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Annex to the

Proposal for a

**REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL
on type-approval of hydrogen powered motor vehicles
and amending Directive 2007/46/EC**

Impact Assessment

**{COM(2007) 593 final}
{SEC(2007) 1302)**

TABLE OF CONTENTS

1. EXECUTIVE SUMMARY

The impact assessment has demonstrated that the introduction of hydrogen powered vehicles in the whole vehicle type-approval framework is necessary in order to retain a functioning internal market and ensuring a high level of public safety and environmental protection.

The present situation regarding the approval of advanced hydrogen fuelled vehicles is of increasing concern and a cause of uncertainty. At the moment, these vehicles are not included in the European Community whole vehicle type-approval framework. This situation results in complicated and costly approval procedures and does not ensure that the vehicles can be placed on the market throughout the entire European Union.

With no change in policy, there is a risk that the functioning of the internal market would be impaired and that the approval remains costly and cumbersome. It is possible that without action at EU level, Member States will adopt diverging standards for hydrogen vehicles, which would result in an unfavourable situation with regard to the single market, economies of scale and design of vehicles.

The impact assessment has shown that with the extension of the existing whole vehicle type approval system to hydrogen powered vehicles, there would be substantial savings for manufacturers with regard to the cost of approval procedures. This is because with the policy option of European Union legislation, one approval would be sufficient for each vehicle type in order to be marketed in the European Union. Thus, it would open up all markets of the 27 Member States of the European Union for hydrogen vehicles. This option is likely to speed up the introduction rate of this environmentally friendly vehicle propulsion technology, which would in turn ensure that the environmental benefits linked to the use of hydrogen vehicles appear earlier.

The option of passing an EU regulation would ensure that all hydrogen vehicles marketed in Europe are constructed according to a common standard and provide at least the same level of safety as conventional vehicles. The impact assessment has demonstrated that the requirements of the draft proposal for a potential EU Regulation contain the necessary provisions to address the safety issues associated with hydrogen propulsion.

With the extension of the type approval framework to hydrogen vehicles, it would be ensured that the European Union keeps up with other important automotive regions with regard to the introduction of innovative vehicles. The investment in these solutions would likely to be boosted which would support the quicker deployment of the hydrogen technology within the European Union.

2. PROCEDURAL ISSUES AND CONSULTATION OF INTERESTED PARTIES

2.1. Organisation and timing

A proposal relating to the type-approval of hydrogen powered vehicles has been included in the 2007 Commission Legislative and Work Programme. The proposal has been identified as a Priority Initiative under the Roadmap reference number 2006/ENTR/044.

2.2. Consultation and expertise

In developing the proposal and the impact assessment, the Commission services have both consulted stakeholders and drawn on external expertise in a number of ways:

- There was consultation with the Hydrogen Working Group. This is a specialist expert stakeholder working group responsible for supporting the Commission on issues related to the type-approval of hydrogen vehicles. A broad range of interested parties is involved in the work of this group: national authorities, vehicle manufacturers, component suppliers and industry associations.

- A questionnaire was sent to stakeholders in June 2006 on possible policy options regarding the approval framework for hydrogen vehicles. The questionnaire aimed at gathering views of stakeholders as to the preferred option and the associated costs of approval under each of these options. The Commission services consulted a wide spectrum of interested organisations through the questionnaire: national authorities, vehicle manufacturers, component suppliers, industry associations and academia. The responses given to the questionnaire were directly used as input for the impact assessment work.

- A consultant was engaged to provide input for the impact assessment and to give technical advice on the draft proposal for a potential regulation. In particular, the consultant carried out the following work:

  – reviewed the relevant literature to identify safety and environmental issues surrounding the introduction of hydrogen vehicles;

  – gathered and evaluated information on the impacts of the various policy options on public safety, the environment and the economy;

  – assessed stakeholder responses to the questionnaire sent out by the Commission services in June 2006 on the available policy options;

  – compared the impacts of policy options regarding public safety, the environment and the economy in qualitative and quantitative terms;

  – in particular, analysed the impacts on administrative costs incurred to manufacturers;

  – reviewed the technical requirements of a draft European Commission proposal for a potential regulation as to its ability to address the identified safety issues.

  The results of the work of the consultant were reported to the Commission services.[1] The study of the consultant is referred to as 'TRL Report' throughout this impact assessment.

- To understand more fully the implications of the policy options, the consultant organised meetings with key automotive companies involved in hydrogen technology to generate additional data on safety, technology and the related costs.

- There were presentations to key stakeholders of the Hydrogen Working Group during the second half of 2006 and early 2007 on the results of the work carried out by the consultant.

- The preliminary draft proposal for a Regulation on the type-approval of hydrogen vehicles was put to public consultation in July 2006. The Commission services aimed to gather the views of all interested parties on the Commission services’ draft and to take into consideration all relevant comments of stakeholders in its proposal. The public consultation provided input to the preparation of the draft proposal's specific requirements.

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1 TRL Limited: Evaluation of the impact of the introduction of hydrogen as fuel to power motor vehicles considering the safety and environmental aspects, April 2007 http://ec.europa.eu/enterprise/automotive/pagesbackground/hydrogen/hydrogen_final_report.pdf

The Commission's standards for consultation of interested parties[2] were met throughout the consultation procedure.

2.3. Opinion of the Impact Assessment Board

A draft version of the present impact assessment report was examined by the Impact Assessment Board (IAB). The opinion of the IAB formulated a number of recommendations on the draft impact assessment. These recommendations have been taken into account in the final document in the following way:

- General recommendation and recommendation No. 1: Sections 3.1 and 3.2 have been restructured and additional explanation has been introduced to address the comments of the IAB relating to problem definition and objectives.

- Recommendation No. 2: More explanation has been introduced in section 6.3.3.1 on uncertainties involved in using the HyWays scenarios. Additional wording has been introduced in section 7.3 on the use of the split-level approach. The use of ranges of values (intervals) in the quantification of benefits was not possible, given that the values are based on the input of the consultant that reported absolute figures. Nevertheless, the extensive discussion of uncertainties in section 6.3.3.1 covers the concern expressed by the Impact Assessment Board.

- Recommendation No. 3: The issue of a "package approach" is discussed in section 3.2 and especially in section 3.2.4.

- Recommendation No. 4: Additional explanation on the impact relating to the employment has been included in section 4.2.1.

- Recommendation No. 5: A summary table has been introduced in section 6.3.1 (Table 1) based on the EU standard cost model.

- Procedure and presentation: An additional section has been introduced on monitoring and evaluation (section 8.2). The technical issues relating to hydrogen vehicles are presented in a user-friendly way in the Glossary in Annex III.

3. PROBLEM DEFINITION

3.1. Nature of the issue or problem that requires action

Air quality and noise levels in the cities of the European Union are of major concern. Despite the efforts taken, the contribution of road transport to these environmental problems is still considerable. Therefore, efforts should be made to facilitate the introduction and placing on the market of environmentally friendly vehicles.

The use of hydrogen as fuel for road vehicles offers an environmentally friendly solution for mobility. However, at present hydrogen powered vehicles are not included in the European Community vehicle type-approval framework. This situation results in the fragmentation of the internal market of these vehicles.

[2] COM(2002) 704 final, 11.12.2002

At the same time, since there are perceived safety issues with using hydrogen for vehicle propulsion, it should be ensured that hydrogen systems are as safe as conventional propulsion technologies.

3.2. Underlying drivers of the problem

3.2.1. Environmental and safety issues

Hydrogen is not a source of energy but a promising energy carrier. It has been identified as a major factor towards the objectives of ensuring the security of energy supply, diversification of energy sources, promotion of more efficient energy systems and reduction of the environmental impact of road transport.

With the use of hydrogen as fuel to power road vehicles, whether in fuel cells or internal combustion engines, there are no carbon emissions and greenhouse gases produced from the vehicle. If the fuel is produced in a sustainable manner, the use of this propulsion technology could significantly contribute to the improvement of the environment. The higher the number of hydrogen vehicles on the road, the sooner these benefits arise.

However, hydrogen is a substance that has different characteristics from conventional fuels that are used for vehicle propulsion. In order to realise the environmental benefits associated with the use of hydrogen vehicles, the share of these in the total vehicle fleet should be increased. One of the major factors contributing to the increasing number of hydrogen vehicles on the roads is the existence of public confidence in this new technology.

3.2.2. Lack of European Community type-approval framework

The EC Whole Vehicle Type-Approval (WVTA) system applies to M and N category vehicles[3] powered by conventional fuels (petrol and diesel) on a mandatory basis. This means that these vehicles must comply with all the relevant EC type-approval directives and regulations in order to be placed on the market.[4] Once a type of vehicle has obtained an EC WVTA certificate from the authorities of a Member State, it can be marketed throughout the European Union.

Currently, hydrogen powered vehicles are not included in the EC WVTA framework. Some Member States issue national or single approval for these vehicles, while others are not doing so because of a lack of national or European Union legislation.

At the same time, the regulatory framework for these vehicles is already established in Japan. The United States is also advancing the introduction of hydrogen powered vehicles on the roads. It has to be ensured that the EU keeps pace with other important automotive regions of the World in terms of introduction of advanced vehicle technologies.

3.2.3. Fragmentation of the internal market

Today, automotive manufacturers are making important investments for developing hydrogen technology and have started to offer vehicles on a commercial basis. Further, a number of large-scale demonstration projects have been launched in the European Union that aim to encourage the deployment of this innovative propulsion technology.

The lack of a clear legislative framework poses problems for hydrogen vehicle manufacturers when trying to place these vehicles on the market in the European Union. Currently, even if a vehicle obtains national or single type-approval in one Member State, it is not guaranteed that

3 For a definition of vehicle categories see the Glossary in Annex III
4 The WVTA is regulated by the Framework Directive (2007/XX/EC)

the registration of this vehicle will be authorised in all the other Member States. Further, Member States have the possibility to establish different requirements and to request the fulfilment of diverging standards in order to issue an approval certificate. This situation results in a fragmented internal market of hydrogen powered vehicles, which discourages the introduction of this environmentally friendly technology.

3.2.4. Production and availability of the hydrogen fuel

The successful deployment of hydrogen vehicle technology necessitates the consideration of a number of other issues.

As described above, hydrogen propulsion is considered to be an environmentally friendly technology. However, care must be taken that the hydrogen fuel is produced in an environmentally sustainable way, preferably with the use of renewable energy sources. Otherwise, there is a risk that the benefits linked to the introduction of hydrogen vehicles are surpassed by the environmental consequences of hydrogen production. At the moment, the majority of hydrogen fuel is produced from fossil fuels. It is crucial that in order to benefit from the use of this technology, hydrogen fuel is produced from renewable resources to an increasing extent. It has to be noted in this context that reaching a binding target of a 20% share of renewable energies in the overall EU energy consumption by 2020 has been endorsed by the European Council.[5] Further, it has been proposed that a target of 10-20% of sustainable hydrogen production is reached by 2015.[6] This target has been endorsed by the industry.

Further, it is important to ensure that an appropriate hydrogen refuelling infrastructure is in place in the European Union that is capable of addressing the perceived safety concerns of the public. Establishing the type-approval framework for hydrogen vehicles is an important step towards realising the potential benefits. However, in order to encourage consumers to opt for hydrogen propulsion, it is necessary to have a sufficiently widespread refuelling network. Given that some Member States prevent the installation of hydrogen filling stations on their territory and/or restrict the use of hydrogen vehicles in other ways, the Commission will have to consider whether to propose measures, including legislation where appropriate, that remove obstacles of this kind.

3.3. Stakeholders affected

A wide range of different groups are affected by the problem:[7]

The citizens of the European Union are affected by the environmental impacts of vehicles, in particular by air pollution and vehicle noise. Exposure to air pollution leads to respiratory illnesses and premature mortalities.[8] Noise, particularly during sleep periods aggravates certain types of heart diseases and mental illnesses. Hydrogen powered vehicles offer the possibility to reduce these harmful impacts on the population in proportion to the number of vehicles introduced on the market. Due to the different characteristics of hydrogen fuel, there is a possibility that citizens would also be affected by the potential safety implications of the large-scale introduction of hydrogen vehicle technology. If there was any significant safety deterioration due to the introduction of hydrogen systems, there would be an erosion of public confidence. This could have the potential to undermine the future of hydrogen technologies.

