Zero-Emissions Bus Propulsion

CEO Recommendation

October 2023

Hello I am Matthew Carpenter the CEO of the Ann Arbor area transportation authority.

This is a recorded presentation of staff's initial recommendation to our community and board of directors regarding the future implementation of zero emissions buses.

About Video

- Complements technical information on www.TheRide.org
- Recorded video allows viewer to watch, and pause, at own pace
- Duration: 50 minutes long

This video complements the written information available on our website www.theride.org.

Feel free to pause or rewind or watch again at your own pace.

Agenda

I. Introduction
II. Technical Proposal
III. Themes, Principles & Key Concepts
    a) Technologies
    b) Implementation
    c) Costs & Priorities
IV. Closing & Next Steps

After some introductory comments, we'll spend the bulk of our time discussing our technical proposal.

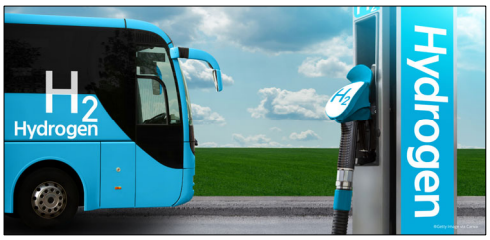
We will wrap up with closing thoughts and reminders about the next steps in our process.

Part I: Introduction

So let's get started…

Recommendation: Hydrogen Pilot Project

- 4-5 year pilot project
- 2 hydrogen fuel-cell buses
- 1 outdoor tank/fueling station
- Workforce Training
- Continue buying diesels in interim
- If successful, full transition starting 2030



Staff are making a recommendation to our Board of Directors regarding zero-emission bus propulsion technology.

Staff's recommendation is for a pilot project with
- two hydrogen buses,
- one outside fueling tank, and
- considerable amounts of staff training.

We will need to continue buying diesel buses until we're confident that the zero emissions hydrogen buses will meet the needs of our passengers and are affordable.

If this project is successful, it could lead to a full transition of the fleet starting in 2030. Since the lifespan of a bus is 12 years, We expect a full transition to take about 12-15 years.

Immediate Timeline

1. **October 2023**: CEO Recommendation for Board
2. **Oct-Dec '23** : Board Discussion & Public Feedback
3. **Jan 2024**: Board Decision (for 2024 grant)
4. **Jan-March 2024**: Grant preparation
5. **March/April 2024**: Anticipated grant deadline
6. **Oct/Nov 2024:** Anticipated grant awards

In many ways we are still at the beginning of our process.

- Staff started in-depth background research in 2021, and provided some preliminary findings in late 2022. We've been working with outside experts and other transit agencies to learn as much as we can. We've spoken to and visited agencies that have already adopted some of these technologies, and even sent our staff mechanics to visit other transit agencies.
- In October 2023 we are providing our recommendation for our board of directors. This marks the start of a public discussion that will continue for a few months. Public comment is welcome at all board meetings.
- We expect our board to continue this conversation in November and possibly through January of 2024.
- We have an opportunity to submit a large grant application in the Spring of 2024. To get prepared, we will likely need a decision from our board by January 2024.
- We will be notified as to whether our grant application is successful around October of 2024. Transit agencies usually have to try a few times before grants are awarded.

Public Feedback

- Visit www.TheRide.org for information and feedback opportunities
- Submit written comments via web form or email
- Attend a board meeting to make public comment

We are still very interested in hearing public feedback throughout this deliberation period.

- Feedback opportunities are available on our website www.theride.org.
- You can also attend one of our monthly board meetings and make a public comment. Meetings happen the third Thursday of each month at 6:30 PM on the top floor of the Ann Arbor downtown Public Library. The meetings are also available on Zoom and we take public comment virtually. Each speaker has three minutes and there are comment periods at the beginning and end of the meetings.

Part II:
Technical proposal

Duration: 40 minutes

Now we are starting Part 2 of this presentation the technical proposal

Agenda

I. Introduction

II. Technical Proposal
   a) Themes & Key Concepts
   b) Technologies
   c) Implementation
   d) Costs & Priorities

III. Closing & Next Steps

In this part of the presentation we'll be addressing:
- key themes & concepts,
- propulsion technologies,
- the rationale for a pilot project, and
- costs, risks, and relative priorities.

Underlying Themes

Risk Tolerance (Action and Inaction)

- Climate and attitudes are changing
- Transitionary period & competing information
- Gap between expectations and performance of technology
- Financial commitments

Priorities & Limited Resources

- Investments: Emissions and/or ridership?

Throughout this presentation we'll be returning to a few recurring themes: Risk Tolerance and Priorities

When we think about risk tolerance we need to think about the risk of action and inaction.

- The risk of **inaction** is clear
    - Climate change is visible on a daily basis with weather extremes, flooding, and fires happening around the globe. Without action our environment and society will be seriously harmed.
    - In addition to this moral imperative, our board has given me direct instruction to look for ways to reduce emissions. We've focused on buses because they are our largest source of emissions.
    - We expect public and political pressure for climate action will continue to grow. While we do not yet have legal mandates forcing us in this direction, such regulation is possible, and we are seeing other important federal grants being restricted until we make general commitments to transition to zero emissions.

  So the risks of inaction are serious. Though the best solutions may not always be clear, TheRide needs to do our part to reduce carbon emissions.

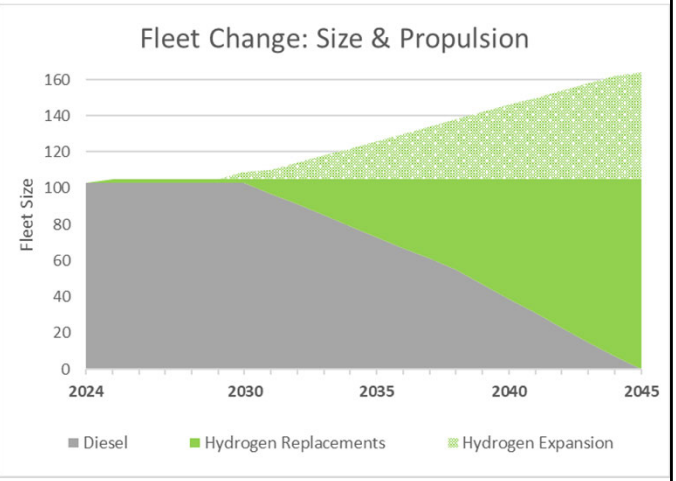
The risks of **action** involve taking financial risks when the best technological path is not clear.

- We are in a **transitionary period** where our society is changing from a reliance on fossil fuels to something better. During this period there is a lot of evolving and even contradictory **information**. During this moment, there are many new solutions being proposed and legitimate uncertainty about which directions are best. We should acknowledge that there is an information vacuum.
- There is a gap between the urgency we feel, and our society's capacity to address the issue. A gap between what we want technology to achieve, are how far it still needs to develop. Asking for the same performance or better, and the same costs, WHILE ASLO eliminating emissions is a tall order. We haven't found a magic bullet yet.
- Our industry is experiencing a rapidly changing technology and economic environment. It is producing a steep learning curve where our staff are learning about as fast as the industry, but there is much we don't know and a great deal of uncertainty.
- Eliminating emissions will be costly, and TheRide has other obligation and aspirations that also require funding. With limited resources, we will need to be certain of our priorities as we make decisions.

