ENGINEERING

eCULT

FH | JOANNEUM
University of Applied Sciences

a lightweight and affordable 48V urban vehicle

By **Martin Gossar**
Thanks to: **Wolfgang Kriegler**, UAS/FH Joanneum , **Thomas Lechner**, UAS/FH Joanneum
Dietmar Hofer, Magna Steyr**, Henning Sommer**, Magna Steyr

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eCULT

a lightweight and affordable 48V urban vehicle

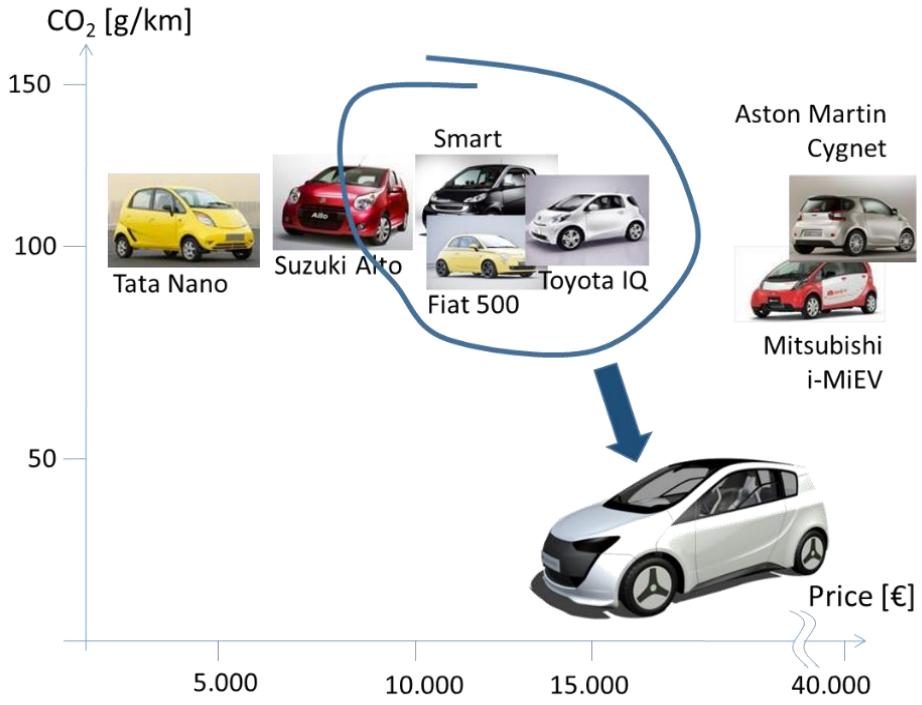
Content

CULT
boundaries and targets

Basic CULT project targets

(Magna Steyr)

- **CNG** powertrain
- Best in class fuel **consumption** – lowest CO_2 **emissions**
- **Lightweight chassis** design
- **Affordable** vehicle
- **Acceleration** as benchmark
- **Top speed** adequate for usage on motorway
- **Premium look and feel**
- **Safety** as benchmark
- **Comfort** as benchmark
- **Range** of 400km (using CNG powertrain)
- Production ~ 30.000 **units** per year



Source: Magna Steyr

Relentless light weight design for best in class CO_2 - emissions

CULT vehicle
holistic weight reduction approach

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Base 900 kg

Weight reduction strategies

app. **-80kg**

- **Integration of functions**
  (cancellation of parts)

app. **-100kg**

- **New materials**
  (selective use of lightweight materials)

app. **-120kg**

- **Downsizing**
  (& use of secondary effects)

