Timber in construction and its sustainability

SW4SW

Dr Wessels
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PhD study for Philip Crafford, March 2019

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Research problem

- International LCA studies – Northern Hemisphere, Developed, Specific primary energy mix

- Less than 1% residential homes are timber based
- Limited local environmental studies available
- Limited wood resources available

- Sustainability in SA with a focus on timber building systems

Outline

- Research problem
- Literature review – rationale and methodology
- Local building materials comparison
- Local building systems comparison
- Local transport and import comparisons
- Scientific outcomes and recommendations

Literature Review

Sustainability and wood constructions: A review of life-cycle assessment methods and rating systems from a South African perspective

Published in: Advances in Building Energy Research (2018)

Crafford, P.L., Blumentritt, M., Wessels, C.B.


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Review Article

Sustainability and wood constructions: a review of green building rating systems and life-cycle assessment methods from a South African and developing world perspective

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ABSTRACT

This study reviews, from a South African and developing world perspective, green building rating tools and life-cycle assessment methods with a focus on wood constructions. Based on existing studies, it seems as if

In this article

ABSTRACT

Related articles

A comparative review of existing data and methodologies for calculating embodied energy

Literature Review

- Timber is unique - absorbs CO_2 during growth
- Wood as energy / associated fossil fuel emissions can be avoided
- Wood products generally require less energy for manufacturing then equivalent alternatives (e.g. Perez-Garcia et al. 2005; Gustavsson et al. 2006; Sathre and O'Connor 2010; Lippke et al. 2011).
- Compared to steel and concrete (LCA) approach, wood is a superior alternative

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Literature Review

Functionality of LCA tools (compiled from: Trusty & Horst 2005; Haapio & Viitaniemi 2008).

	Country	Comment
Level 1: Product Comparison Tools		
SimaPro	Netherlands	Tools are designed for and best used by LCA practitioners. They can be used globally by selecting or incorporating the appropriate data and are not building specific.
GaBi	Germany	
Umberto NXT	Germany	
Team™	France	
Level 2: Whole Building Decision Support Tools		
Athena Environmental Impact Estimator (EIE)	Canada/USA	All of these tools use data and incorporate building systems that are specific to the country/ regions for which they were designed. Many aim to be implemented from an early design stage.
BRI LCA (energy and CO_2)	Japan	
EcoQuantum	Netherlands	
Envest 2	United Kingdom	
LISA	Australia	
Level 3: Whole Building Assessment Systems and Frameworks		
BREEM	United Kingdom	Uses LCA results from Level 2 Green Guide.
SBTool	International	Experimental platform that accepts LCA results or performs rudimentary LCA calculations using build-in calculators.
Green Globes	Canada/ USA	Assigns a high % of resource use credits based LCA using a recognized Level 1 or 2 tool.
LEED v4	USA	Credits can be obtained for a LCA in designs and building material choices.

Conclusion

- Environmental benefits of using wood not sufficiently reflected in GB tools
- LCA powerful tool- resource intensive, highly complex, accurate data
- Critical need LCA based research developing countries

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Local building material comparisons

The potential of South African timber products to reduce the environmental impact of buildings

Published in: South African Journal of Science (2017) 113: 9-10

Crafford, P.L., Blumentritt, M., Wessels, C.B.

Check for updates

The potential of South African timber products to reduce the environmental impact of buildings

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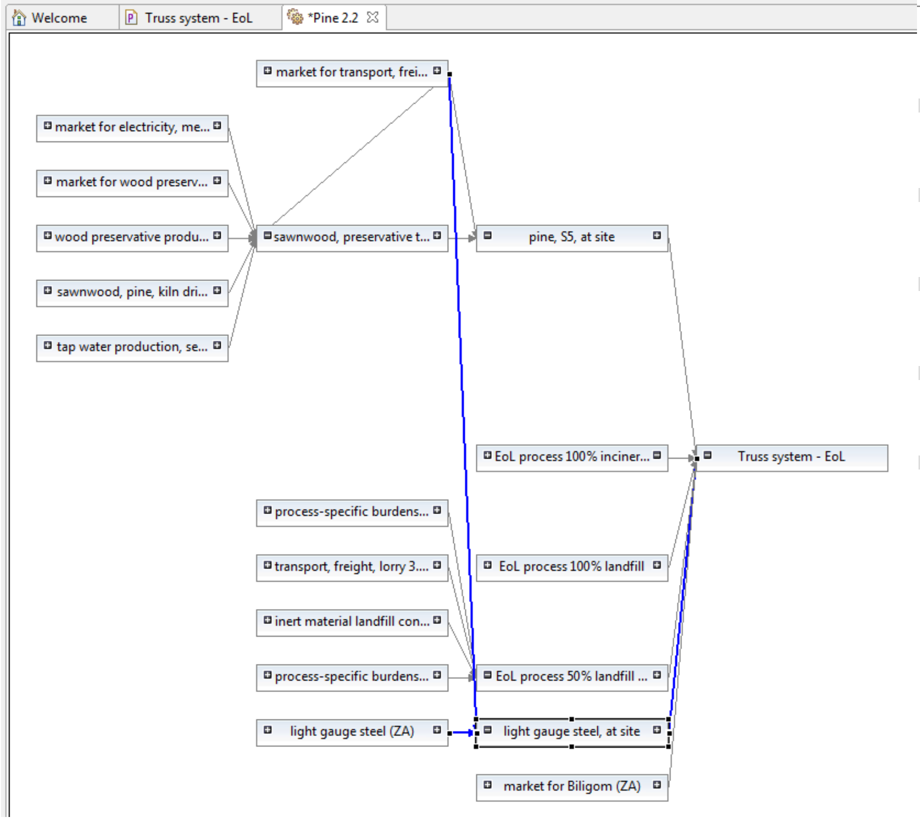
South Africa was the first country in Africa to implement a locally developed green building rating tool and has a growing number of rated green building projects. The method of life-cycle assessment can help to compare and assess the environmental performance of building products. At present, more than 70% of all sawn timber in South Africa is used in buildings, mainly in roof structures. Light gauge steel trusses have recently also been gaining market share. However, to date, no studies have been conducted that quantify and compare the environmental impacts of the different roof truss systems in South Africa. We thus compared several roof truss systems (South African pine, Biligom and light gauge steel) found

