Attachment 1

City of Racine

City Hall
730 Washington Ave.
Racine, WI 53403
www.cityofracine.org

Meeting Agenda - Final

Finance and Personnel Committee

Chairman Q.A. Shakoor II
Alder Mary Land
Alder Jason Meekma
Alder Natalia Taft

Monday, March 9, 2020 **5:00 PM** **City Hall, Room 307**

Call To Order

Chairman Comments

Roll Call

Approval of Minutes for the February 24, 2020 Meeting.

1. 0124-20

Subject: Communication sponsored by Alder Jung requesting authorization for the Mayor and City Clerk to authorize an application to the Federal Transit Administration Low or No Emission Vehicle Program - 5339(c) and agree to use funds awarded under the Wisconsin Transit Capital Assistance Grant Program (VW Mitigation Program) in 2019 as the local match. (Grant Control 00291)

Staff Recommendation to the Finance and Personnel Committee on 03-09-2020: Approve authorizing application to the Federal Transit Administration Low or No Emission Vehicle Program - 5339(c) and agree to use funds awarded under the Wisconsin Transit Capital Assistance Grant Program (VW Mitigation Program) in 2019 as the local match.

Fiscal Note: No fiscal impact.

2. 0125-20

Subject: Communication sponsored by Alder Jung requesting authorization for the Mayor and City Clerk to authorize an application to the Wisconsin Transit Capital Assistance Grant Program (VW Mitigation Program) and agree that the receipt of a grant under this program will result in a reduction of future municipal payments pursuant to § 79.035(7), Wis. Stats. (Grant Control 00292)

Staff Recommendation to the Finance and Personnel Committee on 03-09-2020: Approve authorizing application to the Wisconsin Transit Capital Assistance Grant Program (VW Mitigation Program) for up to two buses and agreeing to a reduction of future State shared revenue payments to pay for the local share.

Fiscal Note: $418,328 in reduced state shared revenue payments amortized over ten annual installments at zero percent interest starting the year that the reimbursement occurs.

3. 0148-20 **Subject:** Communication sponsored by Alder Shakoor II on behalf of the City Attorney, requesting authorization for the City to enter into a Cooperating Internship Site Agreement with Bryant & Stratton College for the placement of students from the paralegal studies program in an unpaid position for a minimum of 90 hours per student placement and from time to time.

Staff Recommendation to the Finance & Personnel Committee on 03-09-2020: That the Mayor and City Clerk be authorized to enter into a Cooperating Internship Site Agreement with Bryant & Stratton College for the placement of students from the paralegal studies program as presented.

Fiscal Note: N/A

Attachments: Memo and Cooperating Internship Site Agreement

Adjournment

All persons, including alderman, interested in committee agenda items shall be permitted to provide input. Immediately after calling each agenda item, the chair shall permit input from any person, including alderman, which input shall be limited to such agenda item. The chair may limit each person providing input to a reasonable time, based upon circumstances.

If you are disabled and have accessibility needs or need information interpreted for you, please contact Human Resources at 262-636-9175 at least 48 hours prior to this meeting.

Attachment 2: Bus Miles and Maintenance Costs

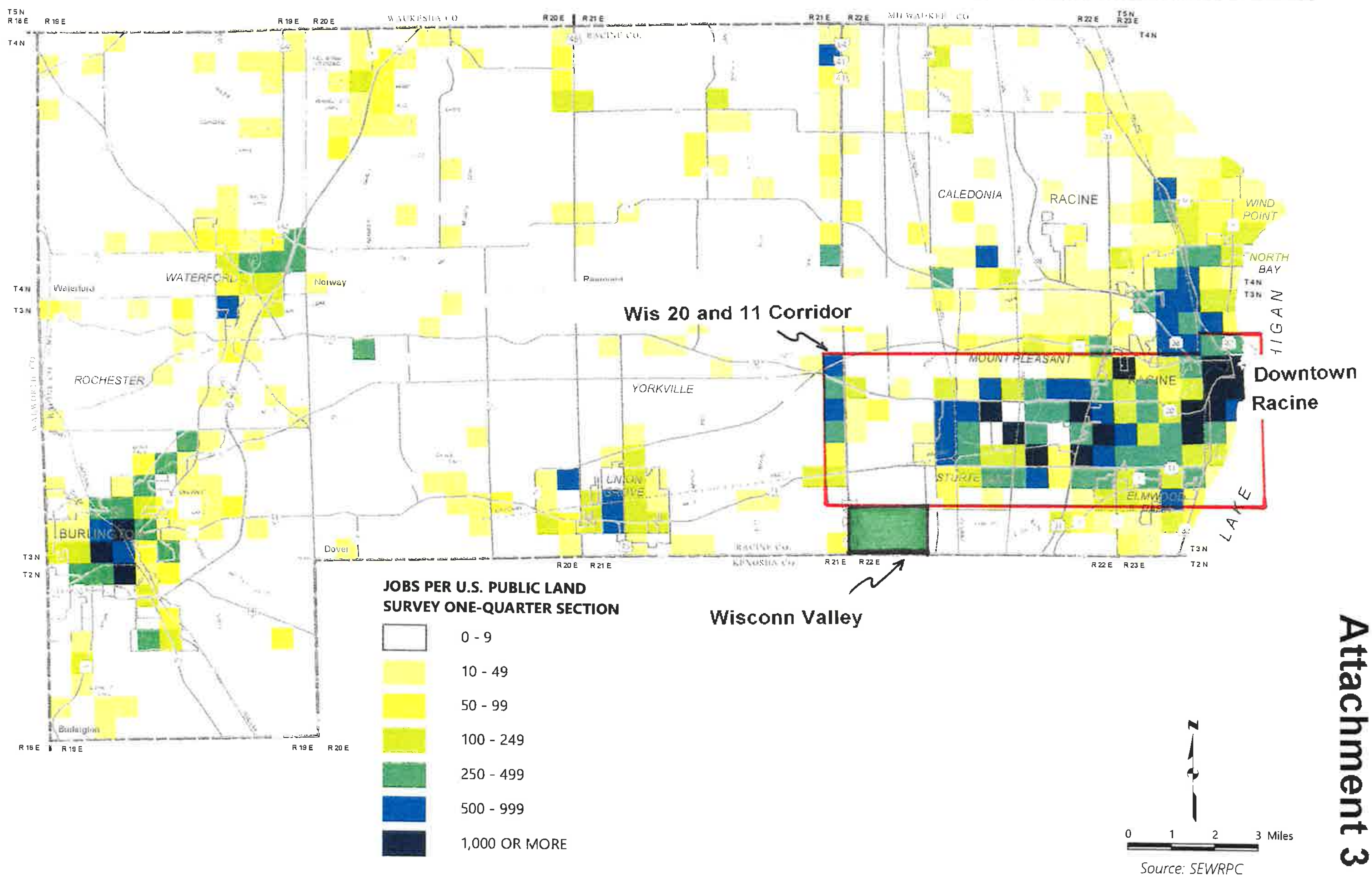
These costs are for parts only, but labor costs and parts costs are correlated. Labor costs for transmissions are more than wiper blades.

Maintenance costs are a growing share of the total budget because of the aging fleet.

