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Quantifying energy savings from replacement of old refrigerators

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Abstract

Energy labelling for refrigerators in Australia has been in force for over 30 years. It is well documented that the label energy consumption of refrigerators and freezers has fallen dramatically over that period. While a number of studies have measured the energy consumption of refrigerating appliances in the field, the data is very complex and difficult to interpret. Field data measured in houses has constantly fluctuating room temperatures and is subject to somewhat random interactions with householders through door openings and the placement of food and drinks to be cooled. Another problem with field data is that household indoor temperatures are quite seasonal and significant periods of data are required to quantify these effects.

This paper analyses the results of 21 refrigerator replacements that have occurred in Melbourne, Gippsland (Victoria) and Sydney over the past four years. Seven of the replacements were part of a Victorian State Government retrofit program that targeted the removal and replacement of older refrigerators with the best on the market. The remaining 14 appliances were replaced during routine monitoring by the author as part of his PhD field work at The University of Melbourne. The study is unique as high quality refrigerator energy and temperature data was broken down into 4 key components: temperature driven energy consumption, energy consumption from user interactions, base defrosting requirements and user driven defrosting requirements. This approach allows the old and new appliances to be directly compared when modelled under identical operating conditions giving a fair and robust comparison. The results are impressive, with average energy reductions of 60%, ranging from 30% to more than 80%, depending on the household circumstances and the old and new appliances.

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Keywords: refrigerators; efficiency; end use energy; retrofit

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1. Introduction

Energy labelling of refrigerators commenced in the Australian states of NSW and Victoria in 1986, more than 30 years ago. Since its introduction, the energy consumption declared on the energy label has fallen dramatically for all types of refrigerating appliances. The average sales weighted energy consumption of all new refrigerators and refrigerator-freezers has decreased 41.4% from 772 kWh/year on the label in 1993 to 453 kWh/year in 2014 [1]. This represents a 2.5% decline in energy per year over a 22 year period. This is despite a 23% increase in average volume over the same period.

Despite the availability of excellent data on the characteristics of new products sold in Australia, surprisingly few studies have investigated or assessed the difference between the label energy consumption measured by the test procedure, which is measured in a hot room (32°C) with no user interactions, and the energy consumption measured during normal use in the home. One formal study by Choice in 1990 measured the energy in a lab and then in the home for two years on eight appliances [2]. Until recently, no other published studies compared in-use measurements with the energy label value. Normal use in Australia is of course highly variable ranging from tropical climates like Cairns and Darwin in the North to cool temperate climates like Victoria and Tasmania in the South, so such a comparison would need to take into account climate and a range of other factors.

In 2014 and 2015 Sustainability Victoria (SV) undertook a program of targeted refrigerator replacements in seven homes in Melbourne. Households with older refrigerating appliances were recruited and these old appliances were replaced with new appliances that were close to the most efficient on the market. The appliances in each house were monitored for about six weeks before replacement and a further six to eight weeks after replacement. As part of his PhD research at The University of Melbourne, the author has monitored some 300 appliances in households all around Australia, typically for periods from six to 12 months. As part of this large sample, 14 of these sites replaced the refrigeration appliance during monitoring, allowing a comparison of energy consumption between old and new appliances in the same household. Unlike the Sustainability Victoria replacements, these routine replacements were undirected by the researcher and in most cases the householder selected the product using their own selection criteria. The periods monitored before replacement also varied considerably.

2. Method

Energy consumption of refrigeration appliances in the residential sector is notoriously complex and field data collected in homes can be very difficult to interpret. Refrigerators are an appliance where the energy consumption is substantially influenced by changes in room temperature. Most houses in Australia exhibit significant seasonal changes in indoor temperatures over the year. There are also changes in temperature from day to day and also by time of day, depending on weather and the operation of space conditioning equipment. A second factor is that user interactions induce significant additional energy consumption in refrigerating appliances. While this interaction does appear to have some broad pattern in terms of seasonality in most houses, in general terms, user interactions are highly variable from day to day.

It is critical to have available high quality energy data collected in the field in order to disaggregate the energy consumption into its key components. Generally this requires energy data at one minute intervals (or equivalent) to allow the assessment of each compressor cycle and the separation of defrost and recovery events (where present). Associated room temperature data is also required. A report published by Sustainability Victoria [3] includes details of a new method developed by the author as part of his PhD research at The University of Melbourne to disaggregate refrigerator energy consumption into its components. The key elements of energy consumption, in order of their magnitude in a typical appliance, as quantified from analysis, are:

- Energy consumption driven by room temperature
- Energy consumption induced by user interactions such as door openings and the insertion of food loads
- Defrosting energy, which itself can be split into a base defrosting requirement with little or no user interaction and additional defrosting energy induced by user interactions
- Energy consumed by heaters that are affected by changes in room temperature conditions and user interactions.