SIEMENS

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Dear Mr Hall

On 27 July 2012, the Queensland Competition Authority (**QCA**) issued its draft decision on the QR Network Electric Traction Services Draft Amending Access Undertaking (**DAAU**). Within the draft decision was an invitation for interested parties to present submissions on the QCA's assessment of the DAAU. Siemens has reviewed the draft decision and provides this submission in response for consideration, prior to the publication of a final decision.

## 1. Competition

Siemens was interested to note in the draft decision that certain stakeholders (as referred to in the DAAU) were of the opinion that:

A. Siemens was the current sole and dominant supplier of narrow gauge electric locomotives in the world; and
B. the DAAU, if agreed, would entrench Siemens' "*monopoly pricing in the narrow gauge electric locomotive market*"[1] in Queensland.

Furthermore, QCA appears to have considered these opinions in its analysis when it stated in the draft decision that "*any new entrant contemplating entry with electric traction would be in a relatively weak bargaining position when negotiating with the sole locomotive supplier.*" [2]

Whilst it is accurate to state that all narrow gauge electric locomotives sold in Australia in the last decade have been either supplied by Siemens or by a consortium comprising of Siemens and UGL Limited, this fact cannot be relied upon as evidence that there is no competition in the narrow gauge heavy haul electric locomotive market both in Queensland and globally.

There are approximately eight major suppliers of heavy haul electric locomotives globally including CNR, CSR, Toshiba/Hitachi, Transmash, Alstom and Bombardier. More than half of these manufacturers are actively tendering in markets where narrow gauge electric locomotives are used. This is evidenced by the fact that five of the major suppliers mentioned above have submitted responses to a tender for 95 heavy haul narrow gauge electric locomotives currently under consideration by operator Transnet in South Africa.

In comparison to these major suppliers Siemens is globally competitive, however, Siemens cannot be considered a monopoly supplier or even a dominant supplier in the global heavy haul electric locomotive market.

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[1] QCA Draft Determination, p.31
[2] QCA Draft Determination, p.35

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As with any established market for complex products, new competitors in the Australian locomotive market face certain barriers to entry including the high transportation costs to bring locomotives into Australia and the complex local regulatory requirements to import and then gain approval to operate a particular type of locomotive on Australian rail networks. However, these barriers to entry are the same for all locomotive suppliers looking to enter the market and as such, provide a level playing field for all suppliers.

Siemens entered the Queensland narrow gauge heavy haul locomotive market as a result of a successful locomotive tender in the early 2000s. This tender was a fair and equitable process with Siemens having no inherent advantage over the other major electric locomotive suppliers that responded. As a result of its success in this tender, Siemens has invested heavily in Queensland over the last decade increasing its resources, infrastructure and refining its logistics and regulatory applications such that it can now import an electric locomotive to Australia for nearly immediate operation and strongly support those locomotives.

In summary, the Australian narrow gauge electric locomotive market is a competitive one. Each of Siemens' current or future customers has the option to purchase narrow gauge electric locomotives from any of the major suppliers in the global electric locomotive market and Siemens prices its locomotives accordingly. This does not indicate a market with structural inefficiencies.

These facts are in contrast to the QCA draft decision which indicates that Siemens operates in a monopolistic environment. As set out above, the Australian narrow gauge electric locomotive market is not a monopolistic environment nor does Siemens attempt (or would have any chance) to apply monopolistic pricing strategies. Siemens would appreciate if the QCA would review and retract the statements regarding Siemens' market dominance as part of the publication of a final decision

## 2. <u>Technology</u>

The QCA draft decision states that some stakeholders to the DAAU were of the opinion that "*the market for diesel locomotive technology is broad enough to be competitive, which incentivises investment in improvements and technology,*" as opposed to the market for electric locomotive technology which is "*currently supplied by one dominant producer*."[3]

Siemens notes that the QCA took these opinions into account in its draft decision when it stated that "*there are a number of competing suppliers of narrow gauge diesel locomotives and that the rivalrous behaviour between the competing suppliers is likely to result in greater technological improvements in diesel technology in comparison to electric locomotives where there is only one supplier.*"

The opinions expressed by the stakeholders, and subsequently adopted by the QCA in the draft decision, only focus on the Australian locomotive market and fail to appreciate that the majority of advancements in technology for both diesel and electric locomotives are based on global market incentives. This "*rivalrous behaviour*" between the competing diesel locomotive suppliers in Australia is also present in other global markets and whilst competition in the Australian locomotive market will have contributed to improvements in technology, it is primarily rivalry and competition on a global scale (in particular the United States, Russia, China and Europe) that has driven continuous innovation in locomotive technology.

