Technische Hochschule Ingolstadt

Upcycling commercial vehicles to FCEVs

Prof. Dr.-Ing. Alexander Gelner
Technische Hochschule Ingolstadt

Mario Mair, B. Eng.
Quantron AG

Elke Schropp, M. Sc.
Technische Universität München

QUANTRON

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Introduction

Master‘s thesis at Technische Hochschule Ingolstadt and Quantron AG

„Development of an Energy Management System for a Fuel Cell Powered Tractor Unit“

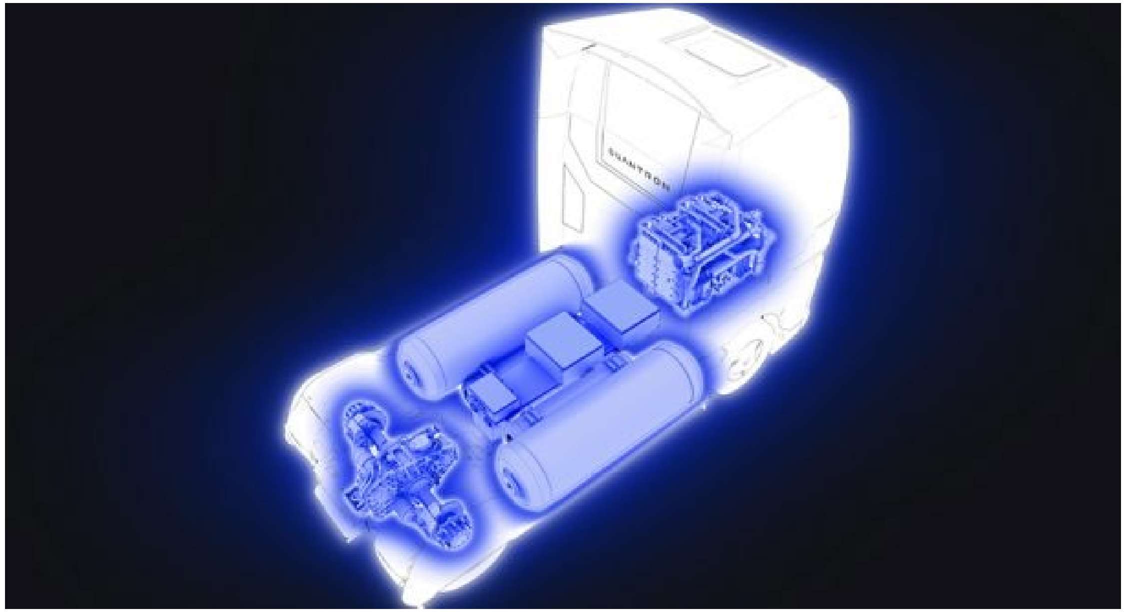
Technische Hochschule Ingolstadt

QUANTRON

+ supporting Life Cycle Assessment

Quantron QHM FCEV

https://www.quantron.net/q-truck/q-heavy/qhm-fcev/



https://www.quantron.net/q-truck/q-heavy/qhm-fcev/

- Base vehicle: MAN TGX
- Fuel cell: 240 kW
- Max. e-axle power cont. / peak: 420/550 kW
- HV-battery: 124 kWh
- Curb weight tractor unit: 8.5 t
- 54 kg H_2 at 700 bar
- 700 km range with 44 t

<u>Key targets energy management:</u>

1. Power availability
2. Efficiency
3. Lifetime of components

What is the environmental impact of this upcycling?

[The impact of newly-proposed emissions standards on commercial vehicles (fleetequipmentmag.com)](fleetequipmentmag.com)

Methodology

Life Cycle Assessment in accordance with ISO 14040 & ISO 14044

Phase 1: goal and scope

→ Definition of research question and boundaries

Phase 2: inventory and analysis

→ Using the *ecoinvent* database and literature

→ Generic data (not vehicle-specific) used

Phase 3: impact assessment

→ Using *Activity Browser* for calculation of greenhouse gas emissions

Phase 4: interpretation

(+ Phase 5: review by TUM)