Weight reduction up to 300 kg

Target weight 600 kg

Curb Weight achieved: 680 kg

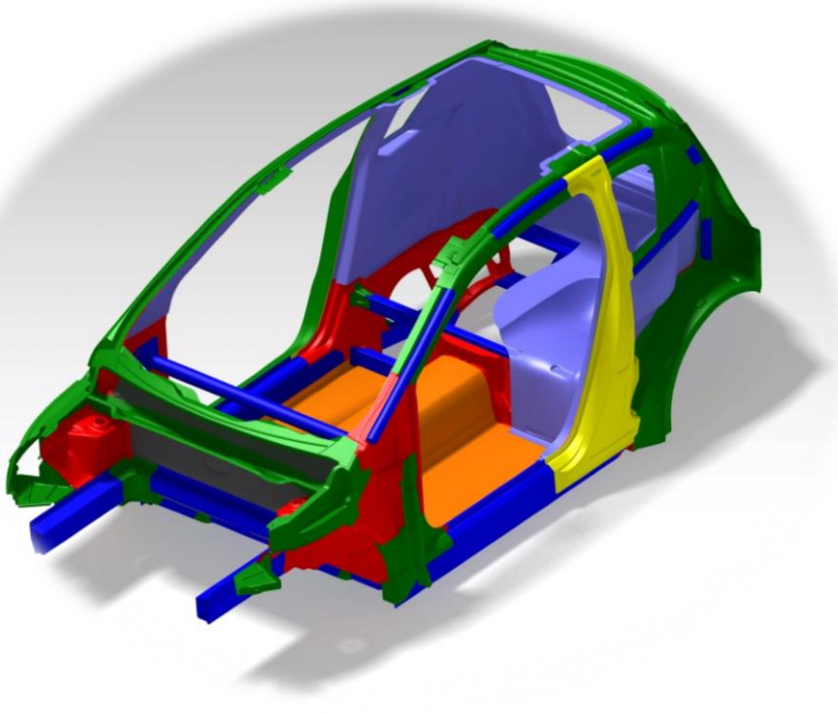
Source: Magna Steyr

Integrated fuel door

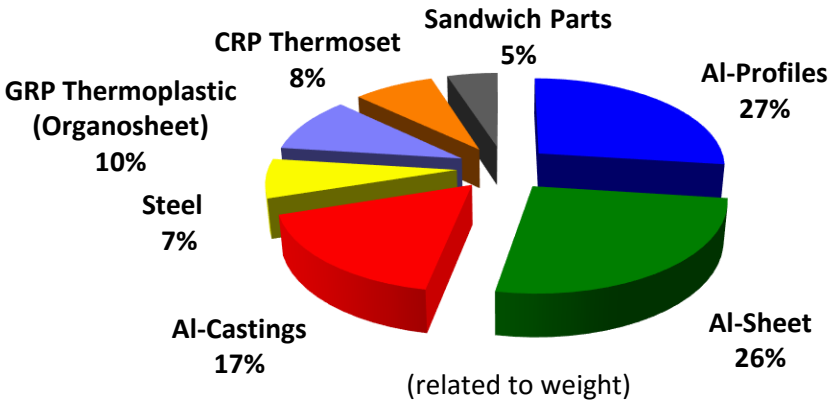
Multimaterial body

Engine: 660 cm³

CULT vehicle lightweight body



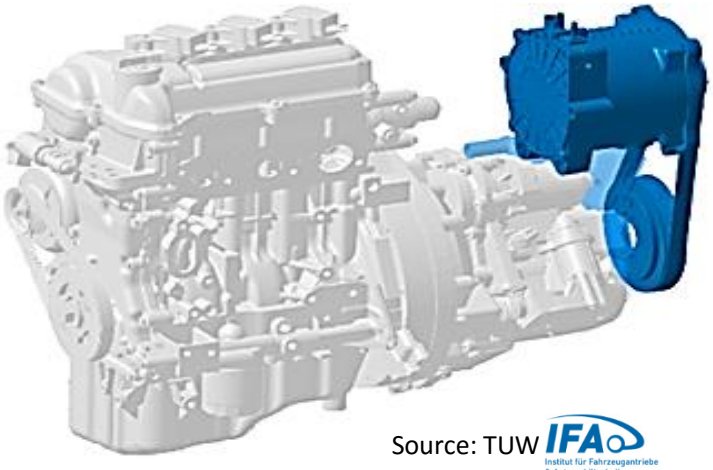
Source: Magna Steyr



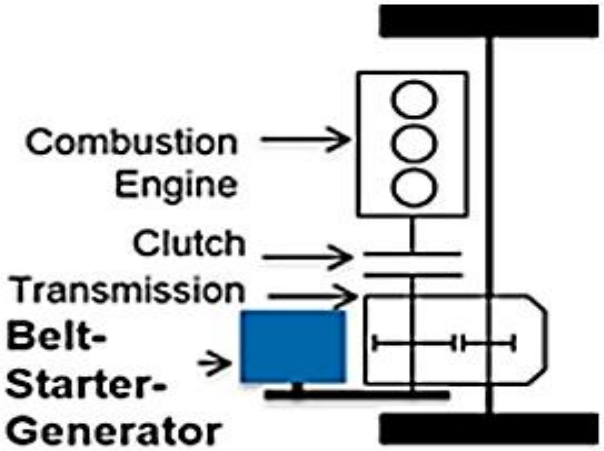
(related to weight)

Multi material light weight design body with 147 kg, doors & closures 62 kg

CULT vehicle
CNG powertrain



Source: TUW IFA Institut für Fahrzeugantriebe & Automobiltechnik



Concept: only the combination of powertrain solutions and lightweight design leads to best possible CO_2 reduction

