NATIONAL RENEWABLE ENERGY LABORATORY





A Cost Effectiveness Analysis of Quasi-In-Motion Wireless Power Transfer for Plug-In Hybrid Electric Transit Buses from Fleet Perspective

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Motivation and Objective

I. Motivation:

A. Wireless power transfer charging technology has made it possible to wirelessly charge a parked vehicle's battery.

B. Transit buses provide an early quasi-in-motion application opportunity.

II. Objective:

A. Perform a cost comparison of plug-in hybrid electric bus (PHEB), hybrid electric bus (HEB), and conventional bus (CB) scenarios.

B. Explore the fuel displacement opportunity.

C. Provide incremental rollout solutions for charging stations and PHEBs.

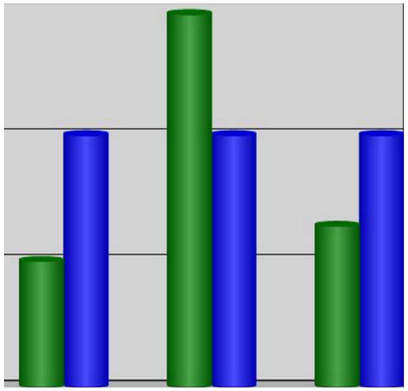
Outline

I. **Charging Station Location Selection**

II. **Economic Assumptions and Design of the Simulation Matrix**

III. **Cost Comparison of Various Scenarios**

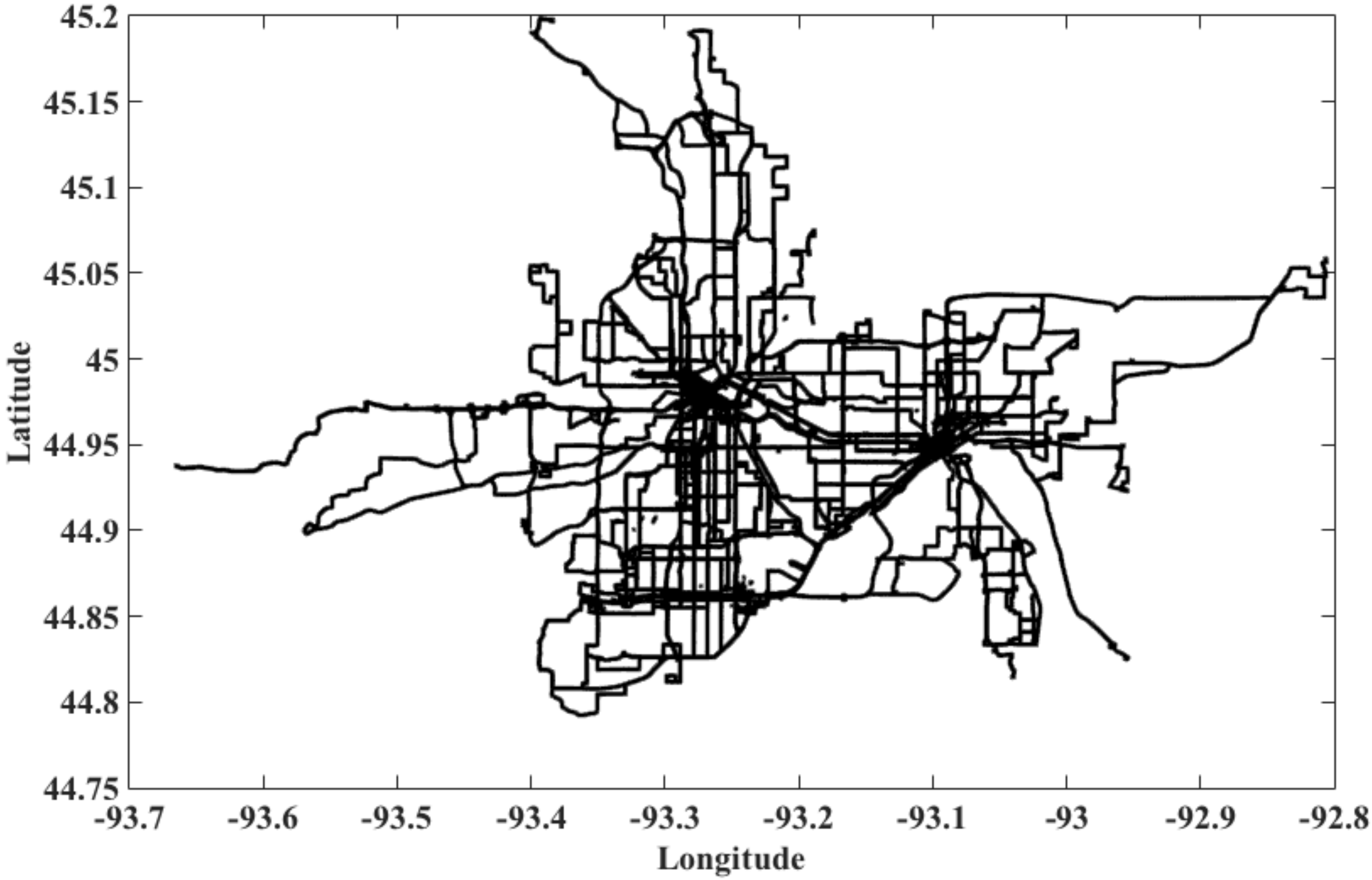
   A. Sweep analysis from a PHEB perspective
   B. Charging station incremental rollout
   C. PHEB incremental rollout
   D. More scenarios