		Prev State/Fed formula		2020 State Grant						INPUT				
		Sep-19	Sep-19	Sep-19	Sep-19		Cost per	Sep-19	Comments	Routine	Major component replacement			
			Avg.		Avg.	Cost per	Mile	Lifetime		Maint.				
Fleet year	Bus #	Parts cost	Parts cost	Miles	Miles	Mile	Index	miles			$	Item	$	Item
2004	66	$ 21,255		18,426		1.15	312	512,421	Rear end included.	9,547	$ 11,708	Transmission		
2004	67	$ 56,993		10,028		5.68	1,539	508,625	Rear end included.	5,198	$ 36,855	Engine and transmission	$ 14,940	Frame
2004	68	$ 5,280		20,274		0.26	70	502,760		5,280				
2004	69	$ 1,845		21,341		0.09	23	481,562		1,845				
2004	70	$ 6,170		13,962		0.44	120	522,846	Rear end included.	6,170				
2004	71	$ 7,438		20,128		0.37	100	485,961	Rear end included.	7,438				
2004	72	$ 5,290		21,188		0.25	68	467,722		5,290				
2004	73	$ 3,839		17,483		0.22	59	565,012		3,839				
2004	74	$ 3,459		12,462		0.28	75	530,022		3,459				
2004	75	$ 3,312		19,110		0.17	47	522,463		3,312				
			$ 11,488		17,440	$ 0.66	178							
2009	76	$ 17,038		24,715		0.69	187	372,252		5,330	$ 11,708	Transmission		
2009	77	$ 19,495		29,885		0.65	177	368,435		$ 8,996	$ 10,499	2019 Transmission		
2009	78	$ 1,336		27,503		0.05	13	342,209		$ 1,336				
2011	79	$ 13,837		40,038		0.35	94	368,599		$ 13,837				
2011	80	$ 12,068		35,834		0.34	91	345,428		$ 12,068				
2011	81	$ 9,036		42,543		0.21	57	368,000		$ 9,036				
2011	82	$ 17,707		40,711		0.43	118	336,643		$ 6,884	$ 10,823	2019 Transmission		
2011	83	$ 3,034		26,061		0.12	32	319,917		$ 3,034				
2012	84	$ 17,875		29,434		0.61	164	257,383		$ 17,875				
2012	85	$ 6,780		30,521		0.22	60	236,475		$ 6,780		Collision $34,541		
2012	86	$ 20,075		30,362		0.66	179	261,709		$ 20,075				
2013	87	$ 16,836		26,735		0.63	170	270,946		$ 16,836				
2013	88	$ 4,597		43,047		0.11	29	275,564		$ 4,597				
2013	89	$ 23,123		33,056		0.70	189	278,564		$ 23,123				
2013	90	$ 12,532		39,736		0.32	85	243,009		$ 12,532				
2013	91	$ 3,242		43,602		0.07	20	278,854		$ 3,242				
2013	92	$ 7,914		37,426		0.21	57	258,966		$ 7,914				
2013	93	$ 13,054		42,523		0.31	83	284,706		$ 13,054				
2013	94	$ 29,967		31,933		0.94	254	236,919		$ 19,535	$ 10,433	2019 Transmission and collision $20,865		
2013	95	$ 5,752		39,040		0.15	40	272,055		$ 5,752				
2013	96	$ 19,330		25,079		0.77	209	274,117		$ 19,330				
2013	97	$ 15,545		38,089		0.41	110	262,037		$ 15,545				
2013	98	$ 20,420		37,709		0.54	147	263,121		$ 20,420				
2013	99	$ 8,405		41,855		0.20	54	256,542		$ 8,405				
2013	1	$ 6,024		42,469		0.14	38	288,661		$ 6,024				
			$ 13,001		35,196	$ 0.37	100.00							

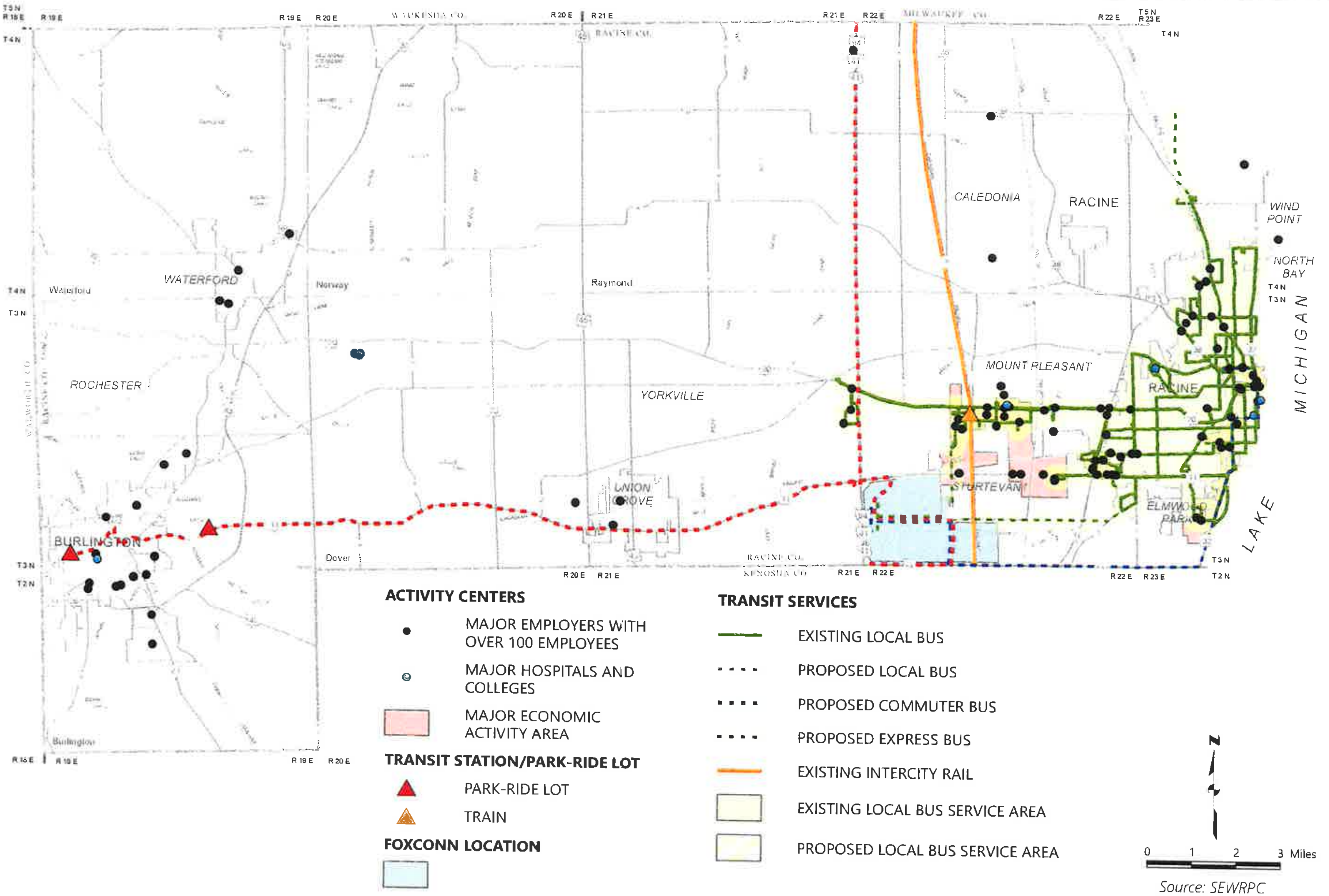
Attachment 3

Job Density in Racine County: 2010



Attachment 4

Major Activity Centers Compared to Public Transit Services in Racine County: 2018

