# 行政院國家科學委員會專題研究計畫 成果報告

## 都市住宅區電力消費解析及預測—以台南市為例
## 研究成果報告(精簡版)

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# 行政院國家科學委員會補助專題研究計畫成果報告

## 都市住宅區電力消費解析及預測—以台南市為例

## Research on Electricity Consumption and Prediction of the Residential Area in Tainan

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**中文摘要**

本文旨在探討住宅區土地與用電密度之關係，希望可以透過對於住宅區之建築用電解析，藉以瞭解其與土地之關係。在用電解析方面，本文區分為透天住宅、沿街店鋪、公寓大樓等單元，希望可以掌握住宅區內之所有用電行為，進而建構合理之用電預測模式，並希望能藉此邁入都市能源解析。

在透天住宅用電分析方面，擇定台南市東區 27 處街廓共 1,386 戶透天樣本。研究結果顯示，透天住宅之平均單位樓地板用電全年達 33.29 度。以平均用電密度而言，2F 建築物為 5F 之 1.56 倍，面西的透天住宅平均耗電為面北的 1.33 倍，平均空調用電約佔全用電之 15.56%。依本文開發之透天住宅街廓用電預測試算程式回測樣本街廓，平均誤差率約為 10.14%～15.62%，而預測與實際數據的相關係數 R 值達 0.78。以東西向為長軸之街廓，其街廓內的住宅用電，確實比南北向的街廓節省，平均節電達 12.89%。

在沿街店鋪用電解析方面，共計擇定 59 處街廓，共 555 戶透天商店樣本，平均使用樓層數僅為 1.31 層。商店平均單位樓地板用電全年達 153.73 度，為了明確掌握多樣化樣本特色，本文將所有樣本分成 38 類，最高類別商店的用電密度為最低者的 54 倍。本文建議以外氣溫度作為預測各類別商店平均用電密度的主要變數，以 38 條迴歸式作為 38 類商店之用電密度預測模式，其平均 R 值為 0.861。為了提高方程式精度，本研究繼續加入使用空調條件、面臨路寬條件、座落三角窗地段條件、建築座向等變數，做成多變數預測方程式，其 R 值提升達 0.932。

在公寓大樓之用電解析方面，以 9 處公寓為例，探討土地條件與開發樓地板面積關係，最後以開發樓地板面積預測試算表，配合公寓之公電及私電密度，以預測公寓土地之總用電量。

最後本文希望未來可以綜合住宅區內不同的透天住宅、商業店鋪、公寓建築等高低密度參雜，住商混合等用電模式，提供多種直接以住宅區域土地條件以預估日後開發完成之用電模式，以供能源供應預測、能源政策、都市氣候解析、電力饋線規劃管控等參酌。

關鍵字：**住宅區、用電密度、用電預測、都市能源**

**Abstract**

## Research on Electricity Consumption and Prediction of the Residential Area in Tainan

In order to predict urban energy consumption, this dissertation focuses on the prediction model of the electricity consumption in urban residential area. The electricity consumption characteristics of 3 categories, including residential town houses, roadside stores, apartment buildings, are discussed in this study.

27 residential blocks with 1386 residential town houses in Tainan, Taiwan are selected as samples. Among them, 599 houses are valid samples. The conclusions are as follows: 1.The average EUI is 33.29 kWh/㎡•yr; 2.Concerning the eletricity consumption density, the two- story building is 1.56 times larger than that of 5-story building. Considering orientations, the west-facing houses are 1.33 times the average electricity consumption of those facing north; 3.The air-conditinion electricity consumption accounts for 15.56% of the total. In addition, a simplified prediction model for electricity consumption of residential blocks is developed in this study. For utterly residential buildings, the deviation of the predicted data is about 10.14% to 15.62%. The coefficient of correlation(R value) between the predicted value and the sample is 0.78. The electricity consumption of residential blocks with west-east major axis is truly lesser than that of north-south axis by 12.89%.

Regarding the roadside stores, 59 residential street blocks 555 commercial town houses in Tainan, Taiwan are selected as samples. Among them, 434 houses are valid samples. The conclusions are as follow: 1.The average story still in business usage is 1.31; 2.The average EUI is 153.73 kWh/㎡‧yr with a high standard deviation of.306.59 which implies a large difference among samples; 3.All the samples are divided into 38 categories. The EUI of the highest category is 54 times larger than the lowest one; 4. Outdoor temperature was used as the main factor to predict the EUI of the 38 store categries; the R value is 0.861; 5. To enhance the predictability of the model, we put in more factore, including air condition status, width od the road in front, whether or not situated at the corner of the block, the orientation of the bilding. By doing this, the R value increases to 0.932

9 apartment buildings are chosen as samples are used to derive the prediction model. The EUI of private and public utilized area is ised to predict the total electricity consumption.

Finally, in order to predict the electicity consumption of the residential area. This research will estiblish several prediction models to apply to different precision and conditions.

***KEYWORD:*** Residential Block, Energy Use Intensity, Electricity Consumption Prediction, Urban energy

## 一、研究方法及流程

### 1.1 研究設計

本文主要探討都市計畫住宅區的土地條件其土地用電密度，因此在研究設計上，首先必須選擇足具代表性之住宅區街廓，並透過對街廓內之建築用電解析，分析其與都市計畫

相關變數之關連性。在取樣的方式上，針對廣大的面積通常可以網格分析法進行，即將全市套以均佈網格，並以格狀交叉點作為取樣街廓，但此舉不但無效樣本率高，且樣本遍布全市，在調查工作的執行上困難度較高，故本文以選取具代表性之住宅街廓為之，必須先經過反覆的試調查之後，以擇定可供操作區域為之。由於在解析的過程中，為避免其他不在本文探討範圍內之變數，影響解析的結果，因此本章在取樣的設計上，盡量考慮可以涵蓋各種座向之都市計畫街廓，亦即鎖定特定街廓型態之變數，同時利用該批街廓內大量的樣本(1386 戶)，希望將其他不相關的變數視為一般情況，而能集中全力來探討都市計畫變因對於街廓內之住宅用電關係。最後據以製作預測住宅區土地用電之方程式。

### 1.2 研究範圍與取樣

本文希望能預測一發展成熟都市計畫住宅區用電，故取樣須能代表發展成熟且符合現行建築法令允建之的住宅區街廓，所以樣本街廓必須先經過篩選，近期開發的街廓入住率過低，連帶使得用電密度過低；開發時間久遠的街廓，市容雜亂、街道狹窄、多有違章，其建蔽率無法符合現行建築法令，代表性亦不足，本文經反覆斟酌街廓代表性後，擇定台南市東區共 59 處街廓（圖 1）。

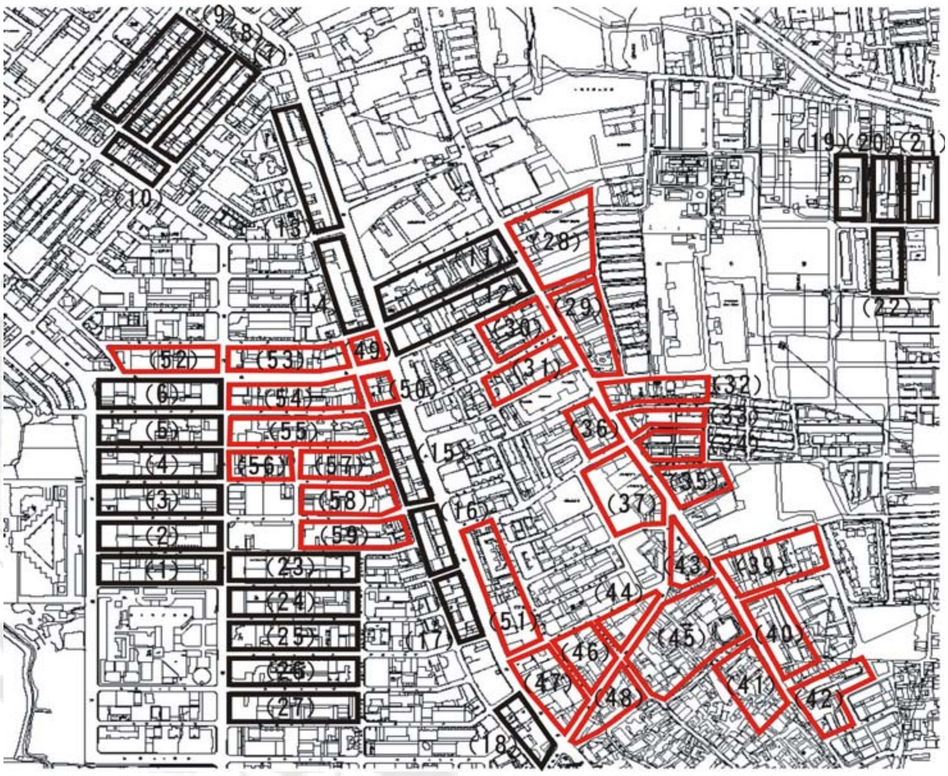

圖 1 住宅區用電調查之 59 處街廓圖

## 二、有效樣本概況分析

本區雖為住宅區，然而住商混合情形普遍，其中編號 1～27 共 27 處街廓乃進行區內全面性調查（包括住宅及店鋪），編號 28～59 等街廓，礙於研究工作負荷，僅調查店鋪部分，前 27 處街廓的調查情形如表 1，以建築面積而言，住商之比為 62.50%：37.50%，以樓地板面積而言，住商之比為 71.16%：28.84%，其中商業用途樓地板面積的認定依據是依現場調查是否設有營業招牌，並依現場實際商業使用的範圍為準，例如：有些店家僅於 1F 設置招牌，然而實際卻是 1F、2F 皆為商業使用，則其商業面積設為二層；又例如：有些店家招牌高達 1F～3F，然而實際商業使用卻僅是 1F，則其商業面積僅設為一層。

而各街廓之單位樓地板面積用電狀況如表 2 所示，各街廓之平均值為 66.64kWh/㎡・yr，標準差高達 43.84kWh/㎡・yr，最高為最低的 8.79 倍(210.51/23.95)，可見各街廓之差異甚高。如比對有效樣本之詳細資料，可發現此與街廓內之商業行為有密切關係，例如最高的 25 號街廓內，其中有 1 戶為麵包廠，其用電密度高達 1899.85 kWh/㎡・yr；而次高的 26 號街廓內，則有 1 戶便利超商，其用電密度高達 2542.70 kWh/㎡・yr，此數值高達最低街廓平均值(23.95)的 106.17 倍。

