Hogeschool van Arnhem en Nijmegen
HAN University of Applied Sciences

Praktijkonderzoek ix35 FCEV



door:

Lejo Buning
(HAN Automotive Research)

Inhoud

- Voorstellen
- HAN Automotive Research
- ix35 project
- Opzet
- Resultaten
- Vergelijk met BEV’s & ICE’s
- Vragen

Lejo Buning

Wie is…

- **1956**
- **1980**
- **1992**
- **Nu**
  - Projectleider ***i***-Mobility
  - PdH-Candidate on Professional Higher Education

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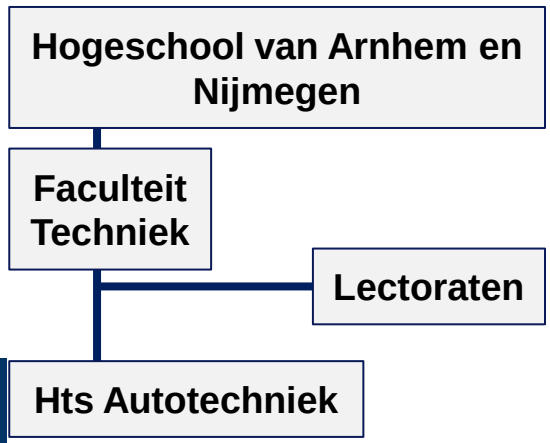
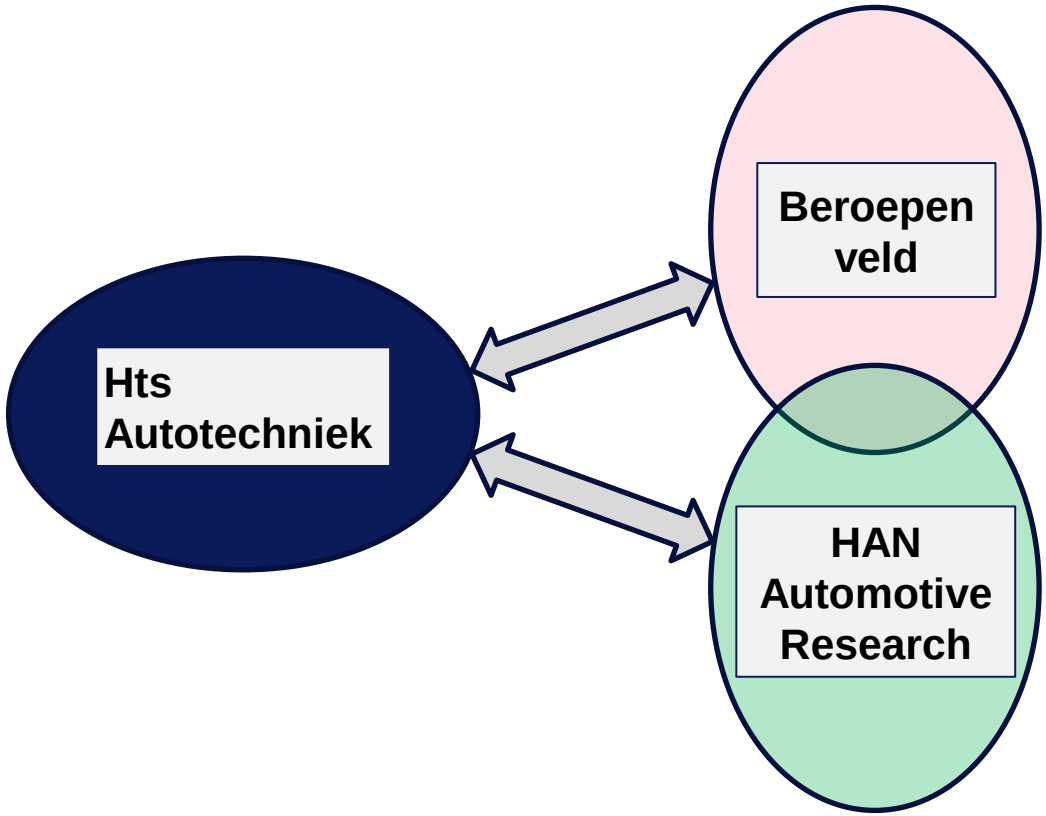
HAN Automotive Research

- Toegepast onderzoek
- Beroepenveld
- Onderwijs





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HANAR - Projecten

- INTRALOG
- VIANOVA
- Ix35 FCEV – Praktijk onderzoek

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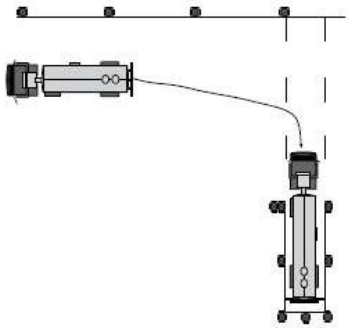
INTRALOG - The project

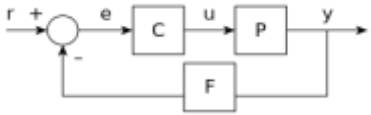
Intelligent Autonomous Truck Applications in Logistics

Main Goal: PPP improvement by AGVs, by

Logistic frame ⇨ (wp2)



Business ⇩ Requirements (wp1)



AGT Control design ⇨ (wp3)

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Two Stage Autonomous Docking (Double Articulated Vehicle)

