



# REWARD

REal World Advanced Technologies for Diesel Engines

EUROPEAN COMMISSION

Horizon 2020

H2020-MG-2014-2015

GA No. 636380



<b>Deliverable No.</b>	REWARD D7.5	
<b>Deliverable Title</b>	Final report for assessment of costs and emissions	
<b>Dissemination level</b>	CO	
<b>Written By</b>	Christian Doppler (ViF)	2018-06-01
<b>Checked by</b>	Herwig Ofner (AVL)	2018-06-06
<b>Approved by</b>	Stefan Bohatsch (VCC) – WP6 leader Ludwig Buergler (AVL) – WP5 leader	2018-06-06
<b>Status</b>	Final (first submission) Final (second submission, after Review meeting)	2018-06-06 2018-07-02

H2020-MG-2014-2015 – 636380 – REal World Advanced Technologies for Diesel Engines

**Acknowledgement:**

The author(s) would like to thank the partners in the project for their valuable comments on previous drafts and for performing the review.

**Project partners:**

- 1 - AVL - AVL List GmbH - AT
- 2 - REN - Renault SAS - FR
- 3 - VCC - Volvo Car Corporation - SE
- 4 - CRF - CRF SCpA - IT
- 5 - CNRIM - Istituto Motori – Consiglio Nazionale delle Ricerche (CNR) - IT
- 6 - JM - Johnson Matthey Plc - UK
- 7 - RIC - Ricardo Plc - UK
- 8 - SCF - Schaeffler AG - DE
- 9 - LMM - Le Moteur Moderne - FR
- 10 - DELPHI - Delphi Automotive Systems Luxembourg S.A. - LU
- 11 - UNR - Uniresearch BV - NL
- 12 - IFPEN - IFP Energies Nouvelles - FR
- 13 - VIF - Virtual Vehicle Research Center - AT
- 14 - CTH - Chalmers Tekniska Högskola - SE
- 15 - CTU - Czech Technical University - CZ
- 16 - UPVLC - Universitat Politecnica de Valencia – Motores Termicos - ES

**Disclaimer:**

*This project has received funding from the European Union's Horizon 2020, programme for research, technological development and demonstration under grant agreement no 636380.*



## Publishable summary

This report describes the final assessment of the demonstrator vehicles Renault Kadjar and Volvo XC60. Further, also the assessment of the Jeep Renegade in WP2 - accompanied by WP7 – is shortly reported. A conclusion towards the cost assessment for the Renault Kadjar and the Volvo XC60 is also given in this report.

The “REWARD Targets” are a 5% improvement in CO<sub>2</sub> and the reduction of harmful emission as stated in the following table:

Passenger Car / LCV	Date	CO	HC	HC + NO <sub>x</sub> in g/km	NO <sub>x</sub>	PM	PN #/km
Euro 5b	2011.09	0.50 / 0.74	-	0.23 / 0.35	0.18 / 0.28	0.005	6.0×10 <sup>11</sup>
Euro 6	2014.09	0.50 / 0.74	-	0.17 / 0.215	0.08 / 0.125	0.005	6.0×10 <sup>11</sup>
<b>REWARD*</b>	<b>&lt; 2020</b>	<b>0.25 / 0.37</b>	<b>-</b>	<b>0.085 / 0.1175</b>	<b>0.04 / 0.0625</b>	<b>0.0025</b>	<b>3.0×10<sup>11</sup></b>

\* In addition to the above targets, REWARD will also take into account other pollutants such as: NO<sub>2</sub>, NH<sub>3</sub>, N<sub>2</sub>O, NMHC and aldehydes that are under evaluation in preparation to future regulations.

The “EURO 6 Targets”, which are also the call targets (see MG-3.1-2014: Technologies for low emission powertrains) are shown in the above table and - for the sake of completeness – they will be also compared to the measurements in the following report.

The “REWARD Targets” for the emissions could be widely reached. The NO<sub>x</sub>-target of 40 mg/km in the WLTC was the most challenging emissions limit. This value could be reached very marginal in the cold WLTC for both vehicles. Nevertheless, measurements showed that the calibration is still not very stable and with slightly changing boundaries the maximum was exceeded.

Especially, when the engine was operated in CO<sub>2</sub> optimized mode, the NO<sub>x</sub>-emissions increased significantly above 40 mg/km. This CO<sub>2</sub>/NO<sub>x</sub>-tradeoff is well shown in the detailed analysis further down. Generally, the CO<sub>2</sub>-targets in the WLTC could be met by both vehicles, however in the expense of too high NO<sub>x</sub>-emissions.

The major challenge was to keep NO<sub>x</sub> as well as CO<sub>2</sub> below the “REWARD Target” in a WLTC at the same time. This tradeoff would need further optimization.

In the RWCs the CO<sub>2</sub>-emissions of both demonstrator vehicles were compared to the baseline CO<sub>2</sub>-emissions. The target of 5% CO<sub>2</sub>-improvement could be held by both vehicles with approximately 8% CO<sub>2</sub> reduction in RWC.

During the final assessment the demonstrators were measured in RDE with PEMS. The limits for RDE are the “REWARD Target”, namely 250 mg/km CO, 40 mg/km NO<sub>x</sub> and 3.0×10<sup>11</sup> #/km PN. CO should be measured and considered with a CF (conformity factor) of 1, NO<sub>x</sub> and PN are considered with a CF of 1.5, like this is officially applied by the EC in the latest RDE legislation.

Post-processing was made unweighted and weighted with CLEAR and EMROAD.

Both vehicles accomplished the RDE-targets in the total cycle. In the urban cycle, which needs to be extra evaluated, the XC60 failed at post-processing with CLEAR considering the “REWARD Targets”. When considering the “EURO 6 Target”, the XC60 accomplished the NO<sub>x</sub>-targets in all parts.

In general, both vehicles showed lower NO<sub>x</sub>-values with EMROAD. Finally, it can be stated that the urban part with cold start is by far the most challenging share of RDE and comprises of nearly all significant NO<sub>x</sub>-peaks in RDE.

The final assessment of the Jeep Renegade shows the same trends in terms of emission challenges. The RDE tests have been also evaluated by VIF/IVT and it is illustrated that also here the urban part comprises the most NO<sub>x</sub>-peaks. The CF for the “REWARD Targets” could be kept below 1.5 in RDE, in the WLTC the NO<sub>x</sub>-values are significantly below 40 mg/km.

Additional costs have been calculated based on a literature research. The additional costs for the Kadjar are in line with the historical evaluation of costs for emission reduction measures in the last 15 years.

The Kadjar baseline was Euro 6b certified and the implementation of the REWARD technology claimed for installing a fully new SCR system which ended in approximately doubling the costs for the aftertreatment system. According

to the historical data it has been the first time for this class (1.5 L) that SCR inevitable needs to be applied, which also explains the significantly higher costs compared to the 2.5 L class.

The XC60 baseline already had Euro 6d temp certification and the additional costs for aftertreatment are negligible. Major oncosts for the premium segment XC60 emerged with the adaption of the combustion and powertrain system towards a highly sophisticated and promising system also capable for the post Euro 6 era.