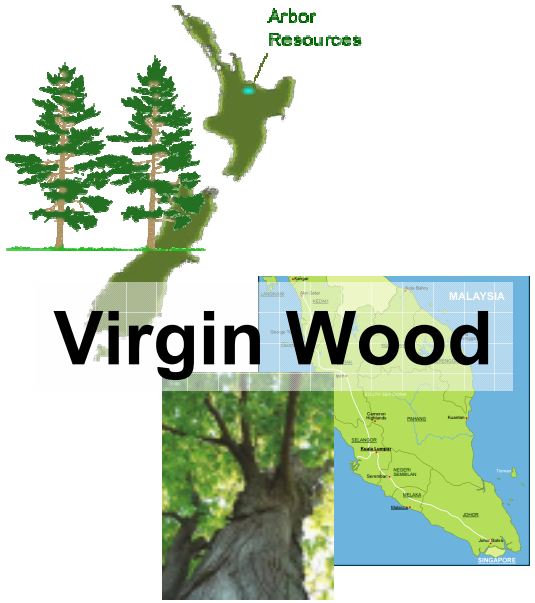
Sustainability Assessment of Applications for Wood Waste and Environmental Assessment of Recycled Technical Wood in Singapore

Ng Ruisheng and Patrick Shi

Sustainability & Technology Assessment Section, 30 June 2010 (Revised version)



The images used in this presentation are taken from internet sources.
They should not be reproduce without the permission of the respective authors.

Project Objectives and Scope

The aims of this project are:

- To assess, quantify and compare the environmental impacts of recycled technical wood with virgin wood in the application of wooden pallet and wooden door using a comparative ***LCA approach***.
- To explore on the environmental feasibility of converting the lower grade wood waste into possible application as biomass for energy.

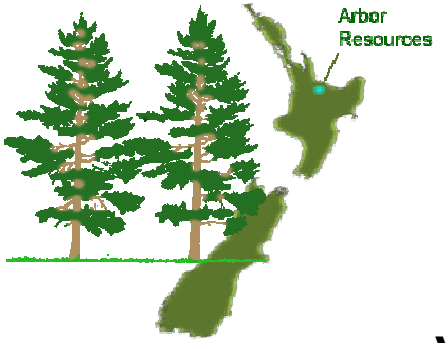
Scope of the project:

- Products identified for the comparative study
  - a standard size 1200 mm X 1000 mm pallet
  - a standard size 2200 mm X 830 mm standard door

- Global Warming Potential Impact Assessment category (GWP_{100}).
- Measures the potential of global warming due to the amount of greenhouse gas (GHG) emissions generated.
- Unit: kg-CO_2eq., the higher the value, the higher the "*environmental burden*".

Life Cycle Assessment of Pallet

Radiata Pine



Wood Waste

Versus

Natural Softwood Pallet

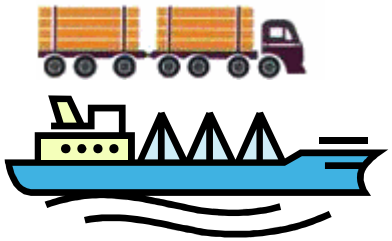
Technical Wood Pallet

Timber Preparation

Natural Softwood

Harvesting & Milling

Transport: Shipped to LHT



Kiln-drying

94.461 kg-CO_2eq / m^3

Technical Wood

Collection of Wood Waste

Wood Waste

Recycling Process

MUF Resin

142.877 kg-CO_2eq / m^3

Pallet Production

Natural Softwood

94.461 kg-CO_2eq / m3

Category	Emissions (kg-CO_2eq / Pallet)
0.02499 m^3 Timber 0.0107 m^3 waste	3.373
36 Steel Nails	0.425
Pallet Assembly	0.115
Post Heat Treatment	0.096
Total for 1 Pallet	4.009

Technical Wood

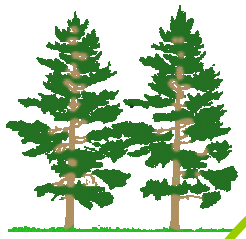
142.877 kg-CO_2eq / m3

Category	Emissions (kg-CO_2eq / Pallet)
0.02425 m^3 Timber 0.0007 m^3 waste	3.572
36 Steel Nails	0.425
Pallet Assembly	0.115
N.A	
Total for 1 Pallet	4.112

Avoided Impact

Natural Softwood

Radiata Pine



Photosynthesis absorbs CO_2

0.03129 m^3 upstream waste

0.02499 m^3 Timber

0.0107 m^3 waste

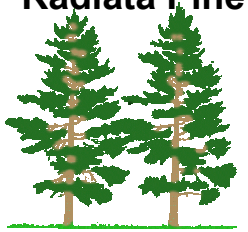
0.067 m^3

Natural Softwood Pallet

Technical Wood

Recycling of wood waste prevented harvesting of Natural Softwood

Radiata Pine



Photosynthesis absorbs CO_2

0.067 m^3 of Riadata Pine continues to store carbon for as long as Technical Wood Pallet can last.

