HYDROGEN AND FUEL CELLS:
A COMPREHENSIVE SOLUTION IN THE FIGHT AGAINST GLOBAL WARMING

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INTRODUCTION

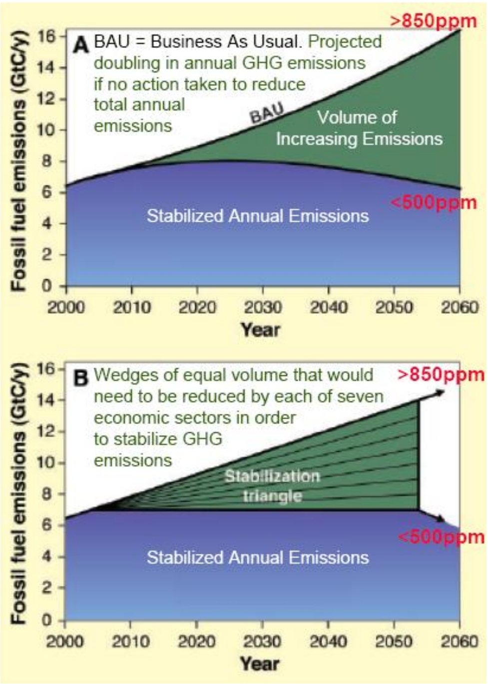
The world's leading climate experts have now declared that human activities — predominantly due to our use of fossil fuels — are unequivocally accelerating global warming.[1] They also warn that, in order to avoid the most devastating consequences of climate change, governments have to develop effective policies to combat global warming within the next 10-15 years.[2] Some governments have responded with renewed urgency in developing and implementing policies while others are moving more slowly.[3]

Electrical power generation and transportation are responsible for the bulk of the greenhouse gas (GHG) emissions from the use of fossil fuels. Transportation accounts for 25-30% of the world's greenhouse gas emissions of which 80% are from on-road transport.[4] As such, transportation should represent a top priority for policy makers, who will be challenged with determining the best approach for reducing GHG emissions.

One approach that is gaining wide acceptance in policy circles is to assign each economic sector responsible for generating GHG emissions their own respective "slice" of the global warming pie (i.e. their own emissions wedge). Then, governments can direct policies towards each sector, centered on available and soon to be commercialized technologies. The transportation "slice" can be addressed by diverse approaches.[5] The challenge for policy makers is "making the right set of choices" and harmonizing these different approaches into a comprehensive strategy. To help position hydrogen and fuel cells in the discussion, this discussion-brief provides an overview of some of the major approaches and the role that each can play in achieving maximum long-term GHG emissions reductions.

OPTIONS TO REDUCE CARBON FOOTPRINT OF VEHICLES

The diverse options being pursued to reduce GHGs from vehicles includes low carbon bio-fuels; flexible fuel vehicles; compressed natural gas vehicles; hybrid electric vehicles (HEV); plug-in hybrid electric vehicles (PHEV); all-battery electric vehicles (BEV or EV); and hydrogen fuel cell vehicles (FCV). Each has a role to play but only one appears poised to provide a comprehensive solution for the long-term stabilization and reduction of GHGs.



<u>Modified From:</u> Pacala,S. and R. Socolow, AUGUST 13, 2004. <u>Stabilization Wedges:</u> Solving the Climate Problem for the Next 50 Years with Current Technologies., Science Volume 305, pp 968-972 (Part of the Special Section on the Hydrogen Economy).

Greenhouse Gas Emissions Wedges: A Slice of the Global Warming Pie.
(**A**) GHG emissions under business as usual (BAU – green area) are projected to double from 7 billion tons per year (GtC/y) today to 14 billion tons per year by mid-century. Climate scientists are urging that CO2 emissions must be stabilized if concentrations are not to exceed 500 ppm (blue area) in order to avoid dangerous climate change. (**B**) A schematic representation of (A). The increased emissions are represented as a triangle cut into 7 stabilization wedges. Each wedge represents a 1 billion ton (IGT) slice of potential annual emissions reductions. The suggested approach requires that policy be directed towards a reduction in GHG emissions from each of seven economic sectors. Hydrogen and fuel cells could contribute significantly in reducing emissions from the transportation sector.

