IMPACT OF CLIMATE CHANGE ON ELECTRICITY DEMAND OF SINGAPORE

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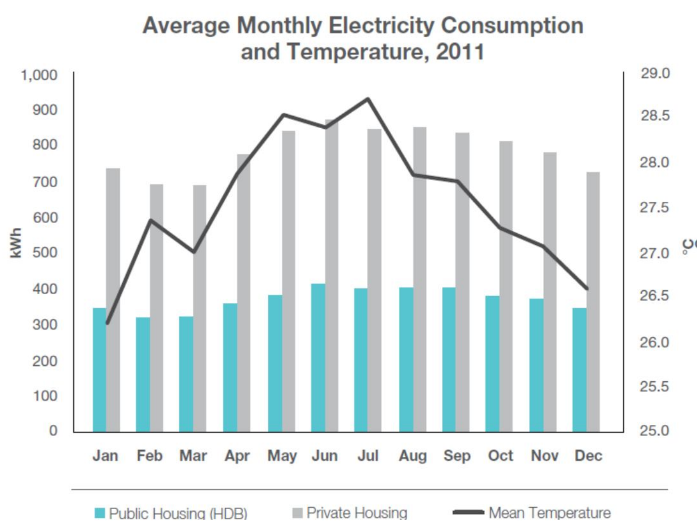
Overview

Climate change might have consequences such as higher average temperatures and greater humidity. The impact of such weather fluctuations on future electricity demand will affect the electricity generation capacity required in the future, a major concern for policymakers throughout the world given the expense and time required to make investments in the electricity sector. Existing studies carried out in different parts of the world have found that weather fluctuations have an impact on the demand for electricity [1] [2] [3]. However, the relationship between weather fluctuations and electricity demand has not been established in the Singapore context to date. The total electricity consumption grew from 37,709 GWh in 2009 to 41,725 in 2011 [4]. The industry sector is the most energy intensive followed by commercial and service sectors. As the figure below illustrates, household energy consumption peaks during the summer months when the temperature is highest. To ensure supply side reliability, it is imperative to estimate the growth in electricity demand due to temperature change.



Source: Singapore Energy Statistics 2012 [4]

In this paper we estimate the relationship between hourly electricity demand and weather variables in Singapore. Our paper will contribute to the understanding of how climate change impacts on electricity demand in countries with equatorial climates. In addition, by estimating separate models for each hour of the day, we are able to capture the effect of weather variables on electricity demand at different times of the day. Crowley and Joutz [2] demonstrate, in the context of the U.S., that the effect of temperature on peak electricity demand is different from the effect on average demand. From a policy perspective it is crucial to understand the effect of climate change on peak energy demand as well as average energy demand in order to adequately plan future generation capacity.

Methodology

A time-series econometric model is proposed to perform simulations for changes in electricity demand with respect to various weather fluctuation scenarios. Electricity consumption depends on temperature and has seasonal characteristics. For example, the demand for electricity is higher during weekdays than weekends. Similarly, demand is higher during daytime. To capture weekly, intraday and yearly seasonality, seasonal variables (days and months) are included. The model will include a number of variables like temperature, humidity and seasonal variables and an assessment of how hotel electricity demand varies according to key variables, in particular temperature, will be provided.

The dataset used consists of hourly electricity loads, dry-bulb temperature and humidity in Singapore for a 10-year period (2003-2012). Other climate variables such as cloud cover may also be considered, and the energy demand model estimated will include non-climate variables, such as electricity prices, GDP and sectoral output shares, that are relevant to explaining electricity demand.

The general model for each hour **h** can be described as:

$$\text{Log}(Y_{ht}) = \alpha + \sum_{i=2}^{6} \eta_i Day_{iht} + \sum_{j=2}^{12} \delta_j Month_{jht} + \zeta_k Holiday_{ht} + \sum_{l} \beta_l W_{lht} + \sum_{m} \gamma_m X_{mht} + \varphi(L) Log(Y_{ht}) + \epsilon_{ht}$$

Time subscripts are denoted using **h** and **t**, where **h** gives the hour and **t** the day of the observation. $\boldsymbol{Y_{ht}}$ is the total electricity demand, $\boldsymbol{W_{lht}}$ represents **l** different weather variables (including temperature and humidity), and $\boldsymbol{X_{mht}}$ represents the other **m** regressors considered, including GDP, electricity prices and sectoral output shares. Dummy variables are used to capture the demand effects of the day of the week, the month of the year and the occurrence of public holidays. The lagged polynomial operator, $\boldsymbol{\varphi(L)}$, captures lagged effects in hourly electricity demand while $\boldsymbol{\epsilon_{ht}}$ is a white noise random disturbance term.

Using the estimated models, we will forecast how future climate trends will affect electricity demand in Singapore under a range of climate scenarios as predicted by the Intergovernmental Panel on Climate Change (IPCC) [5].

Results

The results of the analysis will be estimates of hourly temperature elasticites of electricity demand in Singapore, as well as elasticites of electricity demand with respect to other relevant variables. The scenario analysis will consider the impact of climate change on future electricity demand under both the milder IPCC scenarios as well as scenarios with more extreme climate fluctuations. The results will be helpful to policymakers in making energy policy and electricity investment decisions under conditions of climate uncertainty.

Conclusions

An econometric model is proposed to estimate the impact of climate change on electricity demand in Singapore. The analysis will help in framing guidelines for policymakers in Singapore to maintain a sustainable energy economy under different climate change scenarios. The analysis can form the basis for a number of future research topics. Globally, demand response and other energy efficiency measures in the electricity sector are becoming important policy tools. New models for load forecasting need to be formulated to include the effect of demand response, and it is important for such models to include robust temperature elasticities. In addition a comparison of results under different frameworks of linear estimation and non linear estimation could be an exciting research area.

References

[1] Töglhofer, C., Habsburg-Lothringen, C., Prettenthaler, F., Rogler, N. and Themessl, M. (2012). EL.ADAPT: Impacts of Climate Change on Electricity Demand. Symposium Energieinnovation, Austria, February 15-17.

[2] Crowley, C. and Joutz, F.L. (2003). Hourly Electricity Load: Temperature Elasticity and Climate Change. Proceedings of the 23rd North America Conference of the USAEE/IAEE, Mexico City, October 19-21.

[3] Lam, J.C., et al. (2004). Electricity use characteristics of purpose built office buildings in subtropical climates. *Energy Conversion and Management* 45: 829-844.

[4] Singapore Energy Statistics 2012, Energy Market Authority, Singapore

[5] IPCC, Climate Change 2001: Synthesis Report, Third Assessment Report, Intergovernmental Panel on Climate Change, Cambridge, 2002.