City of Madison

DRAFT TRANSIT FUEL SOURCE COMPARISON

August 27, 2019

Page No.
or Following

Contents

1.0 Background

A. 100% Renewable Madison Report

In 2017, the City of Madison became the 25th city in North America to set a goal of achieving 100% Renewable Energy and Zero Net Carbon Emissions (Leg File 45569). Subsequently the City contracted with HGA and Navigant Consultants to prepare a report on how to achieve this goal, with a report being issued in November of 2018.

In March 2019, the Madison Common Council accepted the 100% Renewable Madison Report and adopted the recommendation that the City follow Scenario 3 measures and timeline (leg file 54508). The following excerpt from the resolution briefly describes Scenario 3.

> ***Scenario 3: 100% Renewable Energy and Zero Net Carbon by 2030***
> *The Scenario 3 objective is to implement known measures to reduce the carbon footprint from city operations and minimize the reliance of external RECs or carbon offsets* ***or reduce emissions from single occupancy vehicles****. By 2030, city government will cut its carbon emissions by 55% with at least 25% of municipal operations' electricity sourced by self-generated renewable energy. Investments in RECs and/or carbon offsets make up the remaining 45% of carbon emissions balance. This path is most consistent with the Paris Agreement requirements, involving more extensive investment over a longer period. Energy efficiency measures with short and longer paybacks are included, such as HVAC retrofits in buildings, in addition to water distribution and street and traffic lights. The City will invest in greening its fleet with most vehicles being converted to operate on electricity or compressed natural gas from non-fossil sources by 2030* ***with the remaining emissions being offset by RECs or carbon offsets****. Electrification of the fleet enables the City to economically further expand its internal renewable energy generation, adding additional renewable generation opportunities to Phase 1 and Phase 2 behind-the-meter solar on city buildings; and,*

The following Figure 1, taken from the report's Table 2-14, illustrates how the study anticipated the city could reduce its carbon footprint, and increase reliance on renewable energy. Notice that Renewable Energy Credits (RECs) are purchased to offset the use of natural gas, electricity, gasoline, and diesel. The RECs for gas and diesel eventually are eliminated because full fleet conversion is assumed.

FIGURE 2-14. FUEL MIX SCENARIO 3: 100% RENEWABLE ENERGY AND ZERO NET CARBON BY 2030

	Unit	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
CO_2 Emissions (Baseline)	ton	81,141	81,699	82,261	82,829	83,402	83,981	84,565	85,155	85,750	86,351	86,957	87,570	88,188
CO_2 Reduction (Demand)	ton	1,416	5,640	9,796	13,882	17,900	21,849	22,644	23,531	24,508	25,577	26,736	27,986	29,328
	%	2%	7%	12%	17%	21%	26%	27%	28%	29%	30%	31%	32%	33%
CO_2 Reduction (Supply)	ton	5,597	7,478	9,136	10,582	11,824	12,871	14,073	15,181	16,191	17,099	17,902	18,594	19,171
	%	7%	9%	11%	13%	14%	15%	17%	18%	19%	20%	21%	21%	22%
CO_2 Remaining	ton	74,128	68,581	63,329	58,365	53,679	49,261	47,848	46,443	45,051	43,675	42,319	40,989	39,689
	%	91%	84%	77%	70%	64%	59%	57%	55%	53%	51%	49%	47%	45%
RECs Electricity	ton	39,337	36,869	34,698	32,813	31,206	29,866	30,513	31,166	31,831	32,513	33,214	33,939	34,694
	%	48%	45%	42%	40%	37%	36%	36%	37%	37%	38%	38%	39%	39%
RECs Natural Gas	ton	6,774	6,310	5,847	5,384	4,922	4,461	4,533	4,607	4,681	4,756	4,832	4,908	4,985
	%	8%	8%	7%	7%	6%	5%	5%	5%	5%	6%	6%	6%	6%
RECs Gasoline	ton	5,145	4,675	4,204	3,734	3,263	2,792	2,395	1,997	1,600	1,202	804	407	0
	%	6%	6%	5%	5%	4%	3%	3%	2%	2%	1%	1%	0%	0%
RECs Diesel	ton	22,872	20,726	18,580	16,434	14,288	12,142	10,407	8,673	6,939	5,204	3,470	1,735	0
	%	28%	25%	23%	20%	17%	14%	12%	10%	8%	6%	4%	2%	0%