Key components:

- 3-Cylinder direct injection 660cm3 CNG engine
- AMT automated manual transmission (Smart)
- Belt-starter-generator linked with transmission input shaft

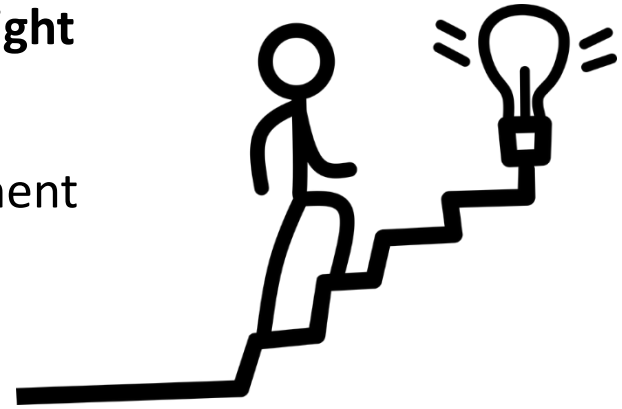
Hybrid functions supported:

- Stop & Go
- Generator management & Recuperation
- Boosting
- Electrical driving at low speeds

eCULT project
boundaries and targets

New eCULT project at UAS FH Joanneum with additional targets:

- **Student project** – involving vehicle engineering dept. in FH/UAS Graz
- Gaining **practice** in EVs
- Learn the outcome of the **combination of a super light weight vehicle and an electrified powertrain**
- Identify the **optimization potential** of each component
- **Develop further researches**



A student project for gaining experience with electric powertrains

Source: https://pixabay.com/en/bright-bulb-career-climbing-light-2855120/

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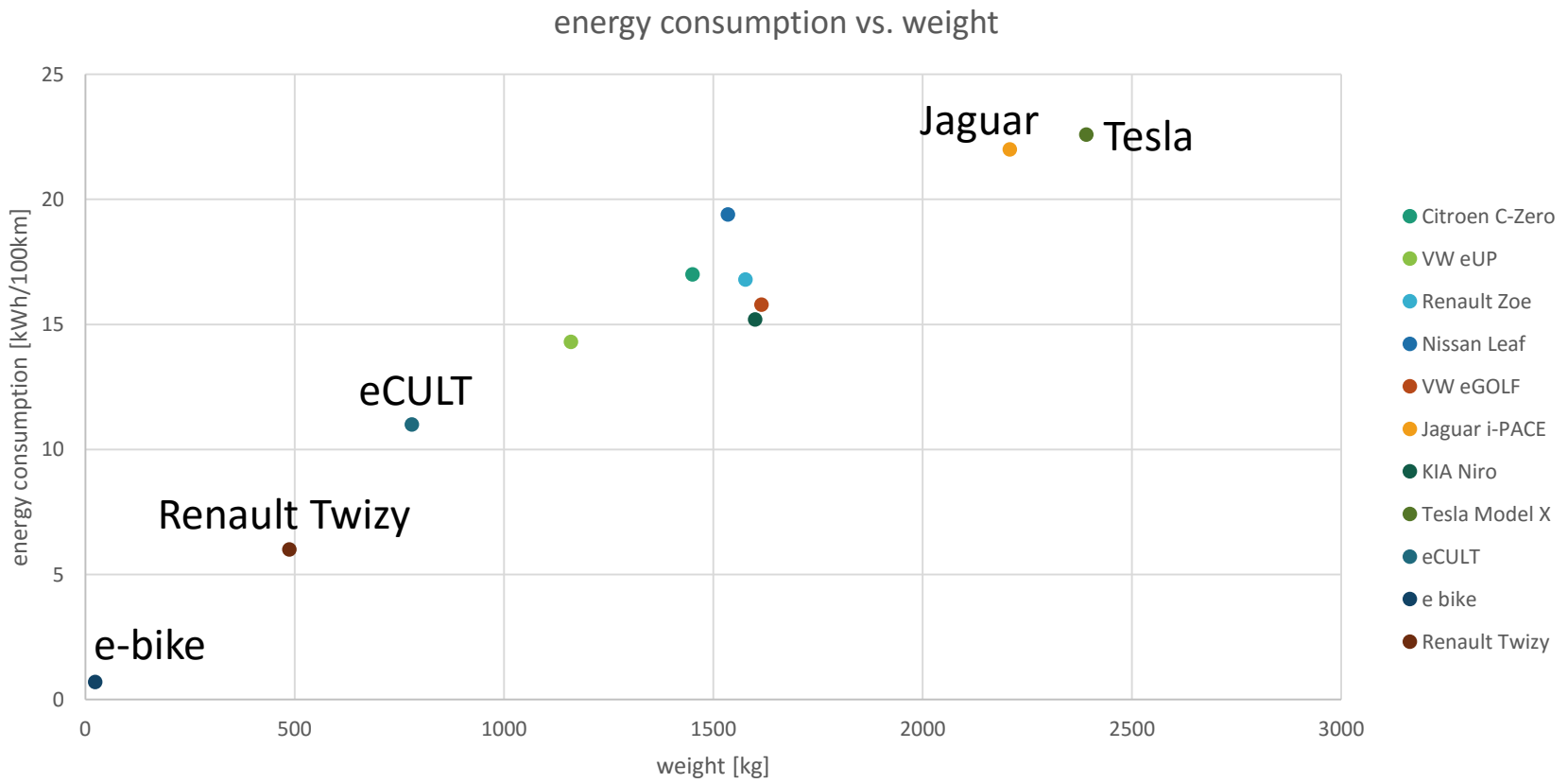
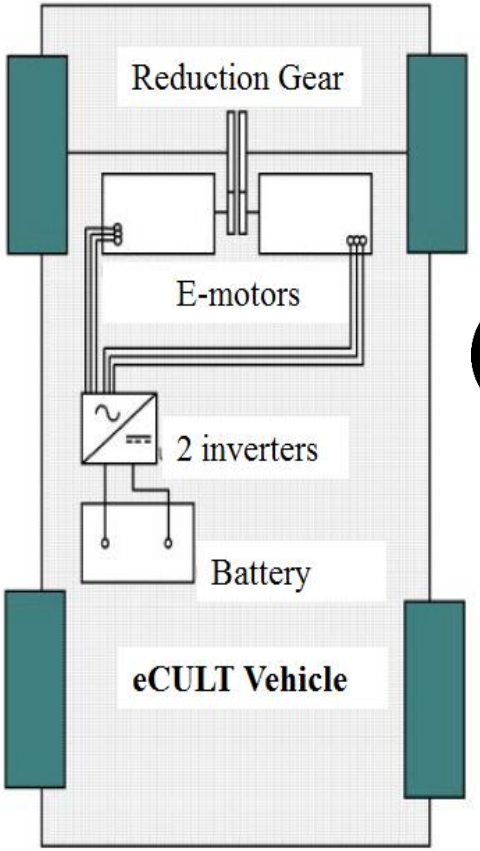
energy consumption comparison



