Reducing the City's Carbon Footprint: An Investigation of Solar Water Heaters and the Rebound Effect in Cape Town Social Housing

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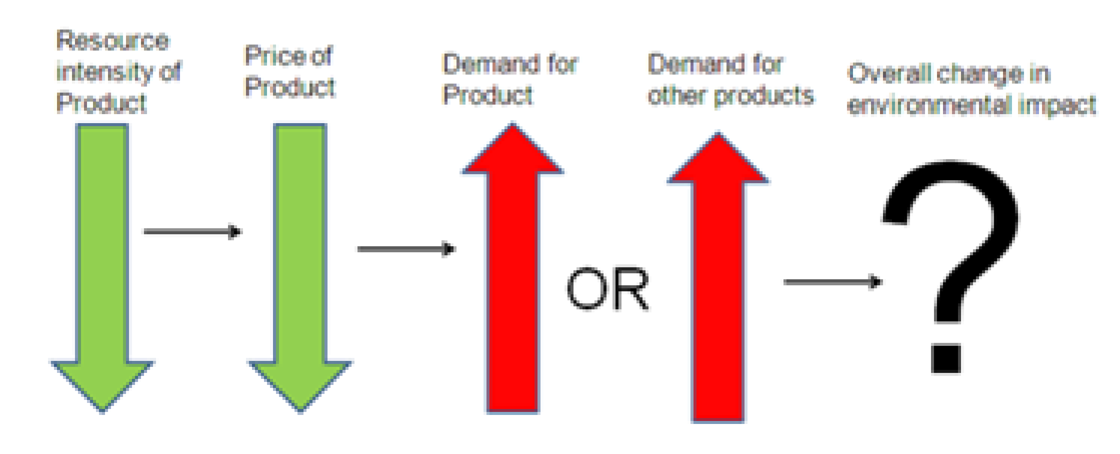
Introduction

- On average, electric geysers account for 39% of all household electricity [1]. Thus, it is believed that replacing electric geysers with Solar water heaters (SWHs) will reduce a household's carbon footprint.
- However, economists acknowledge the "rebound effect" [2], where money saved via energy efficiency interventions will be spent on other goods and services with an environmental impact.



Introduction

- Previous studies conducted on the low-income areas of *Kuyasa* (Cape Town) and *Zanemvula* (Nelson Mandela Bay) confirm that for this income bracket the suppressed demand for electricity is so great that the installation of SWHs fails to produce a significant reduction in electricity consumption. [3 – 4]
- An optimistic assumption about the future of South African cities must recognize significant upward mobility. This assumption leads to the question of whether SWHs result in a significant decrease in the carbon footprint of households in higher income brackets.
- The "gap" housing market consists of households that earn ZAR 3500 - 7500 per month. Unlike the households of *Kuyasa* and *Zanemvula*, they earn too much to qualify for a government housing subsidy, but most cannot afford housing in the private sector. Social Housing aims to provide rental stock for this income bracket. [5]

Introduction

This work aims to answer the following questions:

- Does the installation of SWHs in households falling into the gap income bracket result in these households consuming less electricity than households of the same income using electric geysers?
- If so, what do these households spend this saved money on instead, and how does the carbon footprint of these new goods and services compare?

Methodology

- The methodology included surveys to investigate the electricity consumption and spending habits of a Cape Town social housing scheme that uses solar water heaters (SWHs), and comparing this with a similar block of flats using conventional electric geysers. Quantitative data on electricity purchases were then used to investigate if flats with SWHs do spend significantly less on electricity than those with electric geysers.

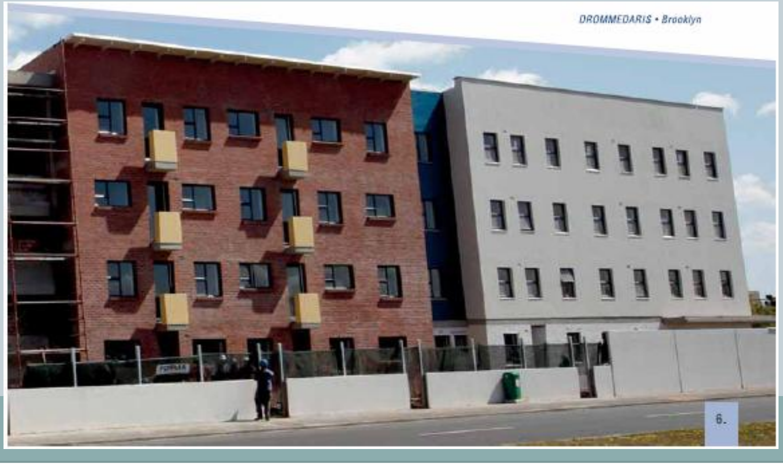
- First, 2 blocks of flats had to be located that would be directly comparable except for one block of flats having SWHs, while the other uses conventional electric geysers.

