Vad vet vi om service och underhåll för bränslecellsfordon?

Hans Pohl

Lindholmen Science Park AB

Outline

- About the project
- Experiences of fuel cell vehicles - interviews
- Maintenance cost assessments
- Maintenance cost comparison
- Tentative conclusions

About the project

Title: Underhåll och reparation av bränslecellsdriven transport – en kunskapsöversikt

Goal: Document existing know-how regarding maintenance and repair of fuel cell drivelines for heavy duty vehicles

Budget: MSEK 1.4 whereof:

- MSEK 1.0 from the Swedish Energy Agency
- MSEK 0.4 from partners: Renova, H2X, Volvo Technology AB, Volvo Construction Equipment AB and Region Stockholm

Project leader: RISE Research Institutes of Sweden

Interviews and cost analyses: Lindholmen Science Park AB

Duration: January – December 2023

Sincere thanks to sponsors and other contributors to the project!

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Experiences of fuel cell vehicles - interviews

Actor	Person(s)	Country	Type of operation	
Renova	Janne Hukkamäki and Kenneth Johansson	Sweden	Two pre-series fuel cell refuse collection trucks from Scania	On-site
H2X	Magnus Olsson and Peter Westh	Sweden	Approximately 2,000 pre-series and series pick-ups and trucks with 2 or 3 axles operated in China	
KATECH	Sunho Yoon	Korea	24 Hyundai Nexo cars being operated as taxis during up to 4 years	
Auto Gewerbe Verband Schweiz	Jörg Merz	Switzerland	48 Hyundai trucks, 47 pre-series, 1 series	
First Aberdeen Ltd	Marcus Montgomery	United Kingdom	15 fuel cell city buses from Wrightbus (2 generations)	
AC Transit	Cecil Blandon and Jose Vega	USA	Transit buses with fuel cells from Van Hool and New Flyer	On-site

Interviews made in the period May - November 2023

Renova

- Delayed start due to lack of hydrogen
- Long waiting period not good for the vehicles
- Hydrogen-adapted workshop in construction

Hyundai Nexo 24 taxis project

- High milage was the goal
- Some cars reached more than 250,000 km within the project
- Regular service - many workshops available
- Service requiring empty hydrogen tanks – only few workshops available
- Few problems, even for cars with high milage

48 Hyundai Xcient trucks in Switzerland

Xcient Fuel Cell

Typ 4 Tanks with 31 kg at 350 bar

2 Fuel Cell System with 90kW power each

72 kWh Battery

7,700,000 km accumulated (September 2023)

Electric engine with 350 kW

Range 4x2 full payload, cooled with trailer: ca. 400 km

(Im Hyundai Xcient mit einer Tankfüllung von Lausanne nach St. Gallen)

48 Hyundai Xcient trucks in Switzerland

- No more breakdowns than with a diesel truck
- Plan to exchange fuel cell stacks at 400,000 km
- Approximately 9 days training for workshop personnel to handle high voltage and hydrogen

Challenges

- Refuelling of green hydrogen; availability, cost
- Workshop personnel, general shortage plus “Many see this new technology as a threat to their jobs”

15 FC buses in Aberdeen, Scotland

- Wrightbus, developed within EU project JIVE
- 27 kg hydrogen @350 bar
- 48 kWh batteries
- Range 320 km

15 FC buses in Aberdeen, Scotland

Hydrogen safe workshop, cost GBP 500,000 (MSEK 6,5).

If major accident, bus must be sent to another workshop and then hydrogen must be removed.