COMPARISON OF VEHICLE TECHNOLOGIES

Vehicle Technology Option			Market Introduction & Timeline	Well to Wheel GHG emissions reductions of Technology Option (Relative to a mid-sized car)	Current Constraints / Limitations	Maximum Total Fleet-Wide GHG Reductions.[6]
ELECTRIFICATION*		Fuel Cell Vehicle	2015 – 2050	30-100% (Natural gas H2 – all renewable including biomass)	Range, cost, performance, infrastructure & availability of near-zero GHG emission hydrogen	100%[7]
		Battery / All Electric	2010[8] – 2050	0-100% (Coal fired electricity generation - all renewable)	Range, battery size, weight & performance, cost, availability of near-zero GHG emission electricity from grid and grid expansion.	100%[9]
		Plug-In Hybrid Electric (40 mile all-electric)[10]	2020[11] – 2050	~50%[12]	Same as for battery all electric and challenges with all electric range	~50%[13]
		Hybrid Electric[14]	1999 – 2050	25-50%[15]	Vehicle cost[16]	≤50%[17]
ADVANCING ICE VEHICLES	POWERTRAIN**	Hydrogen ICE	2007[18] – 2050	100% - see FCV	Same as for fuel cell, moves away form electrification trend, not ZEV, fuel boil off, only one OEM working on LH_2, power & torque issues.	90%[19] – 100%[20]
		Improved Vehicle Efficiency[21]	2002 – 2030	11- 65%[22]	Cost to consumer & greater complexity.	≤40%[23] – 65%[24]
		Improved Vehicle Efficiency[25]	5 – 10 years from adoption	11- 47%[26]	Cost to consumer & greater complexity.	>30%[27] – 47%[28]
	BIOFUELS	Ethanol (indigenous)	2005 – 2012[29]	Subject of continuing research and debate and almost exclusively from corn – 0 – ~20%[30]	Sustainability, impacts on food and commodity prices and limitations of land available to grow.	0 - 1%[31]
		Biomass (indigenous)	2005 – 2050[32]	Subject of continuing research and debate. Depending on fuel type, feedstock and production method, 0 - 85%[33]	Many technical issues, sustainability & assumes use of all potential feedstock.	≤ 33%[34] (assume dominance by cellulosic feedstock)

* *Electrification: The broad industry goal of moving vehicle technology towards greater efficiency, air pollutant and GHG reductions through the use of simpler and more reliable vehicle designs.*

** *Powertrain improvements can include: cam phasing, variable valve lift, camless valve actuation, turbo-charging, cylinder deactivation, variable compression ratio, gasoline direct injection, homogeneous charge compression ignition, high-speed direct injection diesel, 5, 6 and 7 speed automatic transmissions (increased step gear ratio transmissions), automated manual transmissions, continuously variable transmissions, greater electrification of subsystems, improvements in lubricating oil, improved aerodynamics (reduced vehicle drag), weight reduction, rolling resistance reduction, aggressive shift logic, early torque converter lock-up, air conditioning, engine cooling, etc. Greater vehicle efficiencies and GHG reductions are achieved through the use of a greater number of these options in combination, making the design, manufacture and operation of the vehicle increasingly complex.*

ALTERNATIVE TECHNOLOGIES - FURTHER COMMENT

The summary table clearly shows that beside fuel cell vehicles, few technologies (EV's and H_2-ICEs) have the potential to nearly eliminate GHG emissions from transportation. While all three technologies still have constraints, automotive companies are focused on fuel cells as the viable technology solution, while battery technologies for all electric vehicles are viewed as having a longer commercialization horizon.[35] The many other technologies listed are directed towards improving fuel efficiency (eg. hybridization) or the displacement of petroleum fuels (eg. biofuels) but these are not comprehensive in the solution set they offer and most are part of the ultimate technological progression towards hydrogen fuel cell vehicles. Some of the limitations surrounding these alternative technologies are outlined in greater detail below.