Methodology

Identifying 2 blocks of flats:

Drommedaris (Milnerton)
- Contains SWHs
- Social housing – gap market rental
- Well-located

Sakabula (Ruyterwacht)
- Contains electrical geysers only
- Rental flats for gap market
- Well-located



Methodology

Summary of Survey Questionnaire

1	Household size in terms of number of adults and number of children
2	Number of bedrooms
3	Electricity and Direct Energy use (Type of geyser, space heating, list of appliances)
4	Transport (mode of transport to work, shops and school / distance / regularity / cost)
5	Marginal Categories of Spending (rebound effect) (What household would spend extra money on, what they would cut back on if forced to save, and specific questions on categories such as meat electricity, transport)
6	Income and Budget (Income, electricity expenditure, transport expenditure, food and groceries expenditure, rent, school fees)

Methodology

Electricity Purchase Data

- *Communicare* (the housing company managing both *Drommedaris* and *Sakabula*) was able to compile and provide electricity purchase data for the separate households from both blocks of flats for the months of January, February and March 2011. → This allows for a direct comparison between the two blocks of flats to see if the SWHs at *Drommedaris* cause a significant decrease in electricity consumption during the summer months.

Methodology

Carbon footprint of SA electricity modelled according to:

SOURCE	Percentage of SA Electricity Mix (%)
Coal fired Power Plant	89
Hydropower (reservoir power plant)	4.87
Hydropower (pumped storage plant)	1.2
Natural gas (turbine)	0.03
Nuclear	4.9

[6]

Notten (2010) has combined these figures to create a SimaPro database for the South African electricity mix [7]. This simple life cycle assessment gives a carbon footprint of approximately 1.0 kg CO_{2eq} / kWh of South African electricity, or 1.24 kg CO_{2eq} / ZAR.

Results and Discussion

	Drommedaris (16 respondents)	Sakabula (14 respondents)
Type of Geyser	**Solar water Heater, with electric geyser back-up**	**Only Electric geysers**
Average income (ZAR/month)	6 200	6 000
Average rent (ZAR/month)	2 120	2 050
Average expenditure on food and groceries (ZAR/month)	1 375	1 650
Average expenditure on transport (ZAR/month)	660	535
Average school fees (ZAR/month)	450	300
Average household size (people/flat)	**3.3**	**4.5**
Average flat size	2 bedrooms	2 or 3 bedrooms
Need for Space Heating	Very few households used heaters. Those that did only used heaters in winter, which will not effect the summer electricity purchase data	
Appliance ownership	Both groups of tenants had a full list of appliances, including television, refrigerator, oven and stove, kettle and 4-6 overhead lights	

Results and Discussion

	Drommedaris (16 flats)	Drommedaris households with 4 or more people (5 flats)	Sakabula (14 flats)
Average Household size (people / dwelling)	3.3	4.6	4.5
Average income (ZAR/month)	6 200	6 370	6 000
Average Electricity Purchases Jan-Mar 2011 (ZAR/month)	184.50	186.70	320
Average Electricity Purchases: Jan – Mar 2011 (kWh/month)	230	230	370
Average Electricity Carbon Footprint (kg CO_{2eq} /month)	230	230	370

Results and Discussion

- The flats at *Sakabula* consume significantly more electricity than the flats at *Drommedaris* which leads to the conclusion that for the ZAR 6 000/month income bracket, SWHs do reduce a household's carbon footprint due to electricity consumption by 38%, or 140 kWh / month, for the summer months studied (January to March).
- It needs to be determined where the money saved on electricity is being spent instead. The following slide summarizes what households felt they would spend extra money on if they could, or would have to cut back on if they needed to save.

Results and Discussion

Rebound Category	Number of Mentions in Surveys (Drommedaris and Sakabula)
Electricity	12
Transport	3
Meat	3
Groceries	14
Take outs / junk food	4
Entertainment / alcohol	6
Luxuries	5
Appliances	2
Education	3
Clothes	5
Total	**57**

Many different categories → leads to the assumption that the indirect rebound effect may follow the average expenditure profiles of South Africans in the gap income bracket.