Challenges

- Capacity and availability of refuelling station
- Availability of engineer from Wrightbus
- Diagnosis system and dashboard often miss the root cause of the problem
- Availability approximately 70% (improving)

30 FC buses in Oakland, California, USA

Van Hool

- Fuel cell dominant
- 40 kg H2@350 bar
- Range 320 km
- Since 2011

New Flyer

- Battery dominant
- 38 kg H2@350 bar
- Range 480 km
- Since 2020

Liquid (grey) hydrogen trucked in, gasified and fuelled at bus terminals

Total ZEB milage > 8,000,000 km

30 FC transit buses in Oakland, California, USA

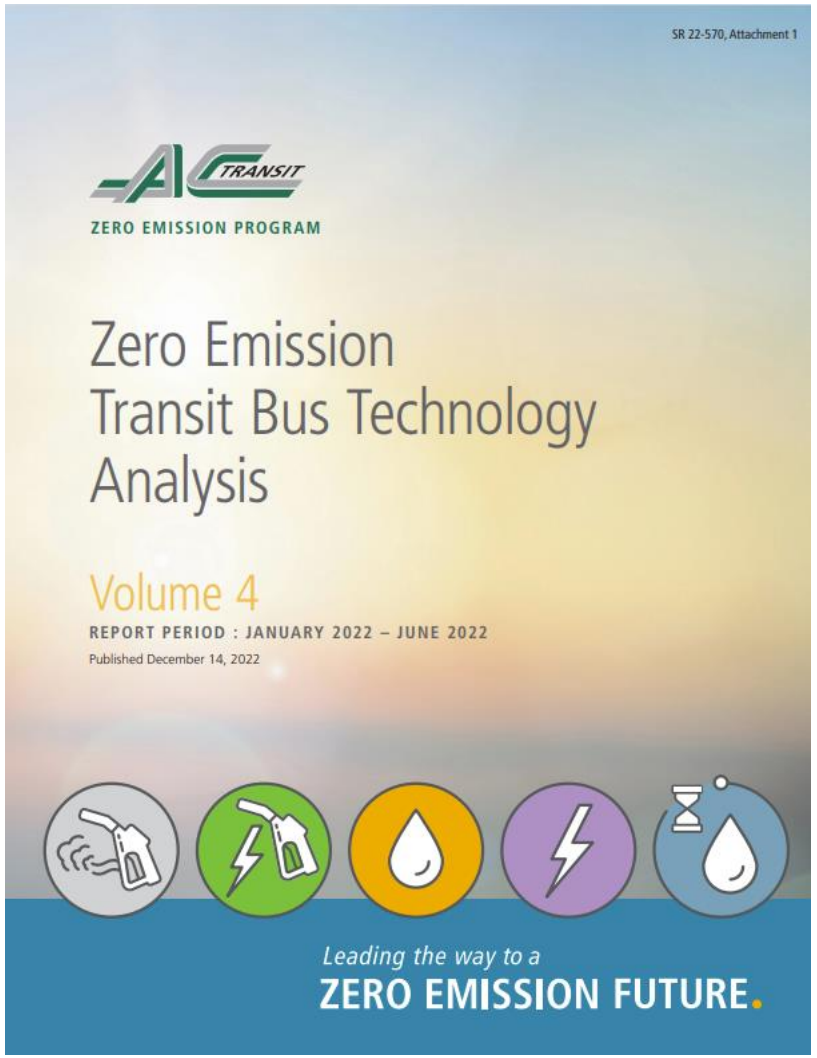
Adaptation of first workshop to become hydrogen safe 1 MUSD (10.5 MSEK). Second workshop, changed regulations, 0.3 MUSD (3.2 MSEK)