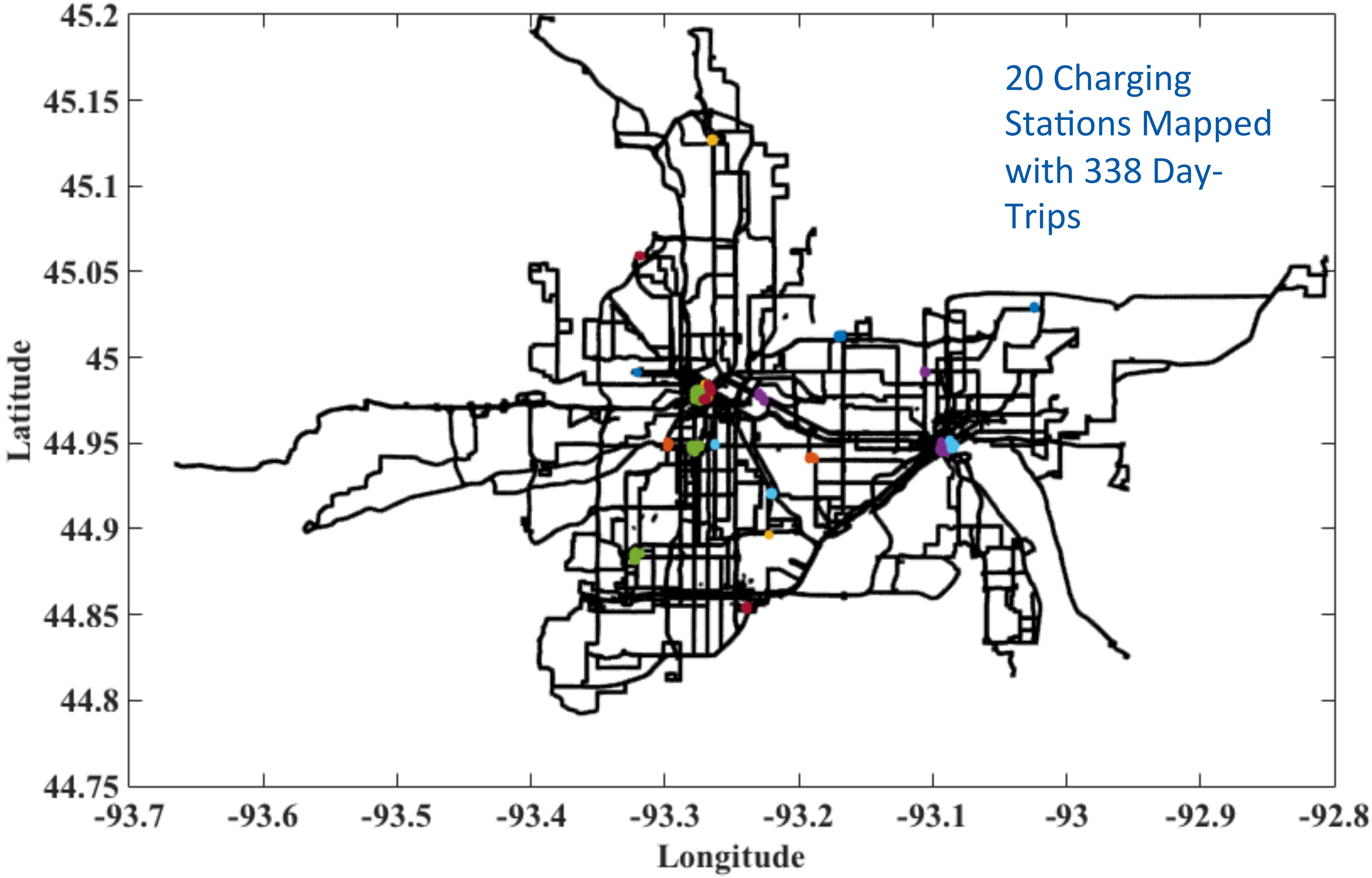
IV. **Sensitivity Analysis**

V. **Summary**

338 Vehicle-Days of Driving



Charging Station Location Selection



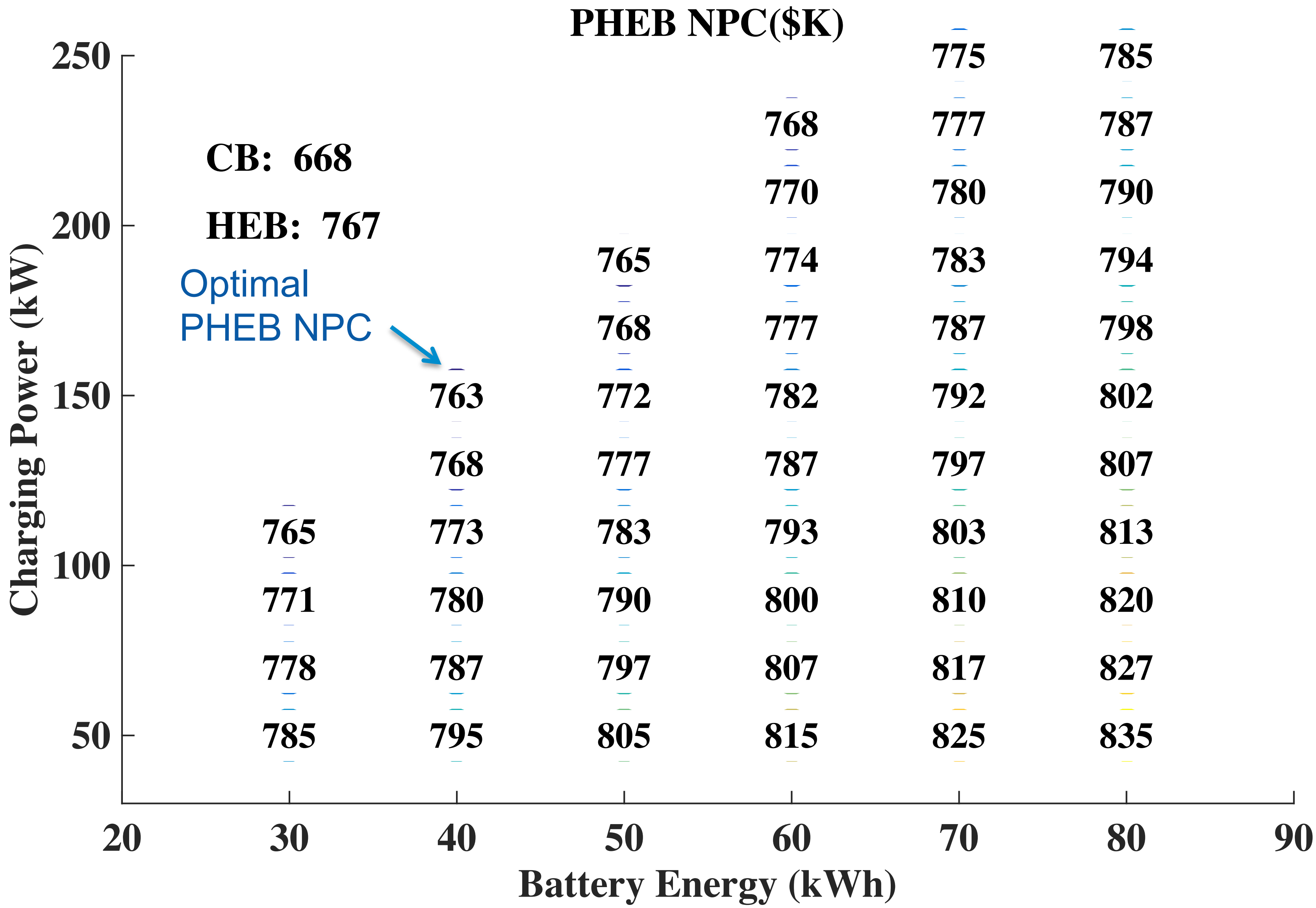
*The overlapped charging stations are considered one

Model Input Assumptions and Design of Experiments Matrix

Inputs	Assumptions
CB cost ($)	338,892 [2]
HEB without battery cost ($)	491,951[2]
Bus stop quasi-static charging station cost ($)	500,000
Bus depot static charging station cost for each bus ($)	5000
Demand charge rate per month ($/kW)	12 [3]
Electricity cost ($/kWh)	0.10 [4]
Five years average diesel price ($/gallon)	3.71 [4]
Vehicle life (year)	12 [5]
First battery cost ($/kWh)	500 [6]
Second battery cost (after 6 years) ($kWh)	300
Battery markup factor	1.5 [7]
Bus service day (days/year)	218
Discount rate	0.042
HEB fuel economy (FE) (mpg)	6.65
CB average FE (mpg)	5.29
PHEB efficiency in depleting mode (kWh/mi)	2.10
280 hp engine cost estimation ($)	30,000

