Future Electric Mobility Design Exercise/Proposal
Design Review of the Transport Bus Requirements of Tompkins County, New York

Introduction

Despite all of the impassioned rhetoric of the United States, New York State in particular, regarding “sustainability” and “environmental protection,” it is highly unlikely that the following small sampling of headlines will be seen *here* any time soon:


France to ban sales of petrol and diesel cars by 2040

Move by Emmanuel Macron's government comes a day after Volvo said it would only make fully electric or hybrid cars from 2019


INDEPENDENT News Voices Sports Culture Indy/Life Tech Daily Edition

News › World › Asia

India to make every single car electric by 2030 in bid to tackle pollution that kills millions

Technology will be introduced 'in a very big way', says minister


Bloomberg Businessweek Markets Tech Pursuits Politics Opinion Businessweek

June 1, 2017, 12:01 AM EDT

The Country Adopting Electric Vehicles Faster Than Anywhere Else

● Fueled by cheap power and government subsidies, Norway is racing to ditch the “fossil car.”


Germany pushes to ban petrol-fuelled cars within next 20 years

The resolution urges the European Commission to implement the ban across the European Union

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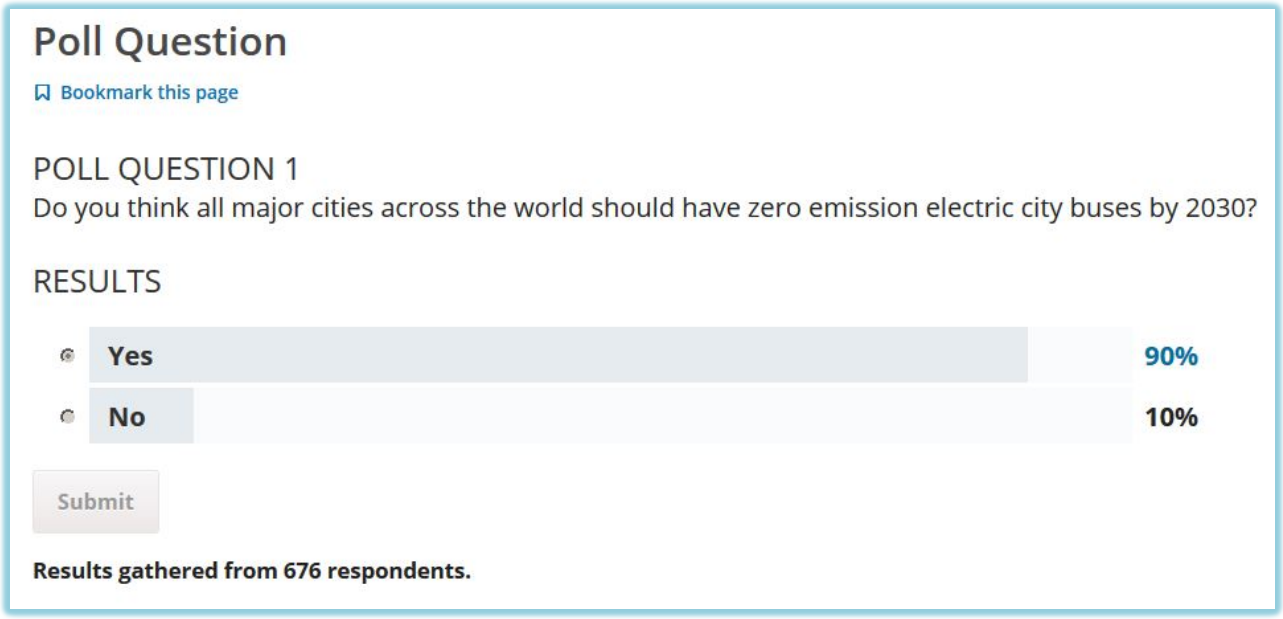
Introduction – con't

The reason these headlines are not prevalent in the USA are many, and that topic deserves fuller, separate treatment. But what connects to the instant topic is recognizing the effect these many reasons have on the implementation and optimization of the three key elements of the Electric Vehicle (EV) paradigm: Technology, Business and Policy. Not only is the USA behind on all three, but the manifestation of this laggardness, at the strategic level, results in the infamous 'chicken-n-egg' malady:

> (1) Without clear substantiated environmental protection goals that connect-to and result-in truly sustainable energy generation, (2) lacking hands-on implementation experience and the expertise that results from it, (3) lacking the educational focus and vocational infrastructure, and (4) lacking a shared vision between (A) public institutions, (B) private enterprise and (C) individual citizens, we find ourselves failing our mutual future and falling further and further behind an ever-increasingly competitive but humanity-oriented world community in the area of transport.