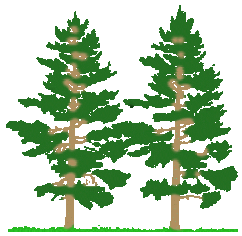
GWP – Cradle to Gate

Natural Softwood		Technical Wood	
Category	Emissions (kg-CO_2eq / Pallet)	Category	Emissions (kg-CO_2eq / Pallet)
 0.02499 m^3 Timber  0.0107 m^3 waste	3.373	 0.02425 m^3 Timber  0.0007 m^3 waste	3.572
 36 Steel Nails	0.425	 36 Steel Nails	0.425
 Pallet Assembly	0.115	 Pallet Assembly	0.115
 Post Heat Treatment	0.096	N.A	
N.A		 Avoided Impact - Carbon Storage for 1 year	- 0.565
 Net Total for 1 Pallet	4.009	 Net Total for 1 Pallet	3.547 11.52% Better

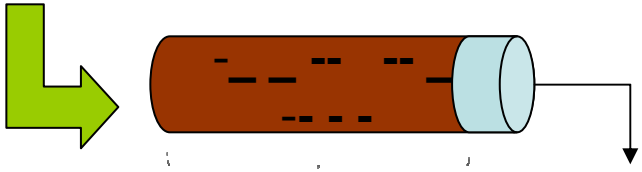
Carbon Sequestration

Natural Softwood

Radiata Pine



Photosynthesis absorbs CO_2



Wood Dry Matter

↓

~50% is carbon

Moisture content

- 0.320 kg-CO_2eq / pallet

Assuming it is stored for 2 years

Technical Wood

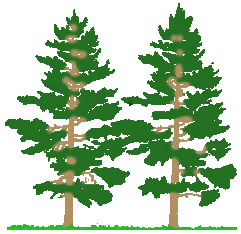
Wood Waste

Carbon is also stored in wood waste

- 0.374 kg-CO_2eq / pallet

Assuming it is stored for 2 years

Avoided Impact due to non-harvesting



Photosynthesis absorbs CO_2

$0.067m^3$ Timber continues to store carbon for another 2 years

- 1.130 kg-CO_2eq / pallet

Net total: - 1.504 kg-CO_2eq / pallet

GWP Comparison at varying Pallet Lifetime

	Pallet Lifetime (Years)				
	1	2	3	4	5
Natural Softwood Pallet ($kg\text{-}CO_2eq/pallet$)	4.009	3.689	3.529	3.369	3.209
Technical Wood Pallet *before* Adjustment ($kg\text{-}CO_2eq/pallet$)	4.112	3.737	3.550	3.363	3.176
Adjustment (Avoided Impact)* ($kg\text{-}CO_2eq/pallet$)	-0.565	-1.130	-1.696	-2.261	-2.826
Technical Wood Pallet *after* Adjustment ($kg\text{-}CO_2eq/pallet$)	3.547	2.607	1.855	1.102	0.350