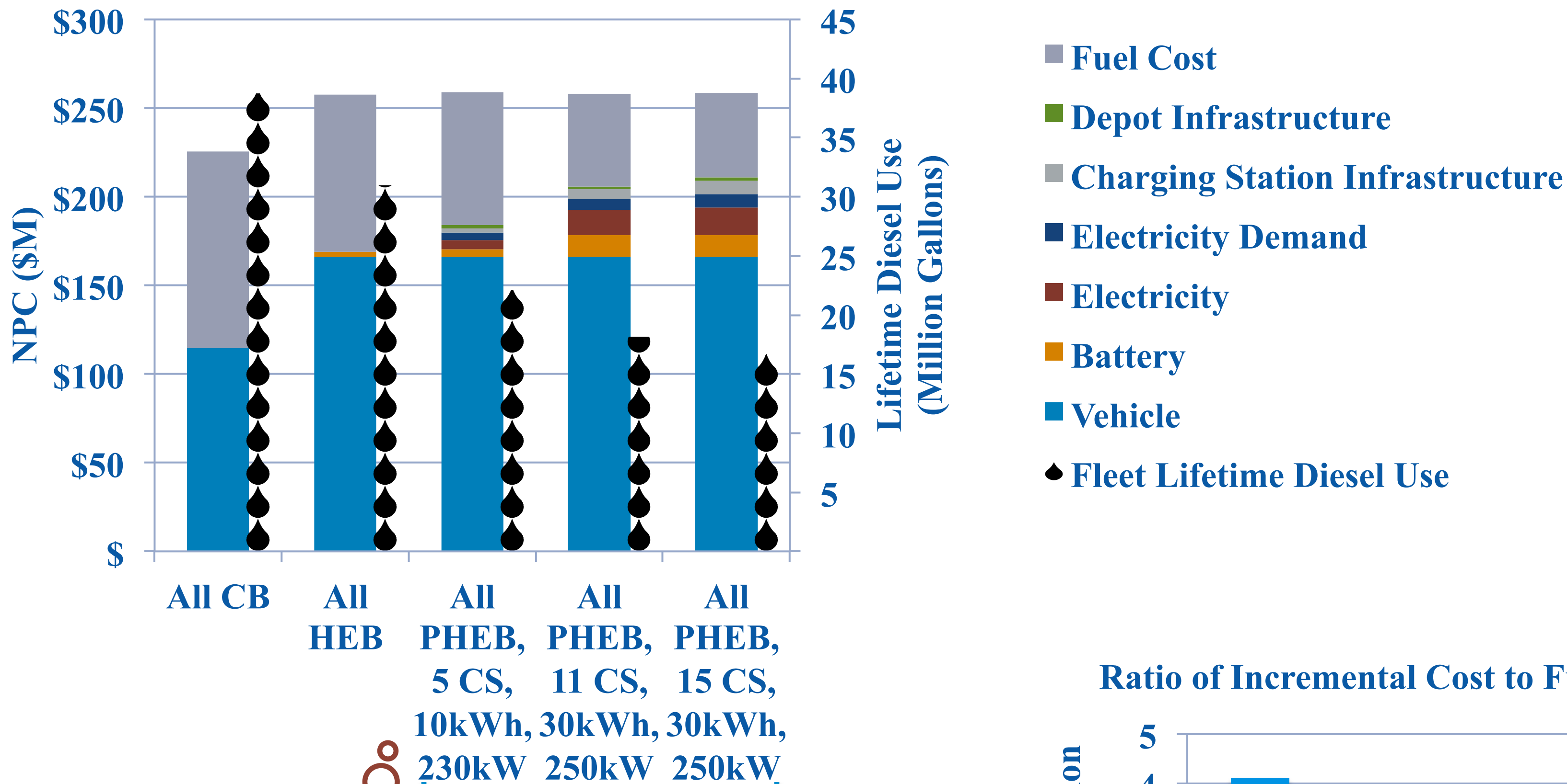
Parameter	Low	High	Step
Battery energy (kWh)	30	80	10
Charging power (kW)	50	250	20
Charging station amount	5	30	1

Sweep Analysis Results from A PHEB Perspective



NPC= Net Present Cost

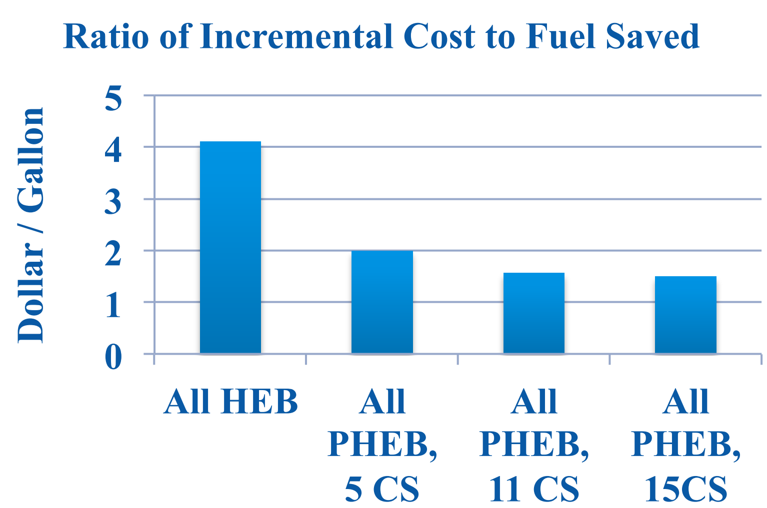
All PHEBs with Charging Station Incremental Rollout



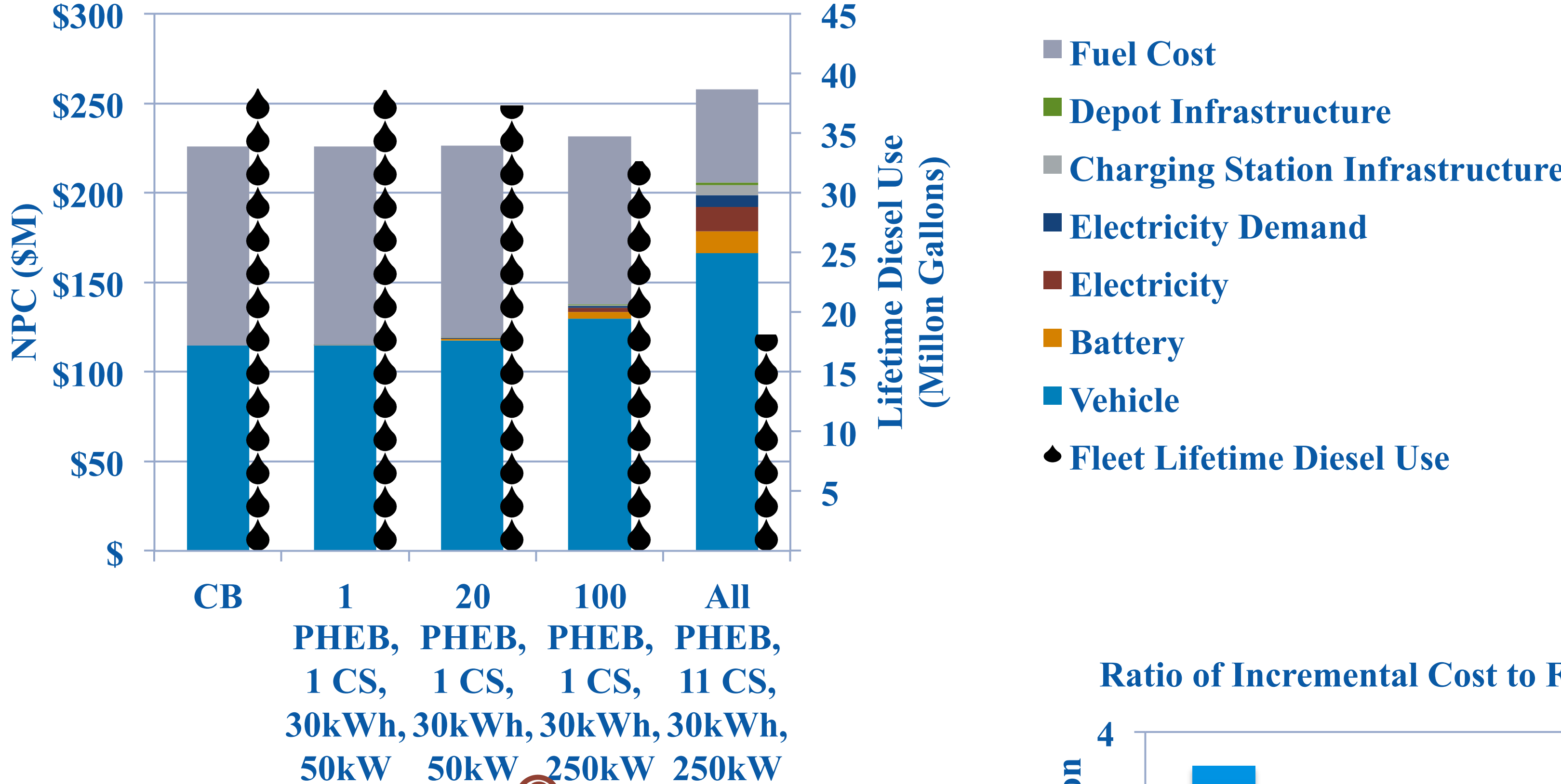
- PHEB comparable to HEB cost with triple the fuel savings