Figure 1 City of Madison Carbon Reduction, Scenario 3

B. Metro Fleet Operations

The above scenario listed in the resolution posed several challenges to Metro. These included the following:

- Electric Charging Infrastructure – At the time of the resolution, the Metro bus barn on East Washington did not have the infrastructure to house electric buses. Electric buses could not fit inside the doors, and there were challenges with charging capacity. These issues are being addressed with the current rehabilitation process. By 2020 Metro will be able to charge 3 electric buses at the East Washington bus barn. After further electrical upgrades, the facility would be able to charge 30 electric buses by 2021. Further upgrades could provide charging capacity for up to 60 buses in the near-term future. Discussions with MG&E indicate that there are available conduits from their main plant, which could provide the charging capacity needed for further electric bus expansion at the East Washington Ave facility. The proposed Oscar Mayer facility also has ample electrical capacity for electric buses.
- Fleet replacement – At the time Metro had 215 buses on a 15 year replacement schedule. Given the high capital costs of buses; diesel, Compressed Natural Gas (CNG), or electric, it is very difficult to accelerate this schedule.
- Electric Bus Limitations – The electric bus industry is expanding very rapidly, outpacing other propulsion sources. It appears to be the current dominant focus amongst major bus suppliers. Despite this growth, the industry is still in its infancy. It is difficult to run electric buses beyond 7 hours without recharging, which is not enough for many Metro routes. Many communities are developing ways to overcome this limitation. Options include, change bus blocking, interim charging at transfer points, and even battery change outs. Metro enlisted the services of a consultant, who indicated that many of the challenges electric buses pose could be addressed by changing blocking.

To address the above challenges, Metro:

- Asked that the bolded portions of the resolution be added, specifically " . . *to reduce the carbon footprint from city operations and minimize the reliance of external RECs or carbon offsets* ***or reduce emissions from single occupancy vehicles****. . . . operate on electricity or compressed natural gas from non-fossil sources by 2030* ***with the remaining emissions being offset by RECs or carbon offsets****. Electrification of the fleet enables the City to economically further expand its internal renewable energy."*
- Internally, Metro was planning to begin converting to electric buses in 2023. Before then, Metro would pilot electric bus use through purchasing three electric buses in 2020 to understand how they perform and what factors need to be considered if the fleet were converted to full electric buses. The conversion would provide an electric fleet by 2038. RECs or carbon offsets would be used until the fleet was converted.
- Allow the electric bus industry to mature. As mentioned, there is considerable focus being placed on electric buses and overcoming their limitations. By waiting until 2023 for fleet conversion, Metro will have a better understanding from other cities experiences.

The following Figure 2 was presented to the TPPB and has since been revised. It illustrates how Metro could convert to electric buses to comply with the resolution.

