eCULT

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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Content

CULT & eCULT Project
CULT – weight reduction
CULT & eCULT - powertrains
Energy Consumption & Driving performance
Life Cycle Assessment
Summary and conclusions
Basic CULT project targets

(Magna Steyr)

- **CNG** powertrain
- Best in class fuel consumption – lowest CO₂ 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

**Relentless light weight design for best in class CO₂ - emissions**
CULT vehicle
holistic weight reduction approach

Weight reduction strategies

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

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

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

Base 900 kg

Target weight
600 kg

Target weight achieved: 680 kg

Engine: 660 cm³

Source: Magna Steyr
CULT vehicle
lightweight body

Source: Magna Steyr

Multi material light weight design body with 147 kg, doors & closures 62 kg
CULT vehicle
CNG powertrain

Concept: only the combination of powertrain solutions and lightweight design leads to best possible CO₂ 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
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

Weight defines directly the energy consumption -> emissions
eCULT vehicle

electric powertrain architecture

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

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

Source: Renault
**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
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.
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
<table>
<thead>
<tr>
<th></th>
<th>ICE Powertrain</th>
<th>Electrical Powertrain</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Engine</strong></td>
<td>3-cylinder CNG ice engine</td>
<td>Asynchronous eMotors</td>
</tr>
<tr>
<td></td>
<td>Displacement 658 cm³</td>
<td>Inverter 48 V / 400 A</td>
</tr>
<tr>
<td></td>
<td>Mixture formation Direct injection</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Power max. 47 kW (@ 5000 rpm)</td>
<td>Power max. 2 x 15 kW</td>
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<tr>
<td></td>
<td>Torque max. 103 Nm (@ 2500 rpm)</td>
<td>Torque max. 2 x 70 Nm</td>
</tr>
<tr>
<td><strong>Transmission</strong></td>
<td>Automated transmission</td>
<td>Reduction gear Comex</td>
</tr>
<tr>
<td></td>
<td>Gears 6</td>
<td>Ratio 7,13</td>
</tr>
<tr>
<td></td>
<td>Dry slump lubrication</td>
<td>Blocked differential</td>
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<tr>
<td></td>
<td>Electrical oil pump</td>
<td>No oil pump</td>
</tr>
<tr>
<td><strong>Energy Storage</strong></td>
<td>CNG Type 4 Carbon fiber high pressure vessel 50 l, 8 kg CH₄ at 200 bar</td>
<td>60 Ah LG Li-Ion 84 Cells 14s6p 18 kWh</td>
</tr>
<tr>
<td></td>
<td>Available net capacity</td>
<td></td>
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<tr>
<td><strong>Electrical Components</strong></td>
<td>Belt- Starter-Generator 12 V</td>
<td>DC/DC converter 13,8 V / 50 A_m</td>
</tr>
<tr>
<td></td>
<td>Power max. generating 2,8 kW</td>
<td>On-board charger 48 V / 25 A</td>
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<tr>
<td></td>
<td>Power max motoring 1,4 kW</td>
<td>Voltage level 12 V / 48 V</td>
</tr>
<tr>
<td></td>
<td>Voltage electrical system 12 V</td>
<td>On-board battery 12 V / 38 Ah</td>
</tr>
<tr>
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<td>On-board battery 12 V / 38 Ah</td>
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<tr>
<td></td>
<td>ICE Powertrain</td>
<td>Electric Powertrain</td>
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<tr>
<td>----------------</td>
<td>-----------------------------------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>Max. Speed</td>
<td>km/h</td>
<td>130</td>
</tr>
<tr>
<td>Accelerations</td>
<td>0 - 30 km/h</td>
<td>4 s * with corrected, real shifting intervals</td>
</tr>
<tr>
<td></td>
<td>0 - 50 km/h</td>
<td>8 s *</td>
</tr>
<tr>
<td></td>
<td>0 - 70 km/h</td>
<td>11 s *</td>
</tr>
<tr>
<td></td>
<td>0 - 80 km/h</td>
<td>12 s *</td>
</tr>
<tr>
<td>Elasticity</td>
<td>30 – 50</td>
<td>4 s *</td>
</tr>
<tr>
<td></td>
<td>30 – 70</td>
<td>6 s *</td>
</tr>
<tr>
<td></td>
<td>30 – 80</td>
<td>8 s *</td>
</tr>
<tr>
<td>Range (City / NEDC)</td>
<td>8 kg CNG</td>
<td>&gt; 300 km</td>
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<tr>
<td></td>
<td>16 kWh net capacity</td>
<td></td>
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<tr>
<td>Empirical evaluation</td>
<td>long torque interrupts during shifting (1st Gen. AMT!)</td>
<td>very smooth acceleration</td>
</tr>
<tr>
<td>Energy consumption</td>
<td>2,8 kg CNG</td>
<td>both in real drive</td>
</tr>
</tbody>
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City driving performance is improved with the eCULT
eCULT vehicle
Power efficiency of motor and gearbox

Source: Neundlinger BAC
## eCULT vehicle

### Operational profile and energy consumption

<table>
<thead>
<tr>
<th></th>
<th>CNG CULT</th>
<th>eCULT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Functional Unit</strong></td>
<td>1,4 person passenger transport</td>
<td>1,4 person passenger transport</td>
</tr>
<tr>
<td><strong>Mileage</strong></td>
<td>150,000 km</td>
<td>150,000 km</td>
</tr>
<tr>
<td><strong>Curb weight</strong></td>
<td>680 kg</td>
<td>780 kg</td>
</tr>
<tr>
<td><strong>Energy consumption</strong></td>
<td>2,16 kg CNG/100 km (NEDC) / 2,8 kg CNG in real drive</td>
<td>8,5 kWh/100 km (NEDC) / 11 kWh/100 km in real drive</td>
</tr>
<tr>
<td><strong>Markets</strong></td>
<td>AT/DE/IT</td>
<td>AT/DE/IT</td>
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AT... Austria, DE... Germany, IT... Italy
Standardised & scientific evaluation of vehicle’s carbon footprint based on ISO 14040
eCULT can achieve up to ~ 30% better CO₂ footprint compared to its CNG brother (Austria)

Compared relative greenhouse gas emissions of different markets for CNG and EV

Source: Magna Steyr
eCULT vehicle
Summary and conclusions

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

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

• Importance of energy mix and powertrain concept
  o original CNG CULT (680 kg) produced ~60 g CO₂/km NEDC (TtW)+ upstream 35 g/km (WtT) results in total 95 g CO₂/km (WtW)
  o eCULT results in < 60 g CO₂/km (WtW) based on worst case German electricity market mix (at low voltage grid)

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