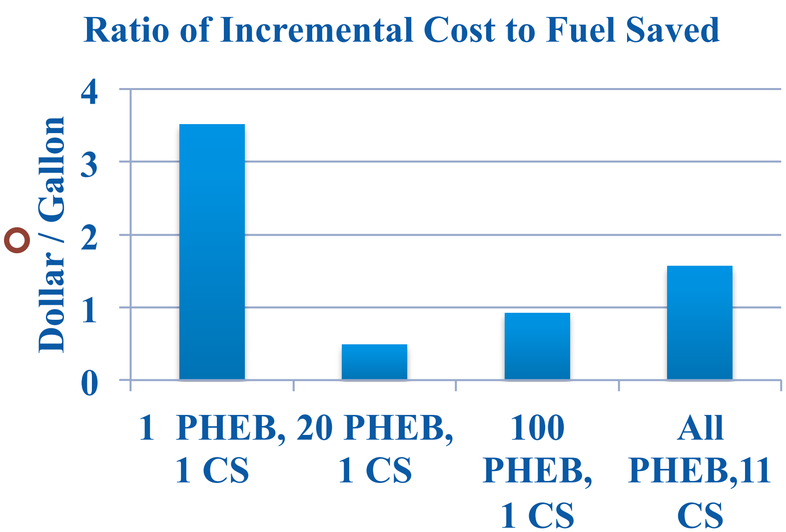
Optimal PHEB design

CS=charging station



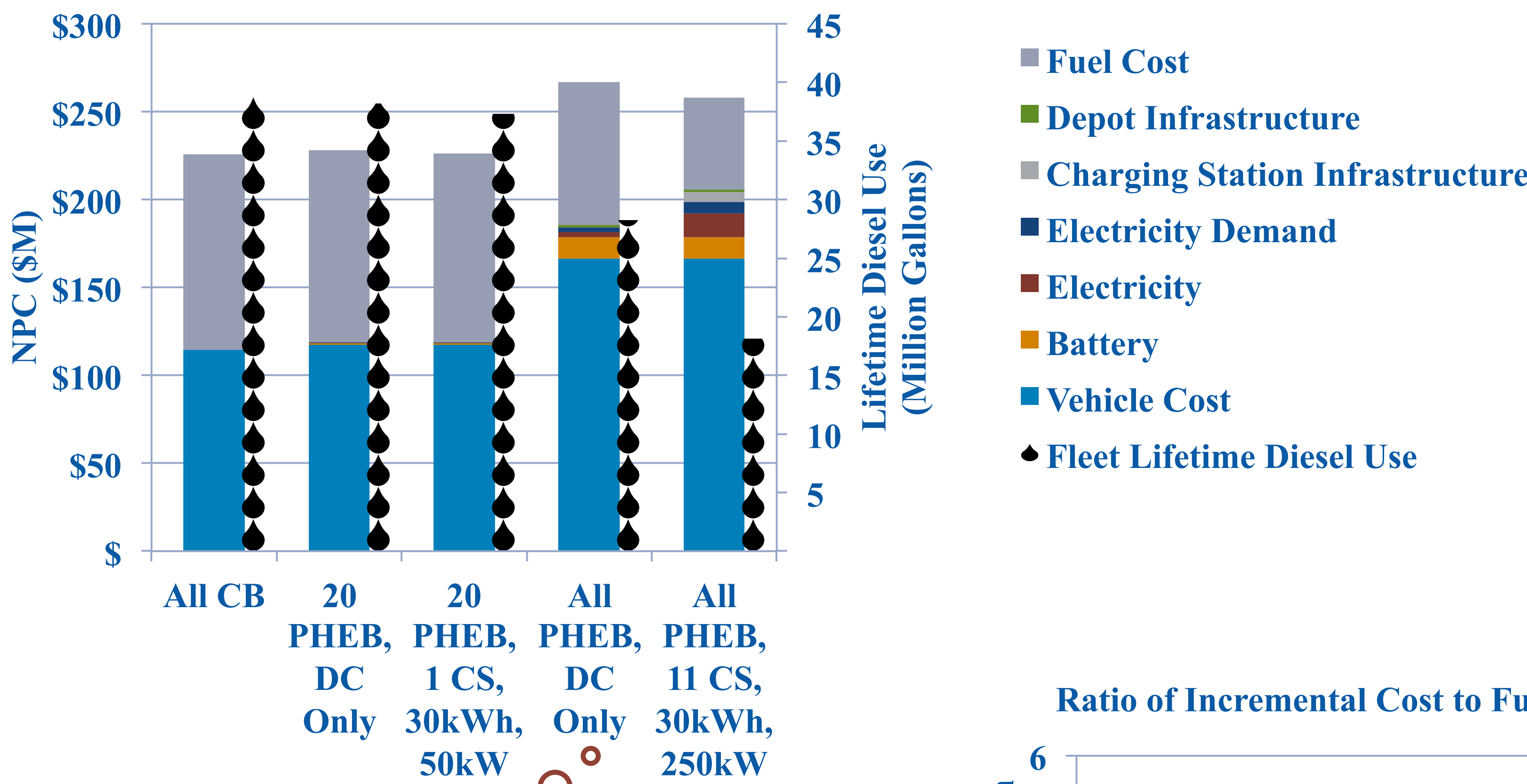
PHEB Incremental Rollout

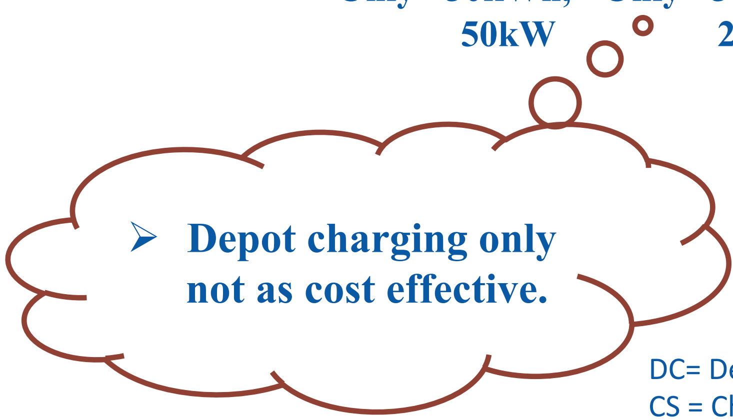


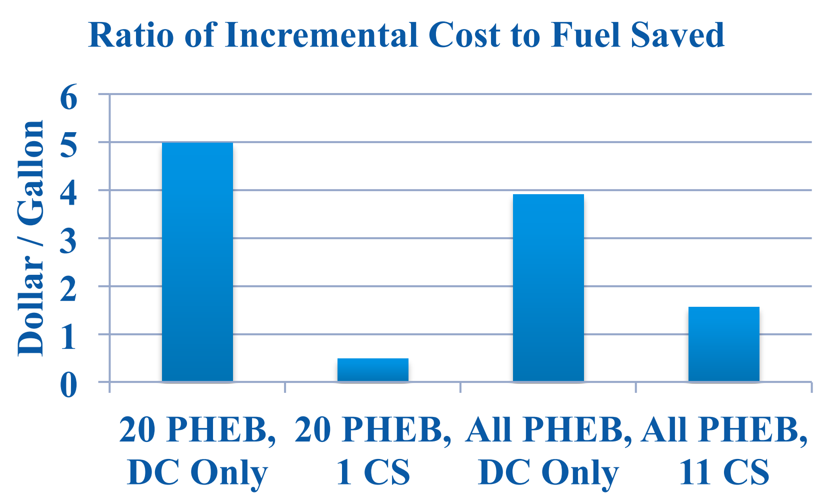


- Fuel savings increase with more PHEBs.
- 20 PHEB with 1 CS gives the lowest incremental cost/gallon saved.