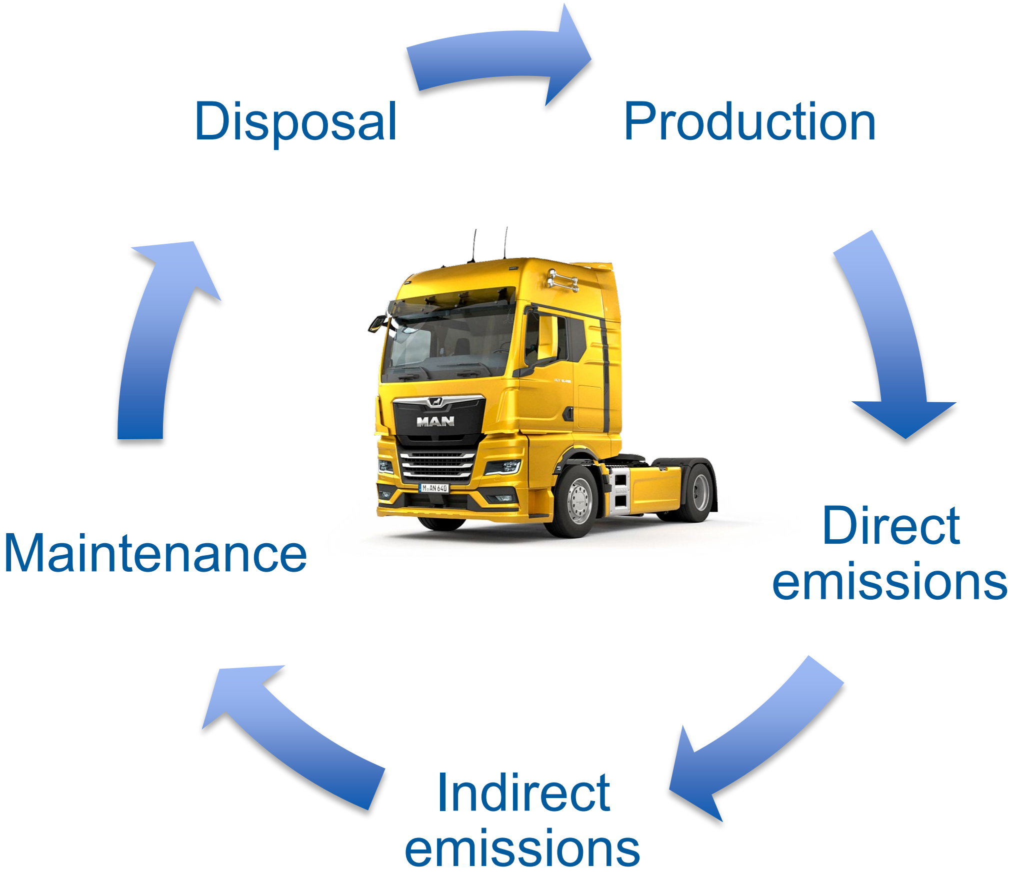
Source: LCA (Life Cycle Assessment) | Fassa Bortolo

Methodology

Scope

Our LCA takes into account:

- Production of the truck
- Usage of the truck for freight transportation:
  - Fuel (Well-to-Wheel)
  - Maintenance
  - Brake, tyre and road wear
  - Road maintenance
- Disposal of the truck



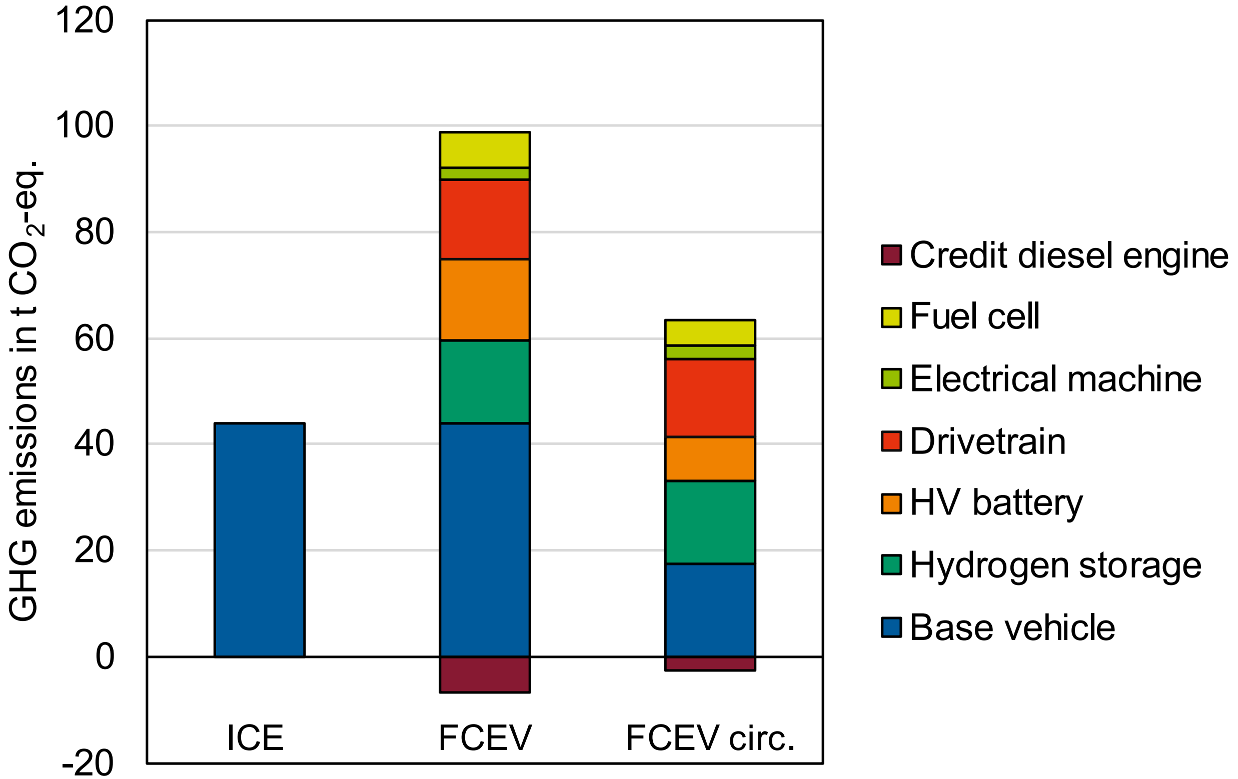
GHG emissions of truck production and disposal

Circular economy approach für all categories added

Note: production includes

disposal/recycling at end of life!