Weight defines directly the energy consumption -> emissions

eCULT vehicle
electric powertrain architecture



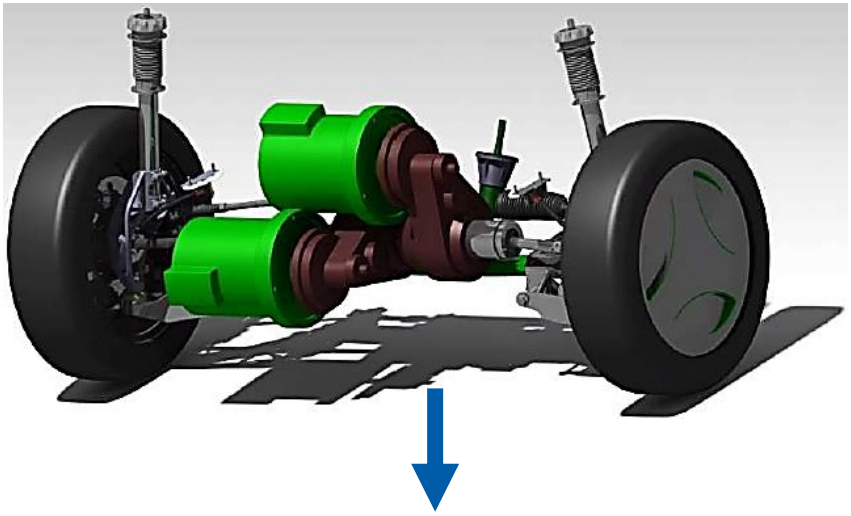
Source: Renault

Renault Twizy vehicle with rear electric powertrain and battery (blue)