That is . . . regarding the chicken-n-egg . . . we aren't doing much on the EV paradigm, so by default we remain pragmatically ignorant. Since we don't really know much about EVs, we better not try because we may make a mistake.

To end this vicious cycle let us focus upon what I have labeled the low-hanging-fruit:



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Introduction – Conclusion

The low-hanging-fruit, in terms of maximum and demonstrable comprehensive benefit to society, derived from a revision *from* a transportation sector that is based on the internal combustion engine (ICE) *to* electrified mobility (EVs), is the transport bus. Sample manufacturers shown below include BYD (China), Gillig and Blue Bird (USA):

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Background

The geographic and landscape details of the host, Tompkins County, New York are summarized in Attachment 1. Demographic facts are presented in Attachment 2. These are offered because of the unique setting of Tompkins County and the Finger Lakes region in general.

Context

The context of this endeavor is three-fold:

A. Proposals that involve (or allege to involve) protection of the environment must ensure that goal comprehensively. Heretofore avoided, the beauty and ecology of the Finger Lakes are not to be diminished in any way, or subjugated to the compromises of **alleged** "sustainability."

B. The attitudes and lack of a **long-term** foresight, of local and state level New York officials, regarding energy plans, specifically as such relates to the incremental power demanded by a **long-term** vision of electric mobility, must be addressed/corrected.

C. Connected to Context B, the world at-large has already determined that transport bus conversion to full EV constitutes the greatest and quickest of comprehensive benefits; the proverbial ***'low hanging fruit.'***

Focus of the 'Future Electric Mobility Design Exercise/Proposal'

There are three major bus transport fleet operators in the Tompkins County, Ithaca New York, Finger Lakes region:

1. The Tompkins County Area Transport (TCAT) public transportation company: An independent private organization with both city and rural routes.
2. The Ithaca City School District (ICSD) student transport fleet: This district is comprised of twelve individual schools teaching kindergarten through 12th Grade High School, and accommodating 77 individual routes for student transport (Attachment 3).
3. The Cornell University Transport: In this context, the 'Campus-to-Campus Bus Service' will be the focus. This service is primarily involved in the daily transport to-and-from the Ithaca, New York and the New York City campuses.

All three fleets involve rigor and burden. Fleet #3 involves the greatest over-the-road non-stop distance; this route/distance presents the greatest challenge in terms of Electric Bus range and charging. Cornell University Transport involves the greatest distance, on a route that lacks an infrastructure with adequate energy levels and/or chargers that can accommodate short recharge times.

Therefore #3 dictates much of the design/options criteria for this exercise (Attachment 4).

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Bus Design / Options Exercise

- Vehicle Type: This will include both 35 foot and 40 foot versions of the vehicles pictured on Page 3 of 5 above.

- Driveline: These will be full electric, battery- energized drivelines (EV).

  Memo 1: The Hybrid and Plug-in Hybrid Electric designs (HEV and PHEV) are too costly, far too complex which drives long and complicated repair and maintenance (e.g. no 'oil changes are required with EVs), do not come close to the vast reductions versus the EV in chemical and noise pollution, and do not act as a "driver" of modern truly sustainable energy such as nuclear power.

  Memo 2: Fuel Cell Electric Vehicles (FCEV) are dismissed because of outrageous cost of non-existent, costly/inefficient fueling infrastructure, and due to the implicit dangers associated with on-board ultra high pressure combustible gaseous hydrogen (Note Attachment 3, page 2, *'Additional and Often Overlooked Safety Benefit.'*).

  Good review of FCEV: The Truth about Hydrogen.

  Although obviously a vested interest (in EVs), Tesla Chairman Elon Musk explains:

  > *"They're mind-bogglingly stupid. You can't even have a sensible debate.*
  >
  > *Consider the whole fuel cell system against a Model S. It's (FCEV) far worse in volume and mass terms, and far, far, worse in cost.*
  >
  > *And I haven't even talked about hydrogen being so hard to handle. Success is simply not possible.*
  >
  > *Manufacturers do it (FCEVs) because they're under pressure to show they're doing something 'constructive' about sustainability. They feel it's better to be working on a solution a generation away rather than something just around the corner.*
  >
  > *Hydrogen is always labeled the fuel of the future – and always will be."*

The instant author agrees, see, Mind-bogglingly Stupid.