Via Nova

Image source: latimes.com

Traffic Conditions

Image source: patternsall.blogspot.com

Incidents

Image source www:.lookers.co.uk

Road Anomalies

Image source : www.infobae.com

Slippery Roads

Image source : nypost.com

Temporary Conditions

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VIA NOVA

Hyundai ix35 FCEV

Opdrachtgevers:

Gemeente Arnhem 1 voertuig en
Rijkswaterstaat 2 voertuigen

Onderzoek(deel)trajecten:

- **Evaluate the fuel efficiency**
- **Assessment of the well-to-wheel energy usage**
- **Gain insight in the user experience of the vehicle**

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Hyundai ix35 FCEV

2 jaar en 3 maanden
63 parameters
Nederland, België, Duitsland
Arnhem, Helmond en Rhoon

Rhoon

Helmond

Arnhem

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Hyundai ix35 FCEV

The fuel tank (1) has a pressure of 700 [bar]…

lithium polymer battery pack (2) of 24 [kWh], charged by the fuel cell (3) and captured when braking…

Inverter converts (4) direct current from the fuel cell to alternating current to the motor and regulates engine speed and torque.

The electronically controlled transmission (5) recovers energy during braking.

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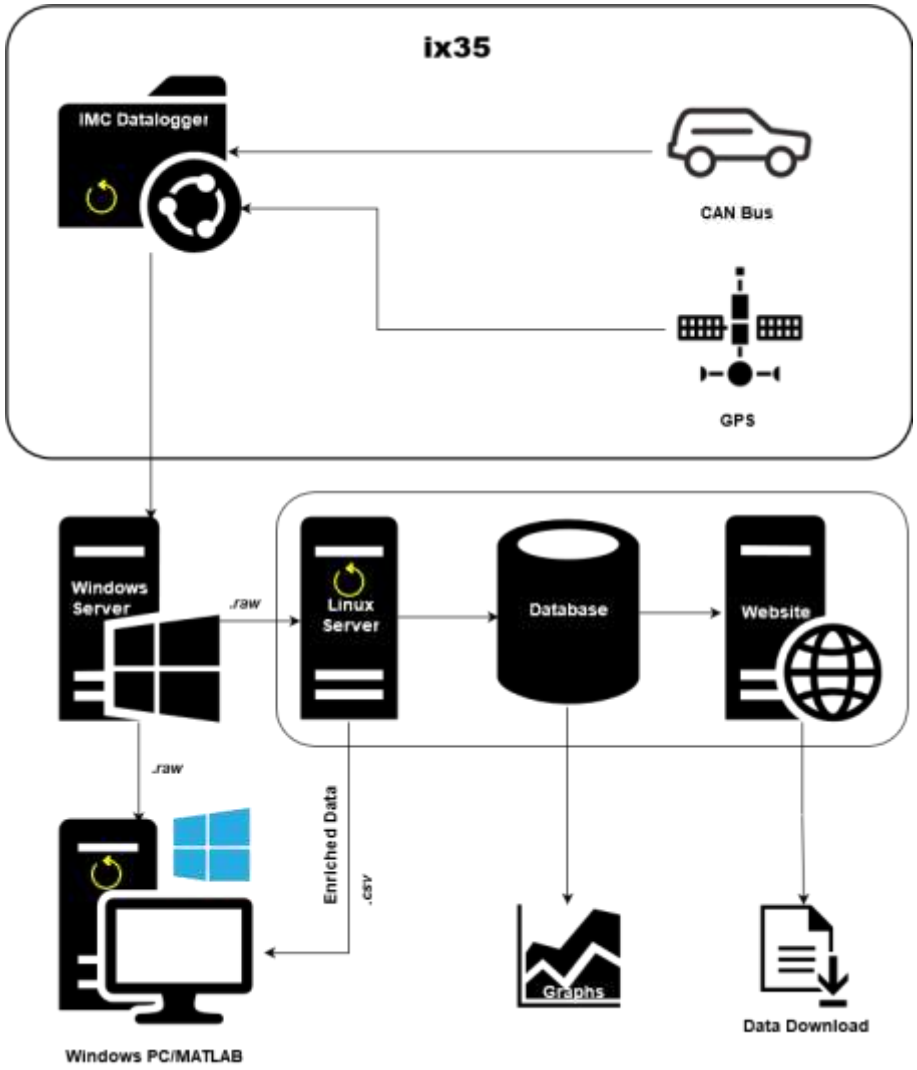
Data acquiring…

For monitoring - while driving - behavior, status and performance of the:

- **Fuel tank**
- **Fuel cell system**
- **Driver**
  - **Subjective: surveys**
  - **Objective: steering, braking, lateral- and longitudinal behaviour (acceleration)**
  - **AC and Drive Selector**



Fuel Efficiency (1)