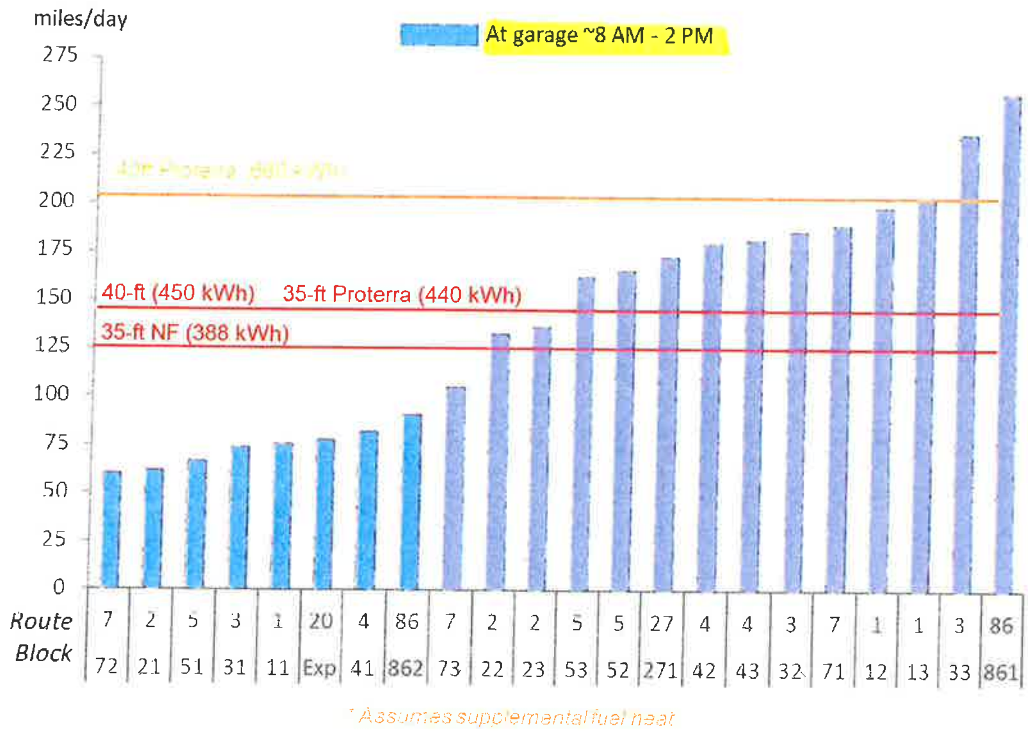


CITY OF RACINE ELECTRIC BUS ANALYSIS

blocks, in which buses are in service for three hours in the morning, sit at the depot for six hours mid-day, and are then in service for another 3 hours in the afternoon.

Also shown in Figure 2 is the projected reliable range per charge for 40-ft electric buses, and the 35-ft Proterra bus, with 450-kWh batteries; the 35-ft New Flyer bus with 388 kWh battery, and a 40-ft Proterra bus with a 660-kWh battery. For all buses the range shown assumes buses are equipped with supplemental fuel heat.

Figure 2 RYDE Weekday Bus Blocks versus Electric Bus Range per Charge



As shown, if RYDE's buses are charged at the depot overnight, only a 40-ft Proterra bus with a 660-kWh battery could be used on virtually every block on every route. The available 35-ft buses, and 40-ft buses from manufacturers other than Proterra, could be used on the split block on each route, and on two of three blocks on Route 7. The Proterra 35-ft bus and all 40-ft buses could also be used on all three blocks on Route 2. However, if only charged at night electric buses with 450-kWh or smaller batteries could not be used on half of RYDE's daily blocks, because they would not have enough range to complete the day's scheduled service. Note, however, that while the Proterra 660-kWh buses could be used on virtually all blocks they would need to charge at 100 kW during overnight charging given available charge time. Buses with 450-kW or smaller batteries would only need to charge at 50 kW for overnight charging.

MJB & A

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October 1, 2019

Michael J. Maierle
Transit and Parking System Manager
City of Racine
730 Washington Ave.
Racine, WI 53403

Dear Mr. Maierle:

M.J. Bradley & Associates has completed the preliminary analysis of Racine's transit bus operations, in order to provide recommendations for how proceed with bus electrification using VW settlement grant funding. This analysis was authorized by City of Racine Purchase Order Number 1900356-00.

Attached to this letter is a brief report that summarizes our analysis and provides several options for City of Racine to consider with respect to purchase and deployment of electric buses. If you have any questions about the analysis or recommendations, please do not hesitate to contact me at (978) 405-1275; dlowell@mjbradley.com.

It was a pleasure working with you.

Sincerely,

Dana Lowell

Dana Lowell
Senior Vice President / Technical director
M.J. Bradley & Associates, LLC

CITY OF RACINE ELECTRIC BUS ANALYSIS

PURPOSE:

This report summarizes an analysis of City of Racine transit bus operations, to identify potential deployment strategies for six 35-ft or 40-ft battery-electric transit buses to be purchased with a grant of $6.2 million received from the state of Wisconsin; this grant is funded with VW Settlement proceeds.

Given limitations on available battery size and range, this analysis was intended to evaluate the capabilities of commercially available battery buses compared to City of Racine operating requirements, to determine how electric buses could be deployed by the City. The issues explored were:

- Projected energy use and electric bus range on City of Racine (RYDE) Transit Routes
- Given available range, the routes and/or blocks on which electric buses could be deployed
- Cost and operational considerations of different charging strategies
- Projected electric bus energy costs
- Operational changes required to accommodate electric buses

EXECUTIVE SUMMARY:

On weekdays, RYDE operates 22 35-ft buses on eight different routes.[1] Daily mileage accumulation for these 22 daily bus block assignments ranges from 60 miles to 250 miles per bus.

Thirty-five-foot electric buses are available from New Flyer with a maximum battery pack size of 388 kWh, and from Proterra with a maximum battery pack size of 440 kWh. While Gillig makes 35-ft diesel buses it is not clear if or when they will offer a 35-ft battery bus. Forty-foot electric buses are available from New Flyer and Gillig with a maximum battery pack size of approximately 450 kWh, and from Proterra with maximum battery pack size of 660 kWh.

In RYDE transit service available 35-ft electric buses will provide a reliable range of 100 -110 miles per charge for buses that use electric heat, and 130 - 150 miles per charge for buses equipped with supplemental fuel heaters. Reliable range for 40-ft diesel buses equipped with a 450-kWh battery pack will be similar. Reliable range for a 40-ft Proterra bus equipped with a 660-kWh pack will be significantly longer - 160 miles with electric heat and 209 miles with supplemental fuel heat.

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[1] This does not include school routes.

This range from available 35-ft electric buses is enough to cover half of RYDE's daily bus blocks, including all three daily buses on Route 2 and the split block assignments on all other routes. Buses on split blocks cover the morning and afternoon peak, but do not operate mid-day. These buses leave the depot at about 5 AM and return at about 8 AM; they then leave again at about 2 PM, returning about 5 PM.

The easiest way to deploy six 35-ft electric buses would be to charge them off-peak overnight at the depot and deploy them only on the daily split blocks. Each day one electric bus could operate peak service on each of six different routes. Alternately, if equipped with supplemental fuel heaters three electric buses could operate all three daily assignments on Route 2 - each of which is less than 150 miles - with the other three electric buses operating peak service (split block) on each of three other routes. If deployed this way, the six electric buses will on average accumulate about 21,000 miles per year (130,000 total annual electric miles), which is about half the annual mileage accumulated by current diesel buses. Monthly fuel savings will be approximately $4,000 compared to operating diesel buses for this service, and over their life these electric buses will produce a net fuel cost savings of approximately $460,000.[2]

If City of Racine would like to be able to use the electric buses on virtually any block assignment on any route there are three ways this could be accomplished: 1) using 35-ft buses do mid-day charging at the depot as well as overnight charging, 2) using 35-ft buses do in-route charging at the downtown Transit Center rather than depot charging, or 3) purchase 40-ft Proterra electric buses with 660 kWh battery packs.

