ON-BOARD FUEL PROCESSING
GO/NO-GO DECISION

DOE DECISION TEAM COMMITTEE REPORT

August 2004
(Revised)

Table of Contents

Executive Summary

For the past decade, DOE funded research and development (R&D) of on-board fuel processing. The R&D focused on fuel-flexible fuel processing of gasoline, ethanol, methanol and natural gas as possible fueling options for fuel cell vehicles. Since it was uncertain whether on-board fuel processing activities would meet FreedomCAR technical criteria in time to support the 2015 commercialization decision for fuel cell vehicles, DOE set an On-Board Fuel Processing Go/No-Go decision milestone for June 2004.

DOE commissioned the National Renewable Energy Laboratory's (NREL) Systems Integrator to convene an Independent Review Panel to provide a technical recommendation regarding the DOE On-Board Fuel Processing Go/No-Go decision. The recommendation was based on a technical evaluation of the status, progress, and potential of on-board fuel processing R&D to meet the time-phased technical targets that were established by FreedomCAR. While some of the targets seem aggressive, meeting them is essential if "gasoline" fuel cell vehicles are to be competitive with conventional gasoline ICE vehicles. Two important technical targets that were emphasized in the Go/No-Go decision process were start-up time (less than one minute at an ambient temperature of 20°C) and start-up energy (less than 2 MJ for a 50 kW system).

The Independent Review Panel determined that no technology reviewed met all the 2004 decision criteria and saw no clear path for reaching all the ultimate criteria simultaneously within the established timeframe. Therefore, the panel recommended a no-go decision. The panel recognized that tremendous progress had been made in demonstrating the feasibility of reforming gasoline and other hydrocarbon fuels on-board a vehicle to provide hydrogen for fuel cells. Additionally, new catalysts and reactor designs were developed that have the potential to meet FreedomCAR weight and volume targets. Considering these significant developments, the panel made a number of recommendations regarding continued funding of fundamental work in fuel processing that could benefit on-board fuel processing concepts as well as distributed power and distributed hydrogen generation.

DOE formed a Go/No-Go Decision Team to develop a DOE position on the go/no-go milestone. The decision team concurred with the technical assessment of the panel. Also strongly considered by the team were the impact of the President's Hydrogen Fuel Initiative and market entry of hybrid vehicles. Specifically, the President's Hydrogen Fuel Initiative accelerated hydrogen technology commercialization from 2030 to 2015 (commercialization decision in 2015), lessening the contribution of on-board fuel processing as a transitional technology. Additionally, since initiating support of fuel-flexible on-board fuel processing R&D, the rapid emergence of hybrid vehicles into the marketplace has provided a vehicle that is almost as efficient and environmentally friendly (on a well-to-wheels basis) as fuel cell vehicles using on-board fuel processing technology. After careful consideration, the decision team recommends ending DOE funded on-board fuel processing R&D and bringing the current on-board activities to an orderly conclusion.

Introduction

This report delivers the recommendations and rationale of the DOE Decision Team on the On-Board Fuel Processing Go/No-Go Milestone. The report also summarizes the activities that supported the recommendations, including the participation of the National Renewable Energy Laboratory's (NREL) Systems Integrator and the findings of their independent review panel.