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[5] Brussels European Council, 8/9 March 2007, Presidency Conclusions http://www.consilium.europa.eu/ueDocs/cms_Data/docs/pressData/en/ec/93135.pdf

[6] European Hydrogen & Fuel Cell Technology Platform: Implementation Plan, March 2007, p. 25 https://www.hfpeurope.org/uploads/2097/HFP_IP06_FINAL_20APR2007.pdf

[7] TRL report, p. 9

[8] Thematic Strategy on Air Pollution, COM(2005) 446 final, 21.09.2005

Citizens of countries outside the European Union are affected in similar ways to EU citizens. This can happen when non-EU citizens work in the EU or visit and also when hydrogen powered vehicles registered in the EU are driven to those countries for business or leisure or are sold outside the EU as second-hand vehicles.

The governments of European Union Member States are affected by the large expenditure as a consequence of vehicle exhaust emissions and noise. This expenditure covers direct health costs and social support for citizens who are unfit to work, but also physical measures to reduce transport noise, such as low noise road surfaces, noise barriers and insulation for buildings. As discussed in Chapter 6.3.3, hydrogen vehicles reduce noise, emissions of particulates and emissions of oxides of nitrogen. To the extent to which hydrogen vehicles come into use, there is a possibility that they will lead to corresponding reductions in expenditure by both central and local governments.

It is likely that with the introduction of hydrogen vehicles, businesses in the European Union could benefit from the possible reduction in hospitalisation, employee illness and premature death due to the lower environmental impacts of road transport. It is possible that the effects on businesses will become more important, as the proportion of workers in older age groups increases. Furthermore, these impacts largely depend on the rate of introduction of hydrogen vehicles and are likely to materialise in the long term.

Vehicle manufacturers and component suppliers will be affected by the impacts of a policy option on the demand for hydrogen powered vehicles and hydrogen powertrain technologies in the EU and in export markets.

3.4. Treaty base and subsidiarity principle

Since the objective of the proposal is to lay down harmonised rules on the construction of hydrogen powered motor vehicles with a view to ensuring the functioning of the internal market, the proposed Regulation is based on Article 95 of the EC Treaty.

The subsidiarity principle is respected, since the policy objectives cannot be sufficiently achieved by actions of the Member States and can be better achieved at Community level. European Union action is necessary because of the need to avoid the emergence of barriers to the single market.

4. OBJECTIVES

4.1. Policy objectives

General policy objectives

The proper functioning of the internal market of motor vehicles in the European Union should be ensured. The policy should provide for a high level of public safety and a high level of environmental protection in the European Union and should make sure that the European automotive industry remains competitive.

Specific objectives

A possible regulatory action should aim at a high level of environmental protection by improving urban air quality with the reduction of pollutants emitted by the road transport sector. Since hydrogen is considered to be an environmentally friendly technology in terms of air pollution, the deployment of the hydrogen technology in the European Union should be supported. At the same time, it is important that the general public has confidence in this new technology and at least the same level of public safety is maintained. This is possible by ensuring that hydrogen vehicles are at least as safe as conventional vehicles.

Operational objectives

- The above mentioned general and specific policy objectives can be attained by setting harmonised rules on the construction of hydrogen powered motor vehicles within the European Union. It has to be ensured that hydrogen vehicles are treated equally in comparison to conventional vehicles with regard to the approval procedure.

4.2. Consistency with horizontal objectives of the European Union

4.2.1. Lisbon strategy

The policy objectives of the proposal are in line with the aims of the European Union's Lisbon strategy, which has three pillars, namely:

- Making Europe a more attractive place to invest and work

The policy objectives are supporting the integrity of the single market, providing for uniform standards for hydrogen powered vehicles constructed and put on the market throughout the European Union. It means that the automotive industry in Europe is required to meet uniform regulations throughout the internal market of the EU. By supporting the deployment of the hydrogen technology, this will ensure that the European car industry remains competitive and an attractive industry to invest in. The proposal will also contribute to enhancing its competitiveness on world export markets.

The CAFE Programme has shown that air pollution has significant effects on productivity.[9] By seeking to reduce air pollution, the policy objectives contribute to increasing productivity in the European Union.

- Knowledge and innovation for growth

Extending the type-approval framework to hydrogen powered vehicles encourages the development and implementation of this advanced vehicle propulsion technology. As it is discussed in Chapter 3.2, it is necessary that the EU keeps pace with the technology and regulatory developments in the United States and in Japan with regard to the introduction of hydrogen powered vehicles. By aiming at establishing the approval framework for these vehicles, the policy objectives promote innovation and development, supporting the deployment of hydrogen technologies and opening up the potential for greater export of European technology to other parts of the world.

- Creating more and better jobs

It is assumed that hydrogen will replace existing conventional technologies in vehicle propulsion and there will not be any change in the number of vehicles sold.10 Further explanation of this is included in Chapter 6.3.3. Therefore, there will not be any direct impacts on the number of employees in vehicle manufacturing with the deployment of this technology. However, retraining of the workforce might be necessary with the shift to hydrogen vehicle mass production.

As explained in Chapter 6.3.3.2, it is likely that in the medium and long term, fuel cell propulsion will be the dominant technology for hydrogen vehicles. Given that it is an entirely different technology from that of internal combustion engines, the mass production of these

[9] Methodology for the Cost-Benefit analysis for CAFE, Volume 2: Health Impact Assessment, AEA Technology Environment, February 2005, p. 85

[10] TRL report, p. 27

will necessitate innovative solutions and further research and development. Therefore, it is likely that indirect employment impacts will be created in companies' research and development activities by the increased demand for advanced vehicle propulsion systems. It is also possible that with higher demand for hydrogen technology, manufacturing opportunities will increase at automotive component suppliers involved in this sector. Therefore, the net employment impact is likely to be some increase between high value added research and development activities and also component manufacturing opportunities.

4.2.2. Sustainable Development strategy

At the core of the European Union's Sustainable Development strategy, as communicated by the Commission to the European Council at Göteborg in 2001[11] and supported by the European Council, is that "*economic growth, social cohesion and environmental protection must go hand in hand*". The policy objectives of the proposal are in line with the strategy by ensuring that the automotive industry grows in a more sustainable way through production of advanced, more environmentally friendly vehicles. Such vehicles bring social benefits through reducing the impacts on human health.

5. POLICY OPTIONS

5.1. Options identified

Four policy options have been identified as possible means of meeting the policy objectives identified in the previous section. These are:

(1) **No** policy change: This option would involve no further changes to the current situation. Currently, the scope of European Community type-approval legislation does not include hydrogen powered vehicles. Thus, Member States may grant individual approvals without introducing legislation.

(2) Legislation at Member State level: This policy option would involve adoption of legislation at Member State level to accommodate the introduction of hydrogen vehicles.

(3) Legislation at European Union level: This policy option would involve the extension of the EC type-approval legislation to include hydrogen powered vehicles and setting out harmonised provisions for these vehicles.

(4) Non-regulatory **approach:** Self-regulation through a negotiated commitment with the automotive industry to establish requirements for hydrogen powered vehicles.

5.2. Options discarded at an early stage

It was considered whether all identified policy options would ensure that the stated policy objectives are attained. Following the analysis, two options were discarded at an early stage, these are:

(1) No policy change

This policy option was rejected because of its detrimental effects on the functioning of the internal market, the resulting cost implications for manufacturers and because of its possible repercussions on public safety. Further, it would constitute a substantial barrier for the development of hydrogen technology in the EU. The policy option would not meet the identified policy objectives.

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[11] COM(2001) 264 final.

There are several reasons for these findings:

- As described in Chapter 3.2, the existing EU type-approval legislation does not contain any provisions that address hydrogen powered vehicles. With no action on the type-approval of hydrogen powered vehicles, the market of these would remain fragmented.
- The current situation results in unduly high costs of the approval of hydrogen vehicles, since manufacturers need to obtain single type-approval for each vehicle. It is possible in some Member States, but not in others. Even if a single type-approval is issued in one Member State, it is not sure that the vehicle can be placed on the market in others. In particular, given the small number of hydrogen vehicles that will initially be placed on the market, the cost and delays of multiple type approvals will make the market introduction of these overly difficult. With no change in the policy regarding type-approval of hydrogen powered vehicles, there is a risk that the approval procedure of these vehicles remains lengthy and cumbersome. In this situation, the functioning of the internal market would be impaired.
- The lack of an approval framework would constitute a competitive disadvantage for the European Union, given that other automotive regions are advancing the introduction of hydrogen powered vehicles.
- There is a high risk that with no policy change, poor air quality and high levels of noise in cities of the European Union will remain an issue as atmospheric pollution and noise will continue to have a detrimental impact on human health.
- It is possible that with no change in policy, vehicles of diverging safety standards would be introduced in the markets of European Union Member States. This policy option would be unable to ensure that a high level of safety is respected when this new technology is introduced and that all hydrogen powered vehicles have at least the same level of safety as conventional vehicles. Moreover, the level of safety required could vary not only between Member States, but even within the same Member State.
- In this context, the TRL Report concluded that "existing vehicle manufacturers have a brand image to protect and dispose of extensive experience of vehicle safety. Therefore, there would clearly be a strong commercial incentive for existing manufacturers to produce safe hydrogen vehicles, even in an unregulated market. However, such safeguards would not apply to new companies who had the opportunity to start hydrogen vehicle production in an unregulated market. This would allow the introduction of new and unknown safety risks. This situation could entail decreasing public confidence in this new technology that would decelerate the pace of deployment."[12]
- For the above reasons, this policy option would form a barrier for the development of hydrogen technology in the EU. On this issue, the TRL Report states: "Automotive manufacturers would be more reluctant to invest in the technology, if offered only a fragmented market. Industry aims to introduce hydrogen vehicles commercially at the earliest opportunity, and this option is not compatible with that aim."[13]
- Further, this policy option would lead to uneven treatment of vehicle manufacturers with regard to the vehicle approval procedure and would lack any predictability for manufacturers to design their vehicles.

[12] TRL report, p. 8

[13] TRL report, p. 8

- Finally, when consulting stakeholders through the questionnaire, none of the parties supported this option in their responses. The majority of comments that were received were in support of regulatory action.[14]. The responses have been submitted by vehicle manufacturers, Member State authorities, technical services and public transport operators. An overview of the questionnaire responses on the policy options is provided in Annex I.

(2) Non-regulatory approach

The policy option of self-regulation through a negotiated commitment with the automotive industry was discarded due to the following reasons:

- Self-regulation would imply a significant departure from an approach that is well established and has proven its effectiveness and proportionality in the past. This approach is the whole-vehicle type approval of conventional vehicles, as described in Chapter 3.2.
- There are no safeguards, that this approach would ensure that hydrogen powered vehicles are not discriminated for or against in comparison to conventional vehicles when submitted for approval.
- It is not clear that a self-commitment provides an adequate guarantee that a specific level of safety of hydrogen vehicles will be reached or that there will be appropriate sanctions available if the self-commitment were to be breached.
- As the introduction and use of hydrogen powered vehicles has repercussions on the protection of the environment, public health and safety, it is questionable whether a self-commitment can be justified.
- A large number of other countries around the world base their vehicle legislation on EU practice. A radical change to a non-regulatory approach risks reducing the EU's leadership in this area. The use of EU regulations by other countries also offers competitiveness benefits to the EU automotive industry which could be affected by a change of approach.
- A self-regulation approach could take too much time to be negotiated and to deliver the hoped-for effects.
- The existence of a self-commitment would not prevent Member States from legislating. That would lead to the situation described under policy option 2.

In addition, it is not apparent that the use of a voluntary approach would offer any additional benefits to the industry, governments or the general public. It is likely that a similar compliance process would be used as currently exists in the type-approval system, however there would be additional transaction costs in establishing an appropriate monitoring and compliance mechanism. A regulatory approach instead would provide industry with a stable and predictable framework in which investment in cutting-edge technology solutions would be stimulated.

In theory, this policy option could meet some of the identified policy objectives, such as the protection of the environment and ensuring a high level of public safety to a certain extent. However, it would represent a significant departure from the current regulatory practice and given the need for a new monitoring and compliance system, the option could result in an increase in administrative costs. Further, an important objective, the 'equal treatment' of different vehicle technologies with regard to approval procedures would not be met.

[14] TRL report, p. 8

Last, but not least the industry has not offered any self-commitment to tackle the issue at hand. Thus, this option remains purely theoretical.

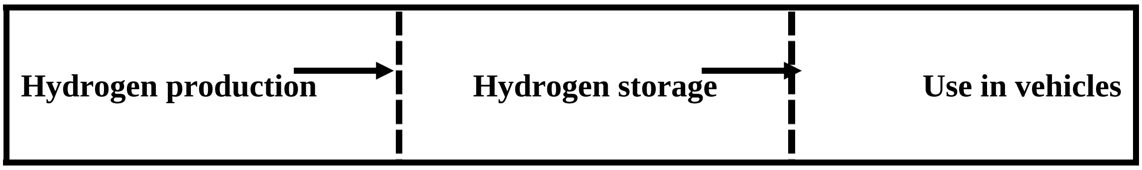
6. ANALYSIS OF IMPACTS

This section analyses the impacts of policy option 2 (Legislation at Member State level) and policy option 3 (Legislation at European Union level) relative to the baseline, which is the No policy change option. The potential social, environmental and economic impacts have been examined.

