Business Case Analysis

Fuel Cell Electric Bus Deployment | Case Study

This publication was prepared by Zachary Karson and Leah Foecke of RebelGroup for the Governor's Office of Business and Economic Development (GO-Biz). The information contained herein is the responsibility of the authors and does not necessarily reflect the views of GO-Biz or the government of the State of California.

Table of Contents

Executive Summary

Executive Summary (1/3)

Fuel cell electric buses (FCEBs) and supporting infrastructure are crucial to achieve the vision of the Innovative Clean Transit (ICT) regulation throughout California, including in areas where battery-electric buses (BEBs) are currently unable to meet transit agencies' operational needs. Transit agencies are the tip of the spear for statewide heavy-duty transportation decarbonization, which presents a unique opportunity through studies like this one to better understand the nuances of full-scale zero-emission deployment.

This business case analysis demonstrates that public transit transition to FCEBs faces an evolving business case and financial picture. Due to the financial and business case factors outlined in this analysis, deploying FCEBs while accomplishing the core mission of delivering quality reliable transit service raises questions about the demands on limited operating funds, how to contain costs, and how to manage financial and operational uncertainties. These business case questions are particularly salient for small and rural transit agencies, for whom the business case environment for FCEB deployment is less mature.

The case study of Humboldt Transit Authority (HTA) demonstrates that HTA and similar agencies will likely face an operating cost deficit in the short-term if they maintain today's service levels and take the bold actions they have planned to continue to reduce VMT and carbon emissions. A thorough study of HTA's future operations with FCEBs estimates an operating deficit of 31% in 2029 (approx. ~3M of its ~10M budget), as compared with an operating deficit of 7% in a counterfactual scenario in which HTA maintains its current fleet.

Executive Summary (2/3)

The business case results in this analysis are driven primarily by the costs of hydrogen (H2) fuel and refueling station operations and maintenance (O&M). These costs are expected to be higher in the short term due to the relatively "young" market for decarbonized heavy-duty transportation, before improving as the market matures over the medium or long term, due in part to key initiatives already underway such as California's hydrogen hub project, ARCHES. Because of this dynamic, this analysis clarifies that long-term supply and market-making initiatives are crucial and complementary to shorter-term "bridge" initiatives optimized for the observed business case environment of today.

A scenario analysis of HTA's 'business case' for FCEB deployment shows that HTA could achieve parity with the net operational cost of its current diesel and gasoline fleet, but only with the support of a wraparound "all of the above" approach providing near-term support addressing key cost drivers.

The HTA case study also includes an evaluation of the market for H2 fuel and refueling station providers through the lens of HTA's procurement process. The case study helps to illuminate the underlying factors of the business case challenges and helps transit agency practitioners be better informed customers in the sector. The market analysis reinforces the high degree of uncertainty for many of the key inputs needed to plan and execute FCEB deployment projects, and the importance of transit agencies understanding and managing these risks.

Executive Summary (3/3)

The results of this analysis point toward a multidimensional policy approach to enable public transit agencies to sustainably deploy and successfully model heavy-duty hydrogen transportation, which is detailed further in a complementary “Interagency Collaboration Findings" report. This approach includes accelerated research and development, funding for O&M in addition to capital, LCFS and other incentive programs, and other cost containment and market development strategies.

Such policies and programs would help bolster HTA's business case for FCEB deployment and would also be applicable and scalable to other agencies in the North State Super Region and elsewhere. HTA’s case study further demonstrates how important it is for California to “lean in” to the crucial progress being made in the transit sector in order to catalyze a larger regional H2 economy and zero-emission transportation network.

Section 1: Introduction

Purpose of Business Case Analysis

This business case analysis was developed to assist transit practitioners with understanding the economics and practical business considerations of deploying hydrogen-powered fuel cell electric buses (FCEBs).

In addition, the findings of this report are intended to inform policy and programmatic decisions in California that would improve outcomes for transit implementers – these recommendations are detailed in a complementary "Interagency Collaboration Findings" report also sponsored by GO-Biz.

Focus of Business Case Analysis

Business Case for FCEB Deployment in the North State Super Region of California

To analyze the business case for FCEB deployment, this report analyzes the specific case study of **Humboldt Transit Authority (HTA)**, a small transit agency based in Eureka, CA within the North State Super Region (NSSR).

Hydrogen-powered FCEBs are an important piece of California's zero-emission bus (ZEB) transition puzzle, as many transit agencies – particularly those in rural areas with longer routes – will be unable to meet Innovative Clean Transit (ICT) mandates with battery-electric buses (BEBs) alone.

The example of HTA within the NSSR illustrates how certain FCEB deployment dynamics are magnified further for small and rural transit agencies in remote regions.

Key Study Questions

The business case analysis and case study seek to address the following key questions:

What are the key drivers of the business case (key benefits, costs and risks) and their relative magnitude?

What are the underlying market factors impacting the business case?

Which elements of the business case are unique to each transit agency or common across FCEB deployers?

Given the economic and market realities, what policy / programmatic solutions could meaningfully improve the business case?

About HTA

HTA is a transit agency organized as a Joint Powers Authority (JPA) to operate local and regional public transit service. HTA provides public fixed-route and paratransit service in the cities of Arcata, Eureka, Fortuna, Rio Dell, Trinidad, Willits, and Ukiah, and unincorporated areas of Humboldt County and Mendocino County along California's northern coast.

HTA provides ~0.9 million passenger trips each year on 13 directly operated routes. HTA's routes currently serve one transit center and connect passengers to four other regional transit providers.

HTA was an early adopter of contactless open loop payments through the California Integrated Travel Project (Cal-ITP) and partnered with Redwood Coast, Mendocino and Lake Transit on that innovative project and joint purchase.

About HTA's Transition

HTA was awarded $39M in 2022 (Cycle 5) by the California State Transportation Agency's (CalSTA's) Transit and Intercity Rail Capital Program (TIRCP). The goals of HTA's project are to a) meet the ICT Regulation, b) directly mitigate climate change impacts, and c) benefit HTA's community by replacing diesel buses with FCEBs.

As part of this TIRCP project, HTA will:

- Construct an intermodal housing and transit center;
- Retrofit its existing maintenance bays to accommodate FCEBs;
- Acquire 11 new FCEBs (HTA worked with New Flyer to develop a new 400-mile long-range FCEB); and
- Develop a liquid hydrogen refueling station on its transit yard in Eureka with an 18,000-gallon storage tank and fueling capabilities for in-yard H35 (transit FCEBs), in-yard H70 (other medium and heavy-duty vehicles), and over-the-fence H70 (light duty vehicles) – this station is one of the first north of the Bay Area, kick starting the North Coast hydrogen supply chain.

HTA is aiming to ensure that the project can be completed while maintaining its core mission of maintaining excellent transit service and increasing ridership.

HTA Project Status

HTA has entered into a contract with New Flyer of America, Inc. to procure one extended range XHE40 bus in December 2024, and ten more extended range XHE40 buses by Fall 2026

HTA has contracted with Linde to design and build a hydrogen fueling station utilizing liquefied hydrogen (LH2) as delivered supply

HTA has contracted with Linde to provide a temporary hydrogen fueler and supply of hydrogen fuel to support the operation of one or more fuel cell electric buses (FCEBs)

HTA has selected LDA Partners, Inc. to provide design consulting services for the retrofit of HTA's maintenance bays to support fuel cell electric buses (FCEBs)

HTA's fleet transition plan leads to fully zero emission by 2036 and fully hydrogen fleet by 2040

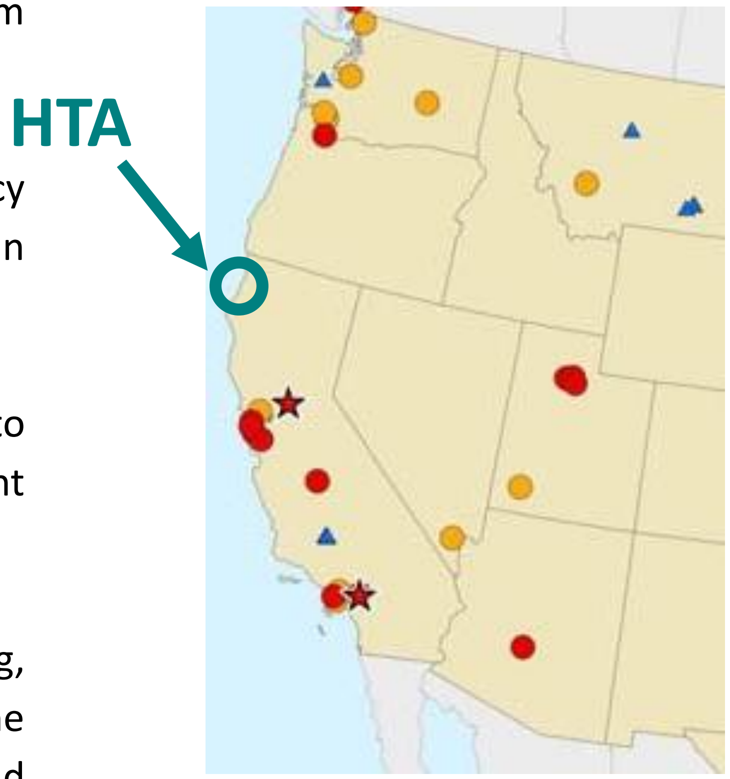
HTA Project Challenges

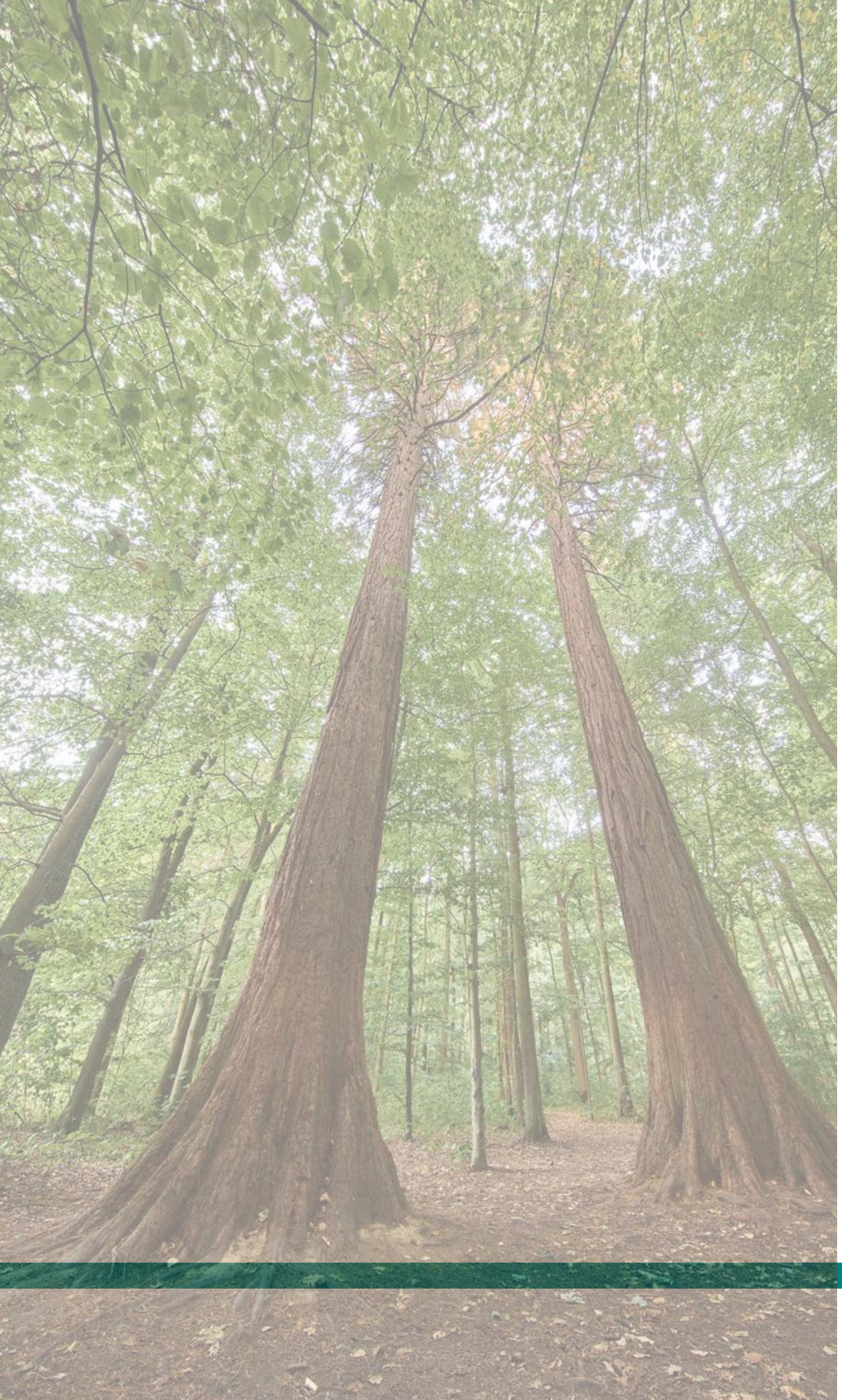
Fuel supply and availability uncertainty: HTA is 300 miles from nearest producer on remote highways that experience frequent closures, leading to short-term uncertainty about fuel availability.

Difficult to optimize for both reliability and cost: Ensuring reliability and resiliency often means building in redundancy or more sophisticated systems, which can increase costs.

