



SARTA Fuel Cell Bus – Columbus, Ohio

Minnesota Hydrogen
Economy Collaborative
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Public Awareness/Outreach Activities

Education

- Middle School outreach program
 - Teacher and student education
 - Renewable energy kits
- University outreach
 - Presentations, events
 - Bus route rides
- Training
 - Bus driver
 - Mechanics
 - Operations

Community

- “Borrow A Bus” program
 - Supported by El Dorado and BAE
- Educate legislators, policy makers
- Present at public forums, trade shows
- Media outreach, including website, social media outlets

Research by RHFCC/MHCoE

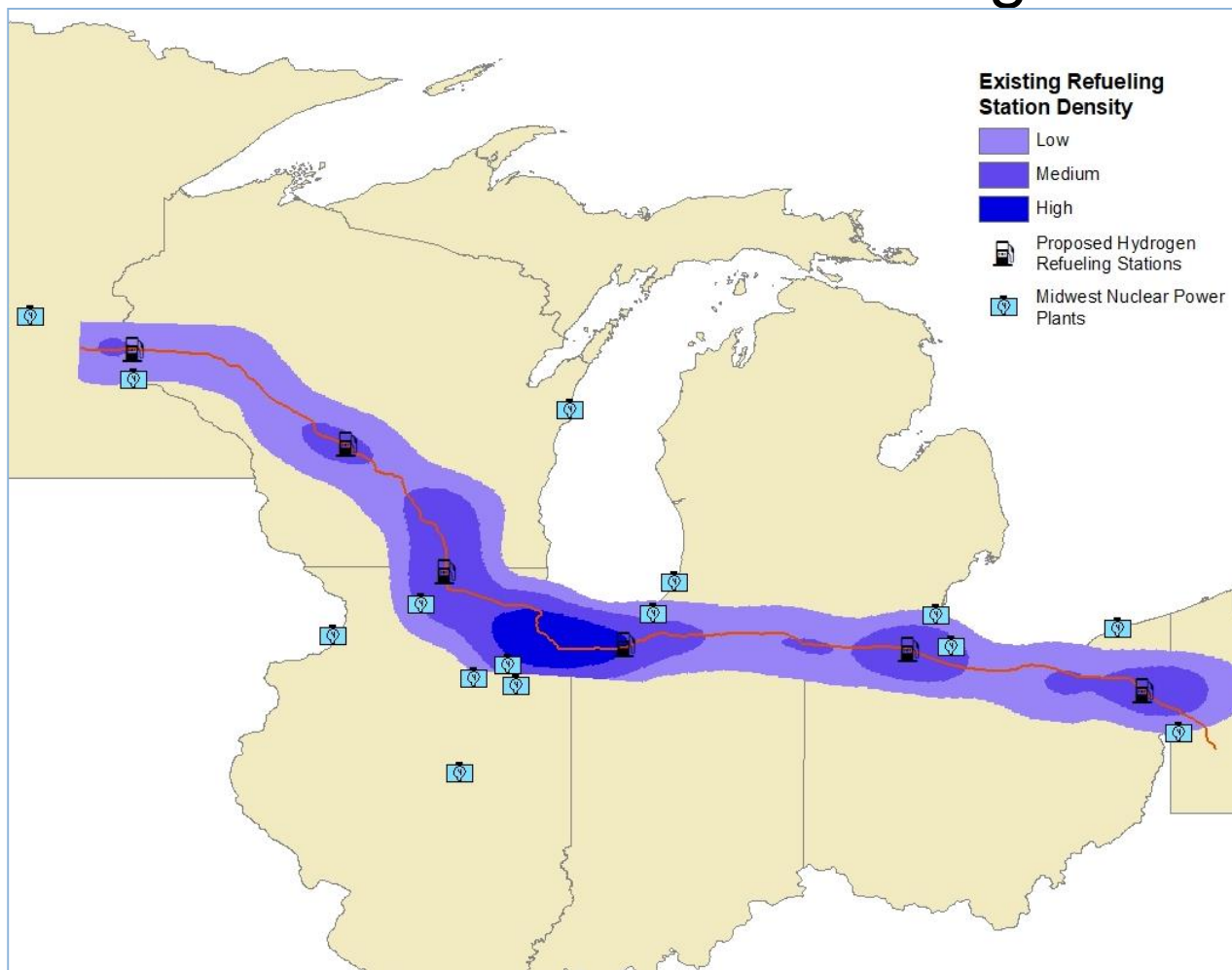
Hydrogen

- Economics of carbon capture for hydrogen refueling infrastructure
- H2 Infrastructure planning for Midwest
- Fuel cell supply chain development
- Survey of interest in FCE heavy duty trucking
- Roadmap for adoption

Transit

- Bus Procurement strategies
- Cold weather effects on fuel cell and battery electric buses
- Onsite hydrogen strategies for transit
- Microgrid strategies for transit
- Hydrogen bus performance metrics

I80/90 Long Haul Corridor H2 Refueling Plan



Strategic Plan:

- Build stations at or near existing truck stops
- Stations placed within FCE truck range
- Re-purpose nuclear energy from grid to H2

FCEV Fleets – First Adopters

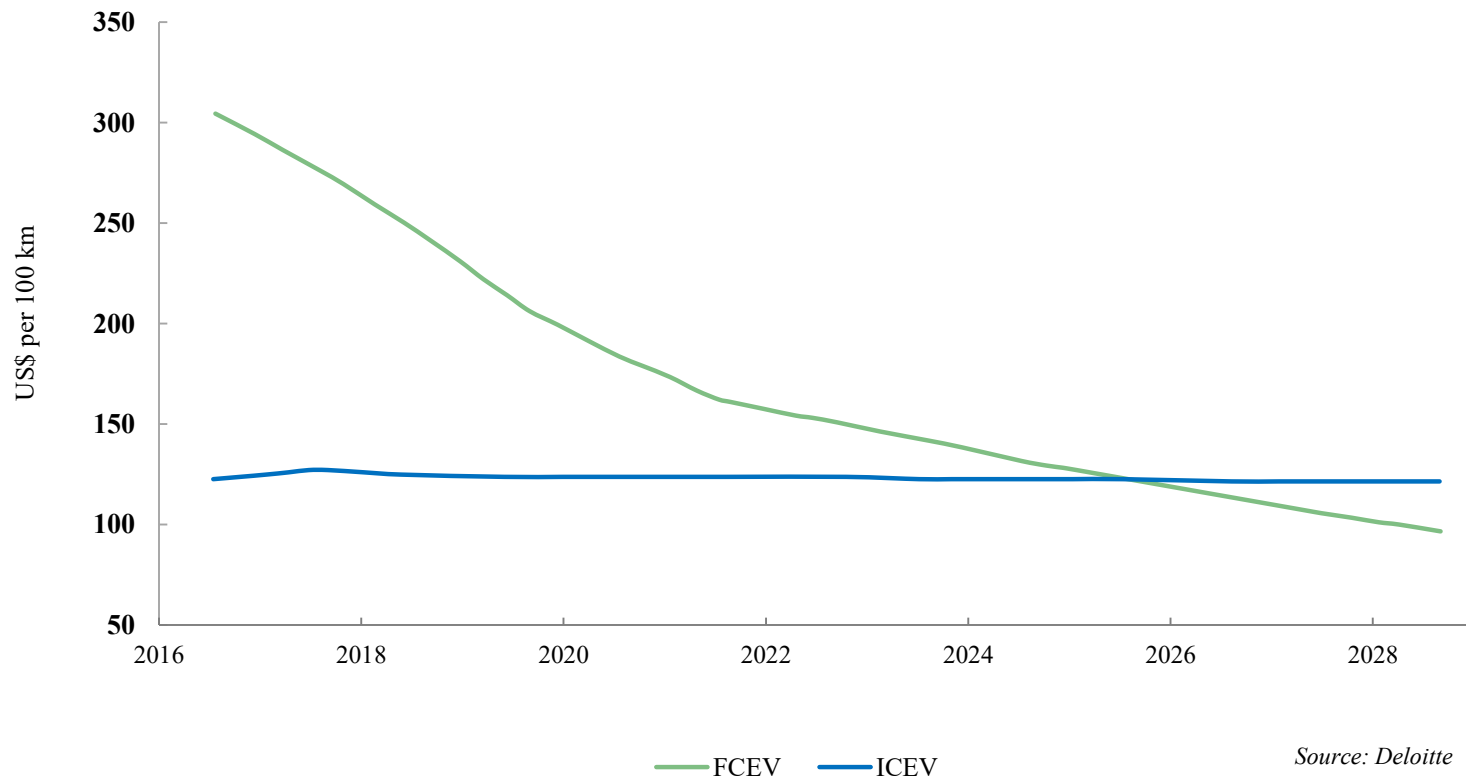
- Stark Area Regional Transit Authority
 - Canton, Ohio
 - 20 FCE buses and paratransit vans in operation
 - El Dorado frame, Ballard cells
 - Third largest operator of fuel cell buses in U.S.
- Advantages
 - Nearly 200 miles per day range
 - Refueling time takes 20 minutes
 - Fuel cost similar to diesel
 - Do not see large range drop off in winter
 - One for one replacement of diesel
- Challenges:
 - Cost: Currently over \$1 mm/bus.
 - Diesel bus is \$450,000.
 - Refueling infrastructure over \$1 mm.
 - Operations: Training of mechanics, access to parts



SARTA Hydrogen Refueling Station

Transit as Hydrogen Economy Driver

US Total Projected Cost of Ownership for a Bus (\$/100 km)



Comparison of Cost and Carbon Intensity for Various Small-Scale Hydrogen Production Options at SARTA.

