

HFCV - SGE

## **Draft Technical Report - Carbondioxide (CO<sub>2</sub>) Emissions of Hydrogen (H<sub>2</sub>) Fuelled Vehicles**

### 1. Explanation and Specification of the issue

In legislation (approval and certification of vehicles) the emissions of CO<sub>2</sub> of vehicles are not limited, but in some cases the emissions have to be measured and calculated and are recorded in the test report in g/km. Light Duty Vehicles (LDV) and motorcycles are tested on a roller test bench, driving a transient test cycle. This test procedure including the test cycle is different for vehicle categories and in national legislation. The concentrations of the emissions are measured and then the CO<sub>2</sub> emissions are calculated in g/km.

In legislation (approval and certification of vehicles) the declared emissions of CO<sub>2</sub> are the end of pipe emissions. The well-to-wheel emissions of CO<sub>2</sub> are disregarded in the test reports. The issue of well-to-wheel emissions is currently considered by the EFV informal group of WP.29 [2]

Fuel cell vehicles don't emit CO<sub>2</sub> emissions, if H<sub>2</sub> is used directly. A fuel cell can also be fuelled with H<sub>2</sub>, that was reformed (on vehicle) from a different base fuel ( C<sub>x</sub>H<sub>y</sub> ). In case of a reformer (on vehicle), CO<sub>2</sub> emissions are relevant, depending on the base fuel and the reforming process.

Internal combustion engines (ICE) fueled with H<sub>2</sub> don't emit CO<sub>2</sub>.

In cases where H<sub>2</sub> is used together with other fuels (H<sub>2</sub>-bi-fuel, H<sub>2</sub>-flex-fuel, H<sub>2</sub>-dual-fuel), CO<sub>2</sub> emissions become relevant. H<sub>2</sub>-bi-fuel systems (BMW) or hydrogen mixtures (e.g. with CNG, [4]) are interesting solutions during the introduction phase of H<sub>2</sub> vehicles, until the infrastructure with H<sub>2</sub> fuelling stations is more developed. For the time being BMW is the only manufacturers producing vehicles with ICE operating as H<sub>2</sub>-bi-fuel.

The level of the CO<sub>2</sub> emissions in H<sub>2</sub> mode of a H<sub>2</sub>-bi-fuel vehicle is very low. In case of the BMW it is 5 g/km. Theoretically it should be equal to zero, but practically the small amount

of emissions are caused by lube oil losses, or in case of H<sub>2</sub>-bi-fuel concepts, because the venting of the active carbon filter (evaporative emissions) goes into the intake system of the ICE.

H<sub>2</sub> can be stored liquid (LH<sub>2</sub>) or compressed gaseous (CGH<sub>2</sub>). The influence on CO<sub>2</sub> emissions by the type of storage is not relevant. The only need is to define different reference H<sub>2</sub>-fuel and reference H<sub>2</sub>-gas for emission testing.

## 2. Application and Scope

### 2.1. Vehicle categories

In principle all vehicle categories defined in Special Resolution No.1 [1] can be powered by H<sub>2</sub>:

- passenger car (category 1-1 vehicle)
- bus (category 1-2 vehicle)
- truck (category 2 vehicle)
- 2 or 3 wheeler (category 3 vehicle)

Because in today's legislation the measurement of the CO<sub>2</sub> emissions is not required for Heavy Duty Vehicles, agricultural and forestry tractors and Non Road Mobile Machinery (NRMM), therefore these vehicle categories will not be further covered by this report - out of scope.

### 2.2. Propulsion system

Internal combustion engine (ICE), positive or compression ignition, or in combination with an electric engine (Hybrid Electric Vehicle).

Also possible, but not developed for the time being, is a combination of ICE and Fuel Cell (Hybrid Vehicle) - out of scope.

### 2.3. Reformer (on vehicle)

For the time being it's improbable that a vehicle in serial production will be equipped with reformer technology. Furthermore a procedure to measure the CO<sub>2</sub> emissions from the reformer process is not defined. Therefore this technology will not be further covered by this report - out of scope.

## 2.4. Fuel Types

- H<sub>2</sub>-fuel - out of scope, because no CO<sub>2</sub> emissions.
- H<sub>2</sub>-bi-fuel with gasoline, diesel, CNG or LPG.
- H<sub>2</sub> blend/mixture (flex-fuel / dual-fuel) with gasoline, diesel, CNG or LPG.
- H<sub>2</sub> reformed ( on board ) from gasoline, diesel, LPG, CNG, methanol - out of scope (see chapter 2.3.).

## 3. Definitions

“Calculation method” - means the calculation method of mass emissions of CO<sub>2</sub>, e.g. defined in annex 6 of ECE-R 101 [9].

“Reference fuel / Reference gas” – means the definition of specifications of the fuel or gas taken for the emission tests.

“H<sub>2</sub>-fuel-vehicle” – means a vehicle that primarily runs on H<sub>2</sub> but may also have a petrol system for emergency purposes or starting only, where the petrol tank does not contain more than 15 litres of petrol.

(this definition is in line with the definition of "mono fuel gas vehicle" in [13])

“H<sub>2</sub>-bi-fuel vehicle” means a vehicle that can run part-time on H<sub>2</sub> and also part time either on gasoline, diesel, LPG or CNG

"Flex-fuel vehicle" - means a vehicle with one fuel storage system that can run on different mixtures of two or more fuels [13].

"Dual-fuel vehicle" – means a vehicle with two storage systems for different fuels, where the both fuels are mixed either in the intake system or during injection into the combustion chamber.

