Characterising the composition of photovoltaic panels for recycling in Australia

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Australia is one of the fastest growing installers of solar power worldwide with an estimated 3.04 million photovoltaic systems installed by the end of 2021 (APVI, 2022). Given the average lifetime of a solar panel is between 20 and 25 years the amount of photovoltaic waste in Australia is set to reach 800000 tonnes by 2050 (Singh et al, 2021). There is currently no federal legislation implemented regarding the end-of-life management of solar panels. Given the varying Environmental Protection Authority (EPA) requirements across different states for the storage and recycling of materials found in solar panels, developing a viable recycling process will require an in-depth knowledge of the material composition of end-of-life photovoltaics (EPA, 2020).

The characterisation of photovoltaic panels is an important part of the recycling process. The amount of economically important materials such as copper and silver that can be extracted from the photovoltaic panels can inform the economic viability of the recycling process (Dias et al, 2016). Most studies examining end-of-life photovoltaics for the recycling process estimate the material composition from a product datasheet or cite the composition data from another paper (Latunussa, 2016 and Lunardi, 2017) however this method is less accurate than experimentally characterised module composition results.

Aim and Approach

This work is designed to characterise the chemical composition of end-of-life photovoltaic panels from different manufacturers to record the variability between different panels. This information will be used to inform economic viability of recycling different components of solar panels as well as eliminating the waste panel landfills in Australia.

Solar panels were collected from solar distributors and manufacturing companies, with 12 solar panels from different manufacturers being used for the study. Brands and model numbers are summarised in Table 1 below.

Table 1: Summary of studied solar panels

Manufacturer	Model	Year Manufactured
1. Schott	Poly 170	2010
2. Seraphim	SRP-315-BMB	2019
3. Jinko	JKM370N-6TL3	2020
4. Ackome	SK6610P-275	2018
5. JA Solar	JAM60S10-330PR	2020
6. TopSola	TSM60-156P-225W	2014
7. Canadian Solar	CS6K-285P	2017
8. Longi	LR4-72HPH-430M	2020
9. Ulica Solar	UL-370M-120HV	2020
10. BYD	BYD260P6F-30	2016
11. LG	LG360Q1C-A5 703K44K1R0FG	2017
12. Flex	FLV-MB-295P60AB	2017

The solar panels were manually dismantled using a variety of tools, with the removal of the glass from the module being the most challenging. Numerous tools were trialled in the removal of the glass including paint scrapers, screwdrivers, knives, chisels, and pliers. The two main methods of removing the glass were by folding the solar panel and then using a paint scraper to dislodge the glass pushed up by the folding. This method was most successful when the aluminium frame of the solar panel had been removed and the glass was already cracked. The second method employed involved loosening the glass with a hammer, heating the glass with a hairdryer to soften the laminate, and then using a chisel to scrape off the glass. Once the glass was removed, solar cells were taken from the panel using a knife. Samples of the aluminium frame were removed from the panel using an angle grinder.

The glass and aluminium were examined using XRF for compositional analysis. The solar cell was digested in heated nitric acid and aqua regia followed by an ICP-OES analysis the quantify the metallic components of the cell.

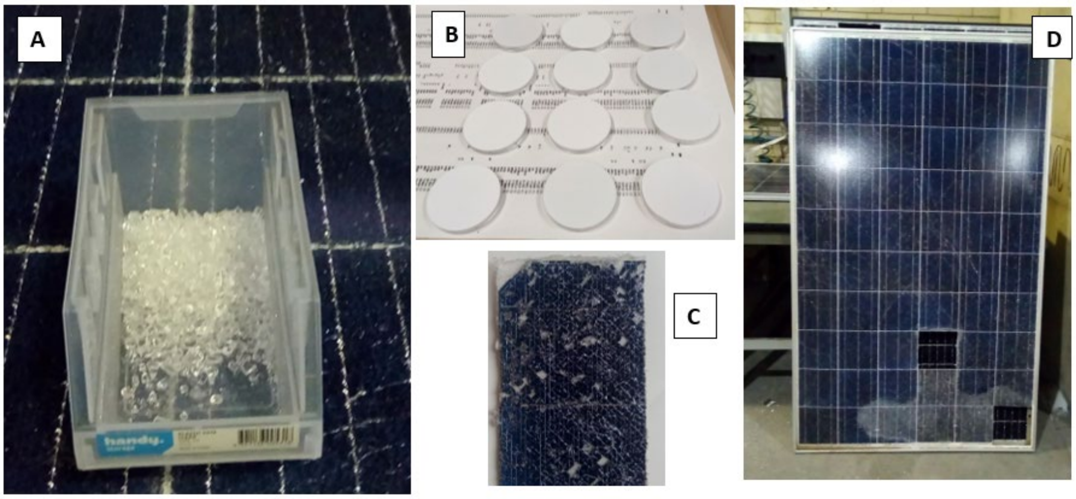

Figure 1. Samples collected for characterisation study. A: glass sample removed from solar panel. B: crushed glass in pans ready for XRF analysis. C: Collected solar cell with EVA encapsulant removed from top surface. D: Waste solar panel after sample collection