Background

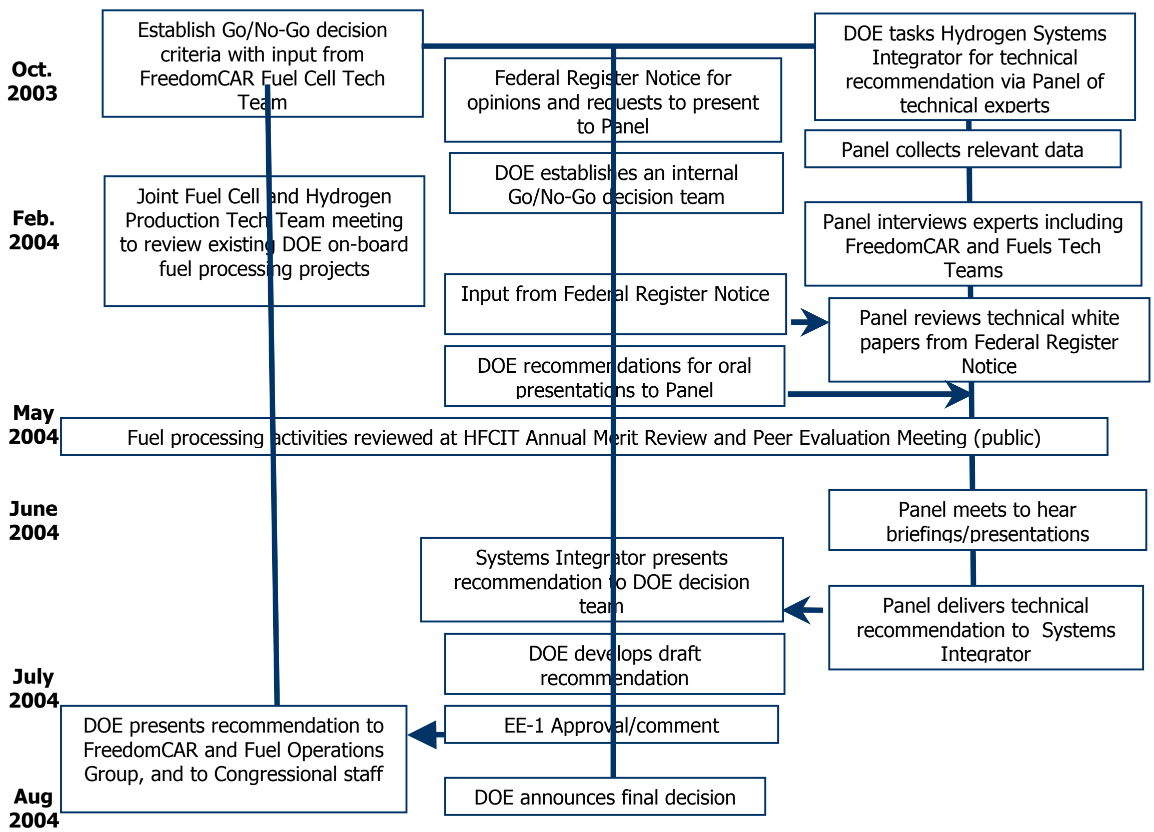
From the late 1980s through the early 1990s, the DOE Fuel Cells for Transportation Program focused on steam reforming of methanol to provide hydrogen-rich reformate for polymer electrolyte membrane (PEM) fuel cells. Methanol possesses high energy density, is simple to store, easy to reform and can be rapidly fueled into a vehicle. The Partnership for a New Generation of Vehicles, a partnership between the U.S. government and USCAR (Chrysler, Ford, and General Motors), was launched in 1993, and DOE became increasingly interested in on-board reforming of gasoline. Studies carried out at the time showed that current hydrogen storage technologies could not meet the volumetric requirements of the OEMs and that the cost of a hydrogen infrastructure would be high. On-board fuel processing was seen as a viable solution to the "chicken-or-the-egg" dilemma of how to simultaneously introduce new vehicles and the fuel they require.

In the early 1990s, DOE initiated fuel processing R&D projects, primarily based on autothermal reforming (ATR) technology because of ATR's fast start-up and transient response capabilities (compared to steam reforming). These early efforts culminated in the world's first demonstration of a fuel cell stack operating on gasoline reformate in October 1997. During the remainder of the 1990s, DOE supported projects developing gasoline fuel processors and fuel processor components as well as novel technologies such as microchannel and plate reformer technologies.

Although tremendous progress was made towards achieving technical targets for on-board fuel processing, DOE and our industry partners began to question whether the targets could be achieved in time for on-board fuel processors to serve as a near-term bridging strategy during the transition to a hydrogen economy. Some even questioned whether the targets could ever be achieved. With the establishment of the FreedomCAR Partnership in January 2002 and the Hydrogen Fuel Initiative in January 2003 (where commercialization of hydrogen technology was accelerated from 2030 to 2015), focus shifted towards the development of the technologies and infrastructure for on-board storage and use of hydrogen in direct-hydrogen fuel-cell vehicles.

