Appendices

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APPENDIX A: TEMPERATURE AND HEATING MODELS

A.1 The Effective Degree Day (EDD)

The Effective Degree Day 'EDD' has been used extensively in the Victorian Gas Industry to measure coldness which is directly related to gas demand for area heating. The EDD formula was developed in the late 70's through extensive research of the impact of weather on Victorian residential gas demand. The EDD is a composite measure of weather coldness incorporating the effect of temperature, windchill, insolation and season.

There are 4 components in the EDD formula:

EDD	**=**	**DD**	**(Temperature effect)**
	+	**0.038 *DD *Avg Wind**	**(Wind chill Factor)**
	-	**0.18 *Sunshine.hours**	**(Warming effect of sunshine)**
	+	**2 *Cos(2π(day - 200)/365)**	**(Seasonal factor)**

EDD = 0 if the calculated value is negative.

The Degree Day (DD)[38]

$$DD = 18 - T \text{ if } T < 18$$
$$= 0 \text{ if } T \geq 18$$

The colder the average temperature the higher the DD and EDD.

18 ^{O}C represents the threshold temperature for residential gas heating – this threshold (of about 65 ^{O}F) is fairly common internationally.

T is the average of 8 three-hourly Melbourne temperature readings (in degree Celsius) from midnight to 9pm inclusive as measured at the Bureau of Meteorology's Melbourne Station.

The gas day begins at 9:00am so the EDD formula implies an average 9 hour lag in demand to changes in ambient temperature.

Average Wind

This is the average of 8 three-hourly Melbourne wind (measured in knots) from midnight (day-1) to 9pm inclusive (day+0) as measured at the Laverton and Moorabbin Stations which are used to estimate a pre 1999 wind level[39] at the Melbourne site.

Sunshine Hours

This is the number of hours of sunshine above a standard intensity as measured at the Weather Bureau's Tullamarine Station[40] for the same duration of time between midnight (day-1) to 9pm inclusive (day+0).

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[38] Sometimes referred to as a Heating Degree Day HDD.

[39] The BOM Melbourne wind station was closed in 1999 and so an estimate is calculated based on regression analysis of 1993 to 1997 wind data. New buildings from 1998 were thought to be materially affecting the Melbourne readings and this data has not been used.

Seasonal Factor (COSINE function)

This factor models seasonality in consumer's response to different weather. It was found that residential consumers more readily turn on the heaters or leave heaters on in winter than in other seasons (early spring, late autumn) for the same change in weather conditions. This change in consumers' behaviour is captured in the Cosine term in the EDD formula, which implies that for the same weather conditions heating demand is higher in winter than in the shoulder seasons or in summer.

The EDD formula was reviewed in early 2000 but no material improvements were identified.

A.2 The EDD Demand Model

In Figure A.1, the strong correlation between demand (excluding gas fired power generation) and EDD for Sep 2000 to August 2001 is evident.