Tension between sizing for resiliency, future needs, and efficiency: HTA had to decide how large to build its infrastructure; larger systems may be more resilient and support future demand, but also increase near-term costs.

Project delivery timing: Separate contracts to deliver FCEBs, temporary fueling, permanent fueling, and maintenance bay retrofits all carry delay risks, yet the timing of these projects must be carefully coordinated to meet HTA's timelines and avoid excessive costs.





About the North State Super Region

The North State Super Region is a consortium of small transit agencies and Regional Transportation Planning Agencies (RTPAs) across 16 counties in Northern California. This mega-region is very large and geographically diverse, with many rugged and remote zones lacking substantial connectivity infrastructure and electric grid capacity. Many transit agencies operate long-distance intercity routes between population centers that cannot be feasibly served by BEBs in the medium-term. Many transit agencies have limited staff resources, meaning that procurement and project management related to zero-emission transition poses both a challenge and an opportunity to build regional capacity.

The NSSR’s long-term vision is to establish a robust and resilient zero-emission transportation network, a sustainable and affordable regional hydrogen economy, and equitable integration of hydrogen jobs into local economies.

NSSR Zero-Emission Challenges

Key challenges include:

- NSSR agencies face significant uncertainty about fuel/electricity availability and cost at many of the locations that will need to be part of a regional network.
- Most NSSR agencies will face many of the same challenges and considerations that HTA faces on technology reliability, resiliency, and operational costs.
- Coordination among the many different users of a fueling network poses an additional challenge (including transit, freight, other municipal fleets, and more).
- There are substantial gaps in specialized technical skills and knowledge required to create projects with first of their kind elements that can’t just be copy-pasted.
- Some areas are struggling to gather the necessary political support for zero-emission infrastructure projects.
- Many NSSR agencies require vehicle types (e.g., hydrogen-powered cutaways) that are not commercially available today.

Regional Role of HTA Project

There are several other agencies in the NSSR that are actively considering projects to deploy hydrogen-powered vehicles, but HTA is playing a leadership role. Regional stakeholders are looking to HTA's project to be an anchor and a demonstration of success. A strong regional network is critical to bring scale, cost reductions, and resiliency to planned and future hydrogen vehicle and refueling infrastructure projects (including HTA's).

HTA's project will be a critical path-breaker for the region, hopefully catalyzing a robust regional network that HTA will eventually benefit from via reduced fuel costs, more resilient supply and redundancy, and a supportive network of peers deploying similar technology.

Case Study Approach

Given the importance of HTA's project to the development of a sustainable hydrogen economy and zero-emission transportation network in the NSSR, this case study is integral to California's fleet transition approach.

This business case report can be used to illuminate key challenges and opportunities for FCEB deployment to help other transit agencies in the NSSR and beyond who are at the forefront of this transition as they plan and implement these projects.

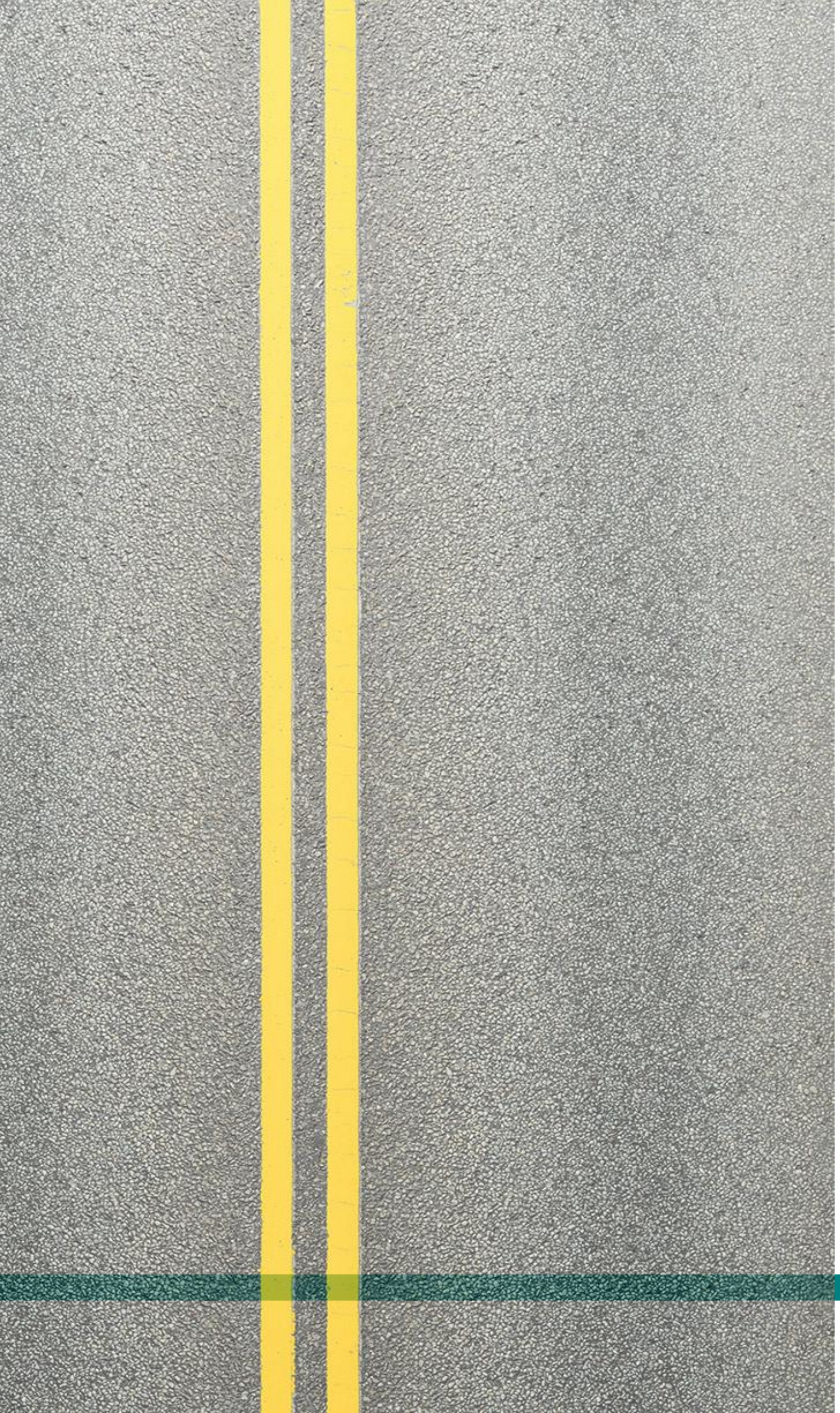
The business case results will also inform state agencies as they continually adapt policies, funding programs, and interagency coordination strategies to realize the goals of ICT.

Section 2:
Business Case Methodology

Business Case Analysis

The business case analysis examines the financial impact of HTA's transition to a ZEB fleet (which consists primarily of FCEBs) by modeling the agency's cash flows over a 20-year time horizon. The model leverages HTA's existing financials and key details of HTA's operations (including vehicles, routes, and staffing) to project future cash flows. Since HTA had already committed and made investments to execute its transition plan, this analysis was not intended to inform HTA's transition plan or analyze alternative transition paths. Instead, the business case analysis is intended to examine the financial impact of HTA's chosen transition path, and the key drivers of those financial results. The project team worked closely with HTA to develop and vet all inputs and assumptions in the model.

The analysis and outputs focus on HTA's operating cash flows since the business case challenges identified by HTA and other NSSR members and early FCEB adopters centered on new or increased operational costs (e.g., hydrogen fuel, station O&M). This challenge is central due to the fact that most existing sources of financial support for the transit ZEB transition are programmed for capital costs only, as is the case for HTA's project which is funded by TIRCP. The purpose of this analysis is not to draw general conclusions about the financial feasibility of FCEB deployment, but rather to develop insights into key business case considerations that will be largely applicable to other agencies. Results of the analysis are included in Section 3.



Overview of Business Case Methodology

The business case analysis comprises three sequential parts:

- Analysis of HTA’s financials before the ZEB transition
- Analysis of the impact of ZEB transition on HTA's financials
- Analysis of the sensitivity of HTA's financials to various changes in inputs and assumptions

The objectives, approach, and outputs of each part is outlined on the following pages.

Part 1 (pre-transition): Modeling HTA's budget and operational fundamentals

Objectives

- Understand HTA's pre-transition fiscal position (both recent actuals and as a long-term counterfactual with no ZEB transition)
- Understand HTA's pre-transition transit operations
- Identify key underlying drivers and trends of HTA's pre-transition fiscal position

Approach

- Review HTA budget and profit-and-loss statements to extract data inputs for the model (2024, prior to FCEB deployment)
- Input key transit vehicle, route, and cost details, and other operational data (2024, prior to FCEB deployment)
- Develop assumptions regarding revenue and expenditure growth over the forecast horizon, differentiating escalation rates where appropriate

Outputs

- Breakdown of pre-transition revenues and expenditures (on a cash flow basis)
- Breakdown of pre-transition fleet and route information

Part 2 (Base Case with ZEB transition): Modeling HTA's long-term financials

Objectives

- Understand HTA's fiscal position as a result of their planned transition over the forecast horizon
- Understand key underlying drivers of HTA's post-transition fiscal position

Approach

- Analyze how each revenue and expenditure item changes as a result of ZEB transition
- Input fleet transition schedule to determine point in time at which each change occurs
- Develop assumptions regarding revenue and expenditure growth over the forecast horizon, differentiating escalation rates where appropriate

Outputs

- Breakdown of post-transition revenues and expenditures (on a cash flow basis)
- Breakdown of post-transition fleet and route information

Part 3 (Base Case with ZEB transition): Modeling sensitivities and scenarios on HTA's financials

Objectives

- Understand changes to HTA's projected fiscal position resulting from changing individual inputs / assumptions ("sensitivity analysis") or pre-defined groups of inputs / assumptions ("scenario analysis")

Approach

- Develop alternative inputs / assumptions to develop insights on business case drivers

Outputs

- Delta between HTA's projected fiscal position in the Base Case and in each given sensitivity / scenario at various points in time throughout HTA's ZEB transition

Key Assumptions (1/2)

The Base Case financial model results rely on the following certain key inputs and assumptions, many of which come with a high degree of uncertainty (which drive the need for sensitivity/scenario analysis):

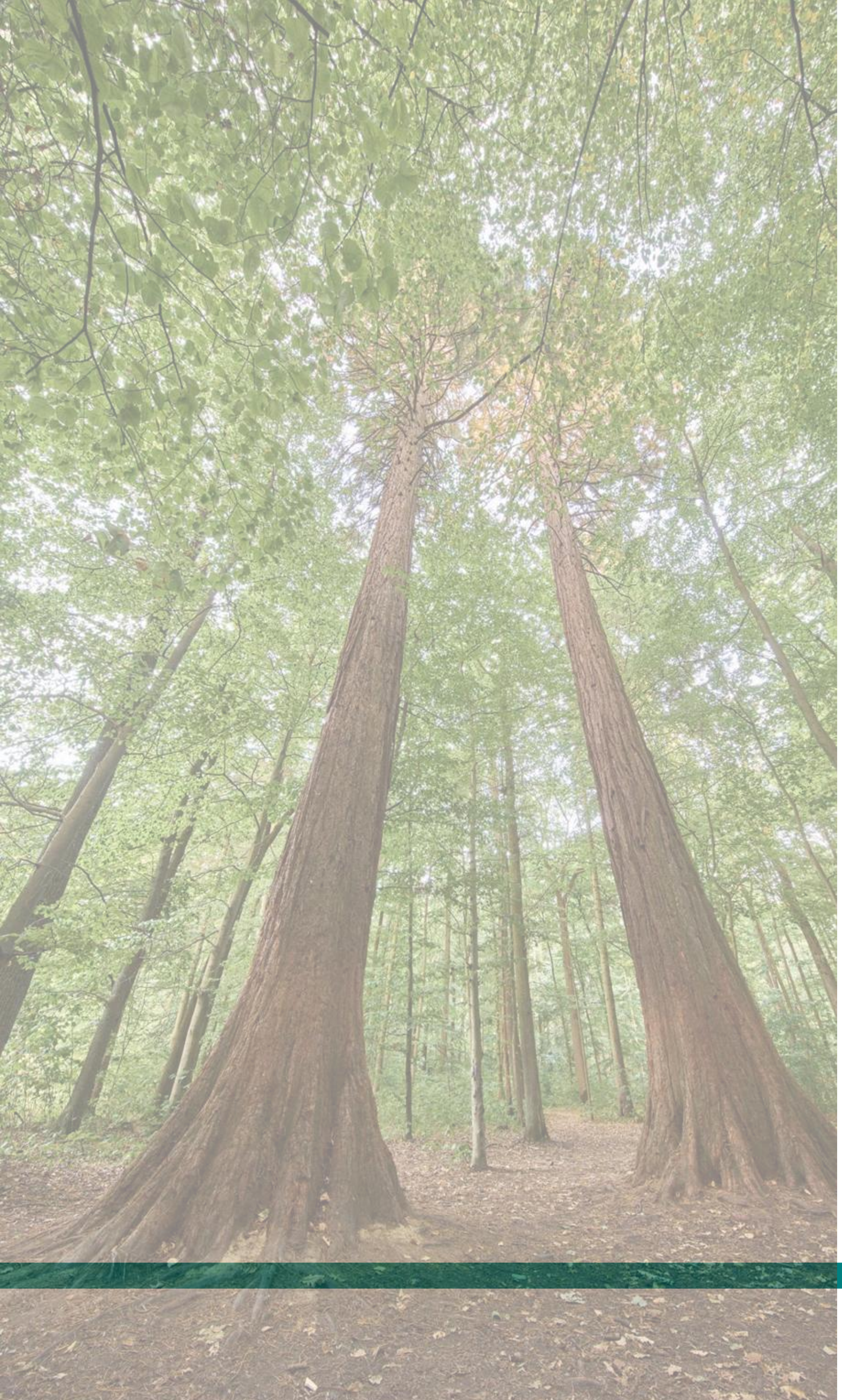
- **H2 fuel price:** HTA's competitively procured contracted price for fuel for its permanent liquid hydrogen refueling station is $14.50/kg, valid for an initial two-year term and three one-year extensions. In the base case, this price is assumed to stay constant in nominal terms (i.e., not escalating with inflation). Please note that when fuel and O&M are provided by the same contractor, costs associated with fuel and with O&M may be somewhat interchangeable; costs assumptions based on the contract may not be strictly attributable to the costs of fuel versus O&M.
- **H2 evaporative losses ("boil off"):** Because of boil off for liquid refueling stations, HTA will need to buy liquid fuel that ultimately will not be consumed by the FCEB fleet. The vendor's estimate for fuel losses varies by the amount of fuel consumed per day, ranging from 5.6% to 14.7% of fuel in the tank lost per day; this analysis assumes 7.5%/day for simplicity based on average fuel consumption over the forecast period. Additional losses from priming the pumps for fueling sessions (which are likely to occur and can also cause significant losses) are not accounted for, meaning the analysis likely underestimates boil off.
- **H2 refueling station operations and maintenance ("O&M"):** Per HTA's permanent refueling station contract, O&M costs will be $74,000/year for the initial two-year term and three one-year extensions. O&M costs for the temporary refueling station are included in the total lease price and not separately modeled.
- **Temporary refueling station lease costs:** Per HTA's contract, total lease costs (including fuel, O&M, deliveries) will be approximately $600k - $650k for the two years that HTA anticipates using the temporary refueling station.