Performance goals, availability and costs as main drivers for the decisions made

eCULT vehicle

electric powertrain architecture



Virtual model showing in green the two 48V motors

Real engine compartment with an entwined arrangement due to preferred direction of the transmissions

eCULT vehicle

electric powertrain components

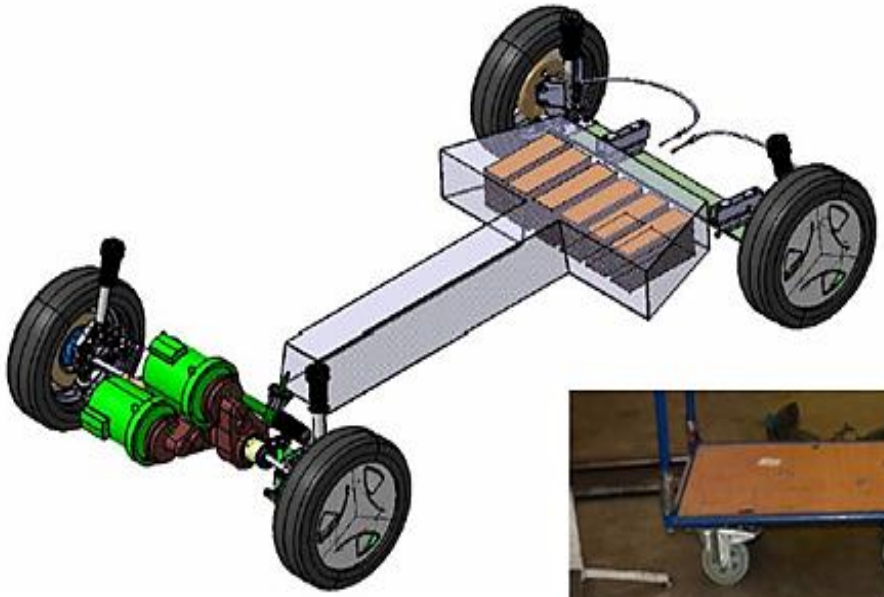
Maximum power for E-Motor (48v)	Maximum torque for E-Motor	Engine speed at max. torque	Reduction ratio of Gearbox
15 kW	70 Nm	2000 rpm	1:7,13

Source: Metron, Mahle, Comex

Standard components provided by Mahle: **two engines** are adopted to obtain the required performance, and **testing** is performed both on track and on test benches

eCULT vehicle

electric powertrain battery



Battery specifications:

- 84 Cells / (70kg Cells) 118 kg
- LG Li-Ion 60 Ah
- 14s6p configuration
- Battery integrated below rear seats
- BMS, switches, fuses, charger and DC/DC integrated in tunnel

eCULT vehicle
powertrain comparison

	ICE Powertrain		Electrical Powertrain	
Engine	3-cylinder CNG ice engine		Asynchronous eMotors	
	Displacement	658 cm^3	Inverter	48 V / 400 A
	Mixture formation	Direct injection		
	Power max.	47 kW (@ 5000 rpm)	Power max.	2 x 15 kW
	Torque max.	103 Nm (@ 2500 rpm)	Torque max.	2 x 70 Nm
Transmission	Automated transmission		Reduction gear	Comex
	Gears	6	Ratio	7,13
	Dry slump lubrication		Blocked differential	
	Electrical oil pump		No oil pump	
Energy Storage	CNG Type 4 Carbon fiber high pressure vessel	50 l, 8 kg CH_4 at 200 bar	60 Ah LG Li-Ion 84 Cells 14s6p	18 kWh
			Available net capacity	16 kWh
Electrical Components	Belt-Starter-Generator	12 V		
	Power max. generating	2,8 kW	DC/DC converter	13,8 V / 50 A_m
	Power max motoring	1,4 kW	On-board charger	48 V / 25 A
	Voltage electrical system	12 V	Voltage level	12 V / 48 V
	On-board battery	12 V / 38 Ah	On-board battery	12 V / 38 Ah

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powertrain performance comparison

	ICE Powertrain		Electric Powertrain
Max. Speed	km/h	130	112
Accelerations	0 - 30 km/h	4 s * with corrected, real shifting intervals	3,1 s
	0 - 50 km/h	8 s*	6,2 s
	0 - 70 km/h	11 s*	11,8 s
	0 - 80 km/h	12 s*	14,09 s
Elasticity	30 – 50	4 s*	3,4 s
	30 – 70	6 s*	8,1 s
	30 – 80	8 s*	11,9 s
Range (City / NEDC)	8 kg CNG	> 300 km	
	16 kWh net capacity		~ 150 km
Empirical evaluation		long torque interrupts during shifting (1st Gen. AMT!)	very smooth acceleration
Energy consumption	2,8 kg CNG	both in real drive	11 kWh