A comparative LCA of roof truss systems impact



- Method: Standard ISO 14040
- Software: openLCA 1.4.2
- Data base: ecoinvent 3.1
- Impact assessment method: CML baseline
- Functional unit: quantity of materials

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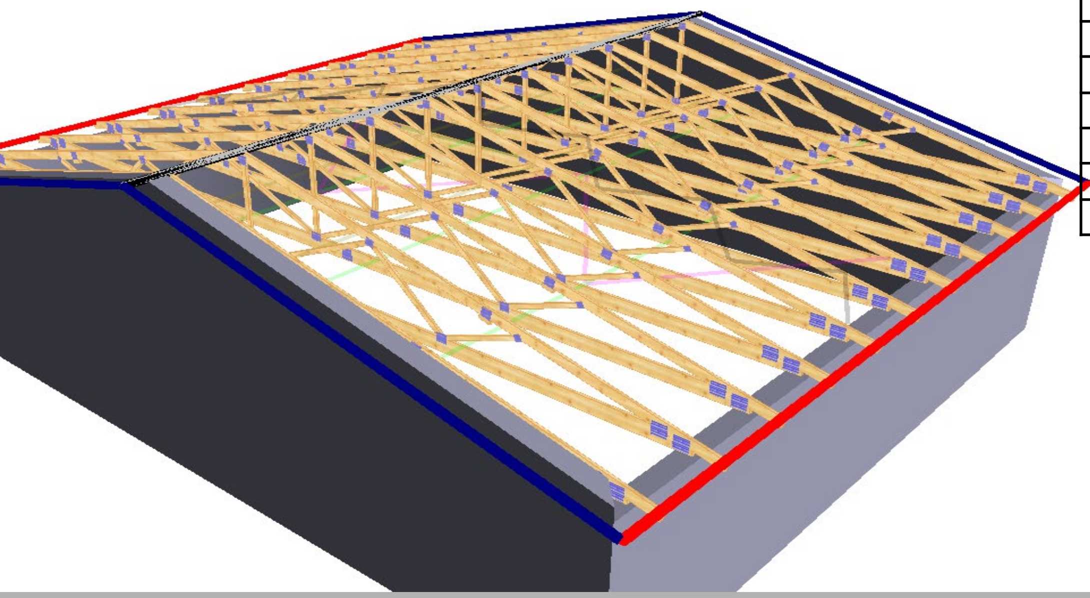
A comparative LCA of roof truss systems impact

Alternative	Truss material	Number of trusses	Cover material	House footprint
1	SA pine S5	10	Concrete tiles	$42m^2$ (6x7m)
2	Biligom	10	Concrete tiles	$42m^2$ (6x7m)
3	Light Gauge Steel	7	Concrete tiles	$42m^2$ (6x7m)
4	SA pine S5	16	Concrete tiles	$168m^2$ (14x12m)
5	Biligom	16	Concrete tiles	$168m^2$ (14x12m)
6	Light Gauge Steel	12	Concrete tiles	$168m^2$ (14x12m)



	SA pine (S5)[1]		Biligom[1]		Light-gauge steel [2, 3]
Alternative	m^3	kg	m^3	kg	kg
1	1.33	598.5			22.5
2			1.33	798.0	23.5
3					167.8
4	6.05	2722.5			180.6
5			6.05	3630.0	186.6
6					1094.0

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System boundaries and limitations