Any of these three options would allow RYDE to double average daily and annual electric bus miles using six electric buses, but they would either require additional capital funds (in addition to the VW settlement grant) or would require significant changes to bus operations. Despite doubling annual electric bus miles these options would not produce significantly higher net cost savings because either capital costs would be higher, or annual electricity costs would be higher due to higher monthly demand charges. These options, and their trade-offs, are discussed further below.

Regardless of the deployment strategy, MJB&A recommends that the electric buses purchased by City of Racine include supplemental fuel heaters in addition to electric heaters. Without supplemental fuel heat daily range will decrease by 20 miles or more on cold winter days.

MJB&A also recommends that RYDE put in place procedures to ensure that all depot charging happens between 9 PM and 9 AM, to coincide with local utility WeEnergies' off-peak demand period (unless RYDE chooses the deployment scenario that includes mid-day charging to extend daily range). Charging outside of this window will incur additional demand charges that will increase monthly electricity costs by $700 for every bus charging concurrently.

[2] Assumes 12-year bus life. This is net of estimated charger maintenance costs.

CITY OF RACINE ELECTRIC BUS ANALYSIS

ANALYSIS & DISCUSSION

RYDE Service

On weekdays, RYDE operates 22 35-ft buses on eight different routes. Most routes require three buses per day. Two buses on each route stay in service for 12 – 17 hours, leaving the depot between 4:30 AM and 6:00 AM, and returning between 5:30 PM and 10:30 PM. One bus on each route operates a "split block", which covers the morning and afternoon peak, but does not operate mid-day. These buses leave the depot at about 5 AM and return at about 8 AM. Between 8 AM and 2 PM they stay at the depot, then enter service again at about 2 PM, returning about 5 PM.

Fourteen buses are back at the depot by 7 PM, and eight stay in service later. Most return by 10 PM, but one bus stays out until after midnight. All buses are at the depot for at least five hours each night and most are there for ten hours or more.

Daily mileage accumulation on weekdays for the 22 buses in service ranges from 60 miles to 250 miles per bus.

Commercially Available Electric Buses

Virtually every full-line bus manufacturer that produces diesel, CNG, and hybrid-electric buses for the North American market also offers at least one battery-electric option, including New Flyer, Gillig, and Nova. Battery buses from these manufacturers use the same bus platform as the other bus types, with only minor modifications to accommodate the electric propulsion system. There are also three manufacturers that produce only electric buses: Proterra, BYD, and Green Power Motor Company; these manufacturers do not offer buses with conventional propulsion systems.

See table 1, which compares relevant characteristics of the 40-ft electric bus models offered by the different manufacturers. New Flyer and Proterra also offer 35-ft versions of their electric bus. Gillig produces 35-ft diesel buses, but it is not clear if and when they will offer a 35-ft electric bus; as the most recent entrant into the electric bus market their product line is still evolving.

All manufacturers except Proterra manufacture electric buses using a welded tubular steel frame, with steel, aluminum, or composite body panels riveted, bolted or bonded to the frame – the same construction used for traditional transit buses with internal combustion engines. The load bearing structure, walls, roof, and floor of Proterra electric buses are all constructed of fiberglass composite, with a design and construction method like that used for many small and medium-sized marine vessels. The composite structure is lighter than a steel structure, and is not subject to corrosion, but may experience other deterioration over time due to structural stress– for example cracking or delamination. The composite structure also behaves differently than steel structures in a crash and will require different repair methods.

Table 1 Commercially Available 40-ft Battery Buses

Parameter	BYD	Gillig	New Flyer	Nova	Proterra
Length (in)	482	501	492	490	512
Wheelbase (in)	240	279	284	243	296
Height (in)	134	134	130	130	134
Front Overhang (in) [1]	101	101	87	120	104
GVWR (lb)	43,431	45,000	44,308	43,000	43,650
Curb Weight (lb) [2]	32,920	29,650/33,750	30,134/32,920	32,000	26,649/33,149
Passenger Capacity [3]	77	75	75	71	70
Battery Type	Iron-phosphate	Lithium-ion	Lithium-ion	Lithium-ion	Lithium-ion
Battery Size Options	324 kWh	148 kWh 296 kWh 444 kWh	160 kWh 267 kWh 388 kWh 466 kWh	150 kWh	220 kWh 440 kWh 660 kWh
Battery Locations [4]	A	A, B, C	A, B	A, B	D
Plug-in Charging	SAE J1772 CCS-Type 1	SAE J1772 CCS-Type 1	SAE J1772 CCS-Type 1	Not available	SAE J1772 CCS-Type 1
Conductive Charging	Not available	SAE J3105-1	SAE J3105-1	SAE J3105-1	SAE J3105-1
Structure	Tubular steel	Tubular steel	Tubular steel	Tubular steel	Composite
Drive Motor	Dual 150 kW AC synchronous	No Data	200 kW Permanent magnet	230 kW Permanent magnet	Dual 190 kW or single 250 kW Perm magnet
Gear Box	None- direct drive	No Data	None – direct drive	None – direct drive	2-speed auto shift
Top Speed	62.5 MPH	No Data	No Data	No Data	65 MPH
Energy Use [5]	1.99 kWh/mi (2014 - CBD)	No Data	1.75 kWh/mi (2014 - CDB)	1.94 kWh/mi (2018 – OCC)	2.01 kWh/mi (2017 – OCC)

[1] Center of front axle to front bumper [2] With smallest/largest available battery

[3] Maximum, with largest battery. Based on GVWR and 150 lb/passenger

[4] A = on roof; B = in rear compartment behind passenger cabin; C = under floor, just ahead of rear axle; D= under floor between front and rear axles

[5] From Altoona testing. For testing prior to 2017 listed results are from track testing on Central Business District (CBD) cycle. For testing in 2017 and 2018 listed results are from dynamometer testing on Orange County (OCC) cycle. Stated values do not include energy for air conditioning or cabin heating.

Since the Proterra composite structure is lighter than a steel structure, the Proterra bus has 2,000 – 3,000 lb lower curb weight than other electric buses with the same sized batteries.

One key parameter for any electric bus is the installed battery energy capacity (kilowatt hours of energy, kWh), which determines how far the bus can go on a single charge (range). Most manufacturers offer 40-ft buses with a range of battery sizes, from approximately 150 kWh to approximately 450 kWh. BYD currently only offers one battery size (324 kWh), but is reportedly working to offer a larger, extended range battery. On 40-ft buses Proterra offers the largest battery currently available in the market, at 660 kWh. Maximum battery pack size on New Flyer 35-ft electric buses is 388 kWh; maximum battery pack size on Proterra 35-ft electric buses is 440 kWh.

The larger the battery the longer the range (miles) per charge. Also, the larger the battery the heavier the bus, and the practical limitation on maximum battery size is primarily weight, not volume. Proterra can offer a larger battery than other manufacturers due to the lower weight of their composite structure.

The smaller battery offerings (<250 kWh) are primarily intended for buses that will use in-route opportunity charging. The larger battery offerings are primarily intended for buses that will charge overnight at the depot.

