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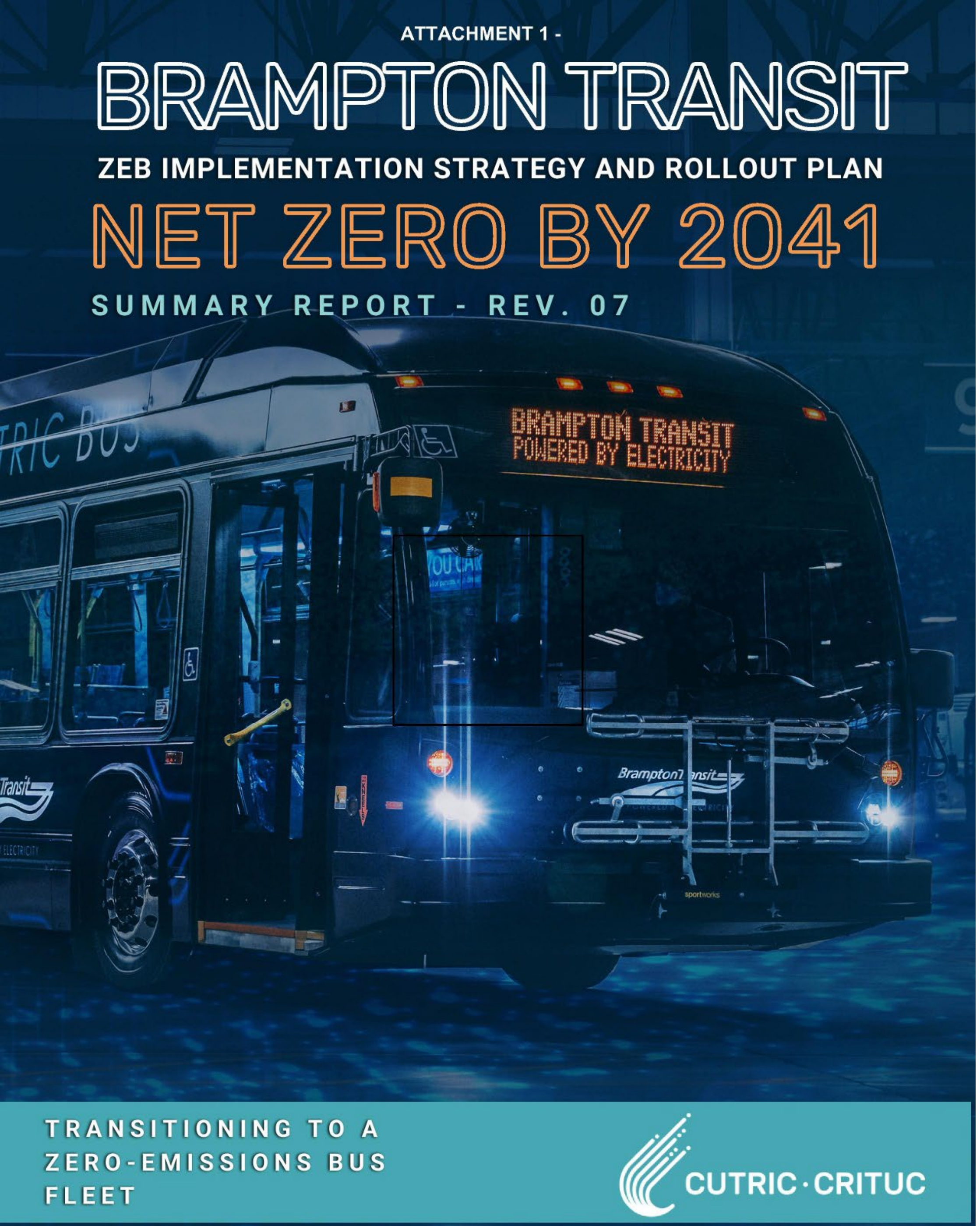
Zero Emission Bus Strategy

Committee of Council

Ivana Tomas, Transit
Dr. Josipa Petrunić, CUTRIC

April 24, 2024

BRAMPTON



The Journey

- Brampton City Council declared a climate emergency
- Community Energy & Emissions Reduction Plan
- Phase 1 BEB Trial (CUTRIC) + studies
- Secured CIB Financing
- Advocating for 3rd Facility Electrification
- More BEBs

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Zero Emission Bus Strategy

- Path to transition
- In-depth analysis
- Phased approach
- Funding and approvals

CUTRIC ZEB Consulting Services

Brampton Transit ZEB Implementation Strategy and Rollout Plan

Dr. Roberto Sardenberg, Senior Scientist and IP Development Lead

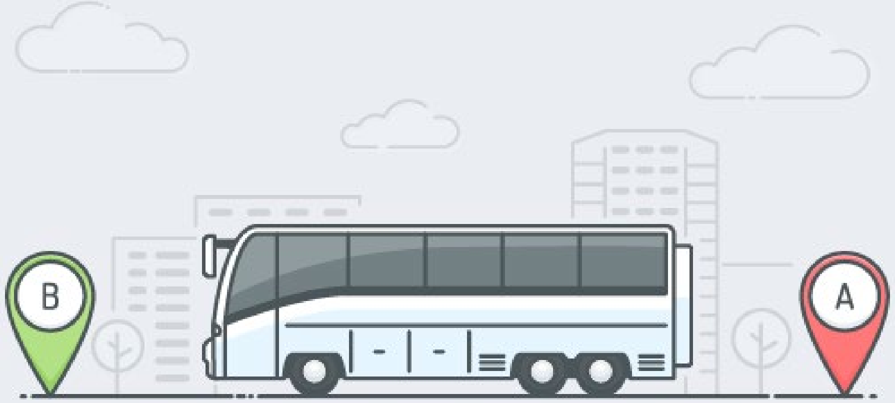
Mr. Ryan Welfle, Zero-Emission Bus Transportation Planner and Developer

Ms. Alexis Dunphy, Project Manager, Sustainable Transit Initiatives

Ms. Melissa Heynes, National Marketing and Communications Manager

Dr. Josipa Petrunić, President & CEO

April 24, 2024



Agenda

1

Study summary

1 Study summary

Study covered

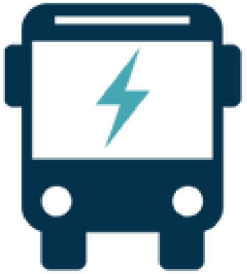
- Energy analysis
- Facilities assessments
- Social analysis
- Real estate assessment
- Total cost of ownership
- Economic analysis
- Environmental lifecycle analysis
- 18 and 15 year life cycle of ZEBs

2

Modelling results summary

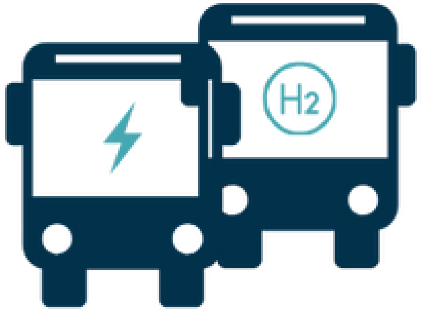
2 Modelling results summary

Scenarios modelled



Scenario One
Full BEB solution

Scenario Two
Full FCEB solution



Scenario Three
Mixed green fleet solution

2 Modelling results summary

Conclusions: Scenario One (full BEB solution)

	Base case	With DFAH	With electric heater
Current Fleet	476	590	633
Growth fleet	938	1161	1240

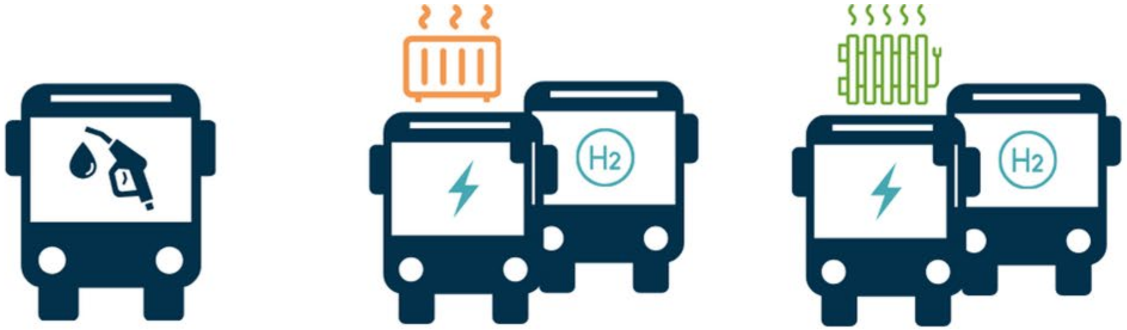
2 Modelling results summary

Conclusions: Scenario Two (full FCEB solution)