The Australian market has enjoyed significant advancement in locomotive technologies over the last 25 years. These advancements include alternating current (AC) traction, distributed power, IGBT traction converters as well as dynamic and electronically controlled pneumatic (ECP) braking. These are all technologies that have been developed for the global rollingstock markets and introduced to Australian locomotives as a result.

Siemens is a world leader for research and development (R&D) employing nearly 28,000 R&D employees in over 170 locations worldwide and investing over five per cent of its revenue in R&D. As a result of the competitive nature of the global electric locomotive markets in which it is a participant, Siemens utilises its strength in R&D to further improve its electric locomotive fleets to provide greater efficiency and cost benefits to its customers. As most of the Siemens electric locomotives in operation globally utilise similar

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[3] QCA Draft Determination, pg.10, 11

technology, any advancements in technology realised by Siemens generally becomes the new standard technology implemented onto any new locomotive manufactured for the global market.

Siemens' customers in Australia are therefore continually in receipt of these technological advancements not only when they purchase new locomotives but also during normal maintenance and overhaul activities on their existing fleets. This process occurs despite Siemens being the sole supplier of narrow gauge electric locomotives in Queensland at this time. Further, given the competitive narrow gauge electric locomotive market (as set out at section 1 above), Siemens has a strong incentive to implement technological advancements on any Siemens locomotives in the Australian market.

These facts contradict the statements made within the QCA draft decision that Siemens has no incentive to invest in improvements and technology within the narrow gauge electric locomotive market. Siemens therefore requests that the QCA reconsiders these statements prior to the publication of a final decision.

## 3. Efficiency of electric versus diesel locomotives

The QCA draft decision discusses at some length the relative efficiency of electric and diesel traction from a total cost of ownership and network operations perspective. Siemens in general agrees with the opinions expressed in the draft decision, and considers, as an experienced manufacturer and maintainer of diesel and electric locomotives for the global market, it is uniquely placed to be able to provide additional input on this topic.

### 3.1 Available Power / Energy

Modern diesel and electric locomotives are based on very similar design principles. Both rely on electric traction integrated into their bogies and driven by similar traction converters. However, the amount of electrical power and energy available to the electric traction systems is very different for the different types of locomotive.

In diesel locomotives, a diesel engine uses the combustion of fossil fuel to drive an electrical alternator to provide power to the electric traction systems. Due to the inherent space and weight limitations of a locomotive combined with the limited power to volume ratio of diesel engines, the amount of power available to the electric traction systems of a diesel locomotive is limited.

The amount of energy available to a diesel locomotive is also limited by the fact that they must carry their energy on board in the form of diesel fuel. The same inherent space and weight restrictions mentioned above apply to limit the amount of fuel that can be carried and therefore the range of diesel locomotives requiring down times for refuelling as further discussed in section 3.8 below.

In the case of an electric locomotive, power is taken from the electrified infrastructure and transformed into a suitable voltage using a traction transformer. The amount of power available is limited by the output of the power network supplying the electrified infrastructure (far greater than what any individual electric locomotive needs), and hence the amount of power available to the electric traction system of an electric locomotive is only limited to what the traction converters and traction motors can manage.

### 3.2 Starting Tractive Effort

A high starting tractive effort is a necessary characteristic of all heavy haul locomotives to enable a fully loaded train to be lifted from standstill on a steep gradient.

Generally, the starting tractive effort of diesel and electric locomotives is limited by the mass (or weight) of the locomotive and the adhesion coefficient of the wheel-rail interface. Since the maximum mass of a locomotive is defined by the capability of the below rail infrastructure and the adhesion coefficient is a function of environmental conditions, the differences between the starting tractive effort of a diesel locomotive powered train and an electric locomotive powered train is due simply to the combined masses of the locomotive(s) hauling the train and has nothing to do with the traction type.