## 表 1 有效樣本中之住商混合比例

| | 有效樣本－住宅部份 | | | | | 有效樣本－商業店舖部份 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 街廓編號 | 建築面積 | 佔街廓比 | 樓地板面積 | 佔街廓比 | 戶數 | 建築面積 | 佔街廓比 | 樓地板面積 | 佔街廓比 | 戶數 |
| 1 | 1033.74 | 55.00% | 3852.54 | 63.52% | 14 | 845.79 | 45.00% | 2212.80 | 36.48% | 15 |
| 2 | 2437.66 | 77.89% | 5442.51 | 85.80% | 23 | 692.12 | 22.11% | 900.64 | 14.20% | 6 |
| 3 | 2118.20 | 43.54% | 5794.61 | 57.93% | 21 | 2746.63 | 56.46% | 4207.91 | 42.07% | 15 |
| 4 | 3263.14 | 73.52% | 8524.63 | 80.97% | 37 | 1175.01 | 26.48% | 2003.40 | 19.03% | 7 |
| 5 | 939.13 | 32.67% | 2640.59 | 40.25% | 11 | 1935.86 | 67.33% | 3920.26 | 59.75% | 12 |
| 6 | 1798.26 | 41.92% | 6219.13 | 62.34% | 19 | 2491.53 | 58.08% | 3757.77 | 37.66% | 9 |
| 7 | 2929.11 | 96.97% | 6405.33 | 96.97% | 32 | 91.53 | 3.03% | 200.17 | 3.03% | 1 |
| 8 | 2656.93 | 90.76% | 8066.68 | 92.65% | 31 | 270.65 | 9.24% | 640.17 | 7.35% | 3 |
| 9 | 4937.34 | 98.18% | 12712.66 | 98.71% | 55 | 91.71 | 1.82% | 166.61 | 1.29% | 1 |
| 10 | 902.58 | 65.61% | 2278.59 | 70.52% | 10 | 473.04 | 34.39% | 952.60 | 29.48% | 4 |
| 11 | 2054.80 | 72.45% | 5481.13 | 75.85% | 23 | 781.51 | 27.55% | 1745.57 | 24.15% | 11 |
| 12 | 3845.67 | 64.29% | 11378.26 | 77.72% | 53 | 2135.82 | 35.71% | 3262.36 | 22.28% | 18 |
| 13 | 2999.96 | 61.34% | 9369.00 | 68.73% | 33 | 1890.66 | 38.66% | 4262.62 | 31.27% | 15 |
| 14 | 275.38 | 11.62% | 1010.03 | 17.45% | 3 | 2094.95 | 88.38% | 4778.82 | 82.55% | 20 |
| 15 | 2861.15 | 68.91% | 6580.83 | 81.20% | 26 | 1290.67 | 31.09% | 1523.60 | 18.80% | 6 |
| 16 | 1417.18 | 45.91% | 3828.40 | 59.98% | 18 | 1669.51 | 54.09% | 2554.29 | 40.02% | 10 |
| 17 | 746.54 | 52.01% | 2425.96 | 64.68% | 9 | 688.72 | 47.99% | 1324.94 | 35.32% | 6 |
| 18 | 0.00 | 0.00% | 0.00 | 0.00% | 0 | 403.03 | 100.00% | 1063.35 | 100.00% | 5 |
| 20 | 1507.72 | 100.00% | 2480.51 | 100.00% | 19 | 0.00 | 0.00% | 0.00 | 0.00% | 0 |
| 22 | 2555.04 | 100.00% | 10220.16 | 100.00% | 54 | 0.00 | 0.00% | 0.00 | 0.00% | 0 |
| 23 | 2214.05 | 69.50% | 5696.46 | 84.54% | 22 | 971.72 | 30.50% | 1041.80 | 15.46% | 5 |
| 24 | 3815.06 | 63.41% | 11377.73 | 84.13% | 42 | 2201.27 | 36.59% | 2146.20 | 15.87% | 13 |
| 25 | 393.14 | 17.55% | 1449.81 | 37.00% | 4 | 1847.54 | 82.45% | 2468.58 | 63.00% | 8 |
| 26 | 1693.37 | 81.77% | 3248.08 | 87.53% | 19 | 377.53 | 18.23% | 462.77 | 12.47% | 4 |
| 27 | 2737.51 | 77.67% | 7564.17 | 90.58% | 21 | 787.07 | 22.33% | 787.07 | 9.42% | 1 |
| 總計 | 52132.65 | 62.50% | 144047.79 | 71.16% | 599 | 27953.87 | 37.50% | 46384.30 | 28.84% | 195 |

## 表 2 街廓整體用電密度表，單位：kWh/㎡・yr

| 台南市當月平均溫度*1 | | 18.10 | 19.20 | 23.00 | 25.70 | 27.00 | 28.90 | 29.10 | 29.00 | 28.20 | 26.80 | 21.50 | 19.30 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 街廓編號 | 戶數 | 1月 | 2月 | 3月 | 4月 | 5月 | 6月 | 7月 | 8月 | 9月 | 10月 | 11月 | 12月 | 合計 | *2 |
| 1 | 29 | 4.83 | 5.13 | 5.43 | 6.25 | 7.08 | 7.76 | 8.43 | 8.09 | 7.76 | 6.73 | 5.70 | 5.26 | 78.44 | 11.39 |
| 2 | 29 | 3.17 | 3.32 | 3.46 | 4.04 | 4.63 | 5.18 | 5.73 | 5.72 | 5.71 | 4.71 | 3.72 | 3.45 | 52.83 | 8.94 |
| 3 | 36 | 5.86 | 6.27 | 6.68 | 7.58 | 8.48 | 8.80 | 9.12 | 9.07 | 9.03 | 7.93 | 6.82 | 6.34 | 91.98 | 10.87 |
| 4 | 44 | 2.21 | 2.31 | 2.41 | 2.67 | 2.93 | 3.31 | 3.69 | 3.63 | 3.57 | 3.00 | 2.43 | 2.32 | 34.50 | 4.94 |
| 5 | 23 | 4.40 | 5.05 | 5.69 | 6.47 | 7.25 | 7.79 | 8.33 | 8.04 | 7.75 | 6.59 | 5.44 | 4.92 | 77.73 | 11.85 |
| 6 | 28 | 3.44 | 3.39 | 3.34 | 3.44 | 3.55 | 4.11 | 4.68 | 4.67 | 4.66 | 4.22 | 3.78 | 3.61 | 46.89 | 4.34 |
| 7 | 33 | 2.49 | 2.65 | 2.81 | 2.88 | 2.96 | 3.53 | 4.10 | 4.00 | 3.90 | 3.38 | 2.86 | 2.67 | 38.24 | 4.91 |
| 8 | 34 | 2.21 | 2.28 | 2.36 | 2.62 | 2.87 | 3.31 | 3.76 | 3.65 | 3.53 | 2.97 | 2.41 | 2.31 | 34.28 | 5.10 |
| 9 | 56 | 2.04 | 2.14 | 2.25 | 2.44 | 2.64 | 3.16 | 3.68 | 3.52 | 3.36 | 2.81 | 2.25 | 2.15 | 32.46 | 5.17 |
| 10 | 14 | 1.71 | 1.77 | 1.83 | 1.92 | 2.00 | 2.18 | 2.36 | 2.38 | 2.40 | 2.04 | 1.67 | 1.69 | 23.95 | 2.33 |
| 11 | 34 | 4.26 | 3.86 | 3.45 | 3.44 | 3.43 | 3.83 | 4.24 | 4.38 | 4.53 | 4.32 | 4.11 | 4.19 | 48.03 | 1.23 |
| 12 | 71 | 4.36 | 4.47 | 4.58 | 5.11 | 5.64 | 6.06 | 6.48 | 6.37 | 6.27 | 5.57 | 4.88 | 4.62 | 64.42 | 7.15 |
| 13 | 48 | 4.49 | 4.92 | 5.35 | 5.90 | 6.44 | 6.75 | 7.07 | 7.06 | 7.04 | 6.29 | 5.54 | 5.02 | 71.88 | 8.13 |
| 14 | 23 | 3.71 | 3.84 | 3.98 | 4.95 | 5.92 | 6.15 | 6.38 | 6.50 | 6.61 | 5.31 | 4.01 | 3.86 | 61.22 | 10.26 |
| 15 | 32 | 3.09 | 3.19 | 3.29 | 3.65 | 4.01 | 4.43 | 4.85 | 4.70 | 4.56 | 4.05 | 3.53 | 3.31 | 46.63 | 5.66 |
| 16 | 28 | 2.56 | 2.62 | 2.68 | 3.20 | 3.71 | 4.37 | 5.03 | 4.82 | 4.61 | 3.72 | 2.84 | 2.70 | 42.86 | 8.25 |
| 17 | 15 | 5.65 | 4.97 | 4.29 | 4.99 | 5.69 | 6.53 | 7.38 | 7.21 | 7.04 | 6.80 | 6.56 | 6.10 | 73.23 | 7.14 |
| 18 | 5 | 5.19 | 5.56 | 5.92 | 6.97 | 8.01 | 9.63 | 11.24 | 10.25 | 9.25 | 8.19 | 7.14 | 6.16 | 93.50 | 17.53 |
| 20 | 19 | 2.26 | 2.50 | 2.74 | 3.21 | 3.67 | 4.36 | 5.04 | 4.68 | 4.32 | 3.46 | 2.60 | 2.43 | 41.29 | 8.47 |
| 22 | 54 | 2.40 | 2.40 | 2.41 | 2.60 | 2.80 | 3.15 | 3.50 | 3.36 | 3.23 | 2.91 | 2.59 | 2.50 | 33.86 | 3.54 |
| 23 | 27 | 3.58 | 3.90 | 4.21 | 4.87 | 5.54 | 6.27 | 7.00 | 6.74 | 6.48 | 5.77 | 5.06 | 4.32 | 63.75 | 10.48 |
| 24 | 55 | 6.00 | 6.40 | 6.80 | 7.48 | 8.15 | 8.72 | 9.30 | 9.34 | 9.39 | 8.20 | 7.02 | 6.51 | 93.31 | 11.03 |
| 25 | 12 | 11.71 | 11.60 | 11.49 | 15.66 | 19.83 | 21.17 | 22.51 | 22.74 | 22.97 | 19.86 | 16.75 | 14.23 | 210.51 | 40.35 |
| 26 | 23 | 11.16 | 12.21 | 13.25 | 14.89 | 16.52 | 16.97 | 17.42 | 17.18 | 16.94 | 15.24 | 13.53 | 12.34 | 177.65 | 19.55 |
| 27 | 22 | 2.13 | 2.17 | 2.22 | 2.51 | 2.81 | 3.14 | 3.46 | 3.38 | 3.31 | 2.84 | 2.37 | 2.25 | 32.59 | 4.52 |
| 平均 | | 4.20 | 4.36 | 4.52 | 5.19 | 5.86 | 6.43 | 6.99 | 6.86 | 6.73 | 5.88 | 5.02 | 4.61 | **66.64** | **9.32** |
| 註：本表統計時間爲2002年1月至2002年12月，總戶數：794戶。 | | | | | | | | | | | | | 標準差 | **43.84** | **7.77** |

*1 依據中央氣象局資料

*2 全年空調用電密度:以6～9月之總用電密度和減去12～3月之總用電密度和得之。

## 三、住宅區用電分析

### 3.1.依建築物座向分析透天住宅用電

599 戶有效的透天樣本其單位樓地板面積用電情形如表 3 所示，各方位之平均值為 35.57 kWh/㎡．yr，標準差 2.89 kWh/㎡．yr，其中以面西向之平均耗能最高，比面北向全年高 33％，次高則為西南向，次低為東北向，其餘各向相較之差值在 0.04 以內(1.25-1.21)。

在空調用電方面，亦是西向最高，全年達 7.82 kWh/㎡．yr，北向最低，最高為最低的 1.70 倍(7.82/4.62)，在圖 2 中可發現，西向之逐月用電約從 4 月起，逐漸比其他各向建築物之耗電高，且差距呈現逐漸擴大的趨勢(例如在 1 月份西向用電密度比北向高 0.25 kWh/㎡，七月則高出 1.42 kWh/㎡)，直到 7 月為最高峰；在空調用電佔全年用電比例方面，各方位所佔比重介於 13.51％～20.02％。

理論上，透天建築除邊間之外，皆前後同時面臨 2 個座向，例如：前面東、後面西，或前面南、後面北等，因此似應同時以 2 個面向來探討建築座落面向與用電之關係，然而從實際調查發現，高達 93.8％(562/599)的住戶皆有後面廚房違章加建的情形，實際上建築物後面的棟距皆相當狹窄，因此針對此次研究的樣本而言，透天住宅後面受日射影響空調耗能的情形遠較正面座向為低，因此本研究僅採用正面座向，作為建築物座落之主要面向。

表 3　599 戶住宅建築用電密度表，單位：kWh/㎡．yr

| 住宅面向 | 戶數 | 1月 | 2月 | 3月 | 4月 | 5月 | 6月 | 7月 | 8月 | 9月 | 10月 | 11月 | 12月 | 合計 | 比值*1 | *2 | *3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 北向 | 134 | 1.90 | 1.95 | 2.01 | 2.21 | 2.47 | 2.89 | 3.32 | 3.18 | 3.05 | 2.51 | 2.03 | 1.96 | 29.47 | 1.00 | 4.62 | 15.67% |
| 西向 | 22 | 2.15 | 2.38 | 2.61 | 3.05 | 3.48 | 4.11 | 4.74 | 4.39 | 4.04 | 3.27 | 2.51 | 2.33 | 39.05 | 1.33 | 7.82 | 20.02% |
| 西北向 | 97 | 2.19 | 2.32 | 2.44 | 2.66 | 2.88 | 3.41 | 3.93 | 3.80 | 3.67 | 3.02 | 2.37 | 2.28 | 34.97 | 1.19 | 5.58 | 15.95% |
| 西南向 | 69 | 2.31 | 2.44 | 2.58 | 2.88 | 3.19 | 3.73 | 4.28 | 4.09 | 3.91 | 3.27 | 2.62 | 2.46 | 37.76 | 1.28 | 6.22 | 16.47% |
| 東向 | 57 | 2.14 | 2.26 | 2.52 | 2.72 | 2.92 | 3.29 | 4.02 | 3.88 | 3.39 | 3.06 | 2.73 | 2.62 | 35.57 | 1.21 | 5.04 | 14.17% |
| 東北向 | 31 | 2.24 | 2.27 | 2.29 | 2.66 | 3.03 | 3.24 | 3.79 | 3.65 | 3.19 | 2.90 | 2.61 | 2.43 | 34.32 | 1.16 | 4.64 | 13.51% |
| 東南向 | 96 | 2.31 | 2.39 | 2.47 | 2.75 | 3.03 | 3.54 | 4.05 | 3.96 | 3.88 | 3.21 | 2.54 | 2.43 | 36.58 | 1.24 | 5.83 | 15.93% |
| 南向 | 93 | 2.31 | 2.39 | 2.47 | 2.81 | 3.15 | 3.57 | 4.00 | 3.95 | 3.89 | 3.24 | 2.59 | 2.45 | 36.81 | 1.25 | 5.79 | 15.73% |
| 平均 | | 2.19 | 2.30 | 2.42 | 2.72 | 3.02 | 3.47 | 4.02 | 3.86 | 3.63 | 3.06 | 2.50 | 2.37 | 35.57 | 1.21 | 5.69 | 16.00% |
| 註：本表統計時間爲2002年1月至2002年12月，總戶數：599戶。 | | | | | | | | | | | | | 標準差 | 2.89 | 0.10 | 1.04 | 1.93% |