Method	Cost (\$/kg H ₂)	Carbon Intensity (kgCO ₂ e/kg H ₂)
SMR: delivered via LH ₂ ^a	5.93	9.81 ^b
SMR: onsite, no capture	3.22	8.98
SMR: RNG, no capture	4.49	2.22 – 5.32 ^c
SMR: onsite with capture (blue)		
- With geological storage	3.65	2.44
- with EOR/ECOF	3.52	4.17
- with EOR/MCOF	3.47	4.40
- with RMC	3.27	2.44
Electrolysis (green) – no grid	7.43	2.58

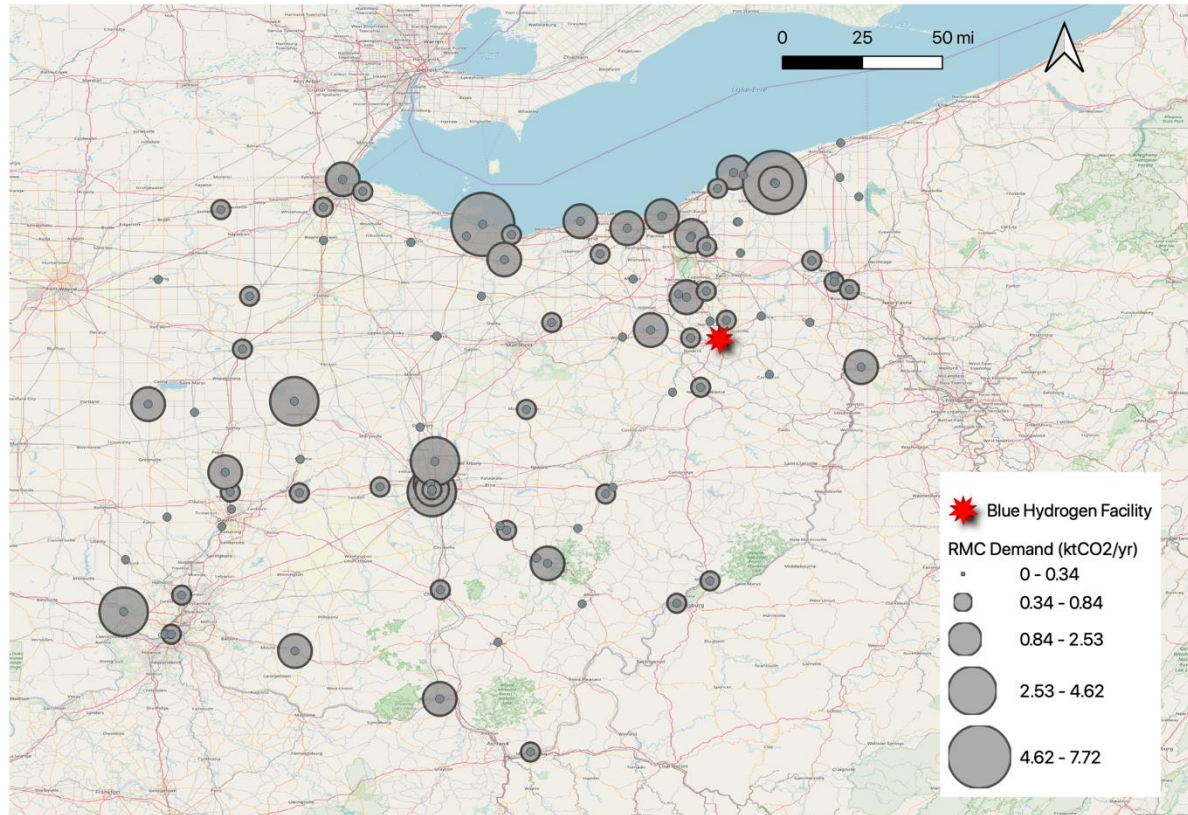
- This hydrogen is compressed and liquified in Sarnia, Ontario, Canada, and delivered ca. 270 miles in LH₂ tanker trailers to SARTA. Importantly, this method of delivery arrives under pressure, and little or no additional on-site hydrogen compression is required for storage. This cost needs to be accounted for in a true apples to apples comparison.
- The incremental carbon footprint assumes negligible boil-off losses at the Sarnia trailer refill and during transit, and emissions of 220 gCO₂e/tonne/mile due to fuel consumption.
- The lower bound represents WWTP RNG at 19.34 gCO₂e/MJ and the upper bound represents landfill RNG at 46.42 gCO₂e/MJ.

Potential CO2 Markets in Ohio and Pennsylvania

Process	2017 Estimated Demand (ktCO2/yr)	Number of Sites
Ohio		
Urea Manufacturing	315.4	1
Food and Beverage	73.7	56
Refrigeration	38.6	111
Methanol	16.0	2
Plastic and Polymers	3.8	9
Pennsylvania		
Food and Beverage	90.2	63
Refrigeration	42.5	143
Chemical Production	16.4	4
Plastic and Polymers	6.5	12
Miscellaneous	0.4	2

Ready Mix Concrete Locations in Ohio

Symbolized by Potential Annual CO₂ Demand for the Purpose of Incorporation into Mixed Concrete Product.



Renewable Hydrogen Fuel Cell Collaborative Midwest Hydrogen Center of Excellence

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<http://www.midwesthydrogen.org/>

<https://www.sartaonline.com/>