All manufacturers except Nova offer plug-in DC charging, using a charge port compatible with an SAE J1772 CCS-Type 1 connector. As such, a single DC charger equipped with this type of connector can be used to charge buses from all manufacturers. All manufacturers provide a charge port on the curb-side rear of the bus and all manufacturers offer the option of a second charge port, on the street-side rear or street-side front of the bus.

Nova, and all other manufacturers except BYD also offer over-head conductive charging, at charge rates up to 450 kW. For overhead conductive charging all manufacturers intend to comply with the forthcoming SAE J3105-1 charging standard, which is still a work in progress but is scheduled to be published by the end of 2019. All manufacturers install the J3105-1 charge port on the roof of the bus, centered over the front axle. Overhead conductive charging is used for in-route charging but can also be used in a depot setting for overnight depot charging.

A bus with an internal combustion (IC) engine uses waste heat captured via the engine cooling system to heat the passenger cabin in cold weather. Electric buses also have waste heat produced by the inverters and drive motor, which are typically cooled with a water-ethylene glycol (WEG) system. However, electric buses produce significantly less waste heat than IC engine buses, and the WEG loop operates at lower temperature. No electric bus manufacturer currently harvests this waste heat for cabin heating.

Instead, electric buses are equipped with electric resistance heating coils fed by energy from the propulsion battery. Details of how the heat is distributed from the coils to the passenger compartment vary by manufacturer, to include heating WEG to feed floor-mounted heat exchangers, distributing heated air from the rear through a ceiling level plenum, and directly re-circuiting cabin air over the coil mounted on the roof in the middle of the bus. The amount of battery energy used for cabin heating can be significant during cold weather and will affect bus range. All manufacturers offer the option of a diesel-fired heater to supplement the electric heating system. Some manufacturers integrate the electric and diesel systems while others keep them separate.

Electric Bus Charging Options

There are two main ways to charge electric buses: depot charging and in-route charging.

Depot Charging:

Depot charging is analogous to home charging for personal electric vehicles; a charger is provided at every bus parking spot in the depot, and buses are plugged in and charged during the time that they are parked, which for RYDE is between about 7 PM and 5 AM for most buses. Given how long RYDE buses spend at the depot at night, most depot-charging scenarios would require a maximum charge rate of 50-kW for each bus. As discussed below, there is one depot charging scenario that would require a 100-kW charger for each bus.

The most common way to implement depot charging is to use direct current chargers equipped with an SAE J1772 CCS-Type 1 connector (CCS charger); the standard connector is plugged into a compatible port on the bus, and power is transferred from the charger to the bus via an electrical cord.

For RYDE, MJB&A recommends locating depot chargers inside the bus parking building, adjacent to the west wall[3]. There is sufficient space there to install six chargers without impacting bus parking. This will be the easiest/least expensive location for depot chargers because the existing electrical distribution panel is on this wall, and the utility feed is from a pole mounted transformer only a few feet from the building. To provide sufficient power the existing distribution panel will

[3] This is where tires are currently stored. Tire storage would need to be moved to the east wall.

need to be replaced or a second panel will need to be installed. It is likely that the local utility WeEnergies will also need to add additional transformer capacity to serve the load.

There are several appropriately sized chargers on the market (50 kW – 62 kW), which are also used for "fast-charging" electric cars. These chargers typically cost $35,000 - $50,000 each, with additional costs for installation. A conceptual design for full implementation of depot charging at Milwaukee County Transit System estimated a total cost of $94,000/charger there. However, a preliminary site investigation indicates that for the six-bus RYDE program charger costs will likely be lower, in the range of $65,000 - $75,000/charger.

The biggest issue associated with depot charging – regardless of the type of charger used - is a limitation on daily bus operating range (miles, hours), due to limitations on the size of batteries that can be installed on the bus.

In-route Charging:

With in-route charging energy is added periodically while the buses are in service each day, rather than buses being charged at the depot overnight. In-route charging requires much higher charge rates than depot charging– typically 300 to 450 kW – but fewer chargers.

In-route chargers are typically installed at one or both termini on a route, and buses are charged for 5 -15 minutes each time they come to the end of the route where the charger(s) is located.

Depending on route length, and whether charging is done at one or both termini, buses may charge once every 1 – 2 hours in service. With 450 kW in-route chargers total in-route charge time will typically be 30 – 60 minutes per day per bus.

In-route charging is typically done using overhead conductive chargers. A movable pantograph, powered by electricity or compressed air, is installed on a pole which extends over the roadway. When a bus pulls under the charger the pantograph moves down, and contacts power rails installed on top of the bus; power is then transferred between the rails on the pantograph and the rails on the bus.

There are two companies that sell overhead conductive chargers in the North American market, ABB and Siemens. Both companies offer chargers with nominal charge rate of 150 kW, 300 kW, or 450 kW.

One of the most significant advantages of in-route charging compared to depot charging is that with a properly designed charging network there is virtually no limitation on daily bus range; buses would leave the depot in the morning with a near full battery and return with a near full battery after periodic charge events throughout the day which replenished all of the energy used on route. In addition, the battery on the bus can be smaller than the battery on a depot-charged bus, which reduces bus weight and cost.

While in-route charging eliminates the range restrictions of depot-charged buses, time will likely need to be added to bus schedules to accommodate the periodic charging.

RYDE could implement in-route charging for the proposed six electric buses using one 450 kW charger located at the Transit Center in downtown Racine. With this one charger the electric buses could be used on virtually any block on any route, since all buses stop there. Under this scenario, an electric bus would charge every time it arrived at the Transit Center (once per round-trip). Depending on the route, the required charging time would range from 5.5 – 7.7 minutes per event, with a system-wide average of 6.7 minutes. To implement in-route charging RYDE would need to change current bus schedules on at least two routes, in order to add lay-over time at the Transit Center for charging. Currently buses on every route are scheduled to arrive at the Transit Center at the same time, to allow for transfers between routes, and no buses pause at the Transit Center for more than a few minutes. To successfully implement in-route charging with six electric buses, bus arrivals at the Transit Center for at least two routes would need to be staggered by 8 - 10 minutes and buses on these routes would need to be scheduled to stay at the transit center while charging.

A cursory review of the Transit Center indicates that there is likely enough space to install an in-route charger, but availability of distribution capacity from WeEnergies is unknown. Other transit agencies have reported total costs of $650,000 - $1 million per charger for installation of 450 kW in-route chargers. A conceptual design of in-route charging for the Milwaukee County Transit System estimated an average cost of $850,000/charger for 450 kW in-route chargers in the MCTS service area.

Projected Energy Use and Range per Charge

The energy required to operate an electric bus includes propulsion energy (i.e. driving) and energy to cool or heat the passenger cabin. Propulsion energy varies with average speed on the route – the lower the speed the more energy required (kWh/mi), primarily because lower speed correlates to more stops.

