Life Cycle Analysis of u-PVC windows containing recycled u-PVC

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Executive Summary

This report presents the findings of a Life Cycle Analysis of the carbon emissions associated with the PVC framed windows that are manufactured and installed by CMS Enviro Window Systems that was undertaken by Glasgow Caledonian University for CMS Enviro Windows to establish the product's environmental sustainability.

The analysis considers the entire life cycle of the product and the carbon saved by installation of the product and the lifecycle impact of the product which is expressed in the table below as a $kgCO_2$.

In the report, it is assumed that the average housing upgrade is a 1970s style, 2 bedroom flatted property with 7 windows replaced as part of the property upgrade.

Element	**Carbon emissions ($kgCO_2$)**
Components of 1.2 x 1.2m^2 triple glazed u-PVC containing recycled PVC	89.72
Carbon savings from installation of 7 windows in a standard CMS 2 bedroom 1970's age property per year and for the lifespan of the window.	-787.34 per year and -27,557.08 for life span (35 years)
Embedded Carbon in 7 window installation	628.04
Payback period for carbon	9.5 months

Contents

1. Introduction

CMS was established in January 2006, and has enjoyed significant and continued success as one of Scotland's market leading manufacturers and installers of u-PVC, Aluminium and timber hybrid, window, door and curtain walling systems. The company employs more than 130 full and part time staff at specialist manufacturing and recycling facilities in North Lanarkshire, Fife and Darlington.

The company is renowned for its first class workmanship, customer care and product excellence which helps to ensure that they remain at the forefront of the industry. Their clients include local authorities, housing associations, utility companies, professional specifiers and homeowners.

Together with their supply chain partners they have been at the forefront of innovative developments and award-winning practices within the industry to create sustainable and environmentally friendly products and systems that benefit their clients, end users and the environment.

Key technological advancements have seen them develop a Krypton-free zero carbon window which is fully reinforced using 100% recycled material and can achieve U values as low as $0.8Wm^2K$ – the first manufacturer approved by the BFRC Ratings Council within the UK to be able to corroborate this claim. CMS were the first window fabricator in Scotland to be awarded the United Kingdom Accreditation Service (UKAS)-accredited BS OHSAS 18001:2007 Health and Safety certificate from BM TRADA.

Together with supply chain partners CMS have been at the forefront of innovative developments and award-winning practices within the industry, to create sustainable and environmentally friendly products and systems that benefit our clients, end users and the environment.

CMS operates under a fully Integrated Quality Management system which is UKAS accredited and externally verified by BM TRADA to ISO 9001:2008 (Quality); ISO 14001:2004 (Environment) and BS OHAS 18001:2007 (Health and Safety).

The company commissioned Glasgow Caledonian University to undertake a Life Cycle Analysis (LCA) their u-PVC windows, with particular focus on the carbon emissions associated with the life cycle of the product.

The Scottish Government is currently developing a Sustainable Housing Strategy which brings together the policies on climate change, energy efficiency, planning and the built environment. An integral part of this process is the provision of retrofitting Scottish housing stock to contribute to reducing carbon emissions.

Modern glazing dramatically improves U-values of dwellings and commercial buildings and represents an obvious building improvement that delivers on carbon reduction, energy efficiency and reducing the overall cost of heating buildings.

CMS Enviro Window Systems is committed to being a leader in delivering high quality products and having a strong environmental commitment, by not only providing products that help reduce the amount of greenhouse gases householders and businesses pollute into the atmosphere, but also running their business operations environmentally responsibly and ensuring where possible that the components of their windows are environmentally low carbon as much as possible.

The u-PVC window that CMS manufactures contains recycled PVC. Figure 1 below illustrates the lifecycle of the u-PVC which is recycled for remanufacture of windows.

Figure 1: Recycling process involving u-PVC in Windows

The unit is composed of a frame (10% recycled), sub-frame (reinforcement – which is 100% recycled PVC) and the rest is glass (approximately 50% of the weight of the

unit is glass) and ironmongery (brass and steel). There are also rubber seals and silicon sealants used. These are included in the carbon footprint. The components are source from manufacturers in Europe (Germany and the Glass is manufactured in Nottingham and assembled in Glasgow). The triple glazed units are filled with Argon gas.