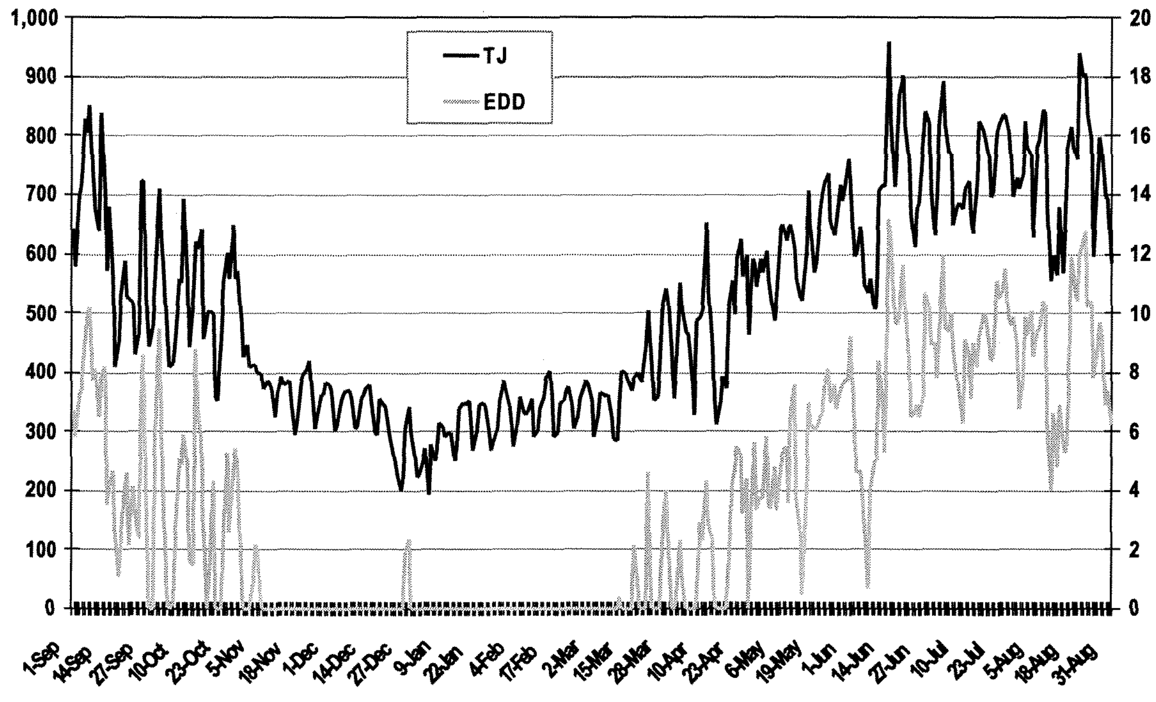

Figure A.1 Correlation between Demand and EDD, 12 months to August 2001

Figure A.2 again highlights the strong correlation between total GTS daily demand and EDD (May to September 2001) together with the day of week effects.

[40] Originally measured at Laverton but moved to Tullamarine in 2000. No material change in sunshine hours readings occurred.

