UNIVERSITY OF MICHIGAN TRANSPORTATION: CLIMATE IMPACT

FINAL PRESENTATION
APRIL 15, 2008

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AGENDA

- Background of University of Michigan Transit
- Problem Statement
- Case Studies
  - Ann Arbor Transit Authority (AATA)
  - Washington Metropolitan Area Transit Authority (Metro)
- Emissions Analysis
- Financial Analysis
- Recommendation

UNIVERSITY OF MICHIGAN TRANSPORTATION

- Quick Facts
  - Operate campus bus service 360 days a year
  - Entire fleet consists of 60 buses
  - 120,000 annual service hours
  - Carried 5.8 million passenger trips in fiscal year 2007
- Environmental Initiatives (implemented in 2003)
  - Using B-20 ultra-low sulfur biodiesel fuel
  - Installing particulate filters
  - Recycling engine fluids

POLLUTANTS OF DIESEL EXHAUST

- Regulated

Pollutant	Environmental and Health Affects
Particulate Matter (PM)	Affect respiratory heath and carry toxic substances into the lungs and bloodstream
Oxides of Nitrogen (NO_X)	Irritates and damages lung tissue Combines with water to form acid rain NO_2 forms ground level ozone (smog)
Hydrocarbons (HC)	React with NO_2 to produce ozone Methane is a principal HC in CNG
Carbon Monoxide (CO)	Binds with hemoglobin in blood impairing it's ability transport oxygen

- Unregulated: CO_2

CASE STUDY
AATA

- Quick facts about AATA
  - Local public transit system for the greater Ann Arbor – Ypsilanti Area
  - Entire fleet of 69 busses
  - 5.6 million passengers per year
  - Increase in ridership on the average of 8 percent per year
- Environmental Initiatives
  - Service 20 hybrid electric buses by March 2008
  - Long term goal of replacing entire fleet
  - Using 5% ULSD biodiesel in 2006
  - Grade school essay competition
  - On bus advertising

CASE STUDY

AATA HYBRID ELECTRIC BUSES BENEFITS

- With the addition of 20 hybrid buses, AATA will save 811,200 gallons of fuel ($2.5 million) over the next 12 years
- 50% better acceleration than conventional buses
- Reducing maintenance costs by 30% to 50%
- Reduction in PM, CO, and hydrocarbons of up to 90%
- Reduction of NO by 50%

CASE STUDY

Washington Metropolitan Area Transit Authority (Metro)

Quick facts about Metro

- Fifth largest bus network in the United States
- Public transit system for the District of Columbia and Maryland and Virginia suburbs
- Entire fleet of approximately 1,470 busses
- 131.5 million passengers per year

CASE STUDY

Washington Metropolitan Area Transit Authority (Metro)

Environmental Initiatives

- Currently run CNG buses, Hybrid buses, and Advanced Diesel Technology buses
- Clean Fleet project – update current buses for improved emissions without total fleet replacement
- Long term goals
  - Add additional 100 hybrid buses per year for 5 years to reduce average fleet age
  - Add additional 25 CNG buses
  - Fuel Cell Program – demonstration fuel cell buses

CASE STUDY

Washington Metropolitan Area Transit Authority (Metro)

Metro Bus Benefits

- With the completion of the Clean Fleet Program visible exhaust has been reduced by 90% by all buses
- Clean Natural Gas Buses provide the best emissions of all currently operated buses
- Currently the Hybrid Buses are getting to 20% - 30% fuel savings over Metro's diesel average and better mileage between maintenance stops

CASE STUDY
Metro Bus vs. Bus Comparison

Legend (Best → Worst)	DIESEL	CNG	HYBRID
			
Capital Cost-Vehicle	●	◕	○
Capital Cost-Facilities	●	○	◕
Operating Cost-Vehicle	◕	◑	●
Operating Cost-Facilities	●	◑	◕
Fuel Economy	◕	○	●
Reliability	○	◕	●
Emissions	◑	●	●

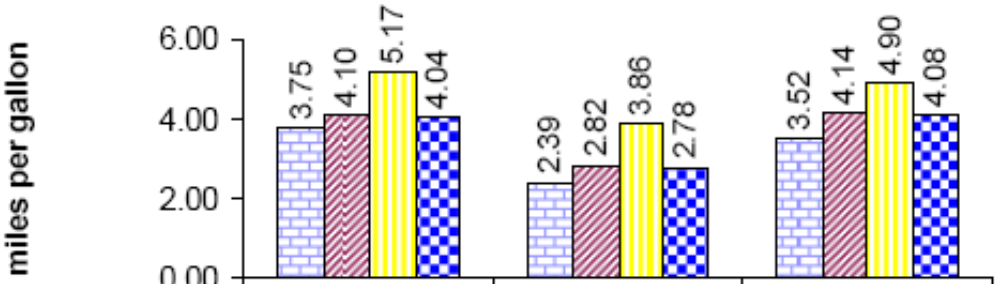
Provided by Metro: Bus Technology Selection: FY08-11, Executive Summary

CASE STUDY FINDINGS

- Large and small bus systems are taking climate change into account when upgrading fleets
- Leads to local, national, and international exposure about the seriousness of climate change
- Larger bus systems act as a resource for smaller bus systems
- Some buses systems are already investing in the future like Metro is doing to develop fuel cell buses