	Base case	Scenario Two (FCEB)
Current Fleet	476	720
Growth fleet	938	1418

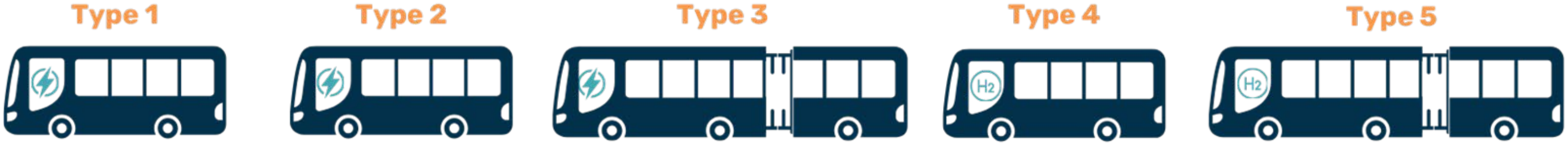
2 Modelling results summary

Conclusions: Scenario Three (mixed green fleet solution)



	Base case	With DFAH	With electric heater
Current Fleet	476	575	602
Growth fleet	938	1,132	1,185

2 Modelling results summary



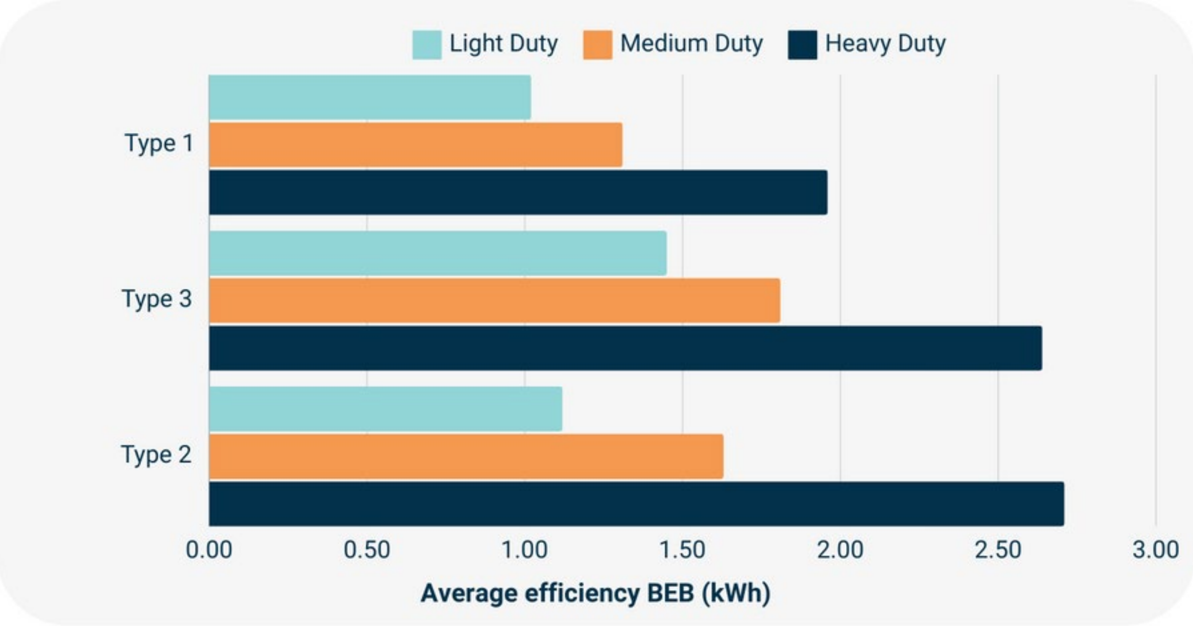
12m BEB (Type 1)
Electric Heater: 400+ kWh
DFAH: 500+ kWH

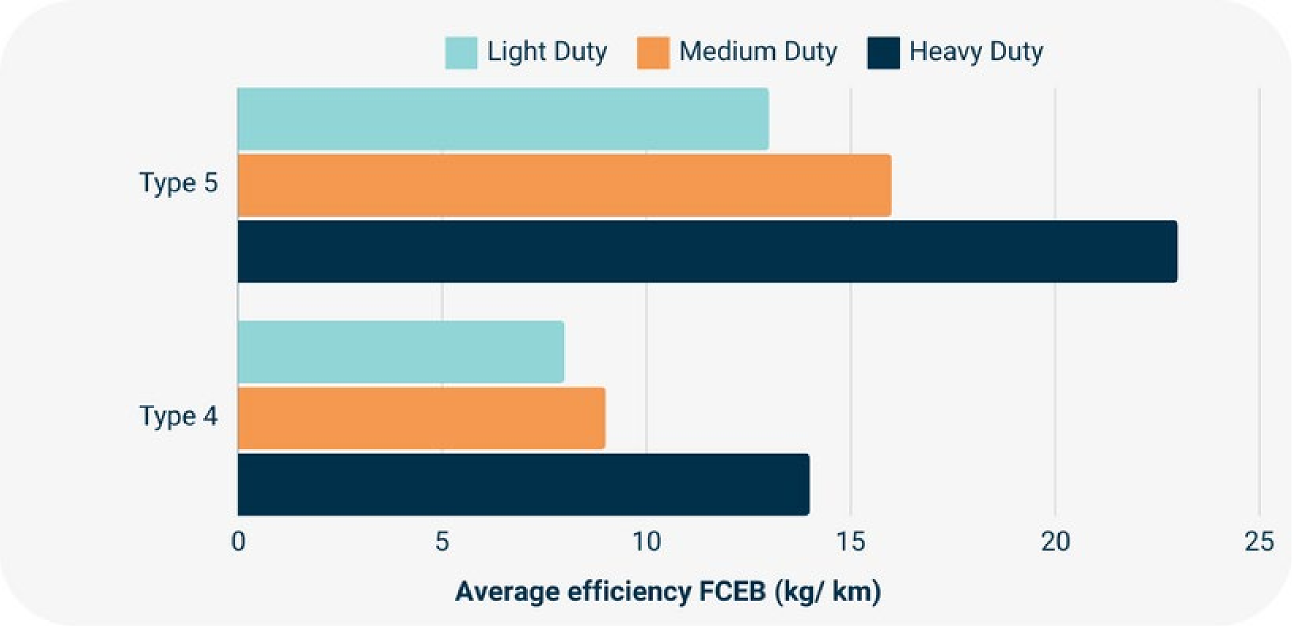
12m BEB (Type 2)
Electric Heater: 500+ kWh
DFAH: 500+ kWH

18m BEB (Type 3)
Electric Heater: 500+ kWh
DFAH: 600+ kWH

12m FCEB (Type 4)
Electric Heater: 30+ kg

18m FCEB (Type 5)
Electric Heater: 50+ kg





2 Modelling results summary

Supplemental heating

Heating can come directly from the battery (electric heating) or, from Diesel Fired Auxiliary Heaters (DFAH)

Canadian agencies using Diesel Fired Auxiliary Heaters:

2 Modelling results summary

Supplemental heating

32% longer range (during winter)