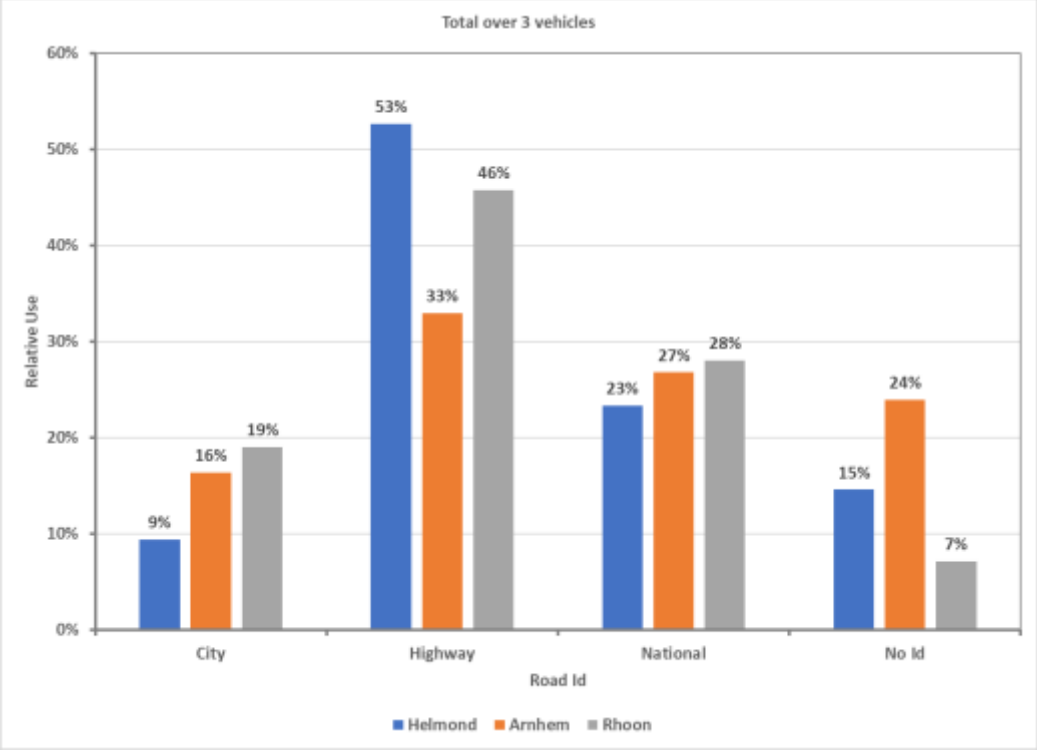
Vehicle	#Trips	Total trip time	Total distance coverred	Total Hydrogen mass	Mean values		
					Trip distance	Speed	Fuel Efficiency
	-	hr	km	kg	km	km/hr	km/kgH_2
Helmond	681	477	32084	358.6	47	67	89.5
Arnhem	596	213	10205	124.8	17	47	81.8
Rhoon	1108	353	20067	257.8	18	57	77.9
Fleet	**2385**	**1043**	**62356**	**741.1**	**-**	**-**	**84.1**

Fuel Efficiency (2), Road type

Impact of road type on fuel efficiency

GPS_road	Mean Speed km/hr	Mean Fuel Efficiency km/kgH2
City	**17,7**	**81,6**
Highway	**88,7**	**83,4**
National	**41,7**	**85,1**
No Id	**40,7**	**81,2**

Helmond, Arnhem & Rhoon – Impact of road usage



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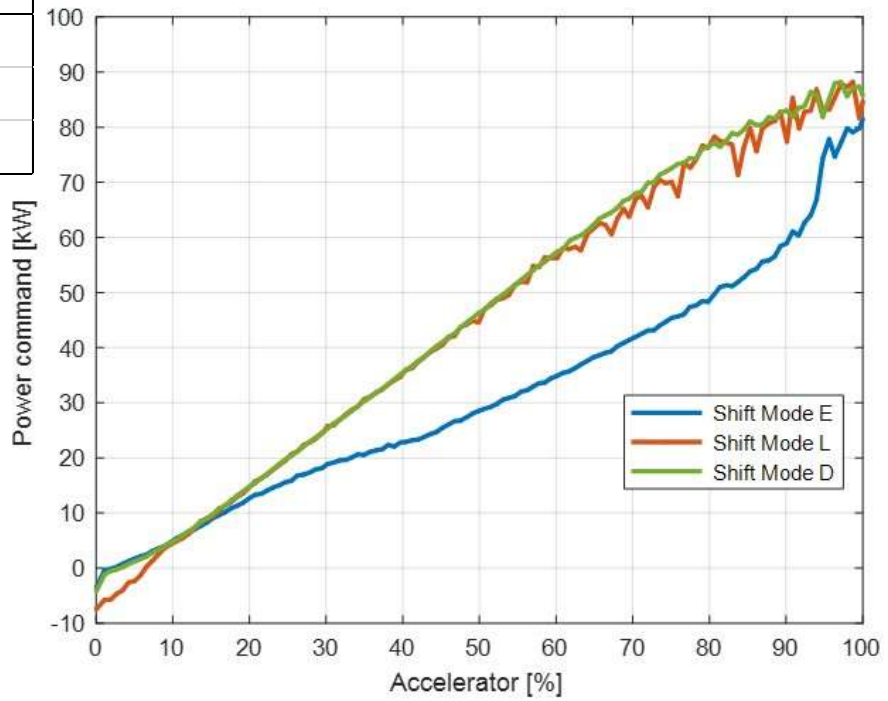
Fuel Efficiency (3), Drive mode

Impact of the drive mode on fuel efficiency

Drive Mode	Mean Acelerator Pedal position %	Mean Vehicle Speed km/hr	Mean Fuel Efficiency km/kgH_2
D	**18,7 (σ:17,6)**	**60,3**	**83,7**
E	**27,4 (σ:23,7)**	**65,3**	**84,0**
L	**15,3 (σ:17,2)**	**45,0**	**85,2**



