GREENHOUSE GAS EMISSIONS AND ENERGY EFFICIENCY

EASTLINK PROJECT TUNNEL

18 August 2005

Version 3

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Energetics

energy
greenhouse
solutions

Energetics Pty Ltd

CONTACT DETAILS

SYDNEY
PO Box 294
North Sydney NSW 2059
Telephone: +61 2 9929 3911
Facsimile: +61 2 9929 3922

MELBOURNE
PO Box 652, CSW
Melbourne VIC 8007
Telephone: +61 3 9602 5511
Facsimile: +61 3 9602 5599

NEWCASTLE
Telephone: +61 2 4963 1782
Facsimile: +61 2 4963 1473

PERTH
PO Box Y3014, East,
St Georges Terrace, Perth WA 6832
Telephone: +61 8 9326 4117
Facsimile: +61 2 9929 3922

WEB: www.energetics.com.au
E-MAIL: info@energetics.com.au

PROJECT DETAILS

Job Reference: J106028

Peter Buchanan	Works Approval Manager
EastLink	Position
John Annas	Principle Consultant
Energetics Project Manager	Position

Description	Prepared By	Reviewed By	Approved By	Approval Date
Final Report V3	MCS	JAN		1 August 2005

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Executive Summary

EastLink will have twin, three lane 1.6 km tunnels at its northern end under the environmentally sensitive Mullum-Mullum Creek near Mitcham. This report estimates the annual tunnel energy consumption and Greenhouse Gas (GHG) emission based on the preliminary design.

This report considers only the energy consumption associated with operation of the tunnel services, including ventilation, lighting, signage, control systems and pumping. It does not consider energy consumption or GHG emissions caused by:

- Construction of either the tunnels or other roadways associated with EastLink
- Operation of other roadways constructed as part of EastLink
- Vehicles using the tunnels or other roads associated with EastLink
- Operation of the tunnels under emergency situations.

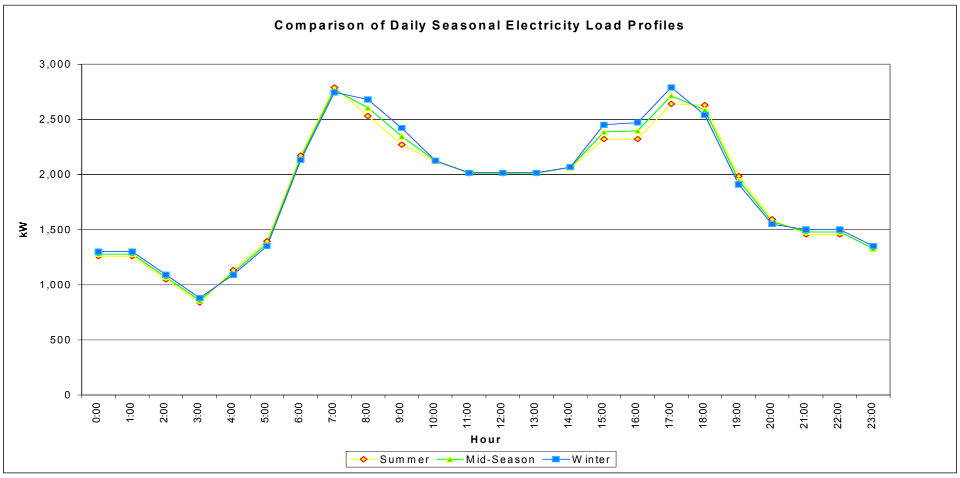
Information contained in this report should be considered as a "works in progress". The preliminary tender design data (Reference mfff001B) and the "Tunnel Ventilation System" preliminary design report (Reference AL-MO4-RFT-VE01-0020) was used to calculate the projected electricity consumption and emissions. As full detailed design and equipment selection for each of the energy systems is completed (over the next 6-12 months) there maybe changes to the forecast.

Electricity will be the only energy source used in the normal operation of the tunnels. The modelled annual electricity consumption and GHG emissions due to operation of the tunnels are as follows.

Item	Electricity usage pa (MWh)	Electricity usage (Wh/vehiclekm)	GHG emission pa (T CO_2-e)	GHG emission (kg/vehiclekm)
Electricity	16,417	256	22,851	0.357

* No of vehicles daily = 109,623 and Klm = 1.5

Tunnel ventilation accounts for 74.9% of the total energy consumption and GHG emissions, followed by lighting (14.2%), portal buildings and control cubicles (8.3%) and signage (2.2%). The graph below shows the typical daily baseline electrical load profile.



Best practice principles have been included in the design of the energy systems. These design principles have been aligned with the number of EPA Works Approvals conditions and clauses in the PS&PR governing tunnel air quality and release.

One of the conditions determines the ventilation requirement for the tunnels and achievement of the conditions requires use of energy for forced mechanical ventilation. The conditions include:

- No net portal emissions
- In tunnel carbon monoxide (CO) limits
- In tunnel visibility limits
- Maximum velocity of tunnel air

A small change in operation of the ventilation system will have a significant impact on tunnel electricity use and cost and resultant greenhouse emissions. Measures that have been included in the preliminary design to minimise ventilation energy consumption and GHG emissions are as follows:

- The use of high energy efficiency jet and ventilation fans have been selected and sized to allow stage control of fans to match traffic flow. The motors have a 2% improvement against standard motors, and achieving an annual reduction of 246 MWh and 342 $tCO_{2\text{-}e}$.
- Relocation of the western portal ventilation stacks close to the tunnel entrance/exit reduces the duct pressure drop by 80 kPa and improves the energy efficiency of the western ventilation fans by 5% calculated to achieve an annual reduction of 207 MWh and 288 $tCO_{2\text{-}e}$.
- Air flow through the tunnel will be maintained by automatic feedback control of jet fans to meet the air velocity requirements. Real-time traffic data, pollutant and visibility data will be used as a trim input to determine the minimum ventilation rate and nominal air flow set points for control.