6.1. Methodology of the analysis

The assessment of the full extent of the impacts of introducing hydrogen as fuel in road vehicles would require a life-cycle analysis. This would comprise three stages as shown in Figure 1.

Figure 1: Life-cycle assessment of hydrogen as fuel for road vehicles



Source: TRL report, p. 6

In fact, the overall environmental impact of using hydrogen as fuel for transport applications would largely depend on the way hydrogen is being produced, stored and transported.

However, as described in Section 4.1, the policy objectives and in particular, the operational objectives are relevant only for the third stage, 'Use in vehicles'. This is because the subject of this impact assessment is the introduction of rules governing the construction of hydrogen vehicles (for classes M1, M2, M3 and N1, N2, N3) and the available policy options. This means that the broader aspects of using hydrogen as fuel in road vehicles, such as production and storage are outside the scope. Therefore, the present impact assessment discusses the implications related to the use of hydrogen fuel in vehicles, excluding the impacts of hydrogen production and storage.

The assessment of the environmental, economic and social impacts of the policy options have been based on the methodology of the consultant of the Commission services supporting this impact assessment. This methodology has been developed based on the Impact Assessment Guidelines of the European Commission.[15] To analyse the impacts of policy options 2 and 3, the following methodology has been chosen:

- The analysis commences with the identification of impacts in the relevant areas;
- To the extent possible, the impacts are quantified under both options. Where it is not possible, qualitative assessment is used;
- In order to identify the preferred option, qualitative and quantitative conclusions are compared and assessed to see which policy option would offer more benefit within a shorter timeframe;

15 SEC(2005) 791 final, 15.06.2005

- Once a preferred option is identified, the technical content of a potential regulatory act is assessed with a view to addressing the issues linked to hydrogen technology.

6.2. Data collection

In the preparation for this impact assessment, the Commission services sent out a questionnaire to stakeholders that requested input on the available policy options and the associated costs. The responses received from the stakeholders were then collected and analysed by the consultant. Some further discussion was held between the consultant and the stakeholders of the Hydrogen Working Group in order to clarify outstanding issues and to generate additional information. The data collected was used as input for the assessment of the impacts of the policy options.

6.3. Impacts of the policy options

6.3.1. Economic impacts

The economic impacts of the identified policy options would materialise in the following areas:

- Single market

At present, manufacturers of hydrogen vehicles face a fragmented situation when applying for type-approval of the vehicles in the European Union. This situation is explained in more detail in Chapter 3.2.

It is apparent that with policy option 2 – legislation at Member State level, it is doubtful whether the policy objectives would be attained. With diverging standards emerging from Member States, this fragmented situation would continue to exist, which would result in manufacturers facing unduly high development and approval costs and limited market accessibility. The policy option would not offer a solution for the present uncertainty regarding the approval of hydrogen vehicles, therefore would discourage further investment in the hydrogen technology.

Policy option 3 – legislation at Community level prevents varying product standards emerging across Member States which results in fragmentation of the internal market and imposition of unnecessary barriers to intra-Community trade. Through harmonised standards on hydrogen powered vehicles it is possible to reap the economies of scale as production series can be made for the whole European market. This policy option would open up markets in some Member States where hydrogen vehicles could not currently be sold.

Harmonised standards for hydrogen vehicles throughout the European Union would have a positive impact on the competition in the internal market by sustaining a ‘level playing field’ for all automotive businesses. Establishing the approval framework is likely to lead to further investment in hydrogen vehicle technologies, since it reduces the uncertainty about the market of these vehicles.

- Competitiveness

The policy option of legislation at EU level would have direct positive impacts on the competitiveness of the automotive industry within the European Union compared to the option of legislation at Member State level. With the EU regulatory policy option, the industry would be able to produce vehicles equipped with advanced propulsion systems that are certified to a common standard. With the establishment of the approval framework, the automotive industry could become more competitive in markets outside the EU, through taking the lead in hydrogen technology. This is due to the following reasons:

Japan already has legislation in force that specifies requirements for the approval of hydrogen vehicles, therefore the placing on the market of these vehicles is already possible in this important automotive region. The United States are also advancing with putting into circulation these vehicles, especially in those states that require manufacturers to develop and sell Zero Emission Vehicles (ZEV). Policy option 3 would represent a significant step towards the large-scale deployment of hydrogen technology in Europe. Encouraging the development of hydrogen vehicle technology will have a positive impact on the international competitiveness of the EU industry through further exporting opportunities.

Establishing the framework for the approval of hydrogen vehicles in the EU could ensure the continued adoption of European vehicle standards by other markets around the world. Current high levels of oil prices and concerns over security of supply are increasing the level of interest in alternative propulsion technologies in a number of markets. Therefore, by setting common standards for these vehicles, it is possible that other countries will adopt a legislation based on the European requirements. So encouraging the deployment of hydrogen technology is an important need which could provide competitiveness benefits for both EU based manufacturers and component suppliers.

Finally, a policy that makes it necessary to develop and introduce new automotive technologies would benefit indirectly the component suppliers in the car industry, who would benefit from increasing revenues.

- European Community budget

The policy options have no impact on the European Community budget.

- Administrative costs

The administrative costs incur to manufacturers when submitting an application for the type-approval of a vehicle. Given that policy options 2 and 3 represent different approaches to type-approval, the administrative costs are substantially different under each option.

The approximate costs to manufacturers per EU type-approval are estimated to be €160,000.[16] It can be assumed that a manufacturer of a hydrogen vehicle would therefore face a cost of around €160,000 for a centralised, single EU type-approval. This corresponds to the approach of policy option 3 (Legislation at EU level). In a worst case, the manufacturer might instead face costs of about €4.3 million (€160,000*27), if each vehicle had to undergo type approval in 27 different Member States that could be the case with policy option 2 (Legislation at Member State level). This estimated approval cost is not likely to differ substantially with different hydrogen technologies, such as liquid or compressed hydrogen storage. This is likely to be the case as well with fuel line components used in the hydrogen system that obtained type-approval on the basis of the requirements of the draft proposal. This is because they are mostly interchangeable independently of the technology used.

If we assume that there will be 30 different hydrogen vehicle types on the market in the period 2017-2025, the total cost of approving these vehicles would be €4.8 million (€160,000*30) under policy option 3, while could be as high as €129 million (€4.3 million*30) under policy option 2. Therefore, policy option 3 would generate substantial savings for manufacturers

[16] UK Department for Transport: Transport analysis guidance, DfT, October 2006. http://www.webtag.org.uk/webdocuments/3_Expert/3_Environment_Objective/pdf/3.3.5.pdf

with regard to the cost of approval of hydrogen vehicles in comparison with policy option 2.[17] A summary of the estimated administrative costs is provided in Table 1, based on the EU standard cost model[18].

17 TRL report, p. 49

18 Impact Assessment Guidelines of the European Commission, SEC(2005) 791 final, 15.06.2005, Annex 10

Table 1: Summary of estimated administrative costs with policy options 2 and 3

Policy option	**Type of obligation**	**Cost (in Euros)**	**Number of approvals needed**	**Total cost of approving one vehicle type (in Euros)**	**Assumed number of vehicle types**	**Total cost (in Euros)**
Policy option 2	Certification	160,000	27	4,300,000	30	129,000,000
Policy option 3	Certification	160,000	1	160,000	30	4,800,000

However, these figures are insignificant in comparison to the additional research and development costs that would be incurred under policy option 2 in a situation where manufacturers have to develop different designs of each vehicle for different Member States.

- Cost of hydrogen vehicles

Hydrogen vehicle propulsion is considered as a new technology and at the moment, vehicles are sold under special arrangements at market prices that are substantially higher than that of conventional vehicles. However, it is expected that the price of hydrogen vehicles will gradually converge to that of conventional vehicles and therefore, mass market introduction will be possible. The choice of policy can play an important role in the time that is necessary to reach competitive price levels.

As explained above, the cost of hydrogen vehicles and the time needed to introduce them will be affected by the choice of policy option. It is possible to give a broad estimation of the impacts of the policy options on the price levels of M1 and N1 hydrogen vehicles in future years. In particular, it was examined, under which policy option hydrogen vehicles would be sold at market prices that are close to that of conventional vehicles and therefore, would allow the general public to afford such vehicles. A competitive price would clearly make the introduction of these vehicles quicker. However, the TRL Report states that "detailed estimates of the costs of producing hydrogen fuel cell vehicles in categories M2, M3, N2 and N3 are not yet publicly available. The cost of developing hydrogen fuel cells for vehicles in classes M2, M3, N2 and N3 depends on how easy it is to scale up fuel cells and hydrogen storage tanks to the increased power demands of these larger vehicles."[19]

"Costs for technology fall over time, for a number of reasons. Two critical factors for hydrogen vehicles will be changes to the technology used in vehicles and cost reductions due to economies of scale as mass production is introduced."[20]

Table 2 shows the cost estimates for different vehicle technologies for category M1 vehicles in Europe in 2010 and beyond compared to the '2010 reference', which is a conventionally fuelled class M1 passenger vehicle in 2010. The cost for such a vehicle is estimated to be 19,560 Euros.[21]

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19 TRL report, p. 48

20 TRL report, p. 45

21 European Commission, DG Joint Research Centre: ‘Well-to-wheels analysis of future automotive fuels and powertrains in the European context’, version 2b, May 2006, Appendix 1

Table 2: Costs of different M1 passenger vehicles in 2010, compared to '2010 reference'

Type of propulsion	Cost (Euros)	Extra cost compared to '2010 reference' (Euros)	Extra cost compared to '2010 reference' (%)
Hydrogen internal combustion engine	24,310	4,750	24.3%
Hydrogen fuel cell	31,193	11,633	59.5%
Hybrid internal combustion engine	25,780	6,220	31.8%

Source: Appendix 1 of 'TANK-TO-WHEELS' section of Joint Research Centre: 'Well-to-wheels analysis of future automotive fuels and powertrains in the European context'

The figures in Table 2 were derived for annual production volumes of more than 50,000 vehicles per annum. Based on this information, the TRL study predicted the rate at which the production costs of hydrogen vehicles will fall using an experience curve.

TRL has identified the threshold of additional price of a hydrogen vehicle, at which they can be competitive with conventional vehicles and which would allow gradual mass market introduction of this highly advanced technology. The threshold was identified as an additional 5,000 Euros above the price of the 'reference vehicle'. This is because at present, cars with an advanced powertrain – hybrid internal combustion vehicles – are on sale at prices that make them profitable for their manufacturers. The figure of 5,000 Euros is less than the extra cost at which today's hybrid vehicles are profitable. The TRL Report concluded that because fuel cell vehicles can be sold profitably from this point onwards, there is no further 'cost' to manufacturers in cost-benefit terms of producing hydrogen fuel cell vehicles. The best fit experience curve shows that the 5,000 Euro extra cost is attained with ca. the 690,000th hydrogen vehicle that is produced. That means that all vehicles produced beyond this number can be profitable for the manufacturer.[22]

The consultant identified that based on the above assumptions and the introduction rates of hydrogen vehicles in Table 6, the time taken for the additional cost per vehicle to reduce to the 5,000 Euro level would be much greater with policy option 2. The number of vehicles sold would reach the required level of 690,000 vehicles in 2018 across the whole of the EU with policy option 3, but the required level would not be reached in any single Member State before 2025 with option 2.[23]

In this context, the TRL Report states that "the average additional cost per vehicle over the 2017-2025 period is also much higher if national legislation is applied."[24] Further, with policy option 3, the development cost of the vehicles will be spread over all the EU markets.

With policy option 2, it would be more difficult for manufacturers to make hydrogen vehicles financially viable in smaller Member States if legislation was introduced at a national level.

22 TRL report, p. 46
23 TRL report, p. 48
24 TRL report, p. 48

Overall, the cost and time for introduction of hydrogen vehicles would be much greater without the policy option of legislation at EU level.[25]

In consequence, assuming that each Member State will develop its own set of differing national legislative requirements, the extra costs and additional time needed for industry to introduce hydrogen vehicles with option 2 compared to option 3 are substantial.[26]

6.3.2. Social impacts

The social impacts of the available policy options are twofold:

- Public health

The introduction of hydrogen vehicles would result in decreasing tailpipe pollutant emissions from vehicles and therefore, in better air quality. Better air quality would improve public health by decreasing morbidity rates and increasing life expectancy of the population, which in turn results in lower mortality.