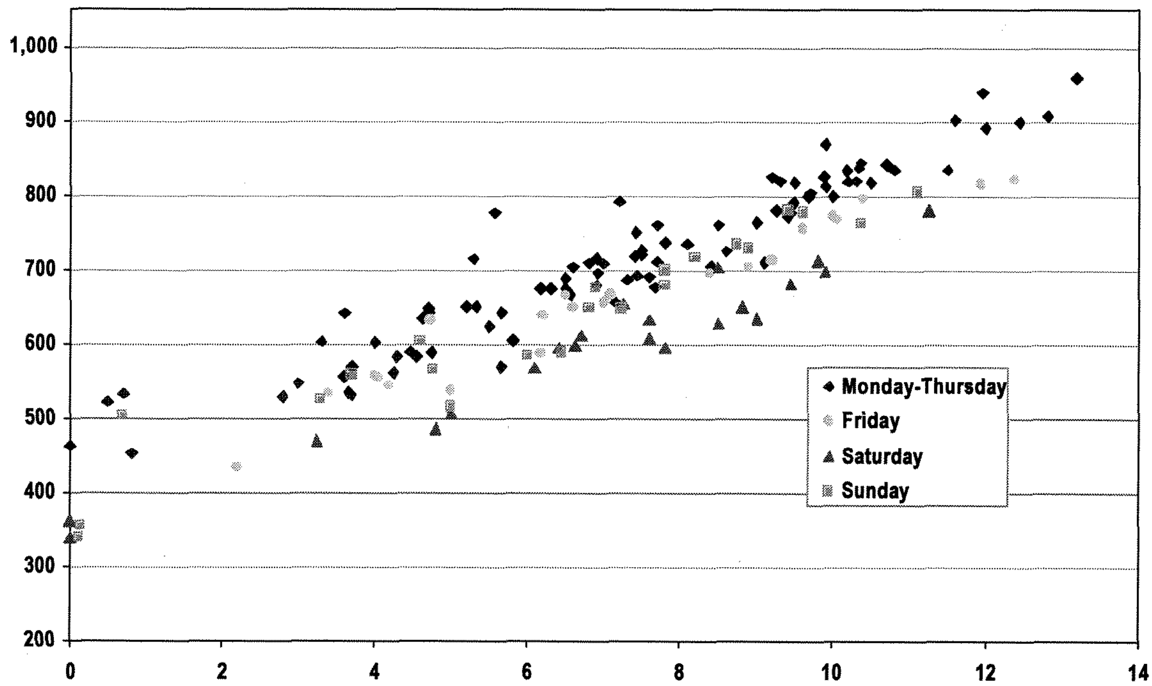

Figure A.2 Daily Demand as a function of EDD May to September 2001

Non-heating demand (base load) is relatively stable on winter weekdays from Monday to Thursday. Based on several recent years of historical data, base load reductions for Friday, Saturday and Sunday are approximately 10%, 25% and 15%, respectively.

The regression analysis of daily demand[41] in May to September 2001 against EDD are summarised in the Table A.1.

Table A.1 Sample Winter 2001 Demand-EDD Regression Analysis

Variable	Coefficients	t Stat
Mon-Thu Baseload TJ	442	60
Temperature TJ/EDD	37.3	42
Friday TJ	-52	-7
Saturday TJ	-105	-14
Sunday TJ	-49	-6
Adjusted R Squared	0.93	

These results can be interpreted as follows:

- the average winter base load was 442 TJ on weekdays (Monday to Thursday) representing demand from industry and demand from commercial and residential gas appliances such as water heaters, cookers, dryers and so on, but excluding demand for area or space heating;
- demand for area heating is directly proportional to the EDD characterised by a system load 'temperature sensitivity' in winter 2001 of 37.3 TJ/EDD; and

[41] General demand only excluding power generation and exports.

- industry production reductions on Friday, Saturdays, and Sundays reduced the base load by 52, 105, or 49 TJ respectively, on average, relative to winter weekdays.

A.3 Melbourne Standard Weather

Melbourne weather has historically been used to forecast system demand on daily, monthly, and annual basis. This is because system demand is dominated by the Greater Melbourne load centre and also because weather across the transmission system generally correlates reasonably well with Melbourne weather.

The Melbourne Weather standard for annual EDD was revised downward from 1504 to 1445 following a revision in 2000 from 1537 to 1504. The revision was based on the long term Melbourne Degree Day DD weather warming trend from 1950 to 2001 discussed in A.4. Previously the standard was a 20 year average, however, urban warming in the Melbourne CBD has resulted in a steady increase temperature observations, particularly in overnight minimums.

Melbourne Standard Weather is used for monthly and annual load forecasts and related analysis.

The revised monthly distribution for Melbourne Standard Weather is shown in the Table A.2 and is based on the last 7 years.

Table A.2 Melbourne Standard Weather 2001- Monthly Weather Distribution

Melbourne Standard Weather		
Monthly	EDD	Average
Jan	2	0.1
Feb	2	0.1
Mar	13	0.4
Apr	73	2.4
May	174	5.6
Jun	266	8.9
Jul	322	10.4
Aug	271	8.7
Sep	174	5.8
Oct	101	3.3
Nov	36	1.2
Dec	11	0.4
Annual	1445	3.9
Std Dev	99	
1 in 20	1607	

The smoothed EDD distribution is shown in Figure A.3. This distribution is a smoothed moving average and does not indicate the daily variation in temperatures which can exceed 10 EDD in any given month.