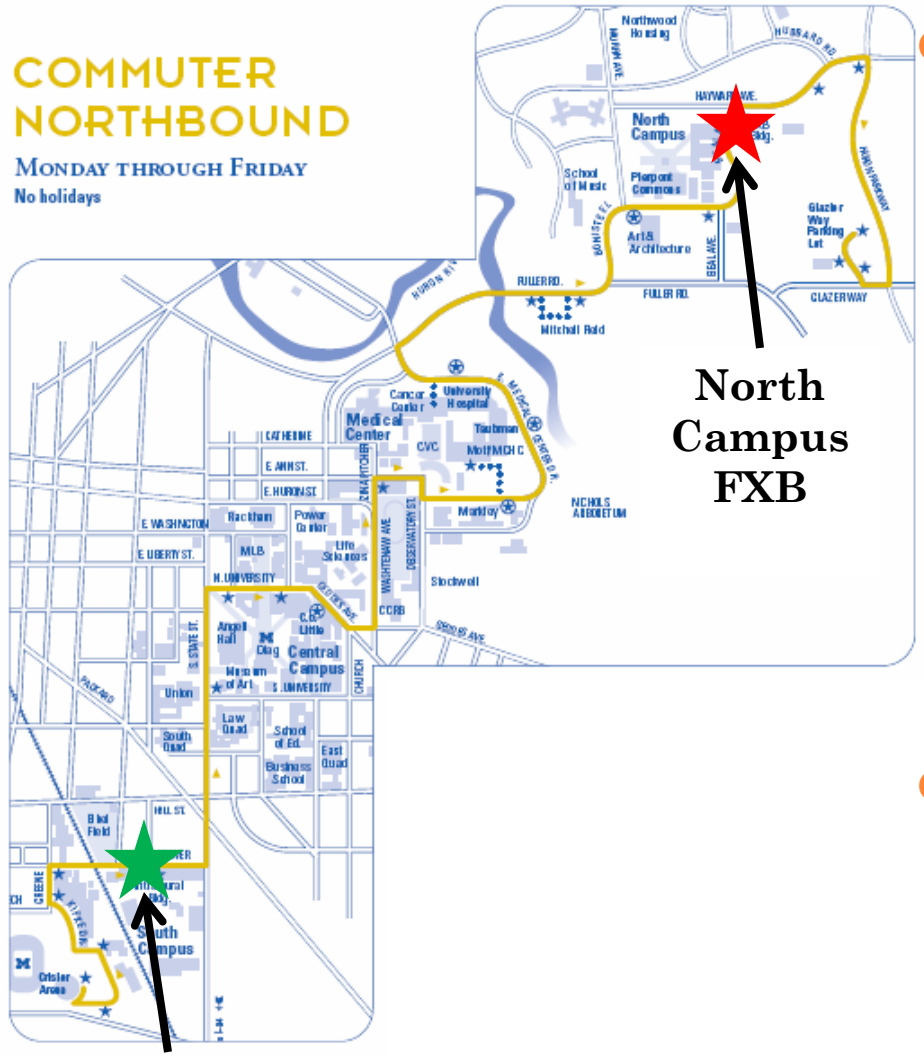
EMISSION AND FUEL ECONOMY MEASUREMENT

- Emissions Test Cycles
  - Simulated driving conditions performed on a chassis dynamometer
  - Strongly dependant on bus route and operation
    - Central Business District (CBD)
    - Manhattan Cycle
    - Orange County Transit Authority (OCTA)



	CBD	Manhattan	OCTA
CNG	3.75	2.39	3.52
ULSD	4.10	2.82	4.14
Diesel Hybrid	5.17	3.86	4.90
B20 Biodiesel	4.04	2.78	4.08

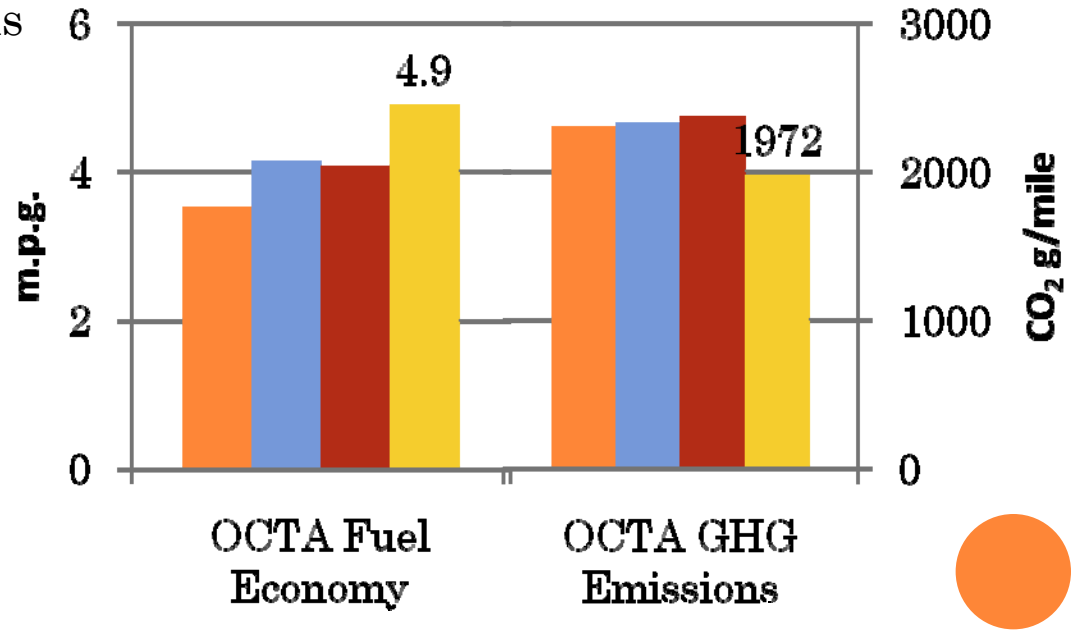
EMISSION ANALYSIS
UM EMISSION TEST CYCLE