As shown in Chapter 6.3.3.1, the introduction rate of hydrogen vehicles would be different with each available policy option, thus, the environmental benefits would materialise at a different time and scale. Chapter 6.3.3 identifies that with policy option 3, the environmental benefits will appear earlier than with policy option 2. This means that health benefits will also become visible sooner with policy option 3 than with option 2. The monetisation of these impacts are included in the same chapter.

- Public safety

Hydrogen as fuel has different characteristics than hydrocarbon based conventional fuels. The major differences are described in Box 1. Therefore, the storage of the fuel on board of the vehicle requires a different approach and there are a number of safety aspects with hydrogen vehicles that are different from those of conventionally fuelled vehicles.

Typically, to date hydrogen fuel is stored on board of the vehicle either:

- under high pressure in gaseous form; or
- at very low temperature in liquid form.

Other forms of on-board hydrogen storage and on-board hydrogen generation technologies are currently in the earlier phase of research.

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25 TRL report, p. 48

26 TRL report, p. 47-48

Box 1: Main characteristics of hydrogen in comparison with conventional fuels

The main characteristics of hydrogen that are relevant with regard to the safety of vehicles are the following:

– The temperature at which hydrogen ignites without an external source of ignition is higher than that of gasoline or natural gas.

– The minimum energy that will result in the ignition of a flammable mixture by an electrical discharge is lower for hydrogen than gasoline or natural gas. Given the electrical systems on vehicles this could present a significant increase in risk unless design mitigates it.

– There are limits on the concentration of a flammable substance in air in which it can ignite when a source of ignition is introduced. Outside of the range there is either not enough fuel or not enough oxygen for the reaction to occur. The lower limit for hydrogen (4%) is higher than gasoline (1%) so a greater amount, by volume, is required before ignition can occur. However, the upper limit for hydrogen is much higher (75%) than for gasoline (7.6%) or natural gas (15%), therefore, where a volume becomes too concentrated for gasoline or natural gas ignition at a relatively low level, the range over which hydrogen can ignite is greater.

– Detonation is the process of supersonic combustion in which a shock wave is propagated forward. It is much more destructive than a subsonic deflagration explosion. The range of concentration of hydrogen in air which will result in detonation is very large. The detonation range is almost 75% of the flammability range, meaning that there is a high likelihood that an explosion will be a detonation.

– The diffusion coefficient of hydrogen is much higher than gasoline or natural gas so it will disperse faster.

It can be concluded that the leakage of a hydrogen system in an open space may be safer than gasoline in the same environment, as a consequence of:

– The higher diffusion coefficient of hydrogen; and

– The lower flammability limit of hydrogen is above that of gasoline.

Source: TRL report, p. 57-58

Given the different characteristics of the fuel, it has to be ensured that the risks are adequately mitigated by the design of the vehicles. In particular, it is important that hydrogen vehicles are designed so that they offer at least the same level of safety as conventional vehicles. With regard to the choice of policy options, it is clear that in line with the policy objectives the preference should be to adopt the option which ensures that all hydrogen vehicles sold in the EU fulfil a minimum set of safety standards that represent the same safety level as conventional vehicles.

The identified safety issues associated with the introduction of hydrogen powered vehicles are outlined in Table 3.

Table 3: Safety issues with hydrogen vehicles

Impact area	Issue	Mitigation
Characteristics of fuel	Hydrogen has different characteristics. For example, it ignites and explodes over a greater concentration range, therefore the fire and explosion risk may be greater if a release is uncontrolled. Hydrogen can be stored under high pressure in compressed gaseous form, increasing the risk of explosion.	Research has indicated that an automobile fire with a controlled release of hydrogen may be no more dangerous than with a gasoline fuelled vehicle. The high diffusion coefficient means that a hydrogen leakage will very quickly dissipate in free air. The risk of hydrogen release from vehicles should be minimised by requiring tests.
	The electrical discharge energy to ignite hydrogen is much lower. A typical electrical discharge contains enough energy to ignite gasoline or hydrogen.	It should be required that no electrical current passes through hydrogen containing parts.
Impact Protection	Insufficient impact protection of a hydrogen storage system would result in a much greater risk of uncontrolled hydrogen release.	The hydrogen storage container(s) must have sufficient integrity to withstand an impact. The rate of leakage from the container(s) after an impact must be limited. The structure used to mount the container(s) to the vehicle must have sufficient integrity. The tank cannot be mounted in a location where it is exposed to a high risk of impact damage without an additional protective structure.
Release in enclosed area	In an enclosed space there is a risk of the concentration of hydrogen exceeding the lower flammable limit.	Hydrogen has a high diffusion coefficient in free air. This means that these situations should only occur infrequently provided vehicles have an in-built monitoring system. Therefore it should be required to fit vehicles with systems which detect and then stop leaks.
	Release of hydrogen into the passenger compartment could present a risk of fire or can cause passengers to lose consciousness due to the presence of too little oxygen or too much carbon dioxide in the blood.	Release of hydrogen into the passenger compartment should not be allowed.
General safety issues	If appropriate materials are not selected hydrogen can cause significant deterioration in fuel system components by diffusing into steel and other metals, causing embrittlement. As a result, the metal will break or fracture at a much lower load or stress.	Hydrogen embrittlement test should be required for components in connection with hydrogen.

	Fuel cell vehicles operate at high voltages so there are issues of electrical shock, isolation and ignition.	Vehicles should be subject to existing legislation which should prevent this risk.
	Electric (e.g. hydrogen fuel cell) vehicles may be quieter than current vehicles, so would give little or no warning of their approach to other road users. This could potentially increase the risk on an injury accident, particularly to vulnerable road users.	This issue is out of the scope of vehicle type-approval and currently the risk it presents is unknown. However, the level of noise reduction is dependent on the technology employed and may not be as great as some sources have reported due to additional noise provided by the tyres and auxiliary components.
	Different procedures for dealing with fires may be required, a hydrogen flame should not be extinguished unless necessary as it could spontaneously/ explosively reignite. A hydrogen flame is invisible and radiates little heat to the surrounding area, which could present an increased risk to those providing assistance.	External identification of hydrogen powered vehicles should be possible by using labels.
	It has been hypothesised that the mass distribution and stiffness of vehicles may change from that of current vehicles to incorporate the new technologies. This may have an effect on the protection to occupants and other road users.	Hydrogen vehicles should be subject to the same type-approval procedures as current vehicles so will be required to meet the same standards.
	The quantity of water vapour emitted from fuel cell hydrogen vehicles has been demonstrated to potentially be no greater than from conventionally fuelled vehicles. However, water vapour emissions from the hydrogen internal combustion (IC) engine may be twice as high. The water vapour emissions from fuel cell vehicles are at lower temperature. An increase in quantity or decrease in temperature could increase the risk of poor visibility or road conditions, although the extent would be highly dependent on the amount of change to the number of hydrogen vehicles.	The extent of this issue is unknown at present and will be highly dependent on the hydrogen system. This issue is out of the scope of vehicle type-approval legislation.
	Current hydrogen bus designs have the hydrogen system mounted on the roof of the vehicle, which could have implications for the vehicle stability and rollover protection. Roof mounted hydrogen systems may be subjected to significant loading in the event of bus rollover.	Vehicles should be subject to stability and rollover protection tests under existing legislation. Rollover protection is only to ensure protection of occupants. Systems such as ESP could be utilised to increase bus safety by reducing the risk of rollover and damage to a roof mounted hydrogen system. Encouragement of these systems would have an additional safety benefit for non-hydrogen fuelled buses.

Source: TRL report, p. 12-16

Statistics on the rate of occurrence of the safety issues identified in Table 3 are currently not available. This is because research has only identified the risks of hydrogen systems which are of equivalent standard to that of the draft proposal for a potential EU Regulation.[27] Further research of sub-standard systems would be necessary to quantify the magnitude of these risks.

However, the TRL Report stated that in order "to ensure that hydrogen systems with unknown safety disbenefits are not introduced, it is necessary to implement legislation. The available research indicates that a hydrogen system can be designed to reduce the inherent risks of the fuel, as described in Table 3."[28]

TRL reviewed the technical content of the draft proposal for a potential EU Regulation with a view to addressing the identified safety issues. The TRL Report concluded that the extension of the type-approval framework to hydrogen vehicles and in particular, the technical requirements of the draft proposal properly address and mitigate the aspects of safety which have been identified in Table 3. It was reported that "there is general agreement world-wide that the requirements of the draft proposal contain the necessary technical content. The development of the technical requirements was carried out in conjunction with international standards to maximise the harmonisation of the legislation. This ensures that an equivalent safety standard is attained across the legislation. Safety research has been conducted with systems of this standard, and in all presented cases the system was able to address the main safety issues."[29]

Research indicates that hydrogen fuel systems designed and constructed to standards equivalent to the technical contents of the examined draft proposal for a potential Regulation would have no significant safety disbenefits when compared with conventional vehicles.[30] The presented research has demonstrated that a high standard hydrogen fuel system has a safety level comparable to conventionally fuelled vehicles. "Implementation of the proposed draft legislation for hydrogen vehicles will ensure a high standard of system. Based on the available data there is no reason to believe that the introduction of systems to the standard of the proposed legislation will have any negative impact on accident frequency or severity."[31] This view was confirmed by stakeholders of the Hydrogen Working Group at the meeting of 14 November 2006.

The characteristics of hydrogen are such that it is hypothesised that it would be unsafe to allow introduction of unregulated hydrogen systems. The consultant recommends that "unregulated production hydrogen systems should not be allowed within any EU member state. Systems of any standard lower than that of the proposed legislation also present an unquantified level of risk so should not be allowed without further research to quantify the risk."[32]

For the above reasons, it is concluded that the preferred option is to introduce uniform provisions on the construction of hydrogen powered vehicles at the European Union level to address the safety issues identified. This approach corresponds to policy option 3 – legislation at EU level. Within the EU regulatory option, it was recommended by TRL to introduce the technical requirements of the reviewed draft proposal for a potential EU Regulation. This

27 TRL report, p. 23
28 TRL report, p. 11, 17
29 TRL report, p. 17-18
30 TRL report, p. 11
31 TRL report, p. 22
32 TRL report, p. 23

would make sure that these requirements are applied on a uniform basis throughout the Community and would provide for a high level of public safety.

6.3.3. Environmental impacts

In order to assess the environmental impacts of the two policy options, the following approach has been taken:

- The significant environmental impacts have been identified;
- The significant impacts have been quantified wherever possible, using a 4% discount rate;
- The difference between the environmental impacts of the two policy options has been assessed.

There is sufficient information available to make quantified estimates of the impacts of hydrogen vehicles in terms of noise and air quality. Table 4 gives an overview and general qualitative description of significant environmental impacts of the policy options.

Table 4: Qualitative assessment of significant environmental impacts

Impact area:	Main issues identified, description of impacts
Air Quality/Human health	Hydrogen powered vehicles in all of classes M1-M3 and N1-N3 will lead to reductions in background levels of particulates and NOx. Hydrogen buses and N1 commercial vehicles will lead particularly to reductions in levels of particulates and NOx in urban areas.
Greenhouse gases	The production and use of mass produced hydrogen vehicles will cause some emissions of carbon dioxide. The amount of the emissions will depend mainly on how the hydrogen fuel is produced, distributed and stored. As discussed in Section 6.1, these issues lie outside the scope of this report.
Mobility	In the light of current EU approaches to fuel taxation, it is assumed that a large proportion of the cost to consumers of any fuel in 2020 will depend on the carbon emissions from the production and use of that fuel. However, taxation policies are difficult to be predicted more than a decade in advance. It is also not clear what the 'well to wheel' emissions from hydrogen as a road fuel will be, when hydrogen is mass produced. We cannot therefore yet conclude that hydrogen fuel would cost consumers less than petrol and diesel. As a consequence, it is not possible to predict whether hydrogen would lead to increased mobility, at any given level of disposable income.
Noise	Fuel cell powered vehicles will have low levels of engine and transmission noise. Their tyres will however still generate noise. If hydrogen powered vehicles are heavier than current vehicles, of equivalent load capacity, then tyre noise may even increase slightly, for example due to the use of wider tyres. It is assumed that noise levels from internal combustion engine hydrogen vehicles will be similar to those of new conventional vehicles.
Material assets; Renewable and non-renewable resources	Fuel cells and hydrogen storage tanks require different materials to internal combustion engines and petrol or diesel fuel tanks. The impacts on material use may be positive or negative. As an example, fuel storage tanks in hydrogen vehicles are likely to require more steel or alloys than modern plastic petrol or diesel tanks. If mass-produced hydrogen powered vehicles were heavier, then they would need stronger brakes, and would

	wear tyres more rapidly. The net effect on material assets depends greatly on whether mass produced hydrogen vehicles are more or less durable than petrol and diesel vehicles, which is currently not known.
Water quality	The quality of water in rivers and in standing bodies of water is affected by vehicles through: (i) Particulates from brakes and tyres, particularly through run off from roads; (ii) Particulates and NOx emissions from vehicle exhausts, particularly when rain removes these from the atmosphere; (iii) Spills of petrol and diesel, from crashed or damaged vehicles, and from leaks in supply tanks and pipelines. Fuel cell hydrogen vehicles will not produce effects (ii) and (iii). Internal combustion engine hydrogen vehicles will not produce particulates from exhaust gases, and will not show effect (iii).