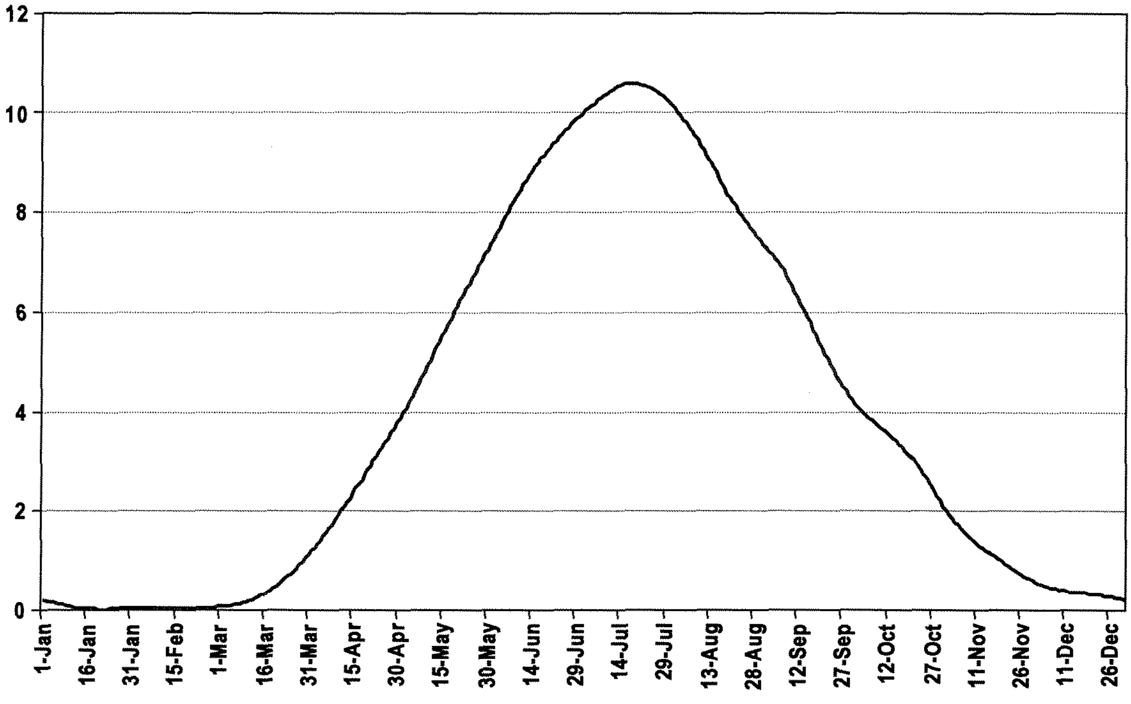

Figure A.3 Melbourne Standard Weather Annual Profile 2001

The EDD weather data and the standard EDD monthly distribution is available on the VENCorp website.

Gas load is highly influenced by weather to a much greater degree than, for example, electricity loads.

Melbourne Standard Weather is assumed for all monthly and annual load forecasts in this planning review.

Melbourne Standard Weather is also used for 'weather normalisation' of actual gas demand to standard weather conditions for comparison with monthly and annual load forecasts or when using historical load data for forecast purposes.

Historical annual and monthly load is weather normalised using the load temperature sensitivity[42] to produce an estimate of the load under average weather conditions used for comparison with forecast data.

A file of Melbourne Standard Weather and weather history is available on the VENCorp Gas Planning website.

A.4 Long Term Weather History

Figure A.4 shows annual DD from year 1950 to 2001 and the trend line. Following three of the four warmest years on record, VENCorp conducted a review of weather forecast standards in 2001 in consultation with Gas Industry *Participants*.

[42] Temperature Sensitivity is usually determined by regression analysis of daily demand against EDD and Day of Week for the period May to September for annual load analysis, and June to August for peak day analysis.

A clear warming trend of about 6 DD/year was found using the last 50 years of annual heating degree day DD based on maximum/minimum temperature observations from the Melbourne weather station at Corner Spring/Victoria Sts. The 30 years of EDD history available was insufficient to show a definite trend. However, using the direct relationship of annual EDD to annual DD, the annual EDD standard of 1504 EDD used in 2000 has been revised to 1445 EDD based on the DD trend line as shown in Figure A.5.

The urban warming effect is most pronounced in the inner city area and is not readily observable in country regions or even at Tullamarine or Laverton. The impact of any global warming in regional temperature data was not discernible in our limited study although it may be a factor. The impact on urban gas heating load is not necessarily large and in any instance, is not easily quantified. What is important here is to use a weather standard that is consistent with the past and that is corrected for systematic changes over time. Hence the trend line approach has been adopted.

The change will result with a reduction of 2.2 PJ in forecast gas demand for area heating in 2002 compared to the previous standard used in 2000 and 3.4 PJ compared to the pre 2000 standard.

A 1 in 20 year severe cold year is 160 EDD higher (colder) or 1605 EDD, which equates to increased gas demand for area heating of 6.3 PJ (in 2002). Similarly, a 1 in 20 warm year will have a reduction of about 6.3 PJ in gas demand compared to forecast.