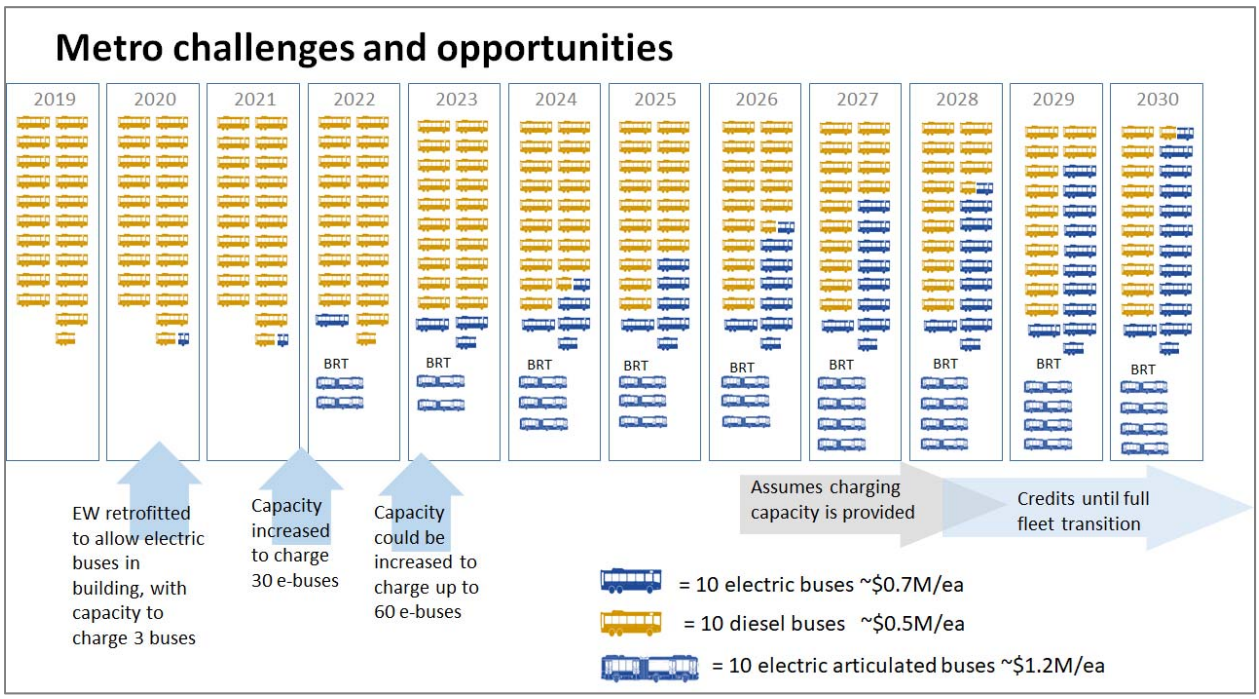

Figure 2 Possible Metro Fleet Conversion with Scenario 3

2.0 Process

A. CNG

If compressed natural gas was used to fuel buses, one potential source would be from the Dane County Land Fill and their bio gas generation. Dane County can treat their biogas by removing carbon dioxide and other chemicals/particles. They then feed their gas into ANR pipeline system, and Metro would draw gas from MG&E's distribution system at either the 1101 East Washington Avenue location, or at the potential Oscar Mayer satellite, which has a high pressure gas line adjacent to the site.

CNG fueling stations would need to be installed at the sites housing CNG buses. They would be installed outside of the building, to avoid very costly building upgrades. There are two types of fueling stations, fast-fill and time-fill. Fast-fill stations are generally used for light duty vehicles that arrive randomly. Time-fill fueling stations are used primarily by fleets and are suited for vehicles with larger tanks. A transit company such as metro would need a station that could deliver 8 to 9 gallons per minute. Cost of a fueling station suitable for Metro could approach $1.8 million or more.[1] Discussions with experts in the field indicates fueling must be monitored, and would take around 15 minutes per bus, longer than the current 5 minutes needed for diesel fueling.

The buildings would also need to be upgraded to house CNG buses. Typical upgrades include substantially increasing ventilation, extra exhaust for purging, methane sensors, electrical disconnects for when methane is detected, high temperature for vehicle exhaust capture systems, and other upgrades.

[1] https://afdc.energy.gov/files/u/publication/cng_infrastructure_costs.pdf With a 218 bus fleet, multiple stations could be needed.

Anecdotally, transit agencies using CNG buses have indicated that maintenance costs for servicing these buses are higher.

