DigiNatal
Born Digital
eBook & eZine Publishing

A *'Distributed'* and Comparative Life-Cycle Inventory for 'Paradigm Progress' by Ravi Karumanchiri

With Modelled Delivery to Los Angeles, California, USA

SYNERLUX
Combined Insight

eBook Edition Delivered as a Digital Download Over the Internet

Scenario #1

eBook Energy & Emissions

To estimate the energy requirements and the emissions that result from the purchase and delivery of our eBooks over the internet; we have relied on the research presented by Christopher L. Weber, Jonathan G. Koomey, and H. Scott Matthews; in their article entitled "The Energy and Climate Change Implications of Different Music Delivery Methods", published in the **'Journal of Industrial Ecology'** (2010, Yale University, Volume 14, Number 5). These researchers applied and/or established a number of statistics that informed our calculations, and we are very grateful to be able to draw on their work.

This means, on average, the online purchase and digital download of 'Paradigm Progress' entails 0.194 kg (0.427 lbs.) of carbon dioxide emissions.

eBook Edition	Electronic File Size	Transaction Data	Internet Power Usage	On-Site Power Usage	Computer Mfg Energy Req't	TOTAL POWER	Carbon Dioxide Emissions
.pdf	0.99 MB	2 MB	0.02093 kWhr	0.2 kWhr	0.08 kWhr	0.30093 kWhr	0.196 kg
.epub	0.389 MB	2 MB	0.01672 kWhr	0.2 kWhr	0.08 kWhr	0.29672 kWhr	0.193 kg
.mobi	0.449 MB	2 MB	0.01714 kWhr	0.2 kWhr	0.08 kWhr	0.29714 kWhr	0.193 kg
Average ▶	**0.609 MB**		**0.018 kWhr**			**0.298 kWhr**	**0.194 kg**

'Total Power' is the sum of 'Internet Power Usage', 'On-Site Power Usage' and the 'Computer Manufacturing Energy Requirement'.

This 'distributed' and comparative life-cycle inventory details the resource requirements and the emissions that would result from the production and delivery of the book entitled 'Paradigm Progress' to the 'LAPL - Central Library' located at 630 West 5th Street, Los Angeles, California, USA (90045-5648). Three different scenarios are examined. The first is for an 'eBook' edition delivered electronically, over the internet, as a digital download. The second scenario models for a hard cover edition of the same book, also bought online but delivered via multi-modal shipping that includes air freight. The third scenario similarly models for a hard cover edition, but this time delivered exclusively by truck. The second and third scenarios both include a corrugated box.

To do this, we have based our analytical estimates on the findings of peer-reviewed research studies and published life-cycle analyses; and on estimates produced by experts in the field, as well as respected non-governmental organizations, regulatory agencies, and preeminent standard-setting organizations. Whenever possible, our analytical estimates are based on actual measurements. Wherever necessary, we have made the most conservative assumptions that we could reasonably make.

As an electronic publishing house, we at 'DigiNatal Publishing' make no qualms about our preference for eBooks. However, in compiling these three 'cradle-to-gate' life cycle inventories, we have applied very conservative estimates in the interest of being *more-than-fair.*

