtained. After achieving performance improvement of 8% against a 3% target in 2009/10, Downer EDI Mining has set a further 2% energy intensity reduction target.

Leighton is using the Best Truck Ratio as a tool to theoretically benchmark and evaluate hauling operations across different sites. The BTR accounts for changes in the distance and depth of the material movement task, and provides an accurate indicator of vehicle and operator performance.

Fortescue's rail operations have installed auto-stop technology on all trains, and operational changes have been made to reduce idle time. The opportunity to reduce wait times at crossings is changing as the train utilisation rate increases to meet higher production targets.

Many of the insights from the energy analysis at existing sites can be applied to green-field sites where the design can be modified to optimise the energy use and productivity of the transport cycle.

The tools and techniques developed during the energy analysis also provide a sound basis for the ongoing systematic tracking and evaluation of energy efficiency projects, and contribute to the design and development of future project operations.

The mining industry has identified many energy savings in diesel using activities. These include but are not limited to:

- payload management
- managing intersections, gradients and distances travelled through better mine planning
- idle time management

Refer to the Register of Significant Opportunities for a list of opportunities identified by the mining sector and provided in a spreadsheet format. The register contains results from EEO assessments that are reported publicly. The Register can be found at

<http://www.ret.gov.au/energy/efficiency/eoo/industry-sector/mining/Pages/Mining%20Sector.aspx>

CAVEATS

These findings are based on the data and analyses carried out by these corporations and their consultants. Findings may not be comprehensively detailed in this document due to intellectual property and business in confidence reasons.

Readers should be aware that this case study outlines key learnings and does not necessarily represent a complete assessment as required by legislation.

CREATIVE COMMONS

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OTHER EEO PUBLICATIONS AND RESOURCES

The EEO program produces a range of guidance materials and case studies relevant to the mining sector, downloadable from www.energyefficiencyopportunities.gov.au.

- EEO Assessment Handbook
- Energy Savings Measurement Guide
- Representative Assessment Guide
- Energy Mass Balance - Mining
- Energy Mass Balance - Resource Processing
- EEO Verification Handbook
- First Opportunities Report - Mining Industry
- Driving Energy Efficiency in the Mining Sector
- Functional skills for an energy efficient assessment
- Mining Sector - Significant Energy Efficiency Opportunities Register
- EEO Trial Case Study – Xstrata Copper
- EEO Trial Case Study – Xstrata Coal
- EEO Case Study – Thies's Australian Mining Business Unit
- EEO Case Study - Iluka Resources Limited Energy-Mass Balance



Australian Government
**Department of Resources,
Energy and Tourism**

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The aim of the Energy Efficiency Opportunities program is to increase the uptake of cost effective energy efficiency opportunities by Australian industry through improving the identification, evaluation and public reporting of energy efficiency opportunities by large energy using corporations.