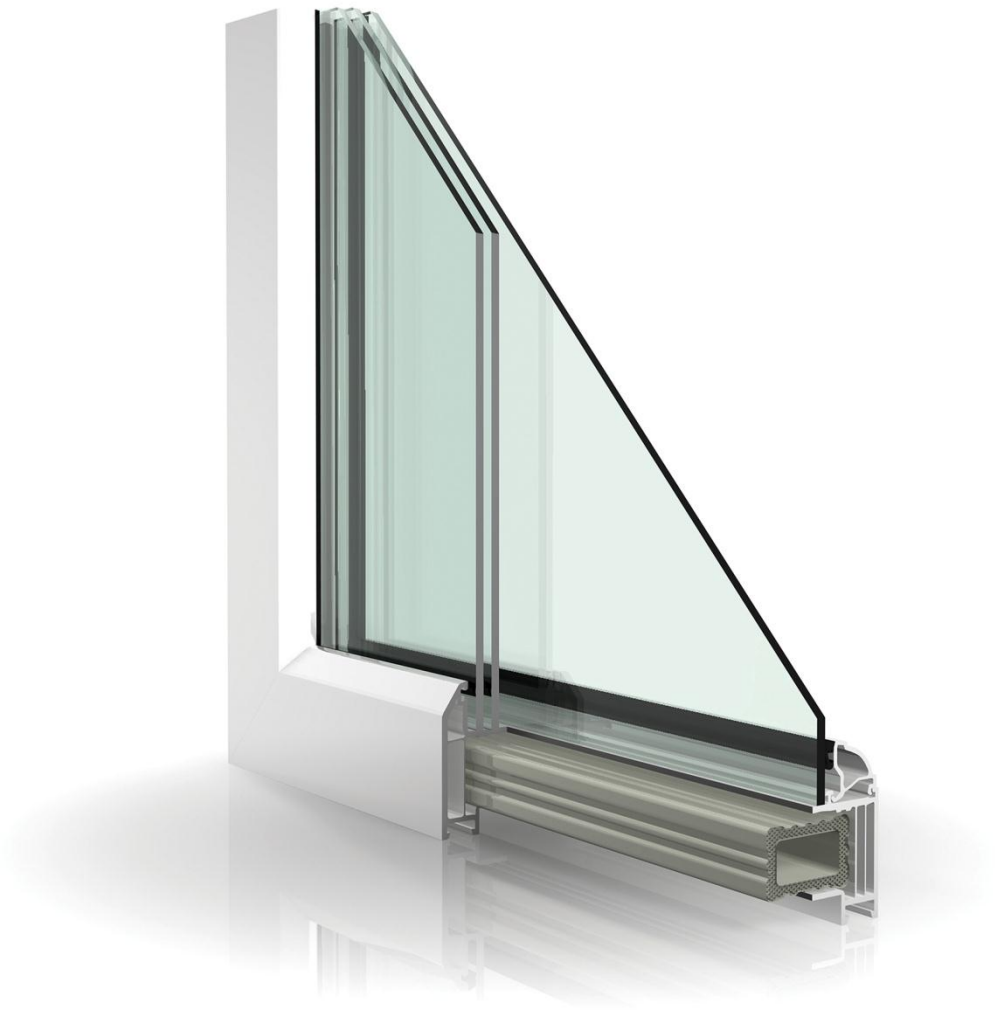

Figure 2: CMS Enviro Windows's u-PVC triple glazed window unit

2. Life Cycle Analysis

2.1. What is a life cycle analysis?

Life cycle analysis is a methodology that examines the environmental impacts of a product, from the raw materials extracted to make the product though to final disposal after the product is finished its useful life. Whilst the idea has been practiced since the 1960s, the relevance and popularity of LCA as a tool in business has increased dramatically since 2000, mainly because the cradle to grave approach allows a complete understanding of the product and the impact and interaction on the environment and provides key information for decision makers who often want a level of detail that gives Life Cycle them confidence in a product's environmental impact.