*1 各方位座向對北向之比值。

*2 全年空調用電密度:以6～9月之總用電密度和減去12～3月之總用電密度和得之。

*3 全年空調用電量佔全年總用電量之比值。

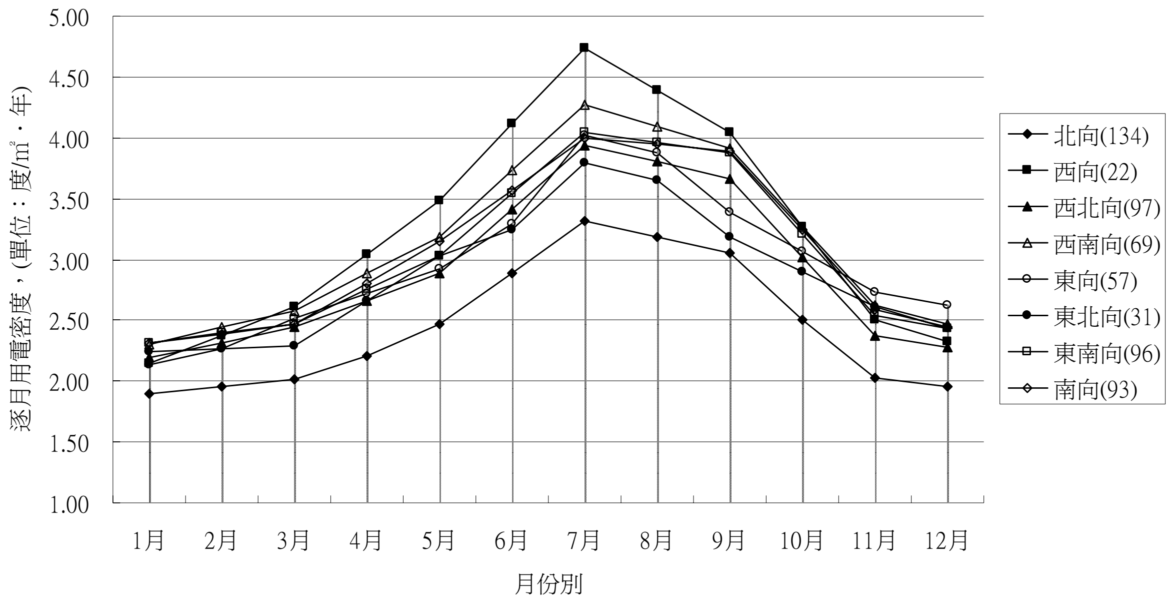


圖 2　各面向之透天住宅全年逐月用電密度，單位：kWh/㎡

### 3.2 透天住宅用電預測

本文以逐月之外氣溫度作為預測工具（公式 1），其 $R^2$ 值接近 0.86，顯著值亦達 1.46E-05，應具相當程度之信賴度。

$$TE = \sum_{i=1}^{12} Yi = aXi + b \cdots \quad R^2=0.859 \quad (1)$$

其中：

TE：透天住宅全年單位樓地板面積用電量[kWh/(㎡・yr)]

Yi：第 i 月單位樓地板面積用電量[kWh/(㎡・yr)]

Xi：第 i 月平均外氣溫度[℃]

a：0.1289，偏回歸係數[kWh/(㎡・yr・℃)]

b：-0.4034，常數[kWh/(㎡・yr)]

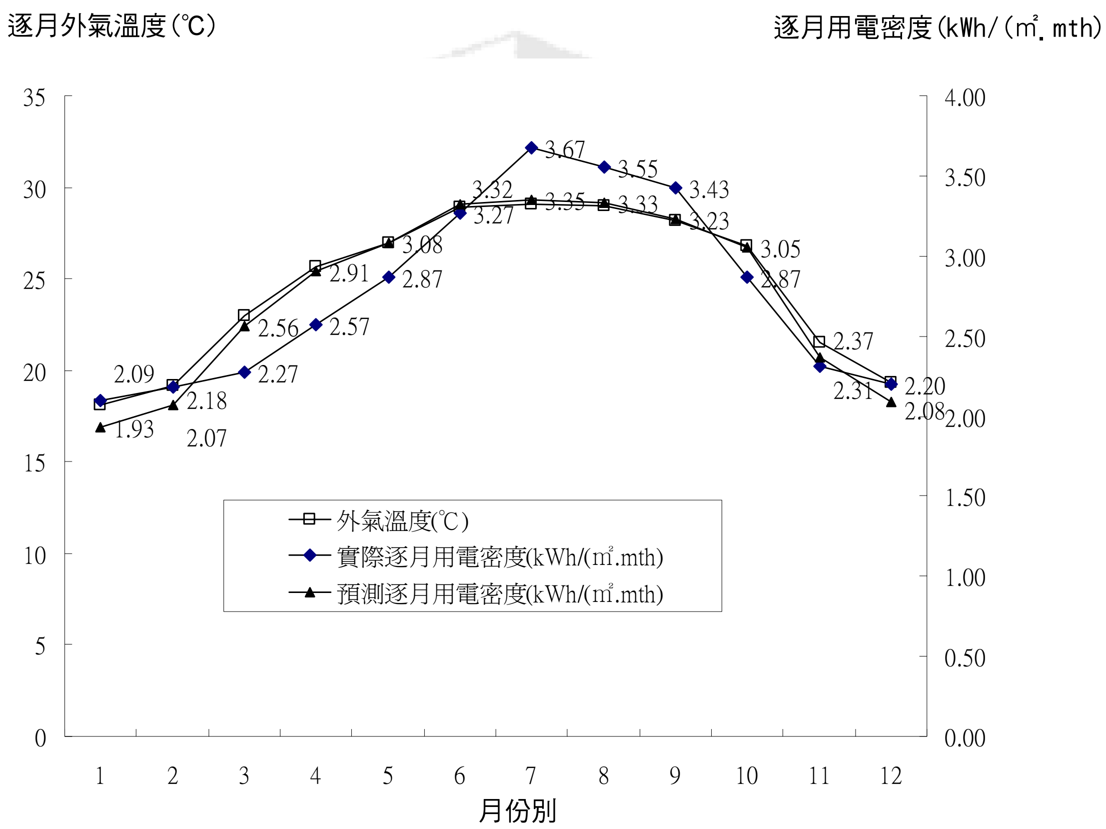


圖 3 以外氣溫度預測逐月用電密度並與實際用電密度比較

### 3.3 沿街店鋪用電分析

全部 434 戶之全年總用電量為 12,633,660 度，平均每戶之全年用電量為 29,110 度，如電價以每度 2.5 元計算，則每戶每年平均電費為 72,775 元，在單位樓地板面積用電方面，全年平均為 153.73 kWh/㎡・yr，標準差高達 306.59 kWh/㎡・yr，顯示商店各樣本之間的差異性極高，最明顯的是各種行業的耗能差異甚高，例如：便利超商的用電密度是機車行的 40 倍，因此必須將所有行業依用電密度高低區分。

本文對於各商店之分類方式考量商店的營業行為及耗能特性等，歸納為 38 類（表 4）。最高的為連鎖超商，約為五金行的 54 倍，在分佈上大致可以區分為四種級距，第一種為全年單位樓地板面積用電量 900 度以上者，包括類別編號 1～5 等類型，其中類別 1～2 皆具有全年營業、全年空調及照明、擁有冷凍及加熱設備、且經常處於空調外洩情形，類別 3 雖無冷凍或加熱設備，但是電

腦及人員等發熱體的密度都相當高，類別 4 則是因為烘烤麵包或糕點需要大量電力及製造大量發散熱，類別 5 則是擁有大量的冷凍設備。第二種級距則為用電密度在 200～400 之間，包括類別 7,8,10,12,14,16 等，此類商店皆具有固定營業時間，較高的照明密度、經常性空調外洩或部分特殊冷凍或發熱設備，造成用電密度較高。值得注意的是用電密度在 400～900 之間僅有 KTV 類，顯示第一種級距的商店用電量超高。第三種級距為用電密度 70～200 之間，該類型商店共計 15 類、194 戶(占全體 44.7%)，為主要類型樣本，用電密度約為住宅的 2～6 倍。第四種級距為 70 以下，此類型商店多為無空調、勤儉營業的傳統零售業或汽機車修理業等，共計 10 種、154 戶(占全體 35.5%)，其用電密度僅為住宅的 1～2 倍。綜合上述可以發現，影響商店行業別用電密度的因素以店鋪營業時間、使用空調及氣密條件、照明條件、冷凍設備、加熱設備等為主。而對於同類型的商店之間用電密度的差異，本研究歸結於如後等四項因素，茲分別論述之。