- Commuter Northbound
  - Measured values between stops
    - Distance
    - Time
  - Results
    - Average Speed 19 m.p.h.
    - Max Speed 37 m.p.h.
    - Duration 720 Seconds
    - Length 3.9 miles
    - Share of idle 38%
- Conclusion
  - Predominately suburban
    - Similar to OCTA Cycle
    - Higher average speed than urban Manhattan Cycle (6.8 m.p.h.)

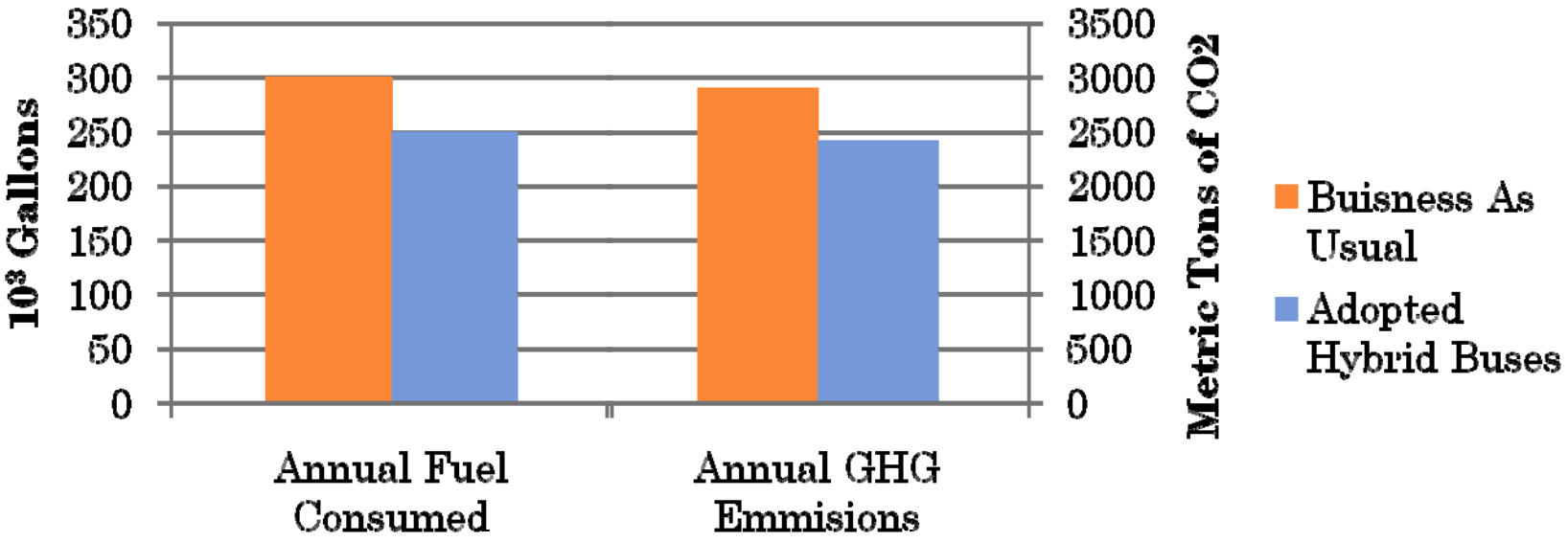
EMISSION ANALYSIS
UM EMISSION PREDICTIONS

- Orange County Bus Cycle (OCTA)
  - Developed by West Virginia University
  - Based on driving patterns of urban busses in the Los Angeles, California area
    - Average Speed 12.5 m.p.h.
    - Max Speed 40.9 m.p.h.
    - Duration 1909 seconds
    - Length 6.6 miles
    - Share of idle 21%



EMISSION ANALYSIS
UM HYBRID-ELECTRIC ADOPTION

- Over 50,000 gallons less fuel consumed annually
  - 17 % decrease
  - Approximately 500 metric tons less CO_2