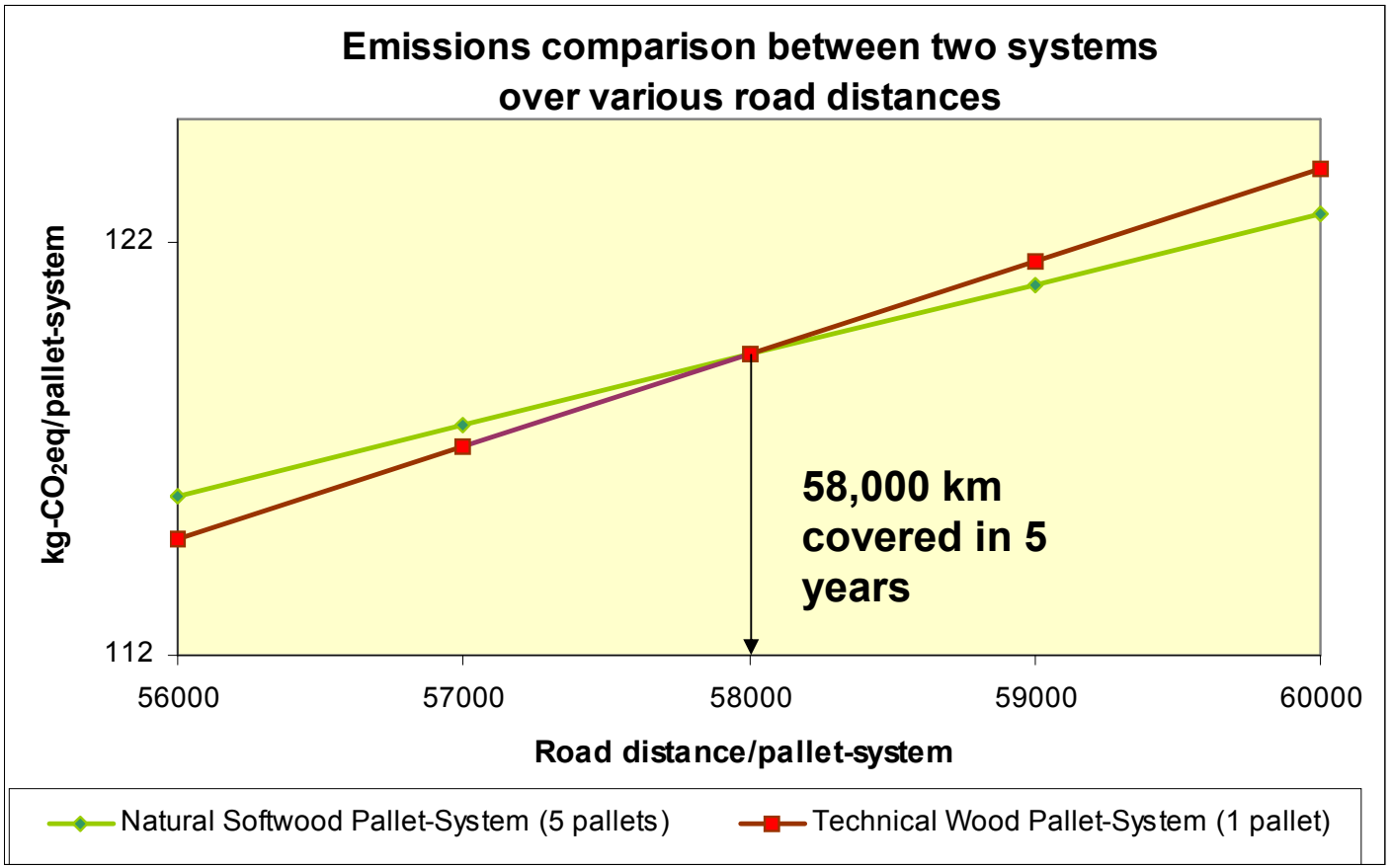
Footnote *

- The avoided impact is due to the non-harvesting of Radiata Pine Tree for Natural Softwood Pallet.
- The longer the Pallet Lifetime of Technical Wood Pallet, the greater the potential avoided impact.
- The avoided impact can only be attributed to the Technical Wood Pallet as savings under scenarios set in this study

What-if Scenario 1 – Increase Pallet Lifetime of Technical Wood Pallet

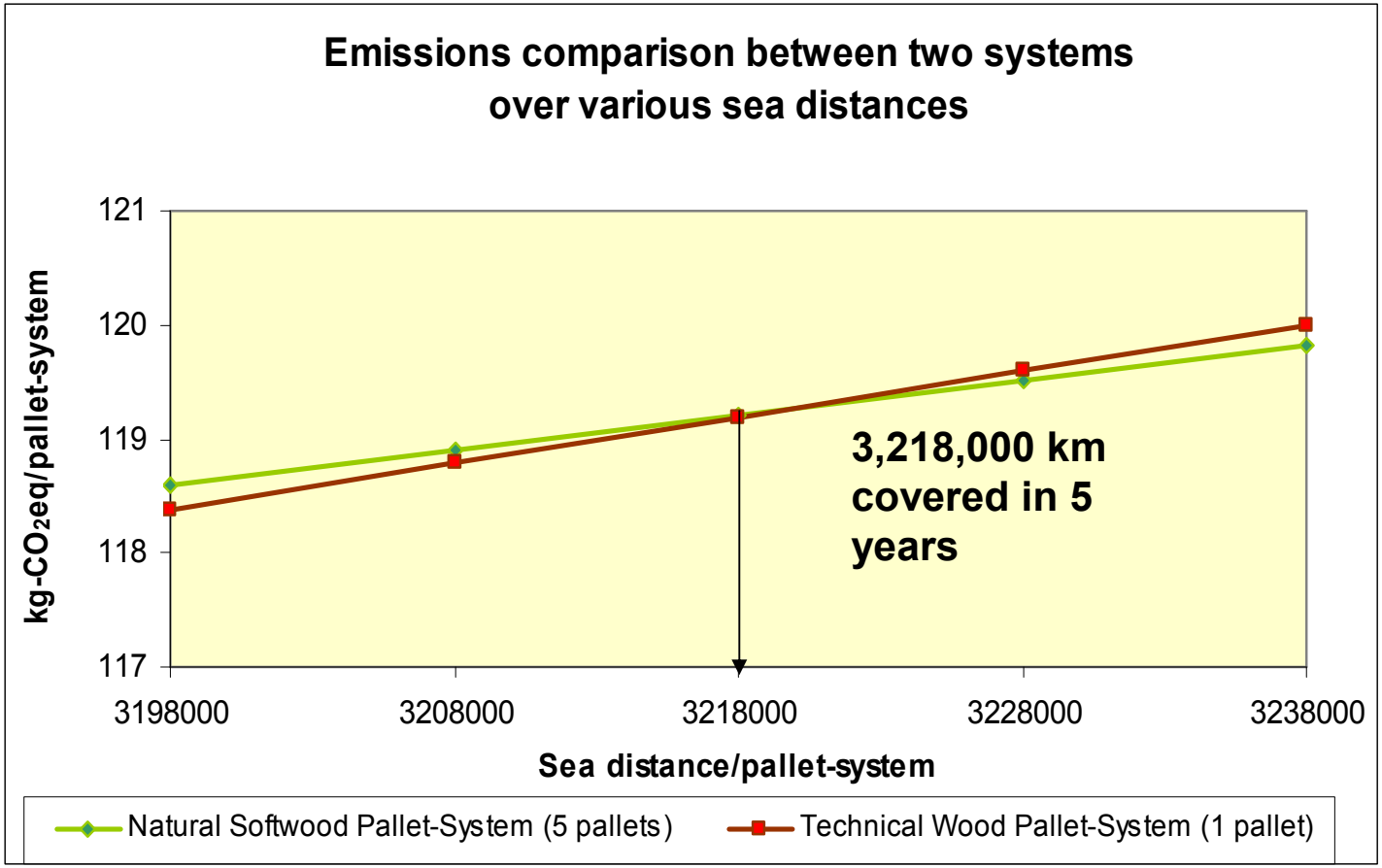
Year	Natural Softwood	Technical Wood
1		 Avoided Impact: 0.067 m^3 Timber
2		Avoided Impact: 0.067 m^3 Timber
3		Avoided Impact: 0.067 m^3 Timber
4		Avoided Impact: 0.067 m^3 Timber
5		Avoided Impact: 0.067 m^3 Timber
		0.335 m^3 Timber store carbon for 5 years
	Total	**Total**
	= 5 pallets x 4.009 kg-CO_2eq/pallet	= 1 pallet x 3.176 kg-CO_2eq/pallet
	= **20.045 kg-CO_2eq/pallet-system**	- 14.130 kg-CO_2eq
		= **- 10.954 kg-CO_2eq/pallet-system**