- There are two ways transit can help reduce emissions: attracting passengers out of single occupant vehicles and reducing our own pollution footprint. While it may be tempting to see these two priorities in competition with each other, I am proposing an approach whereby I believe we can pursue both over a period of time.

Key Concept: Full Deployment is Goal

- Fleet of 103 could double by 2045
- Double emission savings
- Want immediate decisions to contribute to long-term success
- Meet President's 2050 target



So now I'd like to introduce several key concepts that will help us put the technologies and their implications into context.

- The first key concept is how to maximize emission savings. Our goal is not to buy two or six buses. Within 25 years we expect to have 200 buses, double the number we have today. We need a solution that can economically scale up to that size.
- We've recently watched several transit agencies waste a lot of money on premature technologies. We want to learn from others and avoid wasting limited our funds.
- Finally, the timespan involved is important. A buses lifespan is 12 years, and it will take us many years to fully transition our fleet.

As illustrated in this graph, one approach we could foresee is using hydrogen buses to replace naturally retiring diesel buses. This could start in 2030 and be completed between 2042 and 2045, well ahead of President Biden's goals of carbon neutrality by 2050. During this same time, any expansion buses added to the fleet would also be hydrogen.

(This graph is only illustrative. No timelines for full deployment have been finalized.)

Key Concept: Carbon Savings

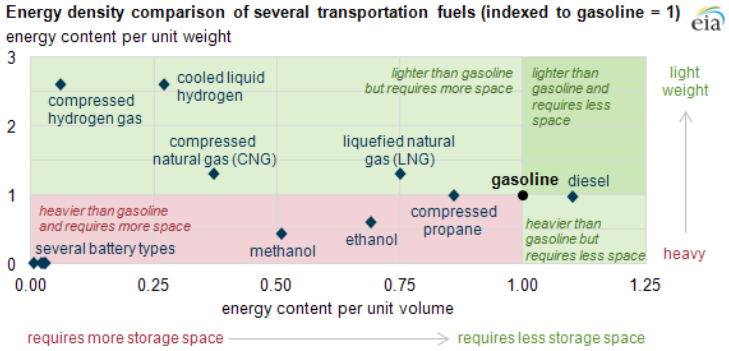
- Produces 7,000 tons (<0.5% of emissions)
- Carries 4.5 million trips/year
- 15,000 trips/day
- Growing ridership can reduce emissions while advancing social goals
- Long-Range Plan foresee doubling service

Our first key concept is to try to quantify the benefits of using transit to reduce carbon emissions. There are two basic ways transit can help fight climate change: reducing its own carbon footprint, and by becoming an attractive alternative to driving alone.

- Today our bus fleet produces about 7,000 tons of carbon each year. This is about half of one percent of total regional emissions. His quantifies the carbon savings we could achieve by adopting zero-emissions technologies.
- Today TheRide carries almost 15,000 people a day. While quantifying the savings from all those emissions is difficult, we believe that transit has the potential to reduce even greater amounts of emissions by serving as an attractive alternative to driving alone.
- TheRide has a 25-year blueprint for expanding our services and infrastructure to help us become a true alternative to driving.
- We feel that pursuing both of these strategies *together* represents the best path forward to reducing emissions in the short and longer terms.

Key Concept: Energy Density = Range

- Vehicles must carry energy with them
- Weight/Range trade-off
- *Power* of fuel matters!



A key concept that will help us differentiate different propulsion systems is the concept of **energy density** from different types of fuel. Energy density is the concept of how much kinetic power can be stored in a certain volume of space.

Because vehicles must carry their fuel with them, a ratio of weight to range becomes a factor when choosing propulsion system. A fuel that isn't powerful enough can reduce the range of a vehicle or even the number of passengers that can be carried. As we can see in this chart gasoline has a very high energy density. In comparison batteries including lithium ion batteries have a very low relative energy density. Hydrogen is in between. This factor will matter a lot as we discuss the range of various propulsion systems.

We do not need zero emission technologies to **equal** the performance of diesel but we do need them to at least meet minimum operational requirements for mass transit.

Key Concept: Customers before Equipment

- Route networks designed for customers, not equipment
- Equity considerations
- Minimum operational requirements for mass transit
  - Reliability/On-time performance
  - Heating during winter
  - Equitably serve all areas
  - Costs

"We need to design our transit service for the customer, not the propulsion system."
– Midwest Transit CEO

Transit services must be designed to as attractive as possible to potential customers. Emissions reductions are a secondary consideration.

Diesel provides very high-performance low cost and reliable service. Other propulsion systems may not be able to meet this same level of performance, and could inconvenience passengers or increase costs. We do not expect to gain any riders from switching propulsion systems but we need to make sure we do not harm existing riders.

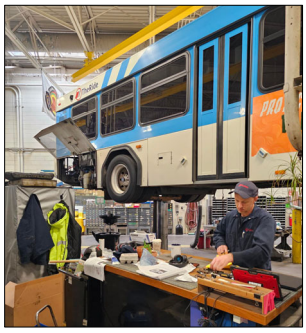
Examples of the sort of operational performance that matters for passengers includes reliability and heating/cooling. We also need to provide the same quality of service through all the neighborhoods we serve.

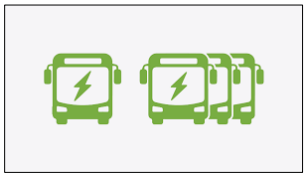
Costs also matter as they impact how much service we can afford to provide. We need to be certain that investments in zero-emissions don't take funds away from services to communities that have been historically marginalized.

So lets discuss how these considerations intersect with running a large fleet in a cost-effective manner….

Key Concept: Fleet Management

- Buses need more energy than cars
- Lower costs via standardization, inter-changeability
- Simplify maintenance, training, parts, etc
- Supporting garage, fueling system, ventilation, hoists,
- Avoid hidden costs





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I'd like to introduce some concepts related to Fleet management.

First, We need to acknowledge the transit buses require much more energy than cars or school buses.

- Most cars are parked most of the time, providing ample time for recharging a slow battery. They also aren't driven all that much each day. Similarly, school buses are usually only in use for a few hours in the morning and afternoon.
- In contrast public transit buses are often in continuous operation for 10-16 or more hours a day. This consumes a lot more energy and leaves little time for refueling. It's common for a bus to leave our garage at 6:00 AM and not return until 1 AM in the morning. This "duty cycle" is even more energy-intensive when we need to heat or cool the passenger cabin.

This means that the energy consumption of a transit bus is much higher than other vehicles, and there are very few opportunities to recharge a battery.

Next, it's important that we explain the economics of how a transit fleet works.