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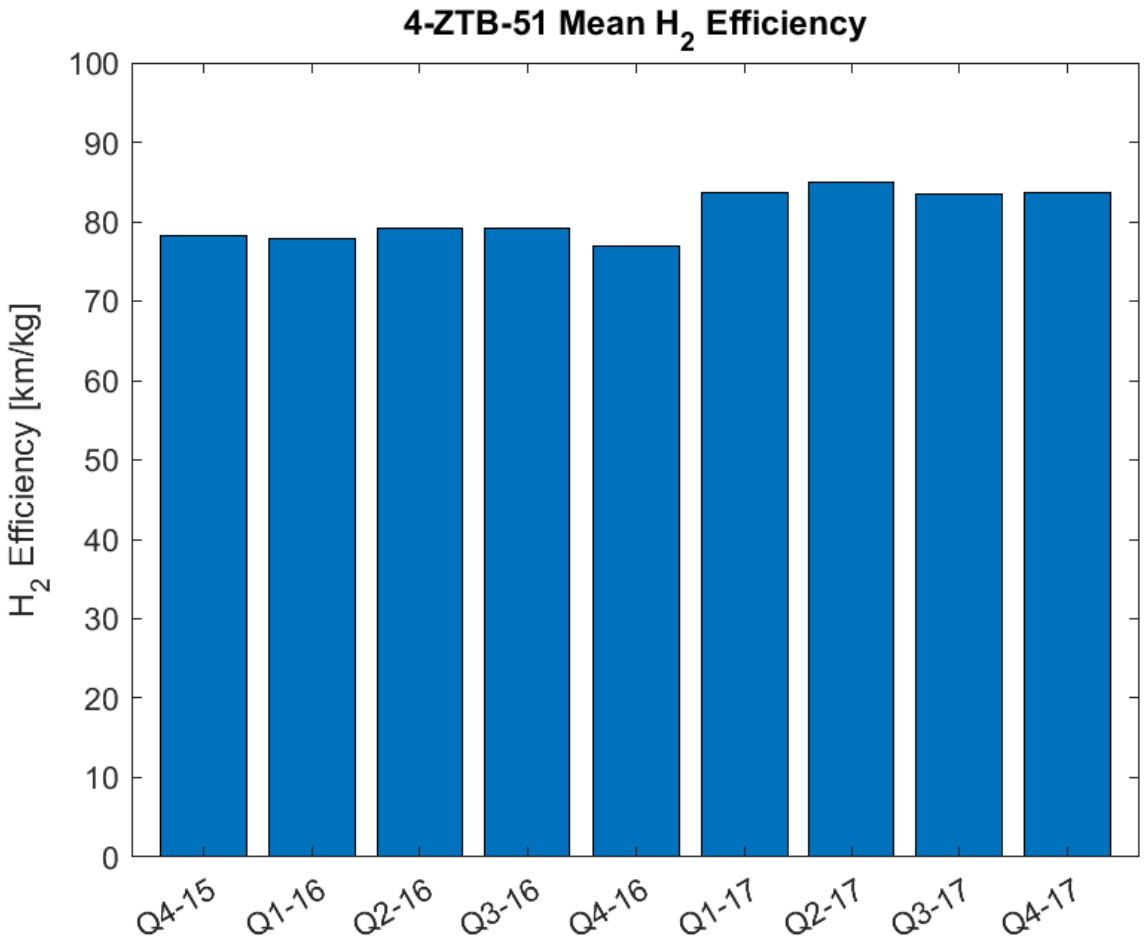
Fuel Efficiency (4 - Arnhem)