Other measures that will ensure tunnel efficiency include:

- The use of highly efficient high pressure sodium (HPS) luminaries for the main tunnel lighting as against a mixture of fluorescents and HPS. The comparison shows that the adopted HPS only option at 351 kW is 27% more efficient than the mixed fluorescent + HPS option at 479 kW. This results in an annual saving of 592 MWh and 824 $tCO_{2\text{-}e}$.
- Control of main tunnel entry and transition zone lights using photometers. The interior tunnel lighting will use six switching levels to control between day and night levels. Energy consumption in winter will be lower as a result.
- Lighting in rooms and areas where occupancy is intermittent will be provided with light controls to detect entry and exit.
- HV losses will be minimised by taking electricity at high voltage (22kV) and constructing a substation at either end of the tunnel, reducing cable losses.
- The installation of Power factor correction equipment at the main supply points to minimise maximum KVA demand and line losses in the distributor’s network. The resulting reduction of GHG emissions has been calculated at 320 $tCO_{2\text{-}e}$ per annum

A number of ongoing actions and initiatives will also be implemented to ensure that the operation of the tunnel is energy and greenhouse efficient as possible whilst still maintaining air quality and lighting conditions. These include detailed final design and equipment selection, commissioning and ongoing monitoring, reporting and optimisation of systems.

1. Background

In October 2004, EastLink was awarded the tender to design, construct, finance, operate and maintain the Mitcham-Frankston Project (MFP). EastLink is a consortium comprised of Macquarie Bank, Thiess, John Holland and Alstom.

The new road will extend for 39 kilometres, connecting Springvale Road in the north to the Frankston Freeway in the south. It will be three lanes in each direction for the majority of its length, with two lanes in each direction for a six kilometre section at the southern end. The EastLink route is shown in Appendix 1.

EastLink will have twin, three lane 1.6 km tunnels at its northern end under the environmentally sensitive Mullum-Mullum Creek near Mitcham. A drawing of the tunnels superimposed on an aerial photo of the area is also shown in Appendix 1.

As part of the Work Approvals process for the tunnels, EastLink must submit an estimation of annual energy consumption and Greenhouse Gas (GHG) emission and also identify energy best practice options. In addition it is a condition of the EPA SEPP(AQM) requirement to submit annual reports on the energy and greenhouse emissions performance.

Energetics produced EastLink's submission on tunnel operating energy consumption and GHG production.

Coverage and Exclusions

Information contained in this report should be considered as a "works in progress". The preliminary tender design data (Reference mfff001B) was used as the baseline. As full detailed design and equipment selection for each of the energy systems is completed (over the next 6-12 months) there will be changes to the baseline.

This report considers only the energy consumption associated with operation of the tunnel services, including ventilation, lighting, signage, control systems and pumping. It does not consider energy consumption or GHG emissions caused by:

- Construction of either the tunnels or other roadways associated with EastLink
- Operation of other roadways constructed as part of EastLink
- Vehicles using the tunnels or other roads associated with EastLink
- Operation of the tunnels under emergency situations.

Electricity is the only energy source used in the normal operation of the tunnels.

Disclaimer

This report draws on information provided by the client and other sources. Energetics has relied on this information in making its assessment.

2. Energy & Emissions Forecast

This section describes in detail the methodology used to develop the energy usage and GHG emissions forecast for the EastLink tunnels and the resulting energy consumption and GHG emission profiles.

2.1 ENERGY MODEL METHODOLOGY

The following methodology and analysis was used to develop the energy usage and GHG emissions forecast for the EastLink tunnels:

- In calculating tunnel electricity consumption in kWh, GHG emission in TCO_2-e and the KPI Watt hour per vehicle kilometre, the following information was used from data and drawings:
  - Hourly operating loads as per Load Profile Calculations Rev C 29/1/04 Ref mff001B under various end-use categories including ventilation, lighting, signage, pumping equipment and others were entered into an energy modelling tool to develop load and monthly consumption profiles..
  - "Tunnel Ventilation System Preliminary Design Report ((AL-M04-RPT-VE01-0020 revision A-01).
  - Projected daily traffic flow through both tunnels: 109,623 vehicles (Hyder Consulting for design Year 2008)
  - Tunnel length (each): 1.6 km
- Data was available for summer and winter electricity consumption, the major difference being lower main tunnel lighting consumption in winter due to shorter days and lower tunnel lighting levels from sunset to sunrise. The lighting load predictions were interpolated in order to estimate mid season (spring and autumn) electricity consumption and GHG emissions.
- An energy profile for a fire incident scenario was available but was not modelled due to its unlikely and irregular occurrence.
- In calculating total GHG emission and GHG emission in $kgCO_2$ per vehicle kilometre, the full fuel cycle emission factor for Victoria from the Australian Greenhouse Office - Factors and Methods Workbook (August 2004) was used. This value, from Table 4, is 1.392 kg CO_2-e/kWh.
- In converting from energy demand in kVA to electricity consumption in kWh, a factor of 0.95 was used. This power factor allowed for the in-built power factor associated with the lighting and high efficiency motors in addition to the installation of power factor correction equipment to the main switchboards.