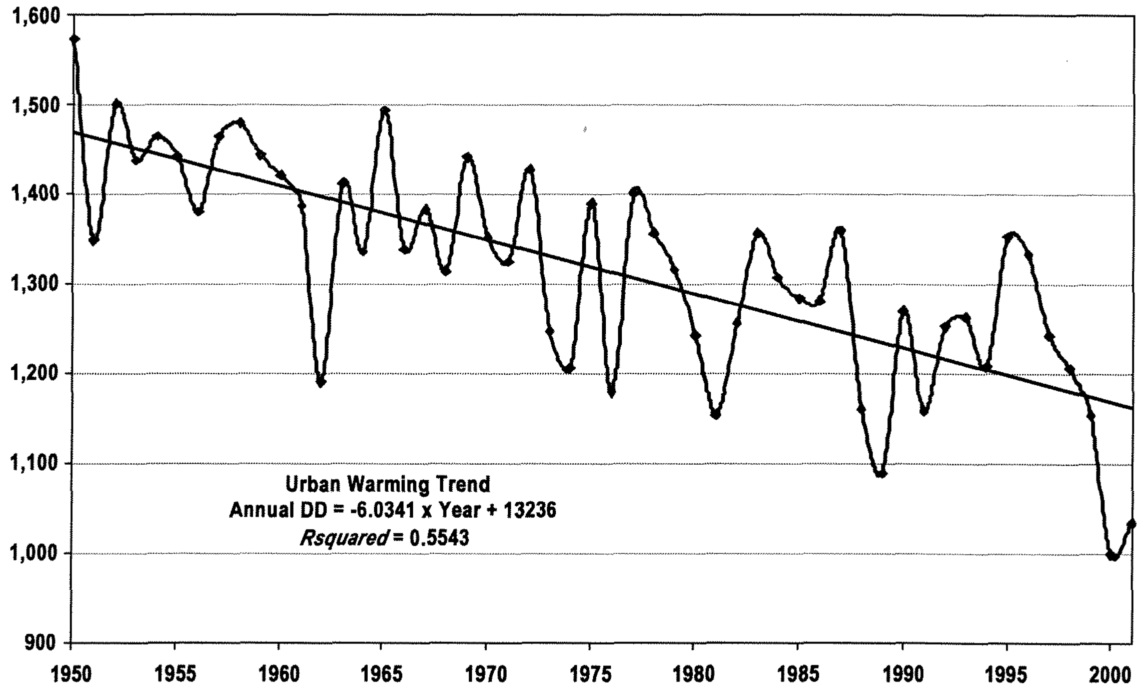

Figure A.4 Melbourne Urban Warming Trend 1950 to 2001 using DD

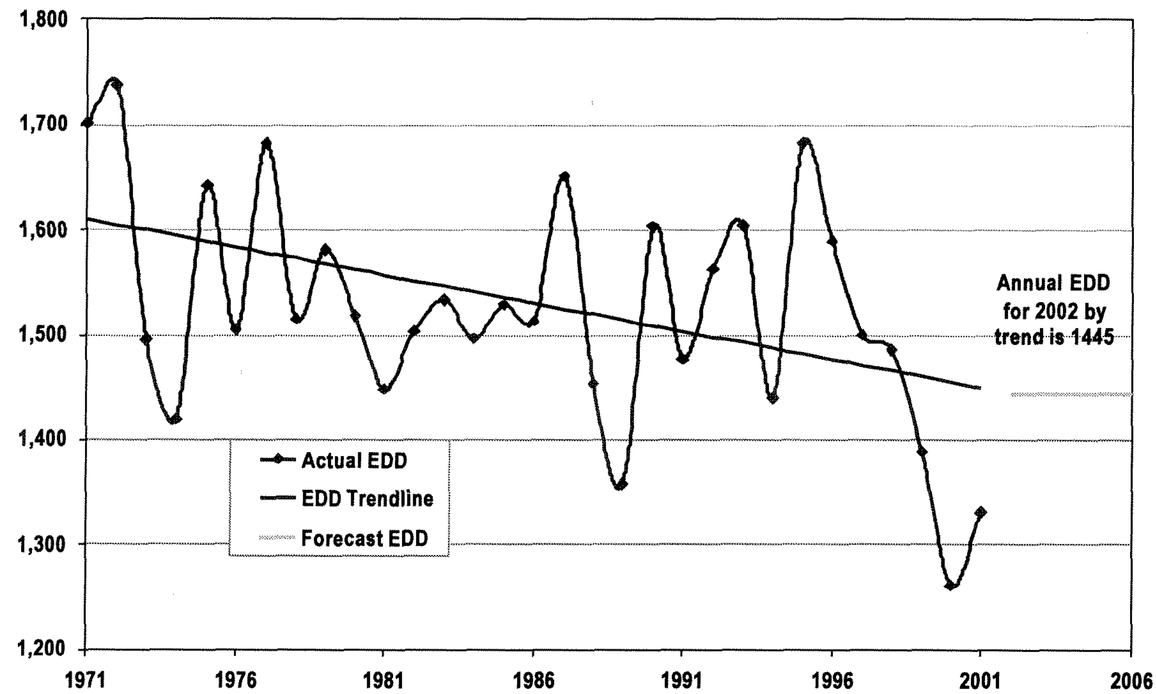

Figure A.5 Melbourne Urban Warming Trend 1971 using EDD correlated to DD

A.5 Peak EDD Weather History

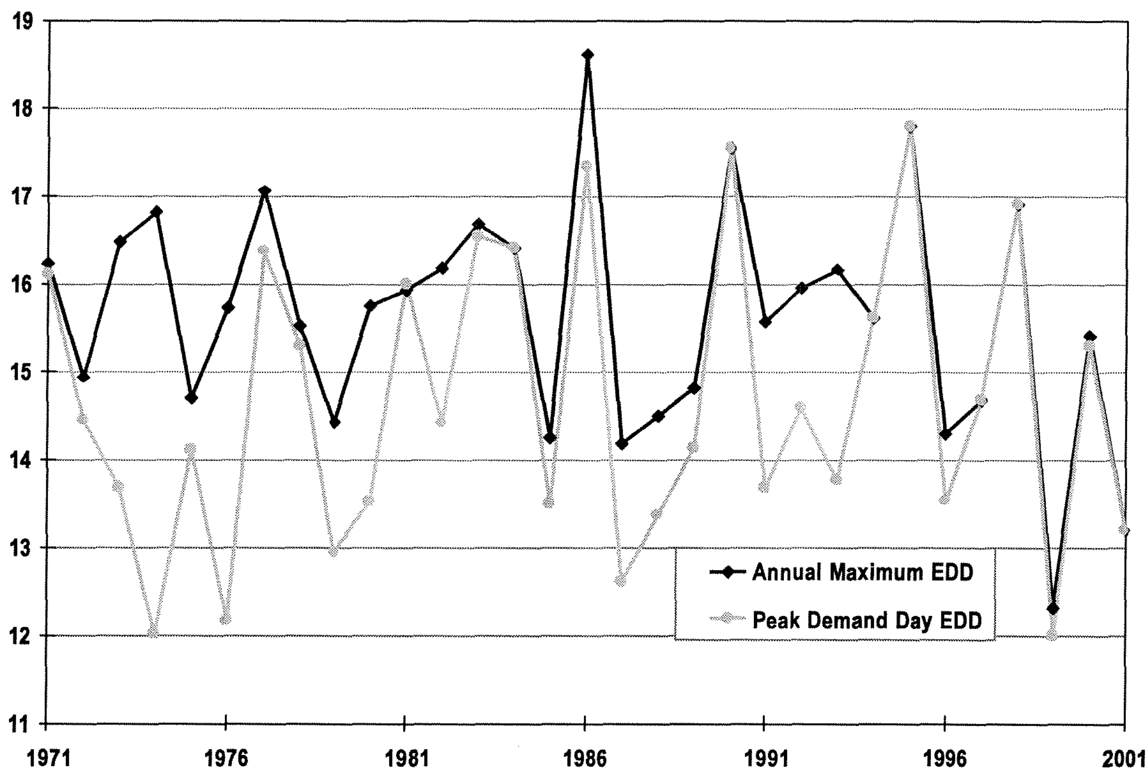

Figure A.6 Peak EDD History

Figure A.6 shows the maximum EDD and the EDD on the system peak demand day for each year from 1971 to 2001. The maximum EDD usually determines the peak day if it occurs on Monday to Thursday, however, weekday fluctuations in the large industrial base load or reduced weekend loads mean that the coldest day is not always the peak day.