Aggregated results Arnhem vehicle - Fuel Efficiency

81.8 km/kgH_2

73.6 km/kgH_2

85.8 km/kgH_2



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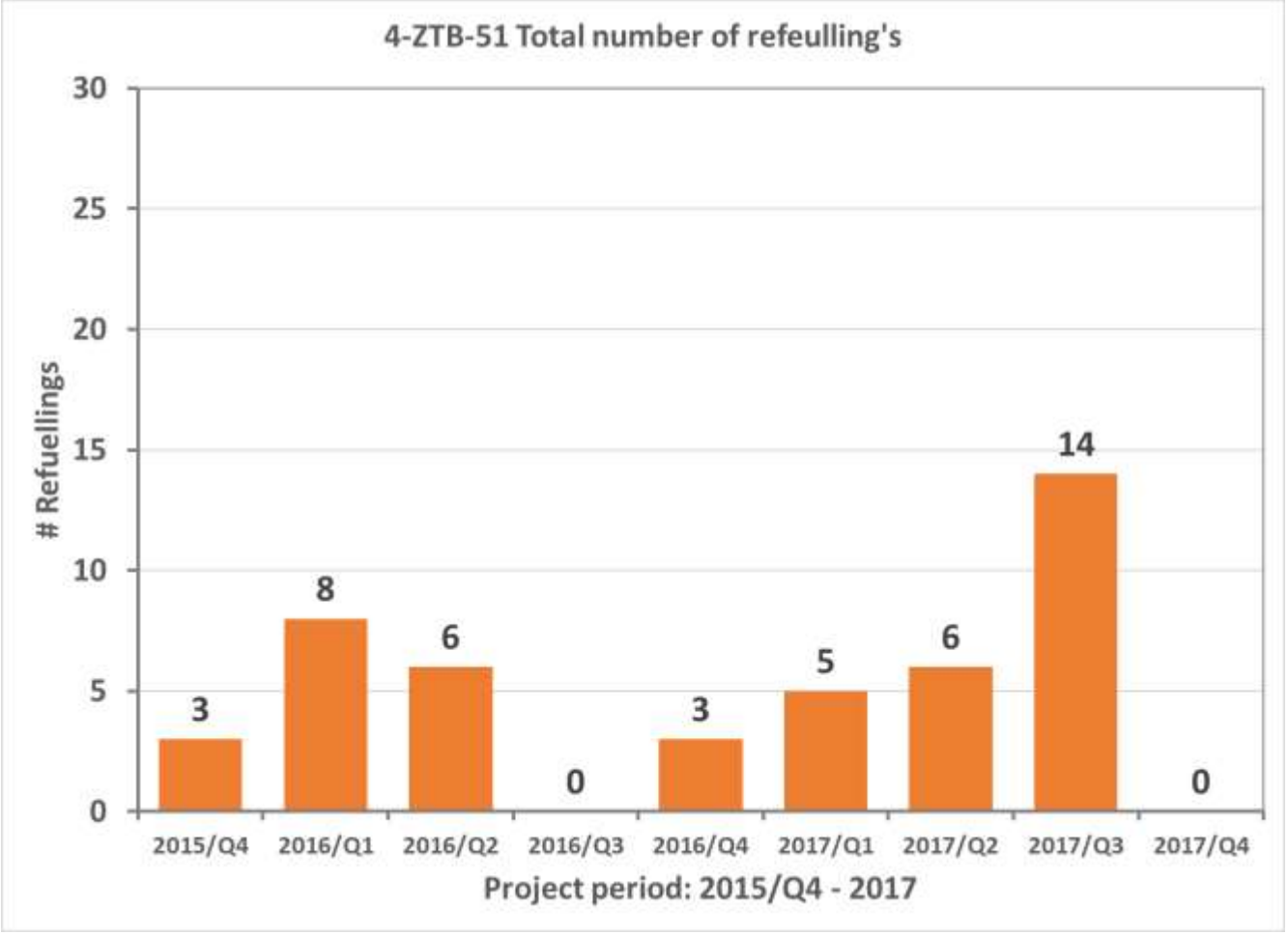
Fuel Efficiency (5 - Arnhem)

Arnhem vehicle - Quarterly refuels (vehicle data)



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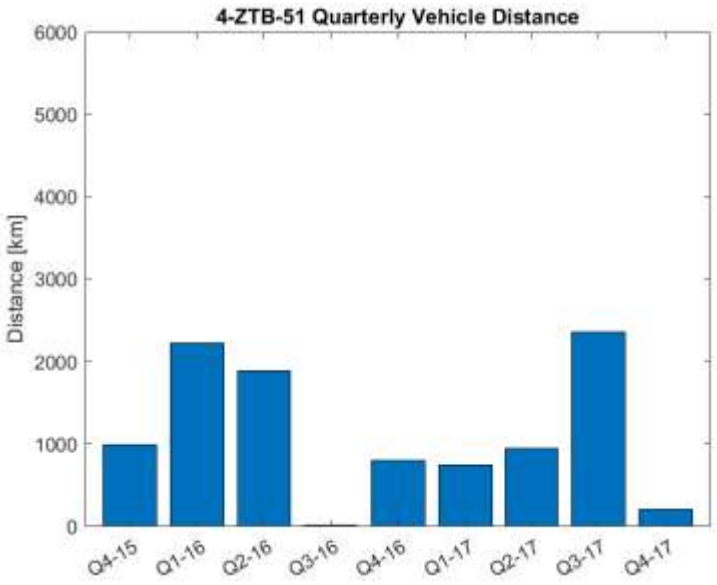
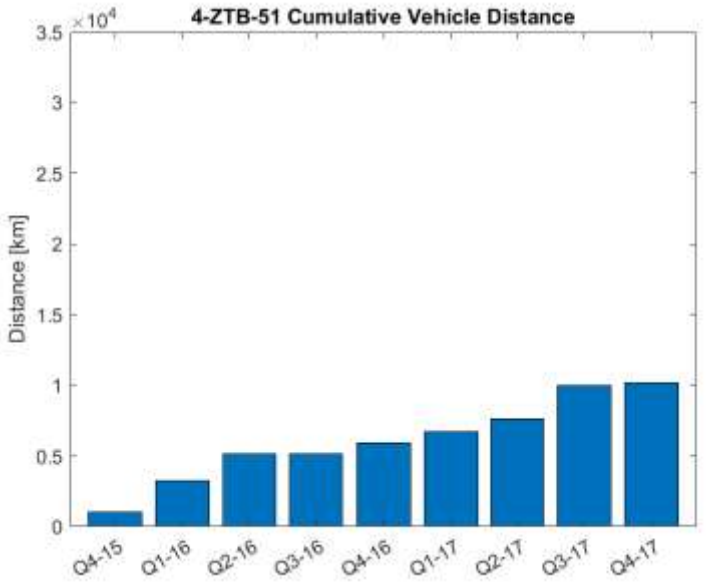
Fuel Efficiency (6 - Arnhem)