2.2 ENERGY & GHG EMISSION BASELINE

The following charts show the projected electricity consumption and load profiles associated with tunnel operation for each month of the year.

Figure 1: Projected Monthly Electricity Consumption

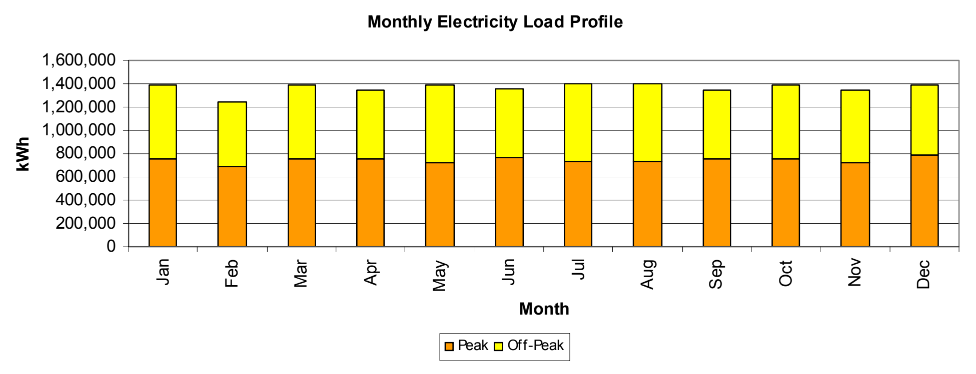
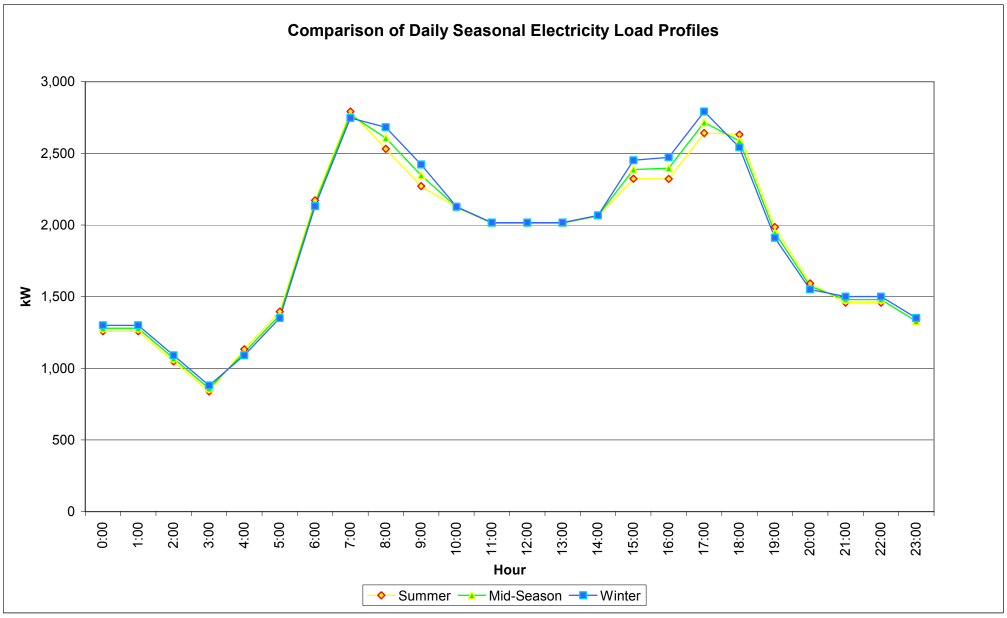
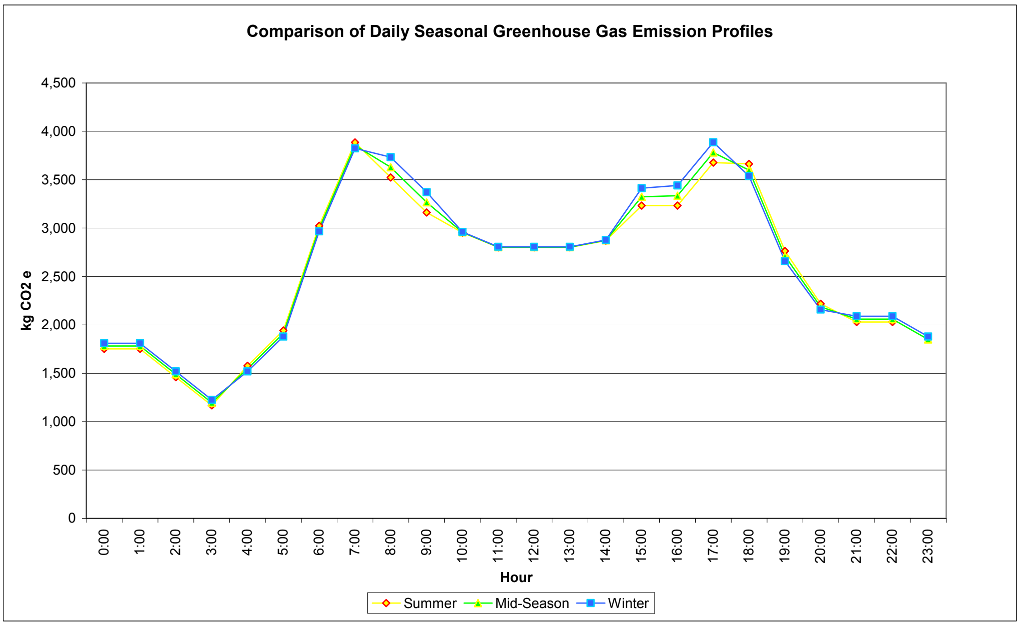


Figure 2: Daily Seasonal Electrical Load Profiles



The projected monthly energy consumption figures and Australian Greenhouse Office (AGO) emission factors for Victorian electricity were used to derive the quantities of GHG emissions. The daily profile GHG emissions are shown in the following figure.