- To minimize the size of the fleet and costs, while ensuring reliable service delivery, transit buses are **standardized** and **inter-changeable**. Buses in our fleet are continually rotating between being in service or in the shop. And we do not assign specific buses to particular routes. Every evening buses are refueled and lined up, at random, for pull out the next morning. The next morning the first driver simply takes the first bus in line. They will likely get a new bus every day. This efficiency is only possible because the buses are standardized. This also reduces the training required for drivers and mechanics, and the complexity and costs of maintenance for 103 buses.
- Every bus is built to handle the *longest* bus assignment we have. Range matters so they have fuel tanks large enough that they could stay out for two days before refueling. We do this to ensure inter-changeability. If a bus breaks down, we need to be able to replace it FAST in order to serve passengers reliably. A high and consistent range also allows us to design our routes and services without concern for the needs of the equipment. This also means all buses must have the capacity or range to operate the longest bus assignment or route that we have.
- Staff training is another significant consideration in this discussion. We have heard from other transit agencies that mechanics, drivers, fueling crews, and others will need to receive extensive new training in order to make them work.
- We also need to acknowledge a great deal of associated infrastructure associated with storing and maintaining our fleet including our one garage such as fueling and ventilation systems.

Undermining fleet management can add **hidden costs** that can increase our operating budget.

Propulsion Technologies

- **Diesel (Status Quo)** 
- **Battery Electric Buses (BEB)** 
- **Hydrogen Fuel Cell Electric Buses (FCEB)** 

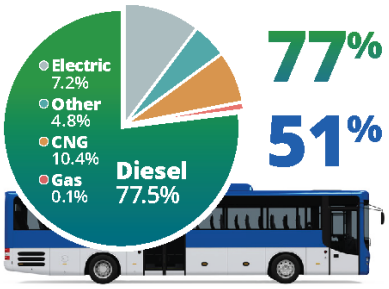
OK with those key concepts behind us, we can now introduce the technologies will be considering:

1. First, we'll discuss diesel propulsion. This is what we presently use and represents the status quo.
2. Next, we'll discuss battery electric buses and hydrogen fuel cell electric buses.

We could talk for hours about the nuances about each of these technologies. I will only be touching on the most relevant considerations, mostly as they related to the principles and concepts we just introduced.

Diesel

- Internal combustion engine
- Large tank and range
- Heats cabin from engine
- Fueled from single station



77% of Transit Buses are Diesel Powered

51% are powered by newest generation of advanced diesel technology

3% increase since 2021

Source: S&P Global Mobility TIPNet Data of U.S. Vehicles in Operation for Class 3-8 (Model Year 2010 and newer [MY 2010+]) as of December 2022

OK let's introduce diesel buses.

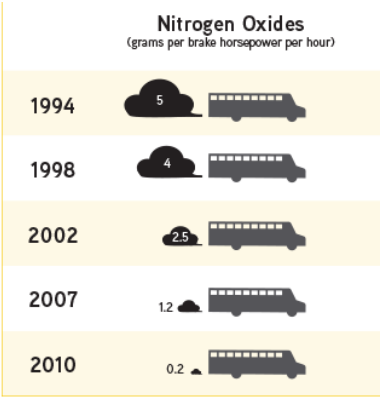
All the buses in our fleet today are diesel powered although some are also hybrid diesel electrics. These use traditional internal combustion engines, have a large fuel tank and range. The engine also heats the cabin. They are fueled from a single pump in our main garage.

Despite recent advances, about 89% of transit buses in the US today are powered by fossil fuels.

Diesel

Pros

- Keep costs & risks low…temporality
- Buys time for ZEBs to get better
- Emission are low and may get better



Cons

- Never gets to zero
- Mechanically complex
- May not be politically viable, emerging mandates, grant restrictions

There are pros and cons to every technology.

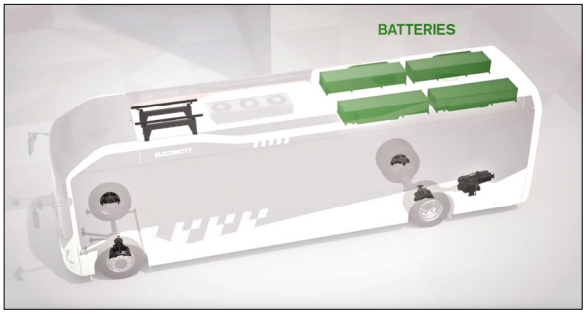
The **strengths** of diesel are that

- The technology is mature and costs and performance is predictable,
- It is relatively low cost (excluding pollution of course),
- It has a mature ecosystem of suppliers and manufacturers and parts are easy to find
- Works well for fleet management and passenger services.
- Emissions from today's diesel buses have dropped considerably and are now roughly equivalent to what a hybrid diesel-electric engine would produce.

Of course as with any technology there are **weaknesses**.

- Diesel propulsion presents no opportunity to eliminate tail pipe emissions, although we do expect it to become even less polluting in the future.
- Internal combustion engines have the most moving parts and are the likely the most maintenance intensive of the propulsion systems.
- Finally, it's possible that diesel engines may need to be phased out either by regulation or public sentiment in the future.

Battery Electric Buses (BEB)



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Now let's introduce battery electric buses.

These vehicles are exactly what the name suggests - Large lithium-ion batteries on the roof directly power motors that turn the wheels and provide heating.

- Battery electric buses need to be recharged frequently.
- Charging takes several hours.
- They can be charged from overhead drop down systems or more conventional plug-in systems.

Battery Electric Buses

Pros

- Cheaper at *small* scale
- Simplest mechanical systems
- Battery tech improving
- In-route charging extends range
- Possibly lowest energy, maintenance costs

Battery electric buses have a number of advantages:

- They are relatively less expensive, especially at a small scale. This is likely why they have seen a surge in popularity in the last few years.
- They have the simplest mechanical systems and the potential to be the lowest cost from a maintenance perspective.
- Electricity can be less expensive and clean, depending on local circumstances,
- Overhead recharging can extend the range, and
- Battery technology has been rapidly improving.

Battery Electric Buses

Cons

- Energy Density & Range Anxiety
  - Cannot run a full day w/o recharge
  - Heating
  - In-route charging may not be practical
  - Impacts fleet management
  - Fleet growth 30%-40%
  - Increased operating costs?
- More complicated/expensive to use for customers

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However today's battery electric buses have a few serious drawbacks.

- Lithium ion batteries have a low energy density and range. As strong as these batteries are, they are proving to be incapable of keeping a bus running for a full day. They are also getting heavier. In addition, the passenger cabin must be heated by the same batteries that drive the motors. In speaking with other cold weather transit agencies we are hearing consistent concerns that these vehicles are underperforming and not able to meet their advertised travel range, making them difficult to use.
- We have explored the concept of enroute recharging, however it presents several serious complications and we are not certain that it will work.

The energy density and range anxiety challenges of today's battery bus technology appear to undermine the fleet management principles of standardization and inter-changability. They also don't seem to be able to meet our minimum operational requirements without a lot of complicated work arounds.