Fleet Lifetime Cost and Fuel Consumption for More Scenarios





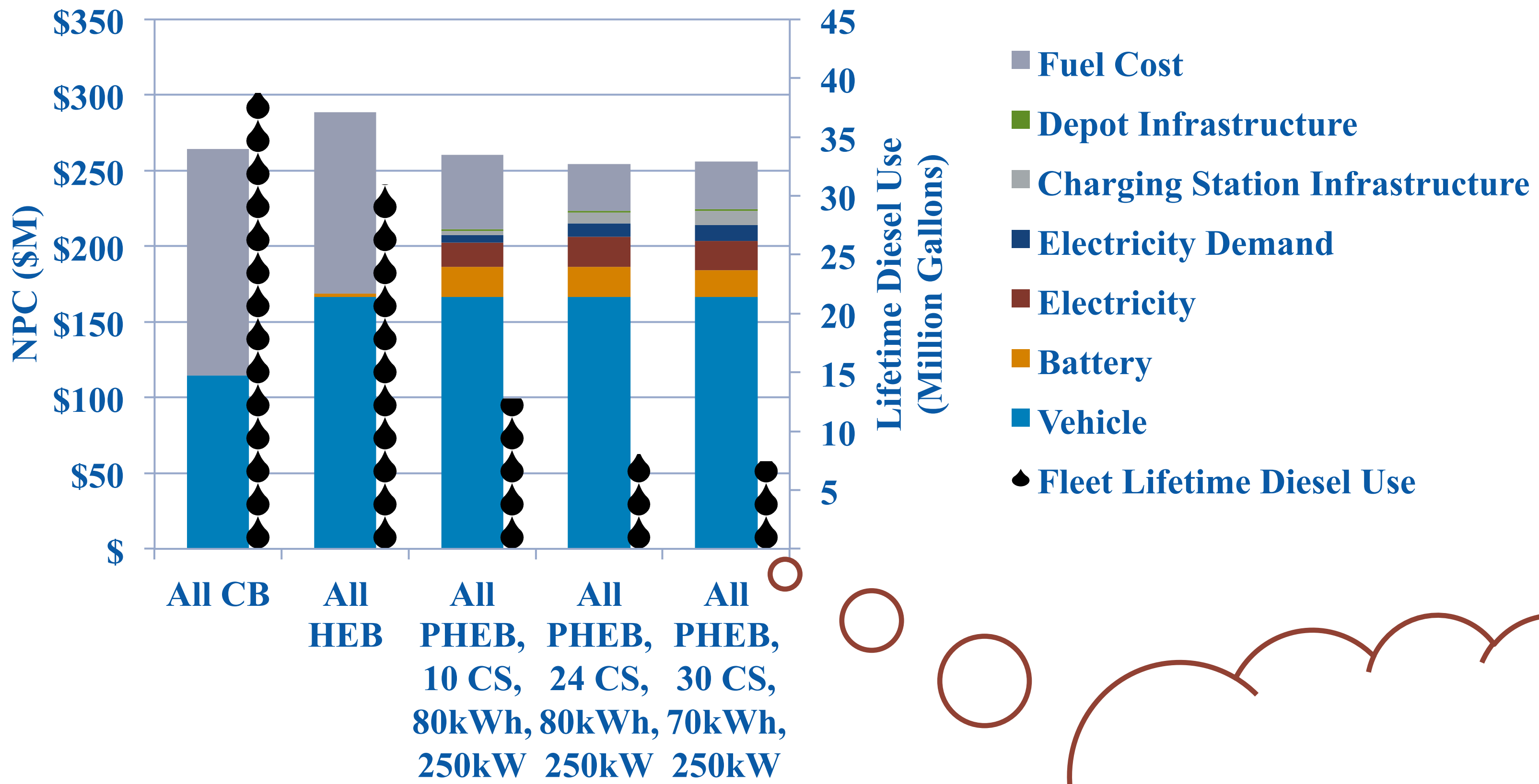


DC= Depot Charging
CS = Charging Station

High/Low Market Potential Assumptions

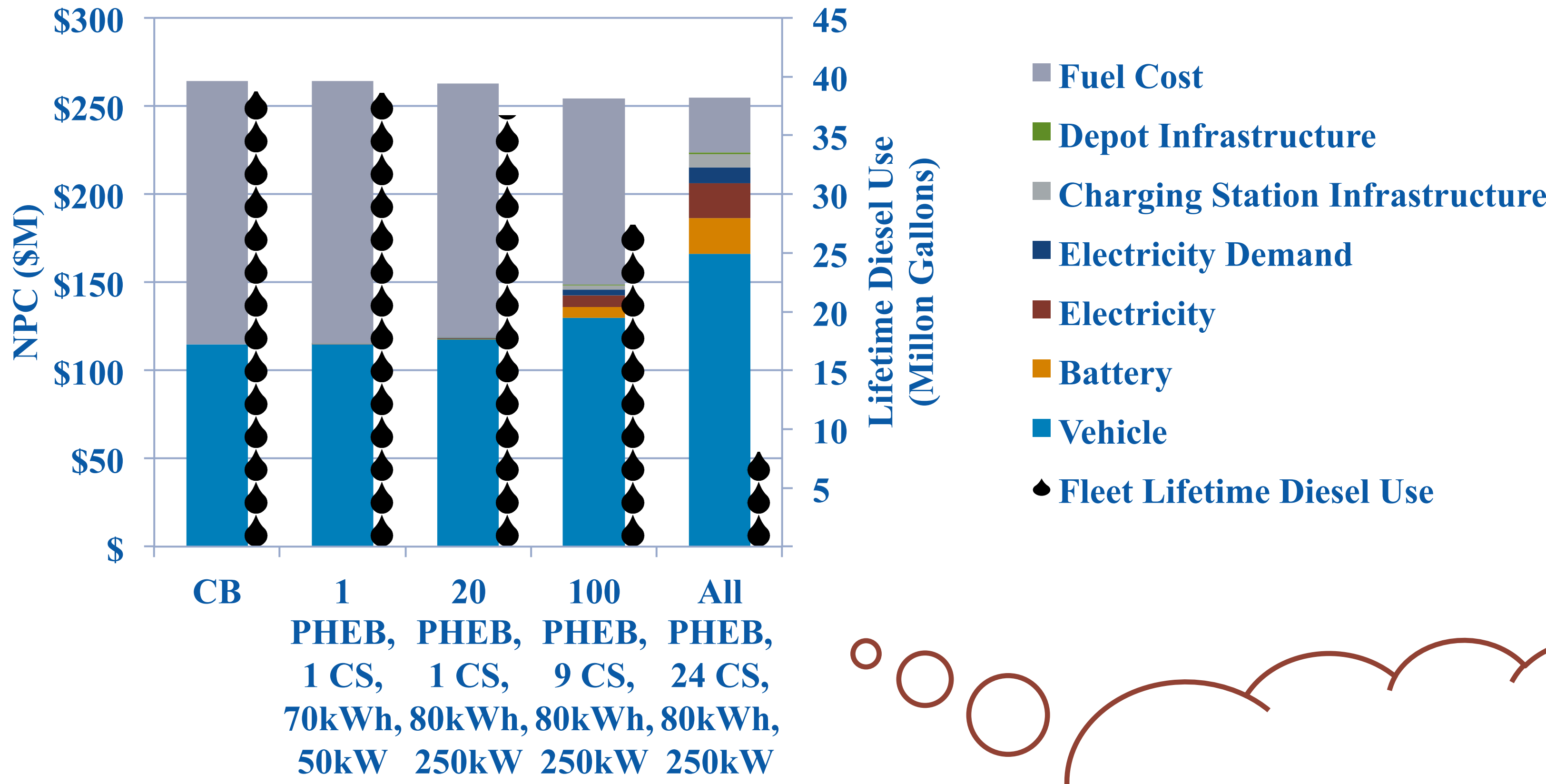
Assumptions	Favorable Market Potential Scenario	Unfavorable Market Potential Scenario
Bus stop charging station cost ($)	300,000	700,000
Depot charging station cost for each bus ($)	3,000	7,000
Electricity cost ($/kWh)	0.08	0.12
Demand charge ($/kW/month)	10	14
Diesel cost ($/gallon)	5.00	2.50
First battery cost ($kWh)	500	600
Second battery cost (after 6 years) ($kWh)	0 (no battery replacement)	400