Category	**Main driver**
Base vehicle	Steel
Hydrogen storage	Carbon fiber
HV battery	Aluminum
Drivetrain*	Gold
E-machine	Aluminum
Fuel cell	Platinum, plastic



** Drivetrain components w/o battery and motor, e.g. inverter, converter, on-board-charger, wiring, power distribution unit*

GHG emissions of truck usage

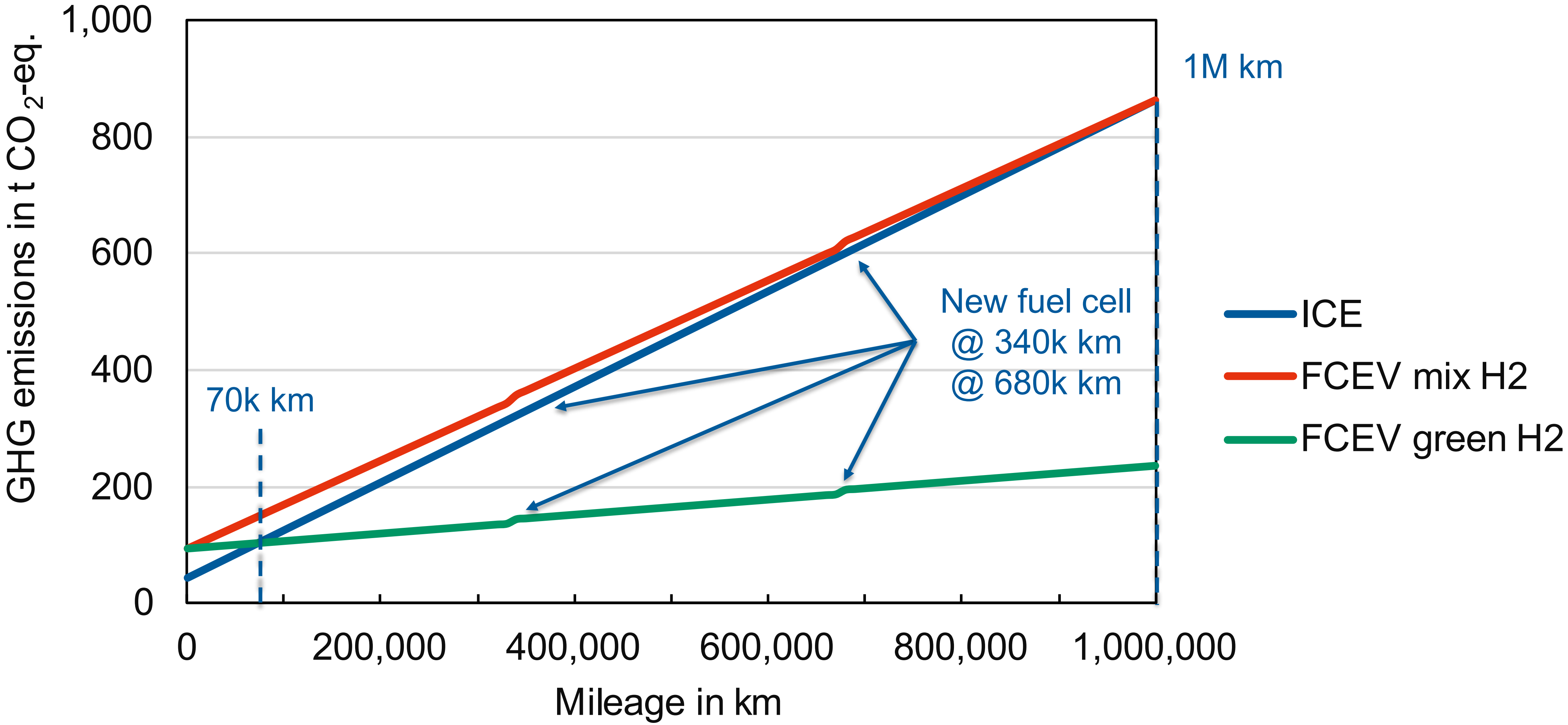
Assumptions for LCA

Main parameters	Value	Source
Average payload	19.3 tons	VECTO[1]
Diesel consumption	26.3 l / 100 km	ETC 2021[2]
WTW diesel	3.07 kg CO_2-eq. / l	[Gu21][3]
WTT H_2 mix (Germany)	9.01 kg CO_2-eq. / kg	ISE[4]
WTT H_2 green (PV + wind)	2.09 kg CO_2-eq. / kg	ISE[4]
Indirect emissions*	$1.89 \cdot 10^{-5}$ kg CO_2-eq. / tkm	ecoinvent