1% less service hours

2% less cost than with DFAH

0% tailpipe emissions

5% fewer vehicles

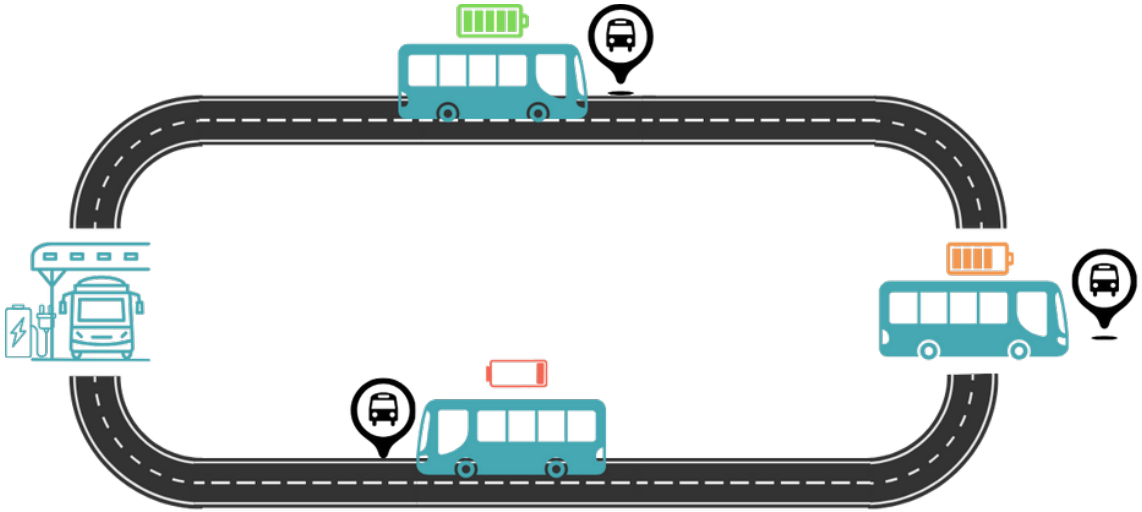
0.1% more life cycle emissions

3

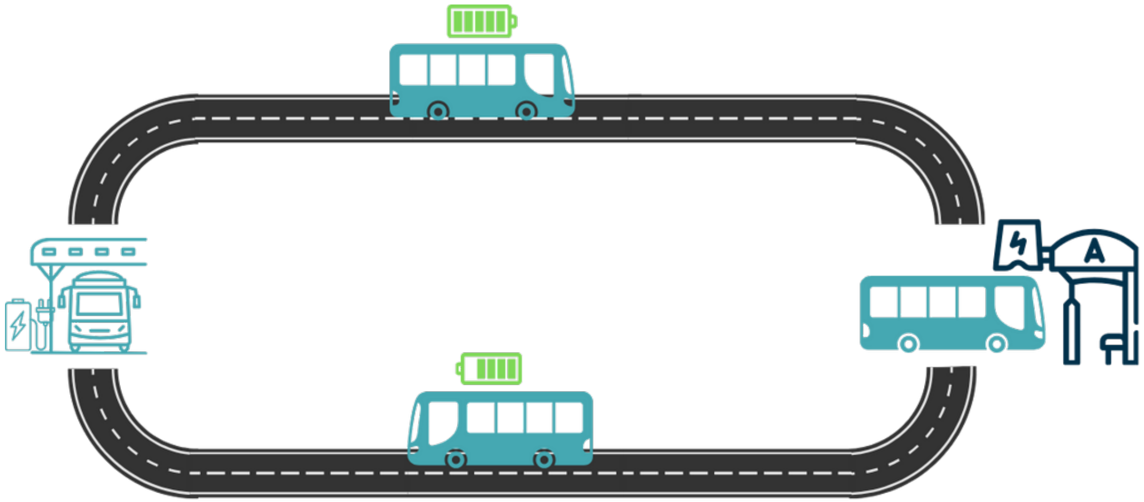
Charging Strategies

3 Charging Strategies

Charging Strategy One: Depot Only

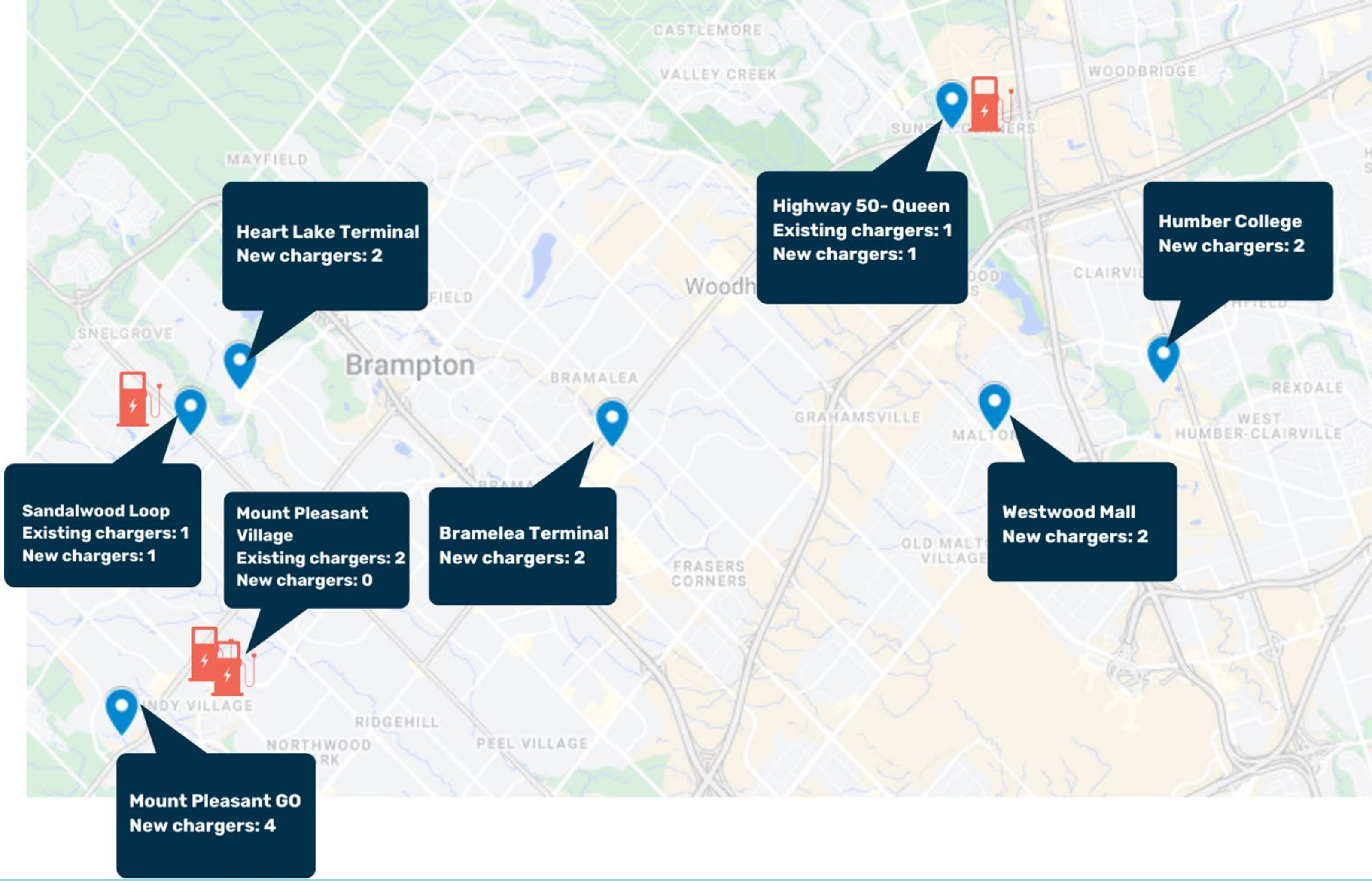