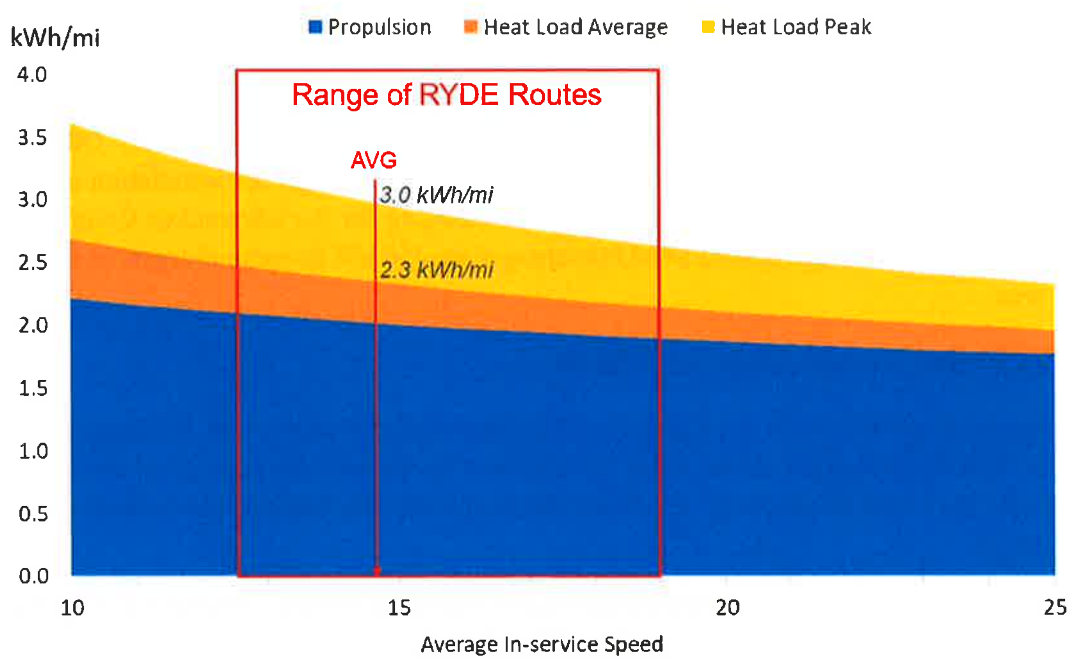
The energy required for heating and cooling varies with temperature – the lower or higher the ambient temperature the more energy is required. In the case of an electric bus, the energy required for heating during cold weather is significantly greater than the energy required for cooling during hot weather. Available in-use data indicates that the average daily cooling load (air conditioning) is approximately 2.5 kW when ambient temperature is 80 ° F, while the average daily heating load could be as high as 14 kW (electric resistance heating) when the ambient temperature is 0 ° F.

See Figure 1 for a summary of the estimated energy use by 40-ft electric buses in service on RYDE routes. The average in-service speed of the different RYDE routes ranges from 12.5 MPH to 19 MPH. As such, the estimated energy required for propulsion will range from 1.9 - 2.1 kWh/mi, depending on the route. On the coldest winter day (0° F), the additional energy required for cabin heating will add 0.7 – 1.1 kWh/mi, for a total load of 2.6 – 3.2 kWh/mi.

Across the entire year, average energy use of 40-ft buses is projected to total 2.1 – 2.5 kWh/mi for the different routes, including both propulsion and heating/cooling, based on historical annual temperatures in Wisconsin. Across all RYDE routes annual average energy use is projected to be 2.3 kWH/mi, but 3.0 kWh/mile on cold winter days (0° F).

Thirty-five-foot electric buses are approximately 10 percent lighter than 40-ft buses and are projected to use approximately 5 percent less energy per mile. Across all RYDE routes annual average energy use for 35-ft electric buses is projected to be 2.2 kWH/mi, but 2.8 kWh/mile on cold winter days (0° F).

Figure 1 Projected 40-ft Electric Bus Energy Use



As discussed above, for most manufacturers the nameplate energy capacity of the largest battery currently available on 40-ft buses is 450 kWh; the exception is Proterra which offers battery packs as large as 660 kWh. The largest available battery on 35-ft buses is 388 kWh (New Flyer) or 440 kWh (Proterra). This is the theoretical capacity when the battery pack is new, but not all that energy is available for use. Batteries degrade (i.e. lose capacity) as they are charged and dis-charged over time, and this degradation typically accelerates if the battery is regularly fully discharged. Most battery manufacturers recommend that batteries not be discharged below 15-20 percent of capacity on a regular basis when new – as batteries age this discharge window can be opened, to allow discharge down to 5% of capacity near battery end-of life.

Even when not fully discharged batteries will lose capacity. Based on manufacturer warranties, MJB&A estimates that capacity loss could be as high as 2.4 percent per year – so that by the time a battery has been in service for 6 years (bus mid-life) it will only retain about 86 percent of its original capacity, and by bus end-of life at 12 years it will retain only 71 percent of its original capacity.

When planning for fleet electrification using depot charging, MJB&A recommends that transit agencies plan to replace electric bus batteries at bus mid-life, and that peak bus requirements be based on the "reliable" range (miles) that can be achieved just before the battery is replaced.

The calculation of reliable range should be based on projected average energy use (kWh/mi) but should account for the fact that on any given day a given bus could use more than the average, based on factors such as traffic, passenger loading, and driver behavior; we recommend using 110% of the projected average to account for these factors. If the passenger cabin will be heated electrically, using energy from the battery, the calculation of reliable range should include energy used for cabin heating, and be based on the expected coldest day, not the annual average heat load. For buses that will use supplemental fuel heaters reliable range can be based on projected annual average energy use.

With a 450-kWh battery on a 40-ft bus, at bus mid-life only 329 kWh (73%) will be reliably available. Assuming average annual energy use of 2.3 kWh/mi, from a planning perspective buses on RYDE routes can be assumed to have a reliable range of 143 miles per charge most of the year. However, unless supplemental fuel heating is used, range per charge on the route will fall to only 109 miles on the coldest winter days in Racine.

For a 40-ft Proterra bus with a 660-kWh battery (largest available in the industry), available energy at bus mid-life would be 482 kWh, and reliable range per charge on RYDE routes would be 209 miles with supplemental fuel heat, and 160 miles with only electric heat.

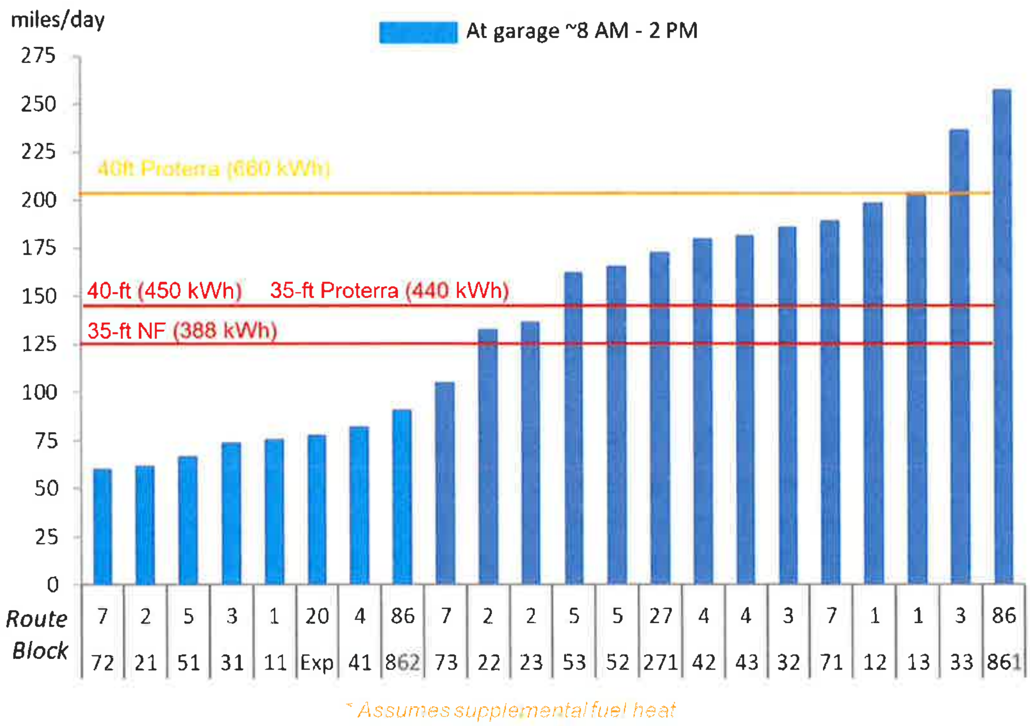
A New Flyer 35-ft bus with a 388-kWh battery would have a reliable range of 98 miles with electric heat and 125 miles with supplemental fuel heat. A Proterra 35-ft bus with a 440-kWh battery would have a reliable range of 111 miles with electric heat and 141 miles with supplemental fuel heat.