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Bus Design / Options Exercise – con't

- Motor: The proposed motor will be a permanent magnet synchronous AC motor (PMAC) due to the inherently **high and instantaneous torque** these configurations offer. Not only is high torque available in the PMAC, but this machine offers great curve flexibility. This torque characteristic is absolutely essential for the bus duty cycle/logistics in-general, and is certainly desired for the terrain of the Tompkins County Finger Lakes region of Upstate New York. Vehicle gradeability is essential for this region/terrain.

  Memo: Many EV manufacturers are implementing this configuration. BYD buses use a PMAC motor. The Tesla Model 3 and the Jaguar I-Pace are PMAC propelled vehicles. The author at the June 2018 Jaguar I-Pace roll-out in Irvine, California:

For an excellent technical review of the various motor configuration designs, see, 'What's the Difference Between AC Induction, Permanent Magnet, and Servomotor Technologies?'

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Bus Design / Options Exercise – con't

- On-Board Power Conversion: Standard DC/DC invertor configuration, with full bi-directional regenerative charging capability; the latter especially benefitting from long down-hill excursions of Tompkins County bus routes.

- Battery: Lithium iron phosphate (LiFePO), aka LFP battery. This existing technology is proven, and increasingly in mass production which portends cost reductions. Practice at BYD, for the 40-foot K-9 series transit bus (at-left on Page 3 above) is a 500 kWh capacity, yielding a range rating of 255 miles, and vehicle gradeability of over 18%.

  Memo 1: Regarding mass production of LFP batteries, BYD, the largest transit bus manufacturer in the world, has completed a major business integration by completing an in-house EV battery manufacturing plant. The present output of 24 gWh will be increased to 60 gWh in 2018. Reports indicate that this facility will cover "140 football fields." See, BYD Builds Battery Plant.

  Memo 2: In a telephone conversation with Livermore, California based GIllag, LLC, the author learned that a prototype of their 40-foot bus will begin testing later in 2018, and will utilize a "600 kWh" battery.

  Memo 3: Assuming the 600 kWh battery becomes generally available, and reasonably translates; this could increase the range rating to over 300 miles. These developments address the route/distance challenges presented by Cornell University Transport (Please see Item 3, Page 4 above.)

- Charging: Because of the lack of action by officials, and because of a lack of industry standardization, this item creates uncertainty especially for the logistics of the Cornell University Transport (Item 3, Page 4 above.) The following uses conductive technology, for both Workplace and Street charging.

  Because of these deficiencies in the New York charging infrastructure, the recommendation for bus charging is to accommodate both AC and DC charging. This complicates the on-board design and increases on-board componentry, but the large bus architecture is the most suited. The New York grid has both single phase and triple phase AC. But AC requires an on-vehicle convertor. DC does not, but very few, if any DC charging stations are installed in New York.

  Therefore the Combined Charging System (CCS) is the most prudent at this time. But the CCS 2.0 standard is recommended, not merely intrinsically, but as a "push" to officials to move on the grid upgrades and CCS networks that accommodate bus battery capacities of 500 to 600 kWh and higher. The AC portion of this combo-connector offers Level 2 power; roughly 19 to 25 kWh, depending on AC phase, voltage and current. The DC connection will charge at a power up to 350 kwh . . . very fast.

  The CCS 2.0 standard does not accommodate 'Vehicle 2 Grid' (V2X) charging.

  Inductive charging not recommended, due to lack of development/related infrastructure.

  Investigation of 'Battery Swap' designs is encouraged.

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Bus Design / Options Exercise – Future Developments

Maintenance & Serviceability, Engineering Design: The buses deployed in the Tompkins County/Finger Lakes region should accommodate maintenance & serviceability, in all respects, and therefore commonality and low engineering design complexity is encouraged.

All-Wheel-Drive: Given the terrain and winter weather demands placed on these buses (Attachment 1), future consideration of an All-Wheel-Drive (AWD) configuration should be pursued. As a point of reference, the Jaguar I-Pace (Page 6 above) offers base model AWD with extremely competent full-time electronic traction control.