Advancing Internal Combustion Engine Vehicles

Bio-fuels

The use of corn-derived ethanol provides little overall benefit in fighting global warming. The main utility in using corn-derived ethanol lies in its ability to lay the groundwork for ethanol derived from plant fibres (cellulosic ethanol). The future ability of biofuels to reduce GHGs is dependent on the maximum exploitation of cellulosic feedstock (predominantly derived from agriculture and forest residues) as well as from high-yielding purpose grown cellulosic crops like switchgrass. Significant challenges exist both in terms of the volume of material that will need to be harvested and the technical solutions required to "free" the sugars trapped within the ligno-cellulosic matrix of the harvested plant fibers. Forest and cropland will also have to be more intensively managed, posing a challenge for the sustainable production of bio-fuels while meeting ever-increasing market demand for both food and fuel. Solutions are also required for the enzymatic breakdown and extraction of the sugars from ligno-cellulose and in developing new plant varieties capable of providing higher yields of bio-fuels. Even if all of these issues are resolved, bio-fuel production from both agricultural crops and cellulosic residues in the US would only be expected to displace a maximum of 33% of transportation fuel supplies. Based on the most optimistic GHG balance for bio-fuels derived from cellulosic feedstock this could also translate into a roughly 33% reduction in GHG emissions.

Powertrain Improvements

Many of the approaches to improving powertrain efficiency require increasing the complexity of the vehicles and can involve considerable expense.[36] With greater complexity comes the challenge of maintaining vehicle reliability. Indeed many of these measures are viewed as a stopgap until more efficient electric-drive technologies are fully developed and ready for the market. The approaches with the greatest potential to improve vehicle efficiency involve the increased use of electrical systems to assist the performance of the vehicle (and hybrid electric vehicles are the first major step to the complete electrification of the car).

Hydrogen ICEs

The use of hydrogen as a fuel for combustion engines (H_2-ICE) is inconsistent with the broader industry's technological goal of developing electric drive and fuel cell vehicles. While the ICE vehicle can be modified to take advantage of the same hydrogen fuel as the FCV, it is still dominated by the use of mechanical systems and will never be as efficient in the use of hydrogen fuel as a fuel cell. Unlike FCV's, H_2-ICE vehicles can only achieve SULEV (super ultra low emission vehicle) emissions performance for criteria pollutants and require the use of exhaust after-treatment in order to do this. Fuel cells are simpler and can power true zero emission vehicles.

Another challenge for H_2-ICEs is that hydrogen easily pre-ignites, and vehicles fueled by compressed hydrogen gas are the most susceptible to pre-ignition. This effect produces engine knock-like effects that must be controlled. One solution is to operate the engine on a lean fuel mixture, with the result that the engine is robbed of both torque and power relative to when similarly run on gasoline.[37] The use of cryogenically stored liquid hydrogen avoids pre-ignition. However, regardless of whether liquid or compressed hydrogen is used, the engine must still be run very lean in order to reduce NOx emissions[38], again robbing the engine of both its torque and power. As a consequence BMW's new Hydrogen-7 vehicles come equipped with a V-12 engine that can run at 260hp. When run on gasoline the same engine can generate 438hp. The challenge of using liquid hydrogen does not end there however. If the vehicle is not used on a regular basis, significant amounts of fuel can boil-off from the fuel tank and be lost.

Electrification

While PHEVs and EVs could also yield significant reductions in global warming and criteria pollutant emissions, these technologies also face challenges, not the least of which are the cost, weight, performance and durability of the battery systems. While the market for PHEVs could develop more quickly, because there are fewer barriers to adoption, these vehicles are not zero emission, and automotive companies appear reluctant to engage in developing either PHEVs or EVs.[39] Moreover, many automotive companies maintain that significant breakthroughs in battery technology will not occur any faster than the development timeline for the commercialization and deployment of fuel cells.[40] Only one automaker has openly committed to a full vehicle development program for PHEVs at this time.[41] Finally, hybrid electric and all-electric approaches require the further development and refinement of electric-drive and battery technologies that will also contribute to the improvement of fuel cell vehicles. In fact automotive companies have as their ultimate goal the development of hybrid electric FCV's[42] because many consider these vehicles to be superior consumer products.