- Life cycle 50 years
- Cradle to grave
- End of life – Incineration or furnace
- Limited local LCI for LGS - RoW

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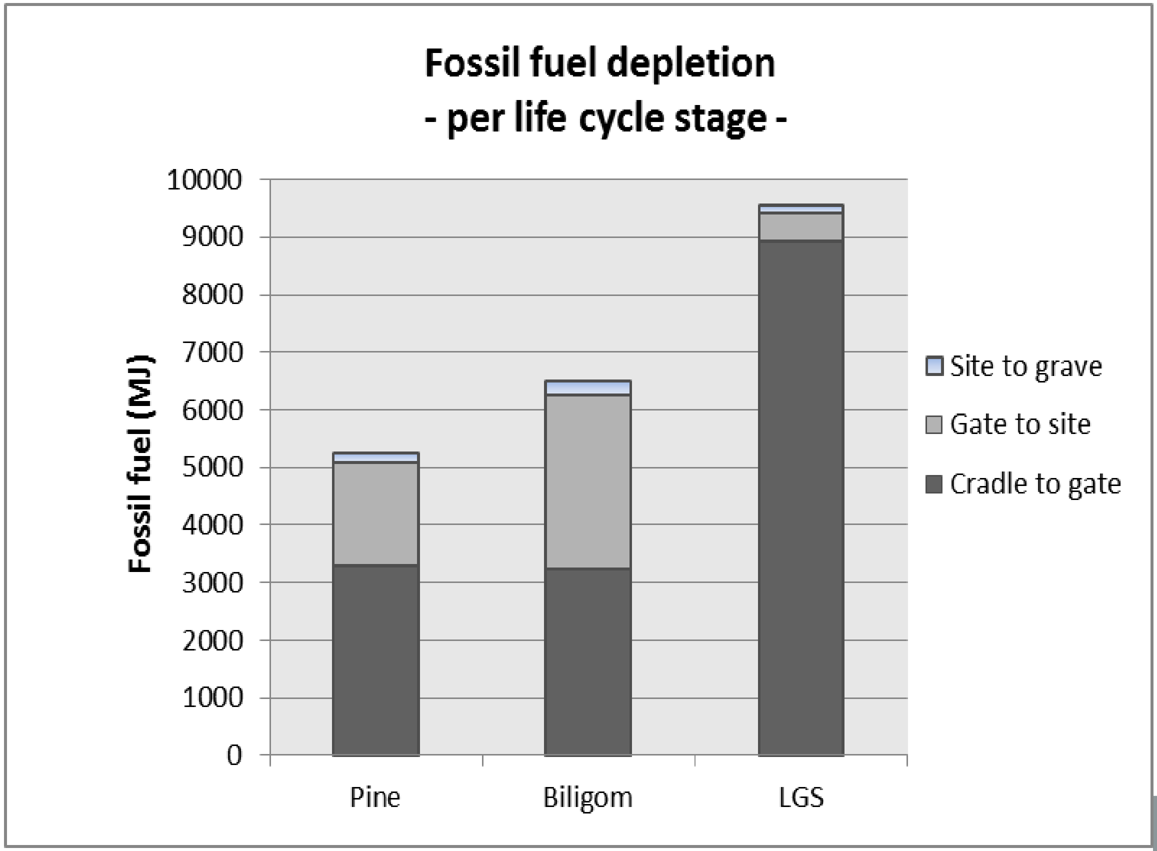
Cradle-to-grave impact assessment summary

Impact category	42 m² house			168 m² house			Reference unit
	Pine (1)	Biligom (2)	LGS (3)	Pine (4)	Biligom (5)	LGS (6)	
Acidification potential	4.21	4.46	9.52	23.60	24.81	62.07	**kg SO2 eq.**
GWP100	**85**	**164**	**1038**	**873**	**1242**	**6769**	**kg CO2 eq.**
Depletion of abiotic resources - elements, ultimate reserves	0.04	0.02	0.11	0.23	0.14	0.74	**kg antimony eq.**
Depletion of abiotic resources - fossil fuels	**5237**	**6513**	**9556**	**28281**	**34165**	**62308**	**MJ**
Eutrophication	1.59	1.72	3.97	9.08	9.72	25.85	**kg PO4--- eq.**
Freshwater aquatic ecotoxicity	737	744	4344	5379	5447	28328	**kg 1,4-dichloroben-zene eq.**
Human toxicity	8284	967	2790	38983	5726	18191	**kg 1,4-dichloroben-zene eq.**
Marine aquatic ecotoxicity	8.88E+05	8.27E+05	3.32E+06	5.59E+06	5.34E+06	2.17E+07	**kg 1,4-dichloroben-zene eq.**
Ozone layer depletion	6.05E-05	7.25E-05	7.33E-05	3.10E-04	3.60E-04	4.80E-04	**kg CFC-11 eq.**
Photochemical oxidation	0.29	1.00	0.44	1.51	4.76	2.85	**kg ethylene eq.**
Terrestrial ecotoxicity	19.28	12.44	69.62	120	89.62	453	**kg 1,4-dichloroben-zene eq.**