To illustrate this point, some actual examples of the starting tractive efforts of three differently powered coal trains currently operating in the Central Queensland coal networks are given in Table 1 below.

| **Locomotives used** | **Total mass of Locomotives (m)** | **Grav. Force from mass ($F_g$=m.g)** | **Average adhesion coefficient (μ)** | **Max starting tractive effort ($F_{TE}$= μ. $F_g$)** |
|---|---|---|---|---|
| **Five DC electric locomotives** | 5 x 110t = 550t | 5,395kN | 30% | **1619kN (train)**<br>324kN (per locomotive) |
| **Four AC diesel locomotives** | 4 x 120t = 480t | 4,709kN | 30% | **1413kN (train)**<br>353kN (per locomotive) |
| **Three AC electric locomotives** | 3 x 132t = 396t | 3,885kN | 30% | **1165kN (train)**<br>388kN (per locomotive) |

**Table 1 – Maximum starting tractive effort for different train types in CQ coal network**

## 3.3 Continuous Tractive Effort

The ability to maintain a continuous tractive effort is another important characteristic for heavy haul locomotives. This feature ensures that the maximum amount of load can be hauled using the minimum number of locomotives.

The continuous tractive effort of diesel and electric locomotives are similar at low speeds due to similar limitations of their electric traction systems. However, at speeds above 15-20 km/h the continuous tractive effort of each locomotive type begins to differ due to the amount of power available to their electric traction systems (as discussed in section 3.1 above). As more power is available to an electric locomotive, the continuous tractive effort available from an electric locomotive is greater at medium and higher speeds. This can be seen by the separation in the example tractive effort curves in Figure 1 below.

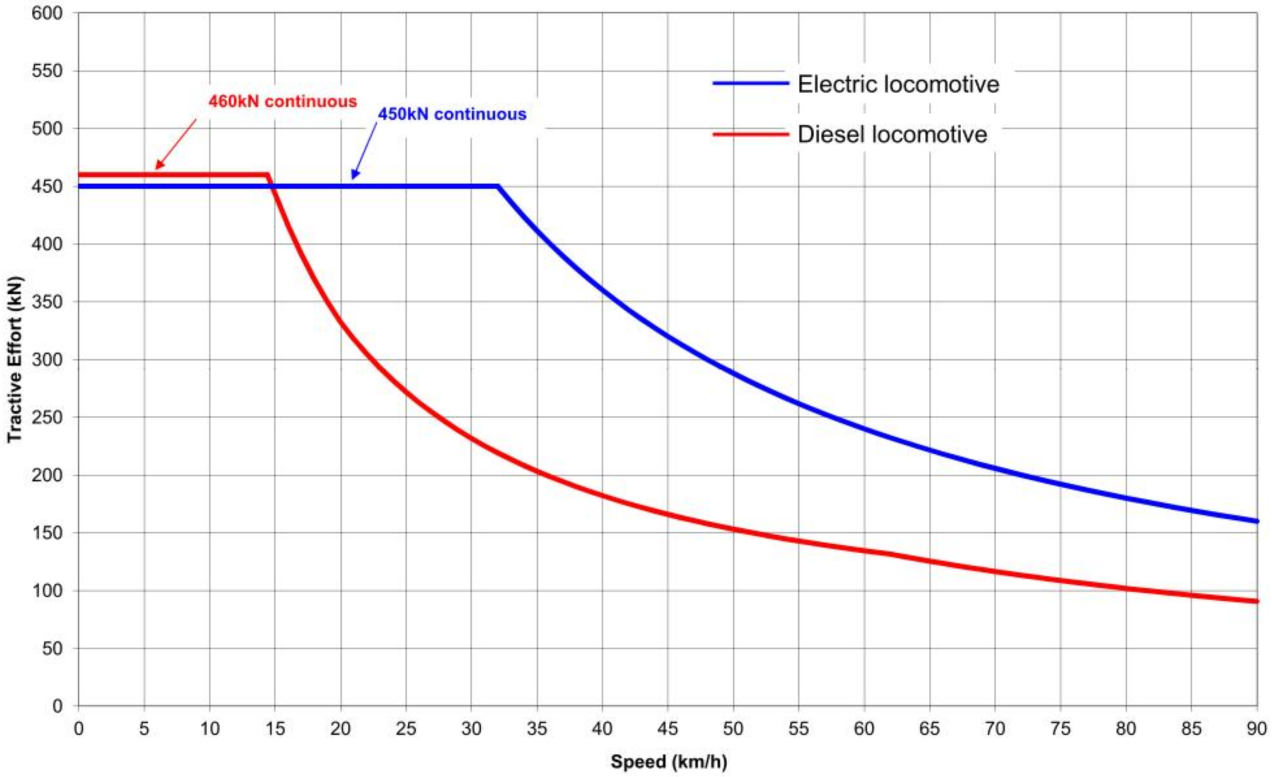

**Figure 1 – Example Tractive Effort Curve – Diesel and Electric**

## 3.4 Average Speed / Acceleration

Another key characteristic of any heavy haul locomotive is an ability to consistently accelerate quickly to the highest possible speed over a period of time in order to produce a high average speed for a given haulage journey. The achievement of a high average speed is an important factor in the efficiency of the rail network as it leads to decreased headways, cycle times and generally improving the throughput without requiring investment in the below rail infrastructure.