At present, we have relied upon two 'organic gas species profiles' to do this (and we intend to add more profiles in the near future). For aviation emissions of NMVOCs; we have relied upon the profile published in "Recommended Best Practice for Quantifying Speciated Organic Gas Emissions from Aircraft Equipped with Turbofan, Turbojet, and Turboprop Engines, Version 1.0" by the 'Assessment and Standards Division Office of Transportation and Air Quality', U.S. Environmental Protection Agency, and 'AEE-300 - Emissions Division' at the 'Office of Environment and Energy', 'Federal Aviation Administration' (in the United States). (Publication ID: EPA-420-R-09-901 May 2009). For trucking emissions of NMVOCs; we have relied upon the data published by the United States Environmental Protection Agency in their "Speciate Data Browser, version 4.2" as profile #2563 - 'Roadway - Vehicle Exhaust Emissions - Raleigh' (with the added assumption that the 50.55% unidentified portion, by weight, is actually 'isobutene/1-butene' (CAS 106-98-9), which has an approximately average hydrogen/carbon ratio as seen among the identified speciate constituents in this profile). Accordingly, the isobutene/1-butene emissions identified for trucking logistics should be considered as suspect, even while they may arguably be considered suitable for our purposes of correcting the carbon balance of our emissions profiles. This profile #2563 is available online at http://cfpub.epa.gov/si/speciate/index.cfm. By applying the 'mass fractions' identified in these two organic gas speciate profiles, we were able to calculate the carbon dioxide equivalent emissions that we needed to subtract from the emission factor-derived quantities of carbon dioxide, in order to bring our emissions profile into stoichiometric balance (thereby avoiding the error of double-counting carbonaceous emissions). The final results of these calculations are reported here, in this poster-report.

This life cycle inventory was last updated on Monday, September 5, 2011.

If you know of some error or problem with this life cycle inventory, or if you have a suggestion for how we can improve it, please let us know by contacting us through either of our websites.

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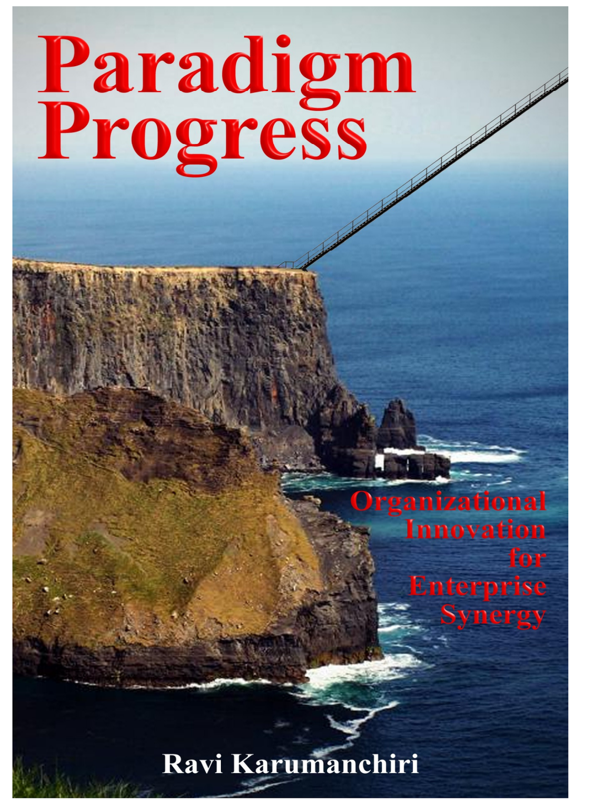
www.synerlux.com



Hardcopy Editions and their Shipping Boxes

Hardcopy Material Resources & Emissions

Environmental impact estimates for forest-source materials used in hardcopy book production and for packaging materials, are based on the Environmental Paper Network Paper Calculator. For more information visit http://www.papercalculator.org

# Element	Material Type	Material Utilization	Gross Material Usage	Scrappage	Net Material Shipped	Virgin Material	Recycled Material	
1 Cover Jacket	Coated Freesheet	16.5" x 9.25" x 1 pg @ 111 GSM (w/ 30% recycled & 70% virgin mat'l)	17.0 grams	6.1 grams	10.9 grams	12 grams	5 grams	See Note #1
2 Cover	Uncoated Unbleached Kraft Paperboard	6.25" x 9.25" x 2 pg @ 352 GSM (w/ 90% recycled & 10% virgin mat'l)	39.3 grams	13.1 grams	26.2 grams	4 grams	35 grams	See Note #2
3 Cover Outer Facing	Coated Freesheet	14" x 10" x 1 pg @ 47 GSM (w/ 30% recycled & 70% virgin mat'l)	9.7 grams	5.4 grams	4.3 grams	7 grams	3 grams	See Note #3
4 Cover Inner Facing	Uncoated Freesheet	12.38" x 9" x 2 pg @ 96 GSM (w/ 30% recycled & 70% virgin mat'l)	14.7 grams	0.9 grams	13.8 grams	10 grams	4 grams	See Note #4
5 Main Text Guts	Uncoated Freesheet	6.19" x 9" x 160 pg @ 104 GSM (w/ 40% recycled & 60% virgin mat'l)	635.0 grams	39.2 grams	595.8 grams	381 grams	254 grams	See Note #5
6 Shipping Box	Unbleached Corrugated	13" x 20" x 1 pc (w/ 100% recycled & 0% virgin mat'l)	52.8 grams	Not Included	54.6 grams *w/ glue	0 grams	53 grams	See Note #6

