Adaptation to Peak Electricity Demand due to Climate Change and Population Growth on the Gold Coast

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Contents

Executive Summary ............................................................................................................. 1

1. Introduction .................................................................................................................. 4
   1.1 Gold Coast Local Government Area ....................................................................... 4
   1.2 Recent research ........................................................................................................ 5
   1.3 Gold Coast Substations ............................................................................................ 6
   1.4 Data processing ....................................................................................................... 10

2. Factors Influencing Electricity Demand ...................................................................... 11
   2.1 Average electricity demand .................................................................................... 12
   2.2 Peak electricity demand .......................................................................................... 23
   2.3 Temperature ............................................................................................................ 30
   2.4 Population and electricity demand .......................................................................... 35
   2.5 Residential air conditioning energy consumption .................................................. 38
   2.6 Commercial office air conditioning energy consumption ......................................... 45

3. How Can Adaptation Occur? ....................................................................................... 53
   3.1 Definition of adaptation to climate change ............................................................. 53
   3.2 Remote control of air conditioners and pool pumps ............................................... 55
   3.3 Energy efficiency of houses ................................................................................... 56
   3.4 Distributed generation ............................................................................................. 58
   3.5 Network upgrades ................................................................................................. 58
   3.6 Solar thermal and solar photovoltaic ....................................................................... 59
   3.7 Education ................................................................................................................. 59

4. Evaluation of Adaptation Options .............................................................................. 59
   4.1 Climate impacts on energy demand ......................................................................... 59
   4.2 Cooling energy for temperature rise ....................................................................... 60
EXECUTIVE SUMMARY

Based on the data from Gold Coast City Council and Energex, which is the electricity distribution company for South East Queensland where the Gold Coast is located, this report analyses in details historical patterns, trends and variability of average and peak electricity demand at regional and sub-station levels for the Gold Coast. It also analyses some possible climate adaptation actions to adjust the fast growing peak electricity demand in this city.

Peak electricity demand and electricity consumption are projected to rise substantially for many metropolitan regions due to climate change, population and economic growth. The increased electricity demand may intensify the existing stress in the electric supply power systems and exacerbate the environmental impact in terms of greenhouse gas (GHG) emissions.

Issues for electricity demand are certainly relevant to the Gold Coast - the sixth largest city in Australia, which experienced the highest relative population growth of 33 % for any Australian city from 2001 to 2009 – from 387,102 to 515,157 residents (Productivity Commission, 2011) It has area of 1402 km$^2$ and it had 526,600 residents and 236,480 rateable properties in 2009-10 financial year.

Average electricity demand

The report finds that the summer season has the highest rate of increase of average electricity demand among the four seasons. The annualised percentage increases in average demand for weekdays are 2.8 % (12.5 MW/year), 4.8 % (23 MW/year), 3.1 % (13.8 MW/year), and 3.3 % (15 MW/year) in spring, summer, autumn, and winter, respectively.

There are four bulk supply (BS) distribution substations that service the Gold Coast. Except Burleigh Heads BS, which tends to have a steady demand, the other three BS substations have an increasing summer demand over time. Overall, Beenleigh BS has the highest level of demand; however, Coomera BS has the highest rate of increase in demand. The annualised percentage increases in the summer demand for weekdays are 5.7 % (4 MW/year), 14.4 % (3.6 MW/year), and 3.6 % (2 MW/year) for Beenleigh BS, Coomera BS, and Molendinar BS, respectively. The winter electricity demands in the four BS substations are somewhat lower than that in summer, however also rising with the exception of Beenleigh BS.

In contrast to many other zone substation in South East Queensland (SEQ), the zone substation of Surfers Paradise, an iconic tourist destination not only for the Gold Coast and Queensland but for the whole Australia, shows no major difference between demand patterns on weekday, Saturday or Sunday. This perhaps could be explained with a big number of hotels and a very big number of tourists that visit Surfers Paradise through the year. The Surfers Paradise zone substation also has slightly decreasing average electricity demand over the last five to six years.
EXECUTIVE SUMMARY

Peak electricity demand
The average daily peak demand in summer is about 7.5% higher than that in winter and about 11.5% higher than in spring and autumn. The annualised percentage increases in averaged peak demand for weekdays are 2.3% (13 MW/year), 3.9% (24 MW/year), 3.4% (20 MW/year), and 3.6% (21.3 MW/year) in spring, summer, autumn, and winter, respectively. We see that summer has the highest average peak demand and the highest rate of increase among the four seasons.

Most frequently the occurrence time of the daily peak demand on weekdays and Saturdays in summer is around 4 pm and on Sundays – around 7 pm

For weekdays in summer, Burleigh Heads BS has a negligible increase of peak demand over time, whereas the annualised percentage increases for Beenleigh BS, Coomera BS, and Molendinar BS are 6.5% (5.8 MW/year), 10.6% (3.8 MW/year), and 3.5% (2.4 MW/year), respectively.

Normalised demand and temperature
The normalised demand – temperature relationship is observed to resemble a U shape as demonstrated in other studies. Normalized demand is defined as the ratio of demand of a given half-hourly interval to the average half-hourly interval demand of the year. The U-shaped demand – temperature relationship may be attributed to the fact that higher temperatures lead to less efficient heat exchange in cooling appliances, requiring more vapour-compression cycles to exchange the same load of heat, and that more people are inclined to turn on cooling appliances on warmer days than on cooler days (Hekkenberg et al. 2009a). The U shape relationship of normalised demand and air temperature can be used to construct a “comfort temperature curve” over 24 hours, which has a pattern similar to the diurnal demand pattern.

Based on calculated monthly demand variation indexes it is easy to rank the months in terms of expected demand. It is not a surprise that summer months are on the top of list in terms of highest demand (January > February > December > March > other months).

Population and electricity demand
This report demonstrates a strong correlation between population and regional electricity demand, both in terms of average and peak electricity demand. Our regression implies that, on average, with an increase in population of 1000, there will be an increase of 1.02 MW in annual average electricity demand and an increase of 2.43 MW in peak electricity demand. The analysis also confirms that the peak demand grows faster than the annual average demand.

Residential cooling energy consumption
Based on detail data and future assumptions about the number and type of residential buildings on the Gold Coast, air conditioning penetration rate, type and efficiency of air conditioners, residential thermal insulation and other factors, residential cooling energy consumption in the Gold Coast City Council Area (GCCCA) is estimated. The cooling energy consumption on the Gold Coast was 67.0 GWh in 2005, and is projected for the low, medium, and high household growth scenarios to rise to 89 GWh, 94 GWh and
EXECUTIVE SUMMARY

105 GWh, respectively, in 2030. This represents 32%, 40%, and 56% increase for the three scenarios of cooling energy consumption over the 2005 level. The difference between the low and high scenarios in 2030 amounts to 16.3 GWh, which is about 16% of the projected consumption for the medium scenario.

Energy consumption and cooling energy for commercial office building

The annual energy consumption and annual cooling energy for commercial office buildings on the Gold Coast is estimated based on a model proposed in the report, which utilises the building energy analysis tool eQUEST. The model assumes three types of commercial buildings – low, medium and high rise buildings. For all three types of the buildings, cooling, heating and equipment show dominant energy consumption having 80% for low rise, 81% for medium and 76% for high rise building, respectively.

Cooling energy for residential and commercial office buildings in GCCCA is compared. Cooling energy consumption from both residential and commercial office buildings is estimated to be 127 GWh in 2005. The cooling energy consumption from residential and commercial office buildings in GCCCA increases 100% every five years and then shows it is expected to be 496 GWh in 2020, which is 3.9 times bigger than in 2005.

Climate adaptation to peak electricity demand

Adaptation to climate change and variability is an alternative and complementary response to “mitigation” – a policy response aiming to reduce greenhouse gas (GHG) emissions (Smit, 2000). The meaning of “mitigation” is to abate, moderate or alleviate GHG levels, while the meaning of “adaptation” is to alter, adjust or modify activities in the socio-economic environment related to GHG emissions and climate change.

Adaptation is a set of responses to actual or expected climatic stimuli and their impacts (Smit, 2000). Adaptation can be characterised by answering the following four questions:

- Adaptation to what?
- Who or what adapts?
- How adaptation does occur?
- How good is the adaptation?

Some specific actions are described briefly, including remote control of air conditioners and pool pumps, increasing energy efficiency of residential and commercial buildings, locating distributed and renewable generators at substations or customer sites, etc.

These issues of fast growing electricity demand are of high importance to policy makers, city planners and electricity utilities.
1. INTRODUCTION

Peak electricity demand and electricity consumption are projected to rise substantially for many metropolitan regions due to climate change, population and economic growth. The increased electricity demand may intensify the existing stress in the electric supply power systems and exacerbate the environmental impact in terms of greenhouse gas (GHG) emissions. These issues of fast growing electricity demand are of high importance to policy makers, city planners and electricity utilities.

Usually the driving forces for these changing energy demand patterns are rapidly growing metropolitan regions – complex mono- or polycentric urban areas, which are the focus of economic development and population growth. The area of Gold Coast, which is defined by the administrative boundaries of Gold Coast City Council (GCC), in South East Queensland (SEQ) in Australia is the focus of this study. The region of SEQ itself is one of Australia’s fastest growing regions (both in terms of population and economic activities) in the last decade.

A special concern to the Gold Coast and the SEQ region is the rising peak electricity demand in hot and humid weather due to wide use of air-conditioners. Climate change is likely to intensify the growing peak electricity demand with increasing temperatures and stronger and more frequent heat waves. To provide the peak demand the transmission and the distribution networks need to keep a significant spare network capacity to be used only for a small percentage of time. The required electricity grid augmentation is usually associated with big investments.

In this report detailed recent electricity data at the substation distribution level for GCC is used to estimate trends, patterns and variability of average and peak electricity demand. Our work demonstrates a strong correlation between population and regional electricity demand, both in terms of average and peak electricity demand.

Based on the historical data and assumptions about the number and types of future residential buildings on the Gold Coast, air conditioning penetration rate, type and efficiency of air conditioners and residential thermal insulation, residential cooling energy consumption on the Gold Coast City Council Area is estimated.

The annual energy consumption and annual cooling energy for commercial office buildings on the Gold Coast is estimated based on a new model described in the report, which utilises the building energy analysis tool eQUEST.

Some specific climate adaptation actions are described briefly, including remote control of air conditioners and pool pumps, increasing energy efficiency of residential and commercial buildings, locating distributed and renewable generators at substations or customer sites, etc.