Depletion of abiotic resources/ fossil fuel (MJ) per life-cycle stage for the 42m^2 roof



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Conclusion

- Biligom and SA pine truss systems showed significant lower environmental impacts compared to LGS
- Advantage of using local timber products to reduce the environmental impact of the truss and building industry in SA
- *SA timber industry has a great opportunity and responsibility to lead the way Africa needs to go*

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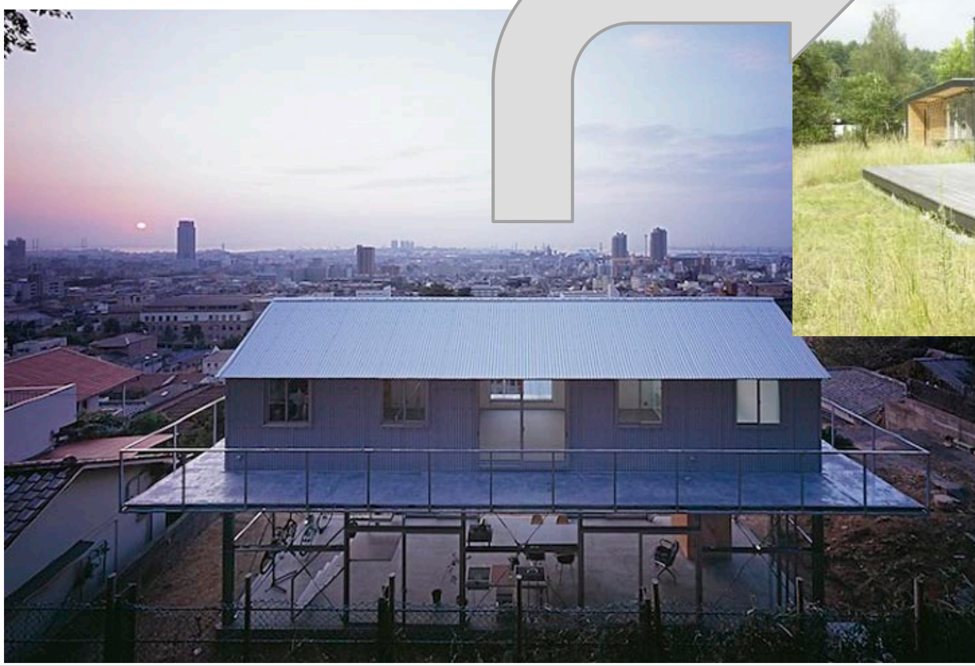
Local building system comparisons

The potential of wood based building systems to reduce global warming potential and embodied energy of residential housing structures in South Africa

In review

Crafford, P.L., Wessels, C.B.

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Research study results on building system EE and GWP impacts