What-if Scenario 2 – Increase Pallet Lifetime and include Usage (Road Transport)



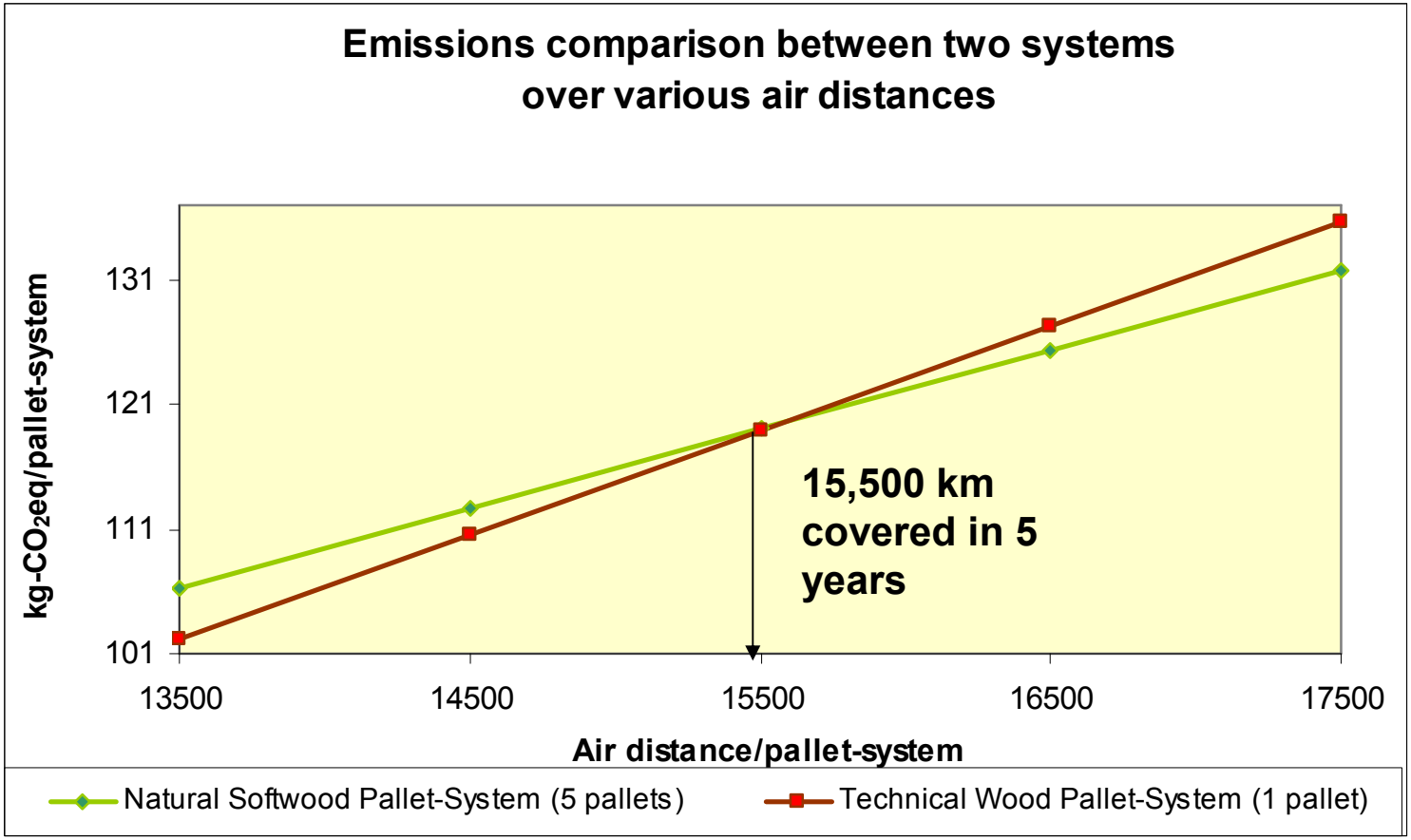
- **On average, a Road distance of 11,600 km is covered per year**
- **This is approximately equivalent to 16 return-trips from Singapore to Kuala Lumpur (Malaysia)**

What-if Scenario 3 – Increase Pallet Lifetime and include Usage (Sea Transport)



- **On average, a Sea distance of 643,600 km is covered per year**
- **This is approximately equivalent to 23 return-trips from Singapore to San Francisco (USA)**

What-if Scenario 4 – Increase Pallet Lifetime and include Usage (Air Transport)



- On average, an Air distance of 2,900 km is covered per year
- This is approximately equivalent to 2 return-trips from Singapore to Penang (Malaysia)

GWP – Emission Factors of Transport

Natural Softwood

Weight = 12.77 kg

Technical Wood

Weight = 16.76 kg

Category	Emissions Factor (kg-CO_2eq / t-km)	Emissions (kg-CO_2eq / Pallet)	Category	Emissions (kg-CO_2eq / t-km)	Emissions (kg-CO_2eq / Pallet)
 Road trip – 100 km	0.134	1.711	 Road trip – 100 km	0.134	2.246
 Sea trip – 1,000 km	2.413e-3	0.031	 Sea trip – 1,000 km	2.413e-3	0.040
 Air trip – 1,000 km	0.500	6.385	 Air trip – 1,000 km	0.500	8.381