1.1 Gold Coast Local Government Area

The Gold Coast is the sixth largest city in Australia. Gold Coast City Council is the second largest local government in Australia with more than 3,300 staff employed by the Council in 2009-10 and an annual budget of $1.312 billion (GCC, 2010a). It occupies an area of 1402 km² and had 526,600 residents and 236,480 rateable properties.
in the 2009-10 financial year. In the same year the Gross Regional Product (GRP) was more than $18 billion. The Gold Coast experienced the highest population growth of 33% among the Australian cities from 2001 to 2009 – from 387,102 to 515,157 residents (Productivity Commission, 2011).

1.2 Recent research

The rising levels of electricity demand are not only a sustainability (due to highly intense GHG coal-based generation) but also an infrastructure planning challenge – how to plan and invest in new generation and for extension of the transmission and distribution grid. A significant concern is the rising peak electricity demand due to the use of air conditioners and heaters during days with extreme temperatures. Parsons Brinckerhoff (2009) estimates that the cost to energy networks in Australia (gas and electricity) from climate change is in the order of $2.5b over 5 years. The largest component of this cost is due to network augmentations to accommodate increased use of air conditioners. The temperature sensitivity of electricity demand is compounded by climate change and potential temperature rises and heatwaves into the future.

Sailor and Pavlova [5] studied the relationship between the market saturation of air conditioning in US cities and cooling degree days. They suggest that per capita electricity consumption response to long-term warming may be much higher than previously thought.

M. Thatcher [2] describes a method for constructing regional electricity demand data sets at half-hour time intervals for the regions in Australia’s National Electricity Market. His method is based on linear regression model between the demand and heating degree days (HDD) and cooling degree days (CDD). The method incorporates intraday variability of electricity demand and it depends on climate parameters such as temperature and relative humidity. In this way the method allows to explore the impact of climate change scenarios on regional electricity demand.

Hekkenberg et al. have studied the relationship between the electricity demand and temperature for a period of nearly four decades (1970-2007) in the relative temperate climate of Netherlands (Hekkenberg et al. 2009b). They have found that the increased use of air-conditioning has shifting the electricity demand dependency on temperature upwards in summer months. They point out that the summer peak average demand has exceeded the winter peak for several European countries, including Greece, Italy and Spain.

In another study Hekkenberg et al. have analysed the temperature dependent patterns of energy demand in the context of climate change (Hekkenberg et al. 2009a). They discuss how socio-economic changes may alter the relationship between temperature and energy demand and they propose that in many current models the impact of socio-economic dynamics on future energy demand is underestimated.

The work related to average electricity demand reported here is closely linked to the approach taken by Wang et al. (2011) who developed a couple of in-house analysis tools for studying the trend and variability of electricity demand in South East
Queensland in a project funded by the SEQ Climate Adaptation Research Initiative (SEQ CARI).

### 1.3 Gold Coast Substations

Substations servicing the Gold Coast LGA region were identified using the GIS data provided by Energex. Two spatial datasets were available; one indicating the location of substations, and the other showing cadastral boundaries with substation identification data. Data from both sets were extracted for the GC LGA and used as a basis for determining the relevant substations. For the first dataset, it was assumed that if a substation was physically located with the geographic boundary of GC LGA that it fully serviced that area. This is not always the case as the service areas of a distribution network do not necessarily conform to administrative boundaries. The second dataset provided fine level details of service area by substation. However that dataset had numerous anomalies and not all the data could be relied upon. For example some very small geospatial features referenced substations in Brisbane City Council LGA. It was assumed that these anomalies were artefacts of the geospatial dissolve operation used to generate the dataset. Additionally, the datasets were inconsistent in the abbreviation codes used to identify each substation.

Figure 1.1 illustrates the location and service area for substations in GC LGA.

Using reference (Energex, 2010), it was possible to identify all substations. Anomalous substations were ignored. Based on the same document, a hierarchy of Zone, Bulk Supply and Connection Point Substations is determined (see Figure 1.2 and Appendix B). Demand data was not available for Customer supplies, and thus they were ignored.
Figure 1.1. Substation locations and service areas
INTRODUCTION

Figure 1.2. Substation hierarchy in Gold Coast Local Government Area
Figure 1.3. Data availability by substation
1.4 Data processing

Demand data was available for all the identified Zone substations (excluding Customer supplies/feeders) and Bulk Supply substations, but not for Connection Points. The data was provided in four sets covering different periods:

- 1st January 2005 to 4th March 2009,
- 1st May 2009 to 30th June 2009,
- 1st January 2009 to 30th June 2009 and
- 1st July 2009 to 30th June 2010.

Some substations were commissioned and/or decommissioned during that period, thus demand data is only available for the range of dates where the station was active.

The demand data was provided in MW at half hourly intervals. In all datasets, there is missing data. Figure 1.3 visually illustrates the operating periods and missing data intervals for each Gold Coast substation. Table A.1 lists the completeness of the data for each Gold Coast substation.

The time periods of the third data set overlaps with the first and the second dataset (for example the third dataset was intended to replace the second). In the case of the first and third dataset, some stations have conflicting data for the same intervals. This did not affect many of the Gold Coast substations, and were resolved on advice from Energex. However, some substations had large amounts of missing data in the third set. Where interval data from the second and third datasets overlapped, the values were consistent.

A software tool was developed to combine all four datasets, producing a single demand data file for each substation and aggregating demand based on the hierarchy described in the previous section. The tool also produced detailed diagnostic reports to identify missing data, conflicts and completeness. The aggregation task was necessary to calculate demand data for Connection Points and for the whole Gold Coast area. As Bulk Supply substations could service Zone substations outside of the region, new demand data files were created for each one by aggregating data from Gold Coast LGA only. This data does not accurately reflect the actual demand for a particular Bulk Supply or Connection Point, just that for the region, with the Bulk Supply and Connection Point being used according to the hierarchy in Figure 1.2.
2. FACTORS INFLUENCING ELECTRICITY DEMAND

This section presents the electricity demand pattern of the Gold Coast. Half-hourly historical data are investigated to identify the trends and uncertainties of electricity demand. Using statistical modelling techniques, this study analyses yearly, seasonal and daily trends, and variability of historical half-hourly demand data for the period from January 2005 to May 2010. Fischer (2010) summarises the principles of energy demand modelling and proposes three criteria for classification of statistical models: (1) linear/non-linear, (2) univariate/multivariate, and (3) parametric/non-parametric. According to these criteria, the current study belongs to non-linear, multivariate, and parametric regression models. Fisher (2010) points out also three most important categories of influence factors for electricity demand are: (1) calendar days (e.g. time of the day, day of the week, seasonality), (2) meteorological conditions (e.g. temperature, humidity), and (3) economic activities (e.g. gross domestic product, population). This study takes into account factors each belonging to one of the three influencing factors.

The electricity demand data used in this study were obtained from ENERGEX (www.energex.com.au), an electricity distribution supplier for SEQ. This set of data represented the aggregated electricity demands from all economic sectors (residential, commercial, and industrial). As information for disaggregation is unavailable, the investigation focuses on the overall electricity demand on the Gold Coast. Hourly climate data used in this study were provided by the Australian Bureau of Meteorology from a weather station codenamed “Gold Coast Seaway,” station number 040764 (27.9389°S, 153.4283°E). The hourly temperature data were reprocessed using a cubic-spline interpolation scheme (Press et al. 2007) into a dataset with half-hourly intervals, consistent with the recorded electricity demand intervals.

The Christmas and summer holiday period (16th December to 15th January) is found to constitute in probabilistic sense a population of its own (low demand due to the holiday season); therefore, we analyse the historical demand data of the four seasons in a year as follows:

- Summer: 16 November – 15 March, but excluding 16 December to 15 January.
- Autumn: 16 March – 31 May.
- Winter: 1 June – 31 August.
- Spring: 1 September – 15 November.

It is observed also that normal weekdays, Saturdays, and Sundays have different demand patterns, generally with weekdays demanding the most electricity usage and Sundays the least. National and state holidays are treated as Sundays. As such, the demand data in each season except the Christmas and summer holidays are further divided into three demand series: Weekdays, Saturdays, and Sundays. This results in a total of thirteen electricity demand data series.

The main purpose of separating the demand data into thirteen data series is to obtain the trend and the associated fluctuation/uncertainty of consumption; therefore, the analysis
FACTORS INFLUENCING ELECTRICITY DEMAND

of trend and uncertainty of the average and peak electricity demand are presented in the following subsections.

2.1 Average electricity demand

This section first presents the average electricity demand for the Gold Coast to see the collective trends and usage patterns of the region, and then the average demand for some substations which exhibit distinctive characteristics electricity usage.

2.1.1 Demand on the Gold Coast

As is commonly observed in other regions of Australia (Thatcher 2007) and of the world (Valor et al. 2001; Psiloglou et al. 2009), Figure 2.1 reveals for the Gold Coast that the electricity demands during weekends are lower than that during weekdays. Due to population and economic growth, the average demand increases over time. Summers had the highest demand, followed by winters. Springs and autumns have almost the same demand levels. It shows also that the demands in weekdays are about 10% and 15% higher than that during Saturdays and Sundays, respectively. Though with higher variability, the trend for the Christmas period is similar to that for Saturdays in summer.

The annualised percentage increases in average demand for weekdays are 2.8% (12.5 MW/year), 4.8% (23 MW/year), 3.1% (13.8 MW/year), and 3.3% (15 MW/year) in spring, summer, autumn, and winter, respectively. We see that summer has the highest rate of increase among the four seasons.

With the exception of the Christmas and summer holiday period, each season as defined in this paper consists of a period ranging from $2\frac{1}{2}$ to 4 months, during which the weather (thus electricity demand) changes, therefore the within-season variation needs to be identified. To do this, we first subtract the average seasonal demand from the half-hour electricity demand data in each season. The residual demand and the within-season trends by regression are shown in Figure 2.2, in which the horizontal axes are expressed in days from the beginning of the seasons. In addition to revealing the general usage pattern in a season, the within-season trends are useful if projection of future demand is to be performed by Monte Carlo simulation.

After removing the yearly and within-season trends shown in Figure 2.1 and Figure 2.2, we obtain the residual demands that depict the diurnal patterns of demand, as shown in Figure 2.3. The 16- and 84-percentile residual demand values in a given half-hour interval are obtained by ranking the data points in the interval, whereas the mean value is estimated by the average of the residual demand values. It is seen clearly that in all seasons the time of lowest demand in a day happens around 3 to 4 am. The summer demand holds approximately steady during daytime, whereas all other seasons exhibit a daily demand peak around 6 pm, coincident with the dinner time activities. In addition to the 6 pm peak, the winter weekdays have another prominent peak at 8 am, while the weekends (except that in summers) have one around 10 am.