Charging Strategy Two: Depot with on-route charging



3 On-route charging

Infrastructure and fleet needs

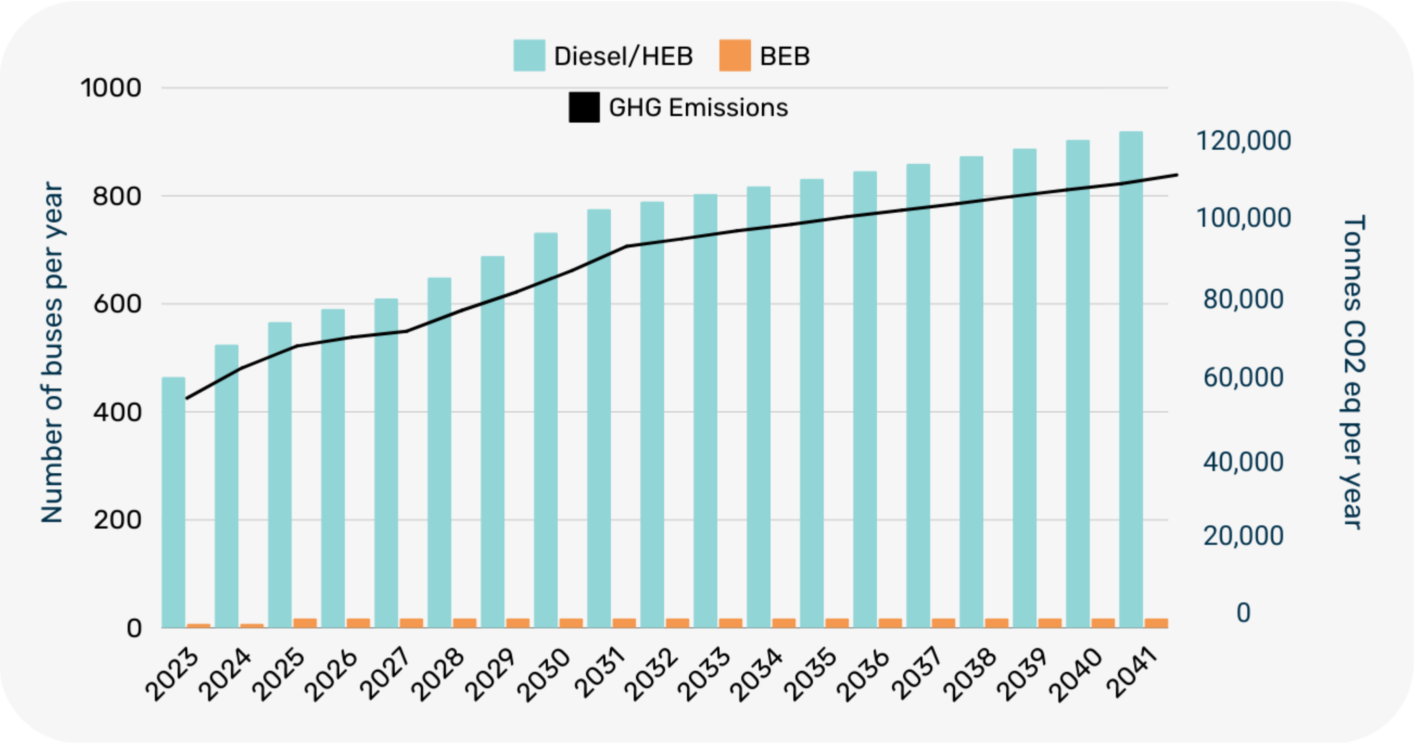


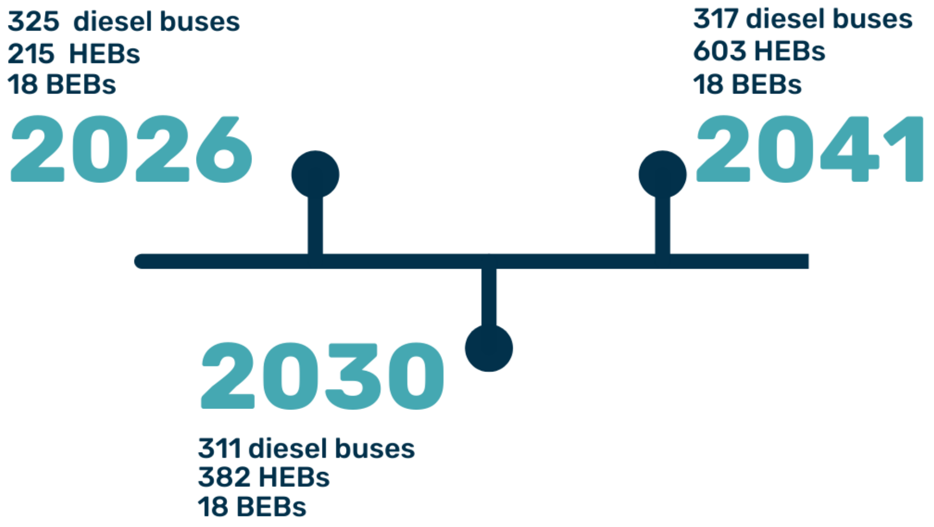
4

Rollout and Operational Greenhouse Gas (GHG) Emissions

4 Rollout and Operational GHGs

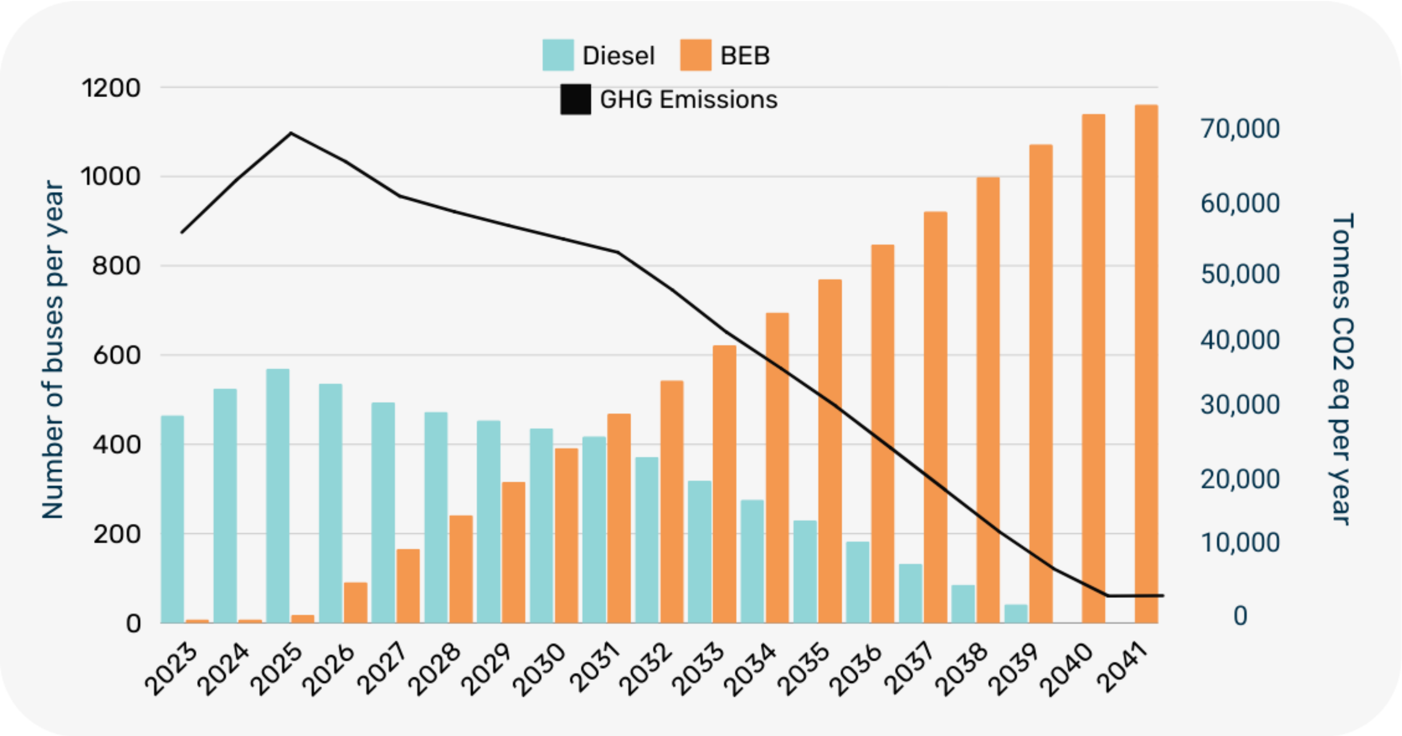
Base case (diesel, hybrid and BEB fleet)