City driving performance is improved with the eCULT

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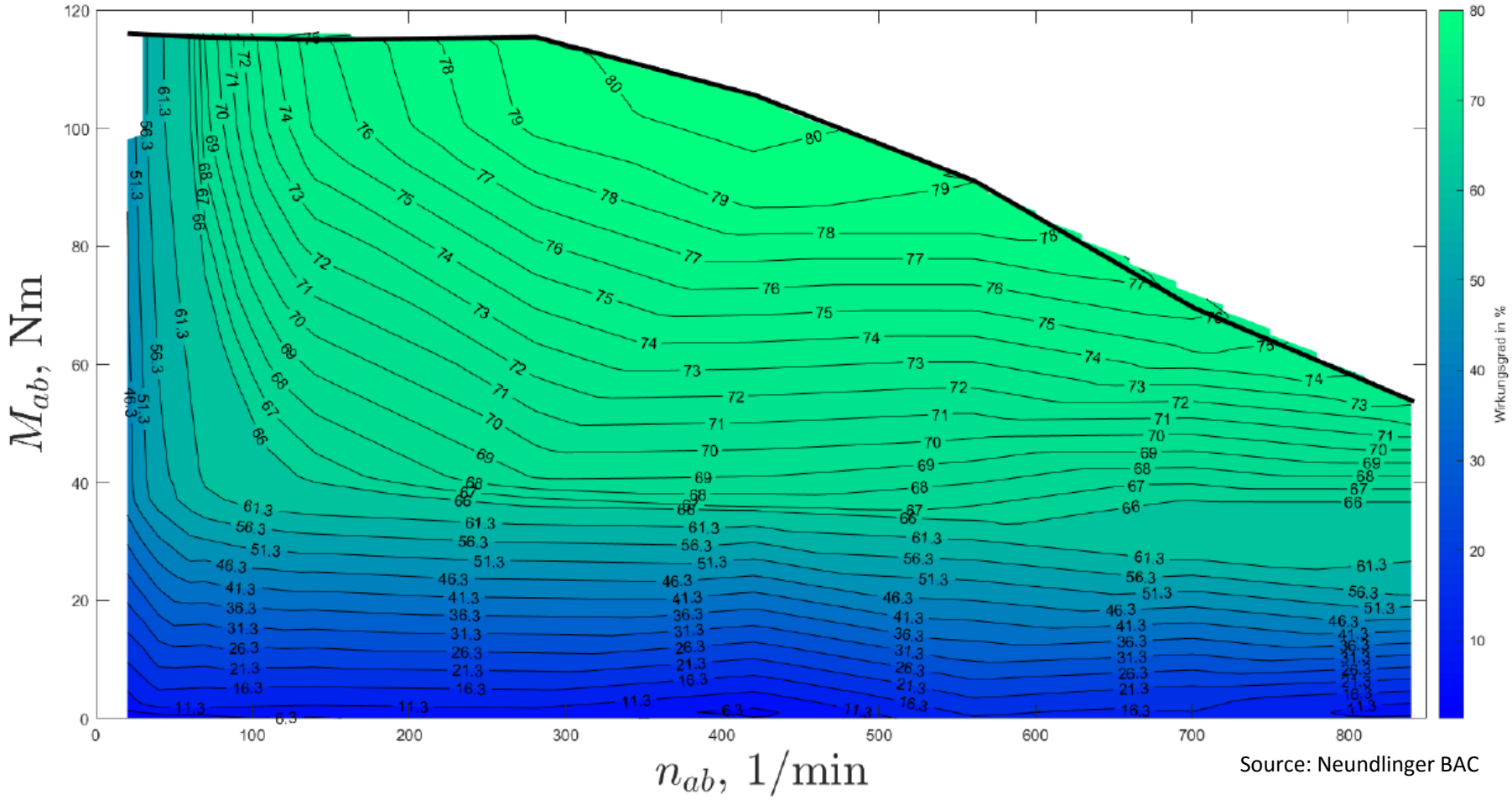
Power efficiency of motor and gearbox



Source: Neundlinger BAC

eCULT vehicle

Operational profile and energy consumption

	CNG CULT	eCULT
Functional Unit	**1,4 person passenger transport**	**1,4 person passenger transport**
Mileage	**150.000 km**	**150.000 km**
Curb weight	**680 kg**	**780 kg**
Energy consumption	**2,16 kg CNG/100 km (NEDC) / 2,8 kg CNG in real drive**	**8,5 kWh/100 km (NEDC) / 11 kWh/100 km in real drive**
Markets	**AT/DE/IT**	**AT/DE/IT**