Results and Conclusions

The aluminium frame was initially sent for XRF analysis and returned the results summarised in Table 2 below. Given the large amount of sulphur recorded in the results, the coating on the aluminium was removed and a second analysis was run so that the true composition of the aluminium alloy used can be found.

Table 2: Results of XRF Analysis on the Aluminium Frame with and without coating

Element	With (%)	Without (%)
Al	70.31583	97.12442
Mg	0	0.760833
Fe	0.585833	0.33225
S	21.14917	0
Si	2.1025	0.689167
Ca	0.715	0.205708
P	0.510233	0.246792
Cl	1.515833	0.403255

The main materials found in the frame apart from aluminium included magnesium, calcium, silicon, phosporous, chlorine and iron. After the coating on the aluminium had been removed the average amount of alumium found in the frame was 97.12% with a variation of 0.5% between the different manufacturers. The amount of the other elements present in frame significantly decreased with the removal of the coating except for magnesium which was only present in the uncoated aluminium

The glass was analysed using XRF to find the general compostion of the glass. All of the glass was soda glass (silica and sodium) with the next most common elements being calcium, magnesium, aluminium and sulfur.

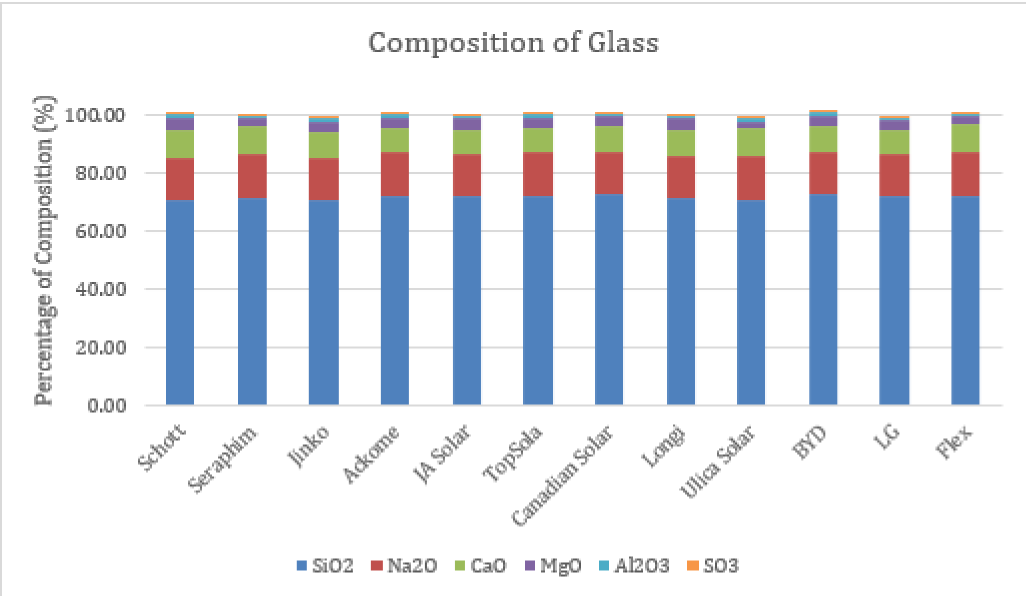

Figure 2: General composition of solar glass

Further analysis was done to determine the level of antimony within each sample. This was done as antimony is a hazardous substance and in Australia, particularly Victoria there are requirements on the amount of antimony able to be processed through waste facilities including recycling. The results from the experimental analysis were compared with values of antimony found in the literature. A two-tailed t-test was performed on the values obtained and returned a p-value of 0.1516.