A possible approach to the front drive system could be the Electrically Powered Wheel (EPW). The author attended the February 2018 Society of Engineers (SAE) Electric Vehicle Symposium in San Diego, California, where Dr. Roland Kasper, of Otto-Von-Guericke University, presented their recent remarkable progress in EPW-II systems:

Comparison Wheel-Hub-Motor EPW II

						
	General Motors	*Schaeffler AG*	*Siemens AG*	*Fraun-hofer*	*Protean Electric*	*EPW II*
Rim Size [Zoll]	17	16	17	17	18	16
Weight [kg]	30	53	50	42	34	16
Power [kW]	16	33	63	55	54	64
Power/Weight [kW/kg]	0.53	0.62	1.26	1.31	1.59	4
Torque [Nm]	200	350	500	700	650	600
Torque/Weight [Nm/kg]	6.67	6.60	10	16.67	19.12	37.5

Note that at a 16" diameter the EPW-II produces 600 NM or over 440 foot-pounds of torque **PER WHEEL**; more than enough to fulfill the needs of a front-drive in a computer coordinated AWD bus system, for use in steep uphill low μ winter/wet road surfaces. The use of the EPW technology in the rear-drive of a future AWD bus design should be pursued; Dr. Kasper indicated to the author that a rear-drive prototype is already being driven in Berlin. [i]

A copy of Dr. Kasper's paper is available here (with permission).

[i] For perspective my 1997 Ford Crown Victoria is rated at 366 Nm, the 4.6L engine weight is approximately 240 kg; that ratio of 1.525 Nm/kg compares to the EPW-II of 37.5 Nm/kg

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Conclusion

As 'low hanging fruit,' conversion of the bus fleets to full electric (the Battery-Electric-Bus, BEB) offers many implicit advantages; greatly reduced noise pollution, zero chemical emissions, and lowered Total Cost-of-Ownership (TCO).

But the Electric Bus of BEB also results in broad public exposure; people of all walks and social strata are users of buses, from grammar school children to inner city business executives. The first time these users experience electric mobility, their likely response is going to be *very* positive.

This positive response translates into broadened awareness through word-of-mouth, and expanded taxpayer acceptance versus public sector investment and other minor developmental/deployment disruptions.

This is another benefit of the electrification of our nation's bus fleets. This subjective response benefit of the EV paradigm will be exaggerated in the Tompkins County and Finger Lakes due to the demographics and attitudes in that region.

More focus and effort is needed in behalf of this region if the benefits of the 'low hanging fruit are to be brought to . . . fruition.