Figure 3: Daily Seasonal Greenhouse Emissions Profiles



2.3 BREAKUP OF ENERGY USAGE & EMISSIONS

The following table and charts show the break-up of energy consumption across the various end-use categories. They show which end users are the biggest energy consumers and hence GHG producers.

Table 1: Electricity Consumption & Greenhouse Emission by End Use

Item	Maximum Daily Load (kW)	Electricity consumption (MWh/annum)	Greenhouse gas emission (TCO_2e/annum)	% of total
Exhaust Fans	1680	8,278	11,523	50.4%
Jet Fans	850	4,015	5,589	24.5%
Main Tunnel Lighting	351	2,192	3,051	13.4%
Emergency Lighting	11.4	100	139	0.6%
Cross Passage Lighting	4.4	38	53	0.2%
Portal Buildings	137.9	1,208	1,682	7.4%
Control Cubicles	15.8	155	215	0.9%
Tunnel Info Signs	22.8	200	278	1.2%
Lane Use Signs	11.4	100	139	0.6%
Variable Message Signs	7.6	67	93	0.4%
Ground Water Pump	7.3	64	89	0.4%
TOTAL	3,099	16,417	22,851	100%

Figure4: Annual Electricity Usage and Greenhouse Emission by End Use

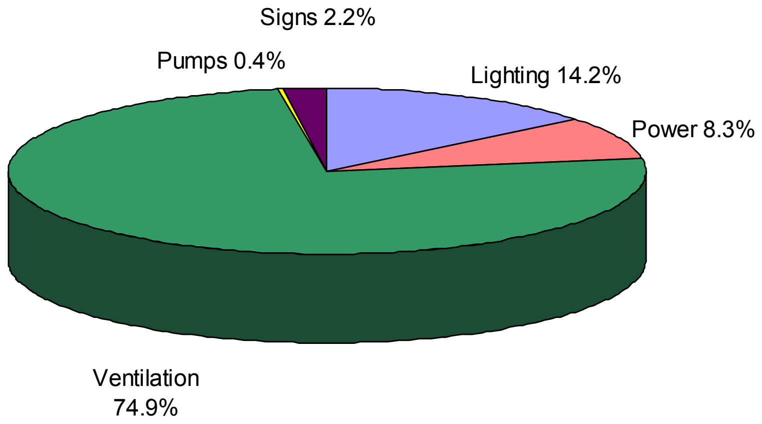


Figure5: Summer Electricity Usage by End Use

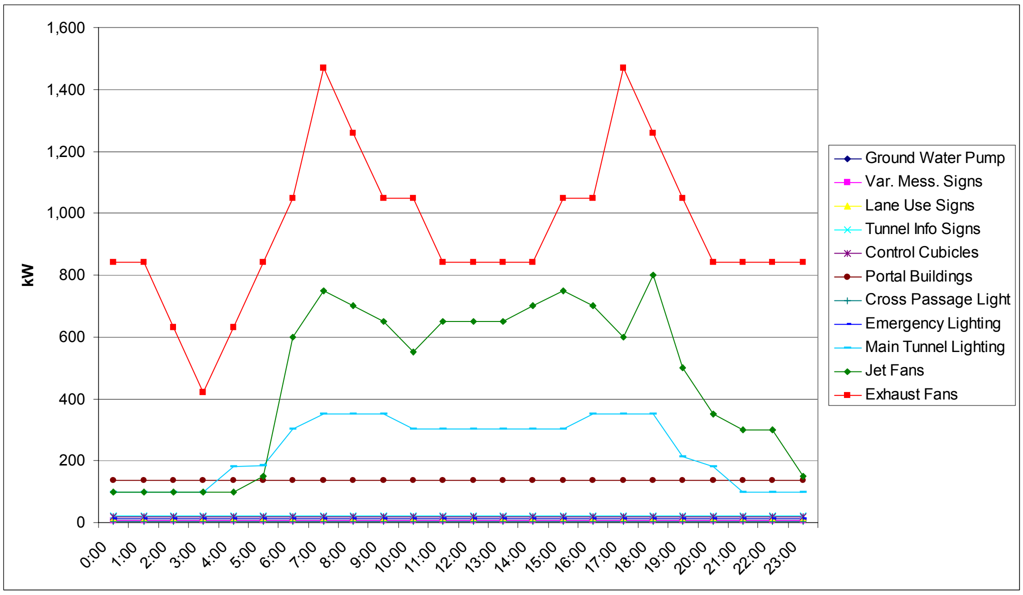
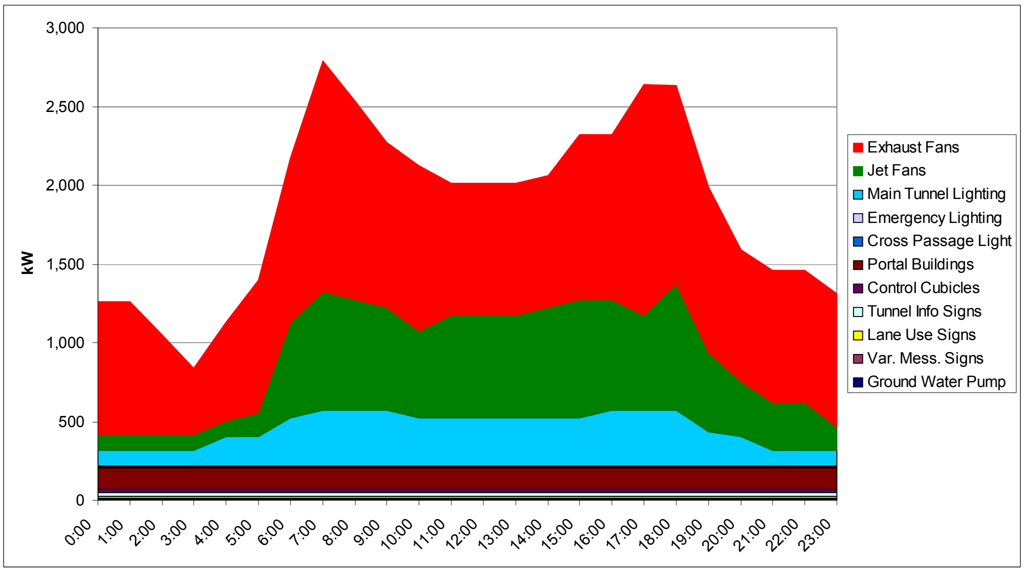