Process

DOE set an On-Board Fuel Processing Go/No-Go decision milestone for June 2004. From January to mid-June, an independent panel of technical experts conducted a review of current on-board fuel processing technical progress. The information used to form a recommendation included presentations by selected organizations involved in fuel processor R&D, two site visits, opinions in the form of white papers collected via a Federal Register announcement, and pertinent publications. The report from this independent panel was submitted to the DOE Go/No-Go decision team in early June and the team drafted a final recommendation for EE-1 approval. Upon approval by EE-1, DOE will brief congressional appropriations staff and the FreedomCAR and Fuel Partnership Joint Operations Group, and announce the final decision to the public.



The DOE Go/No-Go decision team considered the following factors:

1. progress toward meeting technical targets and demonstration criteria,
2. potential pathway leading to successfully attaining the ultimate targets within the established timeframe
3. importance of on-board fuel processing to transitional and long-term hydrogen infrastructure
4. status of competing technologies
5. programmatic and policy considerations

Recommendation

The DOE On-Board Fuel Processing Go/No Go Decision Team unanimously recommends that the current on-board fuel processing R&D be terminated. This decision is recommended in consideration of the current status of the technology and the prospects for technology improvement, as well as other criteria such as the status of competing technologies. Key contributors to this decision include:

- Current on-board fuel processing technology does not meet key 2005 performance targets, including start-up time and start-up energy.
- No clear path has been demonstrated to indicate that the ultimate performance targets are achievable by 2015.
- Even if successful, on-board fuel processing would not result in performance significantly better than that available from hybrid gasoline engine technology
- Lack of sufficient industry interest in pursuing the technology
- Acceleration of hydrogen technology through the Hydrogen Fuel Initiative

On-board fuel processing R&D is currently funded from the fuel processing activity of the Fuel Cell Technologies budget funded under Interior appropriations. The FY2005 budget language includes on-board fuel processing, as well as fuel processing for stationary systems and auxiliary power units (APUs). This decision only affects the on-board portion of the budget (on-board fuel processing for fuel cells providing vehicle traction power). It is recommended that any FY2005 budget appropriations allocated to on-board fuel processing be utilized to conclude and/or transition the individual projects affected.

Rationale

The technical rationale for the decision to end on-board fuel processing technology R&D for transportation fuel cell applications is supported by the Independent panel report. Their findings were based on surveys of the open literature and DOE reports, interviews with fuel cell and fuel processor developers and users, and position papers submitted by stakeholders in response to a Federal Register announcement. The panel considered the current status and the likelihood of meeting the ultimate targets by 2015. The conclusion was that current technology falls short of meeting 2004 targets, and that no clear path was identified to lend credibility to meeting ultimate targets. Although the independent panel recommended a "no-go" decision, they also made a number of specific recommendations that, if implemented, would effectively continue support of on-board fuel processing R&D. These recommendations include the continuation of on-board fuel processing R&D focusing on fundamental work and innovative concepts. The recommendation of continued work is a recognition that impressive progress has been made in the last ten years, and that the possibility exists to eventually approach the technical targets, although not within the 2015 timeframe. The DOE team concurs that continued progress and the development of innovative concepts could result in a viable on-board fuel processing technology, but the team considers this highly unlikely to occur in the next ten to fifteen years.

An important consideration for the DOE decision team was the advanced state of competing technology – gasoline ICE/battery hybrids. As discussed in more detail below, it is clear that on-board reforming technology does not offer clear advantages over hybrid vehicle technology that is available today. The impact of the President's Hydrogen Fuel Initiative to accelerate hydrogen technology commercialization from 2030 to 2015 (commercialization decision in 2015) lessens the contribution on-board fuel processing can make as a transitional technology. After careful consideration, the decision team recommends ending DOE funded on-board fuel processing R&D and bringing the current on-board activities to an orderly conclusion. Where advantageous, existing work should be transitioned to support fuel processing for stationary fuel cell systems and distributed hydrogen generation.