Maximum speed and acceleration of locomotives is calculated by the maximum power available to their electric traction systems. As mentioned above, electric and diesel locomotives both have similar electric traction systems, therefore the maximum speed and acceleration characteristics of electric and diesel locomotives only differ due to the amount of power available to each traction type.

Due to the relationship between power (P), velocity (v) and force (F) being expressed as:

$P = v.F$ or $P/v = F$

the overall available power for a locomotive can be described as the area under its tractive effort curve (see Figure 1 above). This shows again that the overall available power for an electric locomotive is greater than a diesel locomotive and hence the maximum speeds of an electric locomotive are higher than that of a diesel locomotive.

This is more succinctly seen when train resistance curves are overlayed over the example tractive effort curves (see Figure 2 below). A train resistance curve illustrates the relationship between the sum of all forces resisting the movement of the train (e.g. rolling resistance and aerodynamic drag) and the speed of the train. A train resistance curve will typically show the train resistance for a standard train length and/or weight, both on the level or on an uphill gradient. The intersection of the train resistance curve and tractive effort curve gives the maximum speed of the train for a given load (i.e. when the net tractive effort is zero).

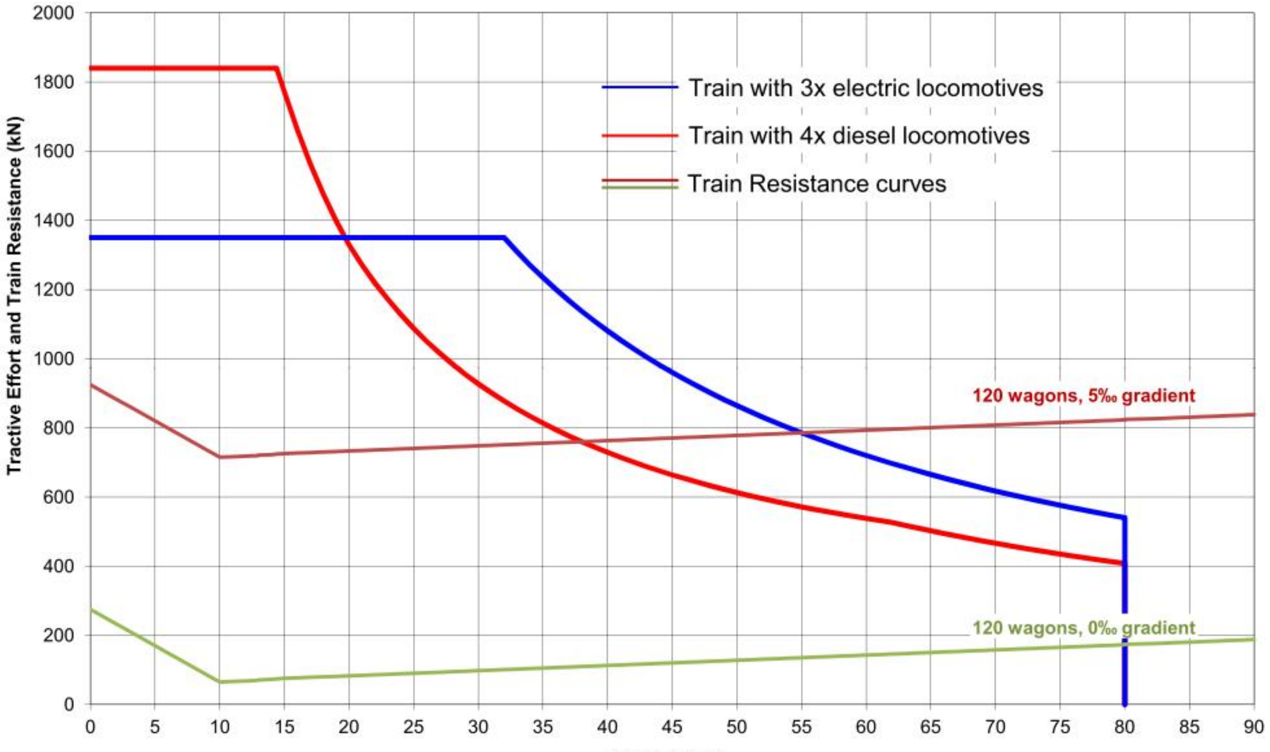

Figure 2 – Example Train Resistance versus Tractive Effort Curves [4]