Mainly used by manufacturing firms as a tool to both reduce their environmental impact, LCA provides information for on the detailed environmental information about the products. An LCA of a product can also provide important information for retailers who require information on the impacts of the products they sell. An LCA assessment can also be important in determining a company's liabilities, for example for carbon emissions or use of freshwater, which are becoming more regulated.

LCA is a variable methodology and may be applied in different ways. Some analysis is very detailed and considers every aspect of the product from the raw materials that are required in the beginning through to the manufacture of the product and its distribution, use and disposal. Other forms of LCA methodology involve a more simplistic approach considering only the main inputs and outputs of a product.

Currently the most rigorous standard on LCA is the International Standards Organisation 14040:2006 and 14044:2006 and adherence to these standards can be required for an LCA to be accepted by other organisations. Under the ISO standard four components need to be present for an analysis to be considered an LCA: goal definition and scoping, inventory analysis, impact assessment and interpretation.

The value of LCA is in how the company uses the results. A detailed LCA will be beneficial in considering supply chain improvements or aiming for carbon neutral certification, however this can require large amounts of data which may or may not be readily available.

Even a basic consideration of the life cycle of a product which considers the main inputs and outputs can help a company in its sustainability decisions. Although this sort of analysis may not meet the requirements to be considered an LCA it can be a valuable first step for a company in determining its impact on the environment.

The LCA carried out on CMS Enviro Window Systems PVC windows was based on the greenhouse gas emissions associated with the product. LCA of construction materials has become very popular in the construction industry with a push to meet higher sustainability standards and reduce to overall impact on the environment by

the sector which contributes more than 50% of total Greenhouse gas emissions in the UK alone.

2.2. What is included in the CMS Enviro Windows Systems LCA?

The following is included in this LCA of the product:

1. Primary constituent ingredients, embodied carbon and transportation to the factory in Cumbernauld.
2. CMS related activities:
    a. Product manufacturing process.
    b. Transport from Cumbernauld to sites.
    c. Waste management.
3. Carbon emissions offset as an average due to the upgrade (reduction) in U-values by installing the windows.

There are numerous steps involved in the manufacture of any product. In the case of CMS Enviro Window Systems, the u-PVC framed window, this is complex as the window units are composed of different materials that are then put together in a final unit. However there is a reasonably thorough body of research in the arena of windows, mainly due to the heightened interest in windows due to the high embodied energy of glass and the frames, and because of the potential to reduce U-values, influence construction design and thereby reduce carbon emissions in building use further. This is very important as the lifecycle carbon use of buildings is widely recognised as being in a 80:20 ratio of use to construction materials, where embodied energy are energy and waste related carbon emissions associated with construction.

In some elements of this study, there was either no information directly, or where there is a gap, the value is assumed to be very small or negligible and not included.

The main rule of thumb used here that over 95% of the emissions associated with the production of u-PVC windows are calculated here. This is mainly the case with all LCAs and it is important to state that where we have no data from the process directly, published equivalent data has been used as a source instead.

LCAs can be often very complex and involve a great deal of time and research. In the limited time and resources allowed in this CIC Start project, the level of detailed in this project is still substantial and will become a foundation for any certification process (ISO 14040:2006 and 14044:2006) should CMS Enviro Window Systems wish to proceed in that manner with the product at a later stage.

3. Methodology of the LCA

A fundamental element of the design of an LCA is to outline the boundaries of the process. In this process, an inclusive approach was applied. This means that the total carbon associated with the product installed to the building was assumed.

3.1. The PVC window Primary Constituent Components

The following components are used to manufacture 1 standard 1.2 x 1.2 u-PVC window unit.

Table 1: u-PVC window Components

Component	Weight (kg)per Unit 1.2/1.2 m	Carbon emissions factor $kgCO_2/kg$	Carbon emissions LCA $kgCO_2$	Where manufactured	Transport Carbon $kgCO_2$
Glass	18.12	0.85	15.402	Nottingham (614 km)	1.39
PVC frame 90:10 Virgin:Recycled	17.81	2.2 / 0.07	35.39	Holland (1140 km)	2.53
Recycled PVC sub-frame	1.38	0.07	0.0966	Derby, England (614km)	0.11
Ironmongery	3.88	2.42	9.39	Gloucester, England (544 km)	0.26
Rubber seals	0.61	4.02	2.45	Birmingham, England (466km)	0.04
Expanded foam	1.0	3.0	3.0	Norwich, England (608 km)	0.08
Silicon seals	1.0	5.91	5.91	Norwich, England (608 km)	0.08
Total	**42.8**		**71.64**		4.49
					76.13

Transport emission factor 0.12467 $kgCO_2$ tonne km articulated vehicle (Defra/DECC, 2012)

The number of u-PVC units produced in 2011 was 24,906, which was an increase, from 21,757 in 2010.