If we subtract the yearly, within-season, and diurnal trends from the half-hourly demands to obtain the demand residuals, the demand variability of the 48 half-hourly intervals in a day can be identified, as shown in Figure 2.4 for the four seasons. Determined by the demand residuals, Figure 2.4 shows the 84- and 16-percentile values
(the upper and lower red curves, respectively), and the ±1 standard deviation ranges
(the black ‘error bars’), of the demand residuals. Note that the demand in summers has
much larger variability, about 2 to 3 times that in autumns and winters, due to the use of
air conditioning. Winter days have large variability in the morning (around 7–8 am) and
in the evening (around 8 pm) due probably to the use of heating appliances.

It is noted that for the electricity demand of the whole region, the yearly trend lines of
the four seasons generally follow the data points closely. This is because the number of
customers in this region is large enough so the collective demand trend to follow a
somewhat stable pattern consistent with seasonality and time of day. By the end of
2010, the Gold Coast had about 248 thousand residential, and about 23 thousand
commercial/industrial, customers. We will see in the next section that the bulk-supply
substations, because of smaller number of customers, exhibit higher variability along
the trend lines.
Figure 2.1. Trends of seasonally averaged half-hourly electricity demand on the Gold Coast.
Figure 2.2. Trends of within-season electricity demand on the Gold Coast.
Figure 2.3. Trends of diurnal electricity demand on the Gold Coast.
Figure 2.4. Variability of diurnal electricity demand on the Gold Coast.
2.1.2 Trends of demand for bulk-supply substations

This section shows the yearly trends of the four seasons for the four major bulk-supply (BS) substations on the Gold Coast: Beenleigh, Burleigh Heads, Coomera, and Molendinar. Compared with the Gold Coast as a whole, each individual BS substation provides electricity to a smaller number of customers; therefore, the trends of substation electricity demand typically exhibit higher variability than the region.

Figure 2.5 shows the summer electricity demand trends for the four BS substations. Except Burleigh Heads BS which tends to have a steady demand, the other three BS substations have an increasing demand over time. Overall, Beenleigh BS has the highest level of demand; however, Coomera BS has the highest rate of increase in demand. The annualised percentage increases in the summer demand for weekdays are 5.7 % (4 MW/year), 14.4 % (3.6 MW/year), and 3.6 % (2 MW/year) for Beenleigh BS, Coomera BS, and Molendinar BS, respectively.

![Figure 2.5. Trends of summer electricity demand for the four bulk-supply substations: (a) Beenleigh, (b) Burleigh Heads, (c) Coomera, and (d) Molendinar. Note that the four panels have different Y scales.](image)
The winter electricity demands in the four BS substations are somewhat lower than that in summer, as seen by comparing Figure 2.6 with Figure 2.5. Burleigh Heads BS has a decreasing demand, whereas the other three BS substations have an increasing demand over time. Similar to the case in summer, Beenleigh BS has the highest demand level and Coomera BS has the highest rate of demand increase. The annualised percentage increases in winter demand increase for weekdays are 4.5% (3 MW/year), –1% (–0.63 MW/year), 16.3% (3.8 MW/year), and 6.8% (3 MW/year) for Beenleigh BS, Burleigh Heads BS, Coomera BS, and Molendinar BS, respectively.

2.1.3 Trends of demand for Surfers Paradise substation

Being voted as one of the best beaches in the world by the American Travel Channel in 2006, Surfers Paradise is globally recognised as a major domestic and international tourism destination. It is, therefore, one of the most electricity-demanding areas on the Gold Coast. Figure 2.7 gives the yearly electricity demand trends for the four seasons at

![Figure 2.6](image_url)

**Figure 2.6.** Trends of winter electricity demand for the four bulk-supply substations: (a) Beenleigh, (b) Burleigh Heads, (c) Coomera, and (d) Molendinar. Note that the four panels have different Y scales.
Surfers Paradise, which shows that electricity demand level at Surfers Paradise is comparable to that in Coomera BS (Figure 2.5c and Figure 2.6c). For the time period the data were collected, however, the demand has been decreasing. The annualised percentage decrease are –1.9 \% (–0.75 MW/year), –1.3 \% (–0.6 MW/year), –1.2 \% (–0.6 MW/year), and –2 \% (–0.75 MW/year) in spring, summer, autumn, and winter, respectively. The percentage decreases are even larger than that we see of –1 \% for Burleigh Heads BS in winter (Figure 2.6b). Note also that the demands on weekdays and on weekends are roughly the same. In contrast to the demand levels for the whole Gold Coast region in Figure 2.1, the winter demand at Surfers Paradise is the lowest among the four seasons.

Figure 2.7. Trends of yearly electricity demand for Surfers Paradise: (a) spring, (b) summer, (c) autumn, and (d) winter.

Figure 2.8 shows the within-season trends for Surfers Paradise. In contrast to the within-season trend shown in Figure 2.2 for the Gold Coast region, the trend in spring at Surfers Paradise is a concave function (negative curvature) rather than a convex function (positive curvature), and the extent of convexity in winter for Surfers Paradise is notably smaller than that for the Gold Coast region.
Figure 2.8. Trends of within-season electricity demand for Surfers Paradise: (a) spring, (b) summer, (c) autumn, and (d) winter.

The diurnal demand trends and variability for Surfers Paradise, as shown in Figure 2.9, is similar to that in Figure 2.3 for the Gold Coast region, except that in summer time the demand peaks in early evening around 6 to 7 pm instead of in the afternoon around 3 to 4 pm. This may be a characteristic of demand in a popular subtropical tourist area.
Figure 2.9. Trends and variability of diurnal electricity demand for Surfers Paradise: (a) spring, (b) summer, (c) autumn, and (d) winter.
2.2 Peak electricity demand

This section presents the peak electricity demand for the Gold Coast, the four major bulk-supply substations, and the Surfers Paradise.

Figure 2.10 shows the trends of peak half-hourly electricity demand on the Gold Coast. Each data point in the graphs is the average of the daily peak demand in a season. The averaged peak demand in summer is about 7.5% higher than that in winter and about 11.5% higher than in spring and autumn. The annualized percentage increases in averaged peak demand for weekdays are 2.3% (13 MW/year), 3.9% (24 MW/year), 3.4% (20 MW/year), and 3.6% (21.3 MW/year) in spring, summer, autumn, and winter, respectively. We see that summer has the highest rate of increase among the four seasons.

In contrast to the average demand in Figure 2.1, the Saturdays and Sundays have roughly the same averaged peak demand level except in winter, in which Sundays have slightly higher demand level than Saturdays. In general, the averaged peak demand data points are more scattered along the trend lines in comparison than the average demand in Figure 2.1, meaning that the peak demand has inherently higher variability than the average demand.

Figure 2.11 displays the occurrence time of the daily peak demand. We see that spring and autumn have fairly similar occurrence patterns: on weekdays the occurrences of peak scattered sparsely between 8 am and 7 pm but more than 80% of the time it concentrated around 6–7 pm, while on weekends it almost always happened around 5–7 pm. For summer (not including the Christmas period), on weekdays it occurred mostly during the business hours with about 1/3 of the time occurring around 4 pm. On Saturdays it occurred almost 1/2 of the time around 4 pm, and on Sundays about 2/3 of the time around 7 pm. For winter, except a small percent (< 10%) of the time on weekdays around 8 am, the peak occurred almost always occurred around 5–7 pm.

The peak demands in summer for Beenleigh BS, Burleigh Heads BS, Coomera BS, and Molendinar BS are shown in Figure 2.12. For weekdays, Burleigh Heads BS has a negligible increase over time, whereas the annualized percentage increases for Beenleigh BS, Coomera BS, and Molendinar BS are 6.5% (5.8 MW/year), 10.6% (3.8 MW/year), and 3.5% (2.4 MW/year), respectively. There seems no conclusive difference between Saturdays and Sundays for the four BS’s, hence the peak demand on Saturdays and Sundays may be combined for analysis. Note that for Burleigh Heads BS, the averaged peak of the 2005-06 Saturdays is significantly lower than the others. This is caused by a likely ‘outlier’ point of which the demand value is 36.756 MW, only about half of the values of other points.

The peak demands in winter for Beenleigh BS, Burleigh Heads BS, Coomera BS, and Molendinar BS are shown in Figure 2.13. Similar to that in summer, for weekdays, Burleigh Heads BS has a negligible increase over time, whereas the annualized percentage increases for Beenleigh BS, Coomera BS, and Molendinar BS are 3.7% (3.3 MW/year), 12% (4.3 MW/year), and 3.4% (2.3 MW/year), respectively. Contrary to case in summer, the winter peak demands on Sundays are almost always higher than on Saturdays. This is opposite to the average demands shown in Figure 2.6, in which the average Saturday demands are all greater than the Sunday demands.
Figure 2.10. Trends of the seasonally averaged peak half-hourly electricity demand on the Gold Coast.
Figure 2.11. Occurrence time of peak half-hourly electricity demand on the Gold Coast.
Figure 2.12. Trends of the summer averaged peak half-hourly electricity demand: (a) Beenleigh BS, (b) Burleigh Heads BS, (c) Coomera BS, and (d) Molendinar BS. Note that the four panels have different Y scales.
Figure 2.13. Trends of the winter averaged peak half-hourly electricity demand: (a) Beenleigh BS, (b) Burleigh Heads BS, (c) Coomera BS, and (d) Molendinar BS. Note that the four panels have different Y scales.

Figure 2.14 gives the peak demand trends for the four seasons at Surfers Paradise, showing that the peak demand has been decreasing for the time period the data were collected. The annualised percentage decreases are −1.9 % (−0.75 MW/year), −1.3 % (−0.6 MW/year), −1.2 % (−0.6 MW/year), and −2 % (−0.75 MW/year) in spring, summer, autumn, and winter, respectively. Note that the demands on Saturdays are roughly the same as that on weekdays, and the winter demand at Surfers Paradise is the lowest among the four seasons.

Figure 2.15 displays the occurrence time of the daily peak demand at Surfers Paradise. We see that the peak demands in spring, autumn, and winter, regardless the days of week, occurred almost entirely around 5–7 pm. In summer time (not including the Christmas period), about 10 % of the time the peak occurred between 10 am and 12 pm, and almost 90 % of the time it occurred between 4 pm and 8 pm.
Figure 2.14. Trends of the averaged peak half-hourly electricity demand at Surfers Paradise (Christmas period not included in summer).
Figure 2.15. Occurrence time of peak half-hourly electricity demand at Surfers Paradise (Christmas period not included in summer).
2.3 Temperature

Of the climate parameters, temperature is the most important affecting the electricity demand. The demand data for workdays (excluding weekends, public holidays and the Christmas period) from all four seasons are used to investigate the demand – temperature relationship. Temperature dependence patterns are essential for projection of future electricity demand, particularly in the context of climate change (Isaac and van Vuuren 2009).