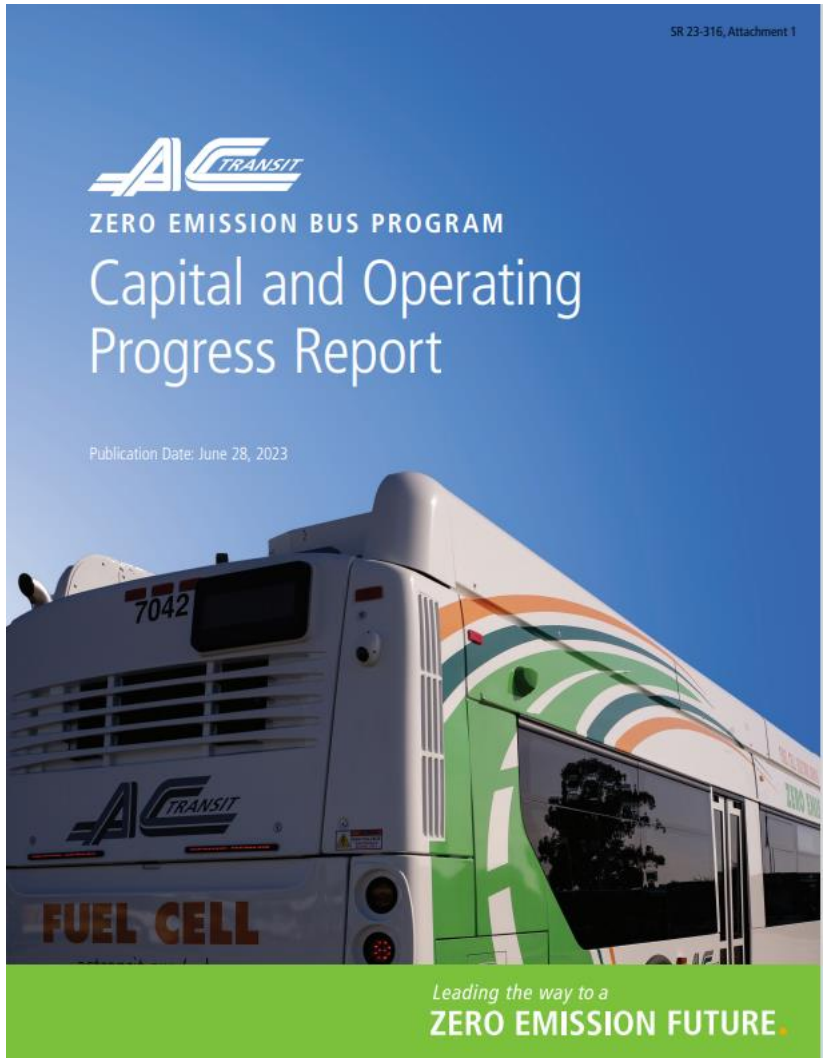
Challenges

- Spare parts
- Lack of trained technicians
- Diagnosing
- Cost

30 FC buses in Oakland, California, USA

Recommended literature



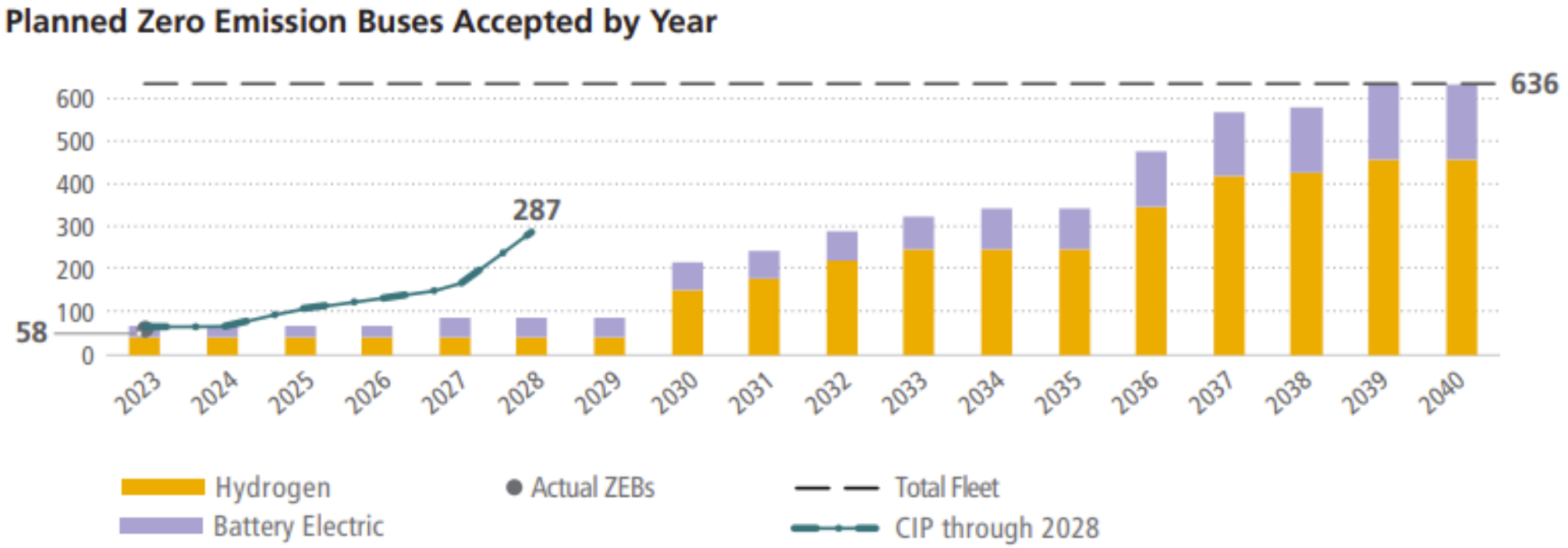


30 FC buses in Oakland, California, USA

From the reports – cost of operation per mile

COST/MILE	DIESEL	HYBRID	FCEB	BEB	LEGACY FC
Maintenance	$1.28	$2.37	$1.33	$1.15	$2.46