Intermediate Conclusions 1

Natural Softwood

94.461 kg-CO_2eq / m^3

4.009 kg-CO_2eq / pallet

x 5

20.045 kg-CO_2eq / pallet-system

Pallet Lifetime = 1 Year

Technical Wood

142.877 kg-CO_2eq / m^3

3.547 kg-CO_2eq / pallet

11.52% reduction

- 10.954 kg-CO_2eq / pallet-system

Pallet Lifetime = 5 Years

Intermediate Conclusions 2

Natural Softwood	Technical Wood
 x 5	
20.045 kg-CO_2eq / pallet-system	- 10.954 kg-CO_2eq / pallet-system
Pallet Lifetime = 1 Year	Pallet Lifetime = 5 Years

Include Usage (Road Transport)

Technical Wood Pallet-System has lower GWP if it covers Road distance that is less than 58,000 km in 5 years

Include Usage (Sea Transport)

Technical Wood Pallet-System has lower GWP if it covers Sea distance that is less than 3,218,000 km in 5 years

Include Usage (Air Transport)

Technical Wood Pallet-System has lower GWP if it covers Air distance that is less than 15,500 km in 5 years

Life Cycle Assessment of Door

Kapur/Nyatoh

Wood Waste

Versus

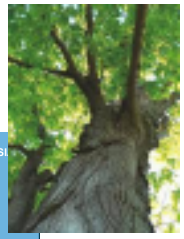
Natural Hardwood Door

Technical Wood Door

Timber Preparation

Natural Hardwood

Harvesting & Milling



Transport to LHT

Kiln-drying

131.181 kg-CO_2eq / m^3

Technical Wood

Collection of Wood Waste

Wood Waste

Recycling Process

MUF Resin

143.294 kg-CO_2eq / m^3

Door Production

Natural Hardwood

131.181 kg-CO_2eq / m3

Category	Emissions (kg-CO_2eq / Door)
 0.026316 m^3 Timber  0.026316 m^3 waste	6.904
 Door Production	11.519
 Impregnation	0.306
 Fire Retardant	0.008
 Post Heat Treatment	0.121
 Total for 1 Door	18.858

Technical Wood

143.294 kg-CO_2eq / m3

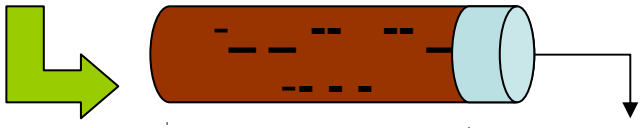
Category	Emissions (kg-CO_2eq / Door)
 0.026316 m^3 Timber  0.000814 m^3 waste	3.888
 Door Production	11.519
N.A	
N.A	
N.A	
 Total for 1 Door	15.406

Carbon Sequestration

Natural Hardwood

Kapur

Photosynthesis absorbs CO_2



Moisture content

Wood Dry Matter

↓

~50% is carbon

- 2.619 kg-CO_2eq / Door

Assuming it is stored for 10 years

Technical Wood

Wood Waste

Carbon is also stored in wood waste

- 2.574 kg-CO_2eq / Door

Assuming it is stored for 10 years

Avoided Impact due to non-harvesting

Photosynthesis absorbs CO_2

0.0526 m^3 Timber continues to store carbon for another 10 years

- 15.772 kg-CO_2eq / Door

Net total: - 18.346 kg-CO_2eq / Door

GWP – Cradle to Gate

Category	Emissions (kg-CO_2eq / Door)	Category	Emissions (kg-CO_2eq / Door)
 0.026316 m^3 Timber  0.026316 m^3 waste	6.904	 0.026316 m^3 Timber  0.000814 m^3 waste	3.888
  Door Production	11.519	  Door Production	11.519
  Impregnation	0.306	N.A	
 Fire Retardant	0.008	N.A	
  Post Heat Treatment	0.121	N.A	
 Carbon Storage for 10 years	- 2.619	 Carbon Storage for 10 years (< dry matter)	- 2.574
N.A		 Avoided Impact - Carbon Storage for 10 years	- 15.772
 Total for 1 Door	16.239	 Total for 1 Door	- 2.940 118% Better

GWP Comparison at varying Door Lifetime

	Door Lifetime (Years)				
	10	15	20	25	30
Natural Hardwood Door (kg-CO_2eq/door)	16.239	14.929	13.620	12.310	8.519
Technical Wood Door *before* Adjustment (kg-CO_2eq/door)	12.832	11.545	10.258	8.971	5.245
Adjustment (Avoided Impact)* (kg-CO_2eq/door)	-15.772	-23.659	-31.545	-39.431	-47.317
Technical Wood Door *after* Adjustment (kg-CO_2eq/door)	-2.940	-12.114	-21.287	-30.460	-42.072

Footnote *

- The avoided impact is due to the non-harvesting of Kapur/Nyatoh Tree for Natural Hardwood Door .
- The longer the Lifetime of Technical Wood Door, the greater the potential avoided impact.
- The avoided impact can only be attributed to the Technical Wood Door as savings under scenarios set in this study