EMISSIONS ANALYSIS
NATIONAL HYBRID-ELECTRIC ADOPTION

Table 18: Projected annual emissions from the national transit bus fleet in 2009

	Number of Buses	CO tons	NMHC tons	CH_4 tons	NO_x tons	PM tons	CO_2 tons	Fuel Consumed thousands of gallons
Total Annual Emissions								
Diesel	50,003	9,577	1,667		53,981	843	6,289,918	573,989
CNG/LNG	10,064	1,331	364	6,902	7,229	9	1,003,149	125,818
Diesel Hybrid	1,525	12	2		489	1	107,814	9,805
Total	**61,592**	**10,920**	**2,032**	**6,902**	**61,699**	**853**	**7,400,881**	**709,612**
Average Emissions Levels per Bus								
		CO g/mile	NMHC g/mile	CH_4 g/mile	NO_x g/mile	PM g/mile	CO_2 g/mile	Fuel Economy mile/gal
Diesel		4.31	0.75		24.32	0.38	2,833	3.51
CNG/LNG		2.98	0.81	15.45	16.18	0.02	2,245	3.22
Diesel Hybrid		0.18	0.03		7.22	0.02	1,592	6.26

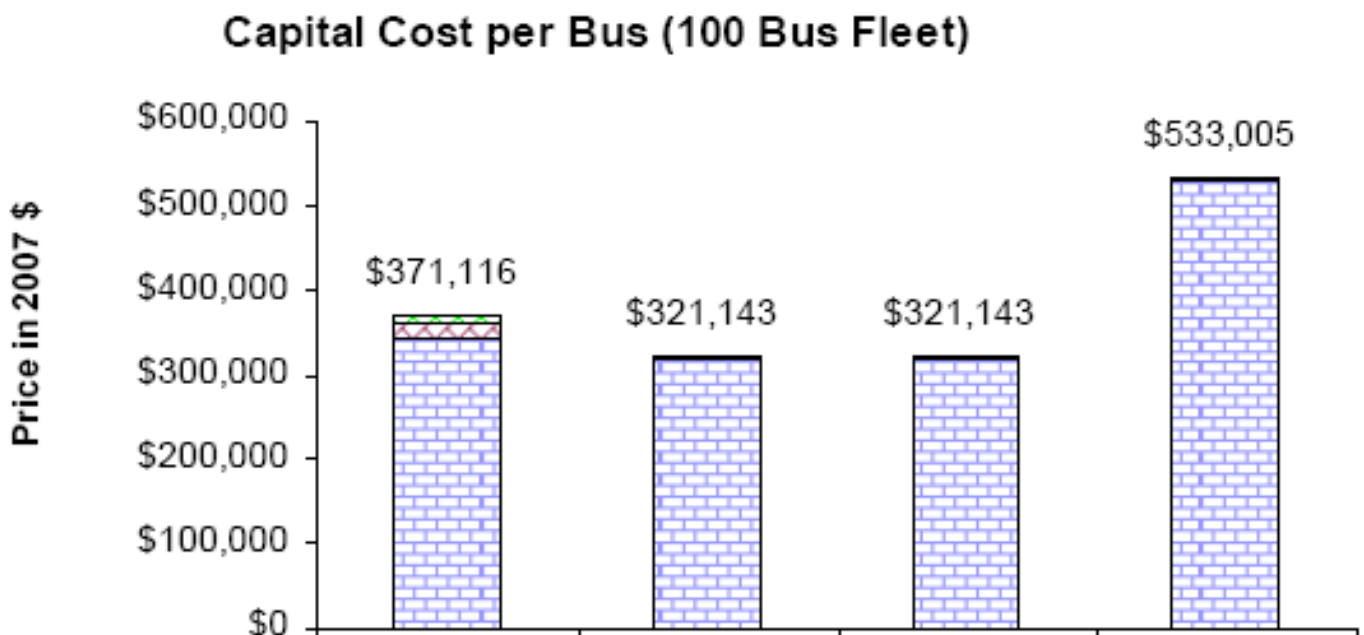
Wayne, Scott W. and Sandoval Jairo A. “Environmental Benefits of Alternative Fuels and Advanced Technology in Transit.” (2007)

- 100% Hybrid Electric Buses
  - 2.8 million metric tons CO_2 savings

FINANCIAL ANALYSIS ASSUMPTIONS

- 36 year financial analysis
- 20 buses every 12 years
- Qualified for Clean Fuels Formula Grant Program
- Capital costs
  - Infrastructure
  - Cost of buses
- Operating costs
  - Compression electricity
  - Maintenance
  - Battery replacement – 3 to 5 years
  - Fuel
- Discount rate ~ 5 % above inflation