表 4 各類商店逐月單位樓地板面積用電量，單位：kWh/㎡

| 類別編號 | 商店類別（統計樣本數） | 1月 | 2月 | 3月 | 4月 | 5月 | 6月 | 7月 | 8月 | 9月 | 10月 | 11月 | 12月 | 全年 | 標準差 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 連鎖便利商店（6） | 131.3 | 135.9 | 147.8 | 150.6 | 165.6 | 166.2 | 171.3 | 170.2 | 165.8 | 163.2 | 151.9 | 141.3 | 1861.2 | 428.7 |
| 2 | 一般便利商店（3） | 72.6 | 74.9 | 75.1 | 71.9 | 81.5 | 87.2 | 88.8 | 87.8 | 88.8 | 86.2 | 82.8 | 78.3 | 976.0 | 155.0 |
| 3 | 網路咖啡店（4） | 82.3 | 90.8 | 100.3 | 105.9 | 140.5 | 150.2 | 154.2 | 155.7 | 142.6 | 125.5 | 101.5 | 82.4 | 1431.9 | 200.2 |
| 4 | 蛋糕店、麵包店（4） | 67.3 | 66.5 | 74.4 | 96.7 | 125.1 | 130.5 | 141.6 | 141.0 | 138.0 | 130.8 | 117.7 | 103.3 | 1332.8 | 608.6 |
| 5 | 生鮮超市（3） | 63.0 | 61.2 | 70.8 | 73.3 | 89.1 | 94.5 | 99.3 | 97.6 | 91.9 | 90.1 | 82.5 | 72.1 | 985.3 | 137.0 |
| 6 | KTV（2） | 48.4 | 45.0 | 52.9 | 48.4 | 48.5 | 57.5 | 75.4 | 75.5 | 73.5 | 69.0 | 59.3 | 39.8 | 692.9 | 60.1 |
| 7 | VCD出租店（4） | 21.0 | 21.1 | 24.9 | 30.8 | 39.0 | 40.1 | 43.3 | 43.2 | 42.5 | 38.1 | 29.6 | 25.6 | 399.3 | 81.3 |
| 8 | 連鎖中西藥局（4） | 21.7 | 22.6 | 24.7 | 25.9 | 27.3 | 28.2 | 29.4 | 29.0 | 28.4 | 26.3 | 24.0 | 22.4 | 310.0 | 115.4 |
| 9 | 一般中西藥局（8） | 4.1 | 3.8 | 4.4 | 4.7 | 5.4 | 5.6 | 6.4 | 6.1 | 5.5 | 5.3 | 4.4 | 4.3 | 59.9 | 22.2 |
| 10 | 連鎖電子通訊專賣店（4） | 13.3 | 14.1 | 17.3 | 19.7 | 22.6 | 24.1 | 25.7 | 24.6 | 22.5 | 20.7 | 17.7 | 15.4 | 237.7 | 75.8 |
| 11 | 一般電器及通訊行（10） | 5.2 | 5.1 | 5.7 | 5.8 | 6.0 | 6.3 | 6.8 | 6.7 | 6.5 | 6.4 | 6.0 | 5.8 | 72.2 | 25.5 |
| 12 | 有空調餐飲店（37） | 14.3 | 14.1 | 16.3 | 17.5 | 20.3 | 22.2 | 24.0 | 23.4 | 22.4 | 21.1 | 18.6 | 16.7 | 230.8 | 115.9 |
| 13 | 無空調餐飲店、小吃店（17） | 3.1 | 2.8 | 3.0 | 3.2 | 3.4 | 3.6 | 3.7 | 3.6 | 3.8 | 3.8 | 3.5 | 3.2 | 40.8 | 12.8 |
| 14 | 連鎖飲料專賣店（6） | 11.3 | 10.9 | 13.9 | 14.1 | 15.5 | 17.2 | 21.3 | 22.2 | 22.6 | 22.7 | 20.8 | 19.8 | 212.4 | 77.8 |
| 15 | 一般飲料專賣店（18） | 7.6 | 7.2 | 8.1 | 8.3 | 8.8 | 9.3 | 10.2 | 10.8 | 11.1 | 10.2 | 9.3 | 8.9 | 109.7 | 21.6 |
| 16 | 影印行、沖洗店（5） | 12.5 | 12.1 | 15.2 | 15.3 | 16.0 | 17.2 | 20.1 | 20.3 | 20.1 | 19.2 | 17.0 | 15.4 | 200.5 | 121.3 |
| 17 | 托兒所（5） | 10.2 | 10.1 | 12.7 | 13.8 | 15.6 | 16.5 | 18.3 | 17.6 | 16.5 | 14.4 | 10.8 | 9.5 | 166.1 | 55.4 |
| 18 | 銀樓（3） | 8.8 | 9.3 | 7.2 | 8.8 | 11.9 | 14.2 | 19.9 | 20.7 | 21.3 | 20.4 | 9.2 | 6.7 | 158.4 | 25.5 |
| 19 | 以年輕小姐號召的檳榔攤（3 | 9.5 | 10.4 | 11.2 | 12.7 | 14.3 | 15.4 | 16.6 | 16.0 | 15.4 | 13.6 | 11.8 | 10.7 | 157.5 | 50.0 |
| 20 | 無年輕小姐號召的檳榔攤（4 | 2.9 | 2.3 | 2.4 | 2.7 | 3.3 | 3.5 | 4.0 | 4.7 | 5.2 | 4.6 | 3.6 | 3.4 | 42.6 | 20.3 |
| 21 | 有空調一般零售店（22） | 10.3 | 10.0 | 10.3 | 11.4 | 12.7 | 13.7 | 15.2 | 15.6 | 15.9 | 15.0 | 13.3 | 12.3 | 155.7 | 59.5 |
| 22 | 無空調一般零售店（37） | 3.2 | 3.0 | 2.8 | 3.0 | 3.2 | 3.4 | 3.7 | 3.8 | 3.7 | 3.6 | 3.3 | 3.2 | 39.9 | 16.7 |
| 23 | 銀行（3） | 10.4 | 9.8 | 11.8 | 12.1 | 13.3 | 13.7 | 15.4 | 15.1 | 14.3 | 13.7 | 11.5 | 12.5 | 153.7 | 25.5 |
| 24 | 美容美髮店（29） | 8.8 | 8.3 | 9.7 | 10.6 | 12.3 | 12.4 | 13.4 | 13.5 | 13.3 | 12.6 | 10.6 | 9.8 | 135.6 | 73.5 |
| 25 | 書局、租書店、文具店（8） | 10.1 | 9.9 | 10.7 | 10.8 | 11.3 | 11.3 | 11.8 | 12.2 | 12.4 | 12.2 | 11.4 | 10.6 | 134.8 | 43.0 |
| 26 | 私人診所（18） | 7.7 | 7.8 | 10.1 | 10.8 | 12.1 | 12.3 | 13.3 | 13.3 | 13.0 | 12.3 | 10.7 | 8.9 | 132.4 | 59.6 |
| 27 | 連鎖早餐店（5） | 7.1 | 6.9 | 8.5 | 8.4 | 8.7 | 9.3 | 10.8 | 10.8 | 10.5 | 10.3 | 9.3 | 8.7 | 109.2 | 16.4 |
| 28 | 一般早餐店（9） | 5.0 | 4.4 | 3.9 | 4.7 | 6.1 | 6.1 | 6.6 | 6.0 | 5.0 | 5.2 | 4.9 | 5.4 | 63.3 | 10.9 |
| 29 | 鐘錶眼鏡行（5） | 8.5 | 8.1 | 9.5 | 8.9 | 8.7 | 9.1 | 10.2 | 9.9 | 9.2 | 9.0 | 8.2 | 8.1 | 107.4 | 56.5 |
| 30 | 連鎖補習班或安親班（5） | 5.5 | 5.9 | 6.4 | 8.0 | 9.6 | 10.2 | 10.8 | 10.8 | 10.9 | 8.9 | 7.0 | 6.2 | 100.4 | 21.3 |
| 31 | 一般補習班或安親班（10） | 1.9 | 2.0 | 2.4 | 2.7 | 3.0 | 3.7 | 4.4 | 4.4 | 4.3 | 3.7 | 3.2 | 3.0 | 38.7 | 12.9 |
| 32 | 洗衣店（9） | 6.8 | 6.2 | 7.2 | 7.3 | 7.9 | 7.9 | 8.5 | 8.5 | 8.3 | 8.5 | 8.1 | 7.7 | 92.8 | 33.3 |
| 33 | 上班型態公司行號（51） | 4.2 | 4.3 | 4.7 | 5.5 | 6.5 | 7.0 | 7.7 | 7.5 | 7.2 | 6.4 | 5.4 | 5.0 | 71.2 | 33.9 |
| 34 | 道壇、寺廟（4） | 2.9 | 3.0 | 3.8 | 4.3 | 5.2 | 5.5 | 6.2 | 6.1 | 5.8 | 5.0 | 3.6 | 3.3 | 54.6 | 19.6 |
| 35 | 家具店（4） | 3.8 | 3.7 | 4.2 | 4.0 | 4.1 | 4.2 | 4.6 | 4.7 | 4.6 | 4.7 | 4.5 | 4.2 | 51.3 | 20.8 |
| 36 | 汽機車修理（37） | 3.2 | 3.1 | 3.5 | 3.7 | 4.1 | 4.2 | 4.6 | 4.5 | 4.3 | 4.0 | 3.6 | 3.5 | 46.3 | 18.1 |
| 37 | 五金行、雜貨店、香舖（19） | 2.4 | 2.4 | 2.7 | 2.8 | 2.9 | 3.1 | 3.3 | 3.3 | 3.1 | 3.0 | 2.8 | 2.8 | 34.6 | 9.5 |
| 38 | 小型加工廠或倉庫（9） | 1.4 | 1.4 | 1.5 | 1.7 | 1.9 | 2.0 | 2.2 | 2.1 | 2.1 | 1.8 | 1.5 | 1.5 | 21.2 | 7.6 |
| 平均每日可照時數(hr)*1 | | 10.88 | 11.37 | 12.00 | 12.67 | 13.23 | 13.52 | 13.38 | 12.92 | 12.27 | 11.62 | 11.05 | 10.75 | | |
| 台南市2003年平均氣溫(℃) | | 17.4 | 20.0 | 21.1 | 25.5 | 27.8 | 28.1 | 30.4 | 29.4 | 29.0 | 26.2 | 24.0 | 18.8 | | |

*1依中央氣象局公告之台南市2003年氣象資料，以每日之日沒時間減去日出時間，再累加逐月之每日可照時數，後除以逐月之日曆天數得之

## 3.4 住宅區透天商店用電預測

本文建議以外氣溫度作為預測逐月用電密度的工具，各類別店鋪用電之預測公式如表 5，整體的相關係數 R 值平均達 0.861，平均顯著值亦達 3.51E-03。其中對於需用空調的商店類別，預測

能力較高，平均 R 值為 0.895、顯著值為 1.03E-03；對於不用空調的商店類別，預測能力稍降，平均 R 值為 0.789、顯著值為 8.88E-03，尚屬於優異範圍。此外，對於各店鋪的個別用電差異，例如：面臨道路寬度條件、雙面以上臨路、建築座落方位等變因時，本文建議以下列公式(2)、(3)為之。

$$TEz = \left( \sum_{i=1}^{12} Yi = aXi + b \right) \times \alpha \times \beta \times \gamma \cdots\cdots (2)$$

其中：

TEz：z 類店鋪全年單位樓地板面積用電量 [kWh/(㎡・yr)]

Yi：第 i 月單位樓地板面積用電量 [kWh/(㎡・yr)]

Xi：第 i 月平均外氣溫度[℃]

a：偏回歸係數[kWh/(㎡・yr・℃)]

b：常數[kWh/(㎡・yr)]

$\alpha$：面臨路寬係數，無單位，依下列認定

1.適用表 6 之 n 類店鋪者，為 1.0

2.適用表 6 之 c 類店鋪者，依公式 3

$\beta$：座落三角窗地段係數，無單位，依下列認定

1. 適用表 6 之 n 類店鋪者，為 1.0
2. 適用表 6 之 c 類店鋪者，為 1.25

$\gamma$：座落方位係數，無單位，依下列認定

1. 適用表 7 之 m 類店鋪者，為 1.0
2. 適用表 7 之 d 類店鋪者，查表 18 之係數值

$$\alpha = \frac{Rw}{15.1} \times 1.16 \cdots\cdots (3)$$

其中：

$\alpha$：路寬係數(8≦$\alpha$≦18)

Rw：店鋪面臨路寬[m]

15.1：常數[m]，取本研究所有樣本面臨道路的平均寬度

1.16：路寬影響用電密度比例係數

表 5 各類店鋪逐月平均用電密度預測公式

| 編號 | 商店類別（統計樣本數） | 預測逐月平均用電密度公式：Y= aX + b<br>a | b | R值 | 顯著值 |
|---|---|---|---|---|---|
| 1 | 連鎖便利商店 | 2.999 | 80.710 | 0.970 | 1.90E-07 |
| 2 | 一般便利商店 | 1.172 | 52.263 | 0.814 | 1.62E-03 |
| 3 | 網路咖啡店 | 6.085 | -31.632 | 0.956 | 1.18E-06 |
| 4 | 蛋糕店、麵包店 | 5.709 | -30.577 | 0.890 | 1.02E-04 |
| 5 | 生鮮超市 | 2.805 | 12.523 | 0.931 | 1.14E-05 |
| 6 | KTV | 2.186 | 3.522 | 0.770 | 3.37E-03 |
| 7 | VCD出租店 | 1.883 | -13.437 | 0.966 | 3.42E-07 |
| 8 | 連鎖中西藥局 | 0.595 | 11.075 | 0.976 | 5.72E-08 |
| 9 | 一般中西藥局 | 0.171 | 0.760 | 0.921 | 2.17E-05 |
| 10 | 連鎖電子通訊專賣店 | 0.920 | -3.020 | 0.974 | 8.77E-08 |
| 11 | 一般電器及通訊行 | 0.106 | 3.397 | 0.873 | 2.13E-04 |
| 12 | 有空調餐飲店 | 0.729 | 1.137 | 0.942 | 4.56E-06 |
| 13 | 無空調餐飲店、小吃店 | 0.562 | 2.010 | 0.778 | 2.87E-03 |
| 14 | 連鎖飲料專賣店 | 0.616 | 2.406 | 0.625 | 2.99E-02 |
| 15 | 一般飲料專賣店 | 0.221 | 3.659 | 0.791 | 2.17E-03 |
| 16 | 影印行、沖洗店 | 0.533 | 3.484 | 0.847 | 5.08E-04 |
| 17 | 托兒所 | 0.663 | -2.601 | 0.944 | 3.96E-06 |
| 18 | 銀樓 | 1.034 | -12.440 | 0.800 | 1.83E-03 |
| 19 | 有西施檳榔攤 | 0.527 | 0.063 | 0.976 | 5.71E-08 |
| 20 | 無西施檳榔攤 | 0.134 | 0.226 | 0.658 | 2.00E-02 |
| 21 | 有空調一般零售店 | 0.396 | 3.140 | 0.823 | 1.01E-03 |
| 22 | 無空調一般零售店 | 0.049 | 2.111 | 0.680 | 1.50E-02 |
| 23 | 銀行 | 0.342 | 4.329 | 0.866 | 2.69E-04 |
| 24 | 美容美髮店 | 0.394 | 1.532 | 0.945 | 3.79E-06 |
| 25 | 書局、租書店、文具店 | 0.159 | 7.295 | 0.853 | 4.18E-04 |
| 26 | 私人診所 | 0.440 | 0.112 | 0.965 | 3.71E-07 |
| 27 | 連鎖早餐店 | 0.244 | 3.052 | 0.832 | 7.91E-04 |
| 28 | 一般早餐店 | 0.115 | 2.436 | 0.643 | 2.41E-02 |
| 29 | 鐘錶眼鏡行 | 0.103 | 6.394 | 0.680 | 1.49E-02 |
| 30 | 連鎖補習班或安親班 | 0.453 | -2.880 | 0.970 | 1.87E-07 |
| 31 | 一般補習班或安親班 | 0.169 | -0.972 | 0.869 | 2.47E-04 |
| 32 | 洗衣店 | 0.130 | 4.511 | 0.788 | 2.32E-03 |
| 33 | 上班型態公司行號 | 0.270 | -0.758 | 0.960 | 8.01E-07 |
| 34 | 道壇、寺廟 | 0.263 | -1.964 | 0.963 | 5.40E-07 |
| 35 | 家具店 | 0.056 | 2.882 | 0.700 | 1.16E-02 |
| 36 | 汽機車修理 | 0.104 | 1.292 | 0.949 | 2.59E-06 |
| 37 | 五金行、雜貨店、香舖 | 0.059 | 1.428 | 0.897 | 7.49E-05 |
| 38 | 小型加工廠或倉庫 | 0.064 | 0.183 | 0.949 | 2.55E-06 |
| | Y：每月單位樓地板面積用電量[kWh/(㎡・mn)] | | | | |
| | X：外氣溫(℃) | | | | |