B. Electric

Electric bus charging is a less mature technology, however there is substantial focus within the industry. Currently the range of electric buses is about 7 hours. Some companies are proposing in-line charging, such as at transfer points, to extend this range. Metro Transit is in the process of purchasing three electric buses from Proterra. Proterra has three power control systems; 60kw (slow), 125kw (medium), and 500 kw (fast). Modifications to the 1101 East Washington Ave site are needed to accommodate electric buses, and additional service would be needed if there were a full fleet conversion. Discussions with MG&E indicate that new conduit banks with capacity have already been laid from their Blount plant along Main Street. Increasing electrical service would be a matter of asking for it and installing some building infrastructure. The system chargers likely would be mounted on the rafters or at-grade adjacent to the bus, with a charger for every bus. The power control system would then regulate the charging between the buses through the night.

To address the range limitations of electric buses, transit agencies are altering blocking. In their scheduling, Metro first schedules trips. A trip is designated as a line in the ride guide, a bus going from one end of the route to the other at a certain time. Then Metro assembles trips together into blocks, a block is what a bus does all day long. Some blocks can be up to 20 hours long, so Metro then cut blocks into runs, a run is a driver's work for the day.

Metro has contracted with the Center for Transportation and the Environment to provide consulting services regarding the potential implementation of electric buses. They performed a blocking exercise that seemed to indicate that some mid-day charging, conversion to an electric fleet is possible without service deterioration.

Electrical energy is only as clean as the power plant producing it. MG&E has pledged to produce a carbon neutral energy by 2050, and supplying 30 percent of their retail energy sales with renewable sources by 2030.

3.0 Emissions

Emissions are broken into two categories, criteria pollutants and greenhouse gases. Criteria pollutants are those that are specifically regulated by the EPA as part of the National Ambient Air Quality Standards, which are listed in 40 CFR 50 and include Carbon Monoxide (CO), Sulfur Dioxide (SO2), Nitrous Oxides (NOx), and Particulate Matter (PM 2.5). Volatile Organic Compounds (VOC) are often included in analyses because they are a precursor to NOx pollution.

US DOT and FTA's Policy Guidance on the Capital Investment Program requires an air quality analysis with the buses being proposed. The following table is taken from that document. [2] Electric buses emit considerably less carbon monoxide and VOCs, yet their generation emits more nitrous oxides and PM2.5.

[2] https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/FAST_Updated_Interim_Policy_Guidance_June%20_2016.pdf

Change in Air Quality Emissions Factors

Mode	For Current Year Estimates (grams/VMT)				For 10-year Horizon Estimates				For 20-year Horizon Estimates			
	CO	NO_x	VOC	$PM_{2.5}$	CO	NO_x	VOC	$PM_{2.5}$	CO	NO_x	VOC	$PM_{2.5}$
Automobile	16.77	0.91	0.60	0.010	11.46	0.28	0.27	0.010	10.26	0.20	0.21	0.010
Bus - Diesel	5.83	8.67	0.73	0.48	3.26	2.08	0.24	0.09	2.89	1.14	0.16	0.03
Bus - Hybrid	5.83	8.67	0.73	0.480	3.26	2.08	0.24	0.09	2.89	1.14	0.16	0.03
Bus - CNG	39.62	3.84	1.46	0.010	20.30	3.41	1.15	0.010	17.16	3.35	1.11	0.010
Bus - Electric	6.45	5.83	0.12	0.378	5.39	4.39	0.10	0.313	5.04	3.98	0.10	0.299
Heavy Rail	7.06	6.38	0.13	0.413	6.85	5.58	0.13	0.398	6.73	5.32	0.13	0.399
Light Rail and Streetcar	10.51	9.50	0.19	0.615	10.20	8.31	0.19	0.593	10.01	7.91	0.20	0.593
Commuter Rail - Diesel locomotive (new) and DMU	16.80	13.20	0.55	0.190	16.80	13.20	0.55	0.190	16.80	13.20	0.55	0.190
Commuter Rail - Diesel locomotive (used) and DMU	16.80	93.00	4.36	4.600	16.80	43.00	1.26	1.330	16.80	20.90	0.44	0.470
Commuter Rail – Electric and EMU	12.81	11.57	0.24	0.750	12.43	10.12	0.23	0.722	12.19	9.64	0.24	0.723