1 Vehicle Energy Consumption calculation TOol - VECTO - European Commission (europa.eu)
2 European Truck Challenge 2021
3 https://doi.org/10.1016/j.trd.2021.102757
4 Treibhausgas-Emissionen für Batterie- und Brennstoffzellenfahrzeuge mit Reichweiten über 300 km (fraunhofer.de)
** maintenance; road; brake/road/tyre wear*

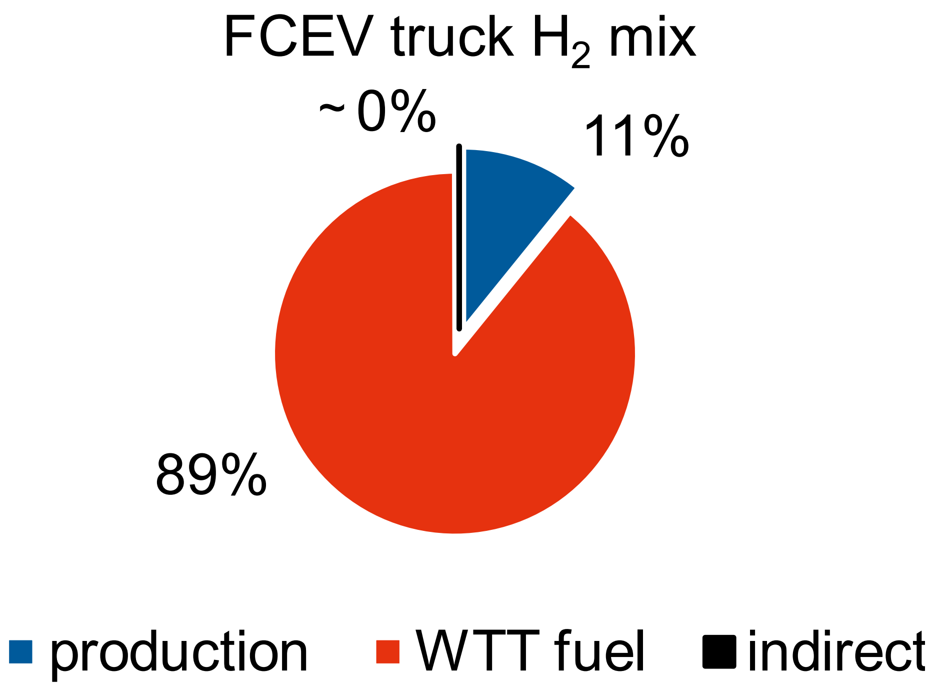
GHG emissions of truck usage

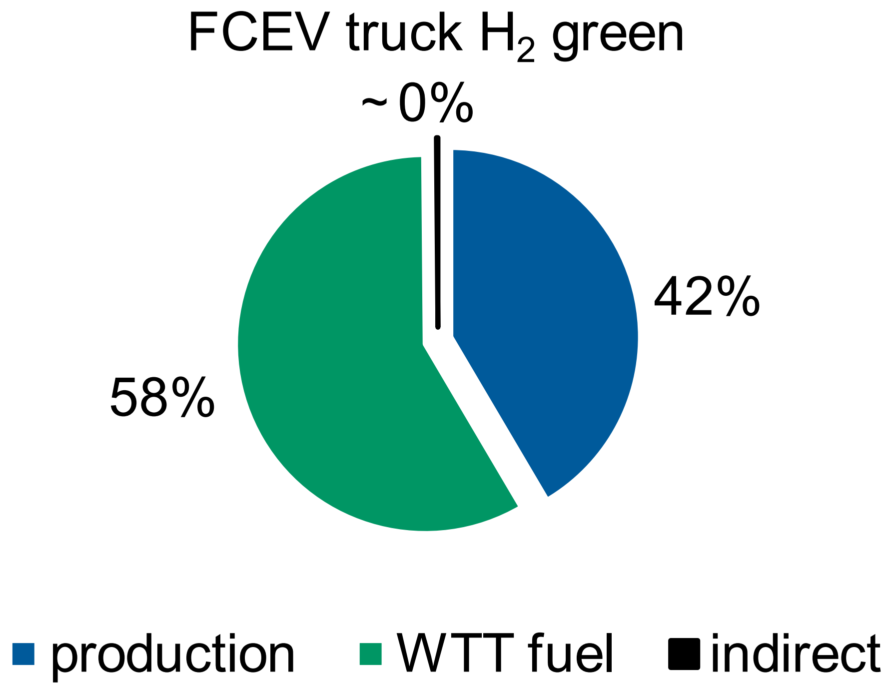
Break-even point with ICE @ 1 million km (H_2 mix) | 70,000 km (green H_2)