#	Wood Use	Net Energy	Purchased Energy	Sulphur Oxides	Greenhouse Gases	Nitrogen Oxides	Particulates	Hazardous Air Pollutants	Volatile Organic Compounds	Total Reduced Sulphur	Wastewater	Biochemical Oxygen Demand	Suspended Solids	Chemical Oxygen Demand	Solid Waste
1	37 grams	157 watt-hours	124 watt-hours	0.2 grams	46 grams	0.08 grams	0.04 grams	0.02 grams	0.02 grams	0.003 grams	1.2 litres	0.06 grams	0.1 grams	0.2 grams	17 grams
2	14 grams	260 watt-hours	218 watt-hours	0.4 grams	60 grams	0.1 grams	0.05 grams	0.02 grams	0.03 grams	0.001 grams	482 millilitres	0.09 grams	0.1 grams	0.07 grams	11 grams
3	21 grams	89 watt-hours	71 watt-hours	0.1 grams	26 grams	0.04 grams	0.02 grams	0.01 grams	0.01 grams	0.002 grams	678 millilitres	0.04 grams	0.07 grams	0.09 grams	10 grams
4	39 grams	139 watt-hours	104 watt-hours	0.2 grams	39 grams	0.07 grams	0.04 grams	0.02 grams	0.02 grams	0.003 grams	1.1 litres	0.07 grams	0.1 grams	0.2 grams	13 grams
5	1.4 kgs	5.8 kilowatt-hours	4.5 kilowatt-hours	8 grams	1.6 kgs	3 grams	2 grams	0.6 grams	0.8 grams	0.1 grams	46.3 litres	3 grams	5 grams	7 grams	515 grams
6	0.0000 grams	335 watt-hours	330 watt-hours	0.6 grams	69 grams	0.2 grams	0.07 grams	0.05 grams	0.04 grams	0.003 grams	442 millilitres	0.1 grams	0.1 grams	0.06 grams	3 grams
Totals	1.5 kgs	6.7 kilowatt-hours	5.3 kilowatt-hours	10 grams	1.8 kg	3 grams	2 grams	0.8 grams	0.9 grams	0.1 grams	50.3 litres	3 grams	5 grams	8 grams	568 grams