Figure6: Summer Electricity Usage by End Use - Cumulative



Ventilation is the largest energy user for the tunnel. Exhaust and jet fans together accounted for more than 74.9% of energy consumption and GHG emissions.

Ventilation rates varied over the day to approximately coincide with traffic flow. Both types of fans ramped up from an overnight low to higher daytime levels. The jet fans had highest consumption during peak conditions as they regulated airflow in the tunnel in accordance with traffic volume. The exhaust fans had a flat profile during the day.

Ventilation rates varied over the day to approximately coincide with traffic flow, ramping up from an overnight low to higher daytime levels.

Note that the traffic model does not account for lower traffic volumes (and hence lower ventilation rates) on weekends. The control system will trim ventilation rates using real-time traffic data.

Cross passage and emergency lighting was constant, but main tunnel lighting varied over 24 hours depending on external lighting. The reduced level of main tunnel lighting at night is required by standards, but also provides a greenhouse benefit. Lighting electricity usage is also slightly lower in winter because there are less daylight hours.

The profiles for the control cubicles and portal buildings, signage and ground water pumping were flat, as consumption was predicted to be constant over 24 hours.

2.4 KEY PERFORMANCE INDICATORS

In reporting energy consumption and GHG emissions, it is useful to provide Key Performance Indicators (KPIs). These can be used to compare the energy consumption and emissions of the proposed tunnels to other relevant energy users.

Table 2: Electricity Consumption & Greenhouse Emission by End Use

Item	KPI Electricity Usage (Wh/vehiclekm)	KPI GHG emission (kg/vehiclekm)**Revised**
Electricity	256	0.357

- Daily traffic flow was assumed to be 109,623 vehicles, based on the most recent estimate of traffic flow in the ‘Tunnel Ventilation System Preliminary Design Report (AL-M04-RPT-VE01-0020) (Hyder Consulting Year 2008).

The tunnel’s gross energy consumption was calculated at 256 Watt hour per vehicle kilometre. GHG emissions totalled 0.357 kilogram CO_2-e per vehicle kilometre.

No publicly reliable energy performance information for other tunnels (Australia or world wide) was available to allow direct comparison.

3. Description of Tunnel Systems

The following section describes the various end uses of energy in the tunnels. The energy use systems are broken up into five categories: ventilation, lighting, signage, electricity to portal buildings and pumping.

3.1 VENTILATION

Ventilation is comprised of identical numbers of exhaust and jet fans in each of the two tunnels. The ventilation system will consist of 12 jet fans (each 50kW) installed in the crown of each tunnel, with a maximum of nine operating at any one time under normal operating conditions. There will be five vent station axial exhaust fans, each 210kW installed in each portal. They will operate as up to 4 duty and 1 standby. Refer to Appendix 2 for the daily operating profile of the ventilation system.

The jet fans will control the velocity of air movement in the tunnel. The exhaust fans extract tunnel air prior to the tunnel exit portal and exhaust it to atmosphere for dispersion.

There are a number of expected EPA Works Approvals conditions and clauses in the PS&PR governing tunnel air quality and release. These determine ventilation requirements for the tunnels. Achievement of the conditions requires use of energy for forced mechanical ventilation. Expected conditions include:

- No net portal emissions. Portal inflow velocity of 0.75-1.00 m/s as a rolling 15 minute average (expected EPA Works Approval condition)
- In tunnel carbon monoxide (CO) limits (Clause S11.8(b)(i) of PS&PR and expected EPA Works Approval condition):
    - CO short term peak: 150 ppm
    - CO 15 minutes exposure: 50 ppm
    - CO in excess of 120 minutes exposure: 25 ppm
- In tunnel visibility limits (Clause S11.8(d) of PS&PR):
    - K_{max} (stationary traffic = 0.009 per metre)
    - K_{max} (congested traffic = 0.007 per metre)
    - K_{max} (design condition = 0.005 per metre)

Conditions are also expected to include a maximum velocity of tunnel air.