AT… Austria, DE… Germany, IT… Italy

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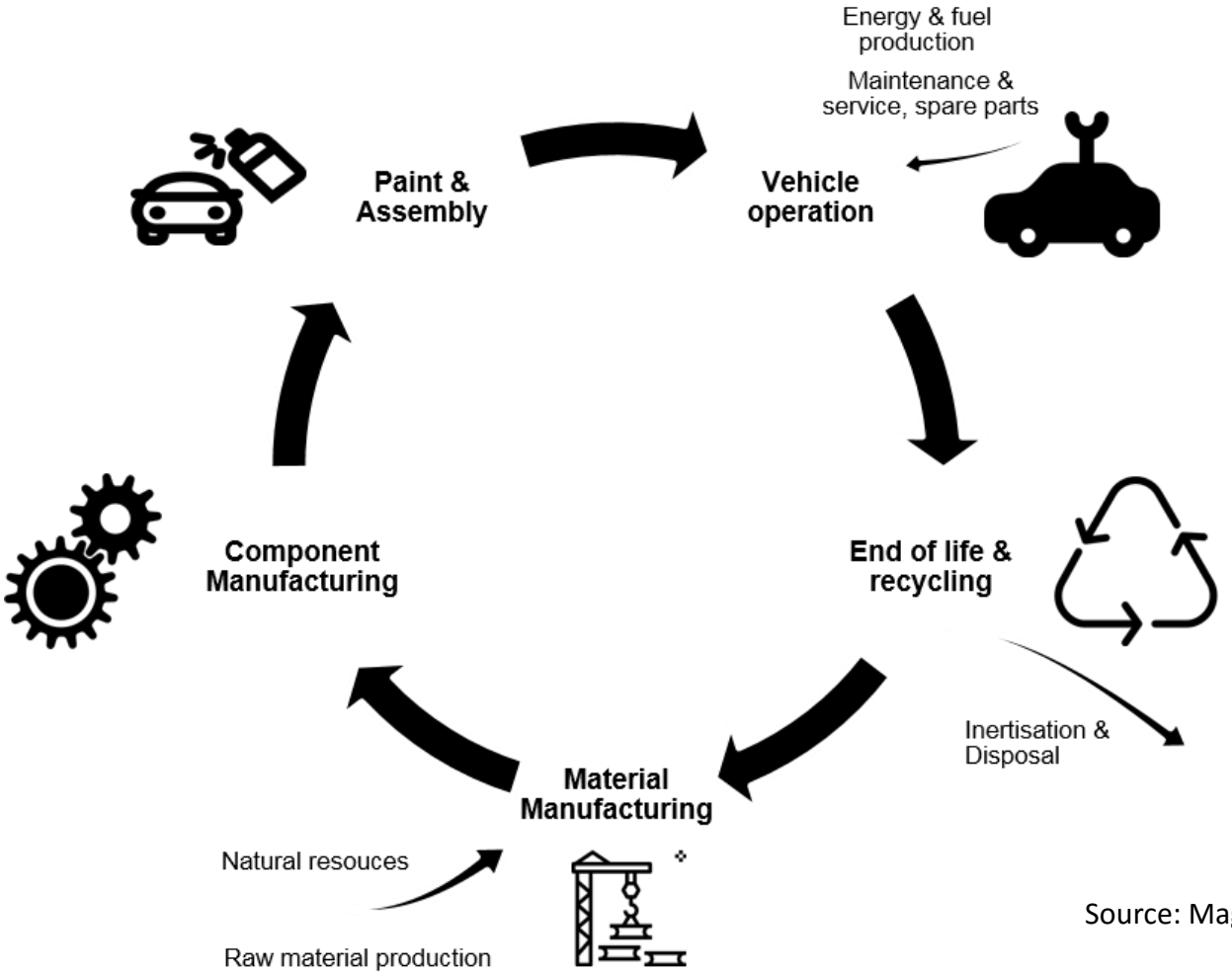
Life Cycle Assessment (LCA)