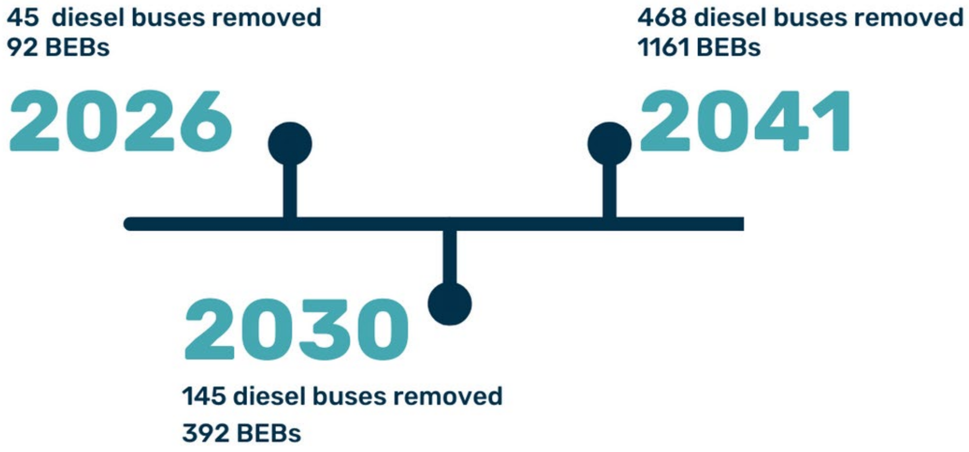




4 Rollout and Operational GHGs

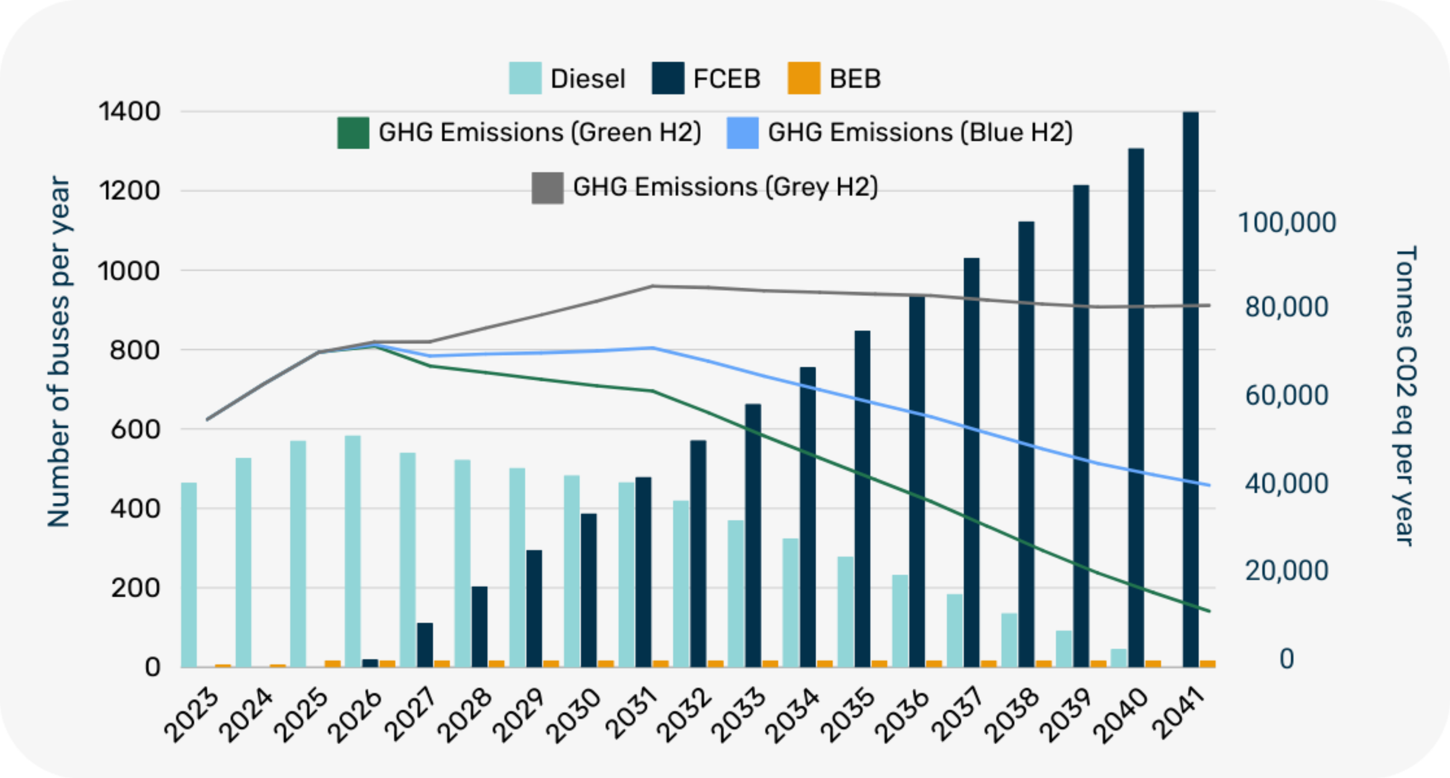
Scenario One (full BEB solution) to 2041

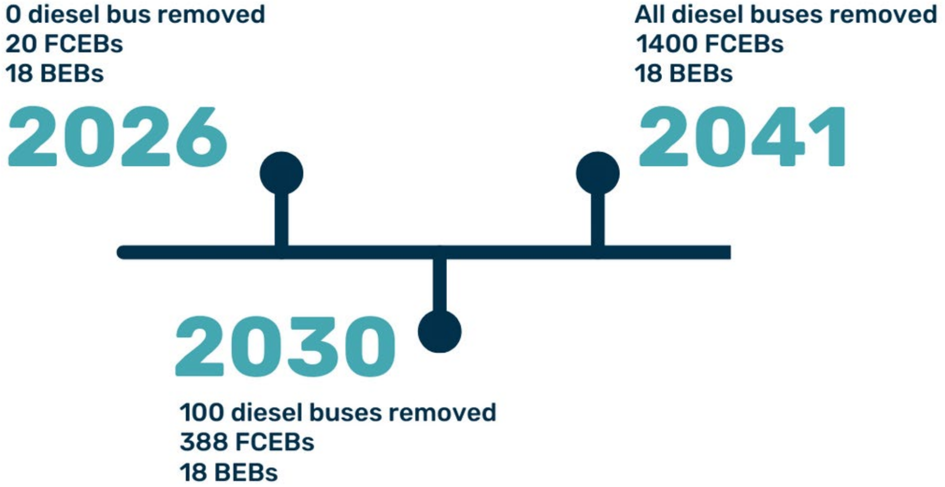




4 Rollout and Operational GHGs

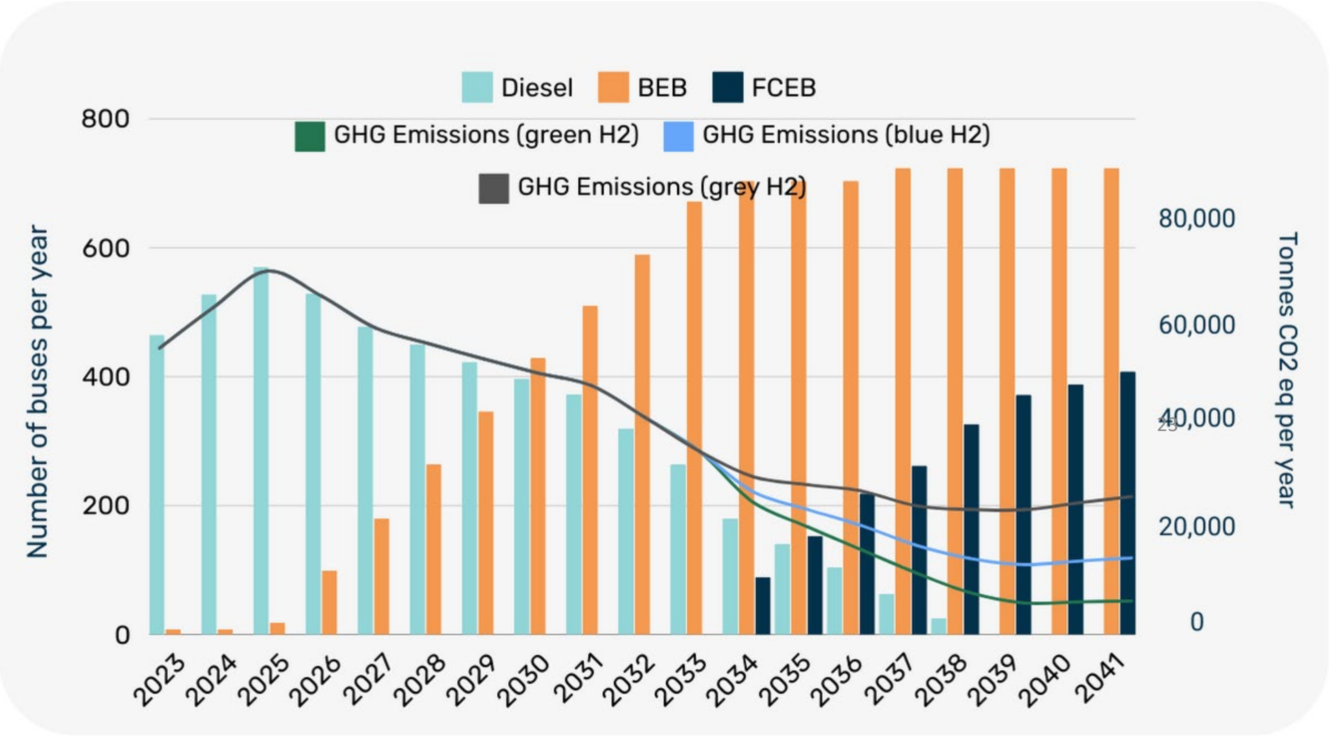
Scenario Two (full FCEB solution) to 2041