Figure 3 FTA Criteria Emission Factors for Different Bus Types

For greenhouse gases, the Union of Concerned Scientists put out a briefing that compared greenhouse gas emissions for CNG, electric, and diesel buses. The following Figure 4 illustrates the emissions, based on national averages. The chart has been modified to represent the average greenhouse gas emissions for Wisconsin.

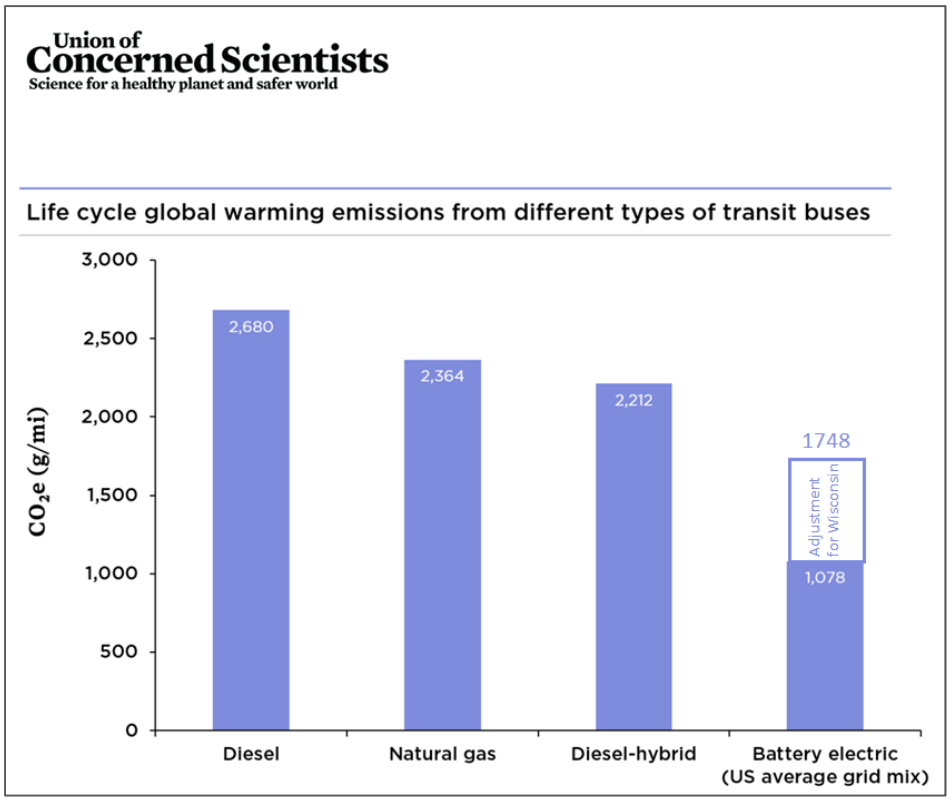

Figure 4 Greenhouse Gas Emissions – Bus Types

The Figure 5 bar chart provides a comparison of carbon emissions based on MG&E's fuel composition in 2020.