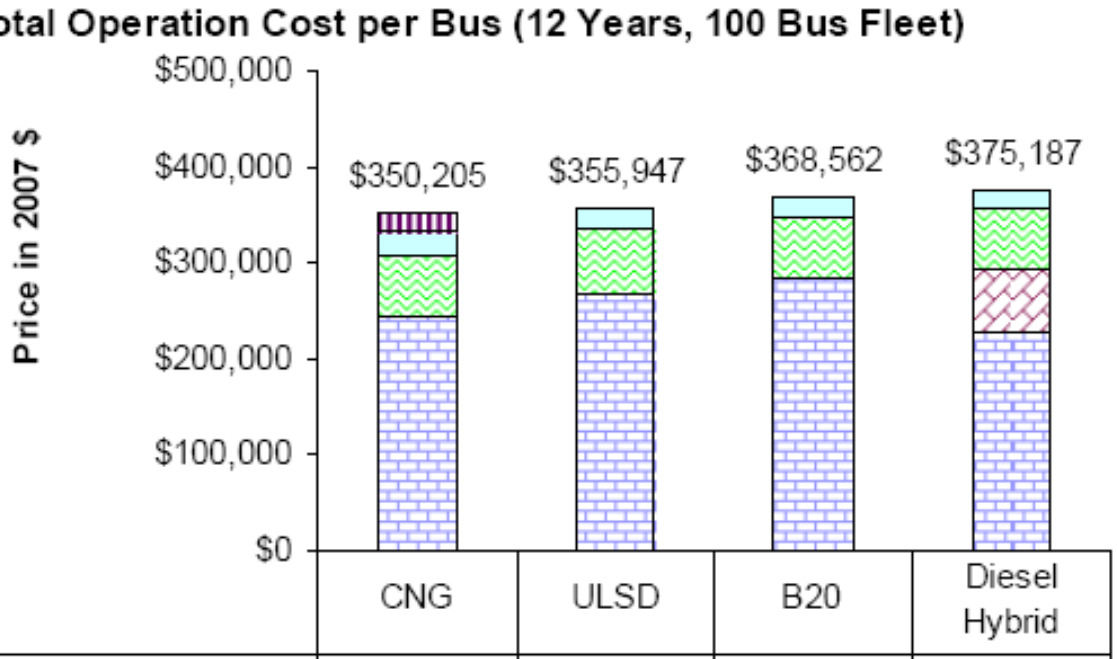
FINANCIAL ANALYSIS
CAPITAL COSTS



	CNG	ULSD	B20	Diesel Hybrid
Total	$371,116	$321,143	$321,143	$533,005
Emissions Equipment	$0	$1,434	$1,434	$0
Depot Modification	$8,750	$0	$0	$1,400
Refueling Station	$20,000	$0	$0	$0
Vehicle Cost	$342,366	$319,709	$319,709	$531,605

Clark, Nigel N., Feng Zhen, Donald W. Lyons, and W Wayne. "Transit Bus Life Cycle Cost and Year 2007 Emissions Estimation." (2007).

FINANCIAL ANALYSIS
OPERATING COSTS

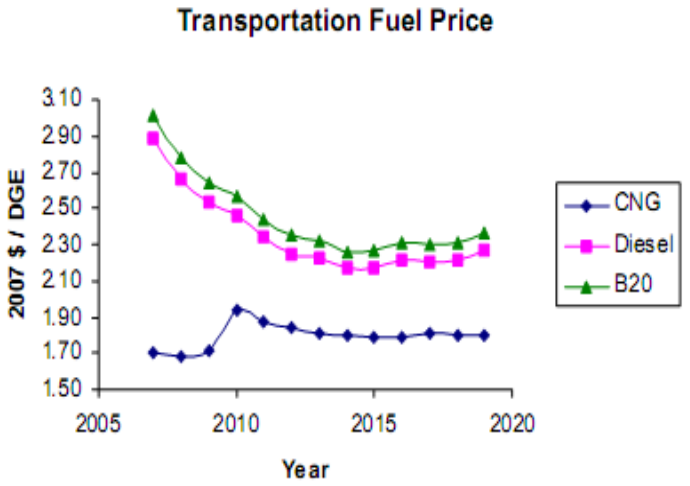


	CNG	ULSD	B20	Diesel Hybrid
Total	$350,205	$355,947	$368,562	$375,187
Compression Electricity	$19,003	$0	$0	$0
Facility Maintenance	$24,433	$20,723	$21,039	$17,470
Propulsion-related System Maintenance	$62,588	$66,394	$62,706	$63,589
Battery Replacement	$0	$0	$0	$67,500
Fuel Costs	$244,181	$268,830	$284,818	$226,629

Clark, Nigel N., Feng Zhen, Donald W. Lyons, and W Wayne. "Transit Bus Life Cycle Cost and Year 2007 Emissions Estimation." (2007).