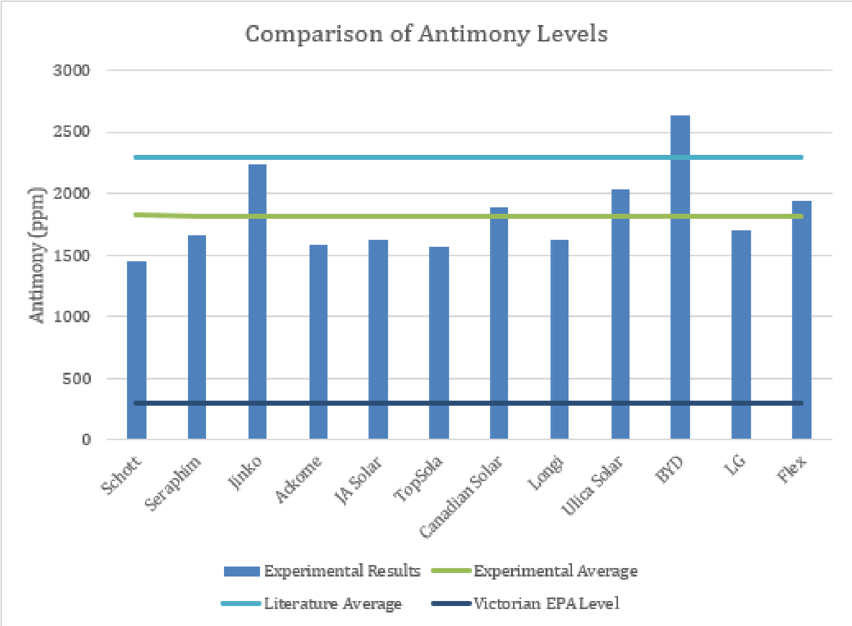

Figure 3: Graph of the levels of antimony in each solar panel compared to the mean

The composition of the solar glass would allow for it to be recycled into glass containers, however there is variability between the panels produced by different manufacturers. In the case of extreme variability, the only option for recycling the glass may be downcycling into concrete, aggregates or road base materials (Vanek, 2020 and Sustainability Victoria,2019). The level of antimony within the sample is higher than the Victorian EPA standard (EPA, 2020), but according to a glass recycler, should still be able to be reused.

One sample of the cell encapsulate was sent for ICP-OES semiquantitative analysis using two different acids to determine the main metallic components of the solar cells, results of which are summarised in Table 3. Both nitric acid and aqua regia were used for the dissolution due to their ability to dissolve different materials.

Table 3: Results of Semiquantitative analysis on photovoltaic cell

Metal	HNO3 dissolution (mg/kg)	AR Dissolution (mg/kg)
Ag	2171.7	6.2
Al	Saturated	Saturated
Cu	Saturated	Saturated
Fe	7.3	20.1
K	105.7	92.0
Mg	469.4	8.3
Si	43.91	52.47
Sn	77.5	5233.9
Zn	8.10	5.78

As expected, the main components of the solar cell were aluminium, copper, silicon, and silver, with the copper and silver being of economic importance to the recycling process. Comparisons between the cells obtained from the different panels has not yet been examined.

References

Australian PV Institute. 2022. Australian PV Market since April 2001. [online]. Available at: https://pv-map.apvi.org.au/analyses#:~:text=As%20of%2030%20June%202022,capacity%20of%20over%2027.2%20gigawatts

Dias, P., Benevit, M. and Veit, H. 2016. ‘Photovoltaic solar panels of crystalline silicon: characterisation and separation’, *Waste Management and Research* 34 (3) p235-245

Environmental Protection Authority (EPA), Victorian Governmnet of Australia. 2020. . ‘Reprocessing e-waste’ [online]. Available at: https://www.epa.vic.gov.au/for-business/find-a-topic/manage-e-waste/reprocessing-ewaste

Latunussa, C., Ardente, F., Blengini, G., Mancini, L. 2016. ‘Life cycle assessment of an innovative recycling process for crystalline silicon photovoltaic panels’ *Solar Energy Materials & Solar Cells* 156 p101-111.

Lunardi, M., Alvarez-Gaitan, J., Bilbao, J. and Corkish, R. 2017. ‘A Review of recycling process for photovoltaic modules’, *Solar Panels and Photovoltaic Materials*

Singh, J., Molinari, G., Bui, J., Soltani, B., Rajarathnam, G. and Abbas, A. 2021. ‘Life cycle assessment of disposed and recycled photovoltaic panels in Australia’ *Sustainability* 13

Vanek, J., Maule, P., and Jandová, K. 2020 'Development of Recycling of Photovoltaic Systems from the Point of View of Prolonging the Total Service Life of Photovoltaic Modules and Circular Energetic,” *ECS Transactions* 99 (1), p211–219

Sustainability Victoria. 2019. “PV Panel Reprocessing: Research into Silicon-Based Photovoltaic Cell Solar Panel Processing Methods, Viable Materials Recovery and Potential End Market Applications”