THE UNIVERSITY OF TEXAS AT TYLER

College of Engineering

Environmental Considerations of Recycled Concrete Aggregates (RCA) for Improved Sustainability of Reinforced Concrete Building Structures

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AGGREGATES

http://www.vulcanmaterials.com/

Background

- Nonrenewable Resource
- Depleted (the easy to get ones)
- 40 to 50% by volume of concrete
- Construction projects use about 3 billion tons/year of natural aggregates in the U.S. alone
- Old Infrastructure
- Landfill Material

http://www.dtmsoftware.com/mine-and-quarry/

What is RCA?

/http://news.thomasnet.com/imt/2012/10/31/used-concrete-once-for-the-landfill-now-heads-to-recycling-facilities

Background

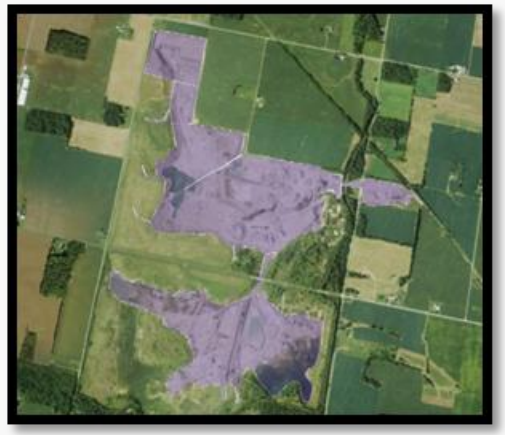
- Little or no previous work exists to quantify the economic and environmental benefits of using RCA in structural applications.
- Little or no previous works exists on the service and ultimate load performance of prestressed and non-prestressed concrete structures utilizing RCA from U.S. sources.
- Even though RCA can readily pass the prescriptive requirements for coarse aggregates in structural concrete (ASTM C33 2008), the variability in material properties and quality needs to be quantified and incorporated into design.
- As a result, no engineering guidelines/standards currently exists for the design and construction of reinforced concrete utilizing RCA.

Presentation Outline

- Quantify land use required to produce NA & RCA
- Quantify water consumption to produce NA & RCA
- Characterize transportation distances for NA and RCA
- Estimate CO2 and energy consumption
- Present an overall environmental impact index for RCA