Key Assumptions (2/2)

The Base Case financial model results rely on the following certain key inputs and assumptions, many of which come with a high degree of uncertainty (which drive the need for sensitivity/scenario analysis):

- **Other H2 transition costs:** ~$25k-100k/year is assumed in miscellaneous costs for staff (specialized training, attending conferences, legal services, etc.), which start out higher at the beginning of transition and then eventually phase out.
- **Low Carbon Fuel Standard (LCFS) revenue:** The analysis assumes that HTA monetizes LCFS revenues during its fleet transition for both its FCEBs and BEBs. A fixed LCFS credit price of $56/ton (spot price in Oct 2025) and assumed carbon intensity of 100 gCO2e/MJ were used based on assumed mix of 66.66% SMR-based hydrogen from the HYFL pathway, and 33.33% from zero-carbon electrolysis. (Note that LCFS revenues decline over time as standards ratchet up.)
- **Fuel efficiency gains:** Modest fuel efficiency gains from H2 relative to diesel are assumed; these efficiency factor assumptions vary based on individual route characteristics and vehicle types.
- **Vehicle maintenance savings:** A ~10% reduction for FCEBs relative to diesel maintenance costs is assumed (based on HTA's actuals).
- **Fare revenue:** HTA's "low growth" ridership estimate is used in the model, in which ridership levels reach 112% of peak pre-Covid ridership by 2040, multiplied by an average fare amount that increases annually by 1%.
- **Grant revenue:** Varying rates of escalation for various local, state and federal grant sources are used in the model, estimated based on relevant authorizing legislation and program rules. It is also assumed that SB125 is replaced by a successor program and similarly escalated over time at inflation (3%).

Section 3:
Business Case Analysis Results

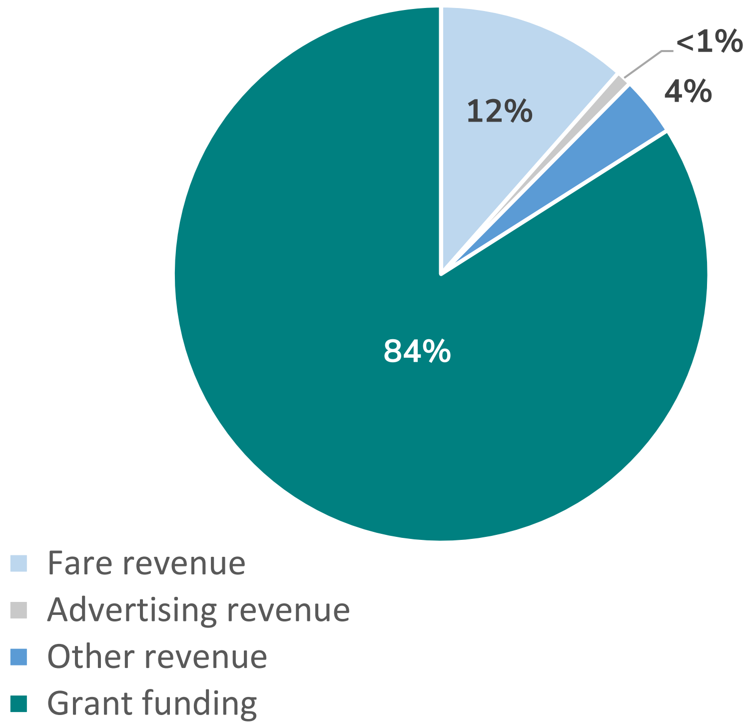


Part 1: Pre-Transition

HTA’s financial position (pre-transition) is stable, as one-time infusions of operating support have allowed HTA to withstand ridership decreases resulting from the COVID-19 pandemic. In addition to federal CARES, CRRSA, and ARPA funds, HTA is benefiting from operating and capital funding support from California SB125 funding, which is enabling the agency to invest in improving service and customer experience to bring ridership to pre-pandemic levels and achieve long-term financial sustainability. HTA has set ambitious targets for ridership growth over the next decade to meet VMT reduction goals (in FY 2024, HTA experienced ridership growth of 8% and fare revenue growth of 6%, as reported in its November 2024 board report).

In the business case analysis, a counterfactual scenario is analyzed in which HTA continues operations with its current fleet composition. In this counterfactual, revenue growth and public funding assumptions remain the same, and it is assumed that SB125 operating funds are replaced by a successor program. This counterfactual shows moderate long-term deficits due to the impact of expected operating cost inflation which may outpace public funding levels

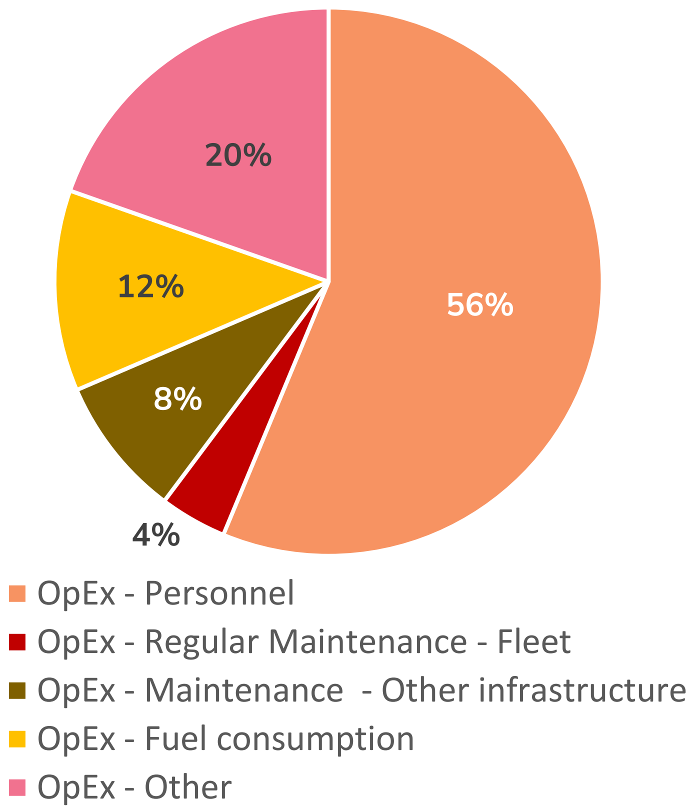
Part 1 (pre-transition): HTA's distribution of revenues



Like many other small and rural transit agencies across the US, fare revenues are a relatively small portion of HTA's overall revenues (12%), with the majority coming from local, state and federal funding sources (84%). Local Transportation Funding makes up ~45%, state funding programs make up ~29% and federal formula funding ~10%.

Practically, what this means for HTA is that if the agency experiences an extraordinary increase in operating costs, even an extraordinary increase in fare revenues may not be sufficient to offset those costs.

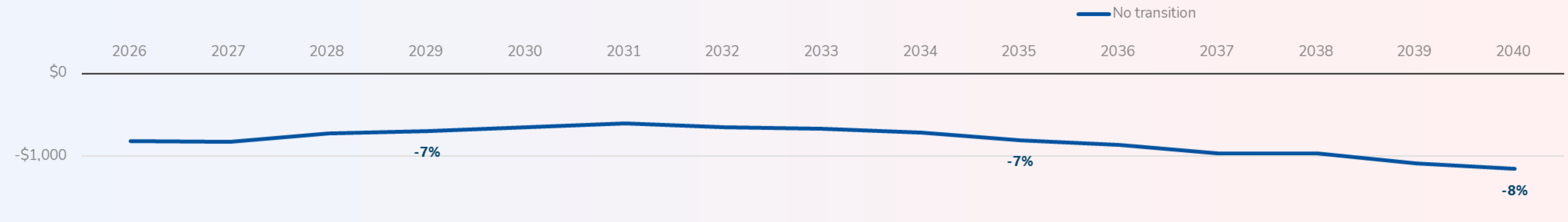
Part 1 (pre-transition): HTA's distribution of expenditures



HTA's breakdown of operating costs is also relatively typical for agencies of comparable size, with personnel costs making up the majority (56%). When personnel costs are added to other general and administrative (G&A) costs, these two categories contribute roughly ¾ of HTA's ~$9M operating budget. Note that maintenance costs outlined in the pie chart exclude the cost of salary/benefits of HTA's maintenance staff, to avoid double counting.

A relevant observation for the purpose of this business case analysis is the relative total cost of fuel, even pre-transition, which makes up 12% of HTA's budget.

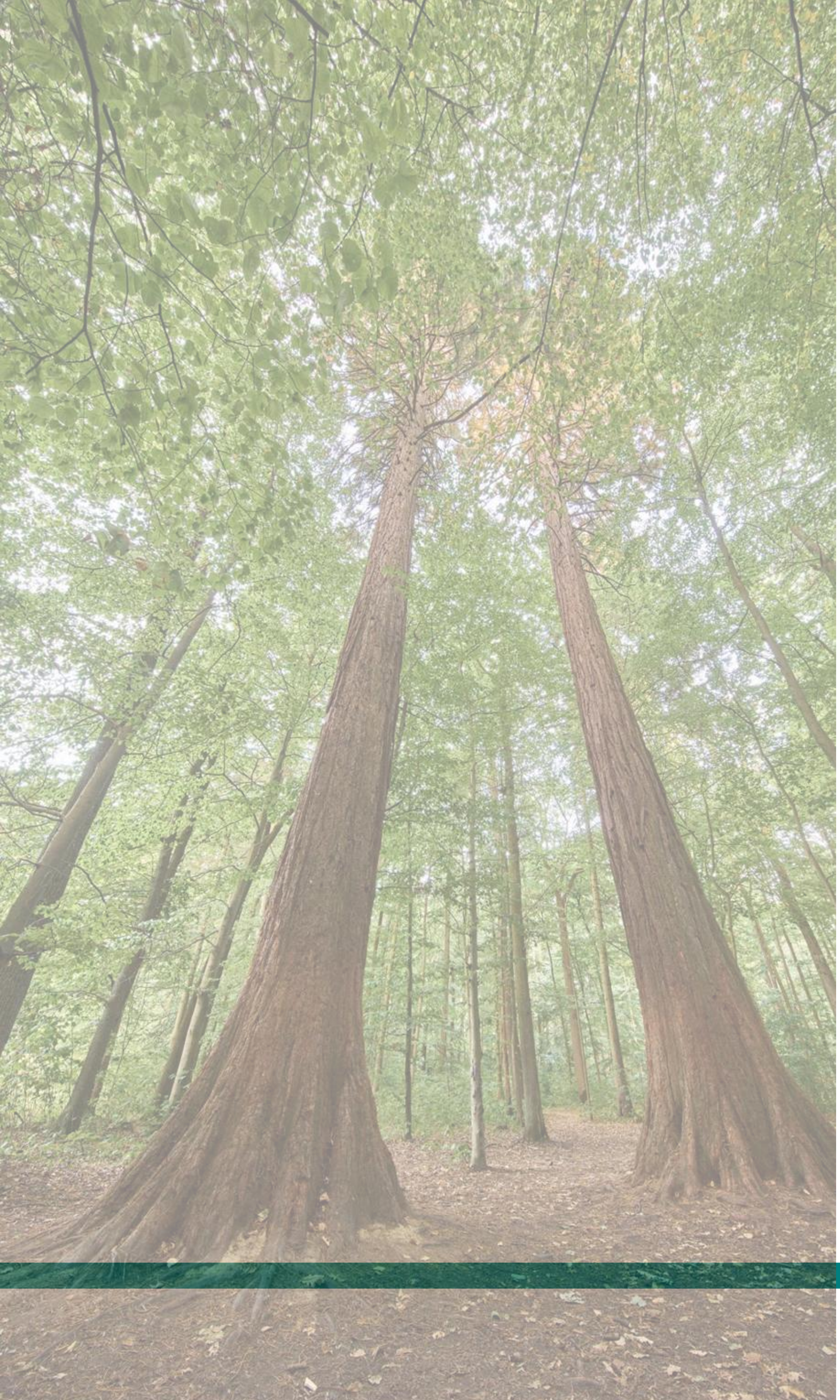
Part 1 (pre-transition): HTA’s budget snapshot



The line chart above illustrates <u>HTA’s projected operating deficit over the forecast period for the counterfactual ‘no transition’ scenario</u>. Key observations include:

Positive signs for near-term sustainability: The effect of SB125 operating funding and capital investments catalyzes ridership and fare revenue increases in the next 5-7 years, bringing HTA toward financial sustainability.