To see the monthly fluctuation of electricity demand, the monthly seasonal variation index (MSVI) (Valor et al. 2001) is used, as defined by

\[ MSVI_{ij} = \frac{E_{ij}}{\bar{E}_j} \]  

(2.1)

where \( E_{ij} \) is the average half-hour electricity demand for month \( i \) in year \( j \), and \( \bar{E}_j \) is the average of the 12 \( E_{ij} \)'s in year \( j \). Similarly, the monthly temperature variation index (MTVI) may be defined as in Eq. (2.1) by substituting the demand \( E \) with the temperature \( T \).

2.3.1 Gold Coast

The electricity demand and the temperature on the Gold Coast between 01/06/2006 and 01/06/2007 are shown in Figure 2.16. The MSVI and the MTVI are shown in Figure 2.17 as box-whisker plots. In a box-whisker plot, the central box represents the inter-quartile (i.e. 25- to 75-percentile) range of monthly mean air temperature, the line in the box is the median value, and the lower and upper whiskers represent the 5\textsuperscript{th} - and 95\textsuperscript{th} -percentile values, respectively. We see clearly that January has the highest demand, mainly due to the usage of cooling appliances. Even though the monthly temperature in February is similar to that in January, the average February demand is notably lower than the January demand, maybe due to the fact that the annual Christmas holiday period ends in January. On the other hand, July is the coldest month and has the highest demand level among the winter months because of the heating requirement. Note that only about 5 years of data are available, the scatter of the boxes and whiskers vary widely from one month to another.
Figure 2.16. Historical electricity demand (top) and temperature (bottom) from 01/06/2006 to 01/06/2007.

Figure 2.17. Box-whisker plot of monthly seasonal variation index (top) and monthly temperature variation index (bottom) from 01/01/2005 to 28/02/2010.
The demand–temperature relationship is observed to resemble a U shape, as shown in Figure 2.18 for the half-hourly intervals 4:00–4:30 am and 6:00–6:30 pm, in which the Y-axis is the normalized demand. Normalized demand is defined as the ratio of demand of a given half-hourly interval to the average half-hourly interval demand of the year. The U-shaped demand–temperature relationship may be attributed to the fact that higher temperatures lead to less efficient heat exchange in cooling appliances, requiring more vapour-compression cycles to exchange the same load of heat, and that more people are inclined to turn on cooling appliances on warmer days than on cooler days (Hekkenberg et al. 2009a).

The regression curves in Figure 2.18 are derived by a class of robust regression models called MM-estimates (Yohai 1987) using the bisquare weight function with efficiency coefficient of 0.85 (Maronna et al. 2006) assuming that the normalized demand is a second-order polynomial function of the air temperature. Compared to the classical least-squares regression, the MM-estimate is advantageous in having high breakdown-point and high efficiency under normal errors (Yohai 1987), thus less sensitive to outliers and fitting more closely to the bulk of data points.

As shown in Figure 2.18, the normalized demand versus temperature relations are typically different from one interval to another, therefore the minimum demands may occur at different temperatures for different half-hourly intervals. The minimum demand for a given interval occurs at the temperature where the slope of the quadratic regression curve is zero. We term the minimum-demand temperature as the ‘comfort temperature.’ Because of the quadratic relation, the change in demand is insensitive to the change in temperature around the vicinity of comfort temperature.

Comfort temperature can be estimated from the demand–temperature relation for each half-hourly interval, as shown in Figure 2.19. It is seen that the diurnal pattern of comfort temperature corresponds roughly to the diurnal pattern of electricity demand, with the lowest comfort temperature (16°C) being around 4 am and the highest (21.7°C) being around 5:30 pm. It should be noted that Figure 2.19 depicts heuristically the comfort temperature pattern for the Gold Coast as a whole; for a local area supplied by an electrical substation, for example, the pattern may be different, as described in the next subsection for the Surfers Paradise.

Figure 2.18. Normalised demand — temperature relationship at 4:00–4:30 am (left) and 6:00–6:30 pm (right) in SEQ.
Figure 2.19. Diurnal pattern of the comfort temperature.

### 2.3.2 Surfers Paradise

The electricity demand and the temperature at Surfers Paradise between 01/06/2006 and 01/06/2007 are shown in Figure 2.20. The MSVI and the MTVI are shown in Figure 2.21 as box-whisker plots. Similar to the case for the whole Gold Coast region, we see clearly that January has the highest demand, mainly due to the usage of cooling appliances, and demand in February is notably lower than in January, though the monthly temperature in February is similar to that in January, maybe due to the fact that the annual Christmas holiday period ends in January. July is the coldest month and has the highest demand level among the winter months because of the heating requirement.

Figure 2.20. Historical electricity demand (top) and temperature (bottom) from 01/06/2006 to 01/06/2007.
The demand – temperature relationship resembles a U shape, as shown in Figure 2.22 for the half-hourly intervals 4:00–4:30 am and 6:00–6:30 pm, in which the Y-axis is the normalized demand. As shown in Figure 2.22, the normalized demand versus temperature relations are different from one interval to another, therefore the minimum demands may occur at different temperatures for different half-hourly intervals. The comfort temperatures are estimated from the demand–temperature relation for each half-hourly interval, as shown in Figure 2.23. It is seen that the diurnal pattern of comfort temperature corresponds roughly to the diurnal pattern of electricity demand. The lowest comfort temperature (13.5°C) occurs around 4–5:30 am. There are two comfort-temperature peaks: one around 10–11:30 am and another around 5:30 pm, both having a temperature around 19.5°C. This is contrary to the comfort temperature pattern of the Gold Coast which has only one peak around 5:30 pm.
2.4 Population and electricity demand

Regional electricity demand is closely associated with the population, economic activity, and climate condition of the region. For the Cold Coast, since we have only about five years of electricity demand data available, it is not sufficiently long for determining the relationship of demand with all of the important parameters. Therefore, we examine the relationship between the demand and the regional population. Being a popular tourist destination, it is estimated for the Gold Coast that the number of tourists staying overnight around the year is roughly 10% of the number of residents (GCC, 2010b). Hence for computation the historical Gold Coast population (Queensland Government 2010) is multiplied by 1.1 to account for the electricity use by the tourists.

Figure 2.24 shows the annual average electricity demand and the population (tourists included) from 2005 to 2009, and Figure 2.25 shows the annual average demand versus the population and the linear regression line. The squared correlation coefficient is 0.988. This means that with the dataset considered, the effect of population accounts for 98.8% the variability of electricity demand, with all other parameters responsible for the remaining 1.2%. The slope of the regression implies that, on average, with an increase in population of 1000, there will be an increase of 1.02 MW in annual average electricity demand.
The relationship between peak electricity demand and population is also investigated. The peak demand in a year (Figure 2.26) is taken as the maximum half-hourly demand in that year. Figure 2.27 shows the peak demand versus the population and the linear regression line. The squared correlation coefficient is 0.989. This means that with the dataset considered, the effect of population accounts for about 99% the variability of electricity demand, with all other parameters responsible for the remaining 1%. The slope of the regression implies that, on average, with an increase in population of 1000, there will be an increase of 2.43 MW in peak electricity demand.

We may use the ratio of peak demand to annual average demands to represent their relative increase, as shown in Figure 2.28. The slope of the regression line implies that, on average, the demand ratio increases by 0.025 each year. This indicates that the peak demand growth faster than the annual average demand; therefore, for future electricity supply the planners may need to pay special attention to the increase in peak demand.
Figure 2.26. Peak electricity demand.

Figure 2.27. Relationship between the peak electricity demand and population.

Figure 2.28. Ratio of peak demand to annual average demand.
2.5 Residential air conditioning energy consumption

Watterson et al. (2007) predicted continuous increase of the temperature in the SEQ region, which includes the Gold Coast area, due to climate change. Because of rising temperature, it is likely that more dwellings in the Gold Coast City Council Area (GCCCA) will have air conditioning systems installed to satisfy the occupants’ comfort requirements. Therefore, this kind of trend will influence the increasing energy consumption for cooling.

There are a number of parameters that influence cooling energy consumption such as temperature, population growth, air conditioning (AC) technological advances, AC penetration rate, and building types.

The annual electricity energy consumption due to cooling requirement in the Gold Coast area, $CE_{ReGC}$ (GWh/year), is estimated as follows,

$$CE_{ReGC} = \sum_{i=1}^{I} (ERG_i \times HH_i) \times \sum_{j=1}^{J} \left( P_j \times ST_j \times \sum_{k=1}^{3} SY_k / EE_{jk} \right)$$  \hspace{1cm} (2.2)

where

i: index for the residential construction types $i = 1, ..., I$;

j: index for the n air-conditioning types, $j = 1, ..., J$;

$ERG_i = (ERG_{ii} + ERG_{ii})$: cooling energy consumption of residential construction type i (GWh/year);

$ERG_{ii}$: cooling energy consumption of insulated residential construction type i (GWh/year)

$ERG_{ii}$: cooling energy consumption of uninsulated residential construction type i (GWh/year)

$HH_i$: household number with construction type i;

$P_j$: penetration rate (%) of air-conditioning type j;

$ST_j$: ratio of the number of air-conditioning type j to the number of installed air-conditioners;

$SK_k$: Proportion of the number of air-conditioners in age interval k;

$EE_{jk}$: average energy efficiency ratio of air conditioning type j in the age interval k.

In Eq. (2.2), the cooling energy consumption for residential construction type $i$, $ERG_i$, is calculated by AccuRate, which includes a natural ventilation model and takes thermal comfort into account in its simulation engine (Delsante, 2005; Baharun et al., 2009).

AccuRate divides the continent of Australia into 69 climate zones. As there is no exact
match between climate zones and the Gold Coast, for this study climate zone 9 is considered for the Gold Coast. The cooling thermostat is set at 26°C for climate zone 9.

### 2.5.1 Residential buildings

The dominant types of residential houses on the Gold Coast are the detached houses and the semi-detached houses, constituting 64% and 31%, respectively, of the housing stock of the region (GA, 2010). For analysis of cooling energy four wall types and three roof types are considered (See Table 2.1).