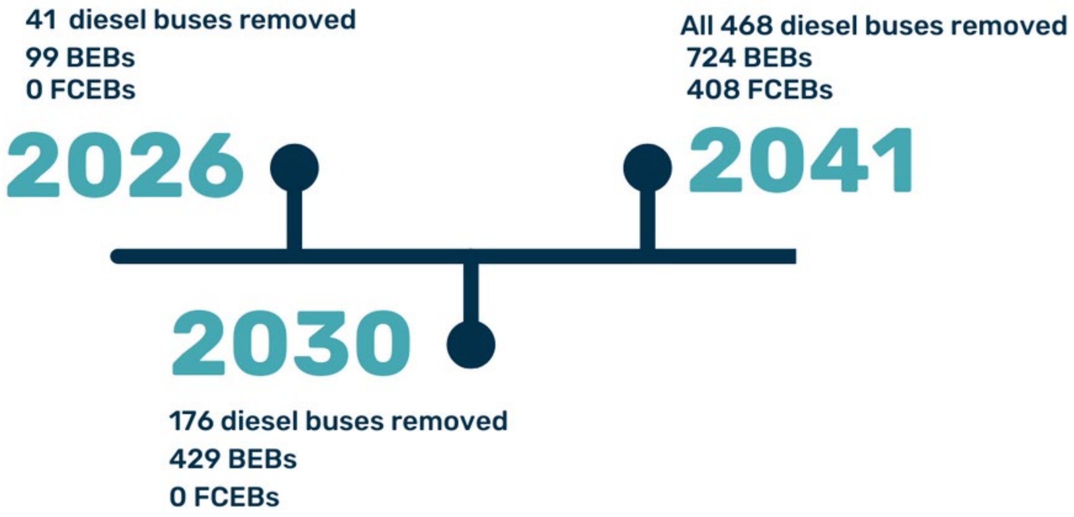




4 Rollout and Operational GHGs

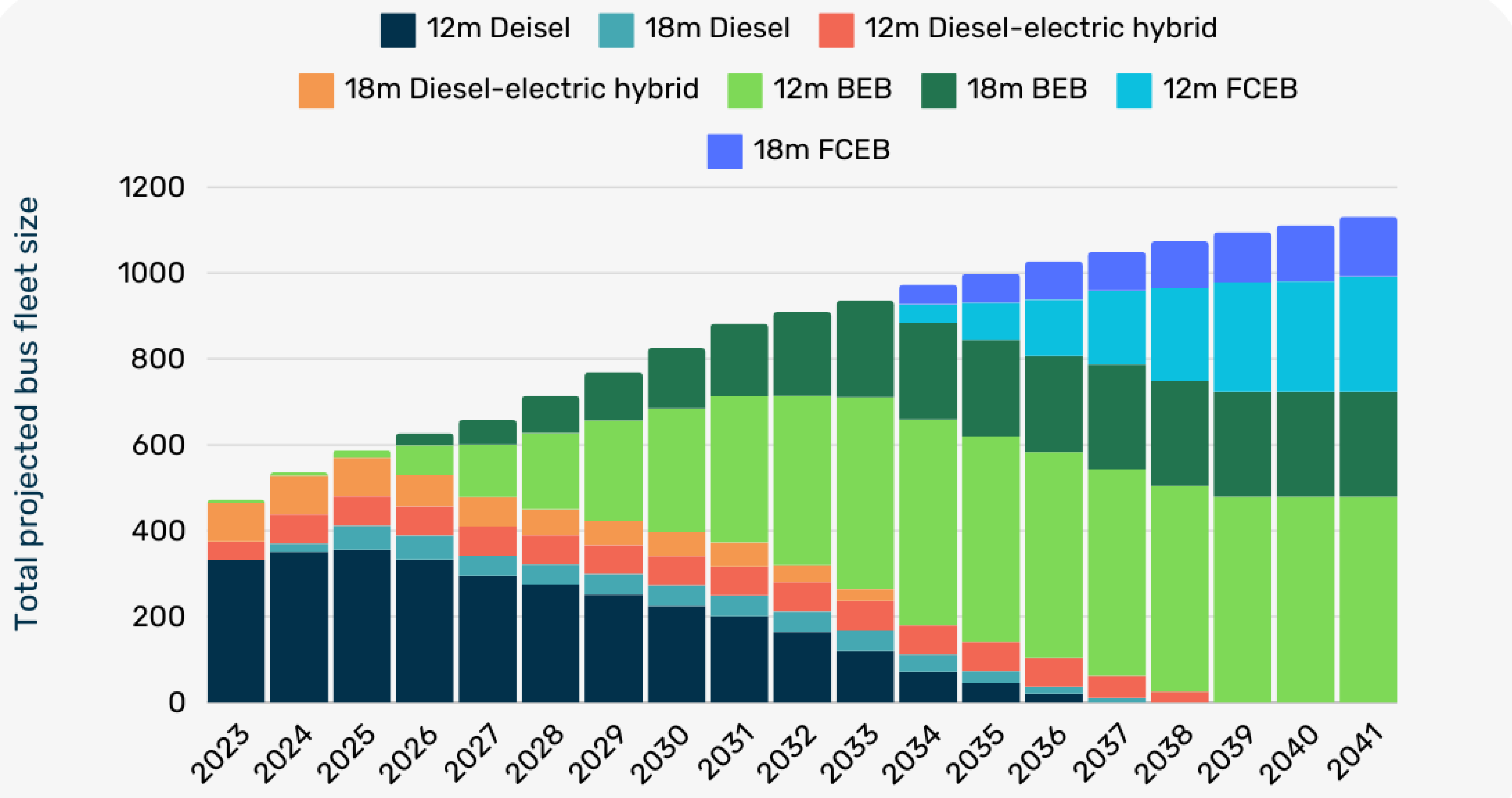
Scenario Three (mixed green fleet solution)





4 Rollout and Operational GHGs

Scenario Three (mixed green fleet solution) detailed plan



5

Service requirements

5 Service requirements

Additional service hours

Increased service hours are due to, charging/refuelling on-route, block splitting, additional buses

6

Facilities assessment

6 Facilities assessment

Facilities retrofit costs (Scenario Three)

