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Review of the December 2003 MVV report on *Alternative automotive fuels – supply, technological and environmental scenarios to 2030* (EP/IV/A/STOA/2002/07/03)

Prepared for STOA, European Parliament

INTRODUCTION

This review has been prepared under the terms of a contract between EASAC and STOA, which provides for EASAC to undertake peer review of the scientific aspects of reports commissioned by STOA from external consultants. The task assigned to EASAC is to give expert, independent comment on the report in question: it is not our role in this instance to draw conclusions about the issue under consideration, nor to make policy recommendations.

The report being reviewed is entitled *Alternative automotive fuels – supply, technological and environmental scenarios to 2030* (December 2003). It was written, under contract to STOA, by MVV Consultants and Engineers.

The process used by EASAC in undertaking this review was to identify suitable experts through the networks of the member Academies of EASAC, brief them about the task and send them the material, collate their reviews into a single document, review that document and submit it to STOA. The process of collation is intended to produce as coherent and accessible a document as possible while respecting the sometimes divergent opinions of the reviewers. So far as possible, the reviewers' own words have been used, with a minimum of editing to improve fluency between passages and provide for a connected text. In particular, the aim has been to present the spirit of each set of comments rather than to give an 'average' position. As a result, it may sometimes happen that mutually contradictory statements are juxtaposed.

The four experts whose reviews are collated in this document came from Denmark, Germany, Ireland and the Netherlands, and their expertise covered catalysis, combustion engines, mechanical engineering, political science and S&T scenarios. In keeping with normal practice, the names of the individual reviewers remain confidential. Also in keeping with normal EASAC practice, the reviewers were not paid for their reviews.

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The remaining sections of this document, apart from the summary, are, essentially, the direct words of the EASAC reviewers.

SUMMARY OF REPORT

The report takes as axiomatic that the key determinant of how automotive fuels will develop between now and 2030 is the limited availability of energy sources. It assumes that mineral oil will become scarce in the second quarter of the century and explores whether it will be replaced through a process of gradual evolutionary development or through new technologies and new fuels, and how changes in personal and social priorities will affect the outcome. The fuels of most interest to the authors are natural gas, biofuels, hydrogen, synthetic fuels and liquefied petroleum gas (LPG), and the main propulsion technologies are fuel cells and hydrogen combustion.

The authors use two scenarios from Shell International to shape their thinking about future developments. The 'dynamics as usual' scenario gives primacy to evolutionary processes in technology and in society and to the interplay between the two. The 'spirit of the coming age' scenario gives greater weight to the aggressive development of new technology and, specifically, the fuel cell. Both scenarios envisage natural gas playing a major role up to 2030, and renewable energy sources thereafter.

The main conclusion is the need for 'massive intervention by the European Commission' in the form of extensive R&D programmes, tactical support for the market breakthrough of natural gas as an automotive fuel, and changes to market price mechanisms. The goals are faster market penetration of biofuels and natural gas vehicles and major R&D efforts in hydrogen and fuel cells.

GENERAL COMMENTS

Does the report take on board the best current thinking about the subject?

There are many analytical methods to assess plausible future fuels and technologies, among which scenarios are a recognized method to analyze future fuel choices and automobile propulsion technologies. The two opposing Shell scenarios are well known and are an acceptable framework for analyzing alternative automotive fuels. However, when choosing this framework there should be consistency between the two scenarios 2030, the technologies foreseen in them and then the various technological options described extensively in the first part of the report. Otherwise, the idea of looking into the longer-term future of science, technology, and economy and society with the aim of identifying the areas of strategic research and the emerging generic technologies likely to yield the greatest economic and social benefit is jeopardized.

For example, the scenario 'Dynamics as usual' foresees a broad range of advanced and competitive internal combustion engines and hybrid engines (page 35). This option is not consistent with the conclusion (page 13) that the report will not deal with hybrid technologies any further: it is unlikely that any of the hybrid technologies will lead to a market breakthrough and they are more complex, more expensive and often less energy-efficient than single technologies. Further, the conclusion is not backed by literature references.

The scenario 'Spirit of the coming age' foresees CO_2 capture and sequestration (section 3.4, page 41), but no such technologies are described in the technological section.

The report is interesting, but it follows closely a report of Shell. In fact the authors mention this. I largely agree with the Shell report and, as a consequence, also with the present report.

Does the report cover the literature sufficiently?

It appears that many references are missing. Many of the statements are supported by only one reference.

Further suggestions are:

- ESTO (2003), Trends in Vehicle and fuel Technologies. Review of Past Trends. Report EUR 20746 EN (www.jrc.es)
- ESTO (2003), Trends in Vehicle and fuel Technologies. Overview of Current Research Activities. Report EUR 20747 EN (www.jrc.es)
- ESTO (2003), Trends in Vehicle and fuel Technologies. Scenarios for Future Trends. Report EUR 20748 EN (www.jrc.es)
- Risø Energy Report 2 (2003), New and emerging bioenergy technologies. Risø-R-1430(EN). (www.risoe.dk).
- Enguidanos, M., Soria, A., Kavalov, B. Jensen, P. (2002), Techno-economic analysis of Biodiesel production in the EU. A short summary for decision-makers. Report EUR 20279. (www.jrc.es).