Technical Progress Toward Targets

As stated elsewhere in this report, the Independent Review Panel has concluded that few of the technical and economic criteria established for this decision have been met and certainly all of the criteria have not been met simultaneously. The status is summarized in Table 1. Furthermore, it is the considered opinion of the DOE decision team that most of the targets set for the mature product will not be met and, again, simultaneous achievement of all of the technical and economic targets is unlikely.

Table 1. 2004 Demonstration Criteria, Ultimate Targets, and Status of On-board Fuel Processing[1]

Attribute	Units	2004 Demo Criteria	Current Status (2/2004)	Ultimate Target	Probability of Reaching Ultimate Target
Durability	hours	2000 and >50 stop/starts	1000	5,000 and 20,000 starts	high
Power density	We/L	700	700	2,000	medium
Efficiency	%	78	78	>80	high
Start-up Energy	MJ/50kWe	<2	7	<2	low
Start-up Time (+20°C)	sec	<60 to 90% traction power	600	<30 to 90% <2 to 10%	low
Transient Response	sec	<5, 10% to 90% and 90% to 10%	10	<1, 10% to 90%, and 90% to 10%	low
Turndown	ratio	20:1	20:1	> 50:1	high
Sulfur Content	ppb	<50 out from 30 ppm in	130	<10 out from 30 ppm in	medium
Cost	$/kWe	n/a	65	<10	low

[1] This table generally identifies the best performance by any of the evaluated systems. There is no evidence that any one system could simultaneously achieve all of the values indicated in the Current Status column.

Programmatic Focus
In early 2003, President Bush announced the Hydrogen Fuel Initiative to accelerate introduction of hydrogen as the primary energy carrier in the United States. An earlier introduction of a hydrogen infrastructure and on-board vehicle storage reduced the need for a bridging technology such as gasoline-powered FCVs because the timeframe for development of the bridging technology was essentially the same as that for the hydrogen technology.

Comparison of Competing Technology
DOE's original intent in funding development of fuel cell vehicles (FCVs) powered by hydrogen produced by reforming gasoline on-board the vehicle was to bridge the gap from today's gasoline/diesel-powered ICE engines to higher efficiency FCVs powered by hydrogen produced in distributed or central fuel processing stations and stored on-board the vehicle. As shown in Table 2, the efficiency gap has been largely bridged by hybrid (battery/ICE) technology not only available today, but in production at performance levels comparable to the projected performance of mature FCV technology operating on reformed gasoline. As a result of these developments, the need for a bridging technology has been obviated.

Table 2. Status of Hybrid Technology
(NREL Modeling, units are miles per gallon of gasoline equivalent)

Vehicle	Urban	Highway	Combined
Gasoline Reformed FCV at 2005 targets	49.9	68.9	57.0
Gasoline Hybrid – 2004[1]	66.6	65.4	66.1
Gasoline Reformed FCV at 2010 targets[2]	61.0	68.9	68.6
Gasoline Hybrid - estimated 2010[3]	73.3	72.0	72.7

1. 2004 Toyota Prius EPA fuel economy, unadjusted. EPA "sticker" ratings are adjusted down to account for actual driving patterns.
2. assumes 40% mass reduction, 5% increase in fuel cell efficiency, 325 W/kg power density. 2015 targets are the same as 2010 except for the cost target.
3. assumes 10% increase in fuel economy - mainly based on 40% reduction in mass

Market Interest
Over the last several years, interest by the domestic automakers has steadily diminished to the point that no domestic manufacturer is currently interested in the technology. It should be noted that at least one foreign automaker (Renault) has indicated continued interest in the technology. Renault has recently invested in Nuvera, a U.S. company with strong on-board fuel processing expertise (Nuvera developed this technology aided by significant support from DOE). The decision team concludes that it is in the interest of neither DOE nor the Nation to support/fund R&D on a technology which has virtually no market.

Path Forward

While it is the recommendation that on-board fuel processing be terminated, the fuel processing activity under Fuel Cell Technologies should continue. Current development projects supporting on-board fuel processing systems will be terminated or redirected to support stationary and auxiliary power unit fuel processing and potentially other applications. Current fuel processing activities to reform natural gas and propane for stationary applications will continue. FY05 will serve as a planning and transition year, bringing on-board fuel processing projects to closure, writing final reports and refocusing the activity.