Source: TRL report, p. 25-26

The approach taken to quantify the environmental impacts assumed that:[33]

- Hydrogen vehicles will enter the fleet in the European Union at the rates predicted by the HyWays project. The HyWays scenarios regarding introduction rates are discussed in Chapter 6.3.3.1.

- In line with the approach followed by HyWays, hydrogen vehicles will be sold as substitutes for conventionally powered petrol, diesel and hybrid vehicles, which would otherwise have been sold. It was assumed that the advent of hydrogen powered vehicles will neither cause an expansion of the total number of vehicles on the roads, nor reduce the number. As explained in Box 5 below, the TRL Report assumed on the basis of the HyWays data that there will be a total stock of 292 million M1 and N1 vehicles in the EU-27 in the period 2017-2025.[34] It is possible that the introduction of hydrogen vehicles will change the turnover rate in the future as consumers change to this more environmentally friendly technology. It could be for example that because of the additional price of the technology, existing cars are kept for a longer time. However, it can also be expected that some consumers are content to pay the additional price of the technology in order to benefit from the improved environmental performance or other perceived advantages of advanced vehicles, similarly to hybrid cars. Furthermore, government taxation policies, such as financial incentives for company cars and vans with low emissions could offer payment of an amount equal to the extra cost of purchase and operation over the lifetime of the vehicle. For many consumers and businesses, a combination of both of these effects will lead to purchase of the vehicle, despite its greater cost.[35] Given the uncertainties involved, the number of vehicles is assumed to be constant in this impact assessment.

- According to the TRL Report, "the impact of a hydrogen powered vehicle on any environmental variable should be measured in comparison to the impact of a new petrol or diesel vehicle, which would otherwise have been sold. For this comparison, information on the environmental impacts of the petrol or diesel vehicles have been used that will be

[33] TRL report, p. 27
[34] TRL report, p. 36
[35] TRL report, p. 46

available in the years when hydrogen vehicles will be sold. Therefore, it has to be considered how much the environmental impacts of conventional vehicles will improve by the period 2017-2025." The projection of future impacts is provided in Box 2. This clearly shows that in order to assess the environmental impacts of hydrogen vehicles, it is sufficient to estimate the impacts of M1 and N1 vehicles.

Box 2: Relative environmental impact of vehicles

The consultant study concluded that "with the Euro 5 and V emission standards, M2 and M3 vehicles have around 6-8 times the environmental impact of M1 and N1 vehicles, per vehicle kilometre driven. With Euro 6 and VI, M2 and M3 vehicles will have around 5 times the impact on air quality of M1 and N1 vehicles, per kilometre driven."

The study demonstrates that "bus and coach traffic represents a small proportion of all traffic. For every vehicle kilometre driven by a bus or coach, around 75 kilometres are driven by vehicles in categories M1 and N1. By 2020, this will rise to around 100 kilometres. If 100 kilometres are driven by category M1 and class N1 vehicles for each kilometre driven by class M2 and M3 vehicles, then the total distance driven in the EU-27 by M1 and N1 vehicles will have around 20 times the impact on air quality of the distance driven by M2 and M3 vehicles in 2020."

"This analysis shows that the rate of adoption of category M1 and N1 hydrogen powered vehicles is the key to understanding the environmental impacts that hydrogen vehicles will bring. Even if 50% of new M2 and M3 vehicles were powered by hydrogen in 2020, for example, the effect on air quality would be equal to the effect that would result from only 2.5% of the M1 and N1 vehicles running on hydrogen."

Source: TRL report, p. 32-33

However, there is uncertainty in three key issues, which are discussed in Box 3.

Box 3: Uncertainties regarding the quantification of environmental impacts

1. The rate of introduction of hydrogen vehicles in categories M1-M3 and N1-N3 into the vehicle fleet.

   It is necessary to know what percentage of road miles will be driven by hydrogen vehicles, in each future year, in each of categories M1-M3 and N1-N3. This can be estimated, based on the HyWays project's data on the share in the total vehicle fleet for hydrogen vehicles in future years. Uncertainty arises, and therefore caution is necessary, because of experience with earlier automotive technologies. The rate at which previous new technologies have actually entered the vehicle fleet has differed greatly from the predictions. For example, sales of petrol electric hybrid vehicles have been far below the predicted levels.

2. The difference in environmental impacts between hydrogen vehicles and future petrol and diesel vehicles.

   It is not clear how much the environmental impacts of new petrol and diesel vehicles will have decreased by the time that hydrogen vehicles become widespread. This depends both on the year of introduction of hydrogen vehicles, and the pace of European Union emissions standards legislation. Projections of the environmental impacts of non-hydrogen conventional vehicles can be made, based on the latest information about future exhaust emissions standards.

3. The incentive effects of government taxation policies.

   Government policies on fuel taxation, together with registration and circulation taxes, will potentially determine the rate at which hydrogen vehicles are introduced. Financial incentives have already been used in some Member States to encourage purchase of vehicles fulfilling more stringent emission standards before the date on which legislation made these mandatory. Taxation policies are likely to be a deciding factor in both the rate of environmental improvement of conventional vehicles, and the rate at which hydrogen vehicles become widespread. Taxation policies remain largely in the hands of the Member States, and subject to relatively frequent change.

Source: TRL report, p. 28

It is possible to quantify the environmental benefits that hydrogen vehicles will bring in the areas of noise and air quality. Chapters 6.3.3.2 and 6.3.3.3 therefore consider the value of benefits that would arise as a consequence of options 2 and 3 respectively, using the data on the number of hydrogen vehicles in the stock and percentage of all vehicle kilometres given in Chapter 6.3.3.1. In the calculations of benefits arising in years 2017-2025, a discount rate of 4% has been used to calculate the values for the 2007 base year.

6.3.3.1. Rate of adoption and use of hydrogen vehicles

- It is apparent that in order to compare quantitatively the impacts of the two policy options, the rate of introduction of hydrogen vehicles in the market has to be established under each of these options.

Rate of adoption of M1 and N1 hydrogen vehicles

Given the timescale involved in introducing the innovative hydrogen propulsion technology at a mass market scale, it is difficult to have prediction of the number of hydrogen vehicles that will be sold in the EU-27 in future years.[36] However, - among other tasks - the HyWays[37] research project established scenarios for the rate of introduction of hydrogen powered passenger cars into the EU-15 Member States. HyWays is an integrated project, co-funded by

[36] TRL Report, p. 34
[37] www.hyways.de

research institutes, industry and by the European Commission under the 6th Framework Programme. The project "aims to develop a validated and well-accepted roadmap for the introduction of hydrogen in the energy system. The main characteristic of this European Hydrogen Energy Roadmap is that it reflects real life conditions by taking into account not only technological but also country specific institutional, geographic and socio/economic barriers and opportunities. Both stationary and mobile applications are addressed, including possible synergies ('spill over effects') between these applications. The Roadmap is based on inputs from European industry, research institutes and government agencies and backed up with the best-available data. HyWays will systematically describe the future steps to be taken for large-scale introduction of hydrogen as an energy carrier in the power market and transport sector and as a storage medium for renewable energy. An action plan for the support of the introduction of hydrogen technologies will be derived from this Roadmap."[38]

The scenarios represent the current understanding regarding the proportion of vehicles in the EU-15 Member States that will be powered by hydrogen and the availability of a hydrogen refuelling infrastructure in future years. The HyWays project established these scenarios by taking into account two parameters: policy support and technical learning. The assumptions behind the scenarios are discussed in Box 4. Given that at the moment, only the interim conclusions are available from the project, these scenarios are unpublished. However, the members of the Hydrogen Working Group confirmed and validated their use for the purpose of this impact assessment.

Box 4: Assumptions of the HyWays scenarios

<u>Scenario a: Extreme high policy support, fast learning</u>

- Describes maximum that could be achieved;
- Begin of commercial sales of hydrogen vehicles in 2013;
- A group of first movers will start serial production in the order of some thousand units per OEM per annum initially;
- Just a few years later production volumes of first movers will reach the order of 100,000 units per OEM per annum and second movers (rest of major OEMs) will follow;
- Extreme high policy support including substantial public procurement will support and facilitate fast technical learning and fast market penetration in the whole EU. This would entail high level of deployment support schemes, the Hydrogen and Fuel Cell Joint Technology Initiative in place for 2008 and the quick adoption of regulations, codes and standards;
- Early adopters will start buying hydrogen & fuel cell vehicles before 2020, paving the way for mainstream customers before 2025.

<u>Scenario b: High policy support, fast learning</u>

- Baseline for target setting, 'ambitious but realistic' scenario;
- Begin of commercial sales in 2013;
- A group of first movers will start serial production in the order of some thousand units per OEM per annum initially;
- Around 2020 production volumes of first movers will reach the order of 100,000 units per OEM per annum and second movers (rest of major OEMs) will follow;
- High policy support including initial public procurement will support and facilitate fast technical learning. The same assumptions as with 'extreme high policy support', but with some delay compared to that;

38 HyWays: A European roadmap http://www.hyways.de/docs/Brochures_and_Flyers/HyWays_External_Document_02FEB2006.pdf

- After 2020 private customers will start considering hydrogen.

Scenario c: Modest policy support, modest learning

- Describes the undesirable situation;
- Begin of commercial sales in 2016;
- A group of first movers will start serial production in the order of some thousand units per annum per OEM initially;
- Remaining OEMs will start to follow with delay (approximately one vehicle generation later);
- Due to still comparatively high production cost for hydrogen storages systems and FC systems main interest of OEMs consist in further learning and loss minimisation; less drag to increase production volumes fast;
- Lacking policy support will limit initial sales activities to selected EU regions. This scenario assumes the lack of policy support and insufficient adoption of regulations, codes and standards.

Source: HyWays presentation, 8 May 2007, http://www.hyways.de/docs/presentations/External_Validation_08MAY2007/HyWays_total_presentation_8_May_2007_final.pdf

The HyWays introduction rates given for the years 2017-2025 are reproduced in Table 5 below. The introduction rates and therefore, the impacts of the policy options have been analysed in this impact assessment in the period 2017-2025. This is because it is considered that 1% of all passenger cars in use would need to be hydrogen powered before the effects are significant enough for consideration in this analysis and this figure is attained the earliest in 2017 with scenario a of HyWays. The HyWays scenarios offer data for years beyond 2025 too, however there are two issues regarding these data. First, the accuracy of forecasts generally falls further into the future these forecasts are made. Secondly, it is difficult to estimate the environmental impacts of conventional vehicles that will be on sale after 2025. It is therefore not possible to assess the environmental impacts that hydrogen vehicles might potentially offer in comparison to those conventional vehicles beyond 2025.[39]

[39] TRL Report, p. 34

Table 5: Introduction rates for hydrogen vehicles in 2017-2025

Year	HyWays Scenario a: Extreme high policy support, fast learning	HyWays Scenario b: High policy support, fast learning	HyWays Scenario c: Modest policy support, modest learning
2017	1.0%	0.2%	0.006%
2018	1.5%	0.4%	0.02%
2019	2.3%	0.7%	0.04%
2020	3.2%	1.2%	0.1%
2021	4.4%	1.7%	0.1%
2022	5.7%	2.4%	0.2%
2023	7.3%	3.2%	0.4%
2024	9.1%	4.1%	0.6%
2025	11.2%	5.1%	0.8%

Source: TRL report, p. 34

Which HyWays scenario corresponds to which policy option?

In order to identify which HyWays scenario corresponds to which policy option of this impact assessment, the following issues were considered:

The assumptions behind the HyWays scenarios, as discussed in Box 4 were assessed with a view to identify the approximate matching between the scenarios and the policy options of this impact assessment.

As a preliminary remark for the purpose of this section, it is clear that the option of legislation at EU level (policy option 3) would have several key effects:

- With option 3, the single market of the European Union would be less fragmented than with option 2;
- With option 3, converging rules for the approval of hydrogen vehicles will be introduced;
- Option 2 would clearly mean a lower degree of policy support than option 3 at the level of the European Union.

It is apparent from the above considerations that with option 3, there would be less delay in the materialisation of the impacts than is likely with option 2. Therefore, it can be assumed that HyWays scenario c approximately corresponds to the rate of introduction of hydrogen vehicles that can be expected with policy option 2, while scenario b corresponds to the rate of introduction with policy option 3.[40]

[40] TRL report, p. 36

However, there are a number of uncertainties arising from this assumption:

- Scenario b in Table 5 specifies both ‘high policy support’ and ‘fast learning’. It is likely that this level of encouragement for the introduction of hydrogen vehicles exceeds the benefits that would be gained only by creating the framework for approval of hydrogen vehicles. It may involve additional policy measures that encourage the deployment of the technology, such as the establishment of a refuelling infrastructure and further adoption of technical standards for other applications.

- The TRL Report states that "scenario b implies more than just the presence of a regulation relating to European type-approval requirements for hydrogen powered vehicles. For example, key components of a package of ‘high policy support’ might include taxation incentives for the early introduction of hydrogen vehicles, policies to scrap older vehicles and encourage fleet renewal, and a public information campaign."

- Scenario c specifies ‘modest policy support’ and ‘modest learning’. As explained in Table 5, this scenario assumes that the lack of policy support will limit the sales of hydrogen vehicles to selected regions in the EU and that regulations and standards will not be in place at a uniform level. The limited sales activity corresponds to the situation that can be expected with policy option 2. This is because with this policy option, it can be assumed that some Member States will pass legislation to facilitate the introduction of these vehicles, while some others will not allow the placing on the market of these. It is likely that the sales of hydrogen vehicles will be limited to those Member States that passed legislation.

- Including hydrogen vehicles in the type-approval framework would speed up the pace of introduction of these vehicles. Therefore, and given that it is not the most optimistic scenario, the consultant report identified that "introduction figures from Hyways scenario b can be considered as a proxy prediction for the rate of introduction of the hydrogen vehicles under policy option 3, legislation at EU level. However, this is likely to lead to a certain degree of overestimation of the benefits that would arise from option 3".[41]

Therefore, it was concluded that scenarios b and c represent approximately the introduction rates that can be expected with policy options 3 and 2 respectively.

The use of the HyWays scenarios and the choice of the corresponding policy options was confirmed and validated by the stakeholders of the Hydrogen Working Group. It was also confirmed by the Working Group that these scenarios represent the most accurate projections regarding the penetration of hydrogen vehicles to date.[42]

Rate of adoption of M2, M3, N2 and N3 hydrogen vehicles

Regarding the rate of adoption of hydrogen powered vehicles in categories M2, M3, N2 and N3, the TRL Report concludes the following:[43]

- Given the relatively small number of M2 and M3 vehicles in the EU compared to M1 and N1 vehicles, their adoption will have relatively low impacts in comparison to those vehicles. This is discussed in detail in Box 2.

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41 TRL Report, p. 35

42 Minutes of the 4th meeting of the Hydrogen Working Group http://ec.europa.eu/enterprise/automotive/wgh_meetings/minutes_4.pdf

43 TRL report, p. 37-38

- The power demands on smaller N2 vehicles are comparable to those of M3 vehicles. At first sight therefore, it might be assumed that hydrogen power would be introduced at a similar rate in category N2 vehicles to the rate for category M3 vehicles. However, there are two main differences:

  – N2 vehicles are operated almost exclusively by the private sector. Without specific incentive schemes, private sector operators have less incentive to introduce technologies that improve urban air quality than the local authorities who operate many bus services.

  – Bus services are often local in nature. The vehicles can therefore be re-fuelled at one or two dedicated hydrogen re-fuelling stations. On the contrary, category N2 vehicles often operate over a much larger area and distance. The lack of a comprehensive hydrogen re-fuelling infrastructure across the EU-27 therefore represents a much larger constraint for purchasers of category N2 vehicles than for operators of M3 vehicles.

- Currently, there is little interest in using hydrogen in category N3 vehicles. The reason for this is that bigger vehicles would require a lot of their cargo space to be transformed into hydrogen fuel tank. The current consensus view is that hydrogen will only be used in N2 and N3 vehicles as a secondary power source.

For these reasons, the rate of introduction of hydrogen vehicles in categories M2, M3, N2 and N3 has not been quantified.

The number of hydrogen vehicles and the kilometres driven

In order to be able to quantify the environmental impacts of the two policy options, it is necessary to have forecasts on the number of hydrogen vehicles in the total vehicle fleet and the number of kilometres driven in the respective years.

Box 5: Total stock of vehicles in EU-27 in 2017-2025:

(3) The HyWays data included estimations of the population of the EU-15 and of the motorisation rate (number of passenger cars per inhabitants) in these countries. On the basis of these figures, the estimation of the number of hydrogen powered cars in the EU-27 could be established in each of the years 2017-25. The consultant estimated that the population of the EU-27 will be a total of 495 million in each of these years. It has been assumed that there will be 540 vehicles per 1000 inhabitants on average in the EU throughout this period. That gives us a total number of 267 million passenger cars in each of the years 2017-25. It has been estimated that in 2020 there will be 9.5% as many N1 vehicles as M1 vehicles. Therefore 9.5% is added to the total number of 267 million passenger cars. Thus, a total stock of 292 million M1 and N1 vehicles in each of the years 2017-2025 is assumed.

Source: TRL report, p. 35-37

Applying the figure of 292 million vehicles to the HyWays scenarios, the total number and share in the fleet of M1 and N1 hydrogen vehicles can be established for policy option 2 and 3. The figures are included in **Table 6**.

In Table 6, a column has been provided for both policy options that converts the number of vehicles into billions of vehicle kilometres driven on the EU's roads. The mean annual mileage figure for M1 and N1 hydrogen vehicles across all Member States has been assumed to be 20,000 km.[44]

Table 6: Predicted rate of adoption and use of M1 and N1 hydrogen vehicles

	Policy option 2 – Legislation at Member State level			**Policy option 3 –Legislation at EU level**		
Year	**Hydrogen vehicles as a % of all vehicle stock**	**Number of hydrogen powered M1 and N1 vehicles (million)**	**Annual vehicle kilometres driven (billion)**	**Hydrogen vehicles as a % of all vehicle stock**	**Number of hydrogen powered M1 and N1 vehicles (million)**	**Annual vehicle kilometres driven (billion)**
2017	0.006%	0.0	0	0.2%	0.6	12
2018	0.02%	0.1	1	0.4%	1.2	24
2019	0.04%	0.1	2	0.7%	2.0	40
2020	0.1%	0.3	6	1.2%	3.5	70
2021	0.1%	0.3	6	1.7%	5.0	100
2022	0.2%	0.6	12	2.4%	7.0	140
2023	0.4%	1.2	23	3.2%	9.3	186
2024	0.6%	1.8	35	4.1%	12.0	240
2025	0.8%	2.4	47	5.1%	14.9	298

Source: TRL report, p. 37, p. 106

The total of all vehicle kilometres driven by hydrogen vehicles in the period 2017-2025 is 132 billion under Option 2, while 1110 billion under Option 3. It is assumed that these distances are a direct substitute for kilometres that would otherwise be driven by new conventional petrol and diesel vehicles in the same years, including some hybrid conventional vehicles.

6.3.3.2. Impacts on noise

For the calculation of the impacts on noise, the derivation of a figure for the noise of hydrogen vehicles is necessary.

The TRL Report states that "hydrogen fuel cell vehicles produce noise from their tyres. It is assumed that there is negligible propulsion system noise, i.e. no ‘engine’, ‘transmission’ or ‘exhaust’ noise. Considering a typical range of vehicle types and speeds, tyre noise can be estimated to be 50% of noise generated by a vehicle. A hydrogen fuel cell vehicle would therefore produce 50% less noise than a comparable vehicle with a conventional internal combustion engine. Hydrogen internal combustion engine (IC) vehicles can be assumed to

44 TRL report, p. 37

emit more noise than hydrogen fuel cell vehicles. It is assumed that hydrogen IC vehicles offer no noise advantages over the conventional vehicles that will be available in the future."[45]

The value of road traffic noise reduction across the EU-27 is estimated to be 5.8 billion Euros per decibel per annum.[46] This figure can then be combined with the estimates of the proportion of all M1 and N1 vehicles that will be powered by hydrogen fuel cells in the years 2017-25, in order to estimate the noise saving.

Box 6: Key assumptions regarding the calculation of noise benefits

1. For every 1% of the category M1 and N1 vehicle stock that is made up by hydrogen fuel cell vehicles, the noise emissions from category M1 and N1 traffic will fall by 0.03dB(A). This is because for a 'line source' of noise, such as a stream of traffic, a reduction in noise of 50% from each vehicle, as discussed above, equates to a reduction of 3 dB(A) in the noise level at any given observation point.

2. Category M1 and N1 vehicles will make up 70% of all traffic noise in 2015-2020, a figure close to that for 2006. The remainder of the noise is from M2, M3, N2 and N3 vehicles.

3. 90% of category M1 and N1 hydrogen vehicles in the fleet will be fuel cells, with the other 10% being internal combustion engines. This is assumed because of the following reasons. Hydrogen fuel cell vehicles reduce noise and emissions of oxides of nitrogen. To the extent to which hydrogen fuel cell vehicles come into use, they will lead to reductions in environmental impacts. On the other hand, while internal combustion (IC) engine hydrogen vehicles will be introduced earlier (because they largely use existing combustion technology), they do not show all the advantages of fuel cell hydrogen vehicles. Current designs of IC hydrogen engines appear to have similar noise and NOx performance as the latest designs of conventional vehicles. Further, hydrogen powered IC engine passenger vehicles appear to be somewhat heavier than the conventional models on which they are based. As explained in Chapter 6.3.3.4, these vehicles are less energy efficient than equivalent conventional vehicles. Although IC engine hydrogen vehicles offer good possibility to be introduced for a transitory period, it is likely that in the medium and long term fuel cell propulsion will be the dominant technology.

4. So for each 1% of the vehicle stock that is made up of hydrogen vehicles, the reduction in traffic noise perceived by the public will be:

   0.03dB(A) x 0.9 x 0.7 = 0.02dB(A).

Source: TRL report, p. 40

Figures in

[45] TRL report, p. 39-40

[46] TRL calculation based on FEHRL, BAST, TRL, TUV Nord, VTI: Final report S12.408210 tyre/road noise: volume 1, http://ec.europa.eu/enterprise/automotive/projects/report_tyre_road_noise1.pdf; TRL report, p. 40

Table 7 and Table 8 below were calculated on the basis of the information on hydrogen vehicle stock under policy options 2 and 3 in each future year, as discussed in Table 6.

Table 7: Policy option 2 (legislation at Member State level) - Value of noise reductions due to hydrogen fuel cell vehicles in categories M1 and N1

Year:	Proportion of stock that is hydrogen powered	Resulting noise reduction from all traffic @ 0.02dB(A) per percentage (db(A) per annum)	Value of reductions in noise @ 5.8 billion€ per dB(A) (million € per annum)	Value of noise reductions after discounting (million € per annum)
2017	0.006%	0.00012	1	0
2018	0.02%	0.0004	2	2
2019	0.04%	0.0008	5	3
2020	0.1%	0.002	12	7
2021	0.1%	0.002	12	7
2022	0.2%	0.004	23	13
2023	0.4%	0.008	46	25
2024	0.6%	0.012	70	36
2025	0.8%	0.016	93	46
Total				**138**

Source: TRL report, p. 106

Table 8: Policy option 3 (legislation at EU level) - Value of noise reductions due to hydrogen fuel cell vehicles in categories M1 and N1

Year:	Proportion of stock that is hydrogen powered	Resulting noise reduction from all traffic @ 0.02dB(A) per percentage (db(A) per annum)	Value of reductions in noise @ 5.8 billion € per dB(A) (million € per annum)	Value of noise reductions after discounting (million € per annum)
2017	0.2%	0.004	23	16
2018	0.4%	0.008	46	30
2019	0.7%	0.014	81	51
2020	1.2%	0.024	139	84
2021	1.7%	0.034	197	114
2022	2.4%	0.048	278	154
2023	3.2%	0.064	371	198
2024	4.1%	0.082	476	244
2025	5.1%	0.102	592	292

Total				**1182**

Source: TRL report, p. 40

It is clear from

Table **7** and **Table 8** that policy option 3 – legislation at EU level – would bring a total benefit of 1182 billion Euros for the period 2017-25, while policy option 2 – legislation at Member State level – would result in a total benefit of 138 billion Euros in the same period in terms of noise emissions from traffic. This is due to the fact that compared to option 2, option 3 would increase the pace of introduction of hydrogen vehicles, which would bring benefits for noise sooner.

6.3.3.3. Impacts on air quality

In the European Union, light- and heavy-duty vehicle emissions legislation currently sets limit values for the following pollutants: particulate matter (PM), oxides of nitrogen (NOx), carbon monoxide and hydrocarbons.

The Commission's Clean Air for Europe (CAFE) Programme[47] has identified that the pollutants from road transport of most concern for human health are airborne particulates and ozone. Ozone is formed by reaction between HC and NOx, both of which are emitted by road transport. In this chapter, only the impacts on emissions of PM and NOx are quantified, given that the monetary impacts of the reduction of other regulated pollutants would show much lower value.[48]

The use of hydrogen vehicles would result in improvement in air quality through reducing the levels of pollution produced by road transport. A decrease in the areas under threat of ozone and eutrophication would be a result of reduced air pollution from vehicles. Furthermore, cleaner air in cities would also reduce damage to buildings and cultural heritage. It is important to note however that these favourable impacts would only materialise if the hydrogen fuel is produced in a sustainable way and it is ensured that the overall environmental balance - including production, distribution and storage of hydrogen - is positive. As discussed in Chapter 6.1 this assessment addresses the impacts of the use of hydrogen in vehicles, in this case the tailpipe emissions.

The impacts of hydrogen vehicles on air quality are considered by estimating the environmental performance of conventional vehicles in the examined timeframe and by assessing the benefit that hydrogen vehicles could bring compared to these, assuming that hydrogen vehicles penetrate into the fleet at different pace under each policy option, as described in Chapter 6.3.3.1.

NOx emissions

To estimate the benefit linked to NOx emissions, an abatement cost figure of €4400/tonne has been used.[49] Using this as a surrogate damage cost figure, we can calculate the damage saving due to hydrogen vehicles in categories M1 and N1. It has to be noted however that the constituents of NOx vary, and may be very different by 2020.[50]

Box 7: Key assumptions regarding the calculation of NOx emission benefits

1. It was assumed that a typical new conventional vehicle in the total fleet of category M1 and N1 vehicles will emit 0.05g NOx/km in the examined period of time. It has to be noted that this figure is based on type-approval emission limit values and not on real-world behaviour of vehicles that

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[47] Thematic Strategy on Air Pollution, COM(2005)446 final, 21.09.2005.

[48] TRL report, p. 41

[49] Commission Staff working document: Impact assessment for Euro 6 emission limits for light duty vehicles, p.12 http://ec.europa.eu/enterprise/automotive/pagesbackground/pollutant_emission/impact_assessment_euro6.pdf

[50] TRL report, p. 41

could be different. It was assumed also that hydrogen internal combustion vehicles will not show any savings in NOx emissions, relative to conventional vehicles.

2. So for each kilometre driven by a hydrogen vehicle in 2017-2025, there is a saving of 0.045g NOx. This is based on the 0.05g NOx/km figure and the assumption of 90% of the hydrogen vehicles being fuel cell powered.

Source: TRL report, p. 41

The assumptions and calculations in Box 7 lead to the valuations in Table 9 and Table 10 below.

Table 9: Policy option 2 (legislation at Member State level) - Value of NOx reductions due to hydrogen vehicles in categories M1 and N1

Year:	Distance driven by hydrogen vehicles in each year (billion vehicle kilometres)	NOx reductions @ 0.045g saving per km (tonnes NOx)	Value of NOx reductions (million €)	Value of NOx reductions after discounting (million €)
2017	0	16	0.1	0.0
2018	1	53	0.2	0.2
2019	2	105	0.5	0.3
2020	6	263	1.2	0.7
2021	6	263	1.2	0.7
2022	12	526	2.3	1.3
2023	23	1051	4.6	2.5
2024	35	1577	6.9	3.6
2025	47	2102	9.3	4.6
Total				**13.7**

Source: TRL report, p. 106

Table 10: Policy option 3 (legislation at EU level) - Value of NOx reductions due to hydrogen vehicles in categories M1 and N1

Year:	Distance driven by hydrogen vehicles in each year (billion vehicle kilometres)	NOx reductions @ 0.045g saving per km (tonnes NOx)	Value of NOx reductions (million €)	Value of NOx reductions after discounting (million €)
2017	12	540	2.4	1.6
2018	24	1080	4.8	3.1
2019	40	1800	7.9	5.0
2020	70	3150	13.9	8.3
2021	100	4500	19.8	11
2022	140	6300	27.7	15
2023	186	8370	36.8	20
2024	240	10800	47.5	24
2025	298	13410	59.0	29
Total				**118**

Source: TRL report, p. 41

It is concluded that under both policy options, the value of the reductions in NOx emissions due to the introduction of hydrogen vehicles in categories M1 and N1 in 2017-2025 is small, in comparison to the value of the noise savings. However, it is clear that similarly to the noise benefits, the impacts on NOx emissions are higher with policy option 3 than they are with policy option 2.

Particulate emissions

To estimate the benefit linked to PM emissions, it was assumed that PM10 emissions in urban areas impose a cost of 11,000 €/tonne in 2007 prices.[51]

Box 8: Key assumptions regarding the calculation of PM emission benefits

1. It is assumed that neither hydrogen fuel cell nor internal combustion engine vehicles emit particulates.

2. So each kilometre driven by a hydrogen M1 or N1 vehicle results in a saving of 0.005g PM. It has to be noted that this figure is based on type-approval emission limit values and not on real-world behaviour of vehicles that could be different.

Source: TRL report, p. 42

51 TRL report, p. 42; figure derived from UNITE project for European Commission: Marginal cost case study 9b: heavy goods vehicle for Finland, April 2002 http://www.its.leeds.ac.uk/projects/unite/downloads/MCCS-9B.pdf

The assumptions and calculations in Box 8 lead to the valuations in **Table 11** and **Table 12** below.

Table 11: Policy option 2 (legislation at Member State level) - Value of particulates reductions due to hydrogen vehicles in categories M1 and N1

Year:	Distance driven by hydrogen vehicles in each year (billion vehicle kilometres)	Particulates reductions @ 0.005g saving per km (tonnes particulates)	Value of particulates reductions (million €)	Value of particulates reductions after discounting (million €)
2017	0	2	0.0	0.0
2018	1	6	0.1	0.0
2019	2	12	0.1	0.1
2020	6	29	0.3	0.2
2021	6	29	0.3	0.2
2022	12	58	0.6	0.4
2023	23	117	1.3	0.7
2024	35	175	1.9	1.0
2025	47	234	2.6	1.3
Total				**3.8**

Source: TRL report, p. 107

Table 12: Policy option 3 (legislation at EU level) - Value of particulates reductions due to hydrogen vehicles in categories M1 and N1

Year:	Distance driven by hydrogen vehicles in each year (billion vehicle kilometres)	Particulates reductions @ 0.005g saving per km (tonnes particulates)	Value of particulates reductions (million €)	Value of particulates reductions after discounting (million €)
2017	12	60	0.66	0.4
2018	24	120	1.3	0.8
2019	40	200	2.2	1.4
2020	70	350	3.8	2.3
2021	100	500	5.5	3.2
2022	140	700	7.7	4.3
2023	186	930	10.2	5.4
2024	240	1200	13.2	6.8

2025	298	1490	16.3	8.1
Total				**32.7**

Source: TRL report, p. 42

Under both policy options, the total saving is less than those for noise or NOx. Although, it is clear that policy option 3 would result in a substantially higher benefit in the examined period than option 2.

6.3.3.4. Impacts on CO2 emissions

At this point in time, it is not clear whether hydrogen vehicles will offer any CO_2 advantages over conventionally powered vehicles by 2017-2025. This is because of the following reasons:[52]

- Regarding the efficiency of hydrogen vehicles, it is predicted that hydrogen fuel cell vehicles will use 47% less fuel than conventional diesel vehicles by 2010. The efficiency gain of a fuel cell vehicle over a conventional gasoline vehicle is estimated to be 50% in the same year. Hydrogen internal combustion engine vehicles would only be 7% more efficient than conventional diesel vehicles and 10% compared to gasoline vehicles by 2010.[53] These values are estimated for vehicles available in 2010.

- Currently available hydrogen powered internal combustion engine vehicles appear to be less energy efficient than equivalent conventional vehicles. The extra weight penalty for the on-vehicle hydrogen fuel system is a major cause of this. Given the improvement in energy efficiency of conventional vehicles by 2020, it appears that hydrogen internal combustion engine vehicles are likely to offer no certain CO_2 reductions over conventional vehicles.

- Hydrogen fuel cells are efficient at converting hydrogen to electric power. However, since no decision has been made on the energy source that will be used to produce hydrogen fuel, the net advantage of fuel cells cannot be determined in this impact assessment.

52 TRL report, p. 43

53 European Hydrogen & Fuel Cell Technology Platform: Strategic Research Agenda, July 2005, p. 58 https://www.hfpeurope.org/uploads/677/686/HFP-SRA004_V9-2004_SRA-report-final_22JUL2005.pdf

7. IDENTIFICATION OF THE PREFERRED POLICY OPTION

7.1. Summary of the impacts of policy options

Tables 13 to 15 below summarise the findings of the analysis of economic, social and environmental impacts and compare the policy options as to the quantitative and qualitative effects.

Table 13: Summary comparison of policy options

Policy option	Effectiveness	Efficiency	Consistency
Option 1: No policy change	Option deemed not feasible		
Option 2: Legislation at Member State level	Medium	Low	Low
Option 3: Legislation at EU level	High	High	High
Option 4: Non-regulatory approach	Option deemed not feasible		

Source: TRL report, p. 8

Table 14: Summary of qualitative impacts of policy options 2 and 3 (values in €)

Impacts	Option 2 – Legislation at Member State level	Option 3 – Legislation at EU level
Internal market	Option 2 would lead to a more fragmented internal market for hydrogen vehicles.	Option 3 would be in accord with the internal market, since it would lead to more uniform safety and environmental standards than option 2. Option 3 would be likely to open up the markets of some Member States, which do not currently allow the use of hydrogen vehicles.
European Automotive Industry	0.16 million cost per vehicle type per Member State requiring separate type approval. 4.3 million cost per vehicle if all 27 Member States require approval.	0.16 million cost per vehicle type submitted to EU type-approval. Option 3 would be more likely to lead to investment in hydrogen technology, since it reduces uncertainty about the market for hydrogen vehicles. Would improve competitiveness of manufacturers.
Impacts on safety	Safety of hydrogen vehicles would not be ensured.	Would ensure that hydrogen vehicles are as safe as conventional vehicles. Is likely to lead to higher, more uniform safety standards than with option 2.
Impacts on environment	Option 2 would lead to a slower introduction of hydrogen powered vehicles, so	Option 3 would improve noise and local air quality by encouraging the more rapid

(noise and local air quality)	improvements to noise levels and local air quality would be delayed correspondingly.	introduction of hydrogen powered vehicles.

Source: TRL report, p. 50

Table 15: Summary of quantitative impacts of policy options 2 and 3 (values in €)

Impacts		**Option 2 - Legislation at Member State level**	**Option 3 - Legislation at EU level**
Impacts on noise		138 million	1182 million
Impacts on local air quality	NOx	14 million	118 million
	Particulates	4 million	33 million
Total benefit		**156 million**	**1333 million**
Total approval costs		**129 million**	**5 million**
Overall benefit		**27 million**	**1328 million**

Source: TRL report, p. 50

7.2. Preferred policy option

In conclusion, in comparison with the option of legislation at Member State level, the option of adopting a Regulation at European Union level will address the problems identified in Chapter 3.1. This option will have the clear benefits of ensuring the proper functioning of the internal market, providing a high level of public safety throughout all EU Member States and improving noise and air quality levels sooner. This, in turn, will improve public health and, thus, will enable governments to generate savings.

As far as the competitiveness of industry is concerned, the impacts of the EU regulatory option might be positive as with including hydrogen vehicles in the approval framework in the EU, the international competitiveness of the European industry might be improved. Further, it would be ensured that the European Union keeps pace with other important automotive regions of the World with regard to the introduction of advanced technologies.

Therefore, the preferred policy option is the 'Legislation at European Union level', which means extending the European Community Whole Vehicle Type-approval framework to hydrogen powered vehicles and establishing common standards for those vehicles. This option was recommended by the consultant on the basis of the impact assessment study carried out and has been suggested by most of the responses received with the questionnaire.[54] The comments have been submitted by vehicle manufacturers, Member State authorities, technical services and public transport operators. An overview of the questionnaire responses on the policy options is provided in Annex I.

This option is seen as an essential means of sustaining a single market for vehicles and providing for a high level of safety and better environment in the European Union. With this policy option, the placing on the market of advanced, environmentally friendly hydrogen

[54] TRL report, p. 51

vehicles will be encouraged and the EU will gain a competitive advantage as to the deployment of cutting-edge hydrogen technology.

7.3. Content of the regulatory measure within the preferred policy option

The impact analysis has identified that the preferred policy option is the adoption of an EU Regulation with the purpose of incorporating hydrogen vehicles of categories M1, M2, M3 and N1, N2, N3 in the EU whole vehicle type approval framework.

The draft proposal foresees the amendment of the Framework Directive[55] in order to include hydrogen vehicles in the approval procedure. It specifies technical requirements to be applied for the type-approval of hydrogen components (hydrogen containers and hydrogen components other than containers) included in the hydrogen system in order to ensure that hydrogen related components are working in a proper and safe way. In addition, it includes requirements for the type-approval of vehicles with regard to the installation of hydrogen components or systems in vehicles. The proposal foresees the amendment of separate type-approval Directives and Regulations in order to include specific requirements for hydrogen powered vehicles.

The proposal uses the "split-level approach" that has been used in other pieces of legislation, e.g. in the case of the Directive for heavy duty vehicle emissions[56] and the Regulation on the Euro 5 and 6 stage of light-duty vehicle emissions[57]. This approach foresees that the proposal and adoption of legislation will be made according to two different, but parallel, routes:

- first, the fundamental provisions will be laid down by the European Parliament and the Council in a Regulation based on Article 95 of the EC Treaty through the co-decision procedure (the co-decision Regulation);
- secondly, the technical specifications implementing the fundamental provisions will be laid down in a Regulation adopted by the Commission with the assistance of a regulatory committee (the comitology Regulation).

It is important that the proposed EU Regulation includes the necessary, most up-to-date technical content in order to address the issues associated with the introduction of hydrogen vehicles. Therefore, TRL was commissioned with the task of providing an independent view as to the requirements of the draft proposal for a potential EU Regulation. As explained in Chapter 6.3.2, the TRL Report concluded that the technical requirements of the draft proposal properly mitigate the identified safety risks and ensure that hydrogen vehicles provide at least the same level of safety as conventional vehicles.

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55 Directive 2007/XX/EC

56 Directive 2005/55/EC (OJ L 275, 20.10.2005, p.1), Directive 2005/78/EC (OJ L 313, 29.11.2005, p.1)

57 Regulation (EC) No 715/2007 (OJ L 171, 29.06.2007, p.1)

8. MONITORING AND EVALUATION

8.1. Indicators of progress towards meeting the objectives

The key mechanism by which the proposed Regulation will take effect is through the vehicle type-approval process. Vehicle manufacturers will need to demonstrate that hydrogen vehicles comply with the requirements set out in the proposal in order to receive a type-approval certificate. The core indicators of progress will therefore be the number of hydrogen powered vehicles which are successfully type-approved.

8.2. Monitoring and evaluation

Monitoring of the effect of the Regulation will be undertaken within the framework of the constant dialogue with type-approval authorities in the Hydrogen Working Group and the regular Type-approval Authorities Meeting.

Annex I: Summary of stakeholder responses to questionnaire

Policy option	Answer
Option 1 - No Policy Change	"Not acceptable, because some of the H2/FC specific safety aspects are not covered by current legislation." "Development of hydrogen cars is constrained because type approval is not possible. Environmental advantages will be delayed."
Option 2 – Legislation at Member State level	"The establishment of regulations with differing contents among each country in Europe will invite delays in development time and higher costs of parts for hydrogen/fuel cells vehicles due to having to adapt to each regulation. This will become a demerit to the users of a hydrogen/fuel cell vehicle" "Development of hydrogen cars is constrained because type approval is not possible. Environmental advantages will be delayed." "This option will be a hurdle for the market introduction of H2/FC vehicles. As a consequence it will hinder the environmental benefits from H2/FC vehicles in the field." "Not desired by global vehicle manufacturers." "Not acceptable, because different requirements (design or performance based) and different safety levels will be a hurdle for the market introduction of H2/FC vehicles." "Different safety policies and safety levels. No legal certainty for international car manufacturers"
Option 3 - Legislation at EU level	"Medium term: Legislation at EU level must come into force ASAP. Long term: Global technical rules on UN platform must be supported." "In a first step the safety of onboard storage systems should be covered by an European Regulation." "Choosing the legislation at the EU level would avoid competitive disadvantages for some manufacturers" "It's rather late for an EU-Regulation because Japan and USA have already developed national regulations." "A higher sense of safety in the public can be expected if standards are established." "Lowest administrative costs for type approval in 25 member states." "To secure safety in vehicles registered and sold in the EU, it is preferable that standardized safety regulations be established." "Legal certainty and economic benefits" "As soon as type approval is possible, serial production for relevant markets will start. Environmental advantages will appear (dependent on the clean production of hydrogen)" "It is urgent to introduce as a first step a European Regulation regarding the safety of H2 onboard storage systems as an important basis for harmonized approval of H2/FC vehicles."

Source: TRL report, Annex D, E, p. 80-94

Annex II: Issues raised during public consultation

A total of 19 replies were received to the request for comment. Of these the breakdown by source is as follows:

• Governmental organisations	1
• Industry and business organisations	17
• Academia	1

During the consultation, a number of issues were raised by stakeholders. This section summarises the substantive issues raised and discusses how they have been taken into consideration.

(1) General comments

A number of stakeholders expressed general support for the proposal. It was argued that the introduction of hydrogen powered vehicles in the European type-approval framework would clarify the legal situation and encourage the placing of the market of the technology. Some stakeholders mentioned that the present case-by-case approval procedure is cumbersome and imposes high financial burden on the industry. It was also highlighted by some that the draft proposal will increase public confidence in this new innovative technology.

(2) Concept of legislation

(1) Performance-based approach

Many stakeholders commented that it is necessary to set common performance-based requirements in the co-decision proposal that would be applicable to all hydrogen storage forms. The specific testing requirements for liquid and gaseous storage systems should be set in the comitology legislation. They argued that by having a framework Regulation, this approach would enable the facile introduction of requirements relating to future hydrogen storage systems other than gaseous or liquid storage.

The Commission services consider that it is necessary to propose technologically neutral requirements. Therefore, the proposal includes performance requirements applicable to all storage forms and foresees the possibility of the introduction of requirements for on-board hydrogen storage forms other than gaseous or liquid storage if necessary.

(2) Scope of proposal

Some stakeholders thought that there is a discrepancy between the scope (hydrogen powered vehicles) and the requirements (the draft addresses gaseous and liquid hydrogen storage systems) of the draft co-decision proposal.

The proposal was restructured in order to reflect the approach suggested. The proposal addresses not only the hydrogen storage systems on board and other components in direct contact with hydrogen, but foresees also the amendment of vehicle type-approval legislation in order to accommodate fully the hydrogen vehicles in the EU whole vehicle type-approval system.

(3) Date of applicability of Regulation

Some responses suggested specifying different application dates of the provisions of the Regulation for M1 and N1 vehicles and M2, N2, M3 and N3 vehicles. One stakeholder *suggested 5 year delay for these latter vehicles. One stakeholder said that it is too early to comment on the date of entry into force or applicability at this stage.*

The Commission services consider that the date of application should be identical for all classes of vehicles. The market introduction should be facilitated in all classes, which is in line with comments received for the stakeholder questionnaire.

(4) Review clause

One stakeholder suggested introducing a review clause in the co-decision Regulation in order to re-examine the specifications with the continuous development of new technologies of hydrogen systems.

It is foreseen in the proposal that its requirements will be amended as technology progresses.

(3) Type-approval issues

(1) System approach - Type-approval of components

A number of stakeholders suggested the use of a system approach for type-approval requirements for hydrogen systems instead of specifying tests for single components of the system. This approach would enable the approval of systems (combination of components). They argued that the safety of single components does not ensure the safety of the whole system, i.e. the vehicle. One stakeholder expressed support for the component-orientated approach.

The type-approval of hydrogen components as well as systems, defined as an assembly of hydrogen components is possible on the basis of the provisions of the proposal. The proposal includes requirements on the performance of hydrogen systems when installed on board of the vehicle.

(2) Small series approval

Some responses suggested allowing for small-scale type-approval in order to facilitate the approval of experimental vehicles.

The Commission services consider that in order to tackle the safety issues that have been identified in the impact assessment, it is necessary to approve all hydrogen vehicles according to the applicable type-approval provisions. Therefore, requirements relating to small series approval are not foreseen in the proposal.

(4) Requirements

(1) Definition of tests

Some stakeholders requested the definition of detailed testing requirements in the co-decision text, while others asked for the reduction of technical content. It was suggested to remove all test requirements applicable for the approval of containers and components from the co-decision text and specify them only in the comitology legislation. At the same time, it was also suggested to refer to applicable standards in the co-decision text.

The proposal pursues the so-called split-level approach that has been used for other pieces of legislation. This means that the main provisions are included in a co-decision Regulation, while the detailed technical requirements such as the definition of test procedures and references to standards will be adopted through comitology. Therefore, the co-decision proposal includes only the more general definitions and requirements. However, the Commission services considered that it is necessary to adopt the list of test procedures applicable to specific components through co-decision.

(2) International harmonization

One stakeholder underlined that the development of technical requirements and safety concepts in the framework of the UN/ECE GTR on HFCV should be taken into account in the European Regulation.

Given that the development of the UN/ECE Global Technical Regulation on hydrogen vehicles is ongoing, it is not possible to align the requirements with that at this stage. However, by establishing the type-approval framework for hydrogen vehicles in the European Union, the proposal enables a possible future introduction of the requirements of a potential GTR in the EU.

(3) Design restrictive requirements

A few consultation responses mentioned that the requirements of the present draft would be design restrictive and would hinder the development of future hydrogen technologies.

The impact assessment work explicitly addressed the review of the technical content of the proposal. It has been concluded that the requirements contain both performance and design requirements and represent the latest scientific knowledge on issues related to hydrogen vehicles. It was also concluded by the consultant report that the proposal addresses the identified safety concerns and ensures that hydrogen vehicles are as safe as those with conventional propulsion technology.

(4) Removable tanks

Some stakeholders argued that the current draft does not allow the consideration of the storage system as a removable tank. It was argued that the possibility of exchangeable fuel tanks should be maintained in the Regulation. Further, it was suggested by some responses to introduce requirements of a removable fuel tank system used in smaller applications.

The use of removable tanks is permitted by the proposal. Further, the proposal allows for the approval of hydrogen powered L category vehicles on the basis of its technical requirements.

(5) Refuelling

A number of stakeholders argued that the draft should not include requirements that relate to the refuelling procedure or refuelling stations (overpressurization, measures to avoid hydrogen leak during refilling, etc.). It was suggested to specify requirements for a harmonized refuelling receptacle for all hydrogen powered vehicles in the Regulation, based on international standards.

The proposal has been modified to reflect the comment received on refuelling. The proposal foresees the application of international standards relating to harmonised refuelling receptacles.

Annex III: Glossary

Euro 5, 6: Emission standards for light duty vehicles

Euro V, VI: Emission standards for heavy duty engines

Fuel cell: An electrochemical energy conversion device, which is designed for continuous replenishment of the reactants

Hybrid vehicle: Vehicle that uses a combination of petrol and electricity for motive power, so as to increase efficiency and thereby reduce emissions

Hydrogen embrittlement: the process by which various metals, most importantly high-strength steel, become brittle and may crack, following exposure to hydrogen

Hydrogen vehicle: A vehicle that uses hydrogen as its primary source of power for motion

IC (Internal Combustion): an engine that burns fuel by combustion at high temperature

Vehicle categories according to Annex II to the Framework Directive (2007/XX/EC):

> Category M: Motor vehicles with at least four wheels designed and constructed for the carriage of passengers.
>
> Category M1: Vehicles designed and constructed for the carriage of passengers and comprising no more than eight seats in addition to the driver's seat.
>
> Category M2: Vehicles designed and constructed for the carriage of passengers, comprising more than eight seats in addition to the driver's seat, and having a maximum mass not exceeding 5 tonnes.
>
> Category M3: Vehicles designed and constructed for the carriage of passengers, comprising more than eight seats in addition to the driver's seat, and having a maximum mass exceeding 5 tonnes.
>
> Category N: Motor vehicles with at least four wheels designed and constructed for the carriage of goods.
>
> Category N1: Vehicles designed and constructed for the carriage of goods and having a maximum mass not exceeding 3,5 tonnes.
>
> Category N2: Vehicles designed and constructed for the carriage of goods and having a maximum mass exceeding 3,5 tonnes but not exceeding 12 tonnes.
>
> Category N3: Vehicles designed and constructed for the carriage of goods and having a maximum mass exceeding 12 tonnes.