Intermediate Conclusions 3

Natural Hardwood

131.181 kg-CO_2eq / m^3

16.239 kg-CO_2eq / door

30 years

8.519 kg-CO_2eq / door

Technical Wood

143.294 kg-CO_2eq / m^3

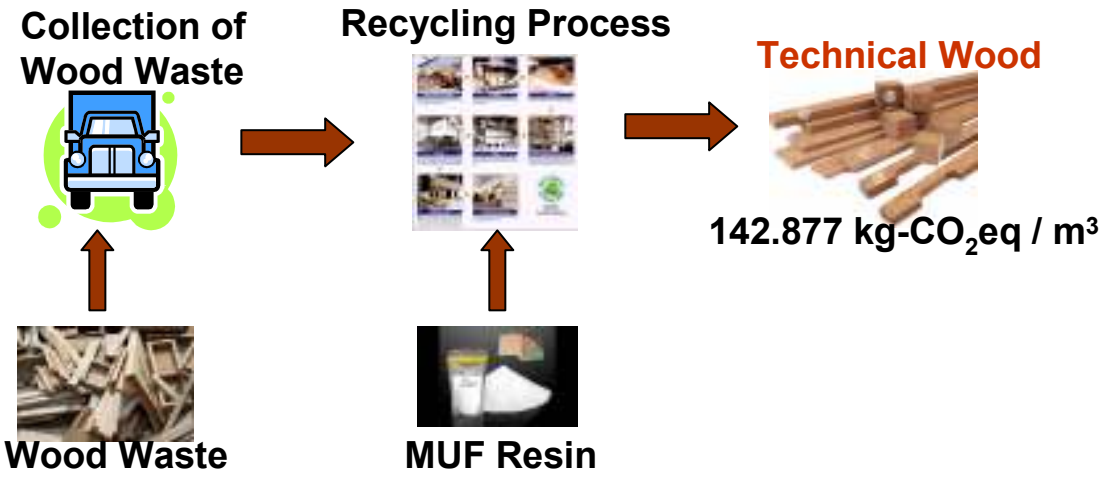
-2.940 kg-CO_2eq / door

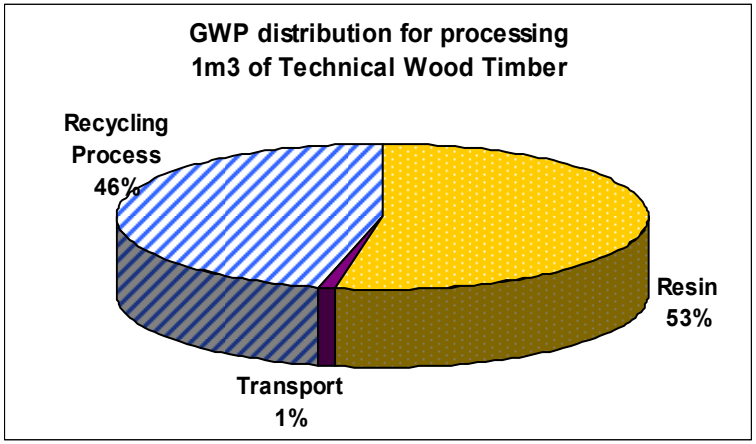
118% reduction

30 years

-42.072 kg-CO_2eq / door

Recommendation 1 – Alternative Energy Source

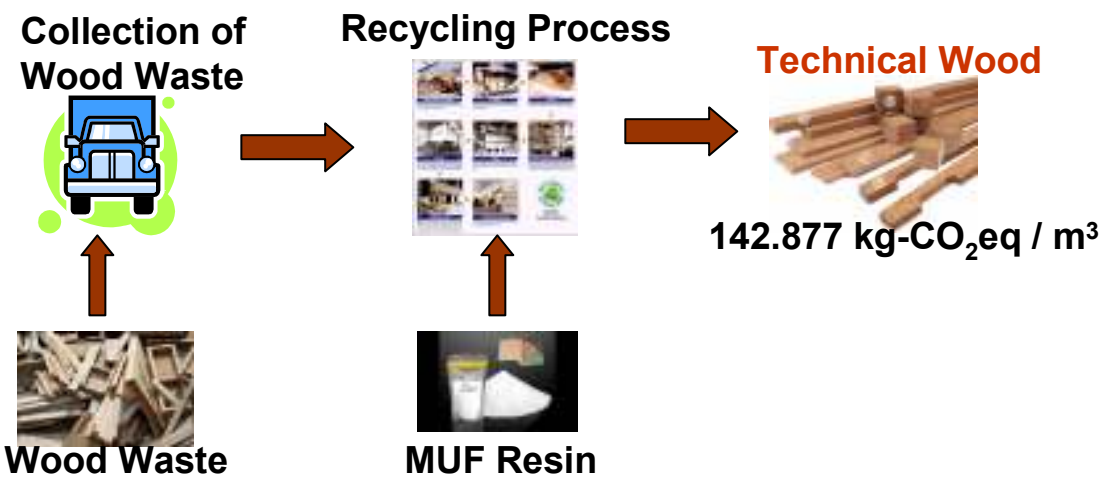


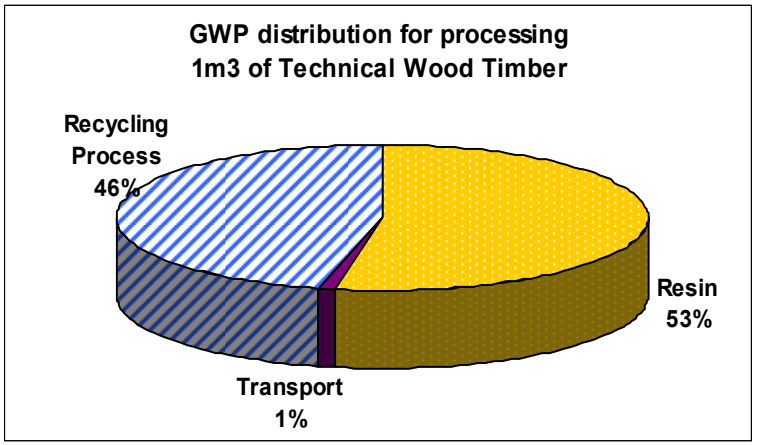


Emissions by using alternative Energy Source for Recycling Process

Energy Source	Emissions Factor (kg-CO_2eq/kWh)	Emissions (kg-CO_2eq/m^3)	% Change	Emissions (kg-CO_2eq/pallet)	% Change
Electricity	0.5759	215.306	+ 50.69	5.622	+ 47.52
Natural Gas	0.2742	142.877	Baseline	3.547	Baseline
Woody Biomass	0.0085	79.120	- 44.62	1.953	- 44.94

Recommendation 2 – Use Resin Alternatives





Emissions by using Resin Alternatives

Resin Type	Emissions (kg-CO_2eq/m^3)	% Improvement	Emissions (kg-CO_2eq/pallet)	% Improvement
MUF	142.877	Baseline	3.547	Baseline
MUF-1241	133.999	6.21	3.325	6.26
UF-1205	133.087	6.85	3.302	6.91
UF-1206	134.725	5.71	3.343	5.75

Resin Alternatives Information

Company Name: Casco Adhesives (Asia) Pte Ltd
Address: 14 Sungei Kadut Way, Singapore 728788
Phone: + 65 6762 2088
Fax: + 65 6365 5852
E-mail: info_sig@akzonobel.com