“Hybrid vehicle” - means a vehicle with at least two different energy converters and two different energy storage systems (on vehicle) for the purpose of vehicle propulsion [9], [13]. ([9] and [13] also contains a definition for a “hybrid electric vehicle”)

#### 4. Overview on existing Regulations & Standards

##### 4.1. Passenger cars

The legislation concerning CO<sub>2</sub> emissions from category 1-1 vehicles is not harmonised. Different test cycles, measurement methods and reference fuels are applicable. None of the existing Regulations includes test methods and requirements for H<sub>2</sub> vehicles (ICE). The current European Euro 5/6 Regulation [13] already mentions H<sub>2</sub> as fuel, but specific test procedures for H<sub>2</sub> will be defined at a later stage.

A (possible) GTR project to develop a worldwide harmonised light vehicles test procedure (WLTP) is under preparation [5]. The documentation in [5] includes a comprehensive overview of the existing national legislation on CO<sub>2</sub> emissions. Currently the emission measurement of H<sub>2</sub> vehicles is not included in the draft roadmap.

ECE-R 101 [9] contains requirements regarding the CO<sub>2</sub> emissions for mono-fuel and bi-fuel vehicles (gasoline, diesel, CNG, LPG). ECE-R 101 will be amended soon to be in line with the European Euro 5/6 requirements [13], including an approach for flex fuel (gasoline and Ethanol).

##### 4.2. 2/3 wheelers

With GTR No. 2 [7], a world wide harmonised emission test procedure for 2-wheeled motorcycles is established, including the measurement of CO<sub>2</sub> emissions . The Appendix to GTR No. 4 (Technical Report) [7] includes an overview about the existing national emission legislation for 2-wheelers and relevant standards. H<sub>2</sub> vehicles are not covered by GTR No.4.

The legislation concerning exhaust emissions from mopeds (< 50 ccm, < 50 km/h) and three wheelers is not harmonised. Different test cycles, measurement methods, reference

fuels and limit values are applicable. None of the existing Regulations includes test methods and requirements for H2 vehicles (ICE).

#### 4.4. Reference Fuel and Reference Gas

The issue of reference fuel and reference gas is described in more detail in Technical Report II [12]. In case of H2-fuel-vehicles the introduction of a reference fuel/gas is not necessary, because the CO<sub>2</sub> emissions are zero.

A specification for H2 as flex-fuel either as dual-fuel is not existing for the time being.

#### 5. Work to be done and state of research

Concerning H2-flex-fuel and H2-dual fuel, experience and emission test data are required for the development of a measurement procedure, including work on specification of reference fuel (s) and the definition of a calculation method (emissions).

#### 6. Regulatory approach

##### 6.1 Need for regulation

The measurement of CO<sub>2</sub> emissions of H2-bi-fuel vehicles should be regulated. The regulatory approach will be decided by national regulatory decision processes, but probably it will be the same as for other bi-fuel vehicles already regulated [9]. Because the CO<sub>2</sub> emissions of H2-bi-fuel vehicles operating in H2 mode are very low, it is suggested to disclaim the requirement to measure the CO<sub>2</sub> emissions during H2 operation mode. The CO<sub>2</sub> emissions should be deemed to be zero for that operation mode.

##### 6.2. Open issues and need for specification

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### 6.3. Assessment of harmonisation - development of a GTR

In case 2-wheeled motorcycles a world wide harmonisation is possible, because GTR's for the measurement of CO<sub>2</sub> emissions already exists. This is not the case for LDV, and the development of a world wide harmonised test cycle and measurement procedure especial for LDV using H<sub>2</sub> in ICE as H<sub>2</sub>-bi-fuel is not efficient and feasible.

In case motorcycles with ICE using H<sub>2</sub> (H<sub>2</sub>-bi-fuel) are ready for marketing, an amendment of GTR No. 2 (WMTC) can easily be developed. Such an amendment of the existing GTR only need the extension of the scope to H<sub>2</sub>-bi-fuel vehicles and the decision about the measurement of CO<sub>2</sub> only in the petrol mode. In this case there is no need to adapt the existing measurement and calculation methods. The amendment of GTR No. 2 can be considered as a mid-term activity.

For LDV it should be considered to introduce this H<sub>2</sub>-bi-fuel approach (see above) with the WLTP GTR [5]. In the meantime, existing national legislation or ECE-R 101 can be amended.

As a conclusion, it is not proposed to develop a special GTR for the measurement of CO<sub>2</sub> emissions of H<sub>2</sub> vehicles.

### 7. References

- [1] Special Resolution No.1; Concerning the common definitions of vehicle categories, masses and dimensions (S.R.1); TRANS/WP.29/1045
- [2] <http://www.unece.org/trans/main/wp29/wp29wgs/wp29grpe/efv04.html>
- [4] Regulation (EC) no 79/2009; Official Journal of the European Union; L 35/32
- [5] WLTP - GTR roadmap phase;  
<http://www.unece.org/trans/main/wp29/wp29wgs/wp29grpe/wltp01.html>
- [6] GTR No. 4; Worldwide harmonised heavy-duty certification procedure (WHDC);  
<http://www.unece.org/trans/main/wp29/wp29wgs/wp29gen/wp29registry/gtr4.html>

- [7] GTR No 2; Worldwide harmonised motorcycle emission certification procedure (WMTC); <http://www.unece.org/trans/main/wp29/wp29wgs/wp29gen/wp29registry/gtr2.html>
- [9] ECE-R 101: <http://www.unece.org/trans/main/wp29/wp29regs101-120.html>
- [12] Draft Technical Report - H2SGE-IP-01, December 2008
- [13] Regulations (EC) No 2007-715 and No 2008-692