Hardcopy Logistics Energy & Emissions

Delivered via Multi-Modal Shipping Including Air-Freight

Scenario #2

Segment	Leg 1 of 3		AVIATION Leg 2 of 3		Leg 3 of 3		-	-	-	-	-
Vehicle	Heavy-Duty Truck		Boeing 767-300		Heavy-Duty Truck		-	-	-	-	-
Fuel	0.7 g of Diesel Oil		452.4 g of Jet Kerosene		0.7 g of Diesel Oil		-	-	-	-	-
Distance	26.9 km (16.7 miles)		3,812.7 km (2,058.7 nautical miles)		27.7 km (17.2 miles)		-	-	-	-	-
Carbon Dioxide	2.2 grams	See Note #17	1.5 kgs	See Note #45	2.3 grams	See Note #64	-	-	-	-	-
Carbon Monoxide	11.2 miligrams	See Note #18	3.9 grams	See Note #46	10.3 miligrams	See Note #65	-	-	-	-	-
Methane	0.1 miligrams	See Note #19	-	See Note #47	0.1 miligrams	See Note #66	-	-	-	-	-
Nitrogen Oxides	17.8 miligrams	See Note #20	7.0 grams	See Note #48	8.3 miligrams	See Note #67	-	-	-	-	-
Nitrous Oxide	0.1 miligrams	See Note #21	49.2 miligrams	See Note #49	0.1 miligrams	See Note #68	-	-	-	-	-
NMVOCs	2.5 miligrams	See Note #22 & #10	341.6 miligrams	See Note #50 & #26	2.0 miligrams	See Note #69 & #57	-	-	-	-	-
Sulphur Oxides	-		484.0 miligrams	See Note #51	-		-	-	-	-	-

We model that this 'Scenario #2' requires three separate major logistical 'legs' (excluding ground handling equipment at airports, conveyor systems, tow motors, forklifts and other pieces of transportation equipment deemed to have had only a very minor part to play in this delivery).

Scenario #2 Multi-Modal Shipping Totals

- 1.5 kgs of Carbon Dioxide
- 3.9 grams of Carbon Monoxide
- 0.2 miligrams of Methane
- 7.1 grams of Nitrogen Oxides
- 49.4 miligrams of Nitrous Oxide
- 346.1 miligrams of NMVOCs
- 484.0 miligrams of Sulphur Oxides

Delivered via Ground-Only Shipping End-to-End via Truck on a Direct Route

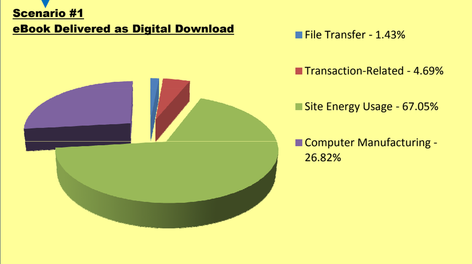
Scenario #3

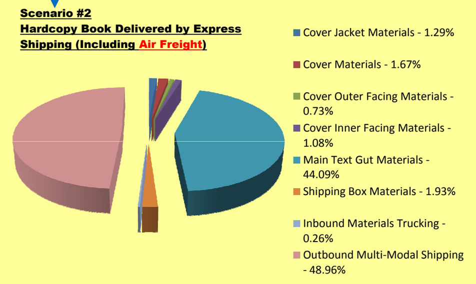
Segment	Scenario #3 All-Truck	
Vehicle	Heavy-Duty Truck	
Fuel	107.7 g of Diesel Oil	
Distance	4,062.0 km (2,524.0 miles)	
Carbon Dioxide	336.1 grams	See Note #80
Carbon Monoxide	1.5 grams	See Note #81
Methane	15.1 miligrams	See Note #82
Nitrogen Oxides	1.2 grams	See Note #83
Nitrous Oxide	8.6 miligrams	See Note #84
NMVOCs	299.3 miligrams	See Note #85 & #73
Sulphur Oxides	-	