<u>RYDE Daily Bus Blocks</u>

See figure 2 for all RYDE weekday bus blocks arranged from the one with the lowest to the longest daily miles. Block 72 on route 7 is the shortest block, covering only 60 miles per day. Block 861 on Route 86 is the longest block, covering 257 miles per day. The first eight blocks are all split blocks, in which buses are in service for three hours in the morning, sit at the depot for six hours mid-day, and are then in service for another 3 hours in the afternoon.

Also shown in Figure 2 is the projected reliable range per charge for 40-ft electric buses, and the 35-ft Proterra bus, with 450-kWh batteries; the 35-ft New Flyer bus with 388 kWh battery, and a 40-ft Proterra bus with a 660-kWh battery. For all buses the range shown assumes buses are equipped with supplemental fuel heat.

Figure 2 RYDE Weekday Bus Blocks versus Electric Bus Range per Charge



As shown, if RYDE's buses are charged at the depot overnight, only a 40-ft Proterra bus with a 660-kWh battery could be used on virtually every block on every route. The available 35-ft buses, and 40-ft buses from manufacturers other than Proterra, could be used on the split block on each route, and on two of three blocks on Route 7. The Proterra 35-ft bus and all 40-ft buses could also be used on all three blocks on Route 2. However, if only charged at night electric buses with 450-kWh or smaller batteries could not be used on half of RYDE's daily blocks, because they would not have enough range to complete the day's scheduled service. Note, however, that while the Proterra 660-kWh buses could be used on virtually all blocks they would need to charge at 100 kW during overnight charging given available charge time. Buses with 450-kW or smaller batteries would only need to charge at 50 kW for overnight charging.

It would be possible to extend the range of 35-ft and 40-ft electric buses with 450-kWh or smaller batteries by charging both at night and mid-day, using the time that the eight split-block buses currently spend at the depot between 8 AM and 2 PM. However, this would require the mid-day depot time to be spread across virtually the entire fleet. Under this scenario, instead of eight buses each spending six hours at the depot mid-day, every bus would need to be scheduled for 2 hours down-time at the depot on a rotating basis. While at the depot mid-day the six electric buses would charge. This would both reduce the length of the longest blocks (because they would be two hours shorter) and also increase the range of electric buses. If the electric buses were charged at 100-kW during mid-day charging the electric buses could be used on virtually any block. However, this would require major changes to current bus block assignments and would likely increase dead-head time to rotate all buses back to the depot mid-day, rather than just eight buses.

Projected Electricity Costs

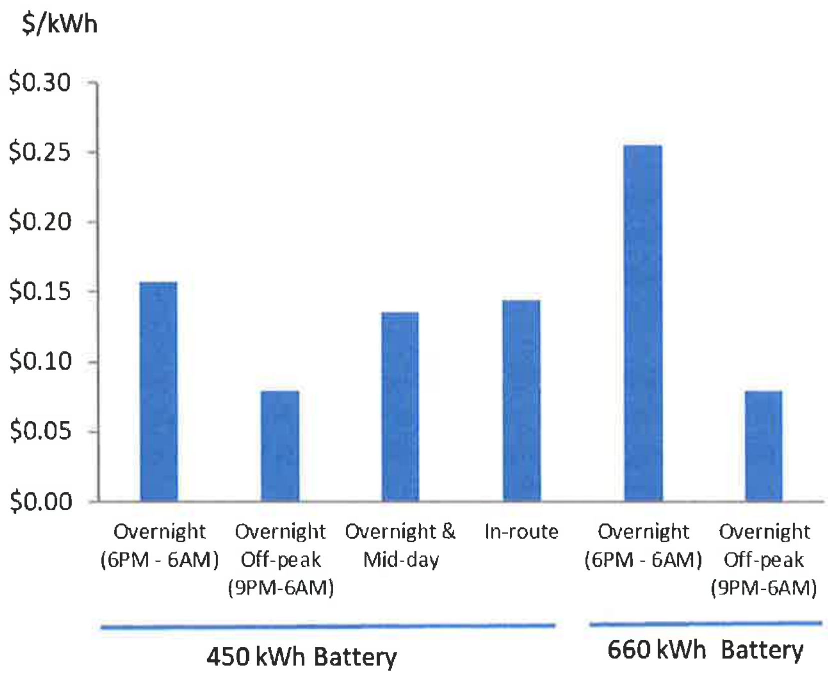
The RYDE bus depot currently has relatively low monthly electricity use, and it is therefore charged WeEnergies' General Secondary Service Rate 1 (CG1). Under this rate, RYDE pays energy charges ($/kWh) but does not pay demand charges ($/kW-month). RYDE's current average electricity cost is approximately $0.135/kWh.

When RYDE puts six electric buses in service, monthly electricity use at the depot will increase by at least a factor of six. This will mean that RYDE will be subject to WeEnergies' CG3 rate, applicable to customers with higher daily energy use. The CG3 rate includes lower energy charges ($/kWh) than the CG1 rate, but it also includes demand charges. Demand charges apply to the highest demand (kW) over any15-minute period throughput the month. The CG3 rate includes $1.85/kW for monthly peak demand that occurs any time of day (customer max demand), and an additional $13.90/kW for monthly peak demand that occurs between 9AM and 9PM on weekdays (On-peak demand). In addition, the CG3 rate charges $0.078/kWh for energy used during peak periods (9AM – 9PM), but only $0.056/kWh for energy used during non-peak periods (9PM-9AM).

See Figure 3 for MJB&A's estimate of the average cost of electricity for electric bus charging under the different charging scenarios discussed above, including overnight, overnight plus mid-day, and in-route charging of buses with 450 kWh batteries; and overnight charging of buses with 660 kWh batteries. For both 450-kWh and 660-kWh buses there are two overnight charging scenarios shown. The first one (overnight) assumes that electric buses will be plugged in and start to charge as soon as they arrive back at the depot, as early as 6 PM. The second one (Overnight Off-peak) assumes that all electric buses will delay the start of charging until the beginning of the WeEnergies off-peak period at 9 PM.

As shown, when and how buses charge has a dramatic effect on average electricity costs. The lowest electricity cost – approximately $0.08/kWh - results from off-peak overnight charging. In-route charging - or a combination of overnight and mid-day charging - will increase average electricity cost to approximately $0.135/kWh (current RYDE average cost), due to higher on-peak demand. The highest electricity costs are incurred with overnight charging if the start of charging is not delayed until after 9 PM; this scenario results in average electricity costs of $0.16/kWh for 450-kwh buses, and $0.25/kWh for 660-kWh buses. The higher average cost for buses with the larger battery results from the fact that these buses would need to charge at a higher rate (100 KW vs 50 kW) to fully charge in the available time, thus incurring higher on-peak demand charges.