Results and Discussion

Estimating carbon footprint of indirect rebound effect: top-down method

The average South African Carbon Footprint is 8 700 kg CO_{2eq} /annum/person [8]. The average income per household in South Africa is ZAR 56 000/annum and the average household size is 3.8 [9].

The average carbon footprint per household = $8700\ \frac{kgCO2eq}{annum.cap} \times \frac{3.8cap}{household} = \frac{33100kgCO2eq}{annum.household}$

The average carbon footprint per Rand spent = $\frac{33100kgCO2eq}{annum.household} \div \frac{ZAR56000}{annum.household} = \frac{0.59kgCO2eq}{ZAR}$

This is a worst case scenario as it includes the carbon footprint of South Africans spending money on electricity, and the rebound effect of buying more electricity has already been estimated as 0%. In addition, it must be recalled that the households in question have a higher income than the average South African household, and will therefore spend a lower proportion of their money on direct energy, reducing the carbon footprint of each additional Rand spent [10-11].

Results and Discussion

Estimating carbon footprint of indirect rebound effect: bottom-up method

Using Statistics South Africa expenditure data [9]:

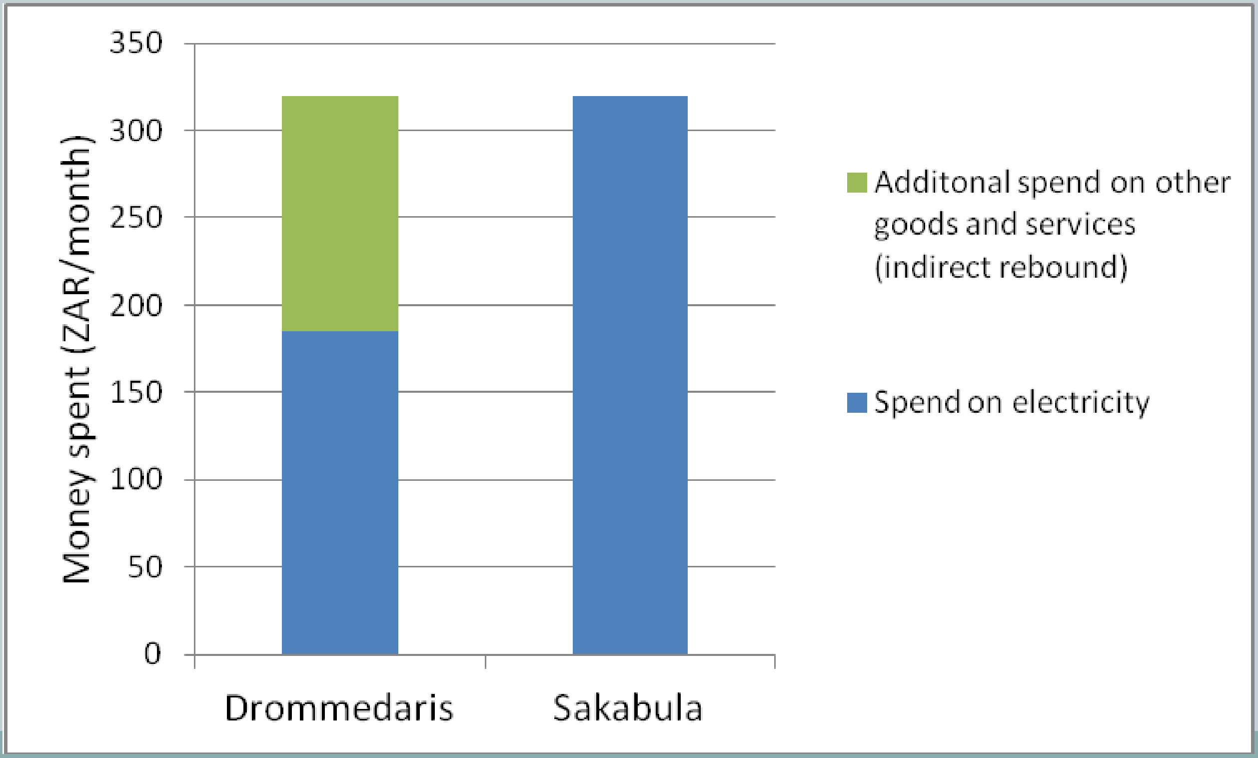
Spending Category	**SA Income decile 8 – Expenditure (ZAR/annum)**	**SA Income decile 9 – Expenditure (ZAR/annum)**	**Percent of additional spending (%)**	**Approximate kg $CO_{2eq.}$/ZAR**	**Carbon Footprint Reference**
Food and non-alcoholic beverages	9225	11990	5.2	0.08	[12]
Transport	9015	24690	29.6	0.17	[13]
Housing, water, electricity, gas and other fuels	12321	26634	27.0	1	[7]
Repeat for other income spending categories					
Total	**55055**	**108025**	**100**	**0.42**	