The two example train resistance curves shown in Figure 2 represent a standard load for a heavy haul train in the Central Queensland coal networks at a 5‰ (1:200) gradient and on level track. It can be clearly seen that the maximum speeds attainable by an electric locomotive powered train for the 5‰ gradient scenario are nearly 50 per cent greater than those attainable by a diesel locomotive powered train.

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[4] The tractive effort curves in Figure 2 have been multiplied by the number of locomotives typically used for a coal train in the Central Queensland coal networks i.e. three electric or four diesel locomotives.

The acceleration characteristics of the train are also related to the power available to the locomotives. Higher power to weight ratios of an electric locomotive corresponds to higher acceleration and therefore not only can an electric locomotive powered train achieve higher speeds, it can also accelerate to those speeds much faster than a diesel locomotive powered train.

### 3.5 Energy Efficiency

The comparison of the energy efficiency of electric versus diesel locomotives is always a challenging topic to assess as there are many factors influencing the analysis. In addition to the usual generation, distribution and locomotive based efficiencies, any energy efficiency comparison should always consider the processes required to access, refine and transport the primary energy source to its point of use (i.e. coal in the case of electric locomotives and crude oil in the case of diesel locomotives - see section 3.7 below). Whilst the processes related to accessing, refining and transporting of crude oil are considered less energy efficient than similar coal related processes, it is difficult to quantify this difference as the necessary information is not reliably available.

In contrast, the efficiencies of the various systems involved in the generation and provision of energy to the wheels of a locomotive are well documented. Table 2 below provides a list of the various systems involved in the generation and provision of energy to the wheels of a locomotive and their relative efficiency figures. The figure at the bottom of Table 2 shows that the total energy efficiency of an electric locomotive is on average much higher than a diesel locomotive.

| **Diesel locomotives** | | **Electric locomotives** | |
|---|---|---|---|
| Diesel Engine (average) (maximum 40%) | 25% [5] | Coal fired power plant (average) | 38% [6] |
| Alternator and Rectifier | 92% | Electricity distribution | 90% |
| Main Inverter | 97% | Main Inverter | 97% |
| Traction Motors (average) | 90% | Traction Motors (average) | 90% |
| Gears | 97% | Gears | 97% |
| **Total Efficiency** | **19.5%** | **Total Efficiency** | **29.0%** |

**Table 2 – Energy efficiencies of various systems**

### 3.6 Dynamic Braking

The overall energy efficiency of both electric and diesel locomotives can be improved through the use of electrical energy generated by its traction motors when they are used to brake the train (dynamic braking). In the case of more modern diesel locomotives, some of the dynamic braking energy is able to be used to power auxiliary systems on the locomotive producing an overall efficiency increase of up to three per cent. In the case of an electric locomotive, the majority of the dynamic braking energy can be regenerated back into the electrified infrastructure to be consumed by other locomotives in the section. Using this advanced but already installed technology, the energy efficiency of an electric locomotive can be increased between 10-30 per cent depending on the operational capabilities of the rail network.

The benefits of regenerative braking on electric locomotives were demonstrated recently as part of trial carried out on a QR National coal train in the Central Queensland coal networks. The energy regeneration measured for one 500km round trip on the Goonyella system with a train made up of three electric

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[5] Average thermal efficiency of diesel motors are dependent on the operating conditions of the motor and so this figure may vary to some extent

[6] Efficiency figure is based on open cycle power generation methodologies predominately utilised in Queensland. Upgrade to a combined cycle methodology can increase average efficiency to in excess of 60%

locomotives and 124 wagons was approximately 4500 kWh which is close to a quarter of the energy consumed by the train during the round trip even when taking into account the efficiency losses in the electrified infrastructure.