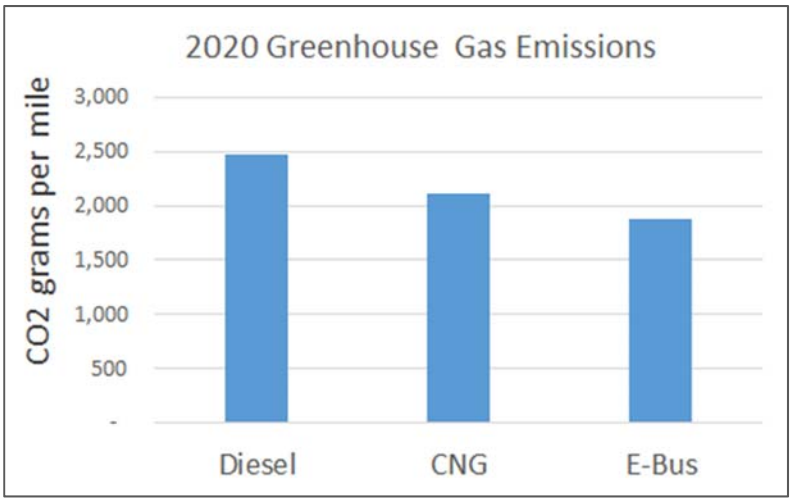

Figure 5 - Greenhouse Emissions Based on Current MG&E Production

As mentioned, MG&E has a stated goal of carbon neutral energy by 2050. This study analyzed the amount of carbon that would be reduced if Metro used CNG or electric buses. For MG&E power production, the analysis assumed:

- Recent MG&E plant investments, such as Oak Creek power plant and Columbia power plant would remain on-line and be retired near the end of the 30 year analysis period.
- That the decarbonization of MG&E energy would step down gradually, and by 2045 40 percent of the energy would still be generated by fossil fuels.
- A consistent 215 bus fleet, each traveling 23,605 miles annually.[3]

The carbon assigned to electric buses includes both the carbon emitted from the vehicle and the carbon emitted in producing the electricity. The carbon assigned to diesel and CNG only includes the carbon emitted from the vehicle, and does not include carbon in the refining or transporting of those fuels. Figure 6 illustrates the carbon emitted from the three vehicle types from 2020 to 2045.[4]

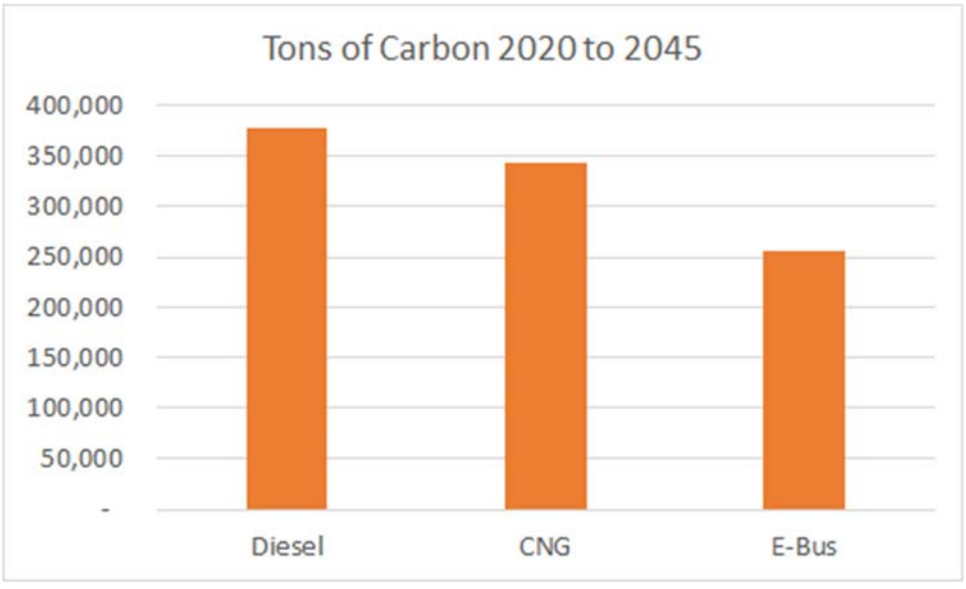

Figure 6 – Tons of Carbon Emitted With a 215 bus Fleet from 2020 to 2045

[3] Actual fleet size will grow, but the analysis provides a consistent basis for evaluation.