Resin Type	Applicability
MUF-1241	• A wood adhesive for laminated beams, which gives a light coloured joint. • It is always used with hardener 2542. • It is suitable for load-bearing structure (subject to approval)
UF-1205	• A wood adhesive, which must be used with a hardener. • Free formaldehyde is 0.7 %. • It is widely used in the European wood working industry for example for flooring, block glueing, furniture, veneering and so on. • It is mostly cured in hot- or high frequency presses, but with suitable hardeners it can also be used at room temperature.
UF-1206	• A wood adhesive, which must be used with a hardener. • Free formaldehyde is 0.7 %. • It is widely used in the European wood working industry for example for flooring, block glueing, furniture, veneering and so on. • It is mostly cured in hot- or high frequency presses, but with suitable hardeners it can also be used at room temperature.

Biomass

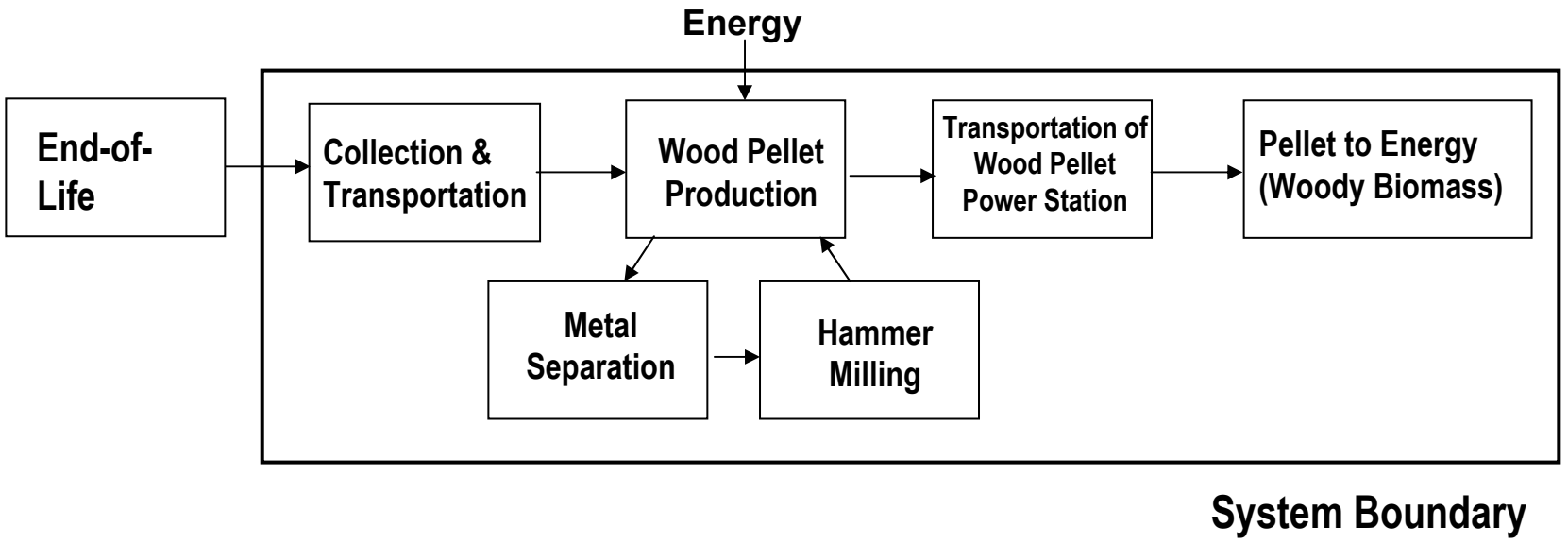
The aims of this project are:

- To assess, quantify and compare the environmental impacts of recycled technical wood with virgin wood in the application of wooden pallet and wooden door using a comparative *LCA approach*.
- **To explore on the environmental feasibility of converting the lower grade wood waste into possible application as biomass for energy.**