### 3.7 Primary Energy Source

Electric locomotives are exceptionally flexible regarding their primary source of energy as they do not discern between the different power generation methodologies (fossil, renewable, nuclear or otherwise) so long as the electricity is available in the overhead infrastructure. The current primary energy source for electric locomotives operating in the Central Queensland coal networks is coal which is securely available in Australia for the entire service life of the current fleet. Although the Central Queensland coal networks are currently powered by aging coal fired power plants, any future efficiency or environmental improvements in the power generation industry will immediately and automatically benefit the efficiencies of all electric locomotives operating in these rail networks. During an electric locomotive's 30 years service life carbon emissions from power plants are expected to reduce dramatically through the introduction of modern filter technology, power generation efficiency will increase through the building of new modern power plants or the upgrade of existing ones and any emerging renewable energy sources will be utilised to power the electrified infrastructure.

The availability of the primary energy source for diesel locomotives (i.e. crude oil) on the other hand cannot be guaranteed for the entire service life time of the current fleet of diesel locomotives, especially given the reliance that Australia has on imported oil with the majority supply coming from cartel-controlled countries (via OPEC). Furthermore, world oil prices are highly volatile and on average increase much faster than the prices of domestic produced primary energy sources and a peak world oil production would most likely result in a dramatic increase in crude oil prices due to supply being unable to keep pace with increasing demand.

### 3.8 Range

Whilst the range of an electric locomotive is effectively unlimited as long as there is electricity in the overhead infrastructure, the amount of diesel fuel a locomotive can carry is naturally limited. As diesel locomotives need to be refuelled regularly this leads to an additional downtime of approximately five per cent of locomotives in operation. Additional infrastructure for refuelling (tanks, refuelling stations, personnel, training, environmental impacts, sidings, etc.) should also be considered in any operational efficiency comparison.

### 3.9 Environmental Efficiency

Besides the different operational characteristics used when comparing the efficiencies of electric and diesel locomotives, aspects affecting the environmental efficiency of locomotives are also important to consider including noise and exhaust gas emissions.

Electric locomotives are generally quieter compared to diesel locomotives since there is no engine and exhaust noise and less mechanical noise. The main sources of noise on an electric locomotive (e.g. brake resistor blowers, compressors) are all components normally also installed on a diesel locomotive.

It has been claimed by a diesel locomotive manufacturer that a key feature of modern diesel locomotives is that they "*emit less carbon per gross-tonne mile moved than electric locomotives, based on current fleets and coal power generation*"[7]. However, with the recent introduction of modern electric locomotives like the Siemens E40AC electric locomotive (proven to save 1,050MWh and 820 tonnes of $CO_2$ per year per train[8]), the increasing use of regenerative braking (see section 3.6 above), and the future improvements expected in the power generation industry in Australia (see section 3.7 above), Siemens strongly believes that this claim will be invalid. Further, it is apparent that the cost to introduce modern filter technology into one power plant providing electrical energy for a fleet of electric locomotives (and for public consumption) will be lower than the cost to individually install a similarly effective filter technology into a fleet of diesel locomotives.

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[7] GE Powerhaul® Series Locomotive brochure, pg. 3

[8] Siemens locomotives: A clean solution brochure, pg. 5

### 3.10 Flexibility

Siemens agrees that diesel locomotives offer greater flexibility to customers compared to electric locomotives as they can be operated on both electrified and non-electrified rail networks.