APPENDIX B: PEAK DAY PLANNING STANDARDS

Although VENCorp is not responsible for planning the system *per se*, the following standards have been adopted for the purposes of providing forecast information to the Gas Market.

B.1 1 in 20 Peak Day

The forecast 1 in 20 peak day is the system coincident peak day corresponding to 1 in 20 years severe winter weather conditions and is about 7% to 8% higher than the 1 in 2 forecast peak day (excluding power generation and exports). The forecast 1 in 20 peak day is calculated using a standard of 17.25 EDD, which has been determined from historical weather and demand simulation models.

In recent years gas power generation has occurred on peak days. It is necessary to consider gas power generation in the supply-demand analysis.

The 1 in 20 peak day is the primary planning standard used in assessing proposals for new connections to the gas transmission system. The details are contained in the *Guideline: Approval of New Connections to the Gas Transmission System*, available on the VENCorp website.

B.2 1 in 2 Peak Day

The forecast 1 in 2 peak day is the system coincident peak day with a 50% probability of being exceeded in a given year and corresponds to standard peak day weather conditions of 15.15 EDD. The 1 in 2 peak day is also referred to in the M&SO Rules as the 'most probable peak day'.

APPENDIX C: NIEIR'S METHOD FOR ANNUAL SYSTEM LOAD FORECASTS

NIEIR has developed an integrated econometric forecast system capable of generating short to long term economic and energy forecasts at the National, State and Regional level.

The key economic outputs from the econometric forecast models (State and Regional) include:

- Gross State and Gross Regional Product (GSP and GRP);
- State and Regional industry sector output projections; and
- State and Regional population, dwelling stock and household disposable income projections.

To meet VENCorp's forecast requirements customised gas demand forecast models have been developed and are linked to the above key economic outputs. Other key drivers included in the forecast models are forecast gas prices, CPI and projected population.

Three integrated gas demand forecast models are used for the GTS in Victoria, the GTS in NSW and the WTS, each with *Tariff D* and *V* load forecasts. The *Tariff D* forecasts are broken down further into broad industry divisions and then by industrial sector (ASIC).

To complement the econometric forecasts, a survey of very large industrial customers has been conducted and where appropriate gas demand forecasts generated from the econometric forecast models were adjusted to include planned load expansion or reduction obtained from the survey. This survey included a focus on gas cogeneration, an expanding technology which is seen as a key growth driver in industrial loads.

NIEIR has also included the results of a detailed analysis of the trend in penetration of reverse cycle air conditioners in Victoria and its impact on winter gas heating demand within the Tariff V load.

APPENDIX D: METHOD FOR SYSTEM WITHDRAWAL ZONE ANNUAL FORECASTS

The MSOR requires that load forecasts are produced by defined regions known as System Withdrawal Zones. Load forecasts were generated for each of *Tariff D* and *V*. These regions are shown in Figure 1.2.

Historical *Tariff D* demand (1999-2001) by industry sector (ASIC) was analysed to determine the share of total system demand by region. The analysis took into account projected growth/contraction due to known expansion/closures. SWZ forecast demand was obtained by applying the projected shares to the ASIC forecasts for the total system.

Historical *Tariff V* demand was analysed to determine heating and non-heating loads in each zone. It was assumed that the projected growth in *Tariff V* for the GTS system applies universally to all zones in the GTS.