Long-term inflationary pressure: The gradually increasing deficit in 2030 onwards is due to the estimated impacts of inflation on operating costs, which may outpace fare revenue and public funding growth – however, HTA can directly control and manage some of these operating cost increases.



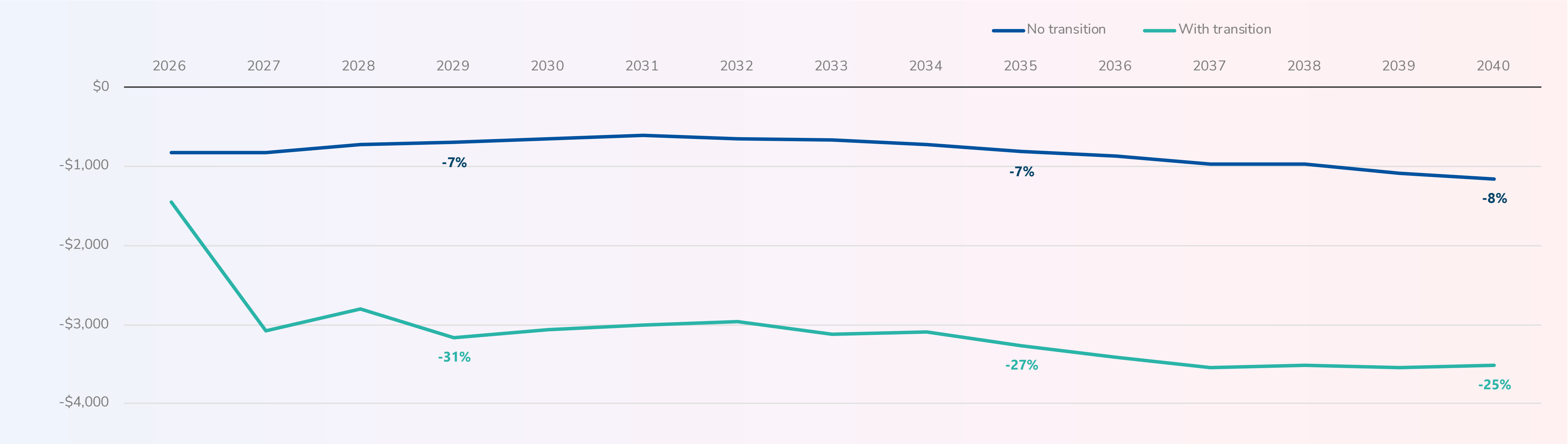
Part 2: Base Case

Part 2 of the business case analysis comprehensively examines both the positive and negative factors influencing the calculation of HTA's budget position as a result of the ZEB transition (see pages 25-26 for Key Assumptions). The result of this analysis is considered the Base Case.

Overall, accounting for both savings and extra expenditures, results show larger short-term operating deficits in the Base Case than the counterfactual analyzed in Part 1. For example, HTA's operating deficit in 2029 is projected to be 31% compared with only 7% in the no transition counterfactual. This trend generally continues through the 2030s and beyond.

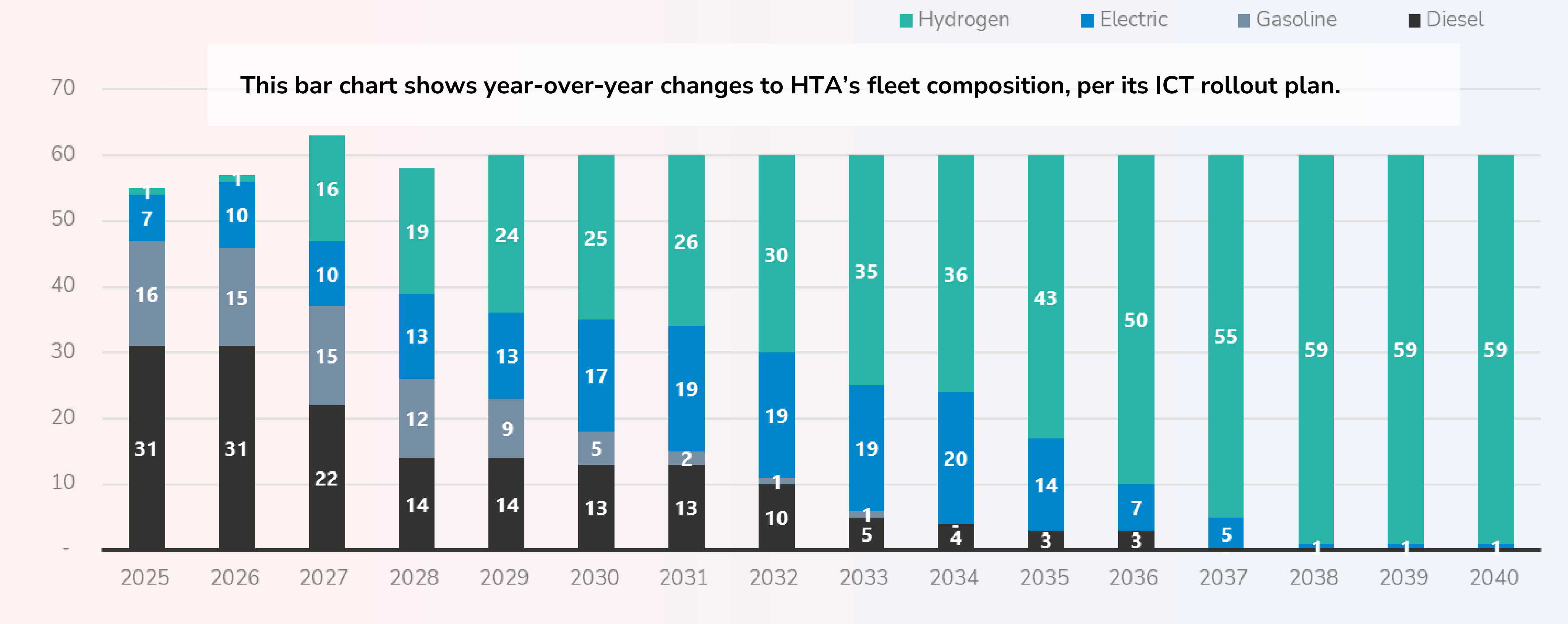
The results show that the higher operating costs are primarily driven by the high costs of H2 fuel, including boil-off, and refueling station O&M (together, over $21/kg). Meanwhile, the positive business case factors from transition (LCFS revenues, improved fuel efficiency, and vehicle maintenance savings) are uncertain and small in comparison to those higher operating costs.

Part 2 (Base Case with ZEB transition): Modeling HTA's long-term financials



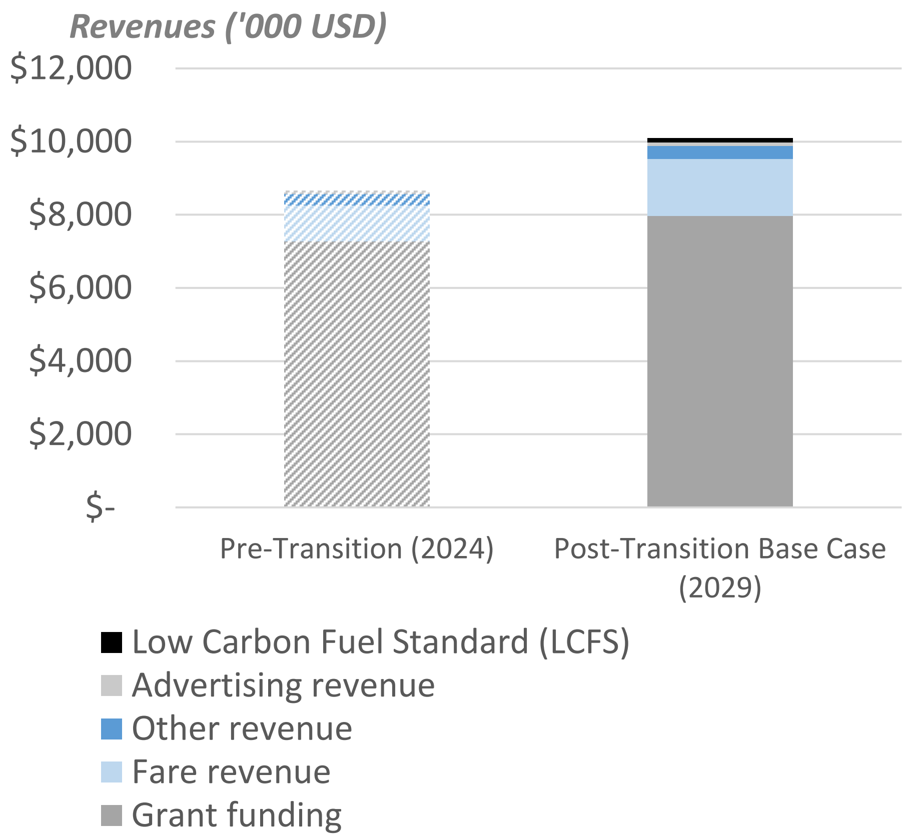
This line chart shows HTA's projected operating deficit over the forecast period for the Base Case compared with the no-transition counterfactual. Key observations and a breakdown of the incremental operating costs from transition are included later in this Section.

Part 2 (Base Case with ZEB transition): Modeling HTA's long-term financials



Note: HTA's transition plan is multifaceted and generally involves transitioning diesel and gasoline vehicles toward a fully hydrogen-powered fleet. Given the current commercial unavailability of fuel cell electric cutaway vehicles, HTA plans to use battery electric cutaways to bridge the gap, meaning it will also need some electric charging infrastructure in addition to hydrogen refueling. HTA faces some additional costs and operational complexity from running a mixed fleet. The infrastructure component of the transition plan also includes its own challenges related to market availability, timing, and cost escalation, which are discussed further in Sections 5 and 6 of this report.

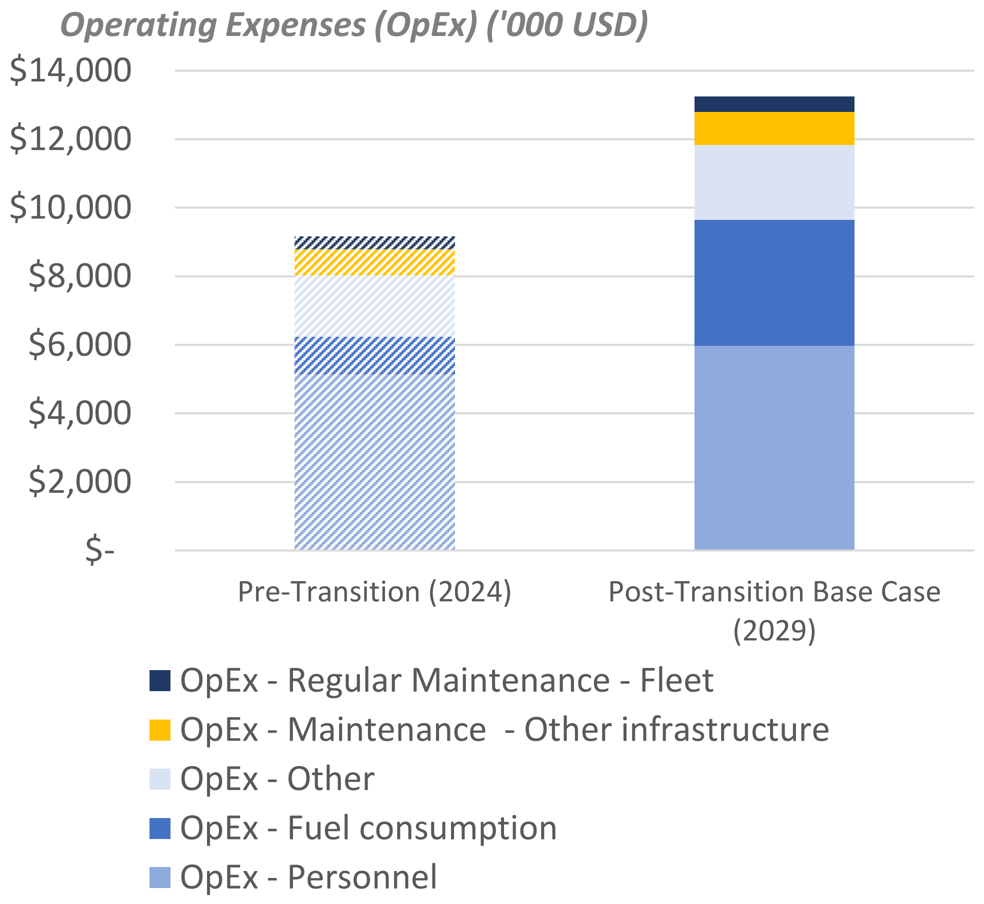
Part 2 (Base Case with ZEB transition): HTA's distribution of revenues



This chart illustrates the same revenue breakdown as shown in Part 1 (Pre-transition Counterfactual) but shows projections for 2029 in addition to actuals from 2024. Note that by 2029, HTA will have been operating a sizable FCEB fleet for at least a full year.