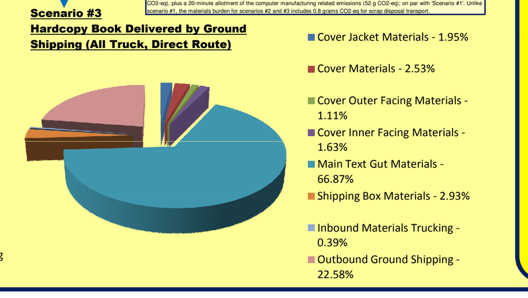
ALL-ROAD delivery from: Fictitious Print Plant @ 11 Havenbrook Blvd., Toronto, Ontario, Canada (M2J 1A5); to: LAPL - Central Library @ 630 West 5th Street, Los Angeles, California, USA (90045-5648). The 'all-road' delivery scenario we modelled also involves the transport of a 0.71 kg (1.56 Lb.) package; HOWEVER, for a total distance of 4,062 km (2,524 miles), establishing a 'workload' for this end-to-end delivery of 2.87 metric-tonne kilometres. After factoring for the energy requirements of the 'Heavy-Duty Truck' we modelled for, the need for 4,586 kilojoules of energy is established, which is the fuel equivalent of 0.11 kg of diesel oil (assuming an NCV of 42,600 KJ/kg). By applying the '2006 IPCC Guidelines for National Greenhouse Gas Inventories'; but using an even more precise method than the one suggested there; we calculated our 'base carbon dioxide emissions' using a CO2 intensity factor of 74 mg CO2 per kilojoule of fuel combusted (at 100% oxidation). We also drew on a select panel of emissions factors to model other emissions, including; carbon monoxide (CO), methane (CH4), nitrogen oxides (NO+NO2), nitrous oxide (N2O), and non-methane volatile organic compounds (NMVOCs). Because the CO, CH4 and NMVOCs all contain carbon, we then reduced our 'base CO2 estimate' to bring all of our emissions estimates into 'stoichiometric balance'. The resulting emissions profile is as follows:

Comparing the Greenhouse Gas (GHG) Emissions from the Purchase and Delivery of an eBook versus a Hardcopy Book

Logistical Greenhouse Gas Emissions ▼	Scenario #1 Internet Delivery Gas Emissions	Scenario #2 Multi-Modal Shipping Gas Emissions	Scenario #3 All-Truck ONLY Gas Emissions	Global Warming Potential	Scenario #1 Internet Delivery CO2-eq Emissions	Scenario #2 Multi-Modal Shipping CO2-eq Emissions	Scenario #3 All-Truck ONLY CO2-eq Emissions
Carbon Dioxide	0.194 kg	1.5 kgs	336.1 grams	1	0.194 kg	1.5 kgs	336.1 g
Carbon Monoxide	-	3.9 grams	1.5 grams	1.9	-	7.4 g	2.9 g
Methane	-	0.2 miligrams	15.1 miligrams	25	-	5.4 mg	376.8 mg
Nitrous Oxide	-	49.4 miligrams	8.6 miligrams	298	-	14.7 g	2.6 g
				Purchase & Delivery	0.194 kg	1.75 kgs	533 g
				Materials	0	1.8 kg	1.8 kg
				TOTAL	**0.194 kg**	**3.58 kgs**	**2.36 kgs**







To compare the environmental impacts of eBooks and traditional hardcopy books is difficult, because eBooks are intangible and are delivered over the internet, while traditional books are concrete and are delivered by vehicles. To make this comparison, what is needed is a "common denominator" to serve as an objective measurement of both eBooks and hardcopy books. We believe that the ideal measure to serve this purpose is the "GHG footprint" of these reading materials, which we have calculated in this section. CONSIDER: As per the multi-modal freight 'Scenario #2'; the production and delivery of a hard cover copy of 'Paradigm Progress' (plus corrugated packaging), to this specific location, entails approximately 3.58 kgs of carbon dioxide equivalent emissions. This makes 'Scenario #2' approximately 18.5 times more CO2-emissions 'intensive' than the digital download 'Scenario #1'. Choosing to buy the eBook edition as a digital download, instead of the hardcopy edition delivered by multi-modal (express) shipping can avoid approximately 3.4 kgs of carbon dioxide equivalent emissions. Now consider the truck-only freight 'Scenario #3'; where the production and delivery of a hard cover copy of 'Paradigm Progress' (plus corrugated packaging), to this specific location, entails approximately 2.36 kgs of carbon dioxide equivalent emissions. This makes 'Scenario #3' approximately 12.2 times more CO2-emissions 'intensive' than the digital download 'Scenario #1'. Choosing to buy the eBook edition as a digital download, instead of the hardcopy edition delivered by truck can avoid approximately 2.2 kgs of carbon dioxide equivalent emissions.

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