<table>
<thead>
<tr>
<th>Construction</th>
<th>Type</th>
<th>Gold Coast Area* (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>House</td>
<td>Detached house</td>
<td>105,070 64%</td>
</tr>
<tr>
<td></td>
<td>Semi-detached house</td>
<td>51,040 31%</td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td>7,880 5%</td>
</tr>
<tr>
<td>Wall</td>
<td>Brick veneer</td>
<td>76,730 47%</td>
</tr>
<tr>
<td></td>
<td>Timber</td>
<td>32,900 20%</td>
</tr>
<tr>
<td></td>
<td>Double brick</td>
<td>36,027 22%</td>
</tr>
<tr>
<td></td>
<td>Fibro</td>
<td>17,725 11%</td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td>608 0.4%</td>
</tr>
<tr>
<td>Roof</td>
<td>Tile</td>
<td>73,496 45%</td>
</tr>
<tr>
<td></td>
<td>Metal</td>
<td>85,554 52%</td>
</tr>
<tr>
<td></td>
<td>Fibro</td>
<td>4,940 3%</td>
</tr>
</tbody>
</table>

* Derived from NEXIS (GA 2010)

The hourly cooling energy is calculated over a period of one year, using the ‘typical mean year’ temperatures determined by the hourly temperatures from 1984 to 2004 for climate zone 9. The cooling energy consumed in 2005 by each of the residential construction types is estimated by AccuRate, as shown in Figure 2.29. It is seen that double-brick wall is the most cooling-energy efficient wall construction, as is terracotta roof among the roof types.
2.5.2 Household projection

The extent of cooling energy increase depends on the future population, cooling appliance efficiency, economic condition, policy/regulation change, and rising temperature due to climate change.

The population of a region is the most important determinant for cooling energy use of a region. For the Gold Coast, the Queensland Government (2007) has developed three household growth scenarios (i.e. high, medium, and low). They were produced based on the 2006 census data and the assumptions for future life expectancy (Queensland Government, 2006).

The Queensland Government (2007) household growth projections go up to 2027 only. They are extrapolated linearly up to 2030 for the cooling energy study, as shown in Figure 2.30.

![Figure 2.29. The estimated 2005 cooling energy consumption for the twelve residential construction types](image)

![Figure 2.30. Three household growth scenarios for the Gold Coast (Queensland Government, 2007)](image)
Besides the number of households, the cooling energy consumption in a region depends primarily on the energy efficiency of cooling units, the rate of installation (or penetration) of cooling units, the residential thermal insulation properties, and the temperature of the region, as described in the following sections.

### 2.5.3 Air conditioning penetration rate

The penetration rate of cooling units in a region is defined as the percentage of households with cooling units among the households of the region. Penetration rate is highly dependent on the affordability of cooling appliances to the households and the summer temperatures. The historical penetration rate of cooling units for the state of Queensland from 1966 to 2005 is shown in Figure 2.31 (EES, 2006). It shows that the penetration rate increased linearly from 1966 to 1985 and was somewhat steady from 1985 to 1997. It then underwent rapid increase from 1997, reaching 58% by 2005. EES (2006) extrapolated the penetration rate linearly from 2006 to 2010. The same linear trend is extrapolated in this study to project the penetration rate up to 2030.

![Figure 2.31. Penetration rate of cooling systems in Queensland](image)

### 2.5.4 Market share of cooling-system technologies

The most commonly used types of cooling units are evaporative, ducted reverse cycle, ducted cooling only, reverse cycle, and cooling only, of which reverse-cycle and cooling-only types combined constitute about 85% of existing cooling units in the state of Queensland. For the different types of air conditioners, Figure 2.32 shows that, since 1999, the non-ducted reverse cycle units have increased sharply, whereas the cooling-only units and evaporative systems have experienced steady decline.

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1 Mr. John Mabb of Gold Coast City Council has advised the authors that more recent data for AC penetration is available from Energex.
2.5.5 Energy efficiency

Air conditioners use a technique called the vapour compression cycle to move energy in the form of heat from one space to another. The amount of heat moved is typically twice or more the energy required for running the compressor system (DCCEE, 2010). This ratio is called the Energy Efficiency Ratio (EER) or Coefficient of Performance (COP). An air conditioner of higher EER indicates that it consumes lower energy. The EER values for domestic air conditioning units have continuously increased in Australia (EES, 2006). The EER of the reverse-cycle air conditioners, for example, was 2.4 in 1987, increasing to 2.77 in 2005 (Figure 2.33). It is expected to increase further due to the improvement of technology and the public awareness for more energy efficient appliances, following the projected trend line as shown in Figure 2.33.
Data on the age of installed air conditioners are poor (EES 2006). According to BIS (2004), it takes 14 years on average to replace the existing AC unit in residential house. However, some of the replaced units would remain in the stock (re-sold or passed on to other households), the average life of the units would be somewhat longer than the reported age of units based on replacement (EES 2006). For the energy consumption calculation, three age intervals of cooling units are considered: 0 to 3 years old, 4 to 9 years old, and 10 to 20 years old, and the proportions of the number of cooling units in these age intervals are 0.36, 0.53, and 0.11, respectively (Summers and Simmons, 2009).

2.5.6 Residential thermal insulation

Thermal properties of ceilings, walls, and floors affect significantly the cooling requirement of residential housing; therefore, proper thermal insulation of these components to prevent heat exchange can effectively reduce residential cooling energy consumption. The thermal resistance of a slab of insulating materials is expressed in engineering practice by the R-value, which is the ratio of the temperature difference across the thickness of insulating slab to the heat flux through it. Several insulating materials such as polyester, fibreglass, wool blends and polystyrene, are available in the Australian market. Of these, fibreglass is the most commonly used for residential thermal insulation because of its proven performance.

The proportion of insulated residential houses in Australia has increased from 52% in 1994 to 60% in 2005, whereas in Queensland it has increased from 28% to 43.2% in the same time period (ABS, 2005), as shown in Figure 2.34. Of the insulated houses, 98% had roof or ceiling insulation but only a small proportion of existing houses have floor or wall insulation (ABS, 2005). This is because the heat exchanged through floor is a relatively small portion of the total heat exchange (normally less than 10%). Even though a significant amount of heat exchange may occur through walls, it is difficult to retrofit the wall systems with insulation without removing the internal lining.

Because only limited thermal insulation data are available, we assume that the percentage of insulated houses in the housing stock increases linearly according to the trend line up to 2030.
2.5.7 Residential cooling energy consumption

Figure 2.35 shows projection of residential cooling energy consumption for the Gold Coast City Council Area. The cooling energy consumption on the Gold Coast was 67.0 GWh in 2005, and is projected for the low, medium, and high household growth scenarios to rise to 89, 94, and 105 GWh, respectively, in 2030. This represents 32%, 40%, and 56% increase for the three scenarios of cooling energy consumption over the 2005 level. The difference between the low and high scenarios in 2030 amounts to 16.3 GWh, which is about 16% of the projected consumption for the medium scenario.
2.6 Commercial office air conditioning energy consumption

Commercial sector energy use has been growing at a rapid pace, partially due to economic trends and the shift from manufacturing to services. Figure 2.36 shows the growth in commercial sector energy use in Queensland over the past three decades.

![Figure 2.36. Commercial sector energy use in Queensland (1973-2007)](image)

The commercial buildings consist of a tremendous variety of building types, thus there is great variation in how energy is used. However, according to EMET (1999), the breakdown of commercial sector energy use in Australia, on average, is shown in Figure 2.37.

![Figure 2.37. Commercial building energy share by end-use (EMET, 1999)](image)
Commercial office buildings are fitted with two different separate meters for each energy source: Base building energy meter and tenant meter. Of these, cooling energy is classified into base building energy part which measures heating, cooling, ventilation, hot water, common area lighting, etc. To estimate cooling energy for commercial office buildings in the Gold Coast City Council Area, this study applied bottom-up approach as detailed building energy data for office buildings and then applied building stock to get annual cooling energy consumption in GCCCA.

The annual cooling energy consumption for commercial office buildings in the GCCCA, $CE_{COGC} \text{ (GWh/year)}$, is estimated as follows,

$$CE_{COGC} = \sum_{i=1}^{M} (ERG_{Oi} \times Stock_{Oi})$$  \hspace{1cm} (2.3)

where

i: index for the commercial office building type, indicating whether it is a low rise, medium rise, or high rise;

$ERG_{Oi}$: cooling energy consumption of commercial office building type $i$ (GWh/m$^2$/year);

$Stock_{Oi}$: commercial office building floor area of building type $i$ (m$^2$);

### 2.6.1 Prototype of office building

The modelling is focused on the office buildings classified as Class 5 (defined as “Office buildings used for professional or commercial purposes”) by ABCB. While ABCB classified all office building as ‘Class 5’, Cordell (2003) classified office buildings further into low-rise, mid-rise and high-rise depending on the structure and storeys. Thus, based on this, this study classicised office building into three different types as followings:

- Low-rise office: concrete construction with 1-3 storeys
- Medium-rise office and: concrete construction with 4-7 storeys and lifts
- High-rise office: concrete construction with more than 20 storeys and lifts

Specification for the prototype buildings is given in Table 2.2.

<table>
<thead>
<tr>
<th>Building type</th>
<th>Low</th>
<th>Mid</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of storeys</td>
<td>2 (less than 3 storeys)</td>
<td>6 (3 to 8)</td>
<td>20 (more than 9)</td>
</tr>
</tbody>
</table>
### Table 2.3

<table>
<thead>
<tr>
<th>Dimension (m)</th>
<th>35 x 35 m</th>
<th>40 x 40 m</th>
<th>40 x 40 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor to ceiling (m)</td>
<td>2.7</td>
<td>2.7</td>
<td>2.7</td>
</tr>
<tr>
<td>Total floor area (m²)</td>
<td>2450</td>
<td>9600</td>
<td>32000</td>
</tr>
<tr>
<td>Wall</td>
<td>Brick</td>
<td>150mm HW concrete</td>
<td>Metal framed glass spandrel</td>
</tr>
<tr>
<td>Floor</td>
<td>6 in concrete</td>
<td>6 in concrete</td>
<td>6 in concrete</td>
</tr>
<tr>
<td>Glazing</td>
<td>20% with single colour tinted</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Building operation</td>
<td>8:00am - 6:00 pm</td>
<td>8:00am - 6:00 pm</td>
<td>8:00am - 6:00 pm</td>
</tr>
<tr>
<td>Cooling system</td>
<td>DX split system air conditioning</td>
<td>Central AC plant with air handling unit</td>
<td></td>
</tr>
<tr>
<td>Temperature setting for cooling</td>
<td>23</td>
<td>23</td>
<td>23</td>
</tr>
<tr>
<td>Temperature setting for heating</td>
<td>22</td>
<td>22</td>
<td>22</td>
</tr>
<tr>
<td>Lifts</td>
<td>-</td>
<td>One of 7 kW of electrical power load</td>
<td>Three of 7 kW of electrical power load</td>
</tr>
</tbody>
</table>

Cooling energy consumption can be varied depending on the internal loads (office equipment usage pattern, lighting etc). In this study, the internal loads recommended by NABERS (2010) are used:

- 15 m²/person of occupant density
- 11 W/m² of office equipment loads
- 12 W/m² of office lighting loads.