The results of this breakdown are very similar to those shown for Part 1, with the exception of the addition of LCFS revenues generated from the hydrogen fleet, which HTA can monetize but provide relatively small additional revenues (~4% of H2 transition costs, as shown on p.37).

Part 2 (Base Case with ZEB transition): HTA's distribution of expenditures



This chart illustrates the same expenditure breakdown as shown in Part 1 (Pre-transition Counterfactual) but shows projections for 2029 in addition to actuals from 2024. Note that by 2029, HTA will have been operating a sizable FCEB fleet for a full year.

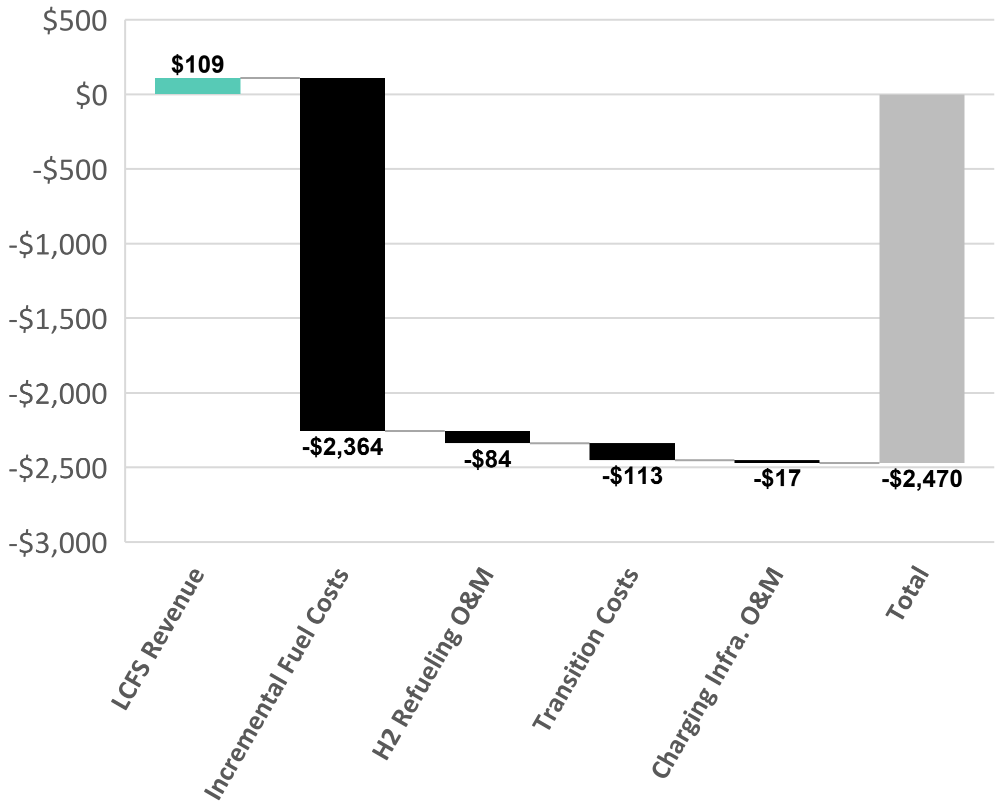
The results of this breakdown diverge significantly from the Part 1 results, due to the increased costs for fuel (driven primarily by the FCEB fleet), which makes up 28% of the total operating budget, versus 12% in the pre-transition business case, plus additional operating expenses.

Part 2 (Base Case with ZEB transition): Modeling HTA's long-term financials

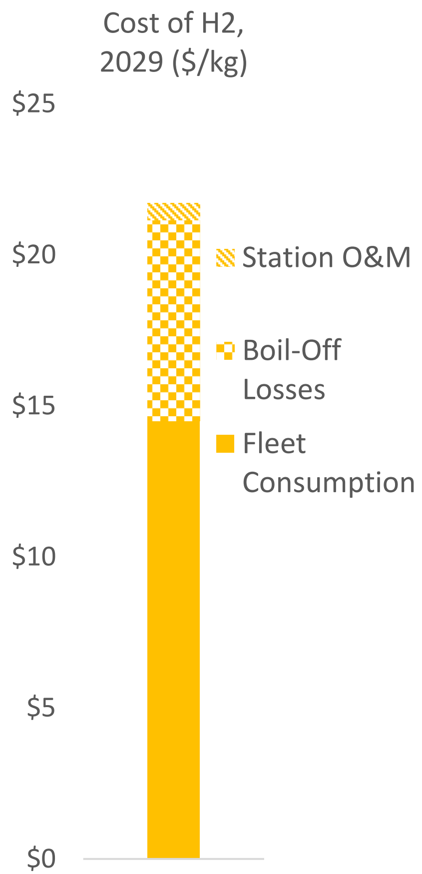
The line chart at the beginning of this Section shows a near-term operating deficit for HTA as a result of ZEB transition (estimated to be 31% in 2029). A significant spike in operating costs occurs immediately after delivery of ten FCEBs occurs in 2025/2026, driven primarily by increased fuel costs. The operating deficit continues to widen largely in accordance with HTA's transition to FCEBs and the resulting increase in fuel costs necessary to operating the growing fleet.

The chart on the right illustrates the key contributing factors to the net operating deficit in 2029 ($3.1M, or $2.5M more than the no-transition counterfactual), with fuel contributing 96% of the difference between the scenarios (i.e., with and without the transition, as shown in the chart to the right), and the rest from station O&M, other transition costs, and electric charging.

Contributions to Financial Impact of Transition, 2029 ('000 USD)



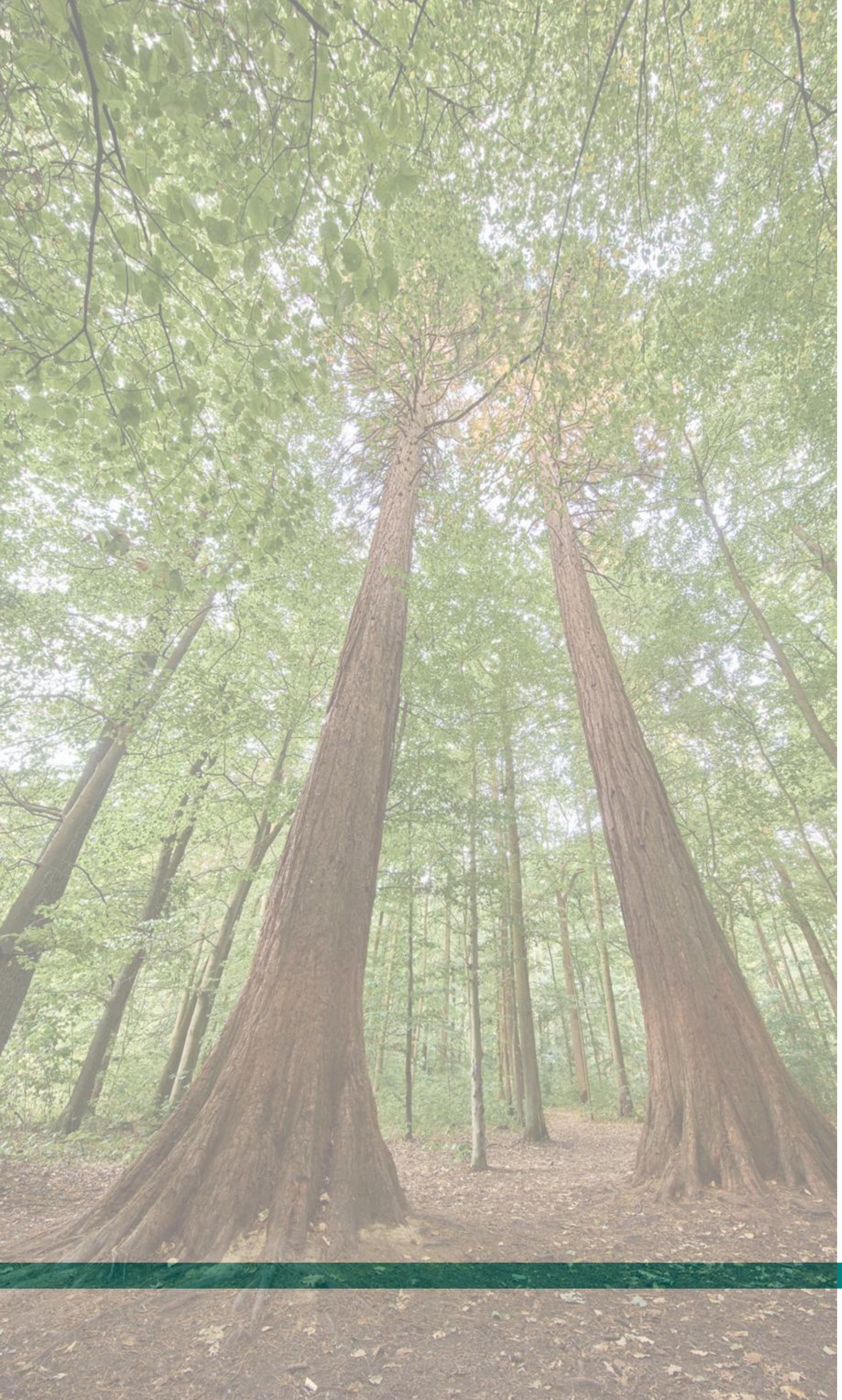
Part 2 (Base Case with ZEB transition): HTA's distribution of expenditures



The calculated "all-in" cost of hydrogen in 2029 (~$22/kg) is over 5x higher than the "all-in" cost of diesel fuel, which is just the contracted price of diesel (~$4/gal).* Given the outsized importance of fuel costs on the Base Case operating costs for HTA, another useful lens for understanding the financial impact of FCEB transition is to compare the current diesel fuel cost for full size transit buses with the "all-in" cost of hydrogen fuel. When HTA's "all-in" cost per kg of hydrogen approaches parity with the cost per kg of diesel, then the largest challenge to the business case for FCEB transition will be mitigated (although other incremental costs and risks remain). The primary driver of the "all-in" hydrogen cost is the contracted hydrogen fuel price, which is also highly uncertain (and therefore one of the key sensitivities examined in Section 4). The "all-in" cost of hydrogen fuel factors in:

- The contracted H_2 per kg price for fuel used by HTA's FCEB fleet (including delivery costs);
- The effect of evaporative losses (known as 'boil off'), expressed as a $/kg amount; this is a conservative estimate, as it does not include other fueling-related losses. As a result of boil off, HTA will need to purchase more fuel than will be consumed by the FCEB fleet; and
- The entirely new cost of station O&M expressed as a $/kg amount. Parallel costs for diesel fueling are negligible and therefore are not factored in. Please note that when fuel and O&M are provided by the same contractor, costs associated with fuel and with O&M may be somewhat interchangeable; costs shown in the chart may not be strictly attributable to the costs of fuel versus O&M.

**Note that 1kg of hydrogen fuel contains roughly the same amount of energy as 1 gallon of diesel fuel.*
Source: https://afdc.energy.gov/fuels/properties



Part 3: Sensitivities and Scenarios

Part 3 of this business case analysis helps us better understand the key drivers of the financial calculations by isolating and varying certain inputs and assumptions.

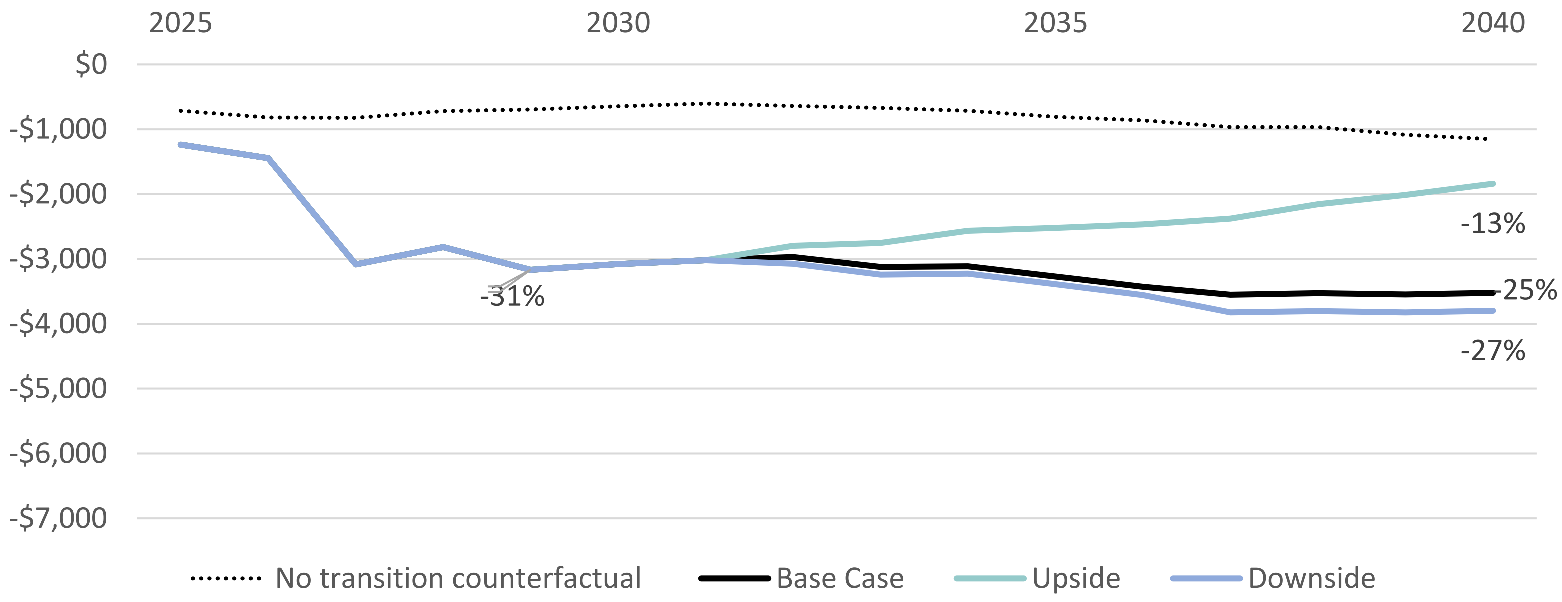
In this report, sensitivity analysis, refers to an examination of changes to HTA's financials resulting from changing individual inputs/assumptions. For each sensitivity, an "upside" and "downside" input are compared with the Base Case input, with respect to HTA's long-term budget picture.