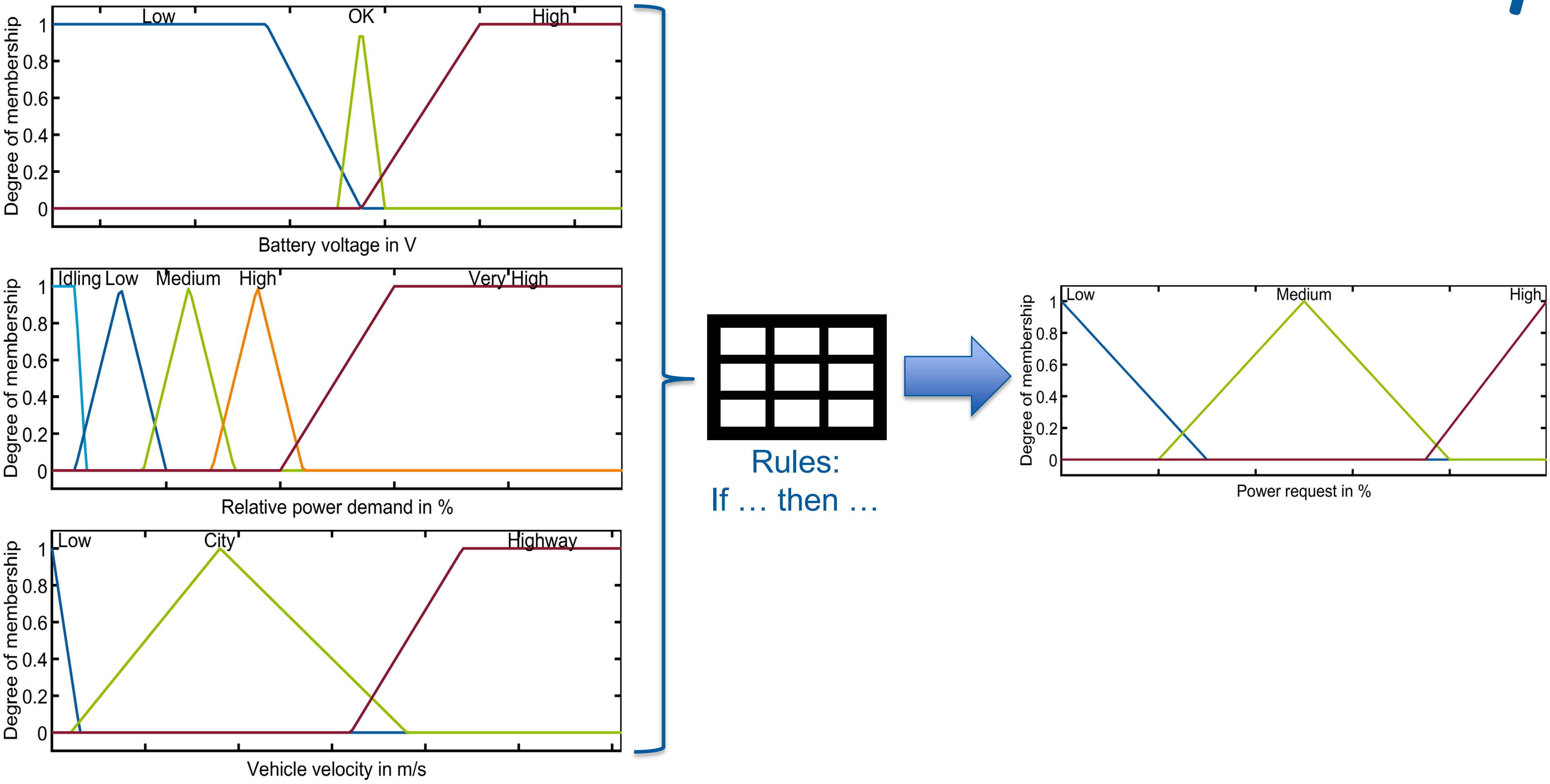
GHG emissions of FCEV truck product life cycle

Fuel-related emissions have the major impact on life cycle emissions!