Paul V. Sheridan
DDM Consulting
Dearborn, Michigan

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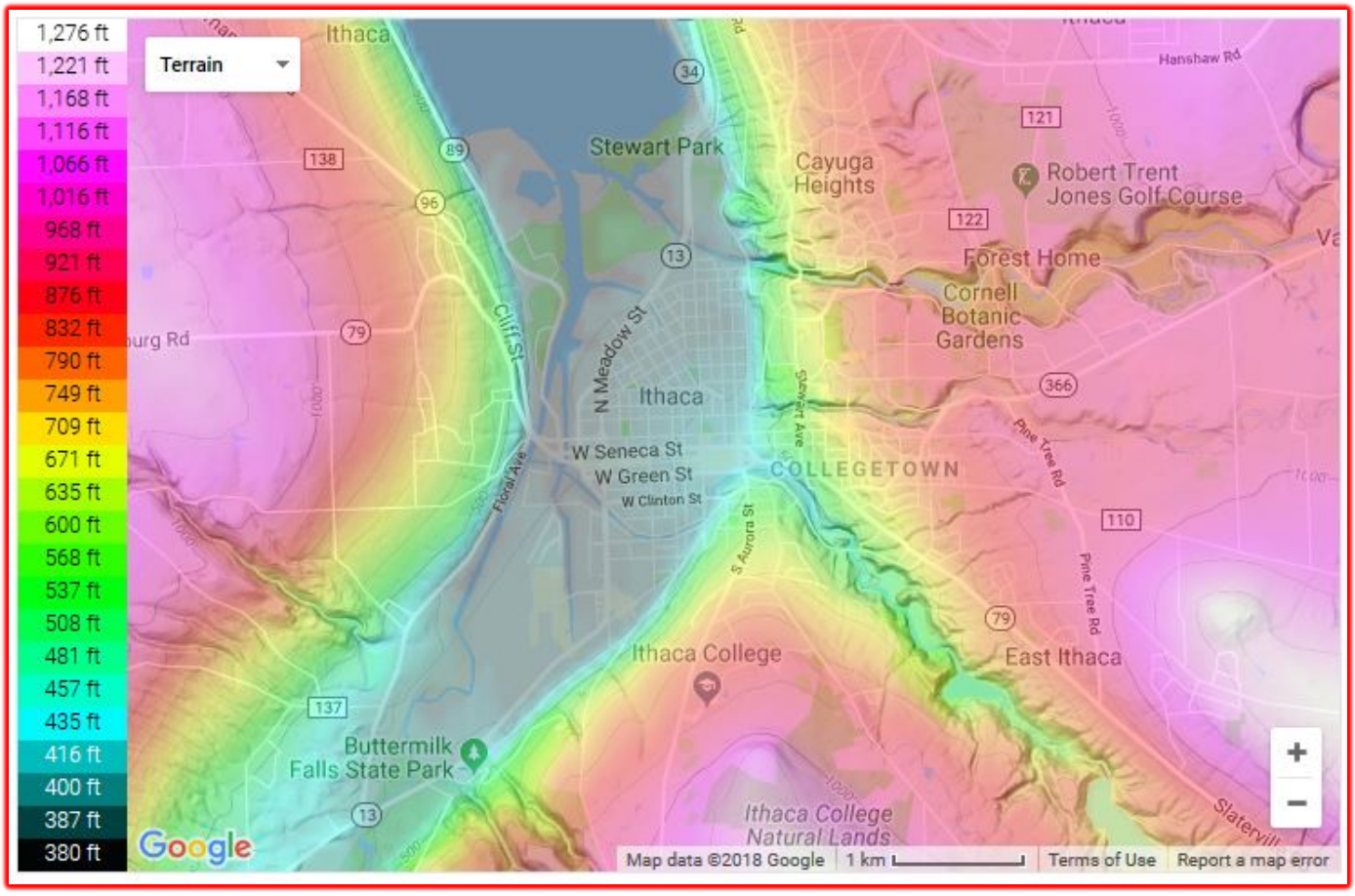
Geographic Review

The beauty of the Finger Lakes Region is world-renown. The landscapes are as rugged as they are appealing. As the song of my alma mater, Cornell University, declares:

"High above Cayuga's waters . . ."

As an example, travel from the basin of Lake Cayuga to the Cornell or Ithaca College campuses requires long uphill drives, **with a change in elevation of up to 1000 feet:**



This terrain is routinely traversed by **diesel and diesel-hybrid buses** operated by (1) Tompkins County Area Transportation (TCAT), (2) Ithaca City School District (ICSD), and (3) Cornell University Transport Services . These fleets negotiate Ithaca and Tompkins County New York throughout the year, serving residents and university students with award-winning reliability (See Attachment 2 Demographic Review).

The steep uphill, passenger-loaded bus routes produce chemical pollution**, and the strain on the diesel powertrains are notoriously noisy.** These issues detract from the beauty and serenity of Ithaca, New York. Full electric buses do note emit chemical pollution and are 'silent running.'

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Demographic Review

One of the most beautiful regions of New York is called the Finger Lakes. Now officially comprised of 12 lakes in-total, the largest most populated county is Tompkins County, which has its spiritual, cultural and commercial center in the city of Ithaca, New York

Ithaca is home to two major academic institutions, making the population especially sensitive to the human condition, and how preservation of the environment is central to their well-being. That preservation however is intimately tied to ensuring that so-called solutions to environmental issues do not impinge in any way on the famous beauty of the Finger Lakes region.

There are two major academic institutions in Ithaca, Ithaca College, and my alma mater, Cornell University. Tompkins County also houses Tompkins County Community College, and many technical and cultural learning centers; education is a major economic activity of the county. This academic focus contributes to a demographic that is much younger than the USA national median for cities/regions of similar population.