Whereas for scenario analysis, this refers to an examination of changes to HTA's financials resulting from changing multiple inputs/assumptions simultaneously, which when taken together represent specific hypothetical scenarios that are designed to provide additional insight when modelled.

Sensitivity and scenario analysis are critical tools in helping implementers and policymakers understand what (combinations of) policy and programmatic solutions could meaningfully improve the FCEB deployment business case.

Sensitivity analysis: Hydrogen cost

The business case results are highly sensitive to changes in the cost of hydrogen fuel. In 2040, depending on the path that fuel prices take, the operating budget could vary by over $2M, with as little as a 13% shortfall or as much as a 27% shortfall. Given the selected likely optimistically low Base Case cost inputs and current market intelligence, the upside scenario of 5% cost decreases per year looks challenging to achieve. Both market dynamics and interventions related to hydrogen costs will have the greatest impact on the modeled business case.



INPUTS

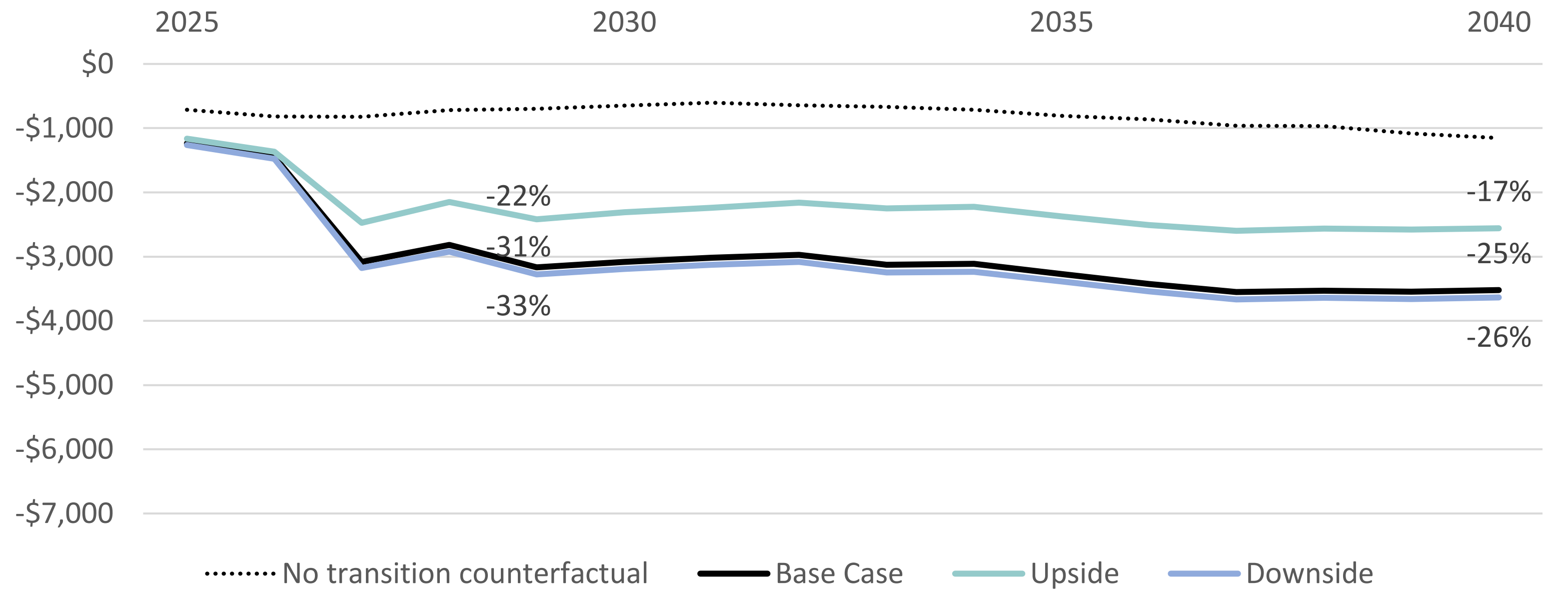
- **Base case:** $14.5 /kg start; Flat in nominal terms
- **Upside:** $14.5/kg start; Rapid decrease of 5%/year, capped at $5/kg
- **Downside:** $14.5/kg start; escalating at less than inflation (3% every 5 years)

RESULTS

- **Base case:** 25% gap in total operating budget (2040)
- **Upside:** 13% gap in total operating budget (2040)
- **Downside:** 27% gap in total operating budget (2040)

Sensitivity analysis: LCFS revenue

The business case results are not highly sensitive to LCFS-related variables, except in extreme upside scenarios. In 2040, there is only a very small difference between the Base Case and the downside scenario (i.e., no LCFS revenues). If very low carbon intensity hydrogen were available without increasing prices and credit prices sustained at their all-time high – a scenario that does not appear likely today – LCFS revenues would be close to as impactful as the upside hydrogen cost scenario (see previous). Impacts from LCFS revenue decline in the long term as the program's standards raise over time, as designed.



INPUTS

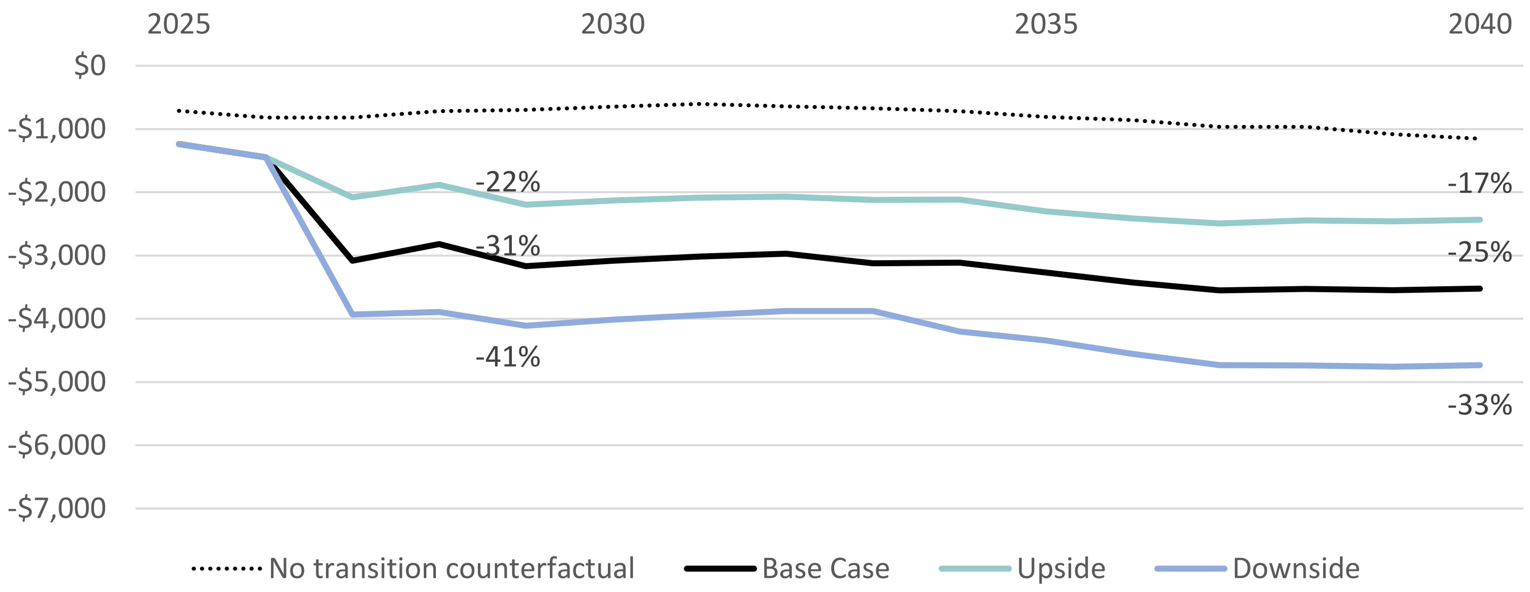
- **Base case:** $56/credit, CI value 100
- **Upside:** $200/credit, CI value 10.5
- **Downside:** $0/credit (no LCFS)

RESULTS

- **Base case:** 25% gap in total operating budget (2040)
- **Upside:** 17% gap in total operating budget (2040)
- **Downside:** 26% gap in total operating budget (2040)

Sensitivity analysis: Boil off

The business case results depend meaningfully on the level of actual boil off. In 2040, in the Base Case, approximately 24% of purchased hydrogen is lost to boil off; if boil off is twice the expected 7.5% rate, then 41% of purchased fuel would be lost. Note that a technological advancement and/or significantly higher capital costs for the refueling station would be required to achieve the upside scenario of eliminating boil off, making the upside again an aspirational upper bound. Despite the seemingly small impacts of boil off, because the daily percentages lost to boil off can be so meaningful, this factor leads to millions of dollars of excess fuel costs in any given year in the modeled business case.



INPUTS

- **Base case:** 7.5% boil off/day
- **Upside:** 0% boil off/day
- **Downside:** 15% boil off/day

Note: No sensitivity accounts for other fueling-related evaporative losses, making all model runs optimistic.

RESULTS

- **Base case:** 25% gap in total operating budget (2040)
- **Upside:** 17% gap in total operating budget (2040)
- **Downside:** 33% gap in total operating budget (2040)

Scenario analysis as a policymaking tool

The results and sensitivity analysis show that the business case for FCEB deployment has multiple important drivers, each of which can be associated with multiple different policy tools and mitigants These contributing factors to HTA's business case will change over time, and there are probabilities associated with these various potential future outcomes.

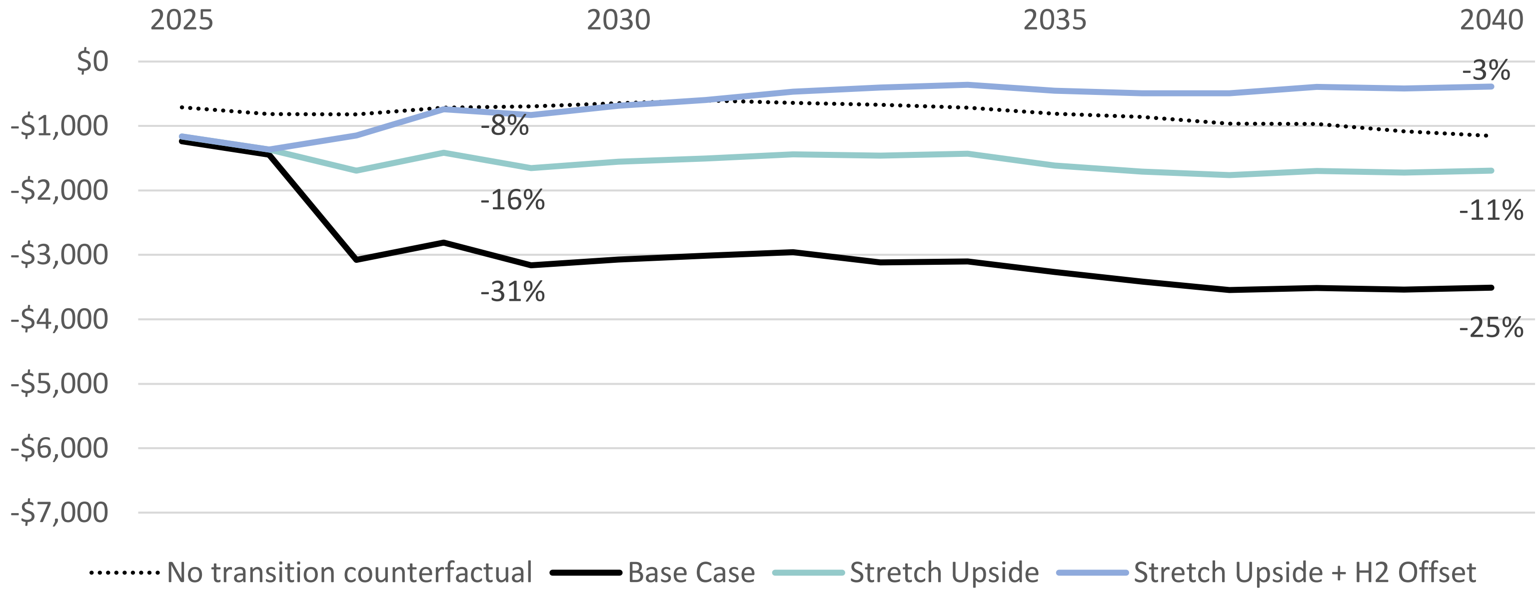
While the analysis does not attempt to quantitatively assign probabilities to assumptions, it is qualitatively evident that a positive business case will require positive future outcomes across multiple factors which are not directly correlated, reducing the overall probability of that positive result (i.e., it is probabilistically unlikely to win a coin toss many times in a row).