Aggregated results Arnhem vehicle - Distance driven





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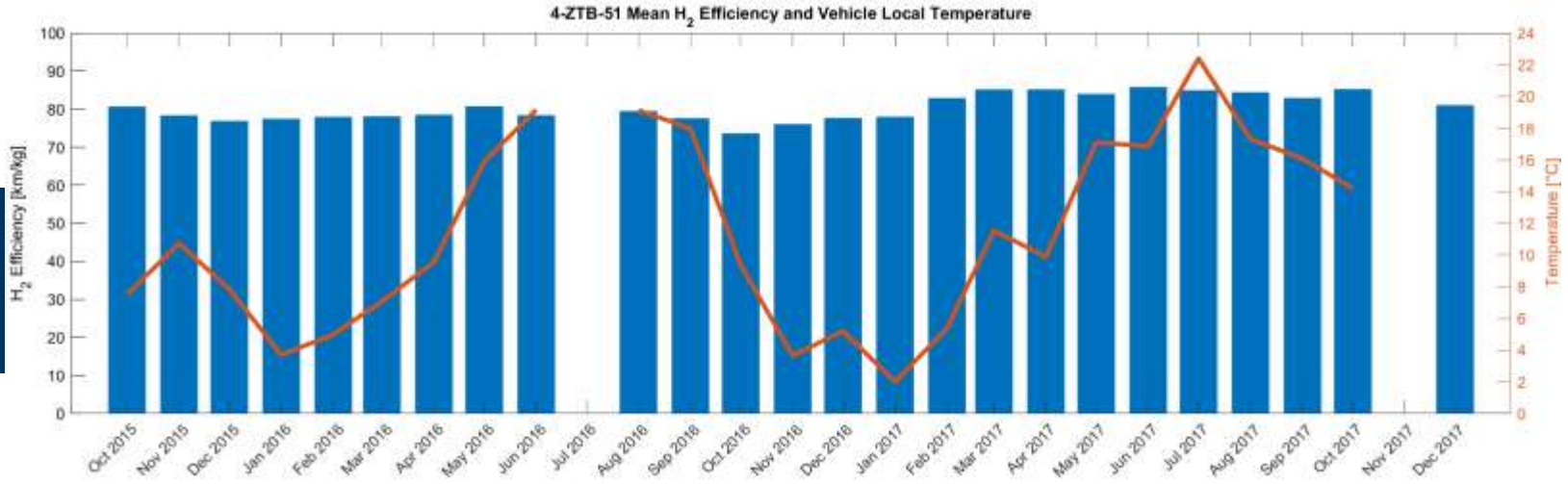
Fuel Efficiency (6 - Arnhem)

Arnhem vehicle - fuel consumption and temperature

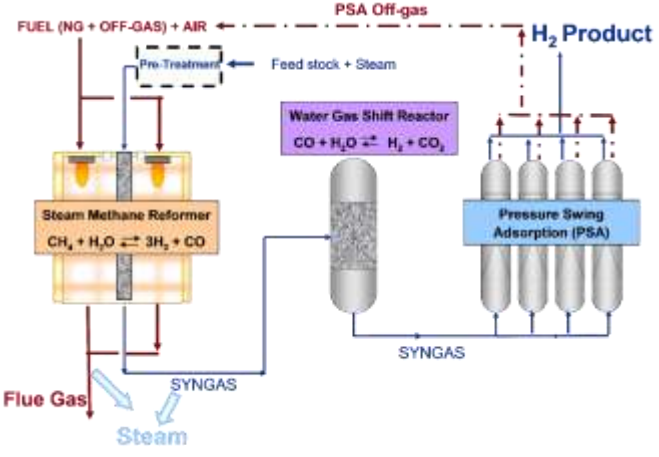
Average fuel efficiency	**81.8 km/kgH_2**.
The minimum	**73.6 km/kgH_2** in October 2016 (T_{AQ} = 9.4^{o}C)
The maximum	**85.8 km/kgH_2** in June 2017 (T_{AQ} = 16.9^{o}C).

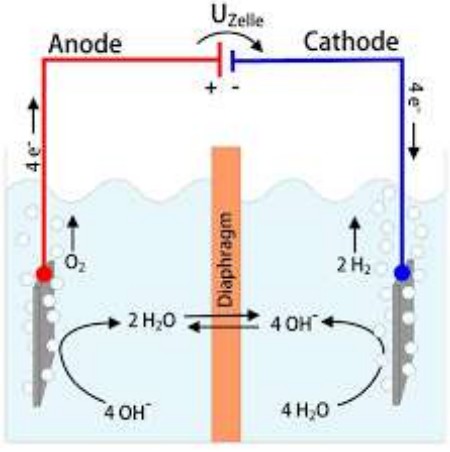
No impact of the environmental temperature on the fuel efficiency could be established.
A minor effect could be seen in the min./max. value; during the summer months these values are little less than the winter months.
The results during the month of august (2016 and 2017) can be affected by the repairs on the vehicle in those periods.



Well-to-Wheel (1)

Well-to-wheel (WTW) fuel chain, consisting of well-to-tank and tank-to-wheel parts.





Tank to Wheel (TTW)

Well to Tank (WTT)

Feedstock production → Transport → Fuel production → Distribution → Fuel use in vehicle

Well-to-Wheel (1)

Helmond Waterstofnet	Rhoon Air Liquide			Arnhem HyGear	
Electrolysis (on site)	Electrolysis (GC)	Electrolysis (GC_P)	SMR (pipe line)	SMR (on site)	
8.5kg CO_{2EQ} per Tank	0.0kg CO_{2EQ} per Tank	9kg CO_{2EQ} per Tank	72.6 – 86.1kg CO_{2EQ} per Tank	72.6kg CO_{2EQ} per Tank	

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GC Green Certificates

GC_P Green Certificates on production, pipe line transport (NOT included in GC)

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Well-to-Wheel (2) - CO_2labels