Relevant statistics[i] of the Tompkins County and Ithaca, New York:

	Ithaca New York	**Tompkins County**
Population	30,625	104,268
Median Age	21.8	30.3
Median Household Income	$30,291	$54,133
Median Property Value	$219,100	$182,600
Number of Employees	11,976	49,581
Poverty Rate	44.8%	20.1%
Households w/ One Vehicle	40%	28%
Households w/ Two Vehicles	31%	41%
Households w/ More than Two Vehicles	13%	24%
Commuter Transport Modes:		
Drove Alone	33.7%	63.2%
Car-Pooled	6.3%	8.6%
Commercial/Public Transport	12.6%	6.5%
Walked	37.8%	14.1%
Climate / Weather	Four Distinct Seasons	Four Distinct Seasons
Average Annual High Temperature	56.5° / 13.6°	~same
Average Annual Low Temperature	36.8° / 2.6°	~same
Average Annual Rainfall	37.3” / 95 cm	~same
Average Annual Snowfall	65” / 165 cm	~same
Sunny Days	154	~same
Precipitation Days	85	~same

[i] *Sources: DATAUSA, usclimatedata.com, nerdwallet.com

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Electric School Bus Roll-outs – New York State

A wonderful subject resource is schoolbusfleet.com . Reported there is the following headline:

"**Lion Delivers 5 Electric School Buses to New York for Pilot."**

The Lion Electric Company, based in Canada, has already delivered 5 of its *eLion* school buses to the White Plains, New York city school district, for opening day of class this September 2018.

Announcing this gala, District Superintendent Dr. Joseph Ricca:

"The White Plains City School District is very excited at the prospect of using electric school buses. With Lion Electric providing five buses to our contractor, National Express, our children will experience the most technologically advanced means of transportation and our community will benefit from the positive environmental impact. We're anxious to roll out the buses in September and continue working to identify innovative and sustainable measures throughout our district."

White Plains seems to have taken the early lead in EV school buses, but they are not alone. Suffolk County and the Islip School District are also actively discussing conversion of their fleet to full EV, with the US-based Blue Bird Bus Company:

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Electric School Bus Roll-outs – Additional and Often Overlooked Safety Benefit

One notices that the Suffolk Transportation Service banner, in the video above, proclaims that the issue of safety is central to their good works.

But a specific issue, that is a subject of long-experience and expertise for this author, is the issue of crashworthiness as such relates to post-collision fires. In any transportation device, that stores on-board large quantities of combustible fluids, there is the inherent danger of a catastrophic and consuming fire. The EV school bus greatly diminishes this risk to our children.

Endnotes for Attachment 2

https://www.schoolbusfleet.com/

https://www.schoolbusfleet.com/news/730190/lion-delivers-5-electric-school-buses-to-new-york-for-pilot

https://thelionelectric.com/en

https://www.whiteplainspublicschools.org/page/1

https://www.nationalexpresstransit.com/

https://www.youtube.com/watch?v=-lVPYEzEPpE

https://www.blue-bird.com/electric

http://www.islipufsd.org/our_district/central_administration

http://cornellsun.com/2018/03/23/tcat-bus-catches-fire-on-state-highway-no-injuries-reported/

https://www.youtube.com/watch?v=9bbfPplWYqI

https://www.youtube.com/watch?v=LxdK-ekrabY

https://www.youtube.com/watch?v=TH_0izSyPk0

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Cornell University Transport - Campus-to-Campus Bus Service

Shown on Page 2 below, the following services involve 230 miles/371km, one-way:

Ithaca to NYC Departure Times

	North Campus	Sage Hall	Vet College B Lot
Monday – Friday	5:30 a.m.	5:40 a.m.	6:00 a.m.
3 trips daily	11:30 a.m.	11:40 a.m.	noon
	5:30 p.m	5:40 p.m	6:00 p.m
Saturday	10:00 a.m.	10:10 a.m.	10:30 a.m.
2 trips daily	5:30 p.m.	5:40 p.m.	6:00 p.m.
Sunday	10:00 a.m.	10:10 a.m.	10:30 a.m.
3 trips daily	12:30 p.m.	12:40 p.m.	1:00 p.m.
	5:30 p.m.	5:40 p.m.	6:00 p.m.

NYC Arrival (in order)

- Cornell Club (44th and Madison)
- F Train to Tech Campus (64th and 3rd)
- Weill Cornell Medical College (69th and York)

NYC to Ithaca Departure Times

	Weill Cornell Medical	64th and 3rd	Cornell Club
Monday – Friday	6:00 a.m.	6:15 a.m.	6:30 a.m.
3 trips daily	11:40 a.m.	12:00 p.m.	12:30 p.m.
	5:40 p.m.	6:00 p.m.	6:30 p.m.
Saturday	11:40 a.m.	12:00 p.m.	12:30 p.m.
2 trips daily	4:10 p.m.	4:30 p.m.	5:00 p.m.
Sunday	11:40 a.m.	12:00 p.m.	12:30 p.m.
3 trips daily	4:10 p.m.	4:30 p.m.	5:00 p.m.
	6:10 p.m.	6:30 p.m.	7:00 p.m.