3.2. The Manufacturing and Distribution Process

The PVC fames are assembled at the company's factory in Cumbernauld.

This represents the direct carbon footprint associated with the factory and therefore to a degree is in direct control of CMS.

Table 2: CMS Carbon Footprint for Factory, including energy, transport and waste

Year	Total CO_2 Emission (tonnes)	Emissions from factory (tonnes)	Emissions from transport (tonnes)	Emissions from waste (tonnes)	Emissions from water (tonnes)	Number of PVC/Aluminum units manufactured	Carbon emissions associated with Manufacture/ transport and waste ($kgCO_2$) of 1.2x 1.2 m^2 window
2010	323	147	160	16	NA	21,757 / 4000	12.54
2011	423.1	215	176	32.1	NA	24,906 / 6226	**13.59**

Waste

CMS Enviro Window Systems have developed a strong on site recycling practice at their Cumbernauld site. Investment into this initiative has provided both jobs and carbon and energy savings accrued from using waste wood (with no paint contamination) in the Biomass burner, reducing heat energy requirements. The figures below are calculated from the Defra/DECC Greenhouse gas emission factors for waste including the lower emissions factors associated with materials that are recycled rather than sent to landfill or incinerated. Through the implementation of the waste management plan, a reduction of 6 tonnes per year was achieved in 2011, indicating that the company are continually making low carbon based management decisions to further reduce the impact of the company's own Carbon footprint. CMS has a clear commitment to waste reduction and recycling. Total tonnage of waste sent to recycling and landfill in 2010 was 850 tonnes. This increased to 1,202 tonnes in 2011, of which 96% was recycled or re-used as part of a waste management strategy the company introduced. However there was still an increase in electricity use by the company from 2010 to 2011 which may simply be explained by the increased manufacturing output, but there is no clear correlation between the use of the wood in heating and expected reduction in electricity use as the energy demand is displaced by the biomass boiler. This does require some further assessment.

Table 3: CO_2 emissions from waste window waste management in 2011.

Material	Recycled (tonnes)	Emissions Factor $kgCO_2$/tonne	Landfilled	Emission Factor $kgCO_2$/tonne	CO_2 emissions $kgCO_2$
Double Glazed Glass	73.96	21	3.848	26	1,653.21
Float Glass	212.82	21	2.66	26	4,538.38
Metal	95.18	1	-	2	95.18
Drop Wood	88.39	21	-	851	1,856.2
Skip wood	419.82	21	-	851	8,816.22
PVC	100	21	-	-	2,100
Inert	112	1	-	-	112
Poly and Cardboard	11	21	-	-	231
General	40.935	21	40.935	290	12,731
Total	**1,154.105**		**47.443**		**32,133.20**

3.3. Carbon emissions offset as an average upgrade in U-values.

The triple-glazed u-PVC windows have very low U-values as compared with windows that they are replacing, often wood, aluminium double or single glazed units. Table 4 represents the carbon saved by installing windows into housing of different types and ages in Scotland. The lifecycle component that is important to establish is the amount of carbon saved by installing the windows in the first place. This is a complex calculation and thus the development of the tool that accompanies this report. CMS replaces windows approximately 80 house per week with a 2 week break over the Christmas period where the factory is closed.