All PHEBs with Charging Station Rollout with Favorable Market Potential Assumptions



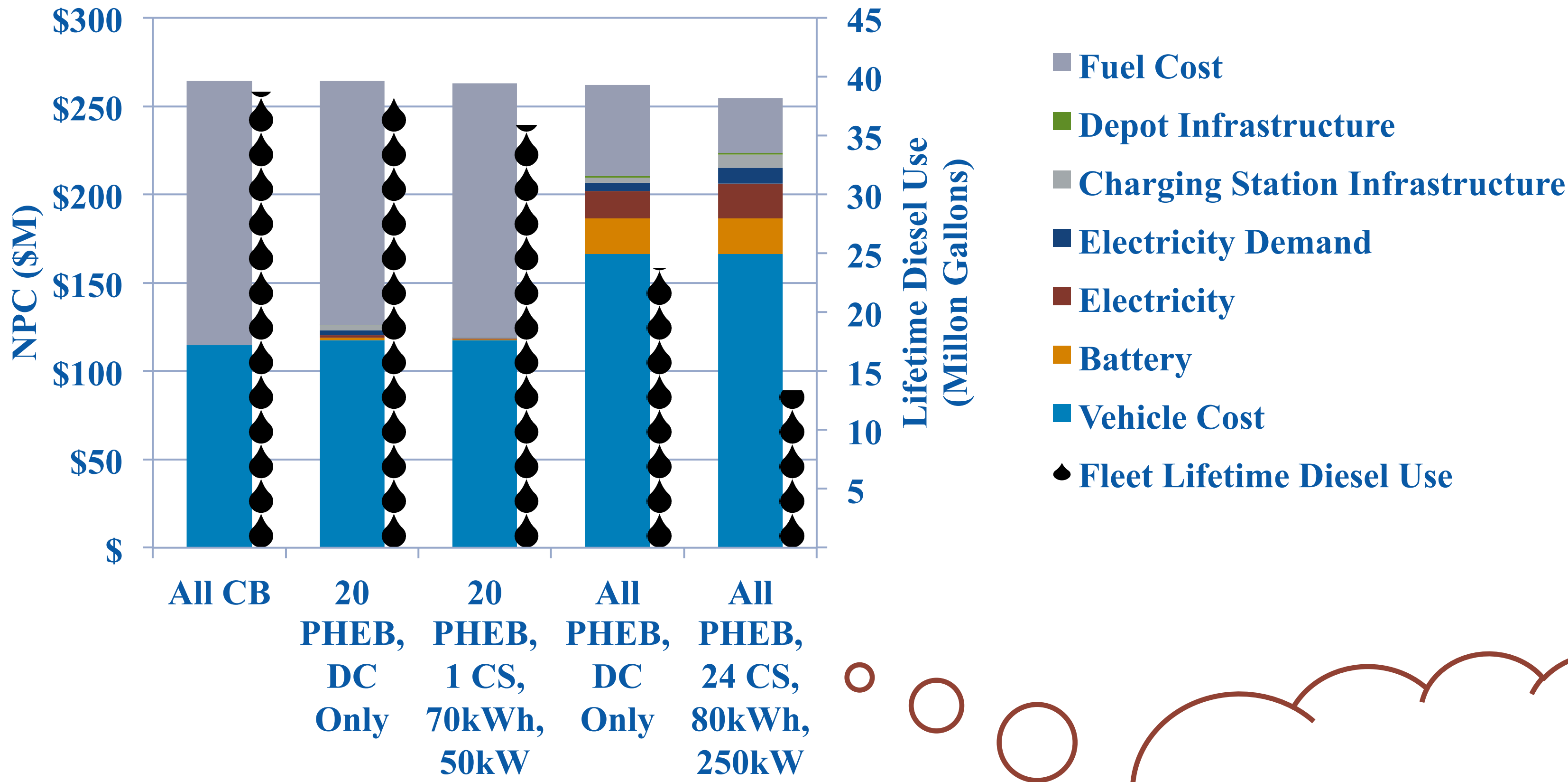
- All PHEB scenarios cost effective with large fuel saving.

PHEB Incremental Rollout with Favorable Market Potential Assumptions



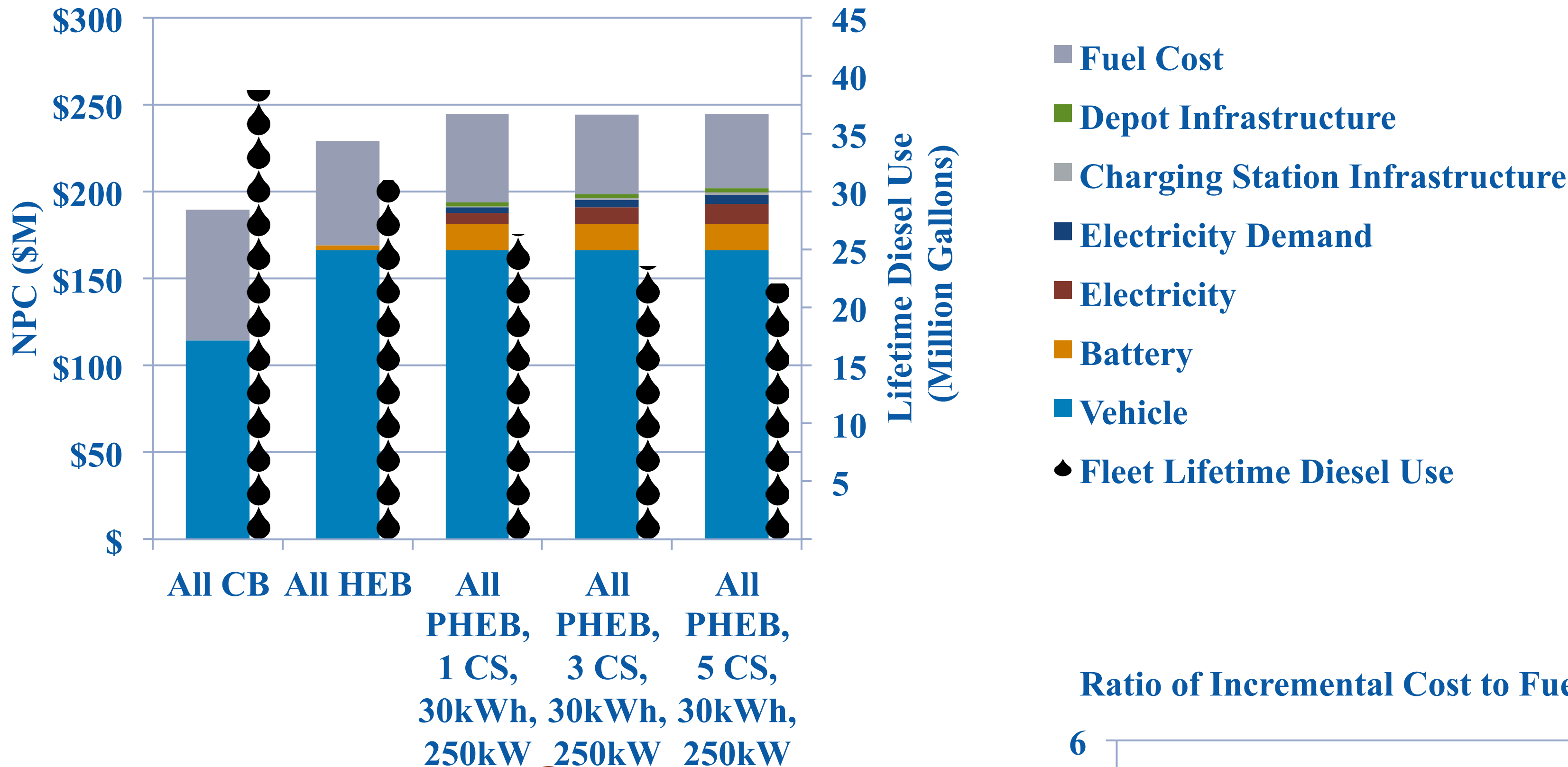
- All PHEB scenario has lowest cost and largest fuel savings.