Natural Aggregate Land Use

Site A



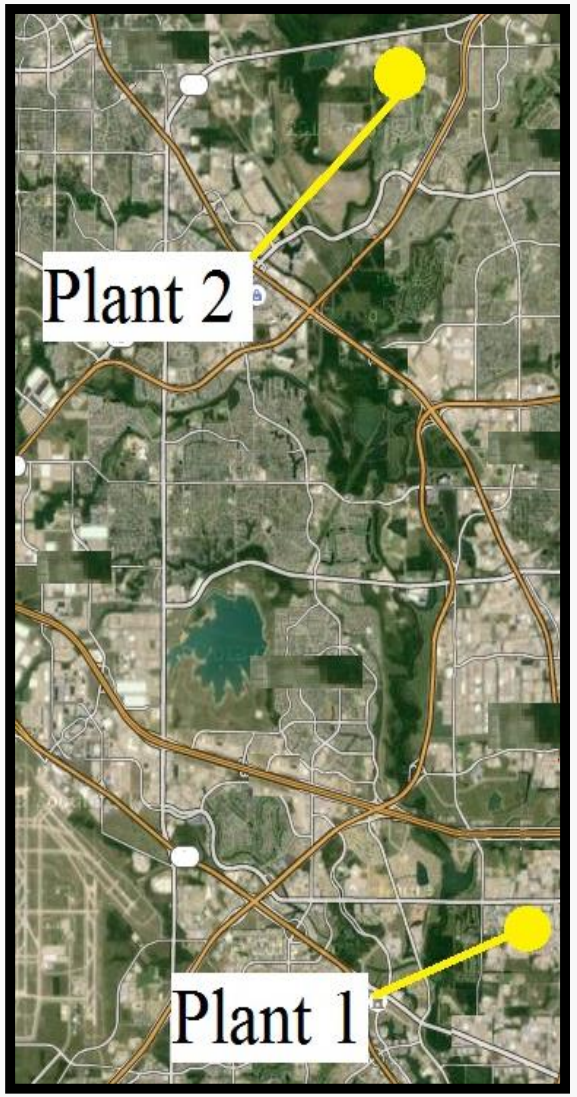
Site B

Site C

Site	Tons	ft2/Ton	Tons/ft2	Tonds/yd2	Tons/Acre
A	4,093,000	7.86	0.13	1.14	5,540
B	1,144,000	13.9	0.07	0.65	3,140
C	750,000	12.1	0.08	0.75	3,609
Average	**1,996,000**	**11.28**	**0.09**	**0.85**	**4,093**

RCA Land Use

Site	Estimation Source	Tons	ft2/Ton	Tons/ft2	Tonds/yd2	Tons/Acre
A	Loader & Scale Data	1,022,000	1.2	0.8	7.5	36,300
B	Reported Data	175,000	1.05	0.96	8.61	41,600
	Average	599,000	1.13	0.88	8.1	39,000



Land Use

Site	Hectares	Tonnes (t)	m^2/t	t/m^2
NA A	299.0	4513000	0.662	1.51
NA B	147.4	1261000	1.169	0.86
NA C	84.09	827000	1.017	0.98
NA Average	**176.8**	**2200000**	**0.949**	**1.12**
RCA A	11.09	1127000	0.098	10.16
RCA B	1.70	193000	0.088	11.36
RCA C	1.62	379000	0.043	23.41
RCA Average	**4.80**	**566000**	**0.076**	**15.0**

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RCA Water Consumption

- Water Use at RCA Plant
  - Water Truck to mitigate site dust
    - Constant movement (aside from filling)
  - Constant running dual hose on crusher
  - Man operated hose on crusher
    - Temp. & Weather Dependent
      - Hot/Summer= Constant
      - Cold/Winter= When needed

Water Consumption (RCA)

- 82,800 kL/Year consumed by water truck
- 9,540 kL/Year consumed by dual hose attached to Crusher at RCA Plants
- 2,860 kL/Year consumed by the manual hose attached to Crusher at RCA Plants
- Total consumption also adjusted for producing aggregates for concrete

Conclusion:

It takes 176 Liters of water per tonne of RCA produced for use in new concrete

Natural Aggregate Water Use

- Calculation performed three ways:
  - National data from USGS for number of mines, water use and mine production combined – 647 L/t
  - Texas data combined with Texas water usage specifically for aggregates – 501 L/t
  - Average of values (83 – 868 L/t) reported from other sources in Nicot et al. (2011) – 355 L/t

Conclusion:

It takes 355 L/t to produce one tonne of natural aggregate

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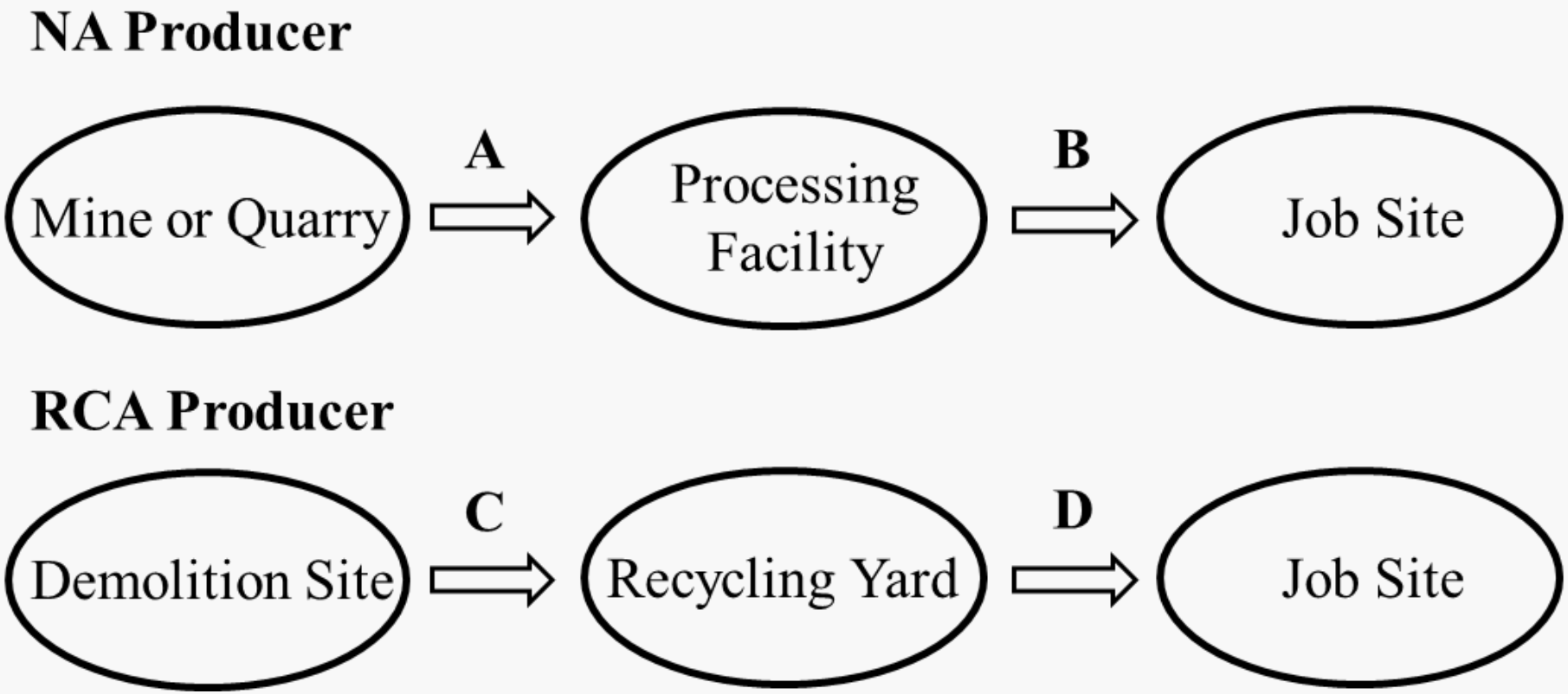
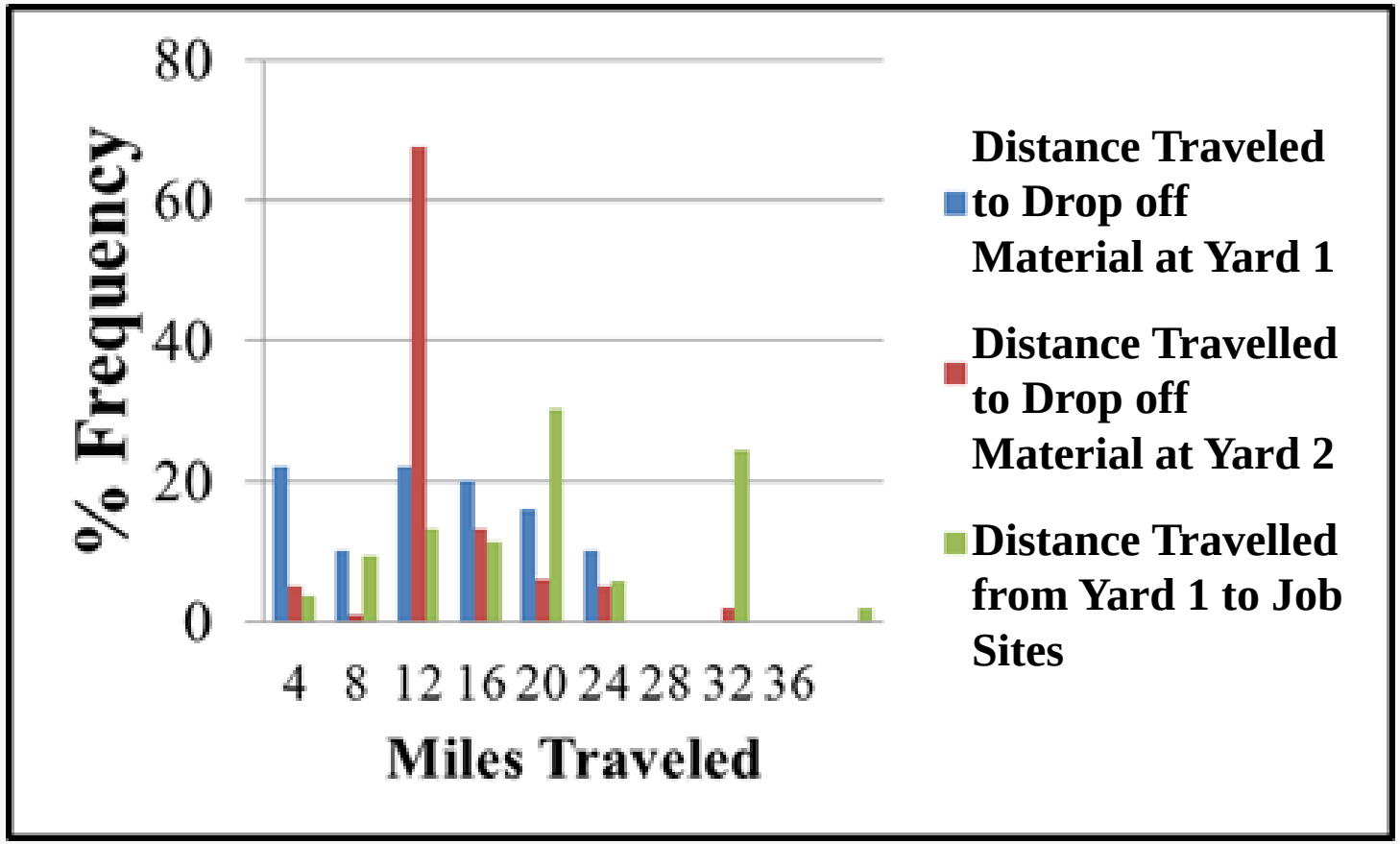
Transportation