In other words, the observation that multiple things will need to move in the right direction to achieve parity or breakeven with diesel is an important observation for policymakers to take into account, as it lends itself to a multi-pronged approach for business case interventions. It makes sense to address as many of these factors as possible, as these interventions will succeed to varying degrees.

In the scenario analysis on the following two pages, it is shown that even when eliminating some of these key business case challenges (either through successful policy interventions or the evolution of the market on its own), the business case shows a "gap" that may need to be addressed to support HTA’s success in meeting ICT requirements, maintain financial sustainability and provide critical transit services to the community.

Scenario analysis: "Stretch upside" scenario, with H2 price offset to reach parity with counterfactual

Combining all previous upside sensitivities simultaneously comes close to closing the business case gap; but an additional $5.50 price offset per kg of fuel would still be required to close the short-term gap with the no transition counterfactual. However, achieving all these optimistic upsides simultaneously is highly unlikely, probabilistically. From a policy intervention perspective, this scenario therefore shows that an "all of the above" approach that stacks many different business case improvements would be both practical and most effective. It also shows that the price offset is mostly needed in the short term, and could potentially be reduced or phased out in later years if other business case improvements are achieved.



INPUTS

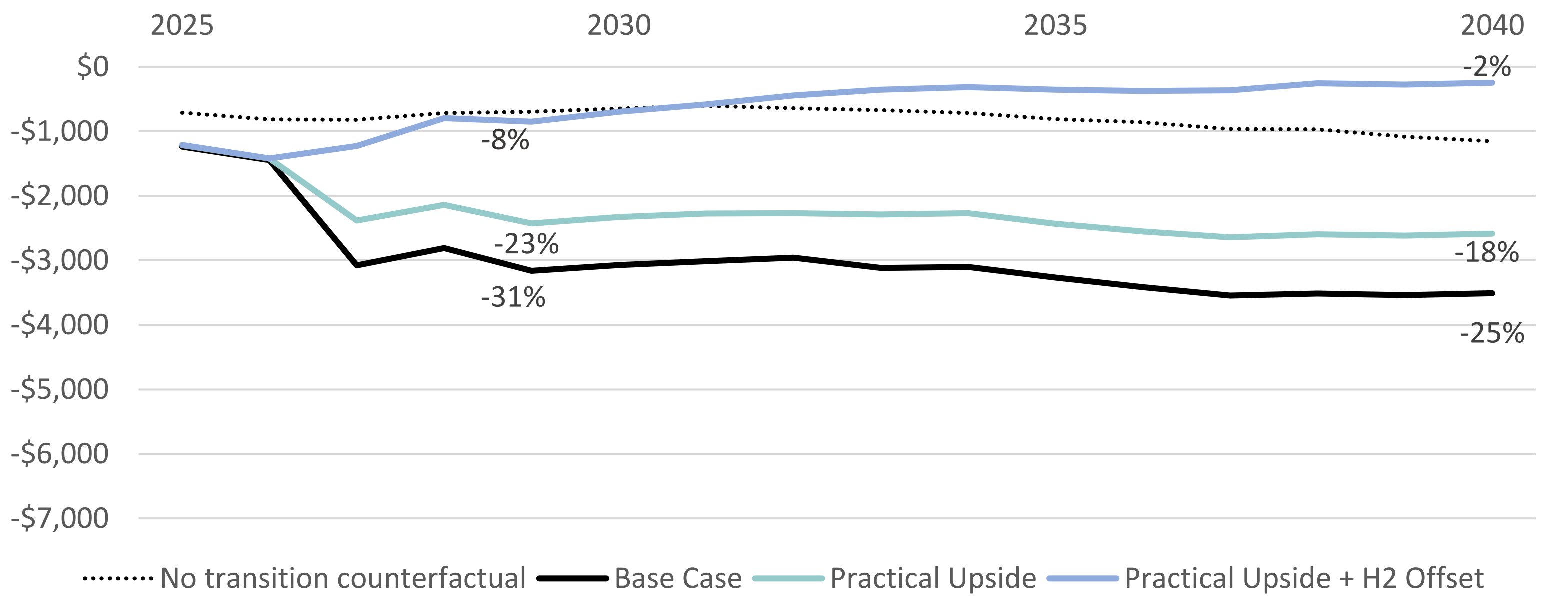
- **Green hydrogen available at Base Case prices (10.5 CI, $14.5/kg to start)**
- **$200/ LCFS credit**
- **0% boil off**
- **$5.50/kg H_2 price offset**

RESULTS

- **Base case:** 25% gap in total operating budget (2040)
- **Stretch Upside:** 11% gap in total operating budget (2040)
- **Stretch Upside + H_2 Offset:** 3% gap in total operating budget (2040)

Scenario analysis: "Practical upside" scenario, with H2 price offset to reach parity with counterfactual

Taking a more practical view of the upside scenario still leaves a meaningful business case gap; an additional $8.50 offset per kg of fuel is required to close the near-term gap with the no transition counterfactual. Once again, this scenario shows that an "all of the above" policy approach that stacks many different business case improvements is ideal, though it also highlights the primary importance of addressing H2 prices for a sustainable business case. Like the "stretch upside" case, this scenario also shows that a price offset of this level is only required in the near term for price parity.



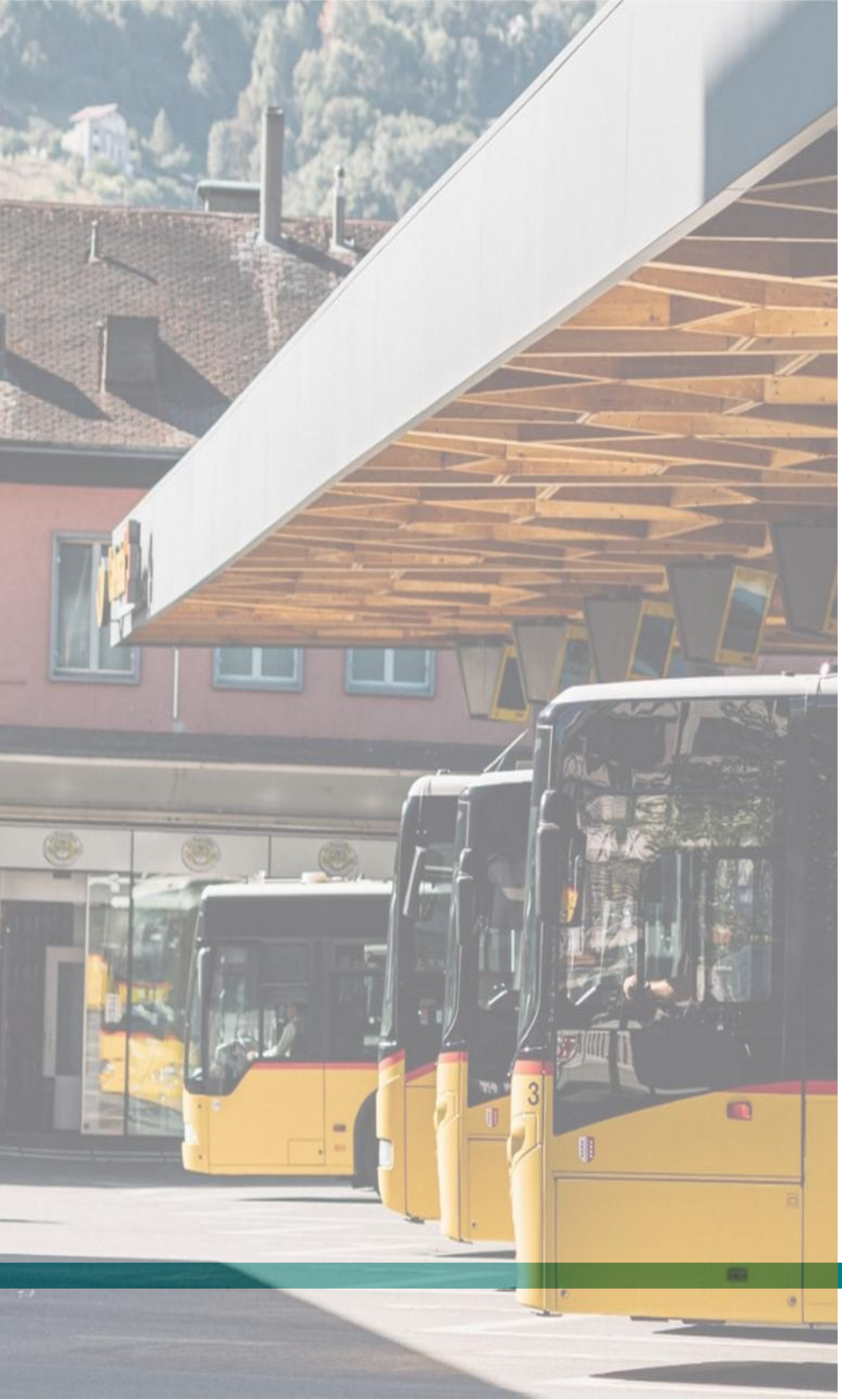
INPUTS

- **Green hydrogen available at Base Case prices (10.5 CI, $14.50/kg start)**
- **$100/ LCFS credit**
- **4% boil off**
- **$8.50/kg H2 price offset**

RESULTS

- **Base case:** 25% gap in total operating budget (2040)
- **Practical Upside:** 18% gap in total operating budget (2040)
- **Practical Upside + H_2 Offset:** 2% gap in total operating budget (2040)

Section 4:
Analysis of Market Factors



Overview

A crucial complement to the quantitative business case financial analysis summarized in the previous Section is a qualitative evaluation on the market for FCEBs, supporting infrastructure, and hydrogen fuel. By examining the market structure, the business case considerations for various types of players in the market, and their capabilities and preferences with respect to transit FCEB projects, it is clearer what levers transit agencies and state policymakers might pull to improve the economics of FCEB deployment in the short, medium and long term.

Engagement with the market illustrates that most critical contributing factors to the current business case will take time to address and will be impacted by ongoing statewide and national market development strategies. While some cost containment and risk mitigation strategies can be implemented at the individual project level, the most impactful strategies are likely to be the larger initiatives to lower the costs of hydrogen fuel and station operating and maintenance costs.

The findings outlined in this section help illustrate the different types of vendors and business models in this ecosystem, practical suggestions for transit agencies developing a hydrogen refueling station project, and key underlying business case drivers and prospects for reducing costs.

Market Engagement for Business Case Study

The HTA Case Study presented a unique opportunity to seek market feedback on specific elements of HTA's project, benefitting both HTA's specific procurement and also California's broader understanding of FCEB market dynamics.

As part of this engagement, the project team interviewed the four shortlisted bidders that participated in HTA's hydrogen refueling station Design-Build RFP. HTA's procurement was initially rebid since HTA only received one response and could not determine that pricing was fair and reasonable. Before launching the rebid RFP, the project team engaged the shortlisted bidders to help HTA determine potential changes to HTA's procurement that would help create a level playing field to encourage competition and a robust bidder response (and therefore lower bid prices). This was an excellent opportunity to build more dialogue into the procurement process, and to determine potential optimizations to the project as well as changes to terms and conditions that would be acceptable to bidders while still protecting HTA's key interests.

These discussions, along with information from the ZEB Market Sounding commissioned by Caltrans, and a recent Request for Information (RFI) solicited by the Redding Area Bus Authority (RABA), helped to form the basis of this qualitative analysis.

Scenario analysis as a policymaking tool

A variety of types of companies are currently responding to transit FCEB infrastructure and fuel supply RFPs in California. Some are focused first and foremost on selling hydrogen molecules – and using their refueling equipment sales and refueling station development businesses primarily to that end – always bundled with a fuel supply contract. Others are not in the fuel business at all and are less interested and/or capable in the full refueling station design-build scope, but instead simply want to sell equipment. Some are not so neatly categorized.

One challenge that transit agencies face in this nascent industry is that it can be difficult to evaluate different proposed solutions and contract terms from companies with different business models and core competencies. A practical suggestion for agencies is to seek to cast a wide net during the solicitation, but to recognize and account for this varied market structure when crafting RFP requirements and evaluation criteria to encourage bids from all qualified vendors.

It is also important to note that not all vendors are willing or able to provide operations and maintenance in remote areas despite general excitement about working with transit on these projects, in a growing market. There is no easy "fix“ for this issue, but creating scale with projects whenever possible can help to encourage OEM local presence.

Photo: Courtesy Victor Valley Transit Authority

FCEB Project Scope (1/3)

Fuel Supply: A key question for transit agencies structuring their FCEB deployment projects is whether and how to bundle project scope components when procuring. Vendors interviewed for this project were split on the key question of whether fuel supply should be bundled with refueling station infrastructure. On one side, vendors commented that fuel supply is not in their core area of expertise (i.e., not their core business), and HTA could access a bigger market and more competition if fuel supply would be separated. On the other hand, vendors commented that incorporation would avoid a second markup on fuel prices, and they know that a single point of contact is likely easier for a transit agency to manage.