A small change in operation of the ventilation system will have a significant impact on tunnel electricity use and resultant greenhouse emissions. Measures proposed to minimise energy consumption and maximise energy efficiency are as follows:

The system will normally be operated under automatic control. In-tunnel air quality will be measured via air quality monitors in the tunnel upstream of the exit portal and vent station inlet opening. Vent station exhaust fans and tunnel jet fans will be switched on to increase tunnel air flow should the in-tunnel air quality approach pre-set lower limit trigger points.

The control system will select the number of jet fans in operation to maintain tunnel air flow rates under varying traffic conditions. Note that the control system will be configured to minimise fan energy consumption by balancing the mix of jet fans and axial fans under conditions where jet fans are operating in reverse to retard air in the tunnel due to the traffic piston effect.

Control system functionality will generally comprise the following elements:

- Predetermined fan tables based on traffic data used as a base point for system operation.
- Real-time traffic data used as a trim input.
- Real-time pollutant and visibility data used as a trim input.
- Traffic and/or pollutant level data and/or stable portal emission management will determine the minimum ventilation rate and nominal air flow set points for control.
- Air flow through the tunnel will be maintained by automatic feedback control of jet fans to meet the air velocity requirements.
- High pollutant levels, as measured by the air quality sensors, will trigger the ventilation system to adjust air flow in the tunnel and increase the total ventilation rate.

Location of the ventilation stacks close to the tunnel entrance/exit also improves energy efficiency based on Eastlink's experience with other tunnels.

Best practice and energy efficient design principles that has been included in the design of the ventilation system includes:

- The use of high efficiency motors on the jet and vent fans. The increased efficiency is approximately 2% higher than the available standard motor. This amounts to annual saving of approximately 246 MWh and 342 tCO2-e per annum.
- The western portal stack has been moved closer to the portal and this has reduced the length of exhaust duct by some 80 metres. This reduces the duct pressure drop by 80 kPa resulting in a calculated decrease in energy fan power usage of the western vent fans of around 5%. This amounts to annual saving of approximately 207 MWh and 288 tCO2-e per annum.

The use of Variable Speed Drives (VSD) had been investigated by the design team. The findings are that VSD deliver no cost effective savings in a high inertia system such as this design. The air column takes a significant time to change velocity in response to a change in demand and therefore rapid changes of motor power for fluctuations in demand are not practical.

The switchroom ventilation system will consist of forced ventilation of these rooms by two speed fans thermostatically controlled so that higher speed is only activated at higher temperatures. There are two HV rooms with 7.5 kW fans (peak demand 5 kW). The two LV rooms have 1.5 kW fans (peak demand 1 kW). These fans run continuously.

3.2 LIGHTING

Lighting includes the main tunnel lighting, emergency lighting and cross passage lighting.

The main tunnel lighting levels are dictated by the Commission Internationale de l'Eclairage standard CIE 88:1990 'Guide for the Lighting of Road Tunnels and Underpasses'. This standard specifies the level of daytime lighting in the tunnel, length of transition zones and level of transition zone lighting and limits the minimum energy consumption required for tunnel lighting.

The lighting design for the main tunnel does not propose using a higher level than the relevant standard. The lighting levels at the entrances and exit zones will be varied thru 5 to 6 steps to accurately match external light brightness levels.

The main lighting design is based for a Threshold Zone Luminance (TZL) of 250 cd/m^2 for the West bound tunnel & 200 cd/ m^2 for the East bound tunnel.

We had carried out an analysis on two (2) design options for the main tunnel lighting, this included:

1) HPS lights throughout the tunnel
2) Fluorescent lamps within the tunnel + boost lighting provided by HPS

The comparison (refer to Appendix 3) shows that the adopted HPS only option at 351 kW is 27% more efficient than the mix Fluorescent + HPS at 479 kW. This results in an annual saving of 592 MWh and 824 tCO2-e.

Rooms and areas where human attendance will be intermittent will be provided with light controls to detect entry. Door will have reed switches and lights will activate automatically on opening. They will then remain on for a predetermined time and after expiry of that time an alarm will be provided at the operator's control desk which will allow the lights to be turned off.

Detailed information on the emergency and cross passage lighting will be developed during detailed engineering and design.

3.3 POWER TO PORTAL BUILDINGS ROOMS

Power is consumed in the various rooms and control functions mainly in the portal buildings. The rooms and control functions include HV and LV switchrooms, supply authority rooms, portal HVAC rooms, fire monitoring control rooms, mobile phone rooms, comms & RRB room, crib rooms and toilets. Power consumption under this heading also includes 21 incident detection CCTVs and six PTZ CCTVs in each tunnel and a CCTV in each of the 14 tunnel cross passages. There are also 28 emergency phones in each tunnel.

Power consumption in the portal buildings and for control functions is currently assumed to be constant as these functions will operate 24 hours a day. More accurate profiles of energy use in the portal buildings and control systems will be developed during detailed engineering end design.

3.4 SIGNAGE

The tunnels will contain electronic information, lane use and speed signs for traffic safety and control. There will be 24 tunnel information signs, 24 lane use signs and six variable speed signs in each tunnel. Predicted electricity consumption for signage is constant as these functions will operate 24 hours a day.