Energy (Fuel)	$1.01	$0.74	$1.19	$0.46	$1.69
Total	**$2.29**	**$3.11**	**$2.52**	**$1.61**	**$4.15**

30 FC buses in Oakland, California, USA



Plans have recently changed from:

- 30% hydrogen and 70% battery electric to
- 70% hydrogen and 30% battery electric

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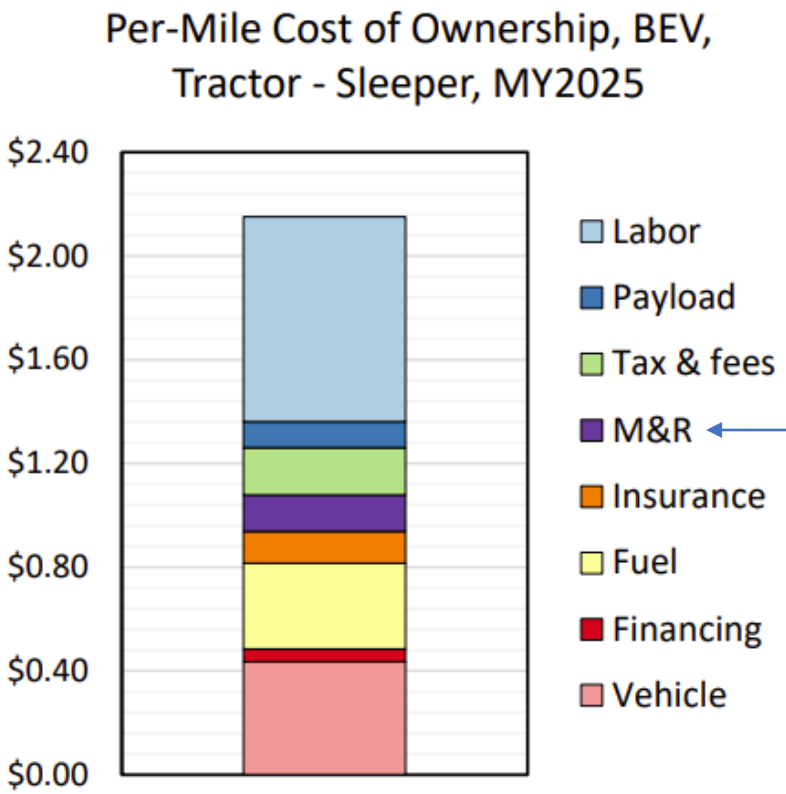
We look at a small part of the total cost of ownership