### 3.5 店鋪用電密度預測之準確性分析

根據前節的預測公式，本研究重新針對 434 戶有效樣本進行用電密度預測，將每一個樣本依據公式(2)及公式(3)的設定帶入，求取 434 筆有效樣本之全年單位樓地板面積用電預測值，再取預測用電密度值相對於實際值之迴歸分析，相關係數為 0.932，平均誤差比率為 35.56%，顯示就整體店鋪而言，本公式具備相當程度的預測能力，迴歸分析結果如圖 4。

### 3.6 公寓建築用電密度

關於公寓之用電調查，國內近期多有文獻，本文採用近期規模最大且最完整之劉心蘭君(2005)調查，按劉氏將公寓建築之用電密度區分為：私有面積範圍內之用電密度（簡稱私電）及公共設施

範圍內之用電密度（簡稱公電）探討。在南部地區劉氏調查 9 棟公寓集合住宅共 1410 戶單元，其全年用電密度的平均值為 41.13 kWh/m2.yr，標準差為 18.77 kWh/m$^2$.yr，其用電量預估如公式（4）及（5）。

$$E_{PR} = 41.655 \times \overline{A}_{PR} \times N \cdots\cdots\cdots(4)$$

$E_{PR}$ : 全年私人用電量，$kWh/yr$

41.665 : 平均單位樓地板面積全年用電量，$kWh/m^2.yr$

$\overline{A}_{PR}$ : 平均一住戶單元面積私有面積，$m^2$ / 戶

$N$ : 每個社區或每棟公寓總戶數，戶

$$\text{公電年用電量} = 0.478 \times \text{私電年用電量} \cdots\cdots\cdots(5)$$

表 6　面臨路寬係數 $\alpha$ 及座落三角窗地段係數 $\beta$ 之適用商店類別

| 商店類別 | n類商店(「文市」型態商店) | c類商店(「武市」型態商店) |
|---|---|---|
| 類別項目 | 小型加工廠或倉庫、五金行、雜貨店、香舖、一般零售店、洗衣店、美容美髮店、上班型態公司行號、道壇、寺廟 | 便利商店、網路咖啡店、蛋糕店、麵包店、生鮮超市、KTV、VCD出租店、中西藥局、電子通訊店、餐飲店、小吃店、早餐店、影印行、沖洗店、托兒所、銀樓、檳榔攤、銀行、書局、租書店、文具店、診所、補習班或安親班、家具店、汽機車修理店 |
| 分類說明 | n類商店取性質接近「文市」，c類店鋪取性質接近「武市」，並參考表3實際調查的數據來調整部分類別。 | |

表 7　座落方位係數 $\gamma$ 之適用商店類別及係數值

| 商店類別 | m類商店(不使用空調商店) | d類商店(使用空調商店) |
|---|---|---|
| 類別項目 | 無空調餐飲店、小吃店、無西施檳榔攤、無空調一般零售店、道壇、寺廟、家具店、汽機車修理、五金行、雜貨店、香舖、小型加工廠或倉庫 | 便利商店、網路咖啡店、蛋糕店、麵包店、生鮮超市、KTV、VCD出租店、中西藥局、電子通訊店、有空調餐飲店、飲料專賣店、影印行、沖洗店、托兒所、有空調一般零售店、銀行、美容美髮店、書局、租書店、文具店、診所、早餐店、鐘錶眼鏡行、補習班或安親班、洗衣店、上班型態公司行號 |
| 分類說明 | m類商店取性質爲「不使用空調」的商店，d類商店取性質爲「使用空調的商店」。 | |

d類商店的座落方位係數值，分別爲W(1.18)、SW(1.09)、E(1.01)、S(0.98)、NE(0.96)、SE(0.96)、NW(0.95)、N(0.86)，此數據代表各方位之比值。如同時面臨2向以上道路，則取最寬道路認定之。

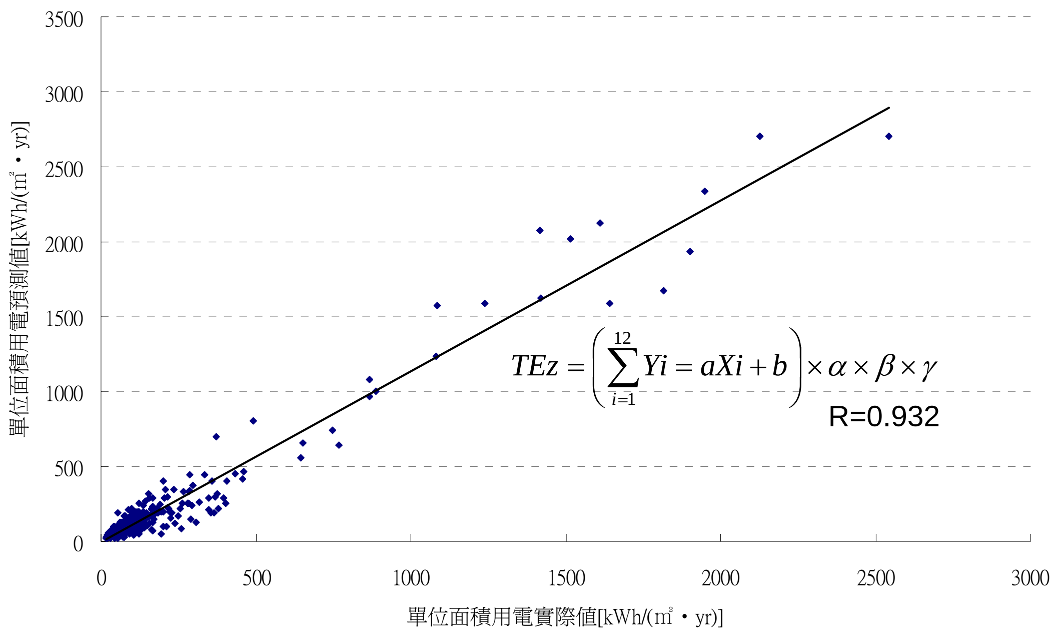


圖 4 全年平均單位樓地板面積之用電密度預測值對實際值迴歸分析

## 四、結論

任何的預測模式皆會面臨預測精準度與操作便利性的兩難取決，通常很難定義何謂最佳預測模式，預測精確度高的方式通常需要輸入的操作因素較多，而簡便的預測方式通常會將許多變數以合理平均值描述之，因此在操作模式的建立上，通常必須適所適用，因此本文建構多種預估模式以預測台南市住宅區街廓之用電密度。茲舉例折衷最適當之輸入變數群與計算難度，公式群如下：

$$E_y = \sum_{i=1}^{n} Bi \times 220.64 + (A_t \times (1 - \mathrm{Pr} - Rr) - \sum_{i=1}^{n} Bi) \times 135.66 \\ + A_t \times \mathrm{Pr} \times 2.92 + A_t \times Rr \times 4.21 \cdots\cdots (4)$$

$$E_y = \sum_{i=1}^{n} Bi \times Ci \times 1.16 \times 47.66 \times 1.478 + (A_t \times (1 - \mathrm{Pr} - Rr) - \sum_{i=1}^{n} Bi) \times 135.66 \\ + A_t \times \mathrm{Pr} \times 2.92 + A_t \times Rr \times 4.21 \cdots\cdots (5)$$

$$E_m = \sum_{i=1}^{n} Bi \times 24.35 + (A_t \times (1 - \mathrm{Pr} - Rr) - \sum_{i=1}^{n} Bi) \times 14.31 \\ + A_t \times \mathrm{Pr} \times 0.22 + A_t \times Rr \times 0.32 \cdots\cdots (6)$$

$$E_m = \sum_{i=1}^{n} Bi \times Ci \times 1.16 \times 5.26 \times 1.478 + (A_t \times (1 - \mathrm{Pr} - Rr) - \sum_{i=1}^{n} Bi) \times 14.31 \\ + A_t \times \mathrm{Pr} \times 0.22 + A_t \times Rr \times 0.32 \cdots\cdots (7)$$

$E_y$：區域土地全年用電量（kWh/yr）。
$E_m$：區域土地尖峰月用電量（kWh/mth）。
At：區域土地面積（㎡）。
Pr：公園佔區域面積比例（--）。
Rr：道路佔區域面積比例（--）。
Bi：第 i 處容積率在 220%以上之街廓面積（㎡）。
Ci：第 i 處容積率在 220%以上之容積率（--）。
220.64：公寓土地全年用電密度（kWh/㎡.yr）。
135.66：透天土地全年用電密度（kWh/㎡.yr）。
2.92、4.21：公園、道路全年用電密度（kWh/㎡.yr）。
1.16：總私有樓地板面積與總法定容積樓地板面積之比值(--)。
47.66：公寓單位樓板面積全年平均私電用電密度(kWh/$m^2$.yr)。
1.478：公共總用電量與私電總用電量之比值。
24.35：公寓土地尖峰月用電密度（kWh/㎡.mth）。
14.31：透天土地尖峰月用電密度（kWh/㎡.mth）。
5.26：公寓單位樓地板面積尖峰月私電用電密度(kWh/$m^2$.yr)。
0.22、0.32：公園、道路尖峰月用電密度（kWh/㎡.yr）。

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## 網站資料


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計畫編號：NSC 95-2221-E-041-024-

# 都市住宅區電力消費解析及預測—以台南市為例

## 出席 IASTED 國際研討會心得報告

出席人：計畫主持人 王仁俊

本次 IASTED(the International Association of Science and Technology for Development)國際研討會由加拿大 Calgary 大學主辦，會議地點選在泰國普吉島，整場會議歷時三天，全部共分 9 個會議場次（本論文歸類於電力負載預測領域），共計 108 篇論文獲得邀請 oral presentation（含本論文），主辦單位為每一位參與發表者皆備有本次會議所有論文之詳細書面及光碟資料，供各位發表學者攜回參酌。

本人此次與會所簡報的研究主題爲”**LOAD FORECASTING OF RESIDENTIAL ROW HOUSES BLOCKS IN TAIWAN**”，主要報告內容爲台灣之都市計畫街廓電力負載預測，參與該會議者多爲電機領域之各國先進，由於電機領域之先進對電力區域負載預測之研究相當深入細節，但是較缺乏的卻是從使用端切入的角度看電力負載，或許也因爲本論文乃從建築的角度出發，從整體街廓之建築物用電調查統計，迴歸到街屋組構之街廓，以返回推測土地用電密度，這方面因涉及建築或都市發展的變數，過去電機領域的先進多未投入探索，這應是本論文有幸獲選 oral presentation 的原因。

此次有幸參與論文發表，行程雖倉促滿檔，然收穫滿載。也深深的感受到台灣其實有許多優質的研究，尤其是許多年輕的學者，或礙於經費問題，卻苦無機會邁入國際，相信未來增加類似的計畫補助，將有助於台灣學者將研究成果分享與國際學者，亦可提升台灣在國際學術交流的能見度。

本報告 P2～P3 爲出席證件、註冊收據、邀請函，P4～P9 爲本發表論文報告。

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April 2, 2007

Welcome to the Third IASTED Asian Conference on Power and Energy Systems (AsiaPES 2007)! I hope that you will enjoy the conference and your time here in the Phuket!