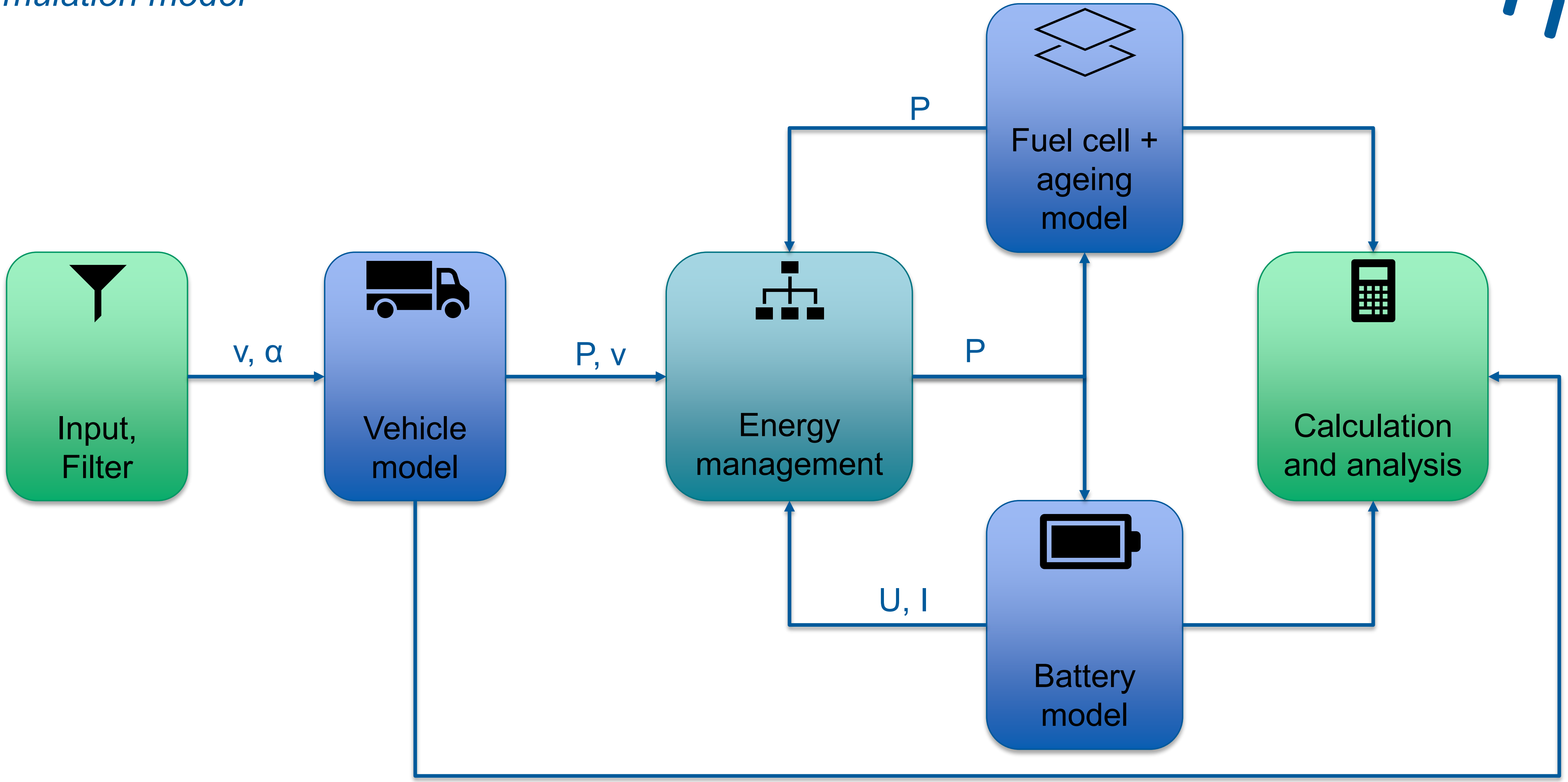




Optimized Energy Management System via Fuzzy-Logic

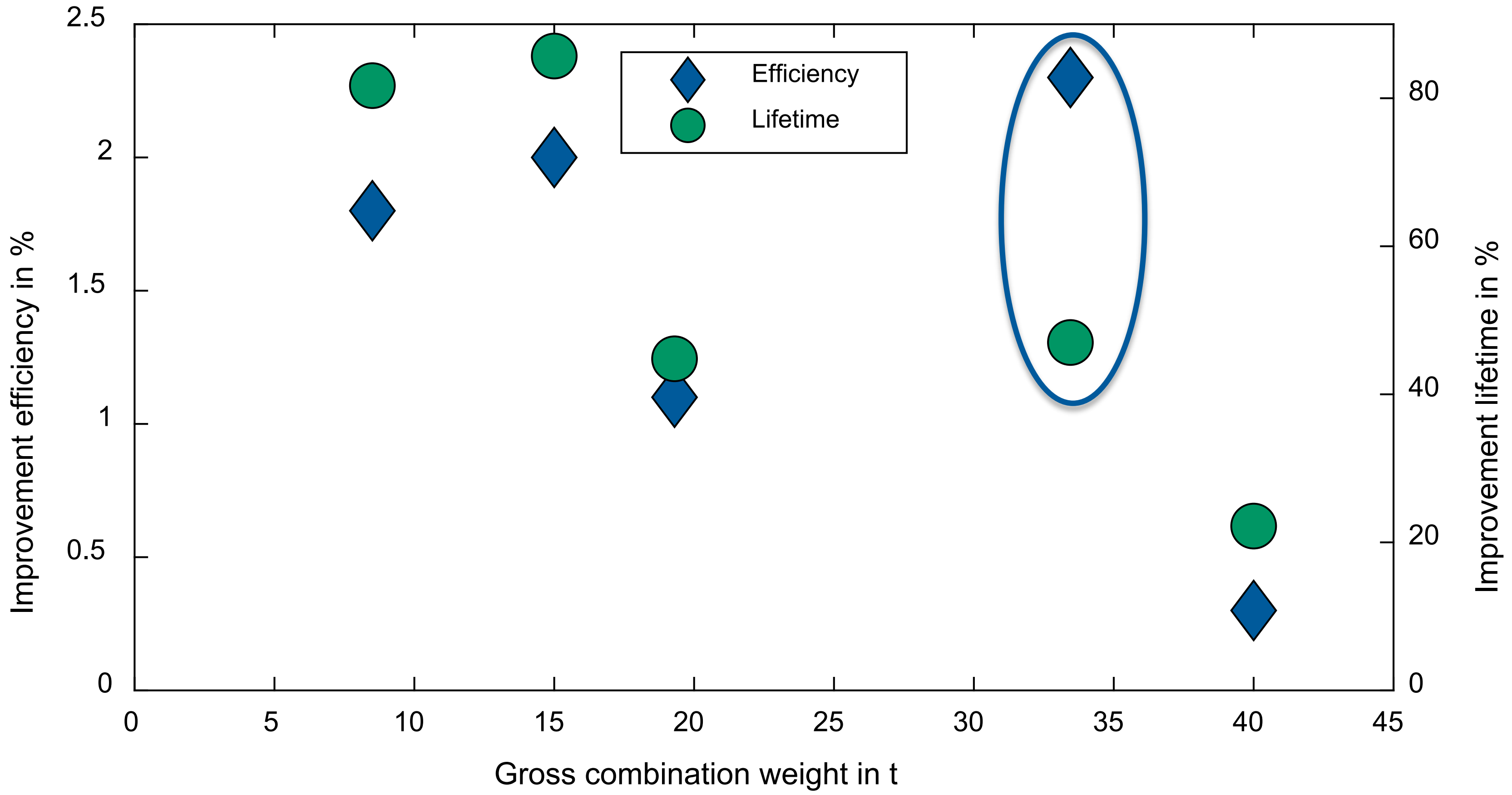


Simulation model

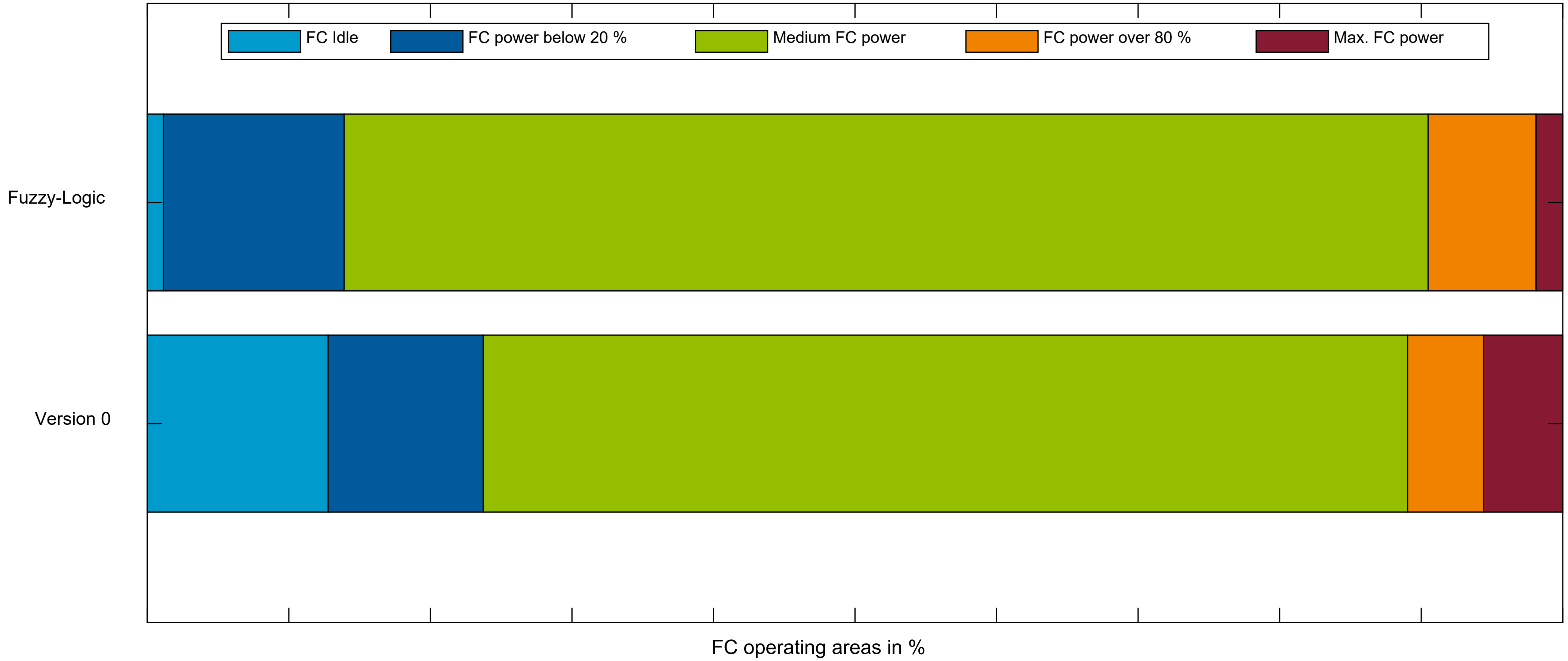


Simulation results - improvements

Efficiency / Range	Lifetime	TCO
0.3 – 2.3 %	**22.2 – 85.7 %**	**11 – 30 %**