M&R = Maintenance and repair for heavy duty vehicles is our focus

Andrew Burnham, David Gohlke, Luke Rush, Thomas Stephens, Yan Zhou, Mark A. Delucchi, Alicia Birky, Chad Hunter, Zhenhong Lin, Shiqi Ou, Fei Xie, Camron Proctor, Steven Wiryadinata, Nawei Liu, and Madhur Boloor (2021) Comprehensive Total Cost of Ownership Quantification for Vehicles with Different Size Classes and Powertrains

US EPA argues like this

2.5.3.2 Maintenance and Repair

Like BEVs, data on real-world maintenance and repair costs for heavy-duty FCEVs is limited. We expect the overall maintenance costs to be lower for a heavy-duty FCEV than a comparable diesel- fueled ICE vehicle for several reasons. First, a FCEV powertrain has fewer moving parts that accrue wear or need regular adjustments. Second, FCEVs do not require regular replacement of certain fluids such as engine oil, nor do they require exhaust filters to reduce particulate matter and other pollutants. Third, the per-mile rate of brake wear is expected to be lower for FCEVs due to regenerative braking systems.

Leads to a scaling factor of 0.75 for fuel cell and 0.71 for battery-electric compared to the M&R cost for diesel trucks

Greenhouse Gas Emissions Standards for Heavy-Duty Vehicles: Phase 3
Draft Regulatory Impact Analysis, EPA-420-D-23-004, April 2023 (page 194)