FINANCIAL ANALYSIS
FUEL COSTS

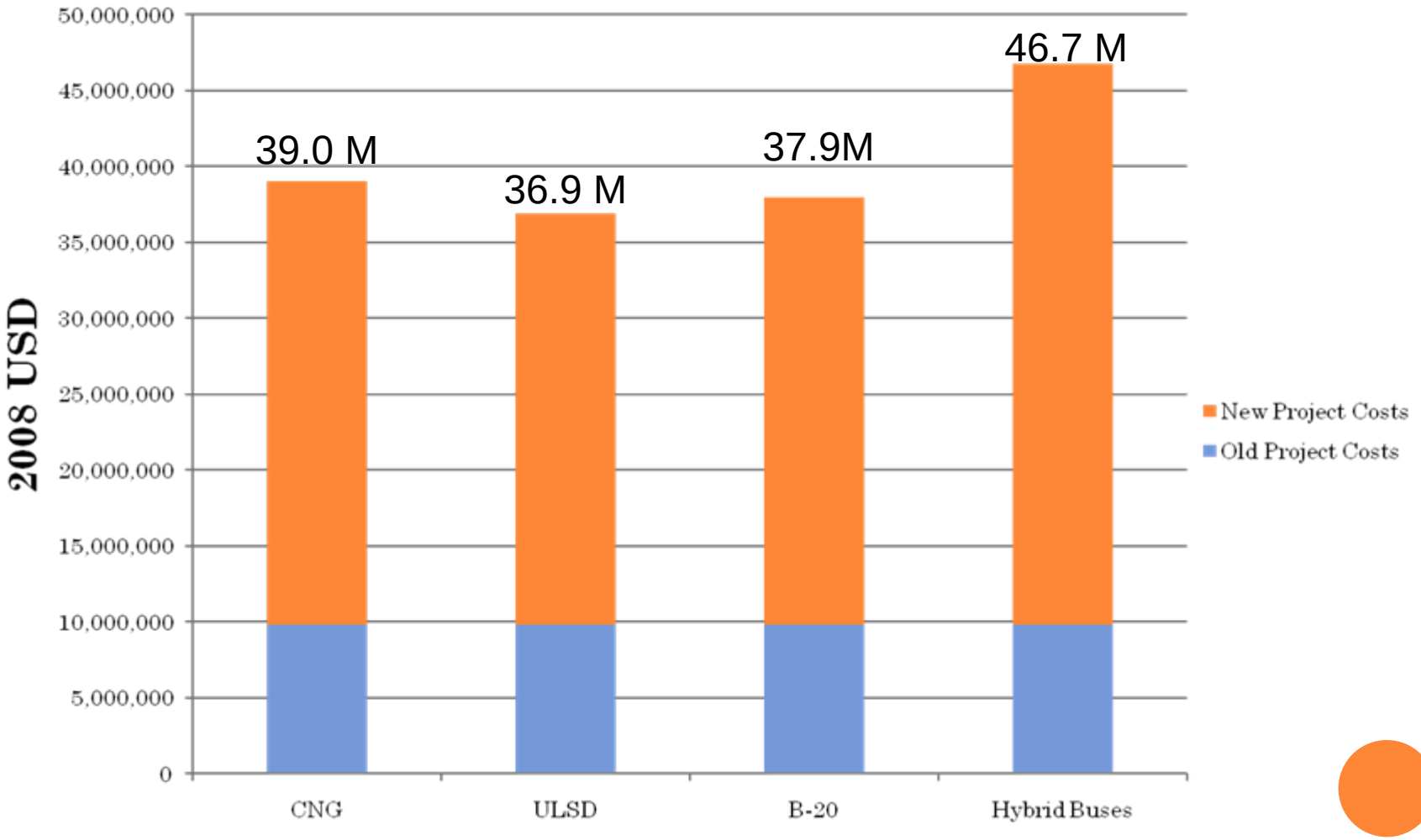
- Used Federal Transit Authority estimates for fuel costs
- Used Orange County Bus Cycle mile per gallon estimates
- Used University of Michigan Transit data for miles per year



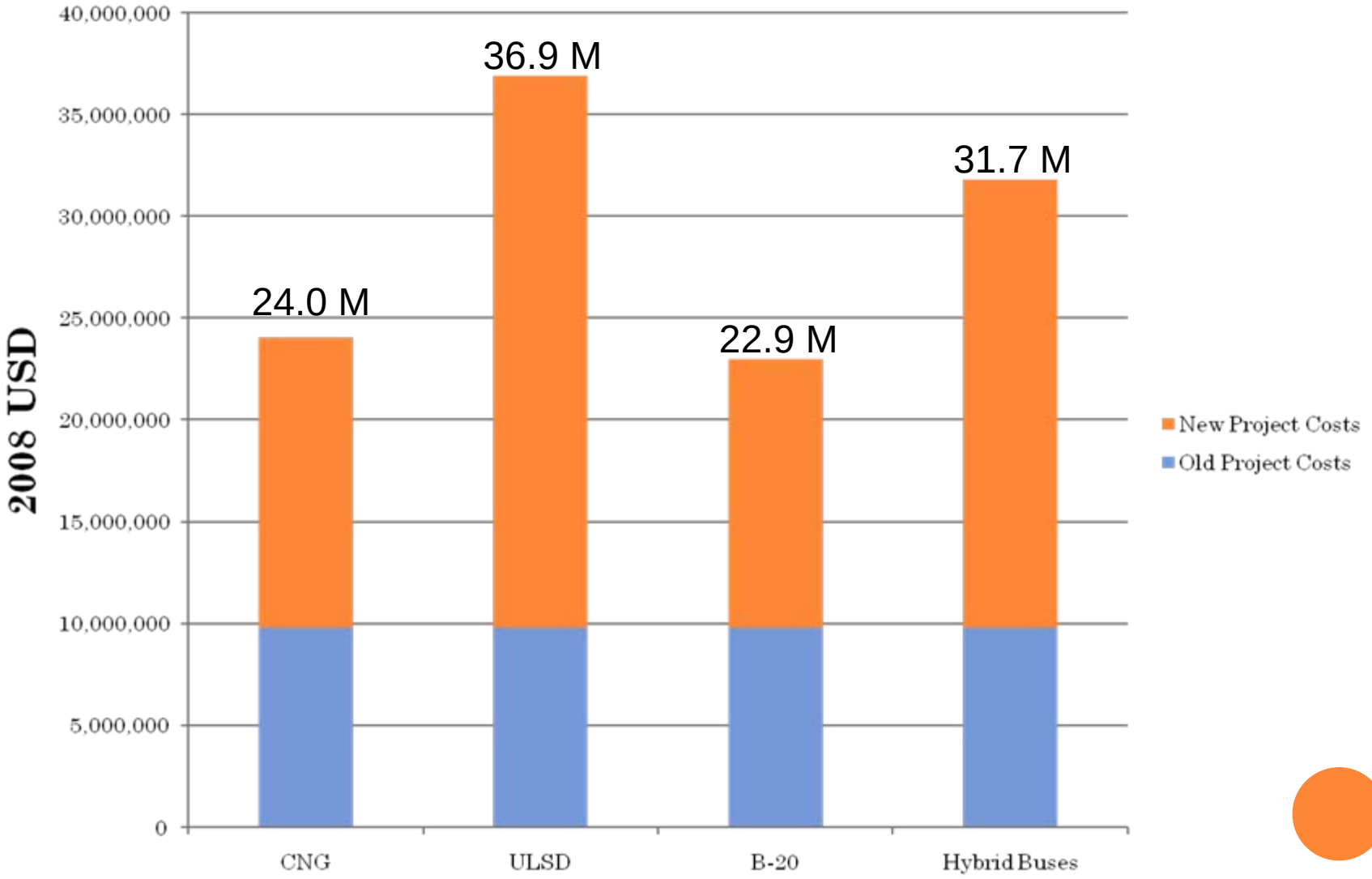
Clark, Nigel N., Feng Zhen, Donald W. Lyons, and W Wayne. "Transit Bus Life Cycle Cost and Year 2007 Emissions Estimation." (2007).