These range limitations create other, compounding challenges**:**

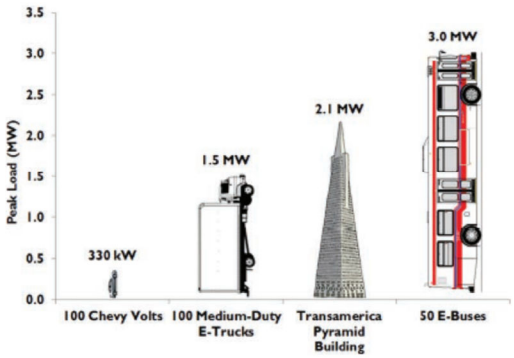
- We have consistently heard from other transit agencies that they are not able to replace one diesel bus with one battery bus, but instead require two or three battery buses to equal the same amount of up-time as one diesel bus. We estimate that our fleet may need to grow by 30 to 40 buses in order to provide the same amount of service that we do today with 103 diesel buses.
- This fleet growth presents serious challenges. Our single garage is full today. Because buses must be stored indoors we would need to build another garage at considerable expense. It is also likely that this fleet growth and unreliability of range will create a series of additional operating costs both obvious and hidden.
- this low range may negatively affect customer service for example buses running out of electricity in the middle of a route.
- There may be other hidden operational costs as well. If the fleet grows, we will need to hire additional staff to ferry the buses in and out of service for example.

Concerns about energy density, range anxiety, and fleet growth are not hypothetical. These are problems that *actual* transit agencies have *already* experienced. For example,

- the transit agency in Reno NV, one of the first adopters of battery electric buses, cannot use battery electric buses on its longer routes and has had to switch back to diesel while they begin to bring in hydrogen.
- In Denver, the transit agency recently had to announce the cancellation of its battery bus procurement because they belatedly realized they did not have space to house the buses.

Electricity Production & Transmission

- Amount of power is enormous
- Garage upgrades
- Grid resiliency
- Emissions from generation



Peak Power Loads, 50 Buses (TCRP 130)

When we look at zero emissions buses we also need to consider how the energy is generated and transmitted to the buses.

- A very large amount of electrical power is necessary to charge a bus fleet. As this graph indicates a bus fleet half our size would require more electricity than a skyscraper. This is a huge amount of demand to place on an already fragile electrical grid. The wiring in our garage dates to 1984 and is inadequate for charging vans, let alone large buses. Significant costs will be needed to upgrade the electrical systems.
- We are concerned about the reliability of the electrical grid and how it could impact the resiliency of our services. Recently the electrical grid in southeast Michigan has failed on several occasions during storms, leading to blackouts and disruptions. In early 2023 a serious ice storm knocked out power to our garage for over 5 days. Our customers did not see any disruption to service because our diesel-powered fleet was not seriously challenged by the loss of electricity. A more buildings and cars electrify, the demands on the grid will increase.
- We also need to acknowledge the uncertainty from ongoing conversations about ownership of the electrical grid while we do not have a perspective on whether a public utility would be better than a private utility, The fact that ownership of the grid could change introduces more uncertainty into this equation.
- A power outage longer than 6 hours could disrupt service to passengers a few hours later. Recovery would difficult.

- Finally, we need to decide whether our role is in just eliminating tailpipe emissions, or if we should also try to consider emissions from where the energy is generated. There is a debate within the transit industry as to whether we should focus on tailpipe emissions and let generation emissions be resolved by others. Today much electricity is generated by natural gas. This is changing, but we can't say how long it will take.

Battery Charging/Charging Management

Con

- Very complicated in fleet context
- Charging management
  - Pricing schemes are opaque
  - Charging: 4-5 hours impacts reliability and costs
  - 1 charger/bus hurts economics of scale
  - DTE only supplier
- Batteries are easy to mismanage
- Impacts reliability, energy, costs, training…

Another area of concern is the evolving practice of charging and battery management. Today transit agencies don't have to put much effort into managing diesel fueling. It is pretty simple and doesn't take long.

However battery buses are very different and the charging and care of the batteries is complicated enough that agencies are having to dedicate personnel purely to managing the process. Some of the key considerations are

- Unlike diesel or hydrogen which is paid for by volume in advance and is predictable, electrical charging price schemes are very complicated for example they can change by time of day. This creates pressure on the agency to optimize when and how the buses would be charged a concern that does not exist today.
- the batteries on buses take four to five hours to fully recharge. Ideally this can be done overnight. And requires a separate charger for every bus. This creates a situation where there are no economies of scale in the charging of the vehicle as every bus needs to have its own fueling station and wiring. In comparison diesel and hydrogen have a single fueling station for the entire fleet.
- The batteries can be damaged by being overcharged.

The intricacies and complications of organizing daily charging and recharging, create the potential for errors and higher costs that could affect passenger services and the budget. For example if a bus needed to be charged quickly during the peak pricing hour in order to

ensure service delivery to passengers, the agency could have to pay peak prices as opposed to overnight prices. However this issue is not insurmountable and probably can be managed but it would be a steep learning curve.

Battery Electric Buses

…Cons

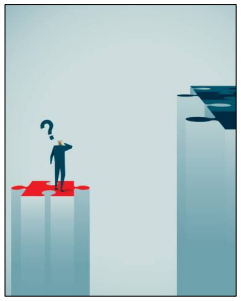
- Significant garage upgrades
- Catastrophic garage fire
- Battery mining & replacements

Battery electric buses also have some other challenges.

- There is also the risk of fire. Battery fires are very aggressive and cannot be extinguished easily. The overhead sprinkler system in our garage would be completely inadequate. In the garage, buses are stored packed very tightly together. If a bus in a full garage began to burn overnight, there is a risk that we could lose a lot of the fleet or our garage and have to reduce service.
- Mining for batteries components is often environmentally destructive. Even if this improves, competition for these materials could drive up prices.

BEB: Summary

- Widest range of performance and cost estimates
  - Best Case: Lowest costs, most efficient, least maintenance
  - Worst: Highest costs, undermines customer focus, dead end
  - Requires major breakthroughs (range, fires) to meet min. requirements
  - Also faces: scaling, managing batteries/charging, pricing, resiliency…
- Numerous challenges to full deployment today
- If battery tech becomes good enough, could be best option



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In summary, electric buses have the widest range between the best case and the worst case scenarios:
- With the most optimistic assumptions they could be the most efficient, lowest cost and provide great service.
- With the worst assumptions they could lead to very high cost, much larger fleet, the need for a new garage, considerable operational expenses, and possibly be a safety hazard.
- Today's technologies are still closer to the worst case scenario.

- Based on ranges reported by other transit agencies the battery technology available today would not meet our minimum operational requirements. A **breakthrough** in battery technology will be needed to meet our minimum level of performance.
- Even if range and fire concerns are addressed, battery buses face additional serious challenges including: expensive chargers, managing the charging process, opaque pricing, and resiliency.