Wood Waste

BIOMASS
ENERGY

System Boundary - Biomass



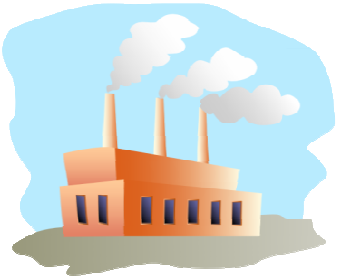
Emissions for biomass production

Total 11.857 kg-CO_2 eq

Wood Waste

Pellet processing

4.488 kg-CO_2 eq



Power Station

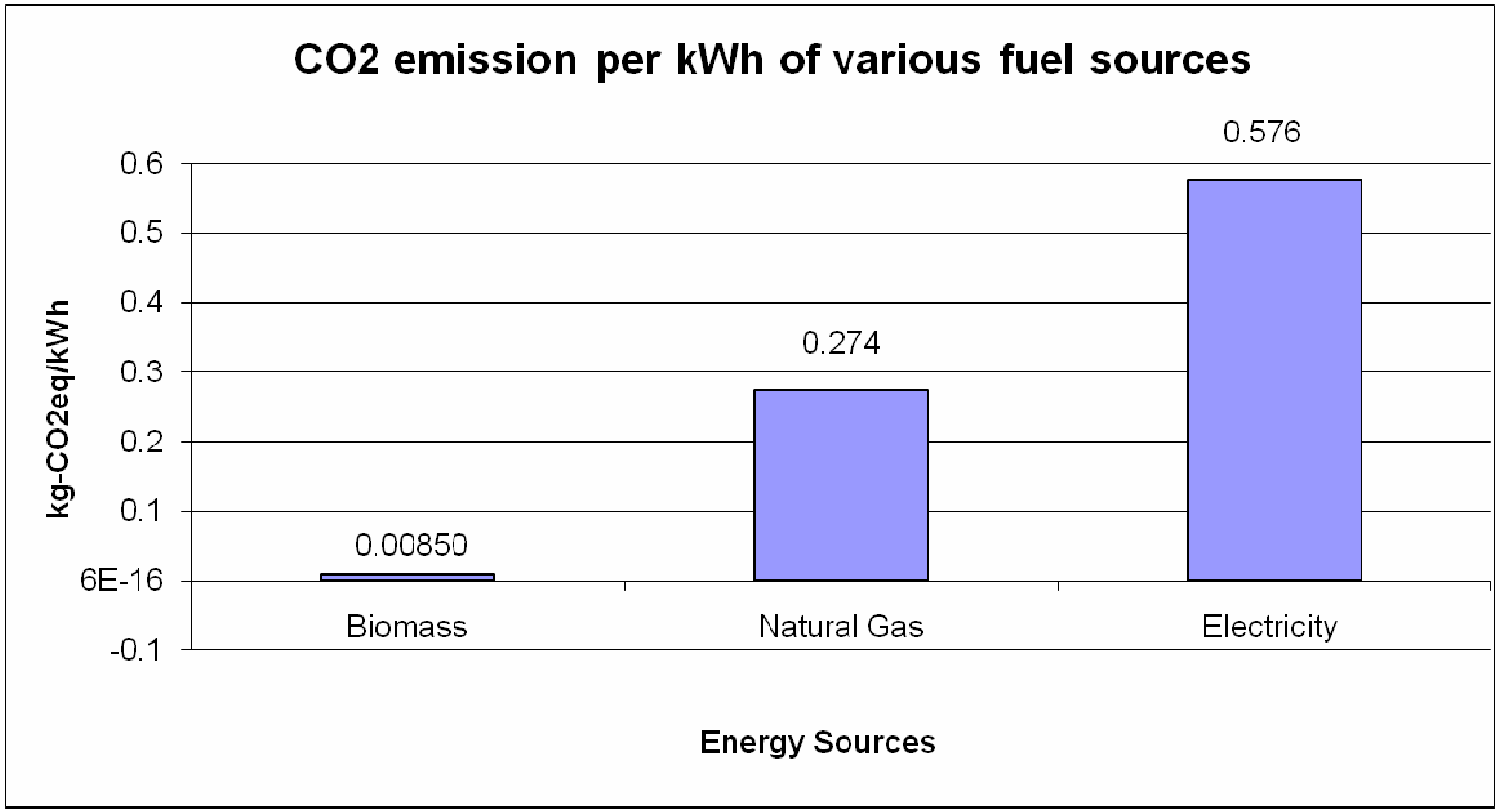
Collection of Wood Waste

4.689 kg-CO_2 eq

Transportation of pellets

2.680 kg-CO_2 eq

Emissions for biomass production



Wood Waste investigation

Materials	HHV (MJ/kg)	LHV (MJ/kg)
Wood Waste	16.8	16.6

Materials	C%	H%	N%	S%	O%
Wood Waste	45.42	6.00	0.91	< 0.5	32.55

Materials	Moisture %	Volatiles %	Fixed Carbon %	Ash%
Wood Waste	8.88	56.39	28.37	6.24

Biomass Conclusion

1. Distance travelled to collect the waste wood is relatively short thus low carbon emission in transportation.
2. Collected waste wood need not be dried to reduce the moisture which translates to low energy consumption in producing of biofuel.
3. Waste wood from LHT factory is recycled to biomass thus no carbon emission in transporting of biomass and also the cost of disposal.
4. Distance to the power plant is relative short thus low carbon emission in transportation.

Questions?