ACKNOWLEDGMENTS

The authors gratefully acknowledge the support of the EPSRC funded Industrial Doctorate Centre in Systems (Grant EP/G037353/1), Useful Simple Projects Ltd and Expedition Engineering Ltd. They would also like to thank Dr Pete Winslow and Clement Thirion at Expedition Engineering for their contributions to early versions of this study.

NOMENCLATURE

A	=	floor area of the building	M	=	quantity of material
C	=	conversion factor	P	=	production phase 'modifier'
D	=	distance	W	=	waste
E	=	non-operational energy	Y	=	life or period of time

Subscripts

build	=	building	*m*	=	material
c	=	component	*n*	=	number of materials
con	=	construction phase	*p*	=	use phase process
des	=	design	*pro*	=	product phase
dis	=	disposal	*rec*	=	recurring
end	=	end of life phase	*un*	=	uninstalling
in	=	installing	*use*	=	use phase
ini	=	initial			

REFERENCES

Adalberth, K. (1997). Energy use during the life cycle of buildings: a method. *Building and Environment*, *32*(4), 317–320.

ATHENA. (1997). *Demolition Energy Analysis of Office Building Structural Systems*.

BCIS. (2006). *BMI Life Expectancy of Building Components*.

EeBGuide. (2012). *Guidance Document Part B: Buildings*.

Fawcett, W., Hughes, M., Krieg, H., Albrecht, S., & Vennström, A. (2012). Flexible strategies for long-term sustainability under uncertainty. *Building Research & Information*, *40*(5), 545–557.

Gustavsson, L., Joelsson, A., & Sathre, R. (2010). Life cycle primary energy use and carbon emission of an eight-storey wood-framed apartment building. *Energy and Buildings*, *42*(2), 230–242.

Hammond, G. P., & Jones, C. I. (2011). Inventory of Carbon and Energy (ICE), V2.0. Retrieved January 10, 2014, from www.circularecology.com/ice-database.html

IPCC. (1996). *Second Assessment Report* (p. 693).

Khasreen, M. M., Banfill, P. F. G., & Menzies, G. F. (2009). Life-cycle assessment and the environmental impact of buildings: a review. *Sustainability*, *1*(3), 674–701.

Kofoworola, O. F., & Gheewala, S. H. (2009). Life cycle energy assessment of a typical office building in Thailand. *Energy and Buildings*, *41*(10), 1076–1083.

Korpi, E., & Ala-Risku, T. (2008). Life cycle costing: a review of published case studies. *Managerial Auditing Journal*, *23*(3), 240–261.

Moncaster, A. M., & Symons, K. E. (2013). A method and tool for "cradle to grave" embodied carbon and energy impacts of UK buildings in compliance with the new TC350 standards. *Energy and Buildings*, *66*, 514–523.

Ramesh, T., Prakash, R., & Shukla, K. K. (2010). Life cycle energy analysis of buildings: an overview. *Energy and Buildings*, *42*(10), 1592–1600.

RICS. (2012). *Methodology to calculate embodied carbon of materials*.

Scheuer, C., Keoleian, G. A., & Reppe, P. (2003). Life cycle energy and environmental performance of a new university building: modeling challenges and design implications. *Energy and Buildings*, *35*(10), 1049–1064.

Yung, P., Lam, K. C., & Yu, C. (2013). An audit of life cycle energy analyses of buildings. *Habitat International*, *39*, 43–54.