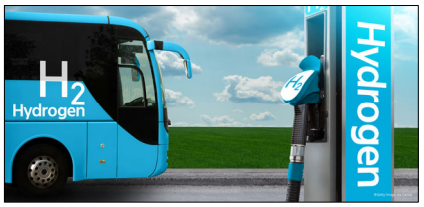
Based on these concerns we do not see a low risk path to full deployment for battery electric buses today. However, if there is a significant breakthrough in battery technology these propulsion system could become the best option.

We've already seen some of the challenges for battery electric buses undermine the efforts of early adopters, leading to additional costs an additional time to reboot their projects.
- There have been numerous instances of battery electric buses underperforming and unable to meet the advertised range.
- Several agencies have bought them without fully understanding the costs of the supporting infrastructure necessary to make them work.
- Fires have become common enough that most battery buses are now parked outside.
- And finally in mid 2023 one of the leading manufacturers of battery electric buses, Proterra, announced that it would be entering bankruptcy, leaving many customers uncertain of how their existing fleets would receive support for proprietary systems.

It is not yet clear whether these challenges will prove to be surmountable growing pains, or fatal flaws.

Hydrogen Fuel-Cell Electric Bus

- On-board gas hydrogen fuel tank
- Fuel cell charges small battery which drives bus, provides heat
- Fuel delivered by tanker, stored on-site
- Single fuel pump
- Hydrogen produced with electricity or fossil fuels



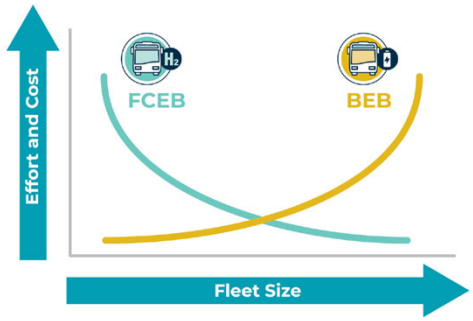
So now let's introduce hydrogen fuel cell electric buses.

- These are also electric buses. - Energy is stored in hydrogen gas in on-board tanks above the roof. The hydrogen is channeled into a fuel cell to produce electricity which then charges a small battery which drives the electric motors.
- The fuel cell also produces heat which is used to heat the passenger cabin.
- Hydrogen would be delivered to the garage as a liquid by tanker and stored on site.
- There would be a single fuel pump much like diesel is today.

Hydrogen

Pros

- No range or heat anxiety
  - No fleet growth, new garage
  - Still put passengers first
- Safer
- Operations similar to diesel, easier for org to adjust
- Smaller batteries (mining, costs, fire)
- Resiliency & diversification



Source: TCRP; CTE

What are the advantages of hydrogen?

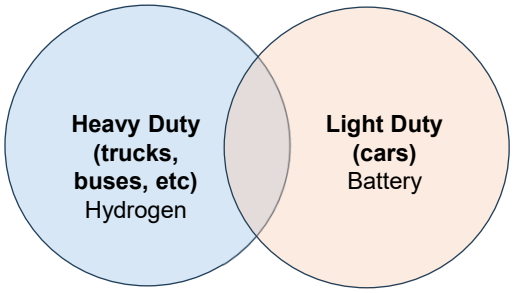
- The primary advantage is the greater energy density and higher range. The reported range from hydrogen buses suggest that these buses would meet our minimum operational requirements. To be clear they likely cannot equal diesel performance, but they can meet our *minimum* requirements. Because there is no range concern we believe we will be able to replace one diesel bus with just one hydrogen bus. This means we do not need a larger fleet to provide the same amount of service.
- The adequacy of hydrogen performance means that we can continue to develop and design the service with customer needs first in mind.
- hydrogen has proven safe. While any type of fuel *can* catch fire, over the last two years we are only aware of 1 hydrogen-bus related fire. Fueling for hydrogen is generally done outside.
- Operating and fueling a hydrogen bus is very similar to diesel and would require fewer changes within the organization and to our fleet management processes. They fuel a little slower than diesels.
- We should acknowledge that these do have batteries that have the same concerns about mining costs and fires, however these batteries are much smaller.
- Since there are less concerns over fires and fleet growth, we could have more confidence in transitioning our existing fleet of 103 buses even before a new garage is available.

There may be value in diversifying our energy sources. In the event of a prolonged electrical power outage a hydrogen bus fleet can continue to operate. This has implications for whether the needs of passengers come ahead of the needs to reduce emissions.

Hydrogen

Cons

- Takes more energy to make hydrogen then produced
  - Battery break-through could render fuel cells obsolete
- Fuel is expensive (5x diesel)
  - $282K vs $53K for diesel
- Capital costs front-loaded
- Significant garage upgrades

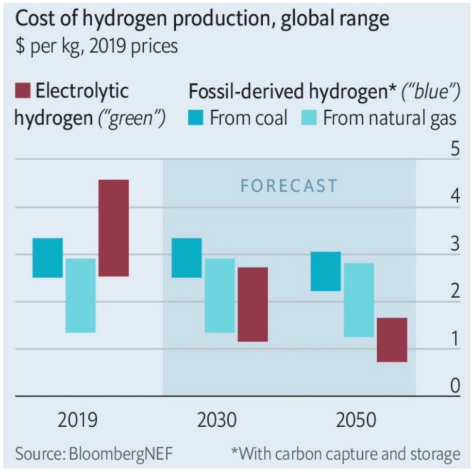


There are significant challenges for hydrogen.

- Perhaps the most important drawback is that it takes more electrical energy to produce hydrogen then the hydrogen is capable of producing in kinetic force. This means that hydrogen will always be less energy efficient then battery power. However the greater energy density of hydrogen allows a vehicle to carry more fuel and reach a larger range than today's lithium ion batteries can. However, the inefficiency is an inherent weakness.
- An important concern is the potential for a breakthrough in battery technology. If there were a breakthrough that could create an adequate battery that was affordable, hydrogen propulsion could be rendered obsolete. Could be a VCR/Betamax moment.
- Other challenges with hydrogen relate to the upfront costs of the large fueling system. Unlike battery chargers which can be purchase in small batches, this fueling system is an all or nothing investment. This large upfront cost has probably dissuaded transit agencies from hydrogen in the past.
- As with batteries, significant garage upgrades would be required to install fueling and ventilation systems in our existing garage.

Cost of Hydrogen Fuel

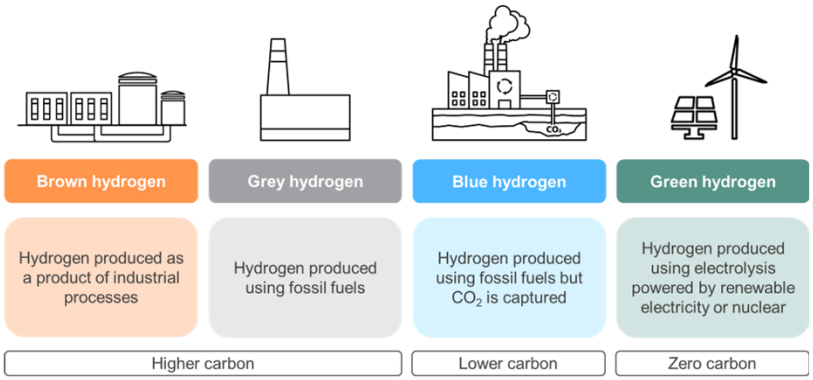
- High cost is largest risk
- Expensive:
  - 2-5 times diesel
  - Limited supply and production.
- If supply grows, costs should fall
- On-site production may be possible



Perhaps the greatest risk of using hydrogen is the cost of hydrogen fuel.