APPENDIX E: METHOD FOR ANNUAL PEAK DAY DEMAND FORECASTS

E.1 System Peak Day Forecasts

The forecast system peak day is determined as follows:

1. The system daily demand temperature sensitivity against EDD for the winter period (May to September excluding holidays) is determined by regression analysis;
2. The actual peak day demand and the EDDs on the five system peak demand days in each of the previous three winters are averaged for each year[43]. The average peak day is weather normalised to the 1 in 2 peak day standard of 15.15 EDD and 1 in 20 peak day standard of 17.25 EDD by applying the temperature sensitivity to the EDD difference. (The annual 1 in 2 peak day EDD and the annual 1 in 20 peak day EDD were originally derived from a Monte Carlo simulation model. A review in 2001 concluded that the levels were still appropriate based on peak day EDD in recent years.);
3. Annual demand was normalised to the new 2001 weather annual forecast standard of 1445 EDD. Load factor (= weather normalised annual demand /365 /(1 in 2 peak day) was calculated for each year and averaged.

   The above analysis was undertaken for total system and by *Tariff D* and V separately.

   The load factors derived from and analysis of 1998, 2000 and 2001 demand data and used in the forecasts were:

Total system	52.5%
Tariff D	80%
Tariff V	41%

The load factors were applied to the forecast annual demand to derive forecast *Tariff D* and *V* peak days, which were reconciled to the forecast system peak day derived on the same basis.

E.2 SWZ Peak Days Forecasts

Similar load factor analysis was conducted for *Tariff D* and *V* in each zone. The regional peak day forecasts derived from the load factors were reconciled using the system peak day forecasts as a control.

[43] 1998 has been used instead of 1999 due to the lack of any very cold days in winter 1999.

APPENDIX F: METHOD FOR MONTHLY LOAD FORECASTS

Monthly demand forecasts were generated separately for *Tariff D* and *V*.

Forecast weather normalised monthly profiles for each region and for total GTS were produced from analysis of historical monthly consumption. This was performed for *Tariff D* and *V* accounting for large load variations due to known expansion/connections or closures at specific sites/locations. The forecast monthly load profiles were used to derive monthly demand forecasts from forecast annual demand in each region. The zonal forecasts were reconciled using the monthly system demand forecasts derived from system monthly load profiles.

APPENDIX G: METHOD FOR MONTHLY PEAK DAY DEMAND FORECASTS

Monthly peak day demand forecasts were generated for each zone and for *Tariff D* and *V*.

G.1 Forecast Peak Day for *Tariff D*

Monthly 1 in 2 peak day for the GTS and for each zone were generated from analysis of historical system 5 peak days for each month of the year and were converted to % of the 1 in 2 winter peak day. The analysis took into account the impacts of large load variations on the peak day profiles.

The forecast monthly peak day for each zone and for total system were generated by applying the profiles to the forecast winter peak day. Final forecasts for each zone were reconciled with total system monthly peak day forecasts.

G.2 Forecast Peak Day for *Tariff V*

Tariff *V* peak day is comprised of heating and non heating components. Heating component is derived from temperature sensitivity and monthly forecast peak day EDD. Non heating peak day is derived using load factor.

Forecast monthly System Withdrawal Zone peak days are reconciled with monthly total system peak day.

APPENDIX H: MONTHLY FORECAST PEAK DAY EDD STANDARDS

The Effective Degree Day (EDD) is the standard weather unit used to model the effect of weather on demand for gas heating.

It is known that the annual peak day can occur in any month from May to September and, for planning purposes, the annual peak day forecasts have been used for these months[44]. The EDD for the 1 in 2 system coincident peak day is 15.15. The EDD for the 1 in 20 system coincident peak day is 17.25, 2.1 EDD colder.

The 1 in 2 peak day EDD for each non-winter month is the average value of the coldest day in the EDD distribution for that month.

The 1 in 20 peak day EDD for each non-winter month is the 95% percentile of the coldest day EDD distribution and is 1.645 standard deviation from the mean (assuming normal distribution).

The above method for calculating the peak day EDD for non winter months produces EDD values slightly higher than the peak day EDD values for winter months derived from the simulation model. This inconsistency will be corrected pending further weather analysis and model development.

[44] Forecast peak days for each individual winter month are theoretically lower than the forecast peak day for the whole of winter.