Michigan Buses	CNG	ULSD	B-20	Diesel Hybrid
Miles per gallon	3.52	4.14	4.08	4.90
Miles per year	759,000	759,000	759,000	759,000
Mile per bus per year	12,650	12,650	12,650	12,650

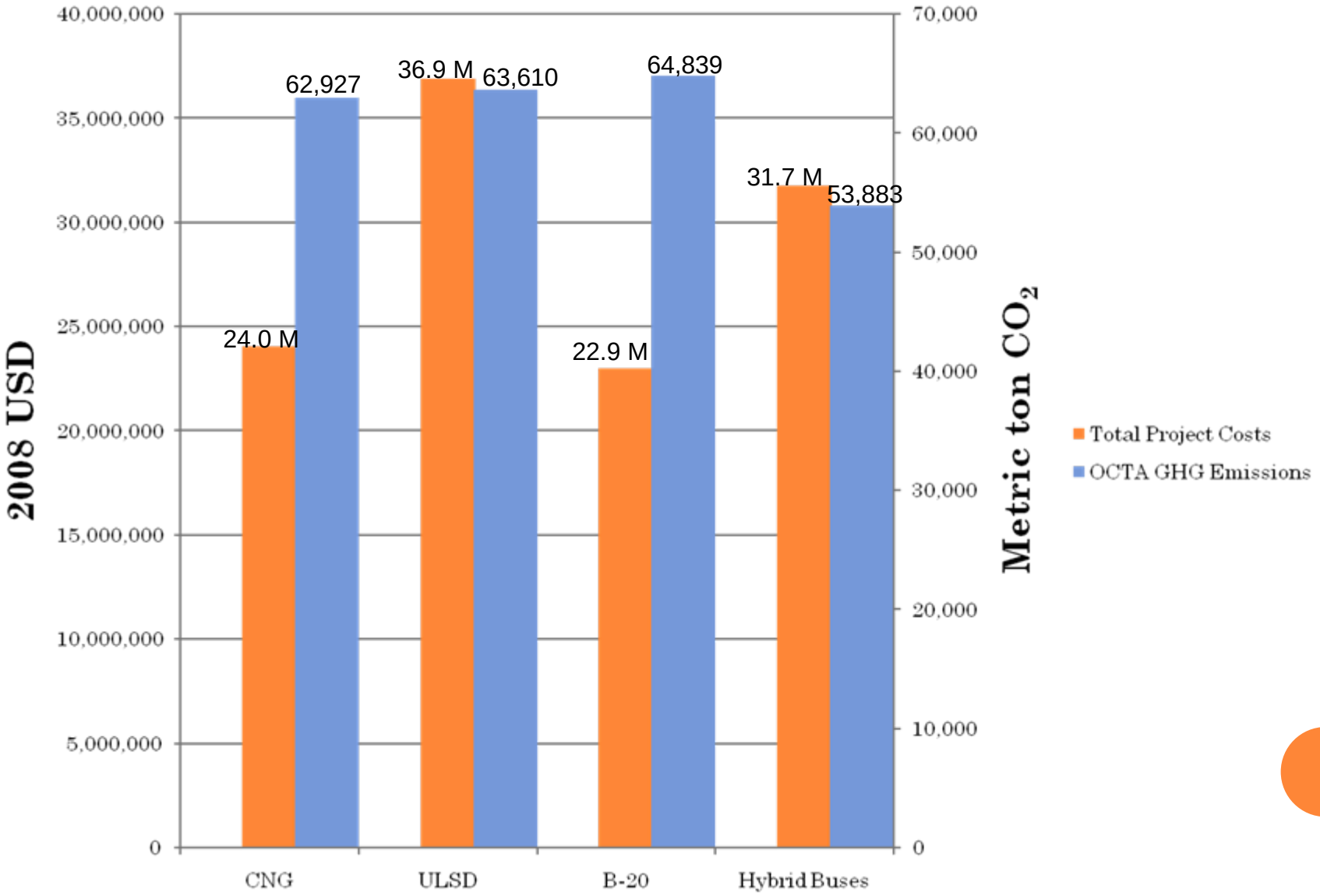
FINANCIAL ANALYSIS
TOTAL COSTS WITHOUT GRANT