- Today hydrogen fuel appears to be four to five times more expensive than the equivalent amount of diesel energy. This is likely because the very small market for hydrogen has not encouraged many companies to produce it and there is little cost competition. However, should demand for hydrogen increase, new suppliers may enter the market and prices may come down.
- On October 13, 2023, the Biden Administration announced a series of grant awards for hydrogen production hubs throughout the country. One of the selected projects reportedly include the construction of a hydrogen facility in our own back yard, at the American Center for Mobility near Ypsilanti. We will be watching this development intently.
- The funding public transit receives is premised on low-cost fossil fuels. If future energy costs are higher, it will strain budgets and may force discussions about higher taxes. However, this is a concern for the future, beyond this pilot project.

Can Hydrogen be “Clean”?



- May start with less clean until **Green** is affordable

Another important question is how clean hydrogen actually is.

- There are different means of creating hydrogen some of which use fossil fuels and create large amounts of emissions.
- Wind and solar energy can also be used to create truly zero emissions hydrogen.
- As with natural-gas fired electrical power, we may need to start with dirtier hydrogen until cleaner hydrogen is available and affordable.
- We will also be exploring the potential for on-site green hydrogen generation via solar panels.

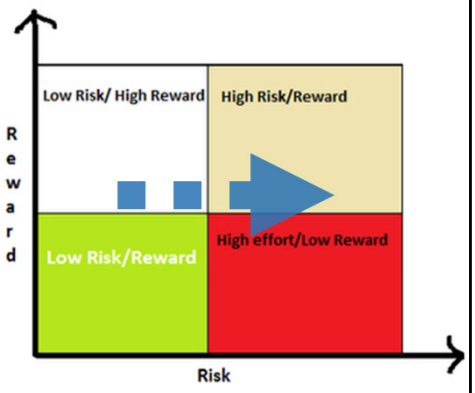
As with electricity, the agency will need to decide whether we should focus on tailpipe emissions, or also be concerned with emissions from energy generation as well.

Technologies Conclusions

- Neither technology is entirely ready

Two key unknowns

- When will sufficient, safe, affordable batteries be available?
- When will clean hydrogen be affordable?



So what can we say in conclusion about these technologies:

- Neither is entirely ready.
- No magic bullet to provide the same performance, same costs, AND eliminate emissions.

There are two key points that we should keep our eyes on:

- when will better, safer, affordable batteries be available?
- And when will clean hydrogen be affordable?

The challenge is today nobody knows the answers to these questions.

At an industry conference in early October 2023 it was very apparent to staff that the industry is still very uncertain which technology will prevail. Some agencies are doubling down on battery buses, others with battery buses are switching to hydrogen, and there's a possibility that mixed fleets could emerge as an optimized solution. Local circumstances such as topography and whether there is nearby hydro power could lead to different outcomes.

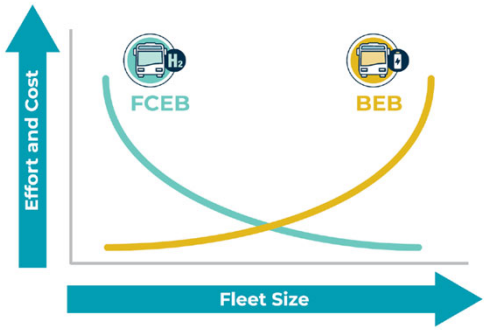
Finally, we have noticed that the perceived urgency of climate change may have an effect on how someone perceives these technologies. For example, if someone feels that immediate action is required, they may like the shorter start-up times of batters, but

minimize the longer term obstacles.

Recommendation: Hydrogen

✓Technology works today
- No range concerns
- Meets min. requirements, few fleet management impacts or hidden costs
- Allows us to design for customers, not equipment
- Few fires
- Needs market growth, not tech breakthrough

✓Better scale for 100-200 bus fleet



Source: TCRP; CTE

However, in our assessment hydrogen fuel cell electric buses have significant advantages.
- Hydrogen technology available today is adequate to meet our minimum operational requirements.
- The future of this approach does not rest on technology breakthroughs, but the maturation of economic markets.
- The simplicity of operation and fleet management does not undermine our internal efficiencies.
- Hydrogen presents several challenges but most of the risks are concentrated into two key questions how much does hydrogen fuel cost and how green can it be
- There are additional benefits pertaining to the diversification of our energy use and the reliability of energy supplies, and safety.
- General staff consensus about hydrogen.
- Finally, hydrogen would continue to allow us to design the transit service for customers not the propulsion system.

As a result hydrogen fuel cell electric buses have a clearer, if narrow, path to full deployment while eliminating emissions and serving passengers.

Why a Pilot Project?

- Learn from 2 buses, before larger commitment
- Makes tangible, visible progress towards to solution that looks best suited to full deployment today
- Minimizes initial investment and risk
- Allows time for outside markets to finish transition

Pilot Successful if…

- We have confidence in a path to full deployment of a solution that eliminates all emissions from bus propulsion, without risking services to customers

So now that we've identified a new propulsion technology, how should we deploy it?

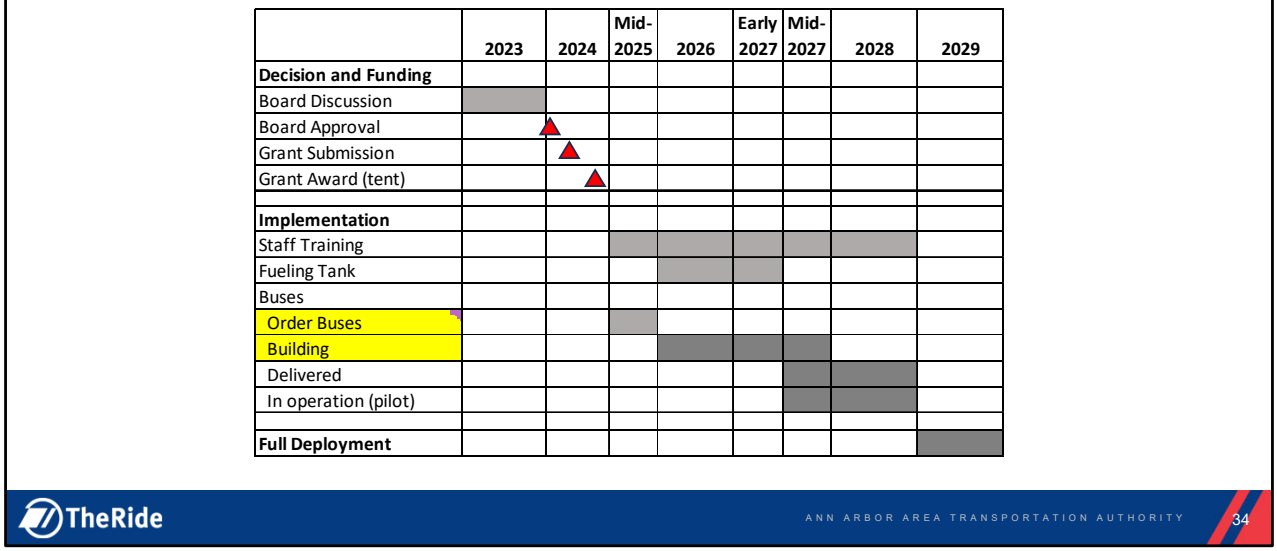
In this section I will speak to the rationale for a pilot project, its timelines and costs, as well as how a pilot can lead to a full deployment and substantial emissions reductions. I'll also speak to how we can reconcile these expenses with our other capital priorities