More Scenarios with Favorable Market Potential Assumptions

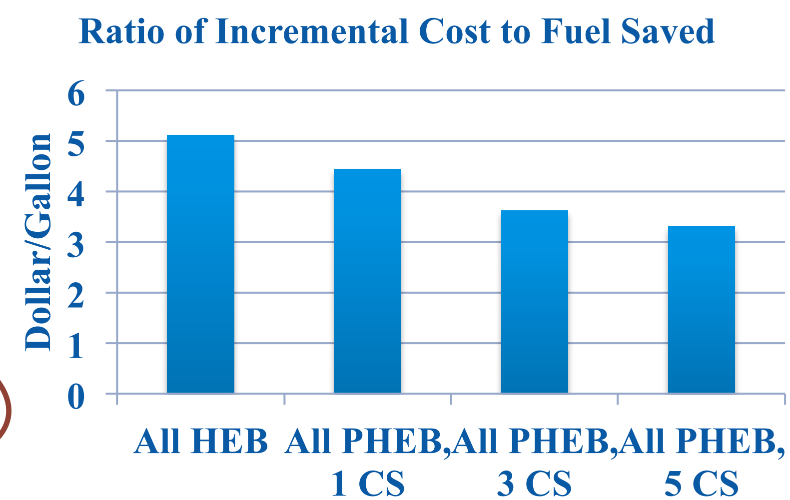


- Depot charging only is again not as cost effective.

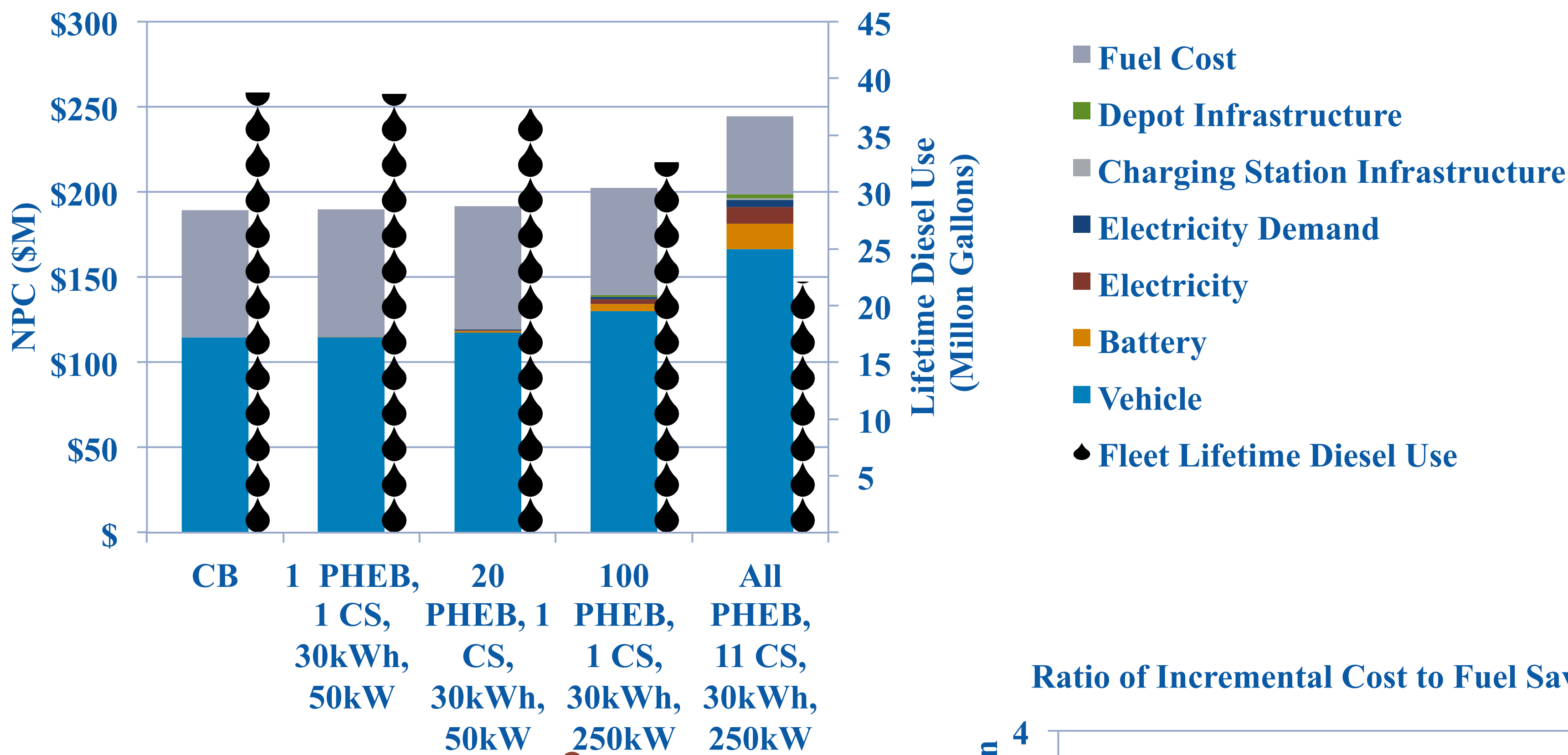
All PHEB with Charging Station Rollout with Unfavorable Market Potential Assumptions