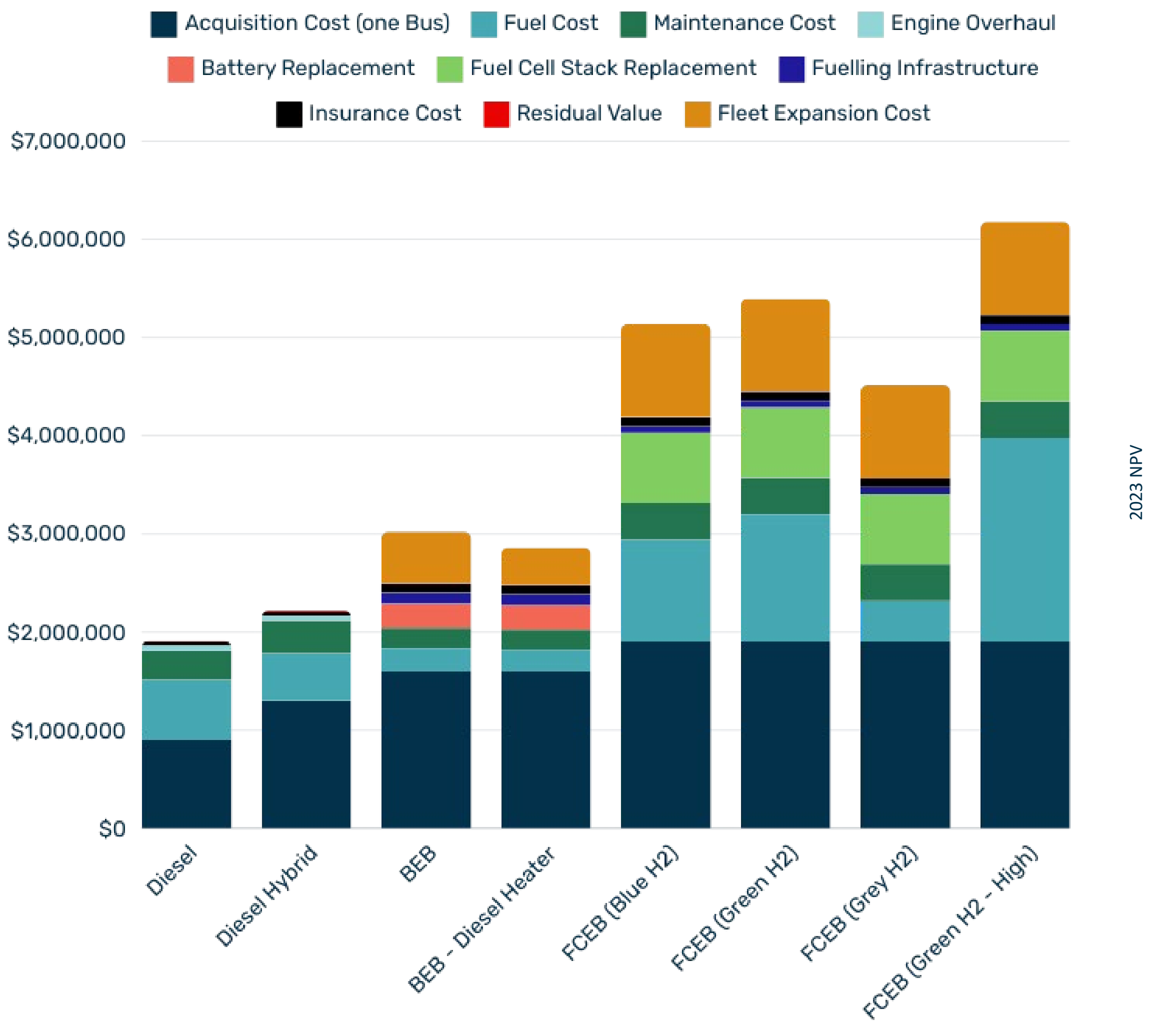
Sandalwood facility retrofit	Clark facility retrofit
$86 million Total retrofit cost	**$46 million** Total retrofit cost
20 000 kg H2 storage capacity	**10 000 kg** H2 storage capacity
17 MW Installed charging power	**7 MW** Installed charging power
11 MW Estimate peak service demand	**5 MW** Estimate peak service demand
371 Vehicle storage capacity	**178** Vehicle storage capacity

7

Economic analysis

7 Economic analysis

Total cost of ownership per bus in NPV (18 year, 12m bus)



7

Economic analysis

Assumptions

CUTRIC worked with Deloitte to assess:

- 18- and 15-year useful life of assets
- Hydrogen price points (from $8 to $40)
- With and without Diesel Fired Auxiliary Heater
- Assuming a 50% rebate on Manufacturer Suggested Retail Price

7 Economic analysis

Base case fleet and asset costs with growth NPV (2041)

Base case scenario (current diesel, hybrid and BEB)

CAPEX: $1.63 billion

OPEX: $6.01 billion

Residual: $76.1 million

TOTAL: $7.56 billion

7 Economic analysis

Scenario One (full BEB solution) fleet with Diesel Fired Auxiliary Heaters and asset costs with growth NPV (2041)

Scenario One (Full BEB solution)

CAPEX: $3.50 billion

OPEX: $5.67 billion

Residual: $215 million

TOTAL: $8.95 billion

7 Economic analysis

Scenario Two (full FCEB solution) fleet and asset costs with growth NPV (2041)

Scenario Two (Full FCEB solution)

CAPEX: $4.26 billion

OPEX: $5.95 billion

Residual: $(359 million)

TOTAL: $9.85 billion

7 Economic analysis

Scenario Three (mixed green fleet solution) fleet with DFAH and asset costs with growth NPV (2041)

Scenario Three (Mixed green fleet solution)

CAPEX: $3.40 billion

OPEX: $5.71 billion

Residual: $(161 million)

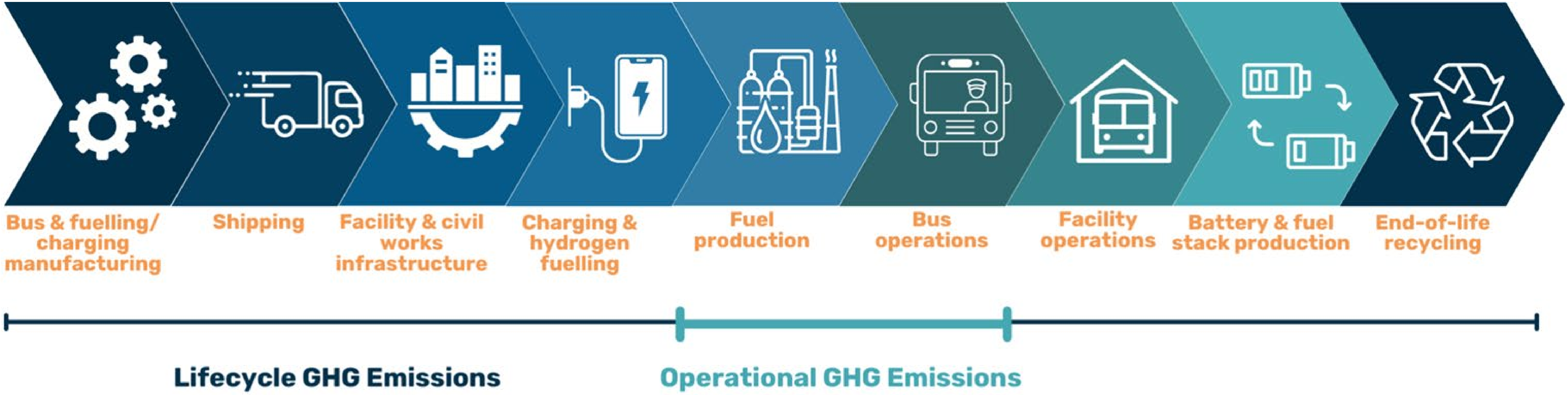
TOTAL: $8.94 billion

8

Environmental Life Cycle Assessment (LCA)

8 Environmental life cycle assessment

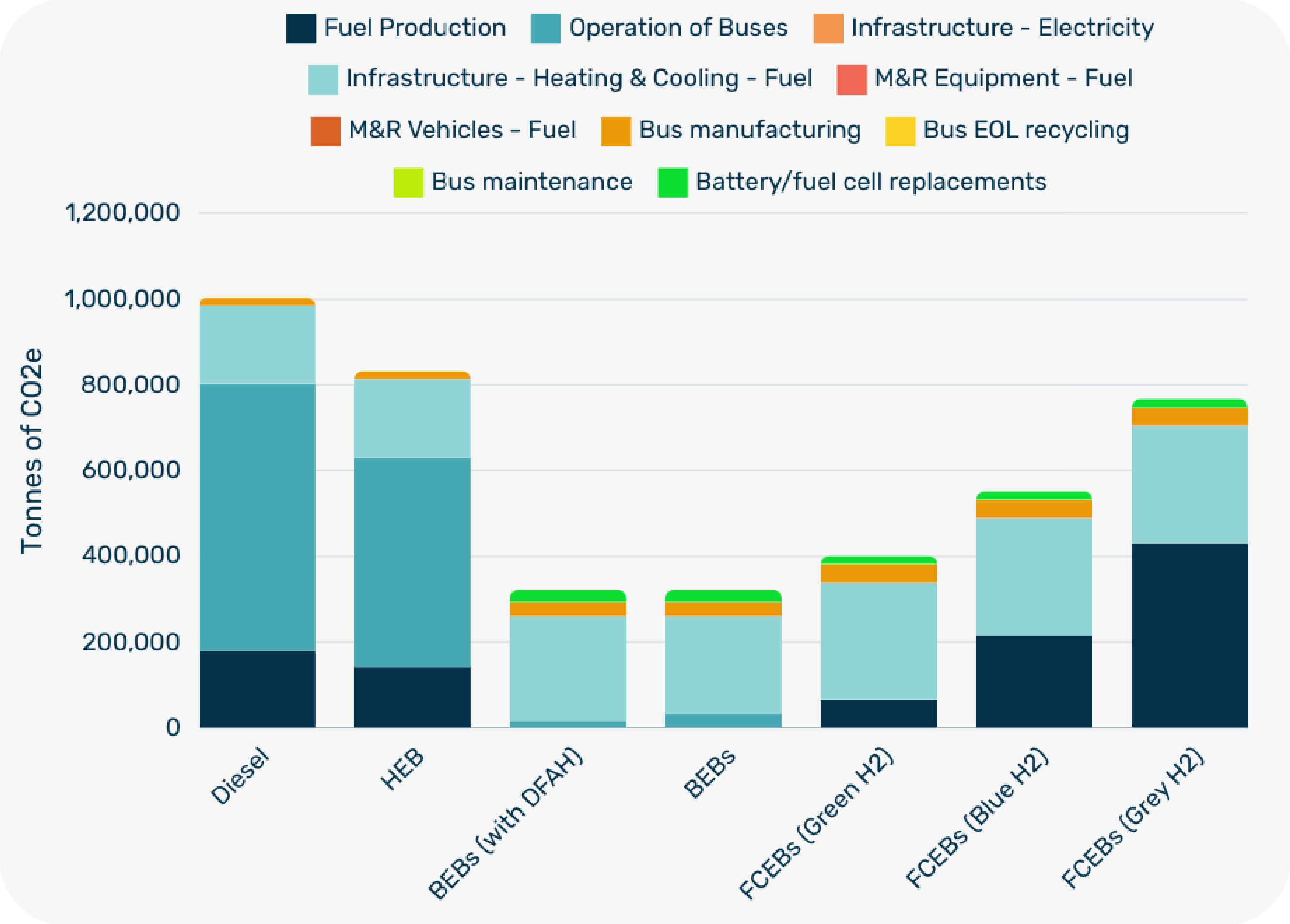
Life cycle versus Operational GHG emissions