The main US EPA reference provides further details

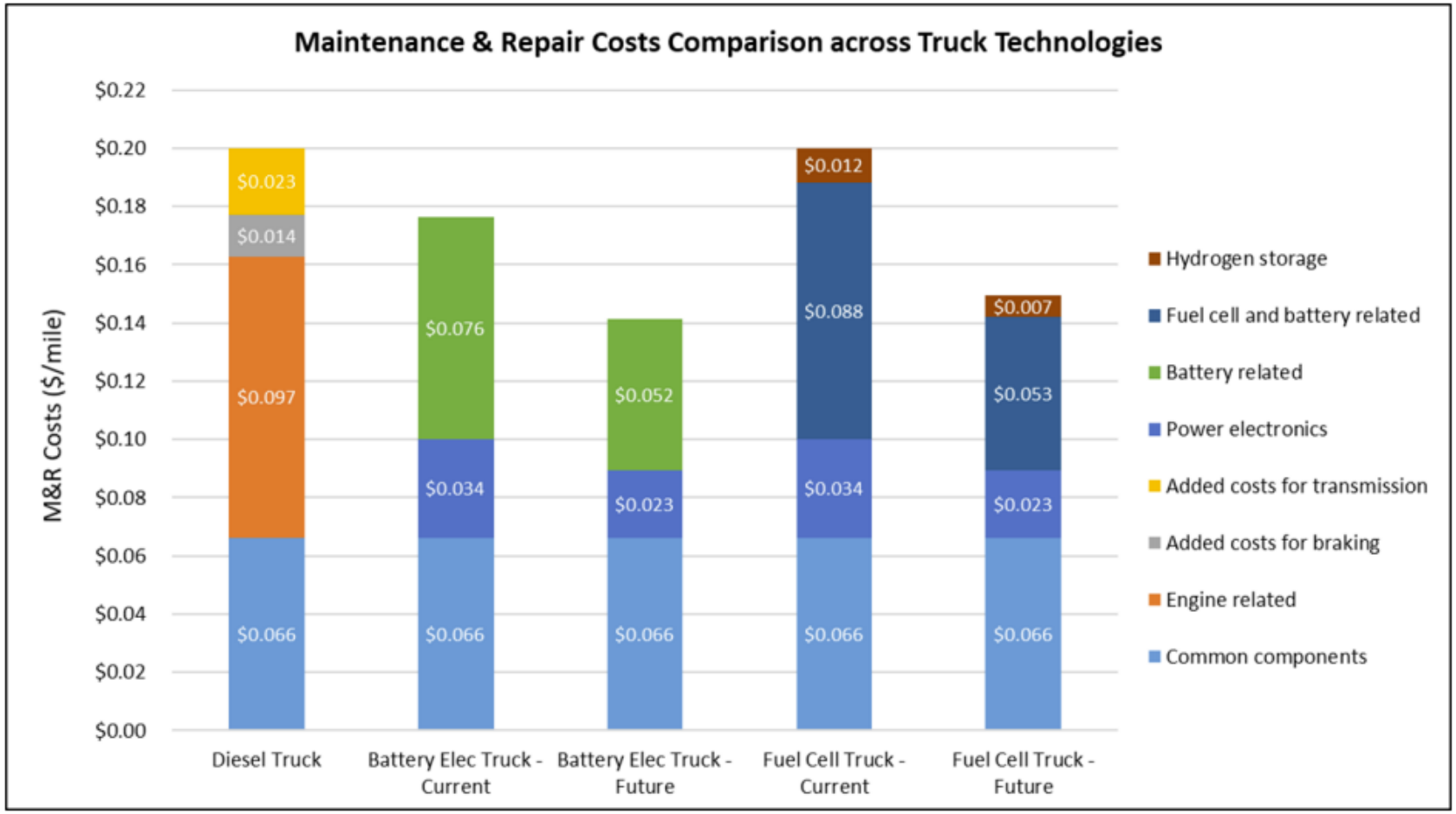


Figure 5. Heavy duty truck M&R cost breakdown and comparison across truck technologies

It should be noted that there are other researchers arguing for lower or higher M&R costs

Guihua Wang, Marshall Miller, Lewis Fulton (2022) Estimating Maintenance and Repair Costs for Battery Electric and Fuel Cell Heavy Duty Trucks