[4] Note that the analysis uses 2020 as the beginning of electric bus conversion. In reality, fleet conversion would not occur until 2023.

The overall difference between carbon emissions between 2020 and 2045 is somewhat modest between the three types of fuel, with electric buses producing 87,000 tons less carbon than a CNG bus fleet. The greater difference occurs when and if MG&E accomplishes its goal of carbon neutral energy by 2050. Then electric buses have essentially no emissions while CNG buses continue to emit 12,400 tons of carbon annually. Figure 7 illustrates this difference in the year 2050, with the same analysis assumptions, and assuming that MG&E still obtains 10 percent of its energy from fossil fuels.

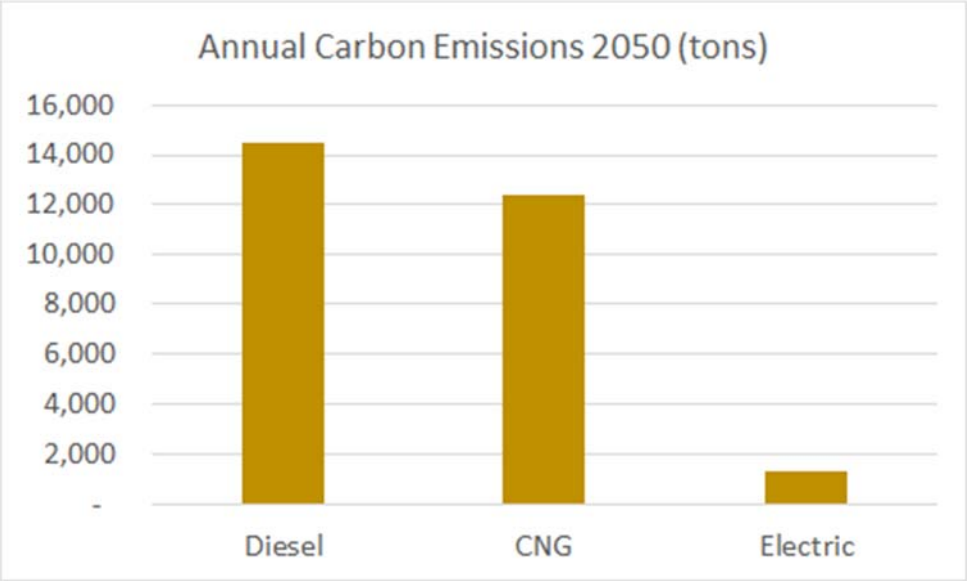

Figure 7 2050 Carbon Emissions

4.0 FTA Grant Competitiveness

The Federal Transit Administration issues a Low/No Emission Grant Program (5339c). The Low or No Emission Competitive program provides funding to state and local governmental authorities for the purchase or lease of zero-emission and low-emission transit buses as well as acquisition, construction, and leasing of required supporting facilities. About $55 million is available for 2020. The program recently has been favoring electric bus submittals over CNG submittals. In the $82 million awarded in 2018, none of the 52 awards were directed towards CNG buses.

While pursuing 5339c grants is advantageous for Metro's bus replacement program, it does not represent a large source of capital funding.

5.0 Lifecycle Cost Analysis

The study performed a life cycle cost analysis, assuming a 15 bus annual transition to either CNG or electric propulsion, and a gradual cleaning of the electrical energy produced by MG&E. The analysis assumes that 40 percent of MG&E's energy will remain fossil fuel based in 2045, as they progress towards carbon neutral in 2050. The cost analysis includes capital costs associate with retrofitting buildings to accommodate the fuel type specified. Appendix A provides the assumptions used in the cost analysis and Figure 8 summarizes the results.