A unique element of HTA's initial procurement was a requirement that the vendor match the eventual pricing set by the California Department of General Services (DGS) in its procurement for hydrogen fuel. Vendors generally opposed this requirement by citing the significant challenge of managing this risk being transferred to them, given the large number of variables determining fuel price, the unknowns about the structure of the forthcoming statewide contract, and the challenges in potentially needing to shift to a different fuel supply partner. One vendor mentioned that this was a particularly difficult ask given HTA's location, as opposed to a geography where fuel supply is more abundant, and the market is more competitive. HTA ended up listening to market feedback and removing this requirement from the RFP in the second version.

FCEB Project Scope (2/3)

Shared Infrastructure: Another critical scoping question for transit agencies is whether and how to include shared infrastructure components for any customers or fleets besides the transit agency itself. HTA had initially required bidders to propose and price a mandatory "add-alternate" scope element for "over-the-fence" light-duty (LD) and medium-duty (MD) vehicle fueling. LD/MD fueling occurs at a different fueling pressure, requiring different equipment (H70 dispensers) than transit vehicles (which use H35 dispensers). The initial RFP also required bidders to propose and price "make-ready" components in the station's design, engineering and construction that "allow for the seamless integration of a future H70 MD/HD fueling system" if HTA does not decide to build the LD/MD refueling component right away.

Vendors mostly viewed the idea of "future-proofing" the station with "make-ready" investments as a significant challenge, feeling that the H70 component should be either removed from the scope entirely or included in the base scope rather than as an add-alternate (although one vendor liked HTA's initial approach). The market expressed skepticism about investing heavily in shared "over-the-fence" infrastructure due to the highly uncertain revenue potential and likely future technological change. While HTA agreed with the market view that inclusion of the H70 component is likely a net negative contributor to the business case, HTA remained committed to serving as a mobility hub and catalyst for the local hydrogen economy (having included such elements in its TIRCP application) and elected to move the H70 piece to the base scope in the RFP's second version.

FCEB Project Scope (3/3)

Temporary Fueling: Many transit agencies that are pursuing a hydrogen refueling station project also require a temporary fueling solution to accommodate their initial fleet of FCEBs before construction is complete, since there is such great timing uncertainty with both bus delivery and station construction. In its initial RFP, HTA required the station design-builder to also provide a temporary fueler capable of meeting HTA's anticipated needs for pilot bus testing. However, in its revised procurement strategy, HTA decided to remove the temporary fueler from the station design-build scope and launch a separate RFP solely for the temporary fueler scope.

During the interviews for this project, HTA's shortlisted bidders offered mixed and inconclusive feedback on the decision to bundle or separate these scope elements but generally leaned more towards separation. The main reasoning cited to keep these scope elements separate revolved around the relatively limited technology options available and the added complexity for the design-build contractor to execute this additional scope element. While at least two vendors expressed a willingness to deliver this element as part of the design-build scope, they preferred to see the RFP scope without it.

Despite HTA's strategy to procure the permanent and temporary fueling stations separately, HTA ultimately selected the same vendor to deliver these elements, based on the bids that were received and HTA's determination of best value.

Project Structure: Risk Allocation

Risk allocation was a major theme of the conversations with the shortlisted bidders, as HTA sought to optimize its procurement by better assigning risks to the party (or parties) best suited to control or manage those risks to hopefully improve the number and quality of bids for its design-build RFP. The inclusion of **responsibility for certain scope elements** being assigned to the contractor was part of that discussion, as outlined above. In addition to the HTA's initial approach to the inclusion of fuel supply, shared infrastructure, and temporary fueling, bidders noted several other custom scope components or requirements that added complexity and risk, including **coordination with the utility** for the station's power needs and **demolition of existing structures** on HTA's lot. In its revised RFP, HTA softened risk transfer to the design-builder with respect to utility costs and timelines and removed the largest demolition element from the scope. These changes came in response to market feedback that HTA was in better position to manage these risks and by retaining them, would thereby avoid an expensive risk premium built into the bidders' pricing.

The other key risk allocation issue was on **operations and maintenance "uptime" and responsiveness**. Vendors expressed serious concerns about their ability to provide responsive, fast support in HTA's remote location. These firms specifically mentioned the need for fast response times and the need to have staff nearby for frequent small maintenance activities. These firms preferred that O&M be procured separately from the design-build. One firm also expressed a view that maintenance issues, parts availability and lead times, and equipment performance may lead HTA to want to build in redundancy to help achieve a certain level of reliability.

Underlying Business Case Drivers

These conversations helped illuminate the market's view on some of the underlying drivers of the business case for FCEB deployment, particularly in an area like the NSSR. Note that given HTA's primary concern, these observations focus on operating costs rather than capital costs. Business case drivers can be summarized as follows:

Fuel Costs

- Local demand for liquid fuel exceeds local supply
- Economics of liquid fuel production/distribution: Hydrogen is a nascent technology, with small and uncertain order volumes, and high capital costs for production facilities
- Pricing dynamics for small and rural agencies: Product is still not a commodity within a competitive marketplace, agencies lack negotiation power, small scale stations are economically inefficient, transportation costs are high, and carbon intensity requirements can add to costs

Other O&M Costs

- Labor costs: FCEB infrastructure requires constant monitoring, agencies lack in-house expertise for FCEB operations and maintenance, need for local OEM presence to respond quickly to outages, proprietary technology and complexity may require external professional involvement
- Operating needs: New processes complicate planning and increase insurance premiums, more contract management required, new training and software upgrades
- Risk management: Novel and higher risks around technological performance and safety (e.g., fire safety)

Section 5:
Risk Analysis

Risk Analysis

The business case study also analyzed some of the key uncertainties and risks relevant to HTA's transition, which are mostly factored in qualitatively or examined through sensitivity analysis.

These dynamics, and potential mitigants, are important for transit agency FCEB adopters to consider and will impact the outcomes of the transition, however not all risks can be quantified in the financial analysis.

Risk Analysis (1/5)

Funding Availability: The analysis assumes that existing sources of operating support for HTA will continue, and that SB125 will be replaced with a successor program. In reality, this is not a given and depends on funding levels and allocations of federal and state programs. The focus of the analysis is not to do a detailed examination of the funding landscape, but rather to look at the impact of FCEB transition on HTA's long-term budget picture (given a baseline funding landscape). As part of the scenario analysis, the study examines the impact on the business case if a new source of operating support were provided to the project.

Cost Escalation: As mentioned above, the principal driver of the business case is the contracted price of hydrogen fuel which is highly uncertain. Hydrogen prices are expected to fall in the long term: Several federal and state programs are underway to bring down the cost of hydrogen fuel, but the timing and magnitude of their impact are unknown. Despite the investment to bring down hydrogen prices, there remains a possibility that hydrogen prices remain stagnant or increase. The Base Case analysis assumes a contracted hydrogen price starting at $14.50/kg, and the sensitivity analysis in Section 3 shows how the Base Case changes under several different profiles of hydrogen price evolution over the forecast horizon.

Risk Analysis (2/5)

Technology Performance: FCEBs and hydrogen fueling infrastructure is still a relatively nascent technology and the early track record of FCEBs and fueling infrastructure shows that the reliability remains an issue (it should be noted that the same observation is made of BEBs and charging infrastructure). For a transit agency that is operating ZEBs as only a small portion of the overall fleet, these issues may not impact transit service, but as the transition expands to encompass the entire fleet, the ability to minimize and quickly remediate downtime of vehicles and infrastructure becomes critical to maintaining transit service quality. For small and rural transit agencies like HTA, the risk of technology performance is magnified due to their remote location and unwillingness of OEMs to commit significant technician resources to the region. This means that when FCEBs or hydrogen refueling infrastructure fails, response times are likely to be slower and outages more impactful. This risk is partially addressed in the financial analysis through the category of other "soft" transition costs, which is meant to capture additional staff time to deal with unforeseen technology issues and troubleshoot problems that will inevitably arise with the new technology. This risk is also baked into the FCEB vehicle maintenance and station O&M cost assumptions.

Risk Analysis (3/5)

Technology Obsolescence: Another risk stemming from the nascency of the FCEB technology is that new products, processes, and standards will emerge making past investments obsolete. While positive for the industry at large, this could pose a challenge for individual transit agencies like HTA that have made investments into "legacy" FCEB technology. The financial model does not directly quantify this risk.

Hydrogen Refueling Station Delays: Similar to any other infrastructure project, a hydrogen refueling station design-build project faces the risk of construction delays, which could be caused by myriad factors. While most of the specific causes of construction delay risk can be transferred to a Contractor through a design-build contract, with financial penalties for the Contractor delivering behind schedule, HTA is still ultimately reliant on the station to be fully commissioned and operational once it has 11 FCEBs in its fleet. If HTA's permanent station is significantly delayed, it will put significant pressure on its operations leveraging a temporary fueling solution (note that HTA must be able to regularly fuel and run the FCEBs to avoid voiding warranties). The financial model does not quantify this risk.

Risk Analysis (4/5)

Fuel Delivery Stoppages / Shortages: Shortages of liquid hydrogen fuel are currently occurring across California and the wider Western US region, driven largely by a dearth of sources of supply and, for California, the state's requirement for 33% renewable content. Beyond the broader underlying challenges with hydrogen fuel supply and distribution, remote rural agencies like HTA face an added degree of risk that road closures (driven by increasing extreme weather events) prevent local distribution for extended periods. The relatively long distances to distribute the fuel from the nearest sources of production to HTA's hydrogen refueling station also significantly increases the cost of the fuel, which is how this risk is quantified in the financial model.

Commercial Availability of Other FCEVs: HTA's transition plan depends on fuel cell electric vehicles -- motorcoaches and cutaways -- that are not commercially available today being available in the medium term. If such vehicles do not become commercially available, it may require HTA to perpetually operate a mixed fleet, necessitating further investments in battery electric charging and utility grid updates, which carries its own set of cost and delay risks. This is not quantified in the financial model.

Risk Analysis (5/5)

Safety and Staff Training: Operating and maintaining a FCEB fleet safely and efficiently requires specialized staff training, which HTA will also need to invest in upfront and on an ongoing basis. There is always a risk of a safety event on any bus yard for a fleet with any technology, but hydrogen has unique properties that require unique safety training. These costs are factored into the "other" soft transition costs in the financial model.

Section 6: Conclusion

Takeaways for Transit Practitioners

By way of a case study and business case analysis approach, this report outlines several practical conclusions and recommendations which other prospective FCEB adopters can learn from and incorporate into their strategic planning. After having reviewed this report, practitioners should have hopefully gained relevant knowledge on how to perform a similar analysis for their own project, how to think about structuring a procurement for a hydrogen refueling station and hydrogen fuel supply, and how to apply various strategies for mitigating and managing project risks. Key takeaways from the report include:

- Transit agencies deploying FCEBs in the near term should expect an increase in operating costs, driven primarily by the higher cost of fuel and new cost of operating and maintaining a hydrogen refueling station; existing and new sources of operating revenue (e.g., LCFS) are unlikely to be sufficient on their own to make up the difference, and any business case examination must factor in a high degree of uncertainty for all these variables.
- More rural and remote projects face additional challenges caused by high fuel transportation costs and market inability to provide strong reliability guarantees until the regional market develops.
- A regional network could help achieve economies of scale needed to bring down operating costs and improve infrastructure resiliency, but first movers in a region must be prepared to bridge the gap on their own until regional benefits materialize.
- The market is nascent and developing quickly, thus it is critical for prospective FCEB deployers to engage the market and to be informed customers, with a strong grasp on the different types of market players, their business case considerations, and their willingness to accept certain contractual terms and conditions.

Acknowledgements

We would like to express our massive gratitude to the whole HTA team for putting their FCEB project in the spotlight and allowing other FCEB deployers to learn from their experience. This report could not have been developed without the unwavering support and collaboration from Greg Pratt, Jerome Qiriazi, Katie Collender, and Jim Wilson. We would also like to share our sincere appreciation for all the members of the GO-Biz Interagency Working Group for guiding this report across the finish line, including representatives from the California State Transportation Agency (CalSTA), California Department of Transportation (Caltrans), California Air Resources Board (CARB), California Energy Commission (CEC), California Public Utilities Commission (CPUC), California Transportation Commission (CTC), California Association of Coordinated Transportation (CALACT), and California Transit Association (CTA). Additionally, we are grateful for the valuable input from all the representatives from the North State Super Region Transit Working Group who participated in discussions about this project. Another special thank you goes to Orange County Transit Authority and Victor Valley Transit Authority for their contributions to this effort and to the rest of the industry as early FCEB adopters.

Contact Information

For any inquiries regarding this report, please contact:

Zachary Karson, RebelGroup
Zachary.Karson@rebelgroup.com

Leah Foecke, RebelGroup
Leah.Foecke@rebelgroup.com

Business Case Model as Available Resource

The project team is making the business case financial model available as an open-source resource for other agencies to do their own business case analysis. While the model is not intended as a one-size-fits-all tool that allows other transit agencies to easily plug and play their own financial and operational information to view ZEB transition projections, it provides a robust starting point for recycling and tailoring the model to fit an agency's unique situation

The financial model is being developed in accordance with the FAST (Flexible / Appropriate / Structured / Transparent) standard which enables other stakeholders to easily review and update model inputs and assumptions. The modeling approach also allows dynamic updates to scenario and sensitivity analyses, as demonstrated by the analysis outlined in Section 4.