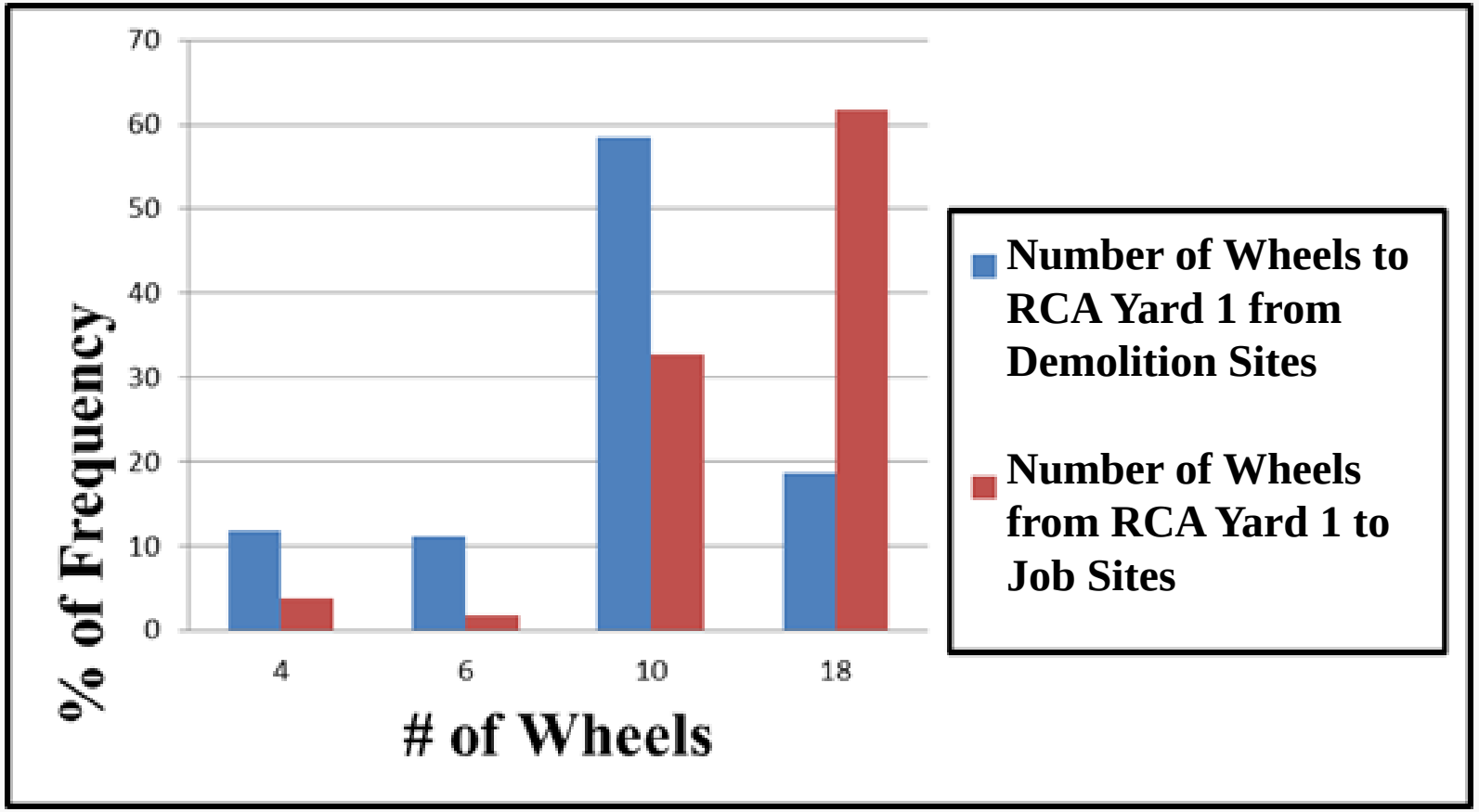
Transportation (RCA)