Please note that you are welcome to attend the sessions, keynote addresses, and tutorials of the two other IASTED International conferences in Advances in Computer Science and Technology (ACST) and Communication Systems and Networks (AsiaCSN 2007), which are being held in conjunction with AsiaPES 2007 this week. You have been given a copy of the Conference Overview in your materials folder, which illustrates the programs of all three conferences.

IASTED is providing wireless Internet cards throughout the conference. If you wish to access the internet you will have to sign out the cards for 30 minute intervals. The cards will be available at the registration desk. For those who have not brought their own laptop, IASTED has also set up an Internet station. The laptops and Internet access provided by IASTED will be available for the duration of the conference.

Please load your presentation file onto the computer provided by IASTED in the appropriate meeting room prior to the beginning of your session. You may do this during the coffee or lunch breaks, or prior to your session in the morning. Please also report to your session chair at least fifteen minutes prior to the beginning of your session. You have been allocated 15 minutes for your presentation, plus another five minutes for questions. Please respect this time limitation.

There will be morning and afternoon coffee breaks on each day of the conference. Please check the conference program for the exact times and locations of these breaks. IASTED is pleased to invite you to the Welcome Address in Siam C Room on Monday, April 2, at 9:00am. Lunch will be provided and more detatiled information will be provided at the Welcome Address. There will also be a Group Photo for all delegates beginning at 6:45 pm, followed by a Cocktail Reception and Dinner Banquet at 7:30pm, on the Rabaing Terrace, Tuesday, April 3, 2007. Please remember to bring the dinner and drink tickets to the reception and the banquet, all of which can be found in your materials folder. You are responsible for your own dinners on the remaining days of the conference. For suggestions on restaurants, please contact the Hotel Staff.

Your feedback is extremely important to IASTED, and therefore, you will receive an email after the conference regarding our online post-conference questionnaire. In order to help us continually improve the quality of our conferences we would appreciate it if you would take the time to complete this questionnaire online.

Again, I do hope that you enjoy AsiaPES 2007, and if you have any questions or concerns please contact the registration staff or myself throughout the conference at the registration desk located in the Foyer.

Best regards,

Amy Christenson
Conference Manager
IASTED

**Proceedings of the Third IASTED Asian Conference**
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# LOAD FORECASTING OF RESIDENTIAL ROW HOUSES BLOCKS IN TAIWAN

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**ABSTRACT**
The purpose of this paper is to probe into the energy consumption of urban in Taiwan. Through the investigation and analysis of electricity consumption data from residential city blocks, this study discusses the difference of electricity consumption in row houses while they are located in different urban block patterns. There are 59 blocks, which 1,941 houses are included in, chosen to be the samples. Among them, 599 households and 434 commercial uinits are valid samples. The average energy use intensity (EUI ) is up to 33.29kWh/(m$^2$.yr). Considering azimuth, the average EUI of the west-elevated house is 1.33 times than that of the north-elevated house. Electricity consumption of air conditioning (AC) in housing accounts for 15.56% of the annual. Furthermore, three prediction equations are proposed in the end. The first is designed for predicting the EUI of household town house, the others are directed against the whole block area. Basing on the confidence of 95%, the $R^2$ is between 0.82 to 0.98.

**KEY WORDS**
Load Forecasting, Urban Energy, Residential Block, Town House, Energy Use Intensity (EUI).

## 1. Introduction

Long and narrow row houses and city blocks, extremely complex building appliance are the particular phenomenon in eastern city. It is difficult to perdict the area load. Moreover, the growing urbanization has led to the over-crowded cities in Taiwan. In order to maintain a quality living, people need to use all kinds of appliances, these all cause the growing electricity comsumption in the residential area. There are several related studies discussing the electricity consumption or load forecasting in the residential area. Some focus on household appliances, equipments or the building characteristics itself [1-3], while others lay emphasis on small-area load forecasting through Petri Net Algorithm[4-6]. However, we try to discuss this issue from a urban planning point of view.

This research investigated 59 representative blocks which are 599 households and 434 commercial units inside. Considering the factors of EUI, including the orientation, construction and stories of the town houses, the width of the roads around the blocks and the outside temperature, some conspicuous explanatory variables were concluded through multiple regression analysis. Three load forcasting equations are created, easier prediction model needs fewer factors, more exact model needs more factors and operation procedure. In the confidence interval of 95%, the $R^2$ of the equations are between 0.82 to 0.98. It is reliable that the electricity consumption of townhouse block can be figured out rapidly through the equations.

## 2. Selected Range and Analyzing Method

The chosen decision was made by a rational procedure. Tainan is a city with 176 km$^2$ areas and having a population of 700,000 people. It is almost impossible to investigate through the whole samples from the city. It is necessary to make some tactics. Firstly, we judge the intensity of building by GIS map and the population

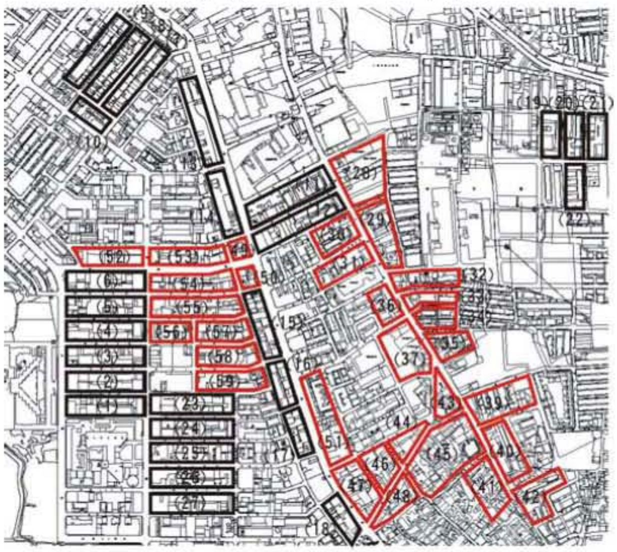

**Fig. 1 Selected blocks in eastern area of Tainan in Taiwan**

distribution from the whole city. That helps us to decide several candidate regions. Secondly, a pre-investigation was carried out on these regions. Thirdly, we take the current building codes and the residential ratio into consideration, the investigation region is shown on Fig 1. Finally, the 59 blocks with 599 households and 434 commercial units are chosen randomly by their different orientation.

The investigation can be divided into two parts. When investigating, we have to take down all the information about buildings first, such as building area, story, floor area, and the width of road faced. Secondly, we get the buildings' electricity consumption data from the power company. All the data will be the basis for analysis later.

## 3. Investigation Result and Analysis

### 3.1 Household Mix-used with Pedestrial Stores in the Residential Blocks

Although the selected blocks are planned as residential area, it's common in Taiwan that the residential area is mix-used with pedestrial stores. In the study, the proportion of residential and commercial usage is 62.50%:37.50% based on their building area; while it's 71.16%:28.84% based on their floor area. The majority of selected samples are composed of 3 and 4 story buildings, which is accounted for 75.46% of the total households. The sum of their floor area is 114,593m$^2$, which is 79.80% of the total floor area.

The electricity consumption of every selected block is shown in Table 1. The average Energy Use Intensity (EUI) is 66.64kWh/(m$^2$.yr) per block, while the standard deviation is 43.84kWh/(m$^2$.yr). The highest one is 8.79 times the lowest (210.51/23.95). The main reason for this high variation between samples is the pedestrial stores within the block.

The average EUI of AC is 9.32 kWh/(m$^2$.yr) and its standard deviation is 7.77 kWh/(m$^2$.yr). The correlation between EUI and the EUI of AC is as high as 0.918. This indicates the higher the block's electricity consumption is, the higher the AC electricity consumption is.

### 3.2 Electricity Consumption Analysis of Household Format

The average EUI of the blocks is 66.64kWh/(m$^2$.yr), the distribution appears the summer is the peak of the whole year. Averagely, the highest monthly EUI is 1.67 times the lowest one. The AC EUI is accounted for about 15.56% of the total EUI. (Table 1)

The EUI of selected samples is categorized according to their orientation (Table 2). The average EUI is 35.57 kWh/(m$^2$.yr), and its standard deviation is 2.89kWh/(m$^2$.yr). Among them, the EUI of the west-facing buildings, the highest of all orientations, is higher than that of the north-facing ones by 33%(Fig 2).Concerning the AC electricity consumption, the AC EUI of the west-facing buildings is also the highest. The value is 1.7 times the north-elevated one which is the lowest one.

The EUI of west-facing houses becomes higher than others from April gradually, and gets to its top in July or August. The AC EUI is accounted for 13.51% to 20.02% of the total EUI depending on the building's orientation.

### 3.3 Electricity Consumption Analysis of Pedestrial Stores

The pedestrial stores area accounts for 28.84% of total area. All the kinds of every stores' EUI refer to the other journal paper[3]. According to different business style, energy consumption characteristics, All the stores are classified into 38 categories in that study. Most kinds of stores are included in Taiwan. Furthermore, there are three main factors, the width of road faced, location(along the streetside or at the corner) and orientation effecting EUI in the same types of stores. At the end, the paper develops 38 regression formulas to predict 38 kinds of stores' EUI. With view of load forecasting of residential blocks, this paper doesn't touch upon the details of stores. An average discription is adopted by this paper. The average EUI of stores is 153.73 kWh/(m$^2$.yr). It is 4.62 times than that of housing. Averagely, the energy consumption of household is neraly equal to commercial purpose in residential blocks. The data will be adapted into this research later.

## 4. Prediction of Electricity Consumption Appendix

### 4.1 Prediction of Household's Electricity Consumption

Equation (1) is used to predict the EUI of unit floor area in row-houses. The equation only adopts one variable temperature to predict the EUI. The coefficient in front of Xi is plus, it explains that he proportion of temperature to EUI is direct ratio. It is a common phenomenon in Tropical or Subtropical zon. With the confidence interval of 95%, the correlation is 0.93 (the $R^2$ is 0.86), and both the constant and the coefficient of variable X are significant.

$$E_f = \sum_{i=1}^{12} Yi = 0.129Xi - 0.403 \cdots\cdots (1)$$

Ef: annual EUI of floor area. (kWh/m$^2$)
Yi: monthly EUI of floor area. (kWh/m$^2$)
Xi: outdoor temperature. (℃)
0.129:regression constant. (kWh/(m$^2$ • ℃))
-0.403: regression constant. (kWh/m$^2$)