#### 2.6.2 Modelling software tool

There are many software packages available these days for whole building performance simulation such as eQUEST, DOE, EnergyPlus, Energy Express etc. This study uses eQUEST, which is simple building energy analysis tool and produces a detailed simulation of building and estimates how much energy it would use.

#### 2.6.3 Commercial office building stock

Existing commercial building stock in GCCCA is shown in Table 2.3 (GA, 2010). Floor area for low rise building is dominant in GCCCA having 53% of total and followed by medium-rise (31%) and high rise building (16%). Also, steel and concrete framed buildings are shown dominant having more than 99% in all different type of buildings. Particularly concrete frame structure buildings are quite dominant in medium and high rise buildings.
Table 2.3. Gold Coast City Council Commercial Building Stock

<table>
<thead>
<tr>
<th></th>
<th>LR</th>
<th>MR</th>
<th>HR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>%</td>
<td>Number</td>
</tr>
<tr>
<td>Building number</td>
<td>1911</td>
<td>62</td>
<td>831</td>
</tr>
<tr>
<td>Floor area</td>
<td>7,163,650</td>
<td>53</td>
<td>4,235,512</td>
</tr>
<tr>
<td>Concrete framed</td>
<td>1,035</td>
<td>54</td>
<td>714</td>
</tr>
<tr>
<td>Masonry</td>
<td>114</td>
<td>6</td>
<td>29</td>
</tr>
<tr>
<td>Steel framed</td>
<td>762</td>
<td>40</td>
<td>88</td>
</tr>
<tr>
<td>Building number</td>
<td>1,911</td>
<td>100</td>
<td>831</td>
</tr>
<tr>
<td>Floor Area</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concrete framed</td>
<td>3,581,675</td>
<td>50</td>
<td>3,425,393</td>
</tr>
<tr>
<td>Masonry</td>
<td>96,105</td>
<td>1</td>
<td>26,518</td>
</tr>
<tr>
<td>Steel framed</td>
<td>3,485,870</td>
<td>49</td>
<td>783,601</td>
</tr>
<tr>
<td>Total floor area</td>
<td>7,163,650</td>
<td>100</td>
<td>4,235,512</td>
</tr>
</tbody>
</table>

Source: GA (2010)

Recently CFC (Construction Forecasting Council, 2010) forecasted future non-residential building stock as monetary base considering GDP, economic situation etc across in Australia. For CFC’s estimation, this study estimated office building stock in GCCCA using current market values (Rawlinsons, 2011) for different type of commercial buildings. Figure 2.38 gives the total floor area (in million m$^2$) of commercial office building stock in GCCCA, which applied CFC (2010) forecasting to the Gold Coast Building stock data in Table 2.3. As seen in this Figure, medium and high rise office buildings show relatively small portion comparing to low rise office building in 2005. But this proportion is estimated to change. The proportions of medium and high rise office buildings are continuously increasing but the proportion of low rise office building shows not much change. In 2020, 85% of total office buildings are estimated to be medium and high rise buildings.
2.6.4 Energy consumption for commercial office building

The energy consumption (kWh/m²) for commercial office buildings was calculated by eQUEST. Then, the energy consumption is multiplied by the office building stock area to estimate total energy and cooling energy consumption in GCCCA. The annual energy end-use breakdown for commercial office buildings obtained is shown in Figure 2.39. It indicates that higher building consumes more energy per unit floor area (m²). The summation of cooling, lighting and equipment energy consumption accounts for 80% for low rise, 81% for medium and 76% for high rise buildings.

Figure 2.39. Energy consumption in commercial office building in GCCCA
The modelling results are based on eQUEST calculations and they are theoretical and thus it would be valuable to compare the results with real energy consumption data.

ABCB (2004) examined energy consumption of 215 office buildings in Australian capital cities and found the mean energy consumption per building to be 1,027 MJ/m²/year (with a standard deviation of 299 MJ/m²/year) for Queensland. According to the Commercial Building Disclosure (Australian Government, 2011), non-governmental office building energy in Queensland shows 1,038 MJ/m²/yr (541 MJ/m²/year for Base building energy, which is the energy usage for building central service) for 2.5 to 3.5 star of whole office building. On the other hand, office buildings owned by governments show relatively less energy consumption in comparison with the non-governmental office buildings, having 861 MJ/m²/year (461 MJ/m²/year for Base and 400 MJ/m²/year for Tenant) (DEHWA, 2009).

Figure 2.40 shows a comparison between real energy consumption for office building in Queensland and our modelling results. If we compare this energy consumption data (Queensland average office building) with modelling results, it shows 4% to 32% difference depending on the building type (32% for low rise building, 15% for medium rise building and 4% for high rise building, respectively).

Figure 2.40. Comparison of modelling with real office energy consumption

The annual energy consumption in GCCCA is shown in Figure 2.41. Of the total energy consumption from commercial office building in GCCCA, low, medium and high rise buildings contribute 45%, 34% and 21%, respectively. Energy consumption from tenant shows slightly higher than base building energy consumption. However, tenant energy shows decrease when building changes from low rise to high rise, as seen in Figure 2.41. This may be interpreted to require more energy for base building in the higher building including lift and common area lighting and heating/cooling energy etc.
Using equation (2.3), the total energy consumption in GCCCA is obtained by multiplying the unit energy consumption by office building stock floor area (Figure 2.38). The results are shown in Figure 2.42.

2.6.5 Cooling energy comparison for residential and commercial office building

Cooling energy for residential and commercial office building in GCCCA is compared. As seen in the Figure 2.43, cooling energy consumption from both residential and commercial office building shows 127 GWh in 2005. The cooling energy consumption from residential and commercial office building in GCCCA increases nearly 100% for the period from 2005 to 2010 and then shows it is expected to be 496 GWh in 2020, which is 3.9 times of the consumption in 2005.
In 2005, the cooling energy proportions of residential and commercial office buildings were 53% to 47%, respectively. From 2005 to 2020, the residential cooling energy consumption is expected to increase with a rate of 2.4% per year, while the commercial office cooling energy consumption is to increase with a rate of 38% per year. Thus, as seen in Figure 2.43, by 2020 the commercial office buildings will account for 82% of the cooling energy consumption.

Figure 2.43. Cooling energy consumption for residential and commercial office buildings in GCCCA
3. HOW CAN ADAPTATION OCCUR?

Given the analysis of historical trends in this report, it is anticipated that the electricity demand, specifically the peak electricity demand, on the Gold Coast will grow significantly in the near future (see the analysis in the previous Section).

3.1 Definition of adaptation to climate change

The role of adaptation to climate change is of increasing importance to policy makers, planners and practitioners of different sectors, including energy sector. The role of adaptation is also increasingly considered in academic (Smit et al., 2000) and technical (World Bank, 2011) literature and it is being recognised at national and international level.

Adaptation to climate change and variability is an alternative and complementary response to “mitigation” – a policy response aiming to reduce greenhouse gas (GHG) emissions (Smit, 2000). The meaning of “mitigation” is to abate, moderate or alleviate GHG levels, while the meaning of “adaptation” is to alter, adjust or modify activities in the socio-economic environment related to GHG emissions and climate change.

Adaptation is a set of responses to actual or expected climatic stimuli and their impacts (Smit et al., 2000). The adaptation refers both to the process of adapting and the condition or situation to be adapted. The importance of adaptation is growing as mitigation has had a limited success to constrain or reduce GHG emission levels so far. Frequently mitigation and adaptation have been considered quite separately at different levels – from research to policy and practical implementation. While from historical and policy perspective grouping actions under mitigation and adaption have served its purpose well, from a practical point of view many climate change responses may be difficult to attribute only to the mitigation or the adaptation group. The complexity of climate change response require many actions from different stakeholders, market players, community and customers at the same time – some of these responses will be easy to classify as adaptation or mitigation responses, however, many will be mixed one, having elements of mitigation and adaptation in the same time. For the purposes of this paper we will put emphasis on adaptation, however, we will not try to put a strict boundary between adaptation and mitigation actions.

Smit et al. (2000) raises four questions to characterise an adaptation response:

- Adaptation to what?
- Who or what adapts?
- How does adaption occur?
- How good is the adaptation?

From the same author we “adapt” and specialise a high level diagram in the case of adaption of peak electricity demand in the context of climate change – see Figure 3.1. We try to answer the above four questions briefly in the next subsections.
3.1.1 Adaptation to what?

The main adaptation focus is peak electricity demand as driven by several climate parameters – mainly high temperature, humidity and heat waves. Significant impacts on peak electricity demand have also several non-climate forces and conditions - population growth, economic growth and more wide penetration and use of air conditioners. Joint consideration of all these influence factors is recommended.

There is an important question about the role of peak and average electricity demand. The average electricity demand is essential for the total energy used and associated GHG emissions, while the peak electricity demand is a main driver for new investment in transmission and distribution networks. Peak electricity demand happens only several times during a calendar year, however, it requires a significant additional capacity of transmission and distribution networks, necessary to supply electricity to customers during perhaps less than 1% of the time. This additional capacity is in order of 10-15%. During periods of peak electricity demand the electricity networks, and frequently electricity generators, work close to maximum capacity with very little reserve capacity and flexibility to withstand failures and blackouts.

3.1.2 Who or what adapts?

Here we need to define our system to be adapted, its boundaries and players. Our initial list includes:
3.1.3 How does adaptation occur?

This question is answered in the next several sections. Several adaptation actions are outlined, at this stage without full cost-benefit analysis. It is likely that a complex issue like fast growing electricity demand will require a set of responses, as it is unlikely to find just a single, very successful, response. Some examples of adaptation actions for adjusting peak electricity demand are remote control of AC during time of peak demand, possible new electricity tariffs to account for air conditioning use or for maximum load for a given customer (discouraging simultaneous use of many appliances), distributed generation located at substation, renewable generation, etc.

3.1.4 How good is the adaptation?

For devising adaptation strategies, there are several useful guiding principles. One of them is resilience (Franco and Sanstad 2007), which is well regarded as a key property for sustainable development (Bruneau and Reinhorn 2006; Walker and Salt 2006; Wang and Blackmore 2009) of engineering and social-ecological systems. Other principles include sustainable development, cost-benefit analysis, building a mix of adaptation options, etc.

3.2 Remote control of air conditioners and pool pumps

Remote control of air conditioners and other “electricity hungry” devices during peak electricity demand periods has been trialled by several companies, including Energex – the electricity distributor for the region of South East Queensland, in which the Gold Coast is located. Energex has implemented a trial called “The cool change – energy smart suburbs” that has run for several summers, starting in the summer of 2007/2008 (Energex, 2011). The trial involves several hundreds of electricity customers who agree to have a remotely controlled device installed at their home and this device cycles off and on the air conditioners, pool pumps and hot water systems usually between 4 pm and 8 pm on days with peak electricity demand.