- Average carbon footprint per marginal SA Rand spent = 0.42 kg CO_{2eq} / ZAR

  Average carbon footprint per marginal SA Rand spent, excluding electricity = 0.13 kg CO_{2eq} / ZAR

Results and Discussion

Using the ZAR 320/month that the average household with electrical geysers spends on electricity as a functional unit, the figure below shows the electricity purchases of households with SWHs (*Drommedaris*), and the extra money spent on other goods and services such as food, transport and clothing.



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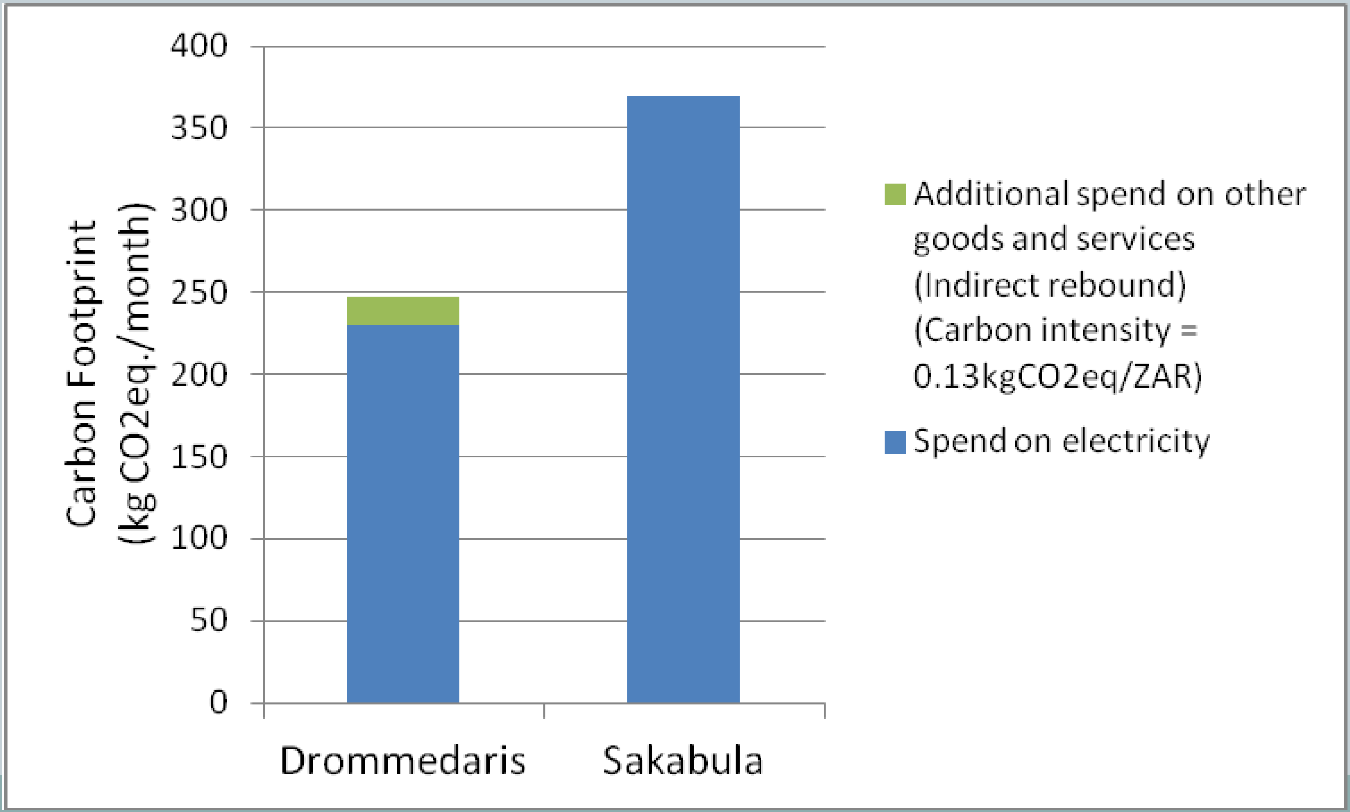
Results and Discussion

The figure below shows the electricity carbon footprint of households with SWHs, and the carbon footprint of spending extra money on other goods and services such as food, transport and clothing.