**Table 1 the EUI of the household blocks, Unit: kWh/㎡**

| Temperature in Tainan*1 | | 18.10 | 19.20 | 23.00 | 25.70 | 27.00 | 28.90 | 29.10 | 29.00 | 28.20 | 26.80 | 21.50 | 19.30 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | Household | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annaul | *2 |
| 1 | 29 | 4.83 | 5.13 | 5.43 | 6.25 | 7.08 | 7.76 | 8.43 | 8.09 | 7.76 | 6.73 | 5.70 | 5.26 | 78.44 | 11.39 |
| 2 | 29 | 3.17 | 3.32 | 3.46 | 4.04 | 4.63 | 5.18 | 5.73 | 5.72 | 5.71 | 4.71 | 3.72 | 3.45 | 52.83 | 8.94 |
| 3 | 36 | 5.86 | 6.27 | 6.68 | 7.58 | 8.48 | 8.80 | 9.12 | 9.07 | 9.03 | 7.93 | 6.82 | 6.34 | 91.98 | 10.87 |
| 4 | 44 | 2.21 | 2.31 | 2.41 | 2.67 | 2.93 | 3.31 | 3.69 | 3.63 | 3.57 | 3.00 | 2.43 | 2.32 | 34.50 | 4.94 |
| 5 | 23 | 4.40 | 5.05 | 5.69 | 6.47 | 7.25 | 7.79 | 8.33 | 8.04 | 7.75 | 6.59 | 5.44 | 4.92 | 77.73 | 11.85 |
| 6 | 28 | 3.44 | 3.39 | 3.34 | 3.44 | 3.55 | 4.11 | 4.68 | 4.67 | 4.66 | 4.22 | 3.78 | 3.61 | 46.89 | 4.34 |
| 7 | 33 | 2.49 | 2.65 | 2.81 | 2.88 | 2.96 | 3.53 | 4.10 | 4.00 | 3.90 | 3.38 | 2.86 | 2.67 | 38.24 | 4.91 |
| 8 | 34 | 2.21 | 2.28 | 2.36 | 2.62 | 2.87 | 3.31 | 3.76 | 3.65 | 3.53 | 2.97 | 2.41 | 2.31 | 34.28 | 5.10 |
| 9 | 56 | 2.04 | 2.14 | 2.25 | 2.44 | 2.64 | 3.16 | 3.68 | 3.52 | 3.36 | 2.81 | 2.25 | 2.15 | 32.46 | 5.17 |
| 10 | 14 | 1.71 | 1.77 | 1.83 | 1.92 | 2.00 | 2.18 | 2.36 | 2.38 | 2.40 | 2.04 | 1.67 | 1.69 | 23.95 | 2.33 |
| 11 | 34 | 4.26 | 3.86 | 3.45 | 3.44 | 3.43 | 3.83 | 4.24 | 4.38 | 4.53 | 4.32 | 4.11 | 4.19 | 48.03 | 1.23 |
| 12 | 71 | 4.36 | 4.47 | 4.58 | 5.11 | 5.64 | 6.06 | 6.48 | 6.37 | 6.27 | 5.57 | 4.88 | 4.62 | 64.42 | 7.15 |
| 13 | 48 | 4.49 | 4.92 | 5.35 | 5.90 | 6.44 | 6.75 | 7.07 | 7.06 | 7.04 | 6.29 | 5.54 | 5.02 | 71.88 | 8.13 |
| 14 | 23 | 3.71 | 3.84 | 3.98 | 4.95 | 5.92 | 6.15 | 6.38 | 6.50 | 6.61 | 5.31 | 4.01 | 3.86 | 61.22 | 10.26 |
| 15 | 32 | 3.09 | 3.19 | 3.29 | 3.65 | 4.01 | 4.43 | 4.85 | 4.70 | 4.56 | 4.05 | 3.53 | 3.31 | 46.63 | 5.66 |
| 16 | 28 | 2.56 | 2.62 | 2.68 | 3.20 | 3.71 | 4.37 | 5.03 | 4.82 | 4.61 | 3.72 | 2.84 | 2.70 | 42.86 | 8.25 |
| 17 | 15 | 5.65 | 4.97 | 4.29 | 4.99 | 5.69 | 6.53 | 7.38 | 7.21 | 7.04 | 6.80 | 6.56 | 6.10 | 73.23 | 7.14 |
| 18 | 5 | 5.19 | 5.56 | 5.92 | 6.97 | 8.01 | 9.63 | 11.24 | 10.25 | 9.25 | 8.19 | 7.14 | 6.16 | 93.50 | 17.53 |
| 20 | 19 | 2.26 | 2.50 | 2.74 | 3.21 | 3.67 | 4.36 | 5.04 | 4.68 | 4.32 | 3.46 | 2.60 | 2.43 | 41.29 | 8.47 |
| 22 | 54 | 2.40 | 2.40 | 2.41 | 2.60 | 2.80 | 3.15 | 3.50 | 3.36 | 3.23 | 2.91 | 2.59 | 2.50 | 33.86 | 3.54 |
| 23 | 27 | 3.58 | 3.90 | 4.21 | 4.87 | 5.54 | 6.27 | 7.00 | 6.74 | 6.48 | 5.77 | 5.06 | 4.32 | 63.75 | 10.48 |
| 24 | 55 | 6.00 | 6.40 | 6.80 | 7.48 | 8.15 | 8.72 | 9.30 | 9.34 | 9.39 | 8.20 | 7.02 | 6.51 | 93.31 | 11.03 |
| 25 | 12 | 11.71 | 11.60 | 11.49 | 15.66 | 19.83 | 21.17 | 22.51 | 22.74 | 22.97 | 19.86 | 16.75 | 14.23 | 210.51 | 40.35 |
| 26 | 23 | 11.16 | 12.21 | 13.25 | 14.89 | 16.52 | 16.97 | 17.42 | 17.18 | 16.94 | 15.24 | 13.53 | 12.34 | 177.65 | 19.55 |
| 27 | 22 | 2.13 | 2.17 | 2.22 | 2.51 | 2.81 | 3.14 | 3.46 | 3.38 | 3.31 | 2.84 | 2.37 | 2.25 | 32.59 | 4.52 |
| Average | | 4.20 | 4.36 | 4.52 | 5.19 | 5.86 | 6.43 | 6.99 | 6.86 | 6.73 | 5.88 | 5.02 | 4.61 | 66.64 | 9.32 |
| PS. Period of data: 2002/1~2002/12, total households: 794 | | | | | | | | | | | | | Stdev | 43.84 | 7.77 |

*1 Data from Central Weather Bureau

*2 Annual AC EUI : The difference between the sum of EUI from June to September and that from December to March.

**Table 2 the EUI of row houses catergorized according to orientations, Unit: kWh/㎡**

| Orientation | Household | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual | Ratio*1 | *2 | *3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| N | 134 | 1.90 | 1.95 | 2.01 | 2.21 | 2.47 | 2.89 | 3.32 | 3.18 | 3.05 | 2.51 | 2.03 | 1.96 | 29.47 | 1.00 | 4.62 | 15.67% |
| W | 22 | 2.15 | 2.38 | 2.61 | 3.05 | 3.48 | 4.11 | 4.74 | 4.39 | 4.04 | 3.27 | 2.51 | 2.33 | 39.05 | 1.33 | 7.82 | 20.02% |
| NW | 97 | 2.19 | 2.32 | 2.44 | 2.66 | 2.88 | 3.41 | 3.93 | 3.80 | 3.67 | 3.02 | 2.37 | 2.28 | 34.97 | 1.19 | 5.58 | 15.95% |
| SW | 69 | 2.31 | 2.44 | 2.58 | 2.88 | 3.19 | 3.73 | 4.28 | 4.09 | 3.91 | 3.27 | 2.62 | 2.46 | 37.76 | 1.28 | 6.22 | 16.47% |
| E | 57 | 2.14 | 2.26 | 2.52 | 2.72 | 2.92 | 3.29 | 4.02 | 3.88 | 3.39 | 3.06 | 2.73 | 2.62 | 35.57 | 1.21 | 5.04 | 14.17% |
| NE | 31 | 2.24 | 2.27 | 2.29 | 2.66 | 3.03 | 3.24 | 3.79 | 3.65 | 3.19 | 2.90 | 2.61 | 2.43 | 34.32 | 1.16 | 4.64 | 13.51% |
| SE | 96 | 2.31 | 2.39 | 2.47 | 2.75 | 3.03 | 3.54 | 4.05 | 3.96 | 3.88 | 3.21 | 2.54 | 2.43 | 36.58 | 1.24 | 5.83 | 15.93% |
| S | 93 | 2.31 | 2.39 | 2.47 | 2.81 | 3.15 | 3.57 | 4.00 | 3.95 | 3.89 | 3.24 | 2.59 | 2.45 | 36.81 | 1.25 | 5.79 | 15.73% |
| Average | | 2.19 | 2.30 | 2.42 | 2.72 | 3.02 | 3.47 | 4.02 | 3.86 | 3.63 | 3.06 | 2.50 | 2.37 | 35.57 | 1.21 | 5.69 | 16.00% |
| PS. Period of statistics: 2002/1~2002/12, total household: 599 | | | | | | | | | | | | | Stdev | 2.89 | 0.10 | 1.04 | 1.93% |

*1 The ratio of every orientation to north

*2 Annual EUI of AC: The difference between the sum of EUI from June to September and that from December to March.

*3 The ratio of the EUI of AC to total annual EUI.

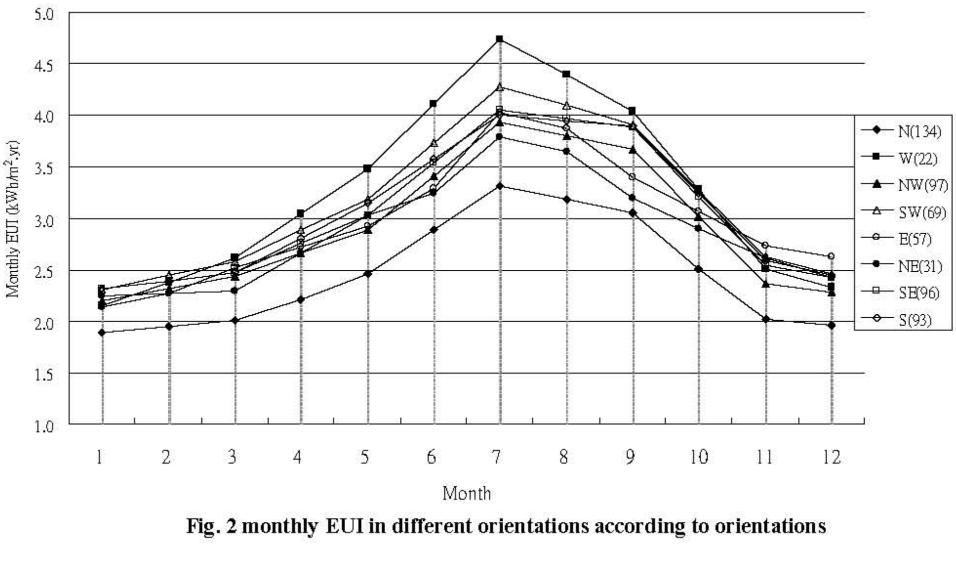


**Fig. 2 monthly EUI in different orientations according to orientations**

### 4.2 Prediction of Residential Blocks' Electricity Consumption

Combining the households with the commercial use, the prediction model was made as Equation(2). With the confidence interval of 95%, the correlation is 0.90 (the $R^2$ is 0.82), and both the constant and the coefficient of variable X are significant. Equation(1) described the average floor EUI of household buildings, but equation(2) is aimed to predict the average block area EUI of residential areas.

$$E_b = \sum_{i=1}^{12} Yi = 0.231X_i - 0.127 \cdots\cdots (2)$$

Eb: annual EUI of block area. (kWh/$m^2$)
Yi: monthly EUI of block area. (kWh/$m^2$)
Xi: outdoor temperature. (℃)
0.231:regression constant. (kWh/($m^2$ · ℃))
-0.127: regression constant. (kWh/$m^2$)

### 4.3 Accurate Prediction of Residential Blocks' Electricity Consumption

Equation (1) and (2) are the simple and rapid method to predict the EUI of residential blocks. The only one variable is temperature. The $R^2$ 0.86 and 0.88 are also still permissible. But it is necessary to add some noteable factors to create a more accurate prediction model. Obviously, the long and narrow block led the town houses to different oriention. It causes a lot of difference in EUI. The following method considerates the factor, and predicts more exactly. Equation (3) is also aimed to predict the EUI of residential blocks. The variables include different orientation area(Ai), EUI of every orientation (Oi), commercial use factors (Rc and C).

$$TE_b = \sum [(Ai \times Oi) \times (1 - R_c)] + R_c \times C \cdots\cdots (3)$$

TEb: annual electricity consumption of block. (kWh)
Ai: area of every orientation. ($m^2$)
Oi: monthly EUI of every orientation block area. (kWh/$m^2$)
Rc: the floor rate of commercial use.(%) The average rate of this investigation is 28.84%
C: the average EUI of commercial use. (kWh/$m^2$)

The operation procedure is divided into 3 steps. Firstly, the predicted block has to be demarcated to 4 areas with different orientation(Fig. 3). It assumes that most row houses face the road just in front, and the houses at the corner have two differfent chances. At every corner, half of the land is included in one direction while half is included in another, but the triangular area for chamfering (25/2) has to be subtracted additionally. Therefore, in Fig. 3, the area of west-faced and east-faced land a=(W×d-1/2$d^2$×2/25/2)$m^2$, and the area of north-faced and south-faced land A=((L-2d) ×W/2+1/2$d^2$×2-25/2)$m^2$. The whole area of block is 2a+2A=(L×W-50) $m^2$, which just equals to the length multiplies the width, then subtracts four triangular area due to chamfering. The floor area of every orientation comes from the product of land area and the average floor ratio C.

In Table 3, the darken blanks should be filled by users, others can be calculated automatically. What users have to fill in are the block length and width of every orientation without chamfering, the average depth of site d, the average building ratio and the average floor ratio C.

Secondly, the EUI of block area due to every orientation is established as table 4. The table shows different orientation causes diffenent EUI by month. The data originates from the invesigtion of this research, should be convinced and present as an average EUI distribution in Taiwan. It has to be remodified while appling to different cities or countries.