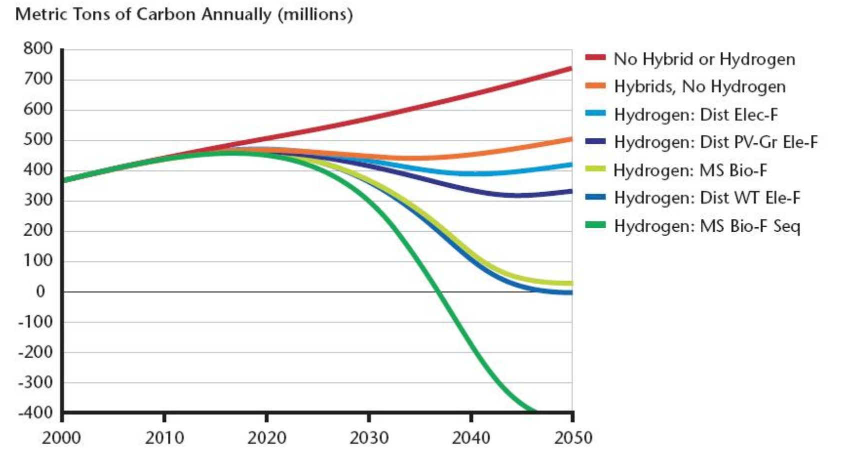
THE FUTURE OF FUEL CELL VEHICLES

"Fuel cell vehicles are attractive potential replacements for ICE vehicles because they can offer performance similar to that of conventional vehicles, along with several additional advantages. These advantages include better environmental performance; quiet (but not silent) operation; rapid acceleration from a standstill, owing to the torque characteristics of electric motors; and potentially low maintenance requirements." … ". FCV's also provide additional attractions to automakers: by eliminating most mechanical and hydraulic subsystems, they provide greater design flexibility and the potential for using fewer vehicle platforms and therefore more efficient manufacturing approaches."

The National Research Council (2004), The Hydrogen Economy: Opportunities, Costs, Barriers, & R&D Needs.

Hydrogen and Fuel Cells

Many of the major technologies outlined above, rather than competing with FCV's, are in fact compatible interim measures along the road to the widespread deployment of FCV's. Indeed most of the alternative approaches by themselves will not realize a zero or near-zero GHG emissions future for transportation, while others fail to embrace the industry trend towards greater electrification. At best, most can only succeed in reducing the overall emissions intensity of transportation, and will not



From: WBCSD, 2004. Mobility 2030: Meeting the challenges to sustainability (based on NRC 2004).

Thinning the Transportation Wedge: A Negative Carbon Future?
Future carbon emissions of passenger cars and light duty trucks with hydrogen production technologies

completely eliminate transportation's emissions of GHGs.

Technical challenges also remain for fuel cell technology. Cost and durability are the main challenges. However, fuel cell makers have recently made great strides in these areas[43] and are presently targeting 2010 as a date for developing fuel cell technology that is commercially viable, when produced at volumes of 250,000 annually, based on the U.S. Department of Energy's publicly stated commercialization targets. Consequently, it will not be until 2010-2015, due to the automakers vehicle development cycles, that this technology will make it into fuel cell vehicles on the road. This delay, and the need for increased volumes to meet cost targets means fuel cells will only be viable when product volumes allow for cost reduction.

The production and use of the hydrogen fuel could potentially have a near-zero well-to-wheels — or more correctly well-to-tailpipe — GHG emissions profile, while taking advantage of diverse non-petroleum feedstocks for hydrogen production.

Hydrogen also has the advantage that it can be flexibly produced from a variety of domestic energy resources including natural gas, biomass, and electrical energy generated from geothermal, solar and wind power. This feature makes it possible for each region to produce hydrogen from its most abundant domestic resource. Initially most hydrogen fuel will be derived from the reforming of natural gas. While this will provide a smaller benefit (30%) beyond existing ICE emissions, the goal is for future hydrogen to be produced without any GHG emissions anywhere along the production chain. This transition and deployment strategy would allow hydrogen fuel produced from renewable energy to gradually penetrate the transportation sector (ex. as new renewable generation capacity comes on line) that would slowly displace carbon-based fuels and significantly alter the emissions profile. Ideally, this will mean that a large portion of hydrogen will come from renewable energy, including biomass. In some regions nuclear energy may be relied upon to produce hydrogen/GHG-free hydrogen. Carbon-rich sources should only be used as hydrogen feedstock if all of the carbon can be sequestered once the hydrogen is extracted.

While the transportation fueling-infrastructure will have to undergo a transition in order to support the hydrogen economy, it will not need to switch overnight. According to projections by the National Academies the increase in the number of FCV's means that the demand for hydrogen would be about equal to the current production of 9 million tons per year beginning in the year 2027. Moreover, hydrogen production costs could be as low as $2-$4 per kilogram, putting it on a par with the price of today's gasoline.[44] (The cost of petroleum distillate fuels such as gasoline and diesel is likely to remain high and could even go higher given the challenges posed by the rapidly growing global demand for new production.[45]) Because fuel cells are more efficient at using hydrogen (a kilogram of hydrogen has about the same energy content as a gallon of gasoline) they will propel a car farther on that kilogram of hydrogen than a conventional car will go on a gallon of gasoline. All of these facts point to the use of hydrogen in fuel cell vehicles as the most comprehensive solution in the fight against global warming.