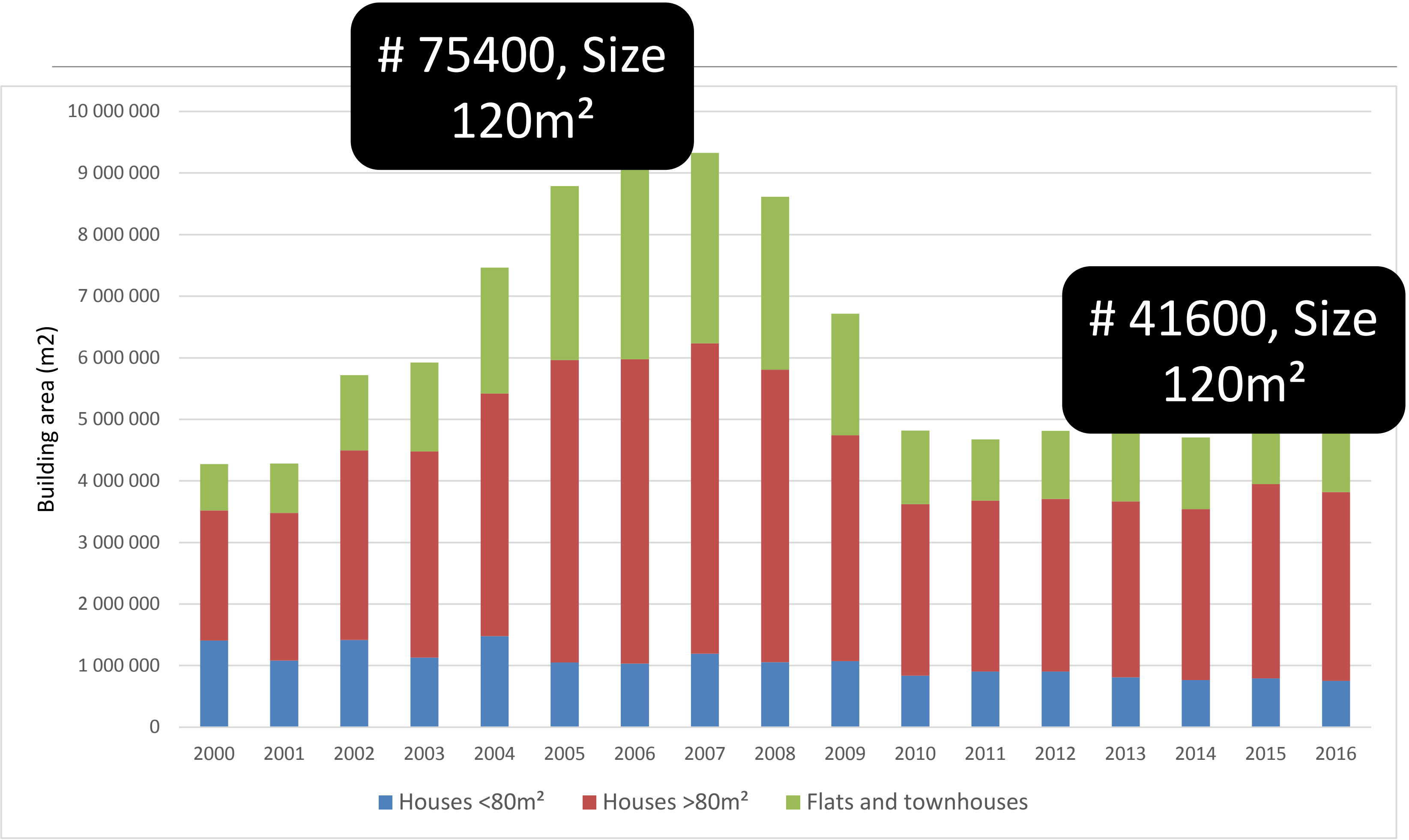
Building system	Description	MJ/m²	CO² eq/m²	Wood m³/m²	Gross floor area m²	Life cycle	Country	Year	Source
Brick	Low energy	5588	527.17[a]	0.1[b]	231	50	Australia	2017	Thomas and Ding
Timber frame	Low energy	4717	445.00[a]	0.3[b]	231	50	Australia	2017	Thomas and Ding
Reinforced concrete	Conventional	1541	308.2	-	4 floors	50	China	2017	Guo et al.
CLT	Low energy	847	-84	-	4 floors	50	China	2017	Guo et al.
Reinforced concrete	Conventional	3095.2[a]	292	-	4 floors	50	Sweden	2014	Dodoo et al.
CLT	Conventional	1208.4[a]	114	0.27[c]	4 floors	50	Sweden	2014	Dodoo et al.
Brick	Conventional	5400	509.43[a]	-	192	70	Italy	2010	Blengini and Di Carlo
Brick	Conventional	6132	578.49[a]	-	150	30	Spain	2006	Casals
Timber frame	Standard-light	2212	208.68[a]	-	94	100	New Zealand	2004	Mithraratne and Vale

Potential future log resources available for timber based housing components such as sawn timber and board products

Description	Log volume (m^3/year)	Availability (years)*	Data source
Current chip export resource. Eucalypt and wattle logs	2 600 000	Immediate	FSA, 2015
Current pulp, board, and other log resource. Eucalypt, wattle and pine	11 850 000	Immediate	FSA, 2015
Import logs or wood products	N.A.	Immediate	
Afforestation Eastern Cape / KZN. 140 000 ha	2 070 000	24 (8)	DEA, 2017
Dryland afforestation Western Cape. 175 000 ha	1 557 500	30 (10)	Von Doderer, 2012

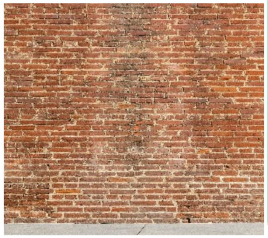
*Value in brackets is for pulpwood rotations and thinning's

South Africa completed residential building area. Source: Statistics SA, 2016



Wood use per (120m^2) building type

Development with current **&** afforested resources



$12m^3$ timber (45% sawmill rec)

$26m^3$ logs (sawn timber)

100 000 or 239 500 homes/year

$0m^3$ = **0 trees**

$36m^3$ timber (55% sawmill rec)

$65m^3$ logs (sawn timber & board)