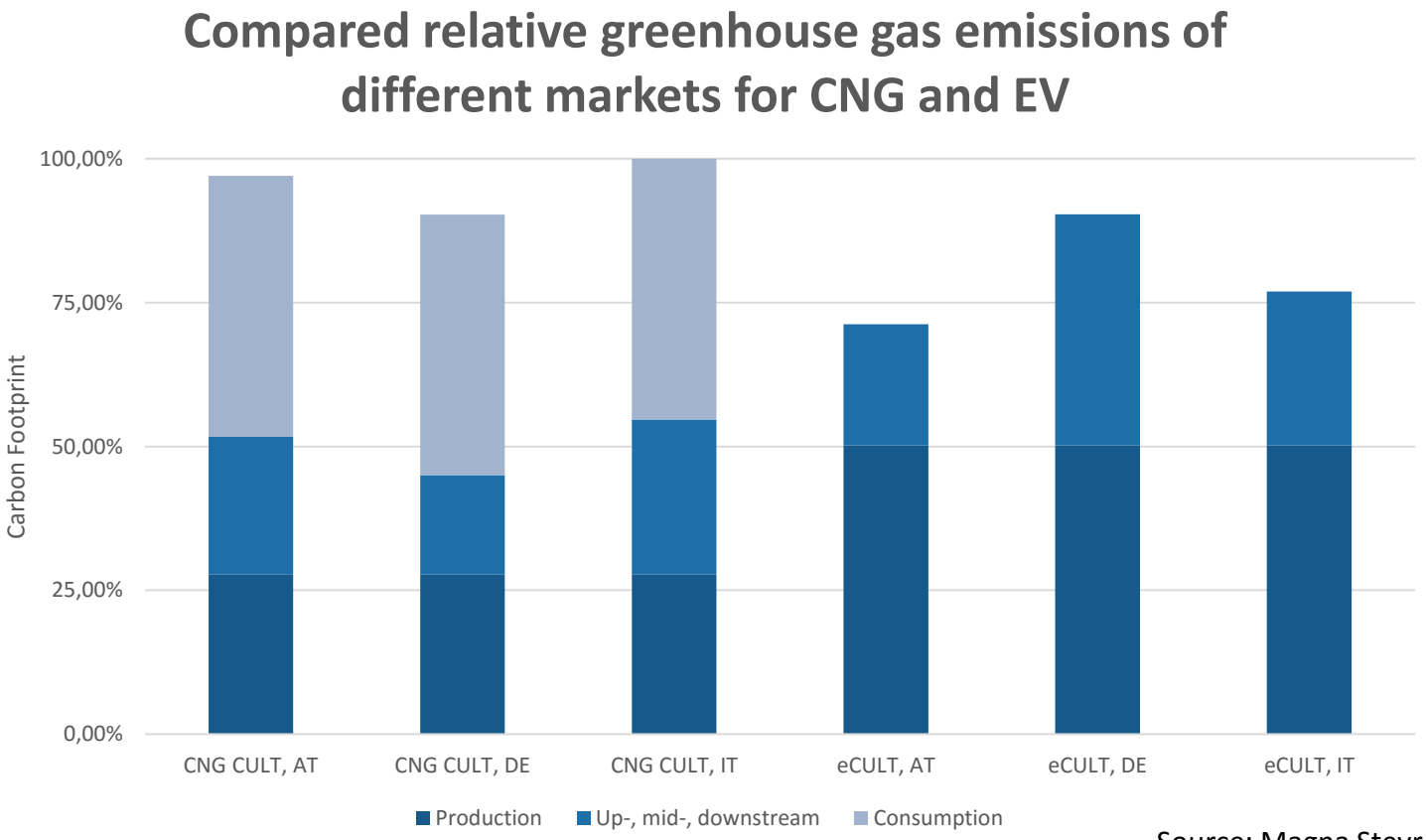


Source: Magna Steyr

Standardised & scientific evaluation of vehicle's carbon footprint based on ISO 14040

eCULT vehicle
Life Cycle Assessment

eCULT can achieve up to ~ 30% better CO_2 foot print compared to its CNG brother (Austria)



Source: Magna Steyr

eCULT vehicle

Summary and conclusions

- **Electric powertrain key figures**
  - two 48 V drive units, one for each front wheel, providing 2x 15 kW/70 Nm
  - 18 kWh battery over the rear axle and under the rear seats
  - BMS, onboard charger, DC/DC converter and on board 12 V battery installed in tunnel

- **Real life behavior comparison**
  - similar and adequate city performance (acceleration and drivability)
  - fluid and continuous speed progression of the eCULT is preferred over the AMT gearbox on the CNG version
  - the range of the eCULT is roughly half of the range of its CNG precursor

- **Importance of energy mix and powertrain concept**
  - original CNG CULT (680 kg) produced ~60 g CO_2/km NEDC (TtW)+ upstream 35 g/km (WtT) results in total 95 g CO_2/km (WtW)
  - eCULT results in < 60 g CO_2/km (WtW) based on worst case German electricity market mix (at low voltage grid)

- **Overall LCA results**
  - best carbon footprint experienced with eCULT and Austrian electricity mix
  - advantages for e-mobility due to high potentials in production efficiency
  - the “right vehicle concept” is defined by: market, market’s energy mix, origin of resources

Thank you for your attention!