Life Cycle Cost Analysis Summary			
	Diesel	**CNG**	**E-Bus**
cost/bus	$500,000	$600,000	$800,000
Bus Emissions (g/mi) 2020	2,476	2,116	1,874
Bus fuel efficiency (mi/DGE)	5	5	19
Bus Fuel Costs ($/DGE)	$2.50	$1.04	$3.80
Bus Fuel Costs ($/mi)	$0.50	$0.23	$0.20
Bus Maintenance Costs ($/mi)	$0.30	$0.36	$0.24
	base	+20%	-20%
Facility Maintenance Costs	$13,500,000	$14,900,000	$12,900,000
	base	+10%	-5%
Capital Costs			
Fueling Station	--	$4,000,000	--
CNG Facility Modifications	--	$4,000,000	--
Electrical Distribution	--	--	$2,000,000
Onsite Photovoltaic (0.5 MW - 1 MW)	$1,250,000	$1,250,000	$2,500,000
Offsite Photovoltaic (8.5 MW)	--	--	$19,300,000
Offsite Photovoltaic	8.5 MW; $10.6M land, $8.6M array; 21.4 acres		
Operation	23,605 mi/yr/bus; 215 buses; ~5M miles per year		
Replacement	Buses replaced every 15 years		
Inflation	1% general; 5% labor		
Inflation - fuel	3%	1%	3%
Grid Decarbonization	10-20% every 5 years; 0 carbon 2056		

2020-2045 - Life Cycle Cost			
	Diesel	**CNG**	**E-Bus**
Total Life Cycle Cost for all buses	**$691,600,000**	**$738,000,000**	**$755,500,000**
Cost Increase	--	$46,400,000	$63,900,000
Carbon (tons)	376,890	343,168	255,695
Carbon Reduction (tons) 2020 to 2045		33,722	121,195
Value in Carbon Reduction ($40/ton in 2018$)	-	$ 1,349,000	$ 4,848,000

2045			
Operating Cost/year	$27,200,000	$29,100,000	$29,100,000
Operating Cost Increase/year	--	$1,900,000	$1,900,000
Carbon (tons/yr)	--	12,388	4,389
Value in Carbon Reduction ($40/ton in 2018$)		$ 496,000	$ 176,000

Offsite Photovoltaic			
2020-45 Cost Increase with Offsite Photovoltaic	--	--	$83,200,000
2020-45 Carbon Reduction with Offsite Photovoltaic (ton	--	33,722	211,250
2045 Carbon with Offsite Photovoltaic (tons/yr)	--	12,388	820

Figure 8 Life Cycle Cost Analysis

The CNG and electric 25 year life cycle costs are greater than diesel by 7 and 9 percent respectively. This difference is within the range of the assumptions that were made for the analysis and does not show an overwhelmingly clear advantage among the three fuel types.

6.0 Observations and Conclusions

The following bullets summarize key observations from this analysis.

- Electric bus technology is not yet mature, and needs to develop in order fully meet Metro's needs.
- Fleet conversion will take 15 years to complete. Because of this, fuel selection should be viewed as a 30 year decision.
- The Oscar Mayer facility can accommodate either CNG or electric buses, and therefore fuel type selection should not be a determining factor in the acquisition of the site. Oscar Mayer has high levels of electrical service along with the ability to expand. A high pressure gas line also runs adjacent to the property.
- The life cycle cost premium for CNG and electric fleet conversion is relatively modest, being 7 and 9 percent respectively.
- CNG conversion requires more upfront capital costs associated with fueling stations and building retrofits than electric buses do.
- The carbon emission reduction of electric buses over CNG from 2020 to 2045 is relatively modest, being only 122,000 tons. It is primarily dependent on MG&E's ability to become carbon neutral by 2050.
- Once MG&E becomes carbon neutral in 2050, electric buses will hold a clear advantage over CNG in regards to carbon emissions. CNG buses will <u>always emit</u> carbon, about 14,000 tons annually. Electric buses have the potential to be fully carbon neutral.