BUILDING THE HYDROGEN ECONOMY TODAY

The development of a hydrogen powered transportation system will not happen in isolation[46] and there are several near term applications for fuel cells (ex. material handling equipment and high quality on-site back-up power) that are gaining market traction and can help facilitate the transition to the use of hydrogen. These early applications will help to lay the foundation for a maturing hydrogen infrastructure — including resolving codes and standards and permitting issues — and facilitate early customer acceptance of hydrogen and fuel cells.

For example, real market drivers exist for materials handling (eg. forklift applications) including the improvement of an end-user's bottom line because: it improves run time (3 times that of battery powered equipment); it eliminates the need to replace/recharge batteries; it increases productivity (no loss of power over work shift and less time for re-fuelling); and thus, it can increase revenue generation capacity. Fuel cells help free up warehouse and factory space once required for battery storage and chargers.[47]

The potential market for replacing lead acid batteries is quite large, with the forklift battery market having annual global sales exceeding $1B. Companies leading efforts to introduce fuel cell and hydrogen technology in this market (ex. Plug Power — formerly Cellex Power and General Hydrogen) are working through customer trials to demonstrate the benefits to end users, while also working to reduce fuel cell cost and to increase reliability and durability. Manufacturers are targeting 2009-2010 as the window for market introduction, with fuel cell cost at $500-$600 per kW and volumes of 5000-10,000 units. The development of these early markets is considered to be synergistic with automotive fuel cell development since the fuel cell stack technology utilized for these markets was initially developed for use in the automotive market.[48]

Similarly, real market drivers exist for back up power as well including: increased reliability, reduced emissions; extended run time; a wide operating temperature; reduced maintenance requirements; and fewer moving parts leading to lower lifecycle costs. The market opportunity to replace lead acid batteries in this market (specifically in telecommunications – wireless and wireline) is also potentially large with approximately $2B in annual battery sales. Companies leading efforts to introduce fuel cell and hydrogen technology in this market such as Dantherm, IdaTech, and Ballard Power Systems, are working to demonstrate the benefits to end users in customer trials, again while also working to reduce fuel cell cost and increase reliability and durability. Commercial introduction for this market segment is also targeted for 2009-2010, with fuel cell cost at $1000-$1800 per kW and volumes of over 3000 units.[49]

All of these fuel cell applications deliver real environmental benefits. For example, residential co-generation fuel cells deployed in Japan have cut carbon dioxide emissions by an average of 30% — with some residential units reducing emissions by as much as 40% — over conventional heat and electrical generation systems.[50] This amounts to an average reduction of 1800 pounds annually per home (3000 ponds maximum) and would translate to an average annual displacement of 1.8 million tons (3.0 million tons maximum) per thousand homes.

Fuel cells for back up power and materials handling/forklift applications would replace lead acid batteries and eliminate the environmental challenges posed by the manufacture, handling and disposal of batteries. Fuel cell back up power units (FCBPs) will often be used to displace diesel generators, and even though they may be used intermittently they will displace diesel emissions that can pose a significant threat to the environment[*] and public health. Initial deployments of FCBPs have already been made in the southeast USA where the hydrogen fuel is replacing battery systems charged from a regional grid dominated by coal-fired electricity.

Success in these early markets will be important not only to build customer acceptance and infrastructure but will also be critical in helping develop manufacturing capacity and expertise, and establishing a sustainable supply chain in the hydrogen and fuel cell sector.

In the auto sector, several of the world's leading automotive manufacturers are committed to developing FCV models and intend to introduce commercial models to the market at a premium price point during the 2010-2015 timeframe,[51] leading to mass production by 2025. The National Academies of Sciences have determined that the market introduction of FCV's in the 2015 timeframe could help the transportation sector to turn the corner on global warming emissions beginning as early as 2025 and — assuming that FCV's achieved complete market penetration — lead to near-zero emissions from light duty vehicles by 2050.[52]

Ultimately, significant green house gas reductions will come from fuel cell product applications in cars and buses. Today a typical fuel cell car running on hydrogen derived from renewable energy

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