Label		Class average CO_{2EQ} GHG emission g/km		149 g/km, based on the Hyundai Tucson family Vehicle type
A	<20%	<120		ix35 FCEV, using electrolysis
B	-20% - -10%	120	134	ix35 FCEV (Helmond) using SMR, natural gas piped over 4,000km
C	-10% - 0%	134	149	Hyundai ix35 - 2.0 CRDi Business Edition (147 g/km)
D	0% - +10%	149	164	ix35 FCEV (Arnhem & Rhoon) using SMR, natural gas
E	+10 - +20%	164	179	
F	+20 - +30%	179	194	Hyundai ix35 - 2.0i Active (177g/km)
G	>30%	>194		ix35 FCEV (Rhoon, using SMR, natural gas piped over 7,000km)

Refuelling station		**at Helmond**	**at Rhoon**			**at Arnhem**
		electrolysis	chlorine electrolysis, with green certificates	Steam Methane Reforming natural gas piped over 7,000k	Steam Methane Reforming natural gas piped over 4,000km	Steam Methane Reforming
GHG-emissions in kg CO_{2EQ}/kgH2		**1.525**	**0**	**15.3**	**12.9**	**11.7**
Vehicle	**km/kgH_2**	g/km	g/km	g/km	g/km	g/km
Helmond	**89.5**	**17**	**0**	171	144	131
Arnhem	**81.8**	**18**	**0**	187	158	143
Rhoon	**77.9**	**19**	**0**	196	166	150

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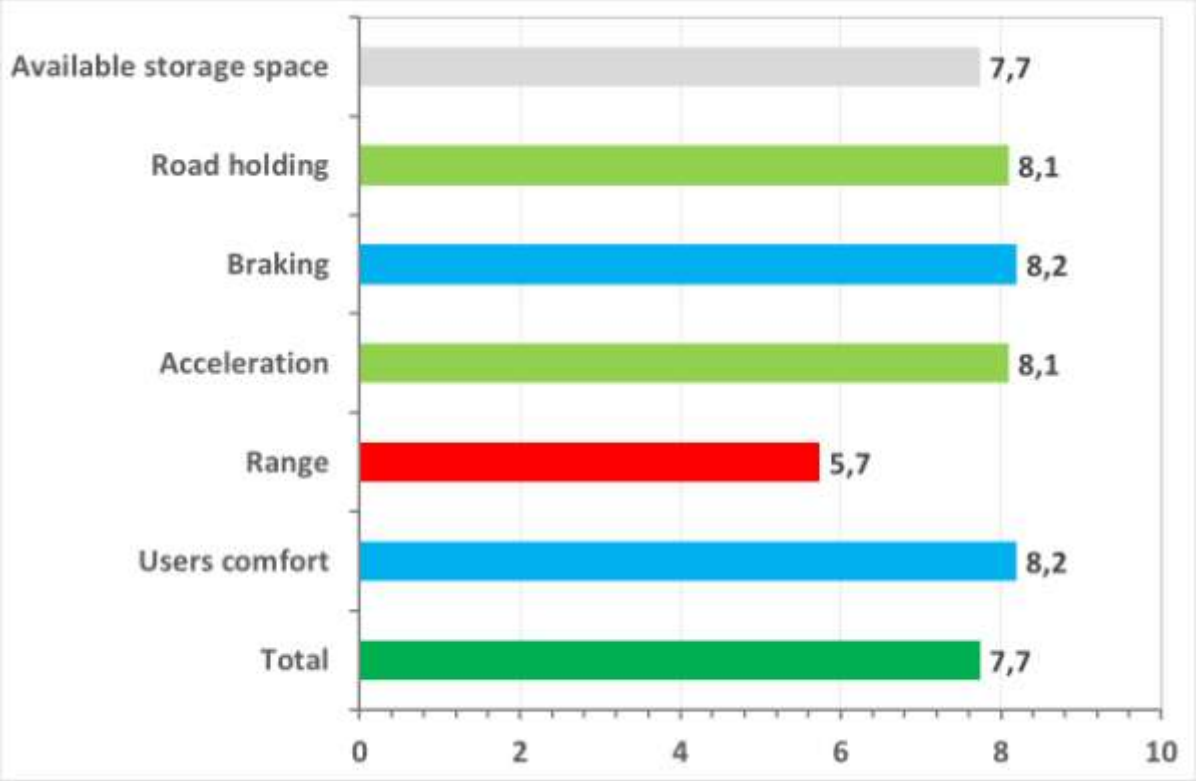
User Experience (1)