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Results and Discussion

The Carbon footprint due to electricity is 370 kg CO_{2eq} /month for the households with conventional electric geysers, which is equal to 13.4% of the household's entire carbon footprint.

Despite the additional spending on other goods and services, installing a SWH reduces the Carbon footprint of a household (income ZAR 6 000/month) by 120 kg CO_{2eq}/month during the summer months in Cape Town. This is approximately equal to 4% of the household's total carbon footprint.

It must be remembered that this calculation is only valid for the summer months in Cape Town. From January to March the solar irradiation levels average 6.95 kWh/m^2.day for a tilted flat plate collector [14]. In winter, from May to August, the solar irradiation levels average only 4.46 kWh/m^2.day, meaning that the SWHs will not work as well, and the electrical back-up geysers will need to provide a larger percent of the energy required to heat water. It should also be remembered that the overall electricity consumption will increase in winter due to space heating and more lighting.

Conclusions

The preliminary results presented in this report suggest that for households accommodated in social housing, earning an average of ZAR 6 000 per month, electricity consumption is reduced by approximately 140 kWh/month in the summer months when SWHs are installed. Survey data suggests that saved money is spent on a wide range of goods and services. The household carbon footprint is still reduced as these goods and services have a lower carbon intensity (at ~ 0.13 kg CO_{2eq}/ZAR) than South African electricity (at ~ 1.24 kg CO_{2eq}/ZAR).

This results in those social housing units provided with SWHs reducing their carbon footprint by approximately 120 kg CO_{2eq} /month, which is equal to approximately 4% of the household's total carbon footprint. These savings will not be as high in winter however, when Cape Town's solar irradiation levels average 4.46 kWh/m^2.day, which is significantly less than that of the summer months, averaging 6.95 kWh/m^2.day.

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Acknowledgments

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Conflict of Interest

The authors declare no conflict of interest.

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References

1. Eskom 2011: Eskom estimation of household water heating requirement. [Online] Available at: <http://www.eskomidm.co.za/residential > [Accessed 20 October 2011]
2. Herring, H., Roy, R., 2007. Technological innovation, energy efficient design and the rebound effect. *Technovation.* 27 (4) 194-203
3. Wesslink, R., 2010. Baseline and follow up survey data on the Kuyasa CDM project. (Personal Communication, 15 October 2010)
4. Davis, S., Cohen, B., Hughes, A., Durbach, I., Nyatsanza, K., 2010. Measuring the rebound effect of energy efficiency initiatives for the future: A South African case study. *The Energy Research Centre, University of Cape Town*
5. Nevin, G., Background information about gap housing income bracket. (Personal Communication, 20 March 2010)
6. Eskom, 2010: Eskom Integrated Report 2010
7. Notten, P., Basic SimaPro database for simple life cycle assessment of South African electricity (Personal Communication, 7 October 2010)

References

8. Millennium Development Goals 2011: Information on carbon footprint of average South African. [Online] Available at: <http://mdgs.un.org> [Accessed 12 August 2011]
9. Statistics South Africa, 2005/2006: Income and expenditure of households 2005/2006
10. Mol, H. C., Noorman, K. J., Kok, R., Engström, R., Throne-Halst, H., Clark, C. 2005. Pursuing More Sustainable Consumption by Analyzing Household Metabolism in European Countries and Cities *Journal of Industrial Ecology* (9/1-2) 259-275
11. Vringer, K., Blok, K. 1995. The direct and indirect energy requirements of households in the Netherlands. *Energy Policy*. 23 (10) 893 – 910
12. Guardian-UK (2010): Information on carbon footprint of groceries. [Online] Available at: <http://www.guardian.co.uk/environment/green-living-blog/2010/nov/12/carbon-footprint-spending-pound> [Accessed 12 August 2011]
13. 90 X 2030, 2011: Information on carbon footprint of transport. [Online] Available at: <http://www.90x2030.org> [Accessed 12 August 2011]
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14. Synergyenviron, 2011: Information on Cape Town solar irradiation. [Online] Available at: <http://www.synergyenviron.com> [Accessed 19 September 2011]