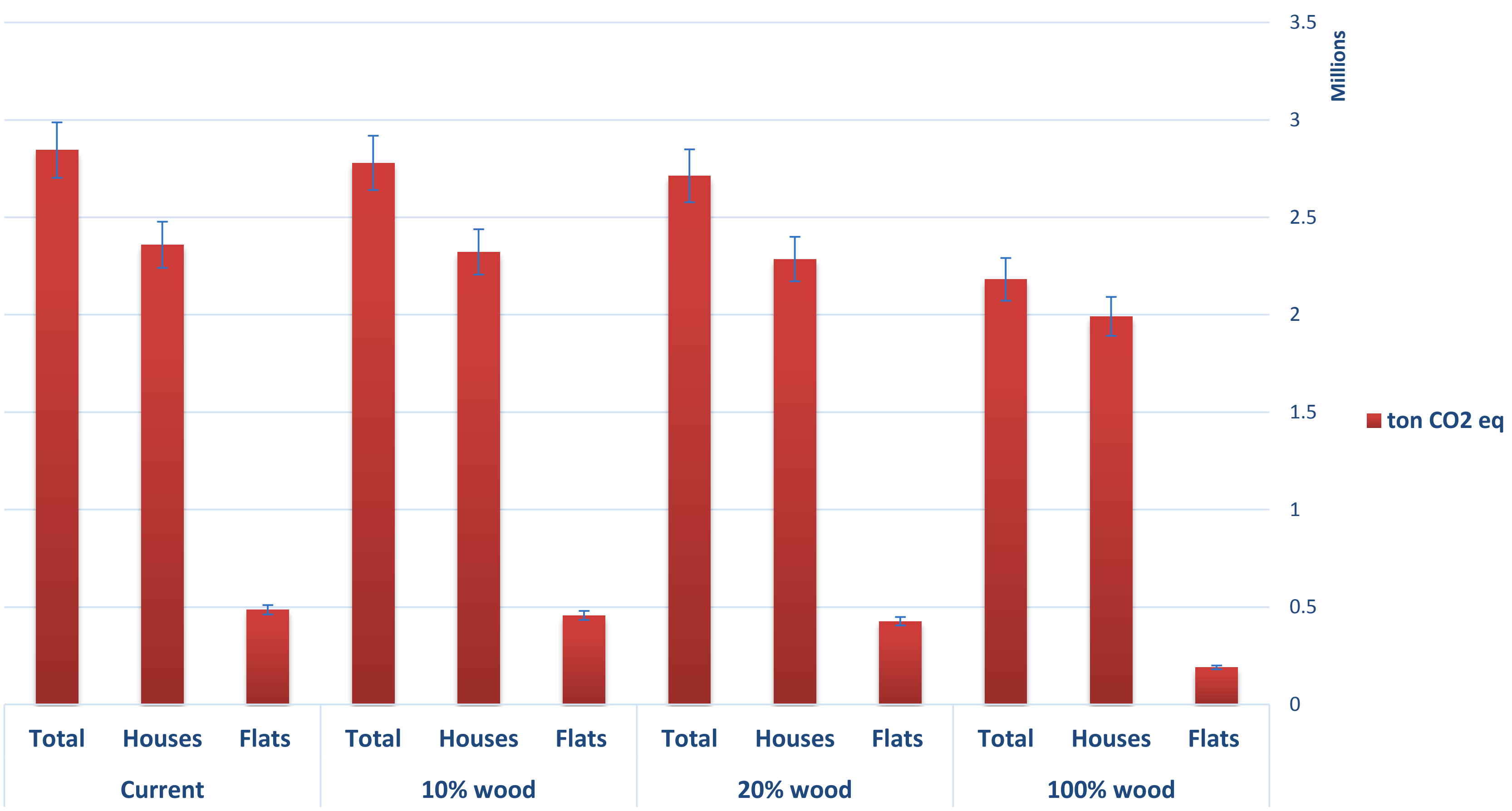
40 000 or 95 800 homes/year

$33m^3$ timber (45% sawmill rec)

$73m^3$ logs (sawn timber)

35 600 or 85 290 homes/year

South African mean annual residential building GWP impacts



Conclusion

- 10% and 20% increases in residential wood based show a moderate environmental benefit
- 100% increase result significant 30.4% GWP saving in residential building impact
- Wood resources, chips, afforestation, will enable market where all constructions are wood based
- Imports of wood building components - rapid growth in wood building occur
- Further research – consider social, economic and OE interaction