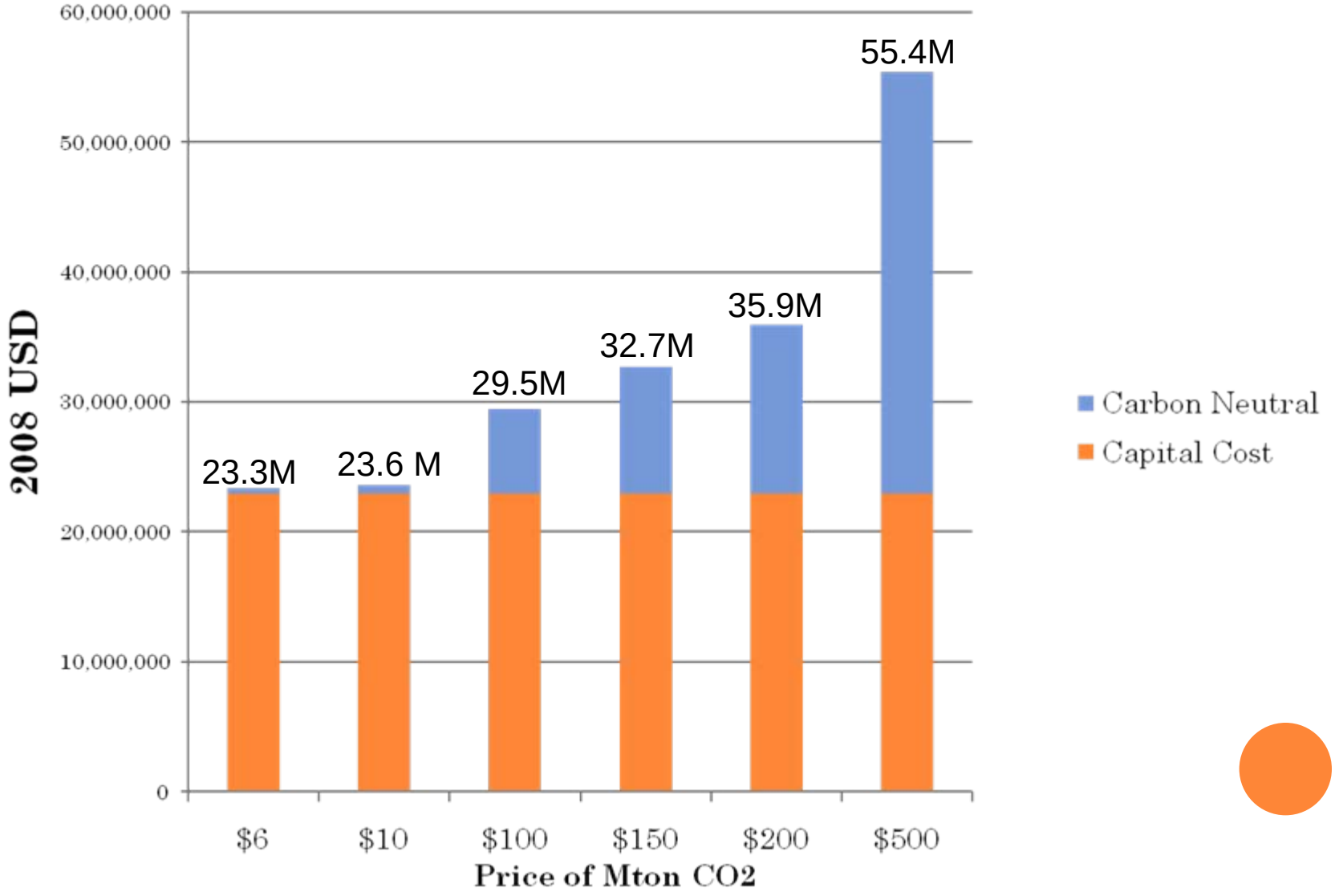
FINANCIAL ANALYSIS
TOTAL COSTS WITH GRANT



RECOMMENDATIONS
EMISSIONS AND FINANCIAL



RECOMMENDATIONS
B-20 CARBON NEUTRAL



RECOMMENDATIONS

- Business as usual – B-20
  - Lowest cost, highest emissions
- Compressed natural gas
  - Second lowest cost, second most emissions
- Hybrid Buses
  - Highest cost, lowest emissions
- Business as usual – B-20 carbon neutral
  - Buy carbon credits to offset emissions
  - Cost of carbon credits ~ $10 per metric ton
  - Total carbon neutral cost ~ $650,000 for 36 year period
  - Total cost ~ 23.6 M for the 36 year period

QUESTIONS?