Table 4: Energy performance improvement and carbon ($kgCO_2$) saved by installation of CMS triple glazed windows.[1]

Housing type/Age	Carbon Savings $kgCO_2/m^2$	
	GAS	ELECTRICITY
Detached 1900-1949	3.42	10.59
Detached 1970	1.58	4.9
Detached 1985	1.6	3.7
Detached 2000	1.29	1.97
Detached New Build	0.46	0.47
Semi-Detached 1900-1949	5.46	12.03
Semi-Detached 1970	1.47	6.01
Semi-Detached 1985	1.32	3.85
Semi-Detached 2000	1.01	3.85
Semi-Detached New Build	0.43	0.54
Mid-Terrace 1900-1949	3.93	12.03
Mid-Terrace 1970	1.99	4.74
Mid-Terrace 1985	1.54	3.73
Mid-Terrace 2000 Existing	1.46	2.76
Mid-Terrace New Build Existing	0.65	0.77
End-Terrace,top floor flat 1900-1949	3.8	11.1
End-Terrace,top floor flat 1970	1.76	5.14
End-Terrace,top floor flat 1985	1.14	2.75
End-Terrace,top floor flat	1.16	2.14

[1] Taken from Leading Energy Consultants data sheets derived from the Elmhurst Design SAP 2009 tool

2000 Existing		
End-Terrace,top floor flat New Build Existing	0.75	0.79
Mid-Terrace,mid floor flat 1900-1949	7.84	16.26
Mid-Terrace,mid floor flat 1970	4.36	8.96
Mid-Terrace,mid floor flat 1985	2.08	4.64
Mid-Terrace,mid floor flat 2000 Existing	1.66	3.5
Mid-Terrace,mid floor flat New Build Existing	0.75	1.08

Calculation methodology

For the purposes of this assessment an average property of a 2 bedroom flat with 7 windows replaced has been selected. In this report the assumption was made that the house were 1970's standard and the mid-terrace mid-floor flat was taken as a common type of property undergoing upgrade by CMS.

Scott Wilson (2009) undertook a report for CABE on dwelling size in England, which has been used to provide the approximate internal area size of the property. A 2 bedroom flat has an internal floor area of 59.11m^2.

Therefore the carbon saved in a property of this type is:

Carbon saved electricity and gas – 1970's mid-terrace, mid floor flat X floor area X life time of u-PVC window.

13.32 $kgCO_2m^2$ per year X 59.11 m^2 X 35 years

= 27,557.08 kg CO_2 or 27.557 tonnes CO_2

This equates to an annual saving **of 0.79 tonnes per property per year**.

The embodied carbon in the window component and the carbon involved in the manufacture, distribution and fitting of the windows is **77.72 $kgCO_2$ per 1.2 by 1.2 m^2 window**. This comes to a total of **466.76 $kgCO_2$** for the average house upgrade.

Therefore the carbon payback period is 7 months for the average house upgraded by CMS.

4. Conclusion and Recommendations

CMS's u-PVC windows do represent a substantial carbon savings in both the embodied carbon of the u-PVC windows and the carbon saved because of the low U-values the product has.

Table 5: Summary of Carbon performance of u-PVC windows.

Element	**Carbon - $kgCO_2$**
Components of 1.2 x 1.2m^2 triple glazed u-PVC containing recycled PVC including transport and assembly.	89.72
Carbon savings from installation of 7 windows in a standard CMS 2 bedroom 1970's age property per year and for the lifespan of the window.	-787.34 per year and -27,557.08 for life span (35 years)
Embedded Carbon in 7 window installation	628.04
Payback period for carbon	9.5 months

This study was carried out purely to calculate the LCA of the u-PVC windows and their performance in terms of carbon reduction over their lifespan. The windows offer a significant carbon reduction potential for householders with a payback period of less than a year in the housing type common to the CMS client upgrade.

There are some gaps and recommendations to address these. Firstly there is the use of biomass boiler and the way the heating and energy used at the CMS site is monitored. Great progress has been made with waste as there is a strong recycling market and the company has shown leadership in taking advantage of the fiscal benefits of recycling and the clear environmental benefits of taking recycling seriously. Energy use did increase and it would be useful for the company to set some targets for energy reduction and developing a reduction plan further, to enhance their environmental credentials and reduce further the product footprint.

Second, it would be useful to undertake a direct comparison of the Aluminium products in a similar form of LCA as the company is producing more of these windows too and it would be useful for comparison and consistency.

Finally, it is recommended that the company develop further the carbon footprint tool which could be used by the company for providing more accurate carbon offset and savings for customers.

5. References

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