For example air conditioning units may be cycled off at the compressor for several minutes in every 30 minute block, while the fan continues to circulate air. Pool pumps are usually switched off for three to four hours at a time between 4 pm – 8 pm. Hot
HOW CAN ADAPTATION OCCUR?

water systems (that are not already on off-peak night tariff) are controlled not to heat water during the period 4 pm – 8 pm (only on days with peak electricity demand).

Energex claims that substantial reductions of peak electricity demand were achieved on hot summer days. Usually these periods with high electricity demand constitute less than 1% of the time in the year, however, they are responsible for up to 15% distribution network capacity utilisation of the 8 billion dollar network. Success with this type of initiative may help to defer substantial network upgrades that are one of the main reasons for the latest electricity price rises.

Remote control of air conditioners, pool pumps and other electricity intense devices is an example of a possible collective adaptation option that involves an electricity utility (in this case a distribution company) and many residential customers. In the future this type of control may be standardised and regulated. One possible rule is that air conditioners without this type of remote control may have separate and higher electricity tariff.

Associated with remote control of AC and pool pumps are other adaptation options such as higher electricity tariffs for air conditioning energy; tariffs that discourage simultaneous use of multiple appliances, etc. On the other hand, air conditioning during the time of heatwaves or high temperature can be vital for aged and vulnerable people. While the aged and the vulnerable are the most likely people who lack access to the cooling units, it provides an opportunity for the community to build up social adaptive capacity and management in times of natural and humanity crises.

3.3 Energy efficiency of houses

Housing energy efficiency means utilizing the minimum amount of energy for heating, cooling, equipments and lighting that are required to maintain comfort conditions in a house. An important factor impacting on energy efficiency is the building envelope. This includes all of the building elements between the interior and the exterior of the building such as: walls, windows, doors, roof and foundations. All of these components must work together in order to keep the building warm in the winter and cool in the summer. Residential building can be rated for its energy consumption.

In 2003, ABCB (Australian Building Codes Board) introduced energy efficiency measures for residential building into the Building Code of Australia (BCA).

House Energy Rating Schemes (HERS) in Australia have traditionally only assessed the thermal performance of residential buildings. HERS tools calculate the heat energy gains and losses associated with the design of the building in a particular location, and determine how much artificial heating and cooling may be required to maintain human thermal comfort (YHD, 2011).
Figure 3.2. Home energy use (Baseline energy estimates, 2008)

Figure 3.2 shows the average Australian household energy usage profile. The energy consumption can vary depending on the design of the building fabric and its systems. The heating and cooling are the major energy consumption areas in household. To reduce this energy usage, a number of options/tips are introduced in existing and new residential buildings. One example for this is the building energy star rating. This is given as part of the Energy Efficiency Rating (EER) assessment of a building. And this star rating provides an indication of how efficient the building is by providing a star rating from 0 to 10.

Figure 3.3 shows a star band of residential building energy in Brisbane. In here, the higher the star rating, the better is the energy efficiency of residential building. For example, a five star rating home means good, but not outstanding thermal performance. A ten star rating home is perfect, which does not necessarily have any artificial cooling or heating.

Figure 3.3. Residential building star rating criteria (example for Brisbane)
Australian typical house, which was built in 1990, has one star energy rating, which consumes more than 203 MJ/m² per year (DEWHA, 2011). From 2010, Queensland government introduced 6-star energy rating requirement for new houses and townhouses including major renovations (Queensland Government, 2011). Comparing to typical residential building, the 6-star rating indicates a building achieves a very high level of thermal energy performance. Also, this building is more comfortable to live in with much less energy usage for artificial heating and cooling energy.

To get 6-star energy rating for new house and townhouse, the most useful design options comprise air flow, shading and orientation. Queensland government (2011) provides high energy efficiency new house and townhouse design tips such as:

- Passive solar design: northern orientation of living rooms
- Ventilation: natural ventilation through windows and doorways
- Glazing: treated glazing
- Insulation: reducing heat entry by increased insulation in roof and walls
- Shading of thermal mass: wider eaves and awnings
- Building materials: light coloured roofs and walls
- Ceiling fans in living areas and bedrooms
- Well-designed outdoor living areas.

### 3.4 Distributed generation

Special attention needs to be given to distributed or local energy, a collective notion for demand side management, energy efficiency and distributed generation (CSIRO, 2009). Distributed generation is a set of small generators connected to the distribution part of the electricity grid close to customers. Distributed generation may reduce the energy required to be produced by central generators (and possibly the emissions of greenhouse gases) and avoid the associated network losses. It can enhance the security of electricity supply and is therefore ideal for emergency backup and as supplement during periods of peak electricity demand. Small generators could be co-located within distribution substations and switched on only during periods of high electricity demand.

### 3.5 Network upgrades

Network upgrades and extensions, both at transmission and distribution level, are required to deliver electric energy from newly built central generators. Under the national electricity law and electricity regulation, the Australian Energy Regulator (AER) is responsible for economic regulation of transmission and distribution.
businesses in the NEM, including ENERGEX which services SEQ. After concluding its distribution determination planning process for the next 5-year planning period (from the financial year 2010 – 11 to 2014 – 15), AER (2010) has accepted the following annual growth projections for that planning period for Queensland: maximum demand growing by 3.8 % pa, number of customers growing by 2.1 % pa, and energy consumption growing by 3.6 % pa. It is projected that over the five years the retail electricity price rise in Queensland due to the additional distribution cost and not counting for inflation is to be 12.4%. As for SEQ in the same 5-year period, the total capital expenditure determined by AER to ENERGEX will be $6,286 million; the total operating expenditure $1,634 million; and the total revenue $7,569 million. These are significant expenditures associated with maintenance and upgrades of the SEQ distribution network.

3.6 Solar thermal and solar photovoltaic

The adoption of solar technologies has been on the increase due to government support and the awareness of the public on greenhouse gas emissions and projected climate change. Solar technologies have a specific advantage for SEQ, where time periods of high solar radiation roughly coincide with that of high temperature and of peak electricity demand; therefore, the solar-technologies should be effective in offsetting the peak electricity demand and in reducing the greenhouse gas emissions. Large-scale solar thermal generators are already in use in several countries (e.g. Spain and the USA); however, they require additional upgrades of transmission and distribution networks, while solar photovoltaic panels can be connected directly to the distribution network, offsetting the local electricity demand.

3.7 Education

Education is critical in raising the public awareness about key challenges related to peak electricity demand as well as cooling, heating, and ventilation energy usage of residential houses and commercial buildings. Through knowledge and experience sharing, prudent use of energy and associated technologies can be more widely accepted by the population and communities. Local knowledge is also important as climate change and climate conditions have frequently different local impacts.

4. EVALUATION OF ADAPTATION OPTIONS

4.1 Climate impacts on energy demand

It is commonly noted that climate change will reduce total energy demand for space heating for buildings. On the other hands, it will increase total energy demand for space cooling. However, it is more common that climate change will affect system operations adversely rather than positively.

Climate change is projected to increase the likelihood and severity of a wide range of extreme weather events, many of which particularly affect urban areas. According to the
IPCC, it is very likely that heat waves will become more intense, more frequent, and longer lasting in a future warm climate, whereas cold episodes are projected to decrease significantly (Meehl et al., 2007).

Heat waves are likely to become longer and more frequent, and thus increasing the likelihood of brownouts or blackouts. More extreme rain events may flood power generation facilities located along waterways and increase the turbidity of water used to cool power plants.

In areas with decreased water availability, competition for water supplies will increase between energy production and other sectors. Temperature increase will decrease overall thermoelectric power generation efficiency. In some regions, energy resource production and delivery systems are vulnerable to effects of sea level rise and extreme weather events. Incorporating possible climate change impacts into planning processes could strengthen energy production and distribution system infrastructures, especially regarding water resource management.

Climate change is expected to mean greater variability in wind resources and direct solar radiation, substantially impacting the planning, siting, and financing of these technologies.

Impact of sea level changes on existing energy infrastructure (e.g., power plants, transmission lines, refineries, oil and gas pipelines, LNG facilities, etc.) and new infrastructure siting options (DOE, 2007).

### 4.2 Cooling energy for temperature rise

Historical temperature records indicate that the average temperature in SEQ has risen during the last decade (1998-2007) from 19.4°C to 19.8°C (Queensland Government, 2009). The future climate projected by CSIRO and BoM (2007) suggests that the air temperature in SEQ may increase between 0.5 °C and 1.5 °C from 2010 to 2030. GCCCA is not an exception. This region also will have increasing annual average temperature. Thus, this section evaluates residential cooling energy requirements when the annual temperature in GCCCA increases 1°C from 2010 to 2030.

Based on the medium household growth scenario in GCCCA, the projected cooling energy consumption without a temperature rise and with a linear temperature rise of 1°C from 2010 to 2030 is shown in Figure 4.1. It is seen that the 1°C temperature rise will cause GCCCA to consume 129 GWh of energy for cooling, compared to 96 GWh without a temperature rise, in 2030. This is 35% increase in cooling energy consumption in 2030 if the temperature rises 1°C from 2010 to 2030. Compared with the 2005 level, it represents a net increase of 62 GWh with 1°C-temperature rise and of 29 GWh without temperature rise. In other words, percentage increase of energy consumption over the 2005 level is 93% with 1°C temperature rise and is 43% without a temperature rise.
4.3 Adaptation for cooling energy

Climate change is likely to result in an increase of cooling energy demand, through more frequent use of existing devices and increasing market penetration of appliances, and a decrease of heating energy demand.

Currently a wide range of adaptation options can be considered for cooling energy increase due to climate change. Strategies for passive building design and retrofitting existing buildings are regarded as one of the key adaptation measures for cooling energy. This is because a passively designed and retrofitted building can adapt to increasing temperature, particularly in summer season due to climate change, without reducing temperature or extra energy consumption for cooling in building. Adaptation
measures for these are solar/heat control, thermal mass and ventilation etc. Solar/heat control and thermal mass reduce internal temperature variation while natural ventilation mixes or circulates internal heat air with external cool air naturally. These options to adapt overheating in building are mostly applicable in both new and existing buildings. Some options are relatively easy to implement in new and existing buildings but some others are not and are costly. For example, it is relatively easy to paint the residential building roof tiles with light colour or to install internal blinds or external shutters to reduce heat gain transmitted through the windows. In contrast, increasing wall insulation is costly and is not easy for an existing building. These are summarized in Table 4.1.