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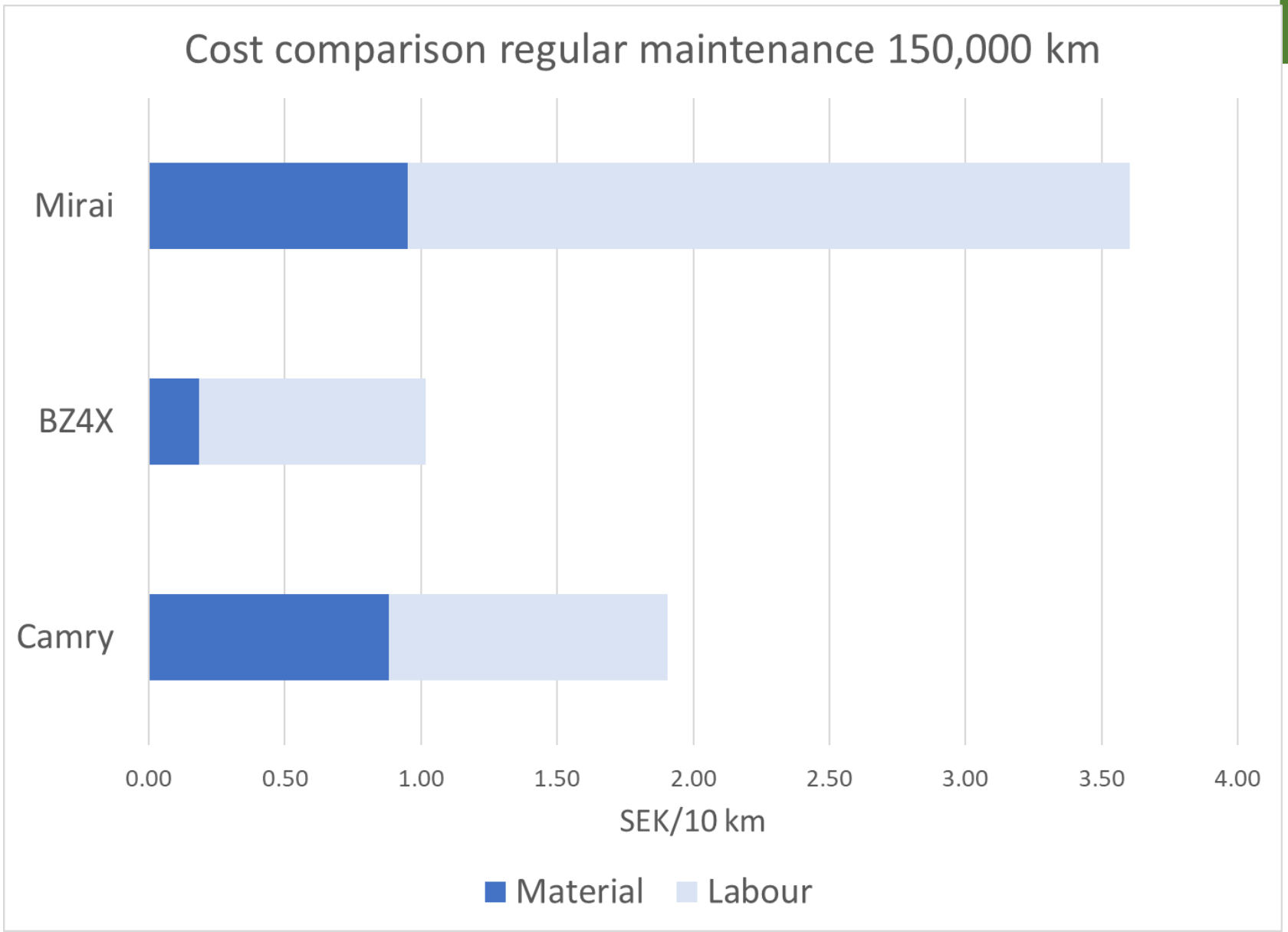
Regular maintenance cars - comparison

Based on data from Toyota, three similar cars with different powertrains were compared:

How often are components exchanged?

Maintenance every 15,000 km			
Kilometres between replacements (*1,000)			
	Camry	**BZ4X**	**Mirai**
Motorolja 0W20 1Liter (pris baserat på 5liter)	15		
Oljefilter	15		
Luftfilter	60		45
Kupéfilter	30	30	15
Oljepluggspackning	15		
Broms/kopplingsvätska 1 liter	30	30	30
HV filter	15		
Tändstift	150		
Packning		60	60
FILTER, EV BATTERY INTAKE			30
ELEMENT, FC COOLING WATER ION EXCHANGER			60
BREATHER, FC AIR COMPRESSOR			90

How much does regular maintenance cost?



Main cost drivers?

Camry
Engine oil (2/3 of material cost)

BZ4X
Labour (more than 80% of total cost)

Mirai
Labour (~3/4 of total cost).
The “ELEMENT, FC COOLING WATER ION EXCHANGER” represents 37% of material cost

Tentative conclusions

- It takes time to establish a complete ecosystem for hydrogen fuel cell vehicles
- Even though the vehicles in some cases are as reliable as internal combustion engine vehicles, additional costs still apply due to:
  - Limited availability of workshops, spare parts and skilled engineers
  - Problems with the hydrogen refuelling infrastructure
  - Lack of scale and time to optimize all details in the whole value chain
- Maintenance and repair of fuel cell vehicles *today* costs similarly, more, or much more than diesel vehicles
- Researchers argue that in the *long term*, costs for maintenance and repair should be lower than for diesel vehicles

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From the reports – availability per month