Vehicle appreciation



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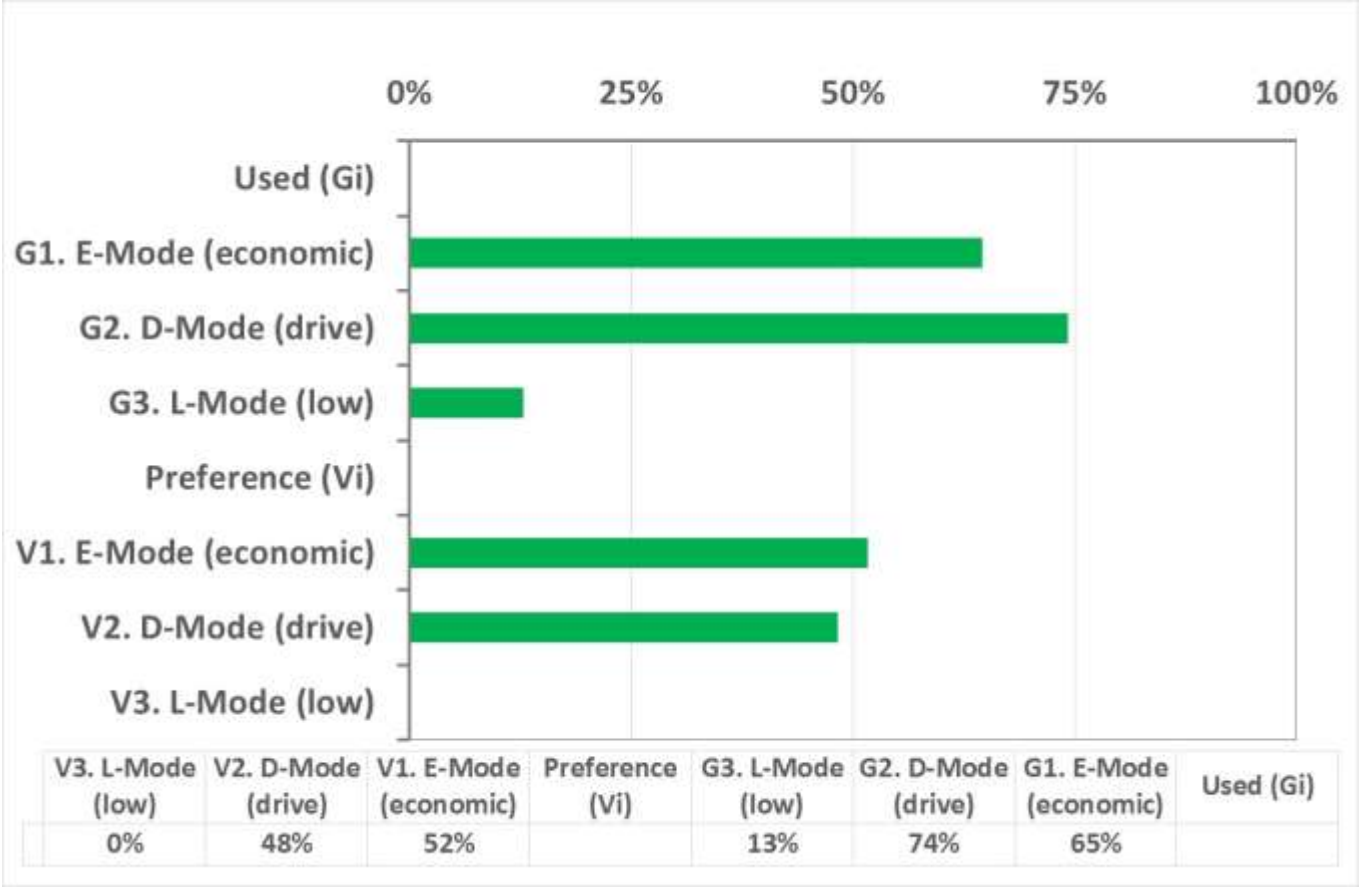
User Experience (2)



V3. L-Mode (low)	V2. D-Mode (drive)	V1. E-Mode (economic)	Preference (Vi)	G3. L-Mode (low)	G2. D-Mode (drive)	G1. E-Mode (economic)	Used (Gi)
0%	48%	52%		13%	74%	65%	

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BEV as a Reference

Overview Energy Consumption, Real Life vs NEDC

ix35FCEV
- (empty) vehicle weight: 1921 kg in Wh/km
- test fleet average is 220Wh/km
- rated to weight: 115 Wh/ton.km

Merk	Type	Weight	Range	NEDC EC [Wh/km]	Real life$_{EQ}$ β=0,7% EC' [Wh/ton.km]	Real life$_{EQ}$ β=14,5% EC' [Wh/ton.km]
Renault Zoe	Q90	1468	240	146	100	116
Mitsubishi	i-MiEV	1085	160	125	116	135
Volkswagen	e-Golf (2017)	1485	300	127	86	100
Hyundai	IONIQ Electric	1420	280	115	82	95
Ford	Focus Electric	1700	225	164	97	113
BMW	is (94Ah)	1440	300	131	92	106
Nissan	Leaf (30kWh)	1525	250	150	99	115
Peugeot	iOn	1140	150	126	111	129
Chevrolet	Bolt EV (2017)	1624	520	145	90	104

J. Kühlwein, ICCT - Impact Of Official Vs. Real-World Road Loads In Europe, Berlin (D): International Council on Clean Transportation Europe, 2016.

ix35FCEV ⇔ Conventional

Energy required for covering 100km

		Fuel Efficiency (km/kgH_2)			Fuel Consumption (km/ℓ)		
#	Vehicle Id	Average	Min.	Max	Average	Min.	Max
1	Helmond	89,5	82	98	$21_{PETROL}/25_{DIESEL}$	$20_{PETROL}/23_{DIESEL}$	$24_{PETROL}/27_{DIESEL}$
2	Rhoon	81.8	75	89	$20_{PETROL}/22_{DIESEL}$	$18_{PETROL}/21_{DIESEL}$	$21_{PETROL}/25_{DIESEL}$
3	Arnhem	77.9	58	87	$18_{PETROL}/21_{DIESEL}$	$14_{PETROL}/16_{DIESEL}$	$21_{PETROL}/24_{DIESEL}$

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Bedankt voor uw Aandacht

Vragen?

en minstens zo belangrijk: Opmerkingen

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