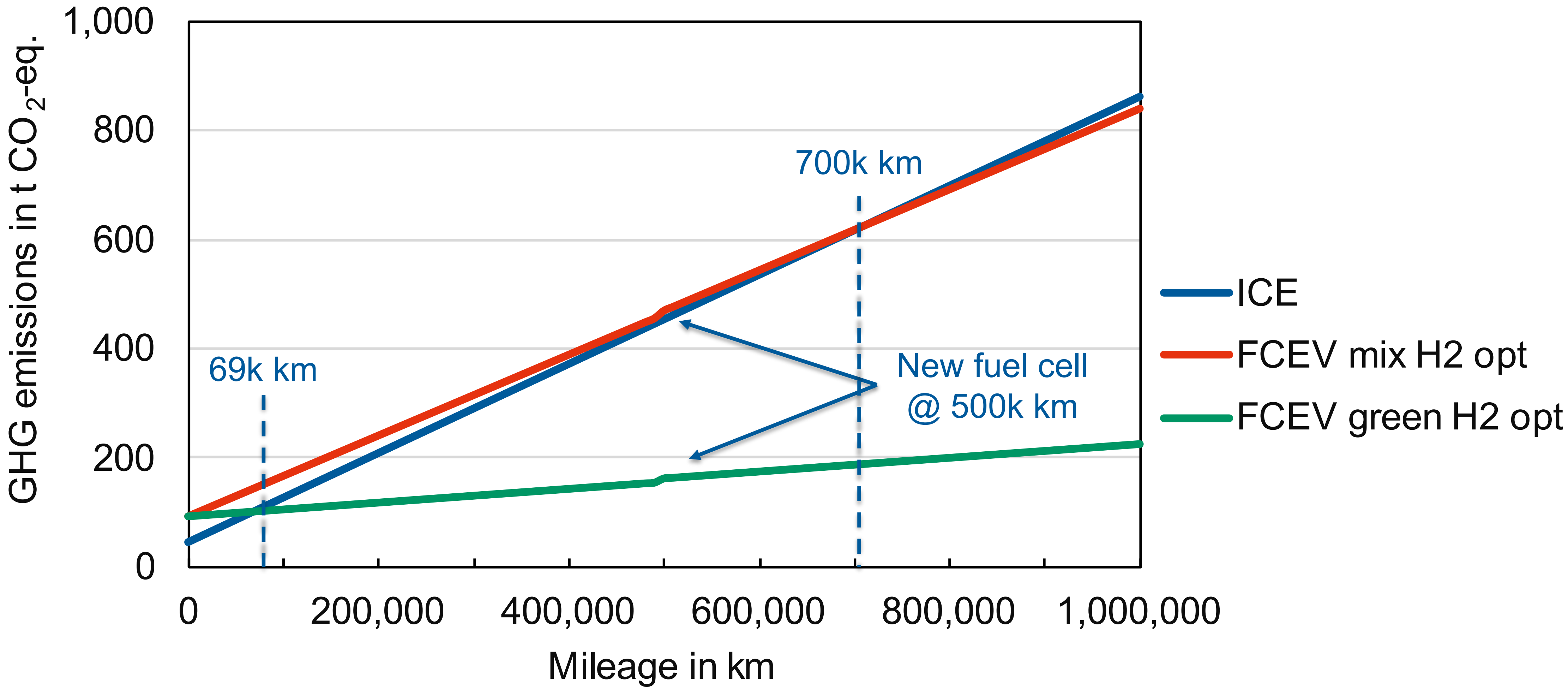


Simulation results – fuel cell operation



GHG emissions of lorry usage

Impact of optimized operation strategy: 24 t CO_2-eq. saved (H_2-mix) | 10 t CO_2-eq. saved (green H_2) | one fuel cell saved



Conclusions and Outlook

LCA performed in accordance with ISO 14040 & ISO 14044:

Fuel-related emissions have the major impact on life cycle emissions.

The optimized energy management system via fuzzy-logic improves fuel efficiency up to 2.3 % and expands lifetime of fuel cell up to 86 % depending on the payload.

With average payload, this saves up to 24 t of GHG emissions per truck.

Thank you for your attention! Remaining questions?