Finally, the values in Table 4 have to be multiplied by the floor area in Table 3 to predict total electricity consumption in row house blocks.the area. (Equation 3). Since all datas are connected with other two tables above, the values of Table 5 can be calculated automatically. The last two columns in Table 5 are the annual eiectricity consumption and EUI of predicted blocks. The current value in Table 5 is an example presenting block No. 6. With the confidence interval of 95%, the correlation of Equation 3 is 0.99 (the $R^2$ is 0.98).

Although equation (3) is more complicated than equation (1) and (2), it provides a more exact prediction method. In fact, what users have to do is only to fill the darken blanks in table 3, the results can be calculated automatically.

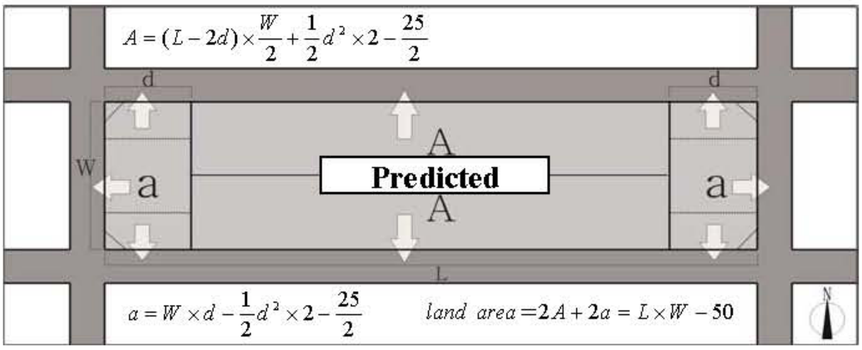


Fig. 3 site plan for predicted blocks

**Table 3 the basic data for predicted blocks**

| Basic data of block | |
|---|---|
| Average length L (M) | 185.92 |
| PS : L≧2d (M) | 35.00 |
| Average width W (M) | 45.28 |
| PS : W≧2d (M) | 35.00 |
| Block area $A_0$ ($M^2$) | 8368.4576 |
| Average depth d | 17.50 |
| Average building ratio | 75.69% |
| Average floor ratio C | 202.26% |

| Length block faces(shorter one) | |
|---|---|
| S | |
| SW | |
| W | 45.37 |
| NW | |
| N | |
| NE | |
| E | 45.19 |
| SE | |

| Length block faces(longer one) | |
|---|---|
| S | 185.74 |
| SW | |
| W | |
| NW | |
| N | 186.1 |
| NE | |
| E | |
| SE | |

| Data needs to be rechecked | |
|---|---|
| Data should meet the value below | |
| 1. (L*W-50)*C | 16926.04 |
| 2. ΣFA | 16926.04 |
| Predicted ratio of commercial area( it needn't be filled if there is no commerce | |
| Ratio of commercial floor use to all | 0.00% |

| Floor area in every orientation($M^2$) | |
|---|---|
| S | 0.00 |
| SW | 0.00 |
| W | 961.19 |
| NW | 0.00 |
| N | 0.00 |
| NE | 0.00 |
| E | 954.82 |
| SE | 0.00 |

| Floor area in every orientation($M^2$) | |
|---|---|
| S | 7496.77 |
| SW | 0.00 |
| W | 0.00 |
| NW | 0.00 |
| N | 7513.26 |
| NE | 0.00 |
| E | 0.00 |
| SE | 0.00 |

## 5. Accuracy analysis for prediction of EUI in residential blocks

We use the formula above to predict the EUI of households and residential blocks, all the equations present acceptable accuracy. Equation (3) is the most complex one with the highest confidence. The prediction result shows as Table 6, Fig. 4 and Fig.5. In the confidence interval of 95%, the $R^2$ is 0.98, and both the constant and the coefficient of variable X are significant. In this formula, Y represents the actual EUI of row house (kWh/$m^2$.yr), and X represents the predicted one (kWh/$m^2$.yr). The mean absolute deviation is only 10.03%, and its standard deviation is also as low as 3.97%.

However, there is still a particular phenomenon in this formula. In the light of this method, the actual EUI gets higher, the equation may over estimate the predicted EUI. The blocks of No. 3, 18, 24, 25, 26 are the same situstion. This is because there are higher ratio of commercial use inside these blocks, and the commercial EUI is a bit over estimated. Fortunately, the error ratio is still in the acceptable range. But if same method applies to commercial blocks in the future, this situation has to be taken into consideration.

**Table 4 datas of monthly EUI in row-house blocks**

| Monthly EUI due to orientation (kWh/$m^2$.month) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Orientation, Oi | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| S | 2.31 | 2.39 | 2.47 | 2.81 | 3.15 | 3.57 | 4.00 | 3.95 | 3.89 | 3.24 | 2.59 | 2.45 |
| SW | 2.31 | 2.44 | 2.58 | 2.88 | 3.19 | 3.73 | 4.28 | 4.09 | 3.91 | 3.27 | 2.62 | 2.46 |
| W | 2.15 | 2.38 | 2.61 | 3.05 | 3.48 | 4.11 | 4.74 | 4.39 | 4.04 | 3.27 | 2.51 | 2.33 |
| NW | 2.19 | 2.32 | 2.44 | 2.66 | 2.88 | 3.41 | 3.93 | 3.80 | 3.67 | 3.02 | 2.37 | 2.28 |
| N | 1.90 | 1.95 | 2.01 | 2.21 | 2.47 | 2.89 | 3.32 | 3.18 | 3.05 | 2.51 | 2.03 | 1.96 |
| NE | 2.24 | 2.27 | 2.29 | 2.66 | 3.03 | 3.24 | 3.79 | 3.65 | 3.19 | 2.90 | 2.61 | 2.43 |
| E | 2.14 | 2.26 | 2.52 | 2.72 | 2.92 | 3.29 | 4.02 | 3.88 | 3.39 | 3.06 | 2.73 | 2.62 |
| SE | 2.31 | 2.39 | 2.47 | 2.75 | 3.03 | 3.54 | 4.05 | 3.96 | 3.88 | 3.21 | 2.54 | 2.43 |
| Avg of commerce, C | 4.66 | 4.80 | 4.94 | 5.76 | 6.57 | 7.09 | 7.61 | 7.69 | 7.77 | 6.72 | 5.67 | 5.17 |

**Table 5 datas of monthly EUI in row-house blocks**

| EUI of block | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Sum |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S | 17,336 | 17,918 | 18,500 | 21,042 | 23,583 | 26,775 | 29,966 | 29,583 | 29,199 | 24,290 | 19,380 | 18,358 | 275,930 |
| SW | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| W | 2,062 | 2,286 | 2,510 | 2,929 | 3,348 | 3,952 | 4,555 | 4,219 | 3,882 | 3,146 | 2,410 | 2,236 | 37,535 |
| NW | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| N | 14,238 | 14,679 | 15,119 | 16,600 | 18,522 | 21,723 | 24,924 | 23,914 | 22,903 | 18,840 | 15,221 | 14,730 | 221,413 |
| NE | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| E | 2,040 | 2,162 | 2,406 | 2,599 | 2,793 | 3,142 | 3,840 | 3,702 | 3,240 | 2,925 | 2,610 | 2,505 | 33,963 |
| SE | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| EUI of commerce | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sum of monthly EUI in block | 35,676 | 37,045 | 38,534 | 43,170 | 48,246 | 55,591 | 63,286 | 61,417 | 59,225 | 49,201 | 39,621 | 37,828 | 568,841 |
| EUI | 4.26 | 4.43 | 4.60 | 5.16 | 5.77 | 6.64 | 7.56 | 7.34 | 7.08 | 5.88 | 4.73 | 4.52 | 67.97 |

**Table 6 comparison between predicted EUI and actual EUI**

| NO. | Actual EUI | Predicted EUI | Inaccuracy Ratio |
|---|---|---|---|
| 1 | 78.44 | 68.56 | 12.60% |
| 2 | 52.83 | 46.86 | 11.31% |
| 3 | 91.98 | 102.22 | 11.13% |
| 4 | 34.50 | 29.59 | 14.23% |
| 5 | 77.73 | 68.26 | 12.18% |
| 6 | 46.89 | 40.28 | 14.10% |
| 7 | 38.24 | 41.28 | 7.95% |
| 8 | 34.28 | 31.26 | 8.80% |
| 9 | 32.46 | 30.58 | 5.79% |
| 10 | 23.95 | 23.58 | 1.56% |
| 11 | 48.03 | 42.36 | 11.81% |
| 12 | 64.42 | 58.64 | 8.97% |
| 13 | 71.88 | 82.26 | 14.44% |
| 14 | 61.22 | 64.69 | 5.67% |
| 15 | 46.63 | 55.56 | 19.14% |
| 16 | 42.86 | 46.89 | 9.39% |
| 17 | 73.23 | 68.56 | 6.38% |
| 18 | 93.50 | 99.96 | 6.91% |
| 20 | 41.29 | 46.56 | 12.77% |
| 22 | 33.86 | 30.55 | 9.78% |
| 23 | 63.75 | 72.39 | 13.55% |
| 24 | 93.31 | 106.55 | 14.19% |
| 25 | 210.51 | 226.68 | 7.68% |
| 26 | 177.65 | 182.36 | 2.65% |
| 27 | 32.59 | 30.02 | 7.89% |
| Average | 66.64 | 67.86 | 10.03% |

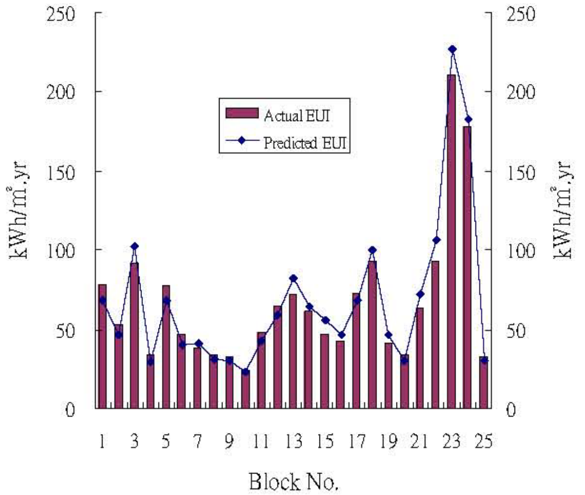


**Fig. 4 comparison between predicted EUI and actual EUI**

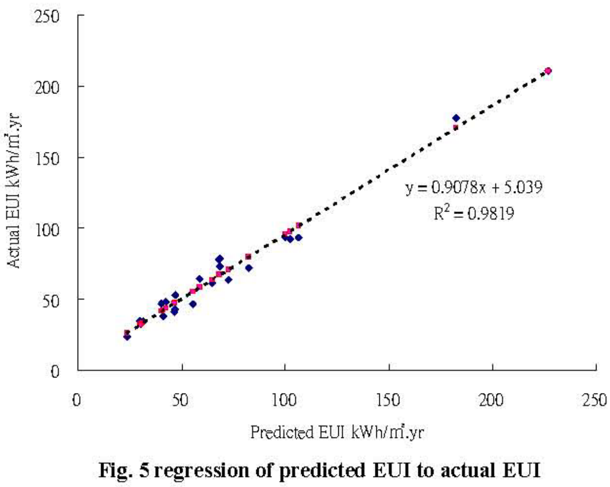


**Fig. 5 regression of predicted EUI to actual EUI**

## 6. Conclusion

This research investigated 59 representative blocks, there are 1,033 valid samples. Among them, 599 are households, 434 are commercial units. 3 prediction formulas are proposed in the study. In the confidence interval of 95%, the $R^2$ is between 0.82 to 0.98. Easier prediction model needs fewer factors, more exact model needs more factors and operation procedure. On account of this prediction model, the electricity consumption of residential townhouse block can be figured out rapidly. Furthermore, when doing the urban planning, the major axis of block should be toward east-west based on electricity reservation. The east-west orientated blocks waste less electricity than the south-north ones in the research by 14.66%. In the study, the ratio of length to width is 3.62. How much electricity reserved in each block depends on its ratio of length and width. While the major axis of block is toward east-west, the higher the ratio is, the less energy it consumes.

Since it's common in Taiwan that residential blocks are mixed with a lot of commercial units. It seriously disarranges the electricity prediction and power supply. In order to predict the energy use or to scheme the power system cycle, the interrelated research is necessary. In addition, there are also lots of apartment buildings or high rised buildings with complex usage inside in residential blocks, both the electricity consumption of commercial houses and apartment buildings have to be discussed sooner or later. Most people predict the energy consumption in cities with the analysis of land-use in the past. Though it can estimate the electricity consumption very quickly, it cannot figure out the difference between every block individually. This study can be part of reference for load forcasting, urban energy prediction, even urban planning basing on the consideration of energy conservation.

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