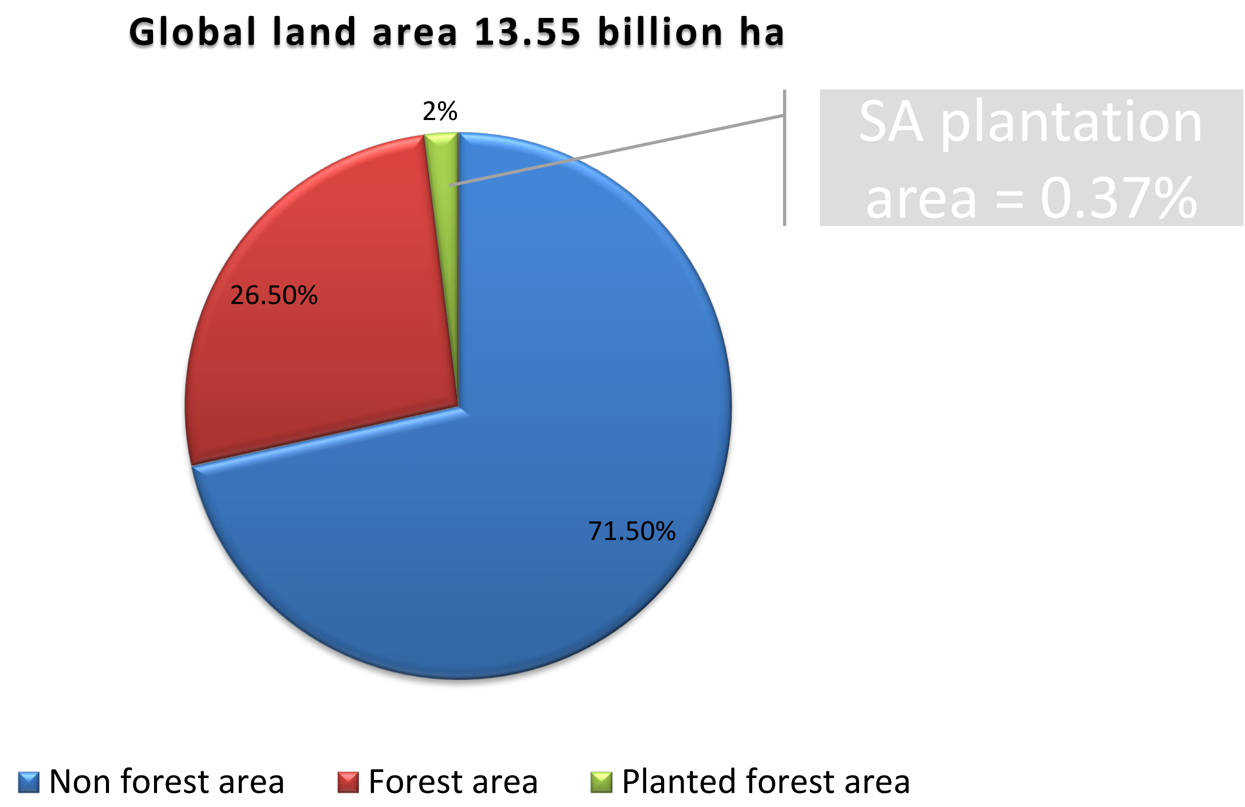
Local transport and import comparisons

An environmental decision support tool for South African timber transport and supply – focus on GWP

Unpublished

Crafford, P.L., C. Wolf, M. Blumentritt, C.B. Wessels

Global land coverage and type in hectares (Evans, 2009)



System boundaries and limitations

- EE and GWP of 4 transport systems per ton/km
- T1 and T2 = 40 ton truck
- T3 = 50 000 ton container ship T4 = 50 000 ton dry bulk ship
- Impacts included fuel production, vehicle production, maintenance, infrastructure and vehicle operation (excl. EoL)
- Assumed equal forest and processing impacts for all locations

Primary energy demand and GWP impacts per transport stage from production plant to building site of **one ton per kilometre** (Bribian et al., 2011)

Impact category	Truck	Rail	Ship
GWP (kg CO_2 eq/km)	0.193	0.039	0.011
Primary energy demand (MJ/km)	3.266	0.751	0.17

Impact calculation coefficients for four transport technologies per one ton (Crafford et al., 2018)

Impact category	Truck – present (t_1)	Truck – potential (t_2)	Ship – container (t_3)	Ship - dry bulk (t_4)
GWP (kg CO_2 eq. /km)	0.092	0.088	0.011	0.005
Primary energy demand (MJ/km)	1.550	1.527	0.148	0.065

Transport impact equation

$TI = (m \times t_1 \times d_1) + (m \times t_2 \times d_2) + (m \times t_3 \times d_3) + (m \times t_4 \times d_4)$……………………………..Equation 1

where :

TI = transport impact, in kg CO_2 eq. or MJ

m = mass, in ton;

t_i = transport technology coefficient, either GWP or primary energy;