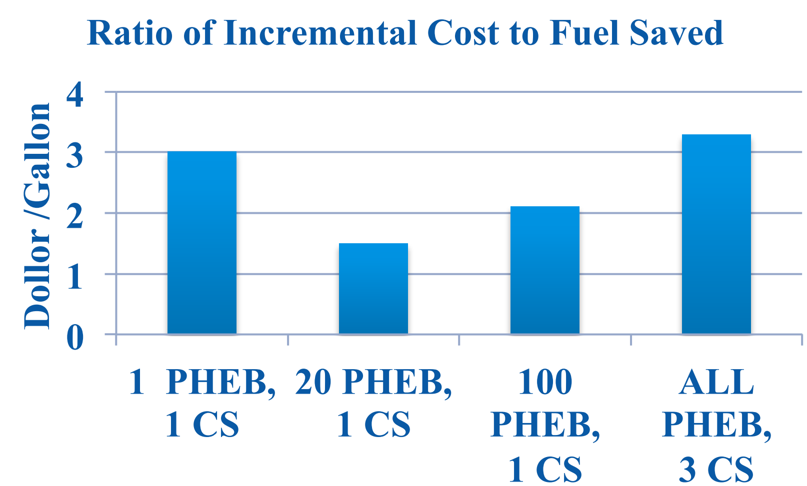


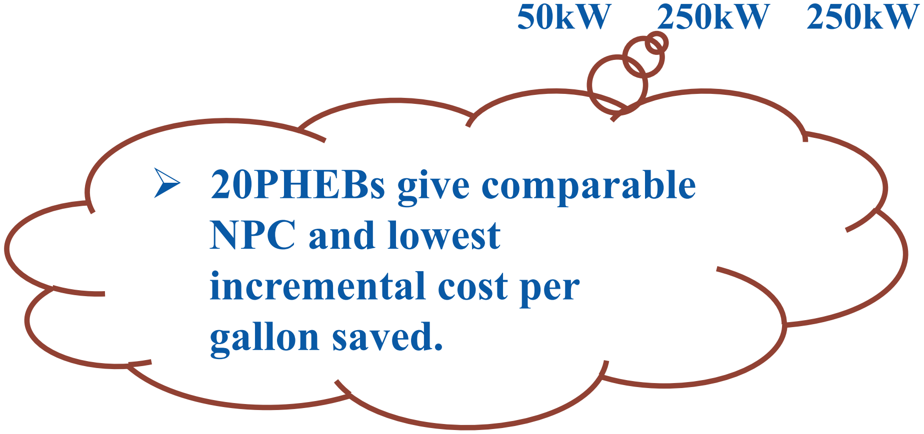
- PHEV unsurprising less cost effective with unfavorable market
- The NPC is higher with more CS, but the dollar per gallon saving is lower.



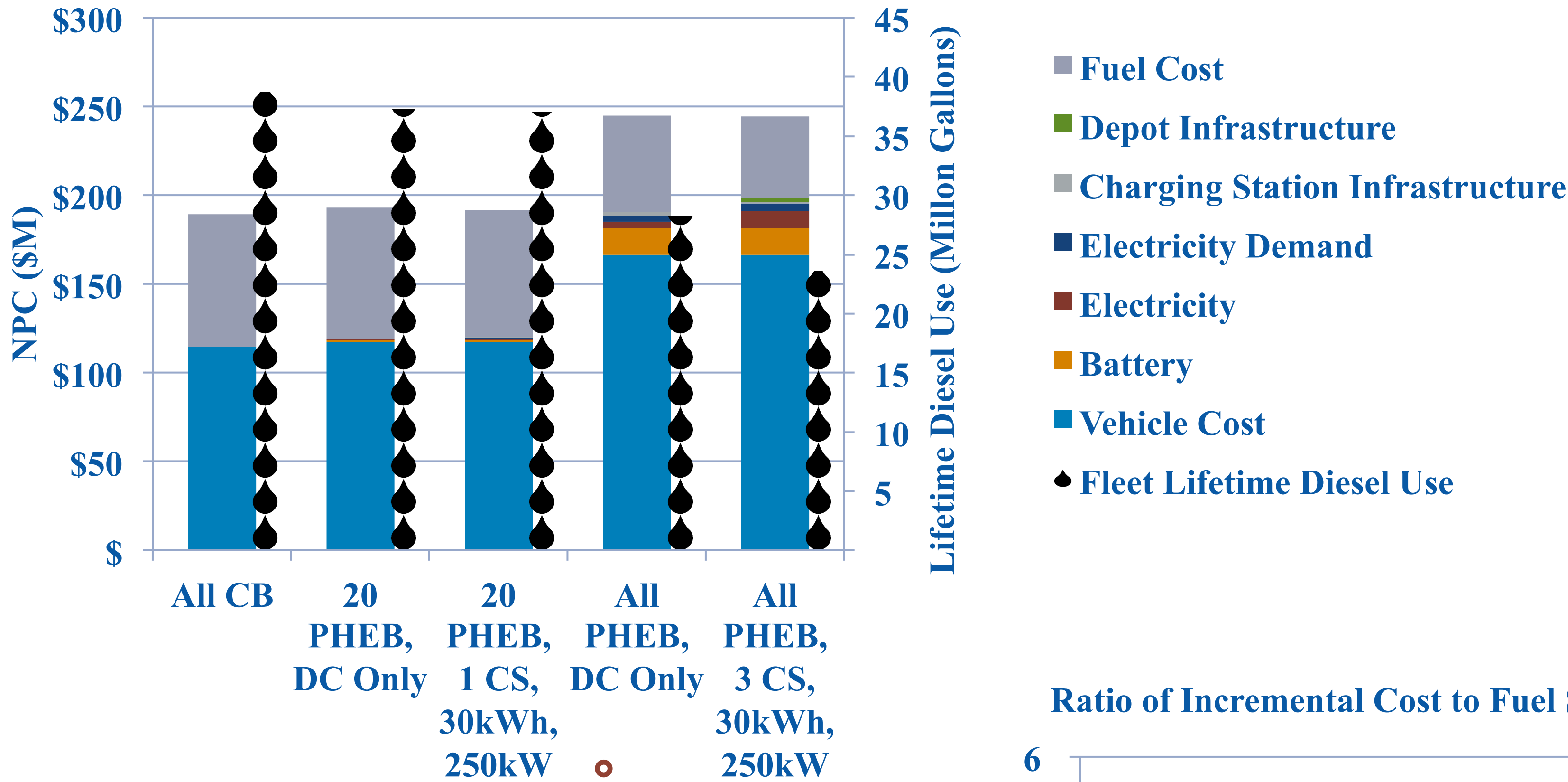
PHEB Incremental Rollout with Unfavorable Market Potential Assumptions







More Scenarios with Unfavorable Market Potential Assumptions



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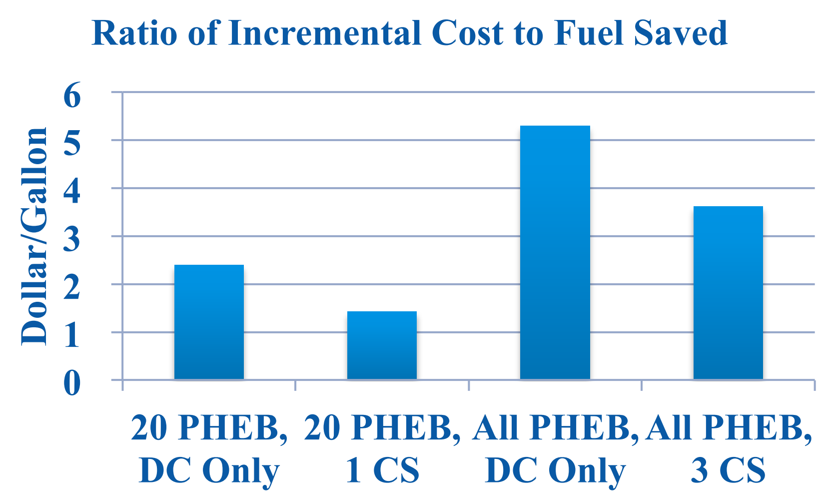

Conclusion

I. Comparison results of various scenarios:

A. Given current economic assumptions, the optimized PHEB scenarios were unable to outpace the NPC of the CB. However, PHEBs could achieve comparable lifetime costs as HEBs but tripled the fuel savings realized relative to CB.

B. The simulation results suggested the incremental rollout should start from 20 PHEB and 1 charging station.

II. Sensitivity analysis:

A. For favorable market conditions, each of the PHEB scenarios have a lower NPC than the CB, and the best fuel and cost savings occurs when all the CBs are replaced by PHEBs.

B. The unfavorable PHEB market potential assumptions unsurprisingly caused the PHEBs to have the highest NPC, but relative to the HEB and the PHEB with depot charging only the PHEBs with charging stations achieved the lowest incremental cost per gallon of fuel saved.

Questions?

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Acknowledgments

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