Distance C – Red & Blue

Distance D - Green

Transportation (RCA)



Transportation Summary

Producer Type	Distance Customer Travels to Plant (km)	Distance from Material Source to Plant (km)	Total Travel (km)
RCA	20.1	31	51
NA	91.5	70	161

CO2 and Energy Estimations

- CO2 emissions and energy use were estimated
- Inputs included:
  - Production energy from industry sources
  - Transportation data
  - Truck mix and transportation mode
  - Fuel efficiency figures

Summary

	Land (m^2/t)	Water (L/t)	Energy (MJ/t)	CO2 Emissions (kg/t)
NA	0.9	355	151	10.3
RCA	0.1	176	89	6.08

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Weighted Environmental Index

	Land	Water	Energy	CO2	Total
NA	1.0	1.11	1.12	1.12	4.35
RCA	0.1	0.55	0.66	0.66	1.94

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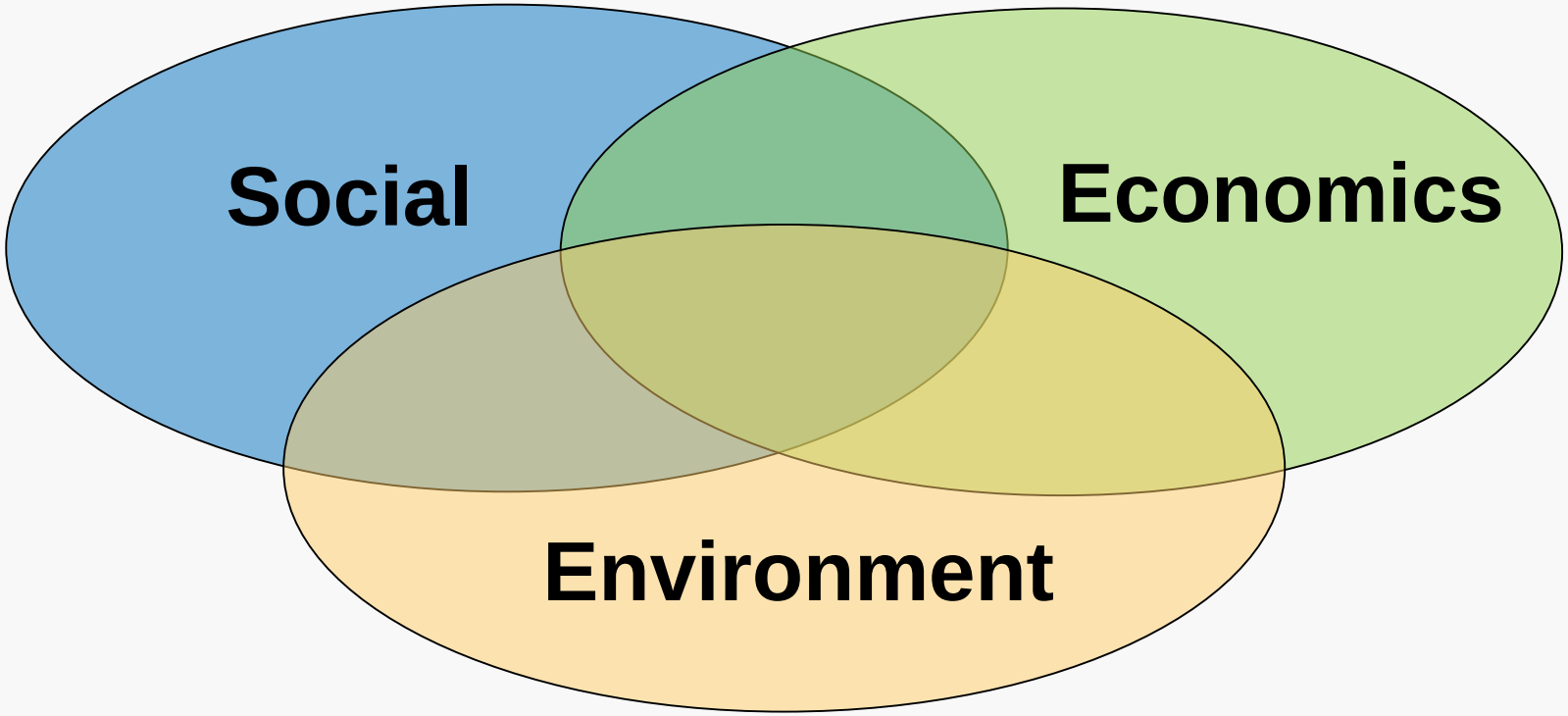
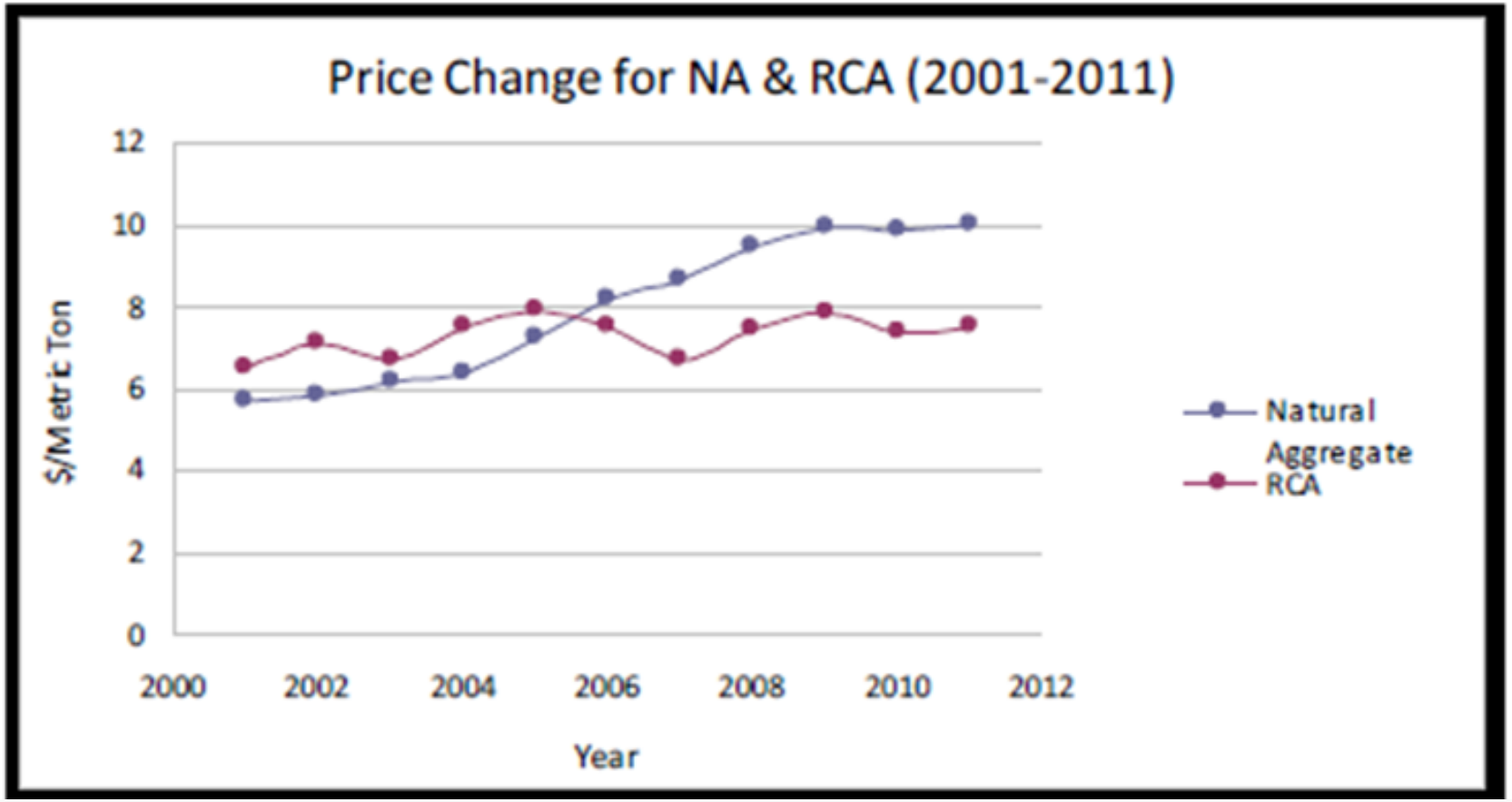
Sustainability