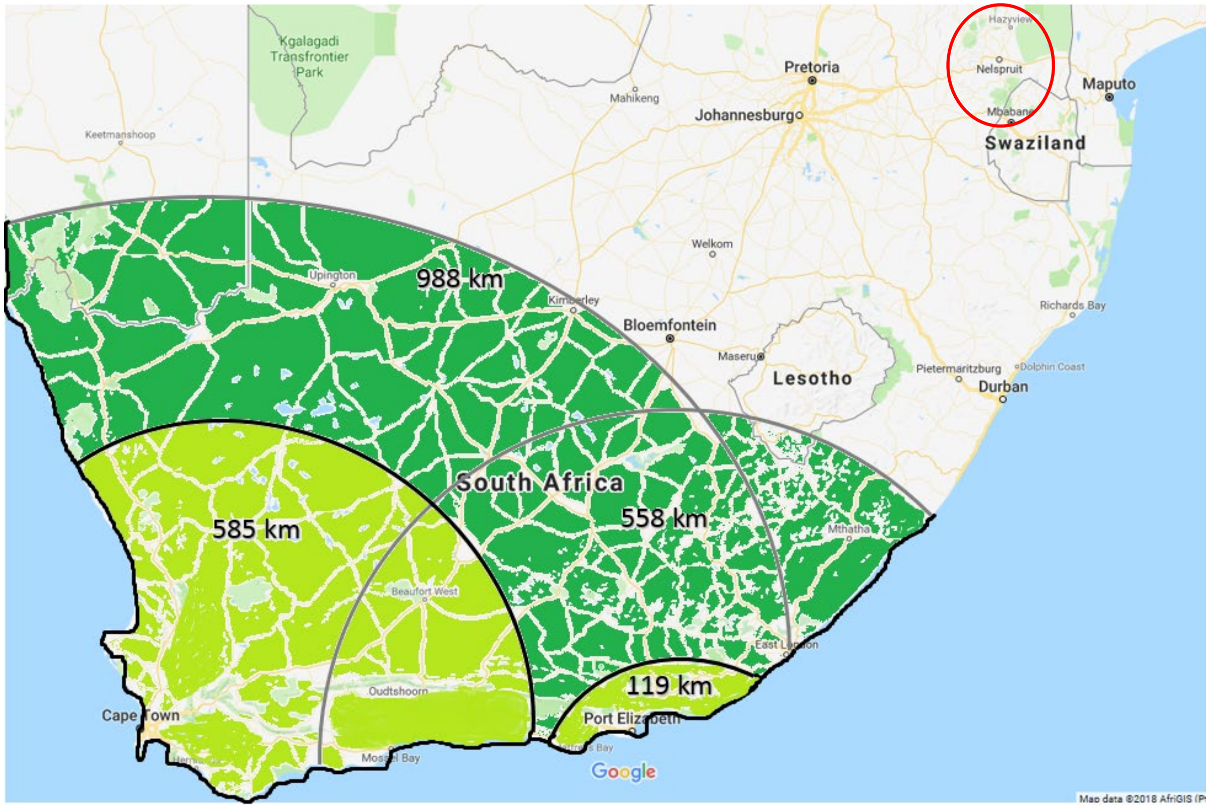
d_i = transport distance per transport technology, in kilometres.

GWP (kg CO_2 eq.) per ton of timber, transported to major markets in SA using container shipping and truck transport (present)

Markets	Timber source							Market share (%)
	Nel-spruit 30 %*	Piet Retief 15 %*	Knysna 5 %*	North Island (NZ)	Canberra (Aus)	Kolmarden (SWE)	Cacador (Brazil)	
Nelspruit	4.60	25.12	136.71	237.72	217.28	238.19	185.08	21.9
JHB	32.02	29.99	104.88	226.68	206.24	227.15	174.04	27.5
DNB	63.20	39.19	107.27	174.52	154.08	174.99	121.88	17.7
PE	125.12	112.70	24.10	176.98	156.54	167.29	114.18	10.6
CPT	160.45	148.58	44.99	183.77	163.33	159.08	106.60	16.4

*Percentage of the total SA timber supply

GWP breakeven border for shipping from Cacador (via Paranagua port) in Brazil to market centres in SA compared to the impact of timber transport from Nelspruit



Conclusion

- JHB, Nelspruit and DNB show lower GWP values per ton km compared with those of CT and PE
- Import to CT and PE show up to a 55 % lower GWP impact than supply by truck transport from Nelspruit
- Increased international resource use - sustainable timber supply to SA
- Future research - electrical transport and other environmental impacts - water pollution, social and economic
- FSC, PEFC or comparable recommend

Scientific outcomes and recommendations

- Environmental benefits of using wood not sufficiently reflected in GB tools
- LCA (truss systems) showed timber systems had overall lowest environmental impact (LGS 40% higher normalized impact)
- SA timber as building material show potential to reduce environmental impacts
- 100% wood based will decrease EE and GWP by 30.4%
- SA wood resources sufficient – moderate to significant expansion
- Major markets well located within current local truck networks and showed lower GWP values per ton km compared to CT and PE – Interim import

Impact and recommendations

Potential impact of this research

- Policy or rating tool modifications - material and building system selection
- Increase timber-based development - significant environmental potential - GHG savings, sustainable resource use
- Growing global trade and certified resources – supports increased timber-based development potential in SA

Recommendations

- Share latest information on sustainable wood use and green building
- Develop easy to use tools, technical resources and accessible platforms for this purpose
- Websites, Social media, etc.

Acknowledgements and contacts

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All my colleagues, friends and family

My heavenly Father for the opportunity to learn, to grow and to persevere

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