Figure 3 Projected Average Electricity Cost for Bus Charging



Given projected average energy use, RYDE electric buses are projected to have average energy costs of $0.19/mile for over-night off-peak charging and $0.34/mile for in-route charging. This compares to current fuel costs of $0.55/mile for RYDE diesel buses.[4]

Energy costs are projected to be 38% - 65% lower for RYDE electric buses than for RYDE diesel buses.

[4] 4.3 MPG, $2.37/gallon

CITY OF RACINE ELECTRIC BUS ANALYSIS

RYDE Electric Bus Deployment Options

The City of Racine has four options for deployment of six electric buses in RYDE service. These options vary in terms of both the specification of the buses (bus size, battery size), and the charging strategy (overnight, overnight plus mid-day, in-route).

The details of these four options are summarized in Table 2 and each is discussed further below.

Table 2 RYDE Electric Bus Deployment Options

	Option 1	Option 2	Option 3	Option 4
Bus Size	35-ft or 40-ft	35-ft or 40-ft	35-ft or 40-ft	40-ft Proterra
Bus Battery	388 - 450 kWh	388 - 450 kWh	200 kWh	660 kWh
Charging Strategy	Overnight at Depot Off-peak 9PM - 5AM	Overnight & Mid-Day	In-route	Overnight at Depot Off-peak 9PM - 5AM
Chargers	6 50 kW	3 100 kW	1 450 kW	6 100 kW
$/kWh	$0.08	$0.14	$0.14	$0.08
Bus Cost	$5.4 million	$5.4 million	$4.5 million	$6.0 million
Charger Cost	$480,000	$320,000	$950,000	$660,000

Option 1:

Option 1 will be the easiest to implement it will require buses with 388-kWh - 450-kWh batteries and six 50-kW chargers to be installed at the depot but will require no changes to bus schedules or daily bus blocks. This option could be implemented with available 35-ft or 40-ft buses from multiple manufacturers.

Under this scenario the electric buses will not be able to be deployed on every bus block on every route; they will be restricted to all blocks on Route 2 and the split block on the other RYDE routes. Under this scenario only Route 2 can potentially be fully electrified. Passengers on the other routes will be able to ride electric buses during peak service hours (5AM – 8 AM and 2 PM – 5 PM) but not at other times.

Under this scenario the electric buses will average about 21,500 miles per year, about half of the annual mileage of current RYDE diesel buses. Total annual electric miles would be approximately 130,000. The annual mileage of the remaining diesel buses in the fleet would increase by about 7,000 miles per year per bus because the electric buses would be accumulating fewer miles.

Option 2:

Option 2 could also be implemented with available 35-ft or 40-ft buses, but it will require all current daily bus block assignments to be changed. Under this scenario, instead of eight buses each spending six hours at the depot mid-day, every bus would need to be scheduled for 2 hours down-time at the depot on a rotating basis. While at the depot mid-day the six electric buses would charge, in addition to charging overnight. The mid-day charging rate would need to be 100-kW per bus, with two buses charging concurrently between 8 AM and 2 PM. It is likely that total dead-head miles would increase, since all 22 buses would need to rotate back to the depot mid-day, rather than just the current eight buses.

Under this scenario the electric buses could be used on any (revised) block on any route, and the electric buses would accumulate the same annual mileage as the diesel buses in the fleet, approximately 43,000 miles/bus/year. Compared to Option 1, total annual electric miles would double, to 260,000 miles. However, compared to Option 1 average electricity costs for bus charging would increase by 75%, to $0.14/kWh.

Option 3:

Option 3 could also be implemented with available 35-ft or 40-ft buses. Under option 3, RYDE would implement in-route charging rather than depot charging, using one 450-kW charger located at the Transit Center in downtown Racine. One 50-kW maintenance charger would also be required at the depot.

This would allow the electric buses to be used on any block on any route, but in practical terms it would be best under this scenario to fully electrify two routes, rather than using one or two electric buses per day on a larger number of routes. This is because existing bus schedules would need to be changed to accommodate the in-route charging; electric bus arrival times at the Transit Center would need to be staggered, and a dwell time of about 10 minutes would need to be added every time an electric bus arrived at the Transit Center, to provide time to charge after every round-trip on the route.

Total charger costs are highest under this Option, but bus purchase costs will be lower because the buses will require smaller batteries. Average electricity costs will be higher than Option 1, but about the same as Option 2. As with Option 2, under Option 3 the electric buses would accumulate approximately 43,000 mile/bus/year for a total of 260,000 annual electric miles.

Option 4:

Option 4 is the same as Option 1, except using buses with the largest battery currently available in the industry (660 kWh), which is only available on 40-ft Proterra buses. The larger battery would provide enough additional range that the electric buses could be used on virtually any block on any route, even if charged only during off-peak hours overnight at the depot. However, due to the higher daily energy use per bus on the longer blocks, the overnight charging rate would need to be higher than in Option 1 (100 kW versus 50 kW), given available charging time. As long as the start of all charging is delayed until after 9 PM (off-peak), electricity costs will be the same as under Option 1, despite the higher charge rate.

As with Options 2 and 3, under this scenario the electric buses could accumulate approximately 43,000 mile/bus/year for a total of 260,000 annual electric miles.

See Table 3 for a summary of the estimated implementation costs of the different electric bus deployment options. Table 3 includes the estimated capital costs for purchase of electric buses and charging infrastructure, as well as estimated life-time costs (12 years) for fuel, including maintenance costs for the chargers. Electric bus maintenance costs are projected to be essentially the same under each scenario, so are not included. All costs in Table 3 are in current dollars, not including inflation.

Table 3 Estimated Life-time Cost of RYDE Electric Bus Deployment Options

	Option 1	Option 2	Option 3	Option 4
Bus	35-ft or 40-ft (NF, Gillig, Proterra)			40-ft Proterra
Battery	388 - 450 kWh		200 kWh	660 kWh
Charging	Depot off-peak	Depot & Mid-day	In-route	Depot off-peak
LIFE-TIME COSTS (2020$ millions)				
Buses	$5.40	$5.40	$4.50	$6.00
Chargers	$0.48	$0.32	$0.95	$0.66
Grant	($6.20)	($6.20)	($6.20)	($6.20)
NET CAP	*($0.32)*	*($0.48)*	*($0.75)*	*$0.46*
Electricity [1]	$0.29	$0.96	$1.02	$0.56
Charger Maint [1]	$0.10	$0.16	$0.20	$0.16
Diesel [1]	($0.85)	($1.65)	($1.65)	($1.65)
NET COST	**($0.46)**	**($0.53)**	**($0.43)**	**($0.47)**

The projected capital costs are less than the VW grant funding for Options 1 – 3. Capital costs are highest for Option 4, due to both more expensive buses (larger battery) and more expensive depot chargers (higher charge rate). Total capital costs for Option 4 are projected to be $460,000 more than the VW grant funding.

Option 1 has the lowest projected electricity costs, but also significantly lower projected diesel fuel cost savings compared to the other options. This is because the restricted daily range of buses under this scenario results in only half as many annual electric miles as under the other options.

Given that most or all of the capital costs will be covered by the VW Settlement grant, all four scenarios are projected to produce a net savings over the life of the buses, compared to continuing to operate diesel buses[5]. The projected net savings is similar under all scenarios, ranging from $430,000 - $530,000 over the 12-year life of the buses, or an average of $36,000 - $44,000 per year. Projected net savings are highest under Option 2, but this option will also require the most significant changes to existing operations; the administrative costs associated with these changes are not accounted for in this analysis.

[5] The calculation of net savings in Table 3 assumes that VW funds can only spent on bus and charger purchase, not operations. It assumes that any excess VW grant funds will be returned to the state.