Ithaca Arrivals, in order:

- Vet College B Lot
- Statler/Sage second
- North Campus
- Best Western hotel on demand only, please inform driver prior to Ithaca arrival.

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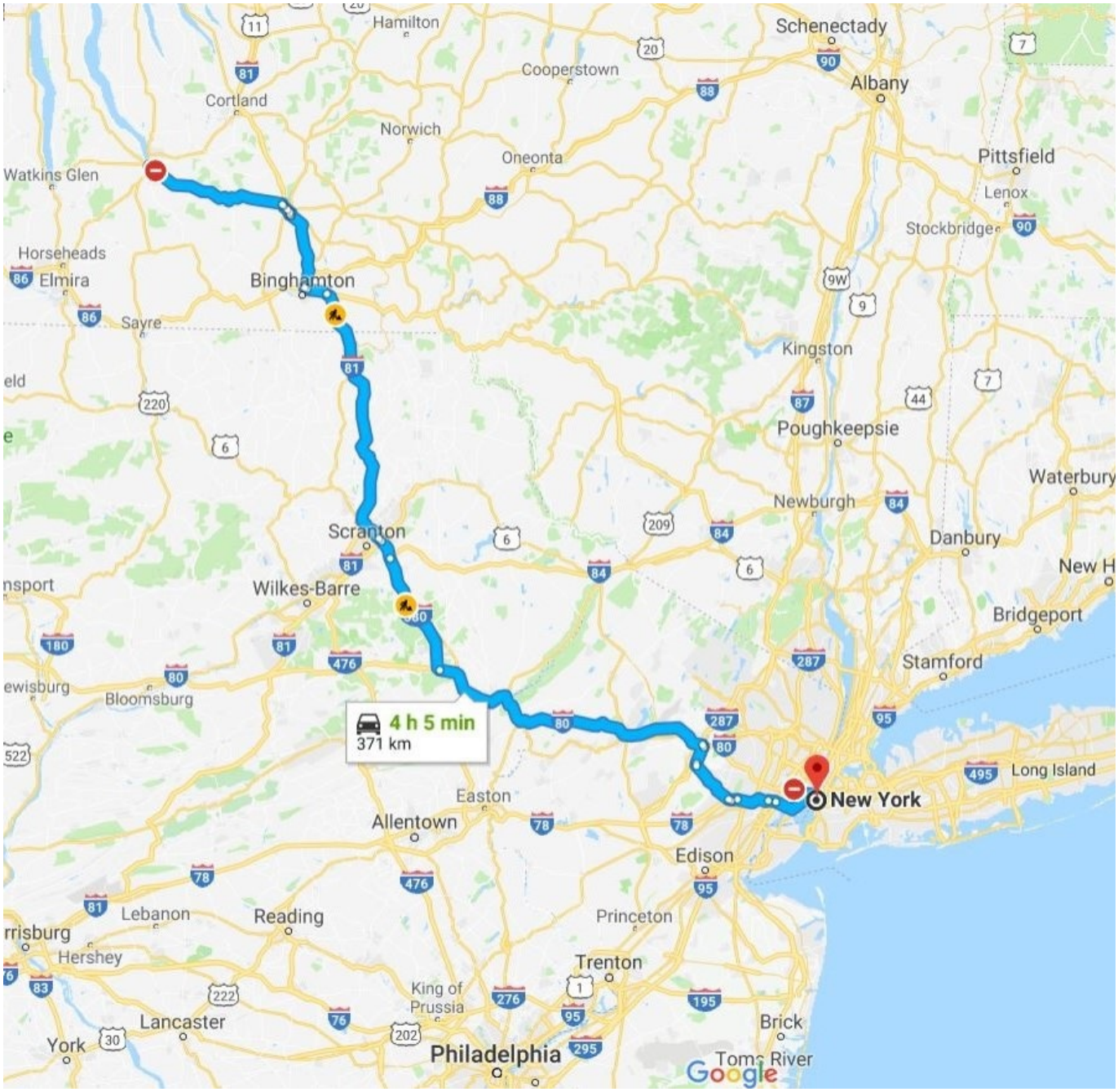
Cornell University Transport – Campus-to-Campus Bus Service

The following is meant to depict the approximate distance of the Cornell Transport only, the exact routing(s) are unknown.



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