As an initial test of a new technology, a pilot project can balance risks and deliver benefits:

- Since we are reasonably confident that hydrogen can work and meet our minimum operational requirements, a pilot will give us time to learn through hands on experience how to manage a larger fleet of hydrogen buses especially for fueling and maintenance but also including driving. These lessons will be critical for accelerating full deployment in later years.
- A pilot will provide tangible, visible proof of the agency's commitment to reduce emissions.
- A pilot also allows time for the continuing development and maturation of hydrogen technologies and markets.

Transit agencies who were early adopters have noted their own learning experiences and recommended that we go slow.

Pilot Timeline



This preliminary timeline illustrates the various major steps and milestones in the pilot project and the lead-in to future deployments. We are showing a 5-year timeline until we are more confident that a 4-year timeframe is possible.

- We start here in 2023 with this recommendation, and public and board discussions.
- In early 2024 our board *may* provide us with authorization to submit a grant application.
- We expect the grant deadline in spring and announcements about successful awards in the fall of 2024.
- If we are successful in receiving a grant, we can begin implementation activities in early 2025. Staff training and procurements will start as soon as possible.
- Ordering the buses and installing the fuel tanks will, unfortunately, take a lot of time. For example lead times for bus manufacturing can require anywhere from 12 to 18 months for delivery after an order is placed. We are hoping the buses can be delivered in 2027.
- After which they will be put into Revenue Service carrying passengers we would need to run them for at least a full calendar year to get experience with operation in all seasons and different types of weather. If the pilot project is successful and if markets have matured and prices have declined to an acceptable and affordable point and if grant funding continues to be available, then the agency may begin to be able to replace its existing diesel bus fleet with new hydrogen buses.

During pilot will need to continue to buy mix of hydrogen and diesel buses to keep the fleet in good working order for passengers.

We expect the pilot to end around 2029. Staff will provide evaluations and assessments to .

We will also update costs estimates with new information.

After pilot, progress depends on costs and outside funding. Will not be able to afford full transition without federal/state funding support.

Pilot Project Financials

Total Project Cost: $6.9-10.8 million

Capital Cost: $5.5-$7.5 million

- 80%-90% federal Lo-No Emission Grant ($4.4-$6 million)

Operating: $1.4-$3.3 million

- 100% locally funded

Total costs to TheRide

- $2.5-$4.8 million over five years

Creating reliable cost estimates is difficult today.
- Markets are still developing, and suffering from post-pandemic confusion.
- We are presenting our preliminary cost estimates as ranges, from low to high, to account for this uncertainty.
- We intend to provide smaller ranges to the Board in November.

Final project figures will come in spring 2024. I need to be clear that the numbers will continue to evolve until the grant is submitted. Based on experience from other agencies, actual costs will differ from expected costs as the markets and technologies continue to change.

Capital costs are approximately 7 to $11 million.
- Capital costs include durable equipment such as the buses themselves the fueling equipment parts and other tangible assets.
- The federal government is providing very generous subsidies for adoption of new technologies.
- The Low-No grant program can provide 80 to 90% of the capital costs, with the remainder paid for by local or state sources. This still means the ride we'll need to find $1 to $2 million of other funding to contribute to the project, most likely from our capital reserve and contributions from the Michigan Department of Transportation.
- The Low-No grant is very competitive. It is not uncommon for agencies to resubmit for a few years before they succeed.

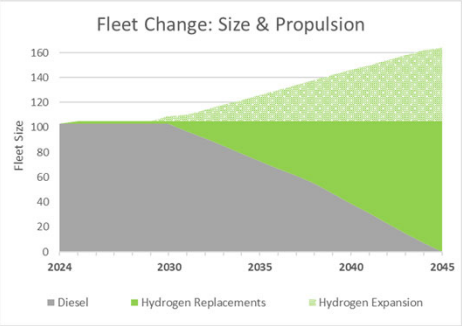
Operating expenses are expected to be in a range of $1.5-$3.5 million over the entire course of the project. These costs must be entirely borne by TheRide and would likely come from the Capital Reserve. I am hopeful that this figure could come down as estimate evolve. However, we will not be saving any money during the pilot.

Overall, we expect the total cost to TheRide to be somewhere between 2 ½ t to $4.7 million over five years.

Full Deployment Financials

If hydrogen successful…

- $16-$30 million for large fueling station (2030)
- $50-$75 million *more* on buses (25 years)
- Still cheaper than battery
  - no fleet growth, garage, operating inefficiencies
- Unfunded



Looking past the pilot project, we have some preliminary information about the long-term costs for transitioning the entire fleet.

Just to replace our existing fleet could require

- up to $30 million for a new fueling station and renovations in our existing garage.
- It would also require somewhere between $50 and $75 million ***more*** to be spent on buses over the next 25 years then we already had budgeted to spend replacing diesels.

However, if this avoids fleet growth and the need for a new garage, it could still be cheaper than batteries.

The main challenge with this and any large aspirational infrastructure project is that at this time there is no way to fund these expenses. I need to emphasize that transit agencies cannot afford this generational transition by themselves. We will be reliant on outside federal and state funding for years, which can be difficult if political priorities change.

(This graph is only illustrative. No timelines for full deployment have been finalized.)

Other Priorities

- Terminals, garage, IT, BRT and emissions
- Infrastructure grant are competitive, require local funding

- Short-Term: local funding *may* be adequate (terminals, pilot)
- Long-term: local funding *clearly* insufficient
  - No local funds for BRT, garage, full emissions deployment

Reducing emissions is not the only large expense the ride is anticipating.

- In 2022 our board of directors approved a new long-range plan that lays out 25 years of service improvements and new infrastructure intended to help double our ridership, often by attracting drivers out of their cars. Our construction needs for this long range plan include new bus terminals, new bus garages, and a new bus rapid transit system.
- Today Federal Capital grants are competitive. They require well-developed, shovel-ready projects that also have partial local funding. The federal government does not provide 100% funding for transit infrastructure, including zero-emissions buses.
- TheRide will need to be clear with itself about its priorities for spending its limited local funding. Our board grapples with similar questions by asking themselves: what should we do, for whom, and at what cost?
- We believe that the agency can afford this pilot project. However, we cannot afford the full deployment of zero-emissions buses without significant outside funding.