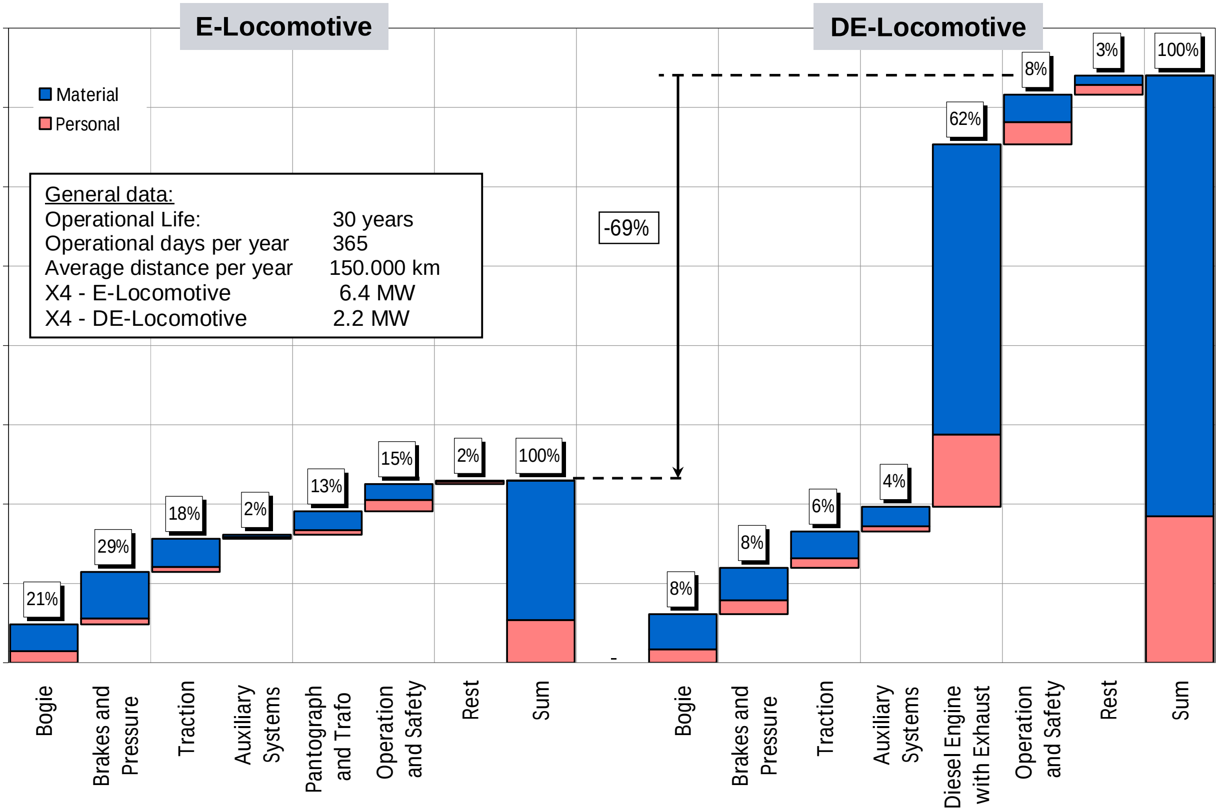
### 3.11 Maintenance

There is no inherent difference between electric and diesel locomotives in the activities undertaken as part of a low level maintenance inspection. The major differences in maintenance costs are realised as part of higher level inspections (overhauls) especially with regard to the major components of the locomotives.

The major components in an electric locomotive (i.e. main transformer and other high voltage equipment not installed on a diesel locomotive) are virtually maintenance free with small subcomponents substituted during overhauls rather than the major component itself being removed. However, the major components in diesel locomotives (i.e. diesel engine, generator, air filter, exhaust, cooling plant, fuel tank, starter battery and alternator and other equipment not installed on an electric locomotive) require regular and ongoing maintenance due to inherent and unavoidable wear and tear occurring during operation. This is especially true for the diesel engine which requires a significant overhaul approximately every eight years.

In Siemens' experience as a manufacturer and maintainer of both diesel and electric locomotives, Siemens can conclude that the overall lifetime maintenance cost is from 30 per cent up to nearly 70 per cent cheaper for an electric locomotive than for a diesel locomotive (see Figure 3 below).

Please note that these figures are on a per locomotive basis and does not consider that a customer usually requires more diesel locomotives than electric locomotives to achieve a given haulage task.



General data:

| | |
|---|---|
| Operational Life: | 30 years |
| Operational days per year | 365 |
| Average distance per year | 150.000 km |
| X4 - E-Locomotive | 6.4 MW |
| X4 - DE-Locomotive | 2.2 MW |

**Figure 3 – Comparison of overall lifetime maintenance cost – Diesel and electric locomotives**

## 4. Summary

In summary, it is evident that the choice of traction is primarily a question of overall system optimisation, taking into account all aspects of the railway system. Equally important is the perception of competitive market forces and future technological developments given the long-term nature of rollingstock and infrastructure investments. Therefore, a view of the total cost of operation is as equally important as achieving energy and environmental policy objectives. As AC locomotive propulsion technology is well established in Australia, there is opportunity to continue to leverage the opportunities presented by the higher performance characteristics of electric traction through continued investment and utilisation of dedicated heavy rail haulage corridors such as the Blackwater and Goonyella systems.

Siemens trusts that the QCA will provide due consideration to the issues and concerns presented when composing its final determination and, in particular, Siemens would ask that the facts set out in this paper are taken into consideration in the QCA's final decision.

Yours sincerely,

[redacted]

Paul Bennett

Vice President

Rail Systems Division

Siemens Ltd