8 Environmental Life Cycle Analysis

12m bus fleet life cycle emissions - 18 year, with DFAH

M&R equipment & vehicle fuel, infrastructure make up less than 300 tC02 and therefore do not appear in this graph



8 Environmental Life Cycle Analysis

12m bus fleet life cycle emissions - 18 year, with DFAH

With electric heaters

68% ↓
681,900
tC02 eq per bus

With Diesel Fired Auxiliary Heaters

68% ↓
682,100
tC02 eq per bus

H2 61% ↓
609,000
tC02 eq per bus

H2 46% ↓
458,000
tC02 eq per bus

H2 24% ↓
243,000
tC02 eq per bus

9

Social impact of ZEBs

9 Social impact of ZEBs in Brampton

Input: Aspects for social impact

- Noise-sensitive areas, highlighting density of care and senior homes, hospitals, schools and transit routes
- Annual median after-tax income in Brampton and transit routes
- Density of population aged 65 and over in Brampton and transit routes
- Density of population with no high school diploma and no post-secondary diploma, aged 25 to 64
- Density of households spending over 30 per cent or more of income on shelter

Output: Six prioritized routes (socio-economic)

Route	Route Name	Age score	Education score	Housing score	Income score	Noise score	Final score	Ease of electrification
AVG	Average (full system)	0.28	0.55	0.54	0.12	0.76	2.24	-
10*	South Industrial	0.5	1	0.5	0.5	1	3.5	Very achievable
12	Grenoble	0.5	1	0.5	0	1	3	Achievable
16	Southgate	0.5	0.5	0.5	0.5	1	3	Achievable
40	Central Industrial	0.5	1	0.5	0.5	0.5	3	Achievable
54	County Court	0.5	0.5	0.5	0.5	1	3	Challenging
56	Kingknoll	0.5	0.5	0.5	0.5	1	3	Challenging

*Only runs on weekdays

Very achievable - depot-only charging
Achievable - on-route charging needed
Challenging -will require block splitting

10

Energy as a Service

10 Energy as a Service

Goal of this scope element

- Introduce the EaaS business model
- Develop EaaS scope definitions for Brampton Transit
- Outline potential commercial contract options
- Develop EaaS qualitative assessment criteria
- Identify potential EaaS partners/stakeholders and their offerings
- Highlight procurement strategy options

10

Energy as a Service

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Energy as a Service vendor engagement and workshops

Outreach & Workshop
Has a relevant EaaS solution

- SIEMENS
- alectra energy solutions
- AUX
- PowerON Energy Solutions An OPG Company
- jule powered by ecamion

Outreach
No market-ready EaaS solutions

- ABB
- Hitachi Energy
- bp pulse
- TECIUM IOT

Market Research
Lack relevant EaaS solution

- Schneider Electric
- AMERESCO

Interviews conducted in 2023

Outreach & Workshop
Has a relevant EaaS solution

- SIEMENS
- alectra energy solutions
- AlphaStruxure
- AUX
- PowerON Energy Solutions An OPG Company
- ABB
- jule powered by ecamion

Outreach
No market-ready EaaS solutions

- Hitachi Energy
- TECIUM IOT

Interviews conducted in March 2024

11

Conclusions

11 Conclusions: Environmental

	Base case scenario (Diesel and HEB)	Scenario One (Full BEB solution)	Scenario Two (Full FCEB solution)	Scenario Three (Mixed green fleet solution)
Operational GHG emissions reductions per bus (18 year life cycle, BEBs with DFAH, Green H2)	0%	97%	85%	95%
Life cycle GHG emission reductions per bus (18-year life cycle, BEBs with DFAH, Green H2)	0%	68%	61%	BEB: 68% FCEB: 61%

11 Conclusions: Economic

	Base case scenario (Diesel and HEB)	Scenario One (Full BEB solution)	Scenario Two (Full FCEB solution)	Scenario Three (Mixed green fleet solution)
Total cost of ownership per bus (NVP) (18-year life cycle, 12m bus, BEBs with Diesel Fired Auxilary Heaters, Green H2)	$1.9 billion	$2.8 billion	$4.5 billion	BEB: $2.8 billion FCEB: $4.5 billion
Economic life cycle costs (NVP) (18-year life cycle, BEBs with Diesel Fired Auxiliary Heater, grey H2)	$7.56 billion	$8.95 billion	$9.85 billion	$8.94 billion

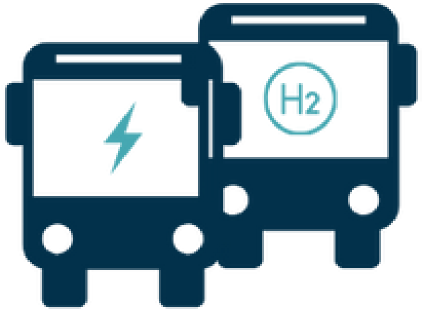
11 Conclusions: Fuelling

	Base case scenario (Diesel and HEB)	Scenario One (Full BEB solution)	Scenario Two (Full FCEB solution)	Scenario Three (Mixed green fleet solution)
Additional on-route chargers required	-	18	-	18
Annual energy consumption (in-depot and on-route) in 2041	-	106 to 131 GWh	-	106 to 131 GWh
Hydrogen consumption annually in 2041	-	-	5.9 million kg	1.3 to 2.2 million kg

11 Conclusions: Fleet size

	Base case scenario (Diesel and HEB)	Scenario One (Full BEB solution)	Scenario Two (Full FCEB solution)	Scenario Three (Mixed green fleet solution)
Fleet size in 2041 (BEBs with Diesel Fired Auxiliary Heater)	938	1,161	1,418	1,132

11 Conclusions: Recommendations



Scenario Three
Mixed green fleet solution

- 95% operational GHG emissions reduction
- Lowest total economic life cycle cost
- Lowest 2041 growth fleet requirement

Integrates both technologies for fleet flexibility, reduces total fleet size and provides for redundancy in operations.

Conclusions

Scenario Three (mixed green fleet solution)

1.3M kg
H2 needed per year

$8.94b
Life cycle transition 18 years

1,132
724 BEB with DFAH
408 FCEBs by 2041

$3.26M/$5.25M
12m BEB / 12m FCEB
over 18 year life cycle

18
On-route chargers

95%
Operational GHG
emission reduction

- Major facility retrofits to Sandalwood and Clark facilities needed with a total cost of **$132 million**
- A total of 30,000 kg of storage capacity for 5.9 million kg H2 annual and **8 MW of electricity** is needed at the Sandalwood and Clark facilities
- Transition cost of **$8.94 billion** assumes BEBs with DFAH and an 18-year asset life cycle.
- A total of **1.3 to 2.2 million kg of H2 per year** is needed to cover Brampton Transit's service levels

Thank you!

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