3.5 PUMPING

This component includes groundwater and clean water pumps. Groundwater pumps remove seepage from the tunnel. Note that the specification required tunnels to be lined and watertight, with less than 1 l/s water ingress. Clean water pumps remove rain which enters the tunnel, mainly on vehicles.

At this preliminary design stage, groundwater pumps have been predicted to operate continuously. Pumps will only operate as required, so the predicted electricity consumption should be a maximum.

The amount of rain ingress to the tunnels and hence the required operation of the clean water pumps will not be know until detailed design is undertaken, so no allowance has been made for these pumps at this stage.

3.6 ELECTRICAL DISTRIBUTION LOSSES

There are losses associated with the operation of any electrical equipment. This includes: transformer, cable, motor and UPS losses. These losses have already been included within each of the end use energy systems.

Measures that have been included in the design to minimise losses and maximise energy efficiency, are as follows:

- HV losses will be minimised by taking electricity at high voltage (22kV) and constructing a substation at either end of the tunnel, thus reducing cable length and losses over distance.
- Power factor correction equipment will be installed to the main supply points (switchboards) to minimise maximum KVA demand and line losses in the distributor's network.

The energy and GHG savings of the transmission and distribution system associated with the reduced line losses installation by the installation of Power Factor Correction equipment and improving power factor from 0.85 to 0.95 is as follows:

- Line losses from the Latrobe Valley to Ringwood is approximately 7% at a 22KV high voltage supply
- 1.392 $tCO_{2\text{-e}}/MWh \times 0.07_{\text{line losses}} \times 16{,}417\ MWh/yr \times [1-(0.85/0.95)^2] = 320\ tCO_{2\text{-e}}$ per annum

4. Ongoing Improvements

A number of actions and initiatives will be implemented to ensure that the operation of the tunnel is energy and greenhouse efficient as possible whilst still maintaining air quality and lighting conditions. These include detailed final design and equipment selection, commissioning and monitoring and reporting. In more detail these include:

1) Detailed system design of ventilation, lighting and other energy systems and equipment selection

2) Commissioning of Ventilation and Lighting system
    - Detailed commission of control systems to be conducted within 3 months of operation
    - Inclusion of energy efficiency requirements in the operators manuals

3) Monitoring and Reporting
    - Monthly tracking of Electricity consumption against baseline
    - Real time monitoring and reporting of air quality, air flows and lighting levels
    - Annual Reporting of energy and greenhouse emissions performance (as per EPA SEPP (AQM) requirements)

4) Optimisation of ventilation and lighting control system
    - Detailed review and optimisation of control to be conducted annually

Action 1 is associated with the design and construction phase of the tunnel.

Action 2 will ensure that the energy and control systems are commissioned at the most optimal energy efficiency level (whilst still maintaining air quality and lighting conditions) at the start (within 3 months of operation). This is important because history has shown that in a number of new installation commissioning has not been performed to a satisfactory level and energy efficiency is not been realised even though it has been included in the design. In addition the operator manuals shall include energy efficiency requirements in the relevant sections.

Action 3 and 4 are ongoing initiatives to ensure that the energy systems are operating at their maximum efficiency (and lowest operating costs), and for EastLink to meet the EPA licence requirements.

Appendix 1 – Projected Monthly Electricity Consumption and Demand

Electricity	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
Monthly Peak Usage (kWh)	753,025	684,568	759,474	759,474	724,952	765,923	731,108	731,108	759,474	759,474	724,952	787,253	8,940,784
Monthly Off-Peak Usage (kWh)	630,842	565,376	634,736	589,762	669,258	593,323	673,446	673,446	589,762	634,736	624,283	596,613	7,475,584
Off-Peak %	46%	45%	46%	44%	48%	44%	48%	48%	44%	46%	46%	43%	46%
Max Demand (kW)	2,792	2,792	2,769	2,769	2,769	2,792	2,792	2,792	2,769	2,769	2,769	2,792	2,781
Total monthly Usage (kWh)	1,383,866	1,249,944	1,394,210	1,349,236	1,394,210	1,359,246	1,404,554	1,404,554	1,349,236	1,394,210	1,349,236	1,383,866	16,416,368