Economics



Conclusions

- RCA ~10% the land per tonne compared to NA
- RCA ~50%the water to per tonne compared to NA
- RCA ~60% as much energy and CO2 emissions per tonne compared to NA
- Overall environmental index (LWEC) shows RCA has approximately 45% the total impact of NA
- RCA is being sold for approximately 74% of NA price of direct competitor (secondary suppliers) – even if process modifications to meet higher concrete aggregate standards need to be emplaced, there is likely economic room to do so.

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- Owen Sanderson and ETTL for providing access to their testing facilities.
- Finally, assistance provided by all natural aggregate and RCA producers is greatly appreciated.

Transportation (Natural)

Natural Aggregate Producer	Miles Traveled To Obtain Material (Plant 1)	Natural Aggregate Producer	Miles Traveled To Obtain Material (Plant 2)
Customer 1-A	9	Customer 2-A	26.6
Customer 1-B	4.3	Customer 2-B	42.4
Customer 1-C	32.2	Customer 2-C	25.4
Customer 1-D	10.2	Customer 2-D	34
Customer 1-E	25.6	Customer 2-E	136
Customer 1-F	34.9	Customer 2-F	94.9
Customer 1-G	32.8	Customer 2-G	27.9
Customer 1-E	99.9		
Average	**31**	**Average**	**55**

Distance B

Transportation (Natural)

Natural Aggregate Producer Quarry	Distance to Plant 1 (Miles)	Distance to Plant 2 (Miles)
Quarry 1	18.6	15.8
Quarry 2	3.1	60.5
Quarry 3	78.1	94.6
Quarry 4	46.6	76.4
Quarry 5	67.4	72.0
Quarry 6	68.6	80.4
Average	**47**	**67**

Distance A