### Table 4.1. Adapting options to overheating of building by reducing cooling energy

<table>
<thead>
<tr>
<th>Option</th>
<th>When it apply</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>New</strong></td>
<td><strong>Existing</strong></td>
</tr>
<tr>
<td>Solar/heat control</td>
<td></td>
</tr>
<tr>
<td>Painting roof tile with light colour</td>
<td>✓</td>
</tr>
<tr>
<td>Green roof design</td>
<td></td>
</tr>
<tr>
<td>Upgrade window with double glazing</td>
<td>✓</td>
</tr>
<tr>
<td>Install internal blind/curtain in windows</td>
<td>✓</td>
</tr>
<tr>
<td>Install external shutter in windows</td>
<td></td>
</tr>
<tr>
<td>Install external awning/eave for shade</td>
<td></td>
</tr>
<tr>
<td>Avoiding northern orientation living area</td>
<td>✓</td>
</tr>
<tr>
<td>Minimising east/west facing windows</td>
<td>✓</td>
</tr>
<tr>
<td><strong>Thermal mass</strong></td>
<td></td>
</tr>
<tr>
<td>Wall insulation</td>
<td>✓</td>
</tr>
<tr>
<td>Roofing insulation</td>
<td>✓</td>
</tr>
<tr>
<td><strong>Ventilation</strong></td>
<td></td>
</tr>
<tr>
<td>Enhance cross ventilation</td>
<td>✓</td>
</tr>
<tr>
<td>Enhance air movement</td>
<td>✓</td>
</tr>
<tr>
<td>Install ceiling fan in living area</td>
<td>✓</td>
</tr>
</tbody>
</table>

* It can be applied existing building but required high cost (thus, more adequate in new building)

Figure 4.3 shows one of the examples to adapt peak cooling energy demand in residential building. When increasing the number of existing residential buildings with ceiling insulation by 10%, cooling energy can be reduced up to 9.7 GWh in 2020, which is 4% less comparing to Base case (not improve residential ceiling insulation). Once improve insulation as 30% then residential cooling energy shows 11% reduced as 29.1 GWh less in 2020 for the Base case.
There are another opportunities to adapt cooling energy to rising temperature. These are increasing energy production with renewable energy sources on site and increasing energy efficiency for cooling system (or apply high energy efficiency technologies). Increasing renewable energy production would release the tension of peak demand of cooling energy in summer seasons. By July 2011, a solar power capacity of 500 MW has been installed in Queensland (Media Newswire, 2011). This will be expected to increase more and more due to government rebate system. Replacing existing low efficient cooling system with high efficient one will ease the cooling energy demand. For example, if we replace 10% more energy efficient lighting system in commercial office building in Gold Coast City Council Area (12W/m² for existing office building lighting), cooling energy reduces 3.7 GWh in 2010. This will be increased to 6 GWh and 8.5 GWh in 2015 and 2020, respectively, as shown in Table 4.2.

Table 4.2. Cooling energy requirements for commercial office building due to increase of lighting system in Gold Coast City Council Area

<table>
<thead>
<tr>
<th>Unit: GWh/year for cooling energy</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base</td>
<td>169.7</td>
<td>285.6</td>
<td>404.7</td>
</tr>
<tr>
<td>10% improve lighting system</td>
<td>166.0</td>
<td>279.5</td>
<td>396.2</td>
</tr>
<tr>
<td>20% improve lighting system</td>
<td>162.4</td>
<td>273.6</td>
<td>387.9</td>
</tr>
<tr>
<td>30% improve lighting system</td>
<td>159.0</td>
<td>268.0</td>
<td>380.0</td>
</tr>
</tbody>
</table>

Many climate impacts (extreme heatwave, flooding, cyclone etc) that happened in last several years in Australia make it clear that adaptation to climate change is more and more important. Some of examples shown above have demonstrated the benefits to manage peak cooling energy demand due to temperature rise caused by climate change. However, these measures may not be enough to manage peak demand for cooling.
energy in Gold Coast City Council. To increase the effect of adaptation measures for peak demand of cooling energy, it may be necessary to combine a number of adaptation measures rather than single measures. To do so, it is necessary to consider simple measures such as natural ventilation, running fans to increase air circulation and install blind/curtain in windows with other adaptation measures.

5. CONCLUSION

In this report detailed recent electricity data at substation distribution level for the Gold Coast is used to estimate trends, patterns and variability of average and peak electricity demand. Relationships between the electricity demand and temperature and the electricity demand and population are investigated. Our analysis finds that there is a strong influence of air temperature on electricity demand and also a strong correlation between the population and electricity demand.

Based on detail data and future assumptions about the number and type of residential buildings on the Gold Coast, air conditioning penetration rate, type and efficiency of air conditioners, residential thermal insulation and other factors, residential cooling energy consumption in Gold Coast City Council Area is estimated. The annual energy consumption and annual cooling energy for commercial office buildings on the Gold Coast is also estimated.

Given the historical trends of average and peak electricity demands, significant increases can be expected in the future that may put the electricity supply system under stress. This stress is likely to be exacerbated by climate change in many locations.

Some specific climate adaptation actions are described briefly, including remote control of air conditioners and pool pumps, increasing energy efficiency of residential and commercial buildings, locating distributed and renewable generators at substations or customer sites, etc.

Some direction for future work:

- Detail analysis and ranking of adaptation options
- Better understanding of the different components of electricity demand (residential, commercial, industrial), their relationship to peak electricity demand and temperature sensitivity.
- Better understanding of capacity and constraints of distribution network.
- Future projections of electricity demand under different scenarios and climate change.

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This study makes use of the methods, tools and data developed and prepared by the South East Queensland Climate Adaptation Research Initiative (SEQ CARI), a partnership between the Queensland and Australian Governments, the CSIRO Climate Adaptation National Research Flagship, Griffith University, University of the Sunshine Coast and University of Queensland. The Initiative aims to provide research knowledge to enable the region of SEQ to adapt and prepare for the impacts of climate change.
REFERENCES

ABCB (2004) Australian Building Codes Board: Class 5 Benchmarking, ABCB


REFERENCES


EMET (EMET Consultants and Solarch Group, 1999) Baseline study of Greenhouse gas emissions from the commercial buildings sector (study commissioned by the Australian Greenhouse Office), Canberra


Franco, G., Sanstad, A.H., 2007. Climate change and electricity demand in California. Climate Change. 87 (Supplement 1), S139-S151.

GA (Geoscience of Australia) (2010). NEXIS database, Australia.


Gold Coast City Council (GCC), 2011 (available online: http://www.goldcoast.qld.gov.au/).


Gold Coast City Council (GCC), 2010b. Priority Infrastructure Plan (PIP): Planning Assumptions and Priority Infrastructure Area.


Table A.1. Substation data completeness

<table>
<thead>
<tr>
<th>Code</th>
<th>Name</th>
<th>Start</th>
<th>End</th>
<th>% Complete</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSARL</td>
<td>Arundel</td>
<td>Tue Oct 25 00:00:00 2005</td>
<td>Wed Jun 30 23:30:00 2010</td>
<td>99.41%</td>
</tr>
<tr>
<td>SSBLH</td>
<td>Beenleigh</td>
<td>Sat Jan 01 00:00:00 2005</td>
<td>Wed Jun 30 23:30:00 2010</td>
<td>99.39%</td>
</tr>
<tr>
<td>SSBLHBS</td>
<td>Beenleigh BS</td>
<td>Sat Jan 01 00:00:00 2005</td>
<td>Wed Jun 30 23:30:00 2010</td>
<td>99.56%</td>
</tr>
<tr>
<td>SSBLN</td>
<td>Beenleigh North</td>
<td>Wed Jul 16 11:30:00 2008</td>
<td>Wed Jun 30 23:30:00 2010</td>
<td>99.75%</td>
</tr>
<tr>
<td>SSBTA</td>
<td>Bethania</td>
<td>Sat Jan 01 00:00:00 2005</td>
<td>Wed Jun 30 23:30:00 2010</td>
<td>99.53%</td>
</tr>
<tr>
<td>SSBBH</td>
<td>Broadbeach</td>
<td>Sat Jan 01 00:00:00 2005</td>
<td>Wed Jun 30 23:30:00 2010</td>
<td>99.35%</td>
</tr>
<tr>
<td>SSBDL</td>
<td>Bundall</td>
<td>Sat Jan 01 00:00:00 2005</td>
<td>Wed Jun 30 23:30:00 2010</td>
<td>99.65%</td>
</tr>
<tr>
<td>SSBHDTR2</td>
<td>Burleigh Heads</td>
<td>Sat Jan 01 00:00:00 2005</td>
<td>Wed Jun 30 23:30:00 2010</td>
<td>96.53%</td>
</tr>
<tr>
<td>SSBHDBS</td>
<td>Burleigh Heads BS</td>
<td>Sat Jan 01 00:00:00 2005</td>
<td>Wed Jun 30 23:30:00 2010</td>
<td>99.36%</td>
</tr>
<tr>
<td>SCCCY</td>
<td>Cades County</td>
<td>Sat Jan 01 00:00:00 2005</td>
<td>Wed Jun 30 23:30:00 2010</td>
<td>97.09%</td>
</tr>
<tr>
<td>CMAT2</td>
<td>Coomera</td>
<td>Thu Nov 17 00:00:00 2005</td>
<td>Wed Jun 16 23:30:00 2010</td>
<td>99.72%</td>
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<td>SSCMABS</td>
<td>Coomera BS</td>
<td>Thu Nov 24 00:00:00 2005</td>
<td>Wed Jun 30 23:30:00 2010</td>
<td>99.59%</td>
</tr>
<tr>
<td>SSCRB11</td>
<td>Currumbin</td>
<td>Thu Oct 02 14:30:00 2008</td>
<td>Wed Jun 30 23:30:00 2010</td>
<td>93.56%</td>
</tr>
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<td>Mon Oct 26 09:00:00 2009</td>
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<td>End Date</td>
<td>Availability</td>
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<td>Wed Jun 30 23:30:00 2010</td>
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</tr>
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<td>HIST1</td>
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<td>SSIPL</td>
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<td>SSLDR</td>
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<tr>
<td>SSLGV</td>
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<tr>
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<td>Wed Jun 30 23:30:00 2010</td>
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<td>SSMAI</td>
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<td>MDRT4</td>
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<td>Wed Jun 30 23:30:00 2010</td>
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<td>Southport</td>
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<tr>
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<td>Yatala</td>
<td>Sat Jan 01 00:00:00 2005</td>
<td>Wed Jun 30 23:30:00 2010</td>
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</tr>
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Figure B.0.1 Substation hierarchy for Loganlea Connection Point
APPENDIX B — SUBSTATION HIERARCHIES

Figure B.0.2 Substation hierarchy for Mudgeeraba Connection Point

Figure B.0.3 Substation hierarchy for Molendinar Connection Point