It can be very daunting to stare at a capital project list and know you can't afford most of it. But this is how infrastructure development often happens. Our job is to:

- make sure we have the right projects in the right sequence,
- to develop those projects as far as we can within existing resources,
- to make them shovel ready and attractive to outside funders, and
- Be clear about how much funding we can bring to the table.

Then trust our partners in the state and federal governments to help find funding..

I'd like to draw your attention to the large spreadsheet attached to this proposal on our webpage. It's called the Illustrative 10-Year Capital Plan. This is the mid-term budget for all our capital projects. It includes Must-Have expenses to maintain our existing infrastructure as well as aspirational projects from our Long-Range Plan. We have now added estimated costs to include zero-emission buses to the fleet, both for the pilot and full deployment. This is an attempt to help illustrates how these next costs will impact other projects.

- The most important line is for our local Capital Reserve. These are the only funds we have to use as a match for competitive federal grants. Once they are gone, we will not be able to advance any major new project.
- We expect to use the Reserve to partially fund the hydrogen pilot project. This will draw down Reserve funds faster. However, we believe that we'll still have enough to pay for other short-term facility projects such and the Ypsilanti and Ann Arbor bus terminals.
- The longer-term, after 2030, things become less certain. The Reserve may be exhausted by this time leaving us without funds for the full zero-emissions deployment or the bus rapid transit and accompanying garage. In a sense these projects are competing for local match dollars. However, we already didn't have enough to pay for the bus rapid transit or garage projects. The result is an increasingly large list of "unfunded" projects after 2030.

Part III:
Closing and Next Steps

Underlying Themes

Risk Tolerance (Action and Inaction)

- Climate and attitudes are changing
- Transitionary period & competing information
- Gap between expectations and performance of technology
- Financial commitments

Priorities & Limited Resources

- Investments: Emissions and/or ridership?

As we begin to wrap up this presentation let's return to our initial themes.

- We've discussed the importance of taking action to prevent climate change, as well as the risks.
- We've discussed in detail the gap between the expectations and performance of the technologies that exist today.
- And we've reviewed the financial commitments both for short term and long term emission reductions, as well as our competing priorities for our limited financial resources.

While the technologies are interesting, the biggest questions continue to be about

- risk tolerance,
- priorities and
- the degree of urgency we each feel between climate action and serving our communities and growing our ridership.

CEO Recommendation

- Move forward with hydrogen pilot grant proposal
- Hydrogen more practical today, better for full deployment
- Pilot project
  - Tangible/Visible symbol of agency commitment
  - Minimizes risk today, allows time for tech/markets to evolve
  - Puts clear date on full deployment decision in future when we may have answers to key questions
  - Is affordable, great federal %

As the CEO of the Ann Arbor Area Transportation Authority my **strong** recommendation to our board is that we move forward with a federal grant proposal based on a hydrogen pilot project.

As described in this presentation we believe hydrogen is more practical today, and is more likely to lead to the emission's benefits of a full deployment. Key benefits include:

- Hydrogen it is most likely to minimize disruption for passengers while eliminating all emissions from bus propulsion,
- It minimizes our financial risk today and allows time for technologies and markets to develop,
- It provides visible, tangible evidence of TheRide's commitment to carbon neutrality,
- It pushes the bigger decision about full deployment into the future where hopefully we have more and better information,
- Unlocks grants we need for other important projects,
- Prepares us for future mandates,
- And finally the pilot project is affordable within existing resources.

Immediate Timeline

1. **October 2023**: CEO Recommendation
2. **Oct '23- Dec/Jan** : Board discussion & Public Feedback
3. **Jan 2024**: Board approval deadline
4. **Jan-March 2024**: Grant preparation, Transition Plan approval
5. **March/April 2024**: Anticipated grant deadline
6. **Oct 2024:** Anticipate grant awards

Quickly, let's recap our process for the next few months.

- In October of 2023 I am tabling this recommendation for our board of directors and community. We welcome feedback until the decision is finalized. I expect the board will discuss this in at least October and November and probably through December of 2023.
- I am letting the board know that to hit our grant deadline in the spring of 24 staff will need a decision from them on this proposal by January of 2024 at the latest.
- Should the board approve a grant submission, staff will move forward in the early months of 2024 in preparing a grant application for the low no emissions grant program from the federal transit administration. We expect the deadline for that grant to be in March or April.
- Our application will be evaluated with dozens of other competing proposals from around the country. Should we be successful we expect notification in the fall of 2024, after which we would begin implementation of the pilot project.

Board Authorizations

The CEO will ask the Board to provide:

- **By January 2024:** A vote to authorize the CEO to submit a grant (clear scope and costs)
- **Spring 2024:** Approve a "Transition Plan" – a formal document required for the grant which articulates our approach, timelines, and commitments

I want to be clear with our Board of Directors about the specific decisions this process will ask of them. There are two steps:

1. First, I need a soft commitment. By January 2024 I am asking the Board to clarify their support for this recommendation and the financial commitment it requires. I need to know which direction the Board supports and whether this is the right time for this grant applications. I don't want to move forward on this without knowing they are in support. Also, preparing the applications material is a significant level of effort for staff.

2. Second, I need a firmer commitment. Around February or March we will need the Board to vote on a federally-required "Transition Plan", which outlines our intent to pursue zero-emissions buses into the future. This Transition Plan can only be approved by the Board and is a requirement of the Low-No grant submission. By this point we intent to have final cost estimates.

With these two Board approvals in hand, staff can submit the grant applications. The application represents a proposal to the federal government whereby we commit to spending future capital dollars. If the feds approve the grant, we will not be able to change our minds and we will need to expend capital funds on this pilot project in the coming years.

To be clear, all of these approvals relate to the pilot project contained in this proposal. The larger decisions about full deployment will not occur until around 2029.

Public Feedback

- Visit www.TheRide.org for information and feedback opportunities
- Submit written comments via web form or email
- Attend TheRide board meeting to make public comment

We welcome feedback this fall and winter. Our project page for zero emissions bus recommendations contains this presentation, Links to all our previous work technical background research and public presentations, and links to helpful videos that provide more context. We encourage everyone to watch this presentation and visit our website. I encourage you to visit our project website right now and leave your own comments.

You also welcome public comment during our board meetings which are held on the 3rd Thursday of every month starting at 6:30pm on the top floor of the downtown Ann Arbor library. We encourage speakers to prepare their comments in advance as each speaker is allotted 3 minutes.

Zero-Emissions Bus Propulsion

CEO Recommendation

October 2023

TheRide ANN ARBOR AREA TRANSPORTATION AUTHORITY 44

Finally thank you for your interest in this very important subject. Staff have learned so much about this subject over the last year. We look forward to learning more from you.

We hope that this presentation and our earlier work has proved helpful for you in developing your thoughts on zero emissions bus propulsion

thank you.