Appendix 2 – Ventilation Profile

WESTBOUND (2000N Thrust Fans)
Vent Station Motor 210 kW
Jet Fan Motor 50 kW

Hour	Sheet No	Vehicles	Jet Fan 60kph	Jet Fan 80kph	Jet Fans	Jet Fan Power	Dilution Flow	Vent Fans	Vent Fan Power	Total Power
		no off	no off	no off	no off	kW	m^3/s	no off	kW	kW
0:00	9.00	340	1.00	1.00	1	50	83	2	420	470
1:00	10.00	199	1.00	1.00	1	50	75	2	420	470
2:00	11.00	159	1.00	1.00	1	50	0	1	210	260
3:00	12.00	171	1.00	1.00	1	50	0	1	210	260
4:00	13.00	314	1.00	1.00	1	50	83	2	420	470
5:00	14.00	1,133	-2.00	-2.00	2	100	92	2	420	520
6:00	15.00	4,708	-5.00	-9.00	9	450	285	3	630	1080
7:00	16.00	5,644	-7.00	-6.00	7	350	336	4	840	1190
8:00	17.00	4,618	-4.00	-8.00	8	400	272	3	630	1030
9:00	18.00	4,084	-4.00	-7.00	7	350	244	3	630	980
10:00	19.00	3,135	-2.00	-5.00	5	250	189	3	630	880
11:00	20.00	2,777	-5.00	-7.00	7	350	161	2	420	770
12:00	21.00	2,682	-5.00	-7.00	7	350	161	2	420	770
13:00	22.00	2,579	-5.00	-6.00	6	300	149	2	420	720
14:00	23.00	2,562	-5.00	-6.00	6	300	149	2	420	720
15:00	24.00	2,811	-5.00	-7.00	7	350	161	2	420	770
16:00	25.00	3,081	-6.00	-8.00	8	400	175	2	420	820
17:00	26.00	3,675	-3.00	-6.00	6	300	216	3	630	930
18:00	27.00	3,006	-2.00	-8.00	8	400	179	3	630	1030
19:00	28.00	2,253	-3.00	-5.00	5	250	136	2	420	670
20:00	29.00	1,552	-2.00	-3.00	3	150	100	2	420	570
21:00	30.00	1,386	-2.00	-2.00	2	100	94	2	420	520
22:00	31.00	1,182	-1.00	-2.00	2	100	92	2	420	520
23:00	32.00	761	-1.00	-1.00	1	50	89	2	420	470
										16890

EASTBOUND (2000N Thrust Fans)
Vent Station Motor 210 kW
Jet Fan Motor 50 kW

Hour	Sheet No	Vehicles	Jet Fan 60kph	Jet Fan 80kph	Jet Fans	Jet Fan Power	Dilution Flow	Vent Fans	Vent Fan Power	Total Power
		no off	no off	no off	no off	kW	m^3/s	no off	kW	kW
0:00	33.00	632	1.00	-1.00	1	50	86	2	420	470
1:00	34.00	319	1.00	1.00	1	50	83	2	420	470
2:00	35.00	199	1.00	1.00	1	50	75	2	420	470
3:00	36.00	146	1.00	1.00	1	50	0	1	210	260
4:00	37.00	177	1.00	1.00	1	50	0	1	210	260
5:00	38.00	370	1.00	1.00	1	50	83	2	420	470
6:00	39.00	1,308	-2.00	-3.00	3	150	94	2	420	570
7:00	40.00	3,006	-2.00	-8.00	8	400	179	3	630	1030
8:00	41.00	3,675	-3.00	-6.00	6	300	216	3	630	930
9:00	42.00	2,355	-4.00	-6.00	6	300	136	2	420	720
10:00	43.00	2,177	-4.00	-6.00	6	300	136	2	420	720
11:00	44.00	2,334	-4.00	-6.00	6	300	136	2	420	720
12:00	45.00	2,511	-4.00	-6.00	6	300	149	2	420	720
13:00	46.00	2,648	-5.00	-7.00	7	350	161	2	420	770
14:00	47.00	3,043	-2.00	-8.00	8	400	161	2	420	820
15:00	48.00	4,203	-4.00	-8.00	8	400	261	3	630	1030
16:00	49.00	5,052	-6.00	-5.00	6	300	310	3	630	930
17:00	50.00	5,644	-6.00	-5.00	6	300	336	4	840	1140
18:00	51.00	4,618	-4.00	-8.00	8	400	272	3	630	1030
19:00	52.00	3,212	-5.00	-4.00	5	250	189	3	630	880
20:00	53.00	2,093	-3.00	-4.00	4	200	124	2	420	620
21:00	54.00	1,926	-3.00	-4.00	4	200	124	2	420	620
22:00	55.00	1,769	-2.00	-4.00	4	200	112	2	420	620
23:00	56.00	1,394	-2.00	-2.00	2	100	94	2	420	520
										16790

Appendix 3 – Lighting Analysis

Power Loads for West bound tunnel - HPS Design

Design for 250 cd/sqm

	QTY	TOTAL	TOTAL
Lamps		KW	KVA
440W HPS	252	110.88	123.20
275W HPS	98	26.95	29.94
165W HPS	344	56.76	63.07
	TOTAL	194.59	216.21

Power Loads for East bound tunnel - HPS Design

Design for 200 cd/sqm

	QTY	TOTAL	TOTAL
Lamps		KW	KVA
440W HPS	162	71.28	79.20
275W HPS	102	28.05	31.17
165W HPS	346	57.09	63.43
	TOTAL	156.42	173.80

Power Loads for West bound tunnel- HPS + Fluro Design

Design for 250 cd/sqm

	QTY	TOTAL	TOTAL
Lamps		KW	KVA
440W HPS	252	110.88	123.20
275W HPS	98	26.95	29.94
116W FLURO	1042	120.872	127.23
	TOTAL	258.702	280.38

Power Loads for East bound tunnel- HPS + Fluro Design

Design for 200 cd/sqm

	QTY	TOTAL	TOTAL
Lamps		KW	KVA
440W HPS	162	71.28	79.20
275W HPS	102	28.05	31.17
116W FLURO	1042	120.87	127.23
	TOTAL	220.20	237.60

Assumptions:

Power factor for HPS lights = 0.9

Power factor for fluorescent lamps = 0.95

Summary:	**Total KVA with HPS throughout the tunnel**	**Total KVA with HPS + fluoro's (in the interior zone)**
West bound	216.21	280.38
East bound	173.8	237.6
Total	**390.01**	**517.98**