Footnote 75: Up-to-date information on EU-US international partnership for the hydrogen economy is available on http://www.usea.org/iphe.htm.

Do the report's conclusions follow from the evidence it presents?

The analytical and concluding chapter III is very brief, in particular in terms of identifying relevant actions fields according to the scenarios. The common features are narrowed down to technologies and thus do not comprise the social, economic, and political drivers behind the development. Likewise there is a gap between the relevant action fields according to the scenarios 2030 and the quantitative targets for EU policy, most of them with the timeframe of 10-20 years.

The policy recommendation chapter IV points to three action plans.

1. Improved market penetration of biofuels, more specifically internalization of externalities into existing energy market price mechanisms. This is too general a recommendation and needs to be made more operational in terms of specific policy measures.
2. Support to natural gas vehicles, more specifically that the EU should take over the coordinating task of different actors towards the market breakthrough of natural gas vehicles (preferably through the STEER programme). Likewise taxation of fuels is mentioned, but disregarded because it falls within the jurisdiction of national governments.
3. Support for hydrogen and fuel cell research, more specifically national, EU and international R&D programmes. In addition the key elements in the EU hydrogen vision paper are also mentioned, including support for the political framework, a strategic research agenda, a strategy for implementation, a European roadmap for hydrogen and FC technologies, and a European partnership for hydrogen and fuel cell technologies.

Two of these action plans are very general and not made operational in terms of concrete policy measures and incentives. On the other hand, action plan 3 is very concrete. This leads me to suggest the use of an analytical framework for policy measures in order to discuss and identify which measures can and should be used. One may distinguish between measures for technology push (R&D policies) or measures for demand pull (regulation, taxation, demonstration and deployment projects, certification and standardisation). A more detailed framework is provided by Lowi (1972) as presented in the table below.

Applicability of coercion Likelihood of coercion	Individual conduct	Environment of conduct
Immediate	Regulative policy	Redistributive policy
Remote	Distributive policy	Constituent policy

Source: Lowi, T.J. (1972), Four Systems of Policy, Politics, and Choice. In Public Administration Review.

Does the report give a balanced account of the advantages and disadvantages of the various approaches?

The very first paragraph of Chapter I suggests that the widespread availability of large quantities of gasoline and diesel fuel is a consequence of the existence of Otto and Diesel engines. I would prefer to take the view that the engines exist because gasoline and diesel fuels are relatively easily derived from mineral oil. In other words, everything starts with the availability of primary energy sources.

The technical descriptions do intend to give a balanced account. However, this is also a very demanding task because of the time horizon of the report and the uncertainties in future developments.

A clear comparison (overview) of the different fuels, in particular efficiencies for generation and costs, is missing. In addition, a clear separation between energy carrier and source is essential. Generally, any combination of energy source and carrier on the vehicle is possible: the key is the conversion efficiency and CO_2 emissions. The pollutant emission requirements will be met with any fuel (carrier).

Biofuels: cost estimates are missing.

Ethanol/Methanol: why is this fuel as a carrier completely left out? Brazil still has a large scale production running.

Hydrogen: a clear explanation of why hydrogen is preferred over other fuels is missing. If one does not dictate the fuel cell, many other alternative fuel carriers, eg Synfuel/Sunfuel BTL are preferable (Hydrogen is difficult to generate, handle and store).

US$ 20 for BTL, being less than crude oil today, does seem unrealistic (page 33).

The statement that nuclear energy is uncompetitive does not reflect the reality, in my view (page 33).

Where will the cost-effective transition to hydrogen come from (page 41), a large scale conversion from fossil fuels makes no sense with respect to efficiency. I expect that the only efficient H_2-generation would be through nuclear power.

The report identifies correctly (in my view) that availability of energy sources is the critical issue but gives the impression that Hydrogen / Fuel Cells offer some sort of solution here. (Chapter II, Section 4.1 does correctly refer to 'hydrogen as the preferred energy carrier and energy storage medium' but this point seems not to have permeated the thinking elsewhere in the report.) Nuclear options were dismissed (Chapter II, Section 1.1) in the most superficial way.

Also, no real analysis has been carried out of the quantitative issues associated with land use, fertilising etc in the context of biofuels. In my experience, a rigorous life-cycle analysis is needed before the viability of any alternative can be assessed.

Does the report give policy makers a clear feel for the subject?

Overall, I found the report to be poorly structured and, I suspect, unlikely to be seriously helpful to its intended audience. A large amount of technical detail has been included, together with nice diagrams. In my view, this serves to obscure the critical issues. I suspect that much of this technical material was assembled by someone who was facing the issues for the first time. It seems to draw very heavily on a few sources (especially Shell) and relies on web sites rather than on serious scientific literature.

Separate sections of the report appear to have been written by different people and very little attempt has been made to pull it together and conduct a coherent analysis.

- It would be more readable if the chapter on scenarios is put before the chapter on technological options.
- The 30 pages presentation of the various technological options can be shortened and improved so that it provides a shorter overview of the current technologies and outlines the future challenges.
- The description of demonstrations can be inserted in the text as illustrative boxes and with focus on both technologies and the context in which they are deployed.
- The policy recommendations need to be elaborated so that policy-makers get the feeling that they point towards the 2030 scenarios. Also they need to be more operational.

Overall, I agree with the increasing importance of natural gas as reflected in the study. However, the projected transition to hydrogen is not supported by arguments very well. While the fuel cell would probably require such a step, the future of the fuel cell is still open and for other machines other fuels might make just as much sense, depending on the energy source. Nevertheless, I agree that research on hydrogen and fuel cells should be continued with large emphasis. Pushing the market introduction before the key problems are solved is not recommendable at this point.

The description of technological options, comprising on the one hand the current state of the art and on the other hand current research activities, is to some extent unbalanced and overlapping.

- The very detailed description of hydrogen storage (section 1.3.2, pages 7-13) could be shortened and merged with description of hydrogen storage research (section 3.3.2, pages 28-29).
- This is also the case with the description of production of hydrogen (section 1.3.1, pages 5-7) and the extensive description of various hydrogen demonstration projects (section 3.3.1, pages 23-28). Many of these technologies are well known technologies, but they are not competitive in a context with hydrogen considered as an energy carrier. The report could be more precise in terms of the future challenges of bringing down costs, improving performance, assuring distribution, meeting safety and environmental requirements and public acceptance.
- However, description of the demonstration projects should be maintained but in such a way that the various components of the project are highlighted: for example the ECTOS and the CUTE projects comprise the whole value chain of production, storage, distribution and application of alternative automotive fuels in the buses and also pay attention to public acceptance.

I have the feeling that the authors could have helped policy-makers by giving a systematic list of possible actions that could lead to the desired results. But perhaps that was not the intention of the report.

My overall view is that this report would benefit from serious editing. Tighter arguments focusing on the really critical issues should be presented - and not obscured by detail.

DETAILED POINTS

Figure 24 seems too simple.

- It does not illustrate the road from the present status towards the situations in the two scenarios (which can be illustrated by means of roadmaps, if the challenges ahead and actions needed are also identified and described).
- It does not comprise the whole value chain of producing, distributing, converting and applying alternative fuels, but only focuses on different fuels and propulsion technologies, the latter excluding hybrid technologies.

I have the following technical comments:

- Storage of hydrogen is stated to be critical. That is absolutely the case. The report states that materials research is most crucial, in particular with respect to carbon nanotubes. I doubt that. An alternative, at least as promising, is based on catalytic hydrogenation and dehydrogenation of a suitable organic liquid.
- GTL (gas-to-fuel) is concluded to be counterproductive for the environment. For remote fields that is often not the case. Here, at present flaring is most economical (and safe). GTL is a good option in those cases for efficient transport of the energy carrier.
- Solar energy is important and in the report coupled to photovoltaic (PV) cells. According to the report hydrogen production from water takes place by a combination of PV cell technology and electrolysis of water. There is nothing against this option but direct photo-catalytic dissociation is also feasible, in principle. The future will show what is best, dependent on the specific application.
- It is stated that hybrid technologies are not efficient. This is not really my field but I thought that this is not the opinion of many experts.

Chapter I, Section 1.3.1 quotes hydrogen quantities but makes no reference to what these mean in global energy terms (eg tons of oil equivalent, fraction of annual oil consumption). Energy issues in producing, storing and transferring hydrogen into vehicle fuel tanks are given scant attention in the following sections although related points are scattered in later parts of the report. Hydrogen safety issues are not highlighted adequately.

Chapter I, Section 2 dismisses hybrid vehicle technology (Toyota Prius, Honda Insight) unreasonably.

Chapter I, Section 2.1.2 is very light on analysis of the overall energy efficiency issues associated with producing hydrogen - in combination with its use in fuel cells.

Chapter IV, Section 2 suggests that natural gas could be a 'bridge fuel'. The technological issues associated with combustion of natural gas in vehicles are well understood. Storage is really the only issue. It seems unlikely that conversion of this into hydrogen first would really make energetic sense. It may serve to reduce toxic emissions slightly but does not, in my view, address the issue of finding an alternative and sustainable primary energy source.

CONCLUSIONS

The EASAC reviewers find some value in the report, but also point out that it suffers from being too focused on a narrow range of technology options to the exclusion of other possibilities that should form part of a balanced analysis. Nor is it comprehensive in its review of the literature. So the report is not regarded as providing an authoritative account of the subject. And the reviewers consider that it will not be easily accessible to policy-makers.

31 January 2004