# Sectoral Electricity Demand in New Zealand: Fresh Evidence on Sectoral Rebound Effects and Demand Elasticities

*Rabindra Nepal (University of Tasmania), Muhammad Indra al Irsyad (University of Queensland) and Tooraj Jamasb (Durham University)*

## Overview

New Zealand uniquely saw its residential electricity demand decline from 47% in 1974 to 32% in 2015 (IEA, 2017). The reduction was driven by less electricity consumption particularly in the winter and autumn periods due to improvements in energy efficiency where demand generally tends to peak. Traditionally, households in New Zealand typically encountered under-heating problems since their average indoor temperature is below 18-21oC which is the standard temperature recommended by the World Health Organisation (WHO) (Howden-Chapman et al., 2009; Isaacs et al., 2010; Lloyd et al., 2008; O'Sullivan et al., 2016). Factors explaining the poor heating conditions included the relatively old-age of the houses and its inferior thermal insulation (Howden-Chapman et al., 2009; Isaacs et al., 2010; O'Sullivan et al., 2015). Retrofitting houses with insulation will not only increase the indoor temperature but also gain significant energy and electricity savings (Grimes et al. 2011).

Electricity is the main source of energy followed by solid fuels and natural gas for New Zealand residential sector. Electricity alone meets 69% of household energy demand while 34% of the total energy use is catered towards space heating among New Zealand homes (Isaacs et al., 2010). However, solid fuels are the most important energy source used for residential space heating with electricity and natural gas following in prominence (Grimes et al. 2011). Total electricity demand in New Zealand is likely to more than double from around 40 terawatt hours (TWh) per annum in 2018 to around 90 TWh by 2050 (Transpower White Paper, 2018). New Zealand electricity system exhibits unique features. No other country generates electricity from the same generation mix, low levels of energy storage and without a grid connection to another country (Transpower White Paper, 2018). A rapid electrification of the industrial and transport sectors in the push towards decarbonisation is expected to pose energy security risks to the New Zealand electricity sector. For instance, electric vehicles (EVs) are expected to reach 40% of the market share by 2030 and 85% by 2050. Globally, the share of electricity in transportation is expected to double between 2015 and 2040 as more plug-in electric vehicles enter the fleet (IEA, 2017). New Zealand ranks as the 10th highest per capita electricity consuming country among the OECD members in 2014 (IEA, 2015; WB, 2017).

Meeting this demand requires energy planning based on periodic and reliable electricity demand studies to guide the significant and timely investments required in New Zealand's electricity generation and transmission networks. Underestimating the demand may result in supply shortages and forced power outages, while overestimating demand may result in overinvestment in generation capacity and ultimately even higher electricity prices (Steinbuks, 2017). However, the findings of existing demand studies in New the Zealand are inconclusive partly owing to the omission of important price and non-price variables. The omission of price variable such as 'own price' and 'price of close substitutes' and non-price variables such as temperature is problematic since an analysis of these factors is necessary to design policy measures for electricity conservation.

This study models electricity demand in residential, industrial, and commercial sectors in New Zealand during 1980 to 2015 using structural time-series econometrics. Time-series forecasts yield good predictions for modelling electricity demand when data are available (Steinbuks, 2017). Most importantly, our findings on rebound effects are important to New Zealand as the launch of the Energy Efficiency and Conservation Strategy 2017-2022 recognises the need for improving energy efficiency and productivity especially among the industrial and commercial users of electricity (MBIE, 2017b). Second, our study uses the 'real price of natural gas' as proxy for close substitute to model electricity demand of the residential and commercial sectors in New Zealand. Incorporating price of natural gas in energy demand analysis is important given the key role of gas in facilitating the energy transition as the rise of the renewables in energy generation continues globally (Fattouh et al., 2018). The 'substitute energy price' factor is important because households with access to lower-cost substitute energy tend to have higher requirements for space heating (Howden-Chapman et al., 2009; Isaacs et al., 2010). Third, we focus on sectoral electricity demand in an OECD economy where the changes in demand patterns are unique. Fourth, we explicitly model the effect of temperature on sectoral demand for electricity in New Zealand unlike previous studies. Electricity demand and supply are becoming increasing weather dependent (Staffell and Pfenninger, 2018). Hence, there is a need for considering the effects of temperature on energy supply and demand, as our study does.

## Methods

This paper examines the rebound effects in sectoral electricity demand based on sectoral price decompositions and estimates electricity demand elasticities in New Zealand during 1980 – 2015. An autoregressive distributed lag models is used for this purpose. The bounds testing approach has more precision and reliability than other cointegration tests (Pesaran et al., 2001).

$$\begin{aligned}\Delta LEC_t = a_0 &+ \sum_{i=1}^{n} a_{1i}\Delta LEC_{t-i} + \sum_{i=1}^{n} a_{2i}\Delta LY_{t-i} + \sum_{i=1}^{n} a_{3i}\Delta\, LPE_{max,t-i} + \sum_{i=1}^{n} a_{4i}\Delta\, LPE_{cut,t-i}\\ &+ \sum_{i=1}^{n} a_{5i}\Delta\, LPE_{rec,t-i} + \sum_{i=1}^{n} a_{6i}\Delta\, LPG_{t-i} + \sum_{i=1}^{n} a_{7i}\Delta\, LT_{t-i} + a_8 LEC_{t-1} + a_9 LY_{t-1}\\ &+ a_{10} LPE_{max,t-1} + a_{11} LPE_{cut,t-1} + a_{12} LPE_{rec,t-1} + a_{13} LPG_{t-1} + a_{14} LT_{t-1}\\ &+ \varepsilon_{1t}\end{aligned}$$

Once the long-run equilibrium relationship is confirmed through the existence of cointegration relationships, we estimate the following ARDL $(p_1, q_1, q_2, q_3, q_4, q_5, q_6)$ specification:

$$\begin{aligned}LEC_t = b_0 &+ \sum_{i=1}^{p_1} b_{1i} LEC_{t-i} + \sum_{i=0}^{q1} b_{2i} LY_{t-i} + \sum_{i=0}^{q2} b_{3i}\, LPE_{max,t-i} + \sum_{i=0}^{q3} b_{4i}\, LPE_{cut,t-i}\\ &+ \sum_{i=0}^{q4} b_{5i}\, LPE_{rec,t-i} + \sum_{i=0}^{q5} b_{6i}\, LPG_{t-i} + \sum_{i=0}^{q6} b_{7i}\, LT_{t-i} + u_t\end{aligned}$$

to obtain the long-run coefficients in Equation 2, where:

$$\gamma_0 = \frac{b_0}{1-\sum_{i=1}^{p_i} b_{1,i}}$$

$$\gamma_j = \frac{b_m}{1-\sum_{i=1}^{p_i} b_{1,i}}$$

with $j = 1, \ldots, 6$ and $m = 2, \ldots, 7$. The last step of the estimation is following short-run relationship model to measure the adjustment speed (ECT) for a deviation in the short-run:

$$\begin{aligned}\Delta LEC_t = c_0 &+ \sum_{i=1}^{n} c_{1i}\Delta LEC_{t-i} + \sum_{i=0}^{n} c_{2i}\Delta LY_{t-i} + \sum_{i=0}^{n} c_{3i}\Delta\, LPE_{max,t-i} + \sum_{i=0}^{n} c_{4i}\Delta\, LPE_{cut,t-i}\\ &+ \sum_{i=0}^{n} c_{5i}\Delta\, LPE_{rec,t-i} + \sum_{i=0}^{n} c_{6i}\Delta\, LPG_{t-i} + \sum_{i=0}^{n} c_{7i}\Delta\, LT_{t-i} + c_8 ECT_{t-1} + e_t\end{aligned}$$

## Results

We find a partial rebound effect with values estimated to be 54% and 23% for the industrial and commercial sector respectively. Therefore, expected reduction in electricity demand from energy efficiency improvements alone may not be achieved in these sectors. The rebound effect is insignificant in the residential sector. Residential electricity demand is also inelastic to income and temperatures level.

## Conclusions

These findings lead to policy recommendations for more effective energy conservation and policy in those sectors. Our results signal for other intervening energy policies alongside energy efficiency improvements to mitigate the possibilities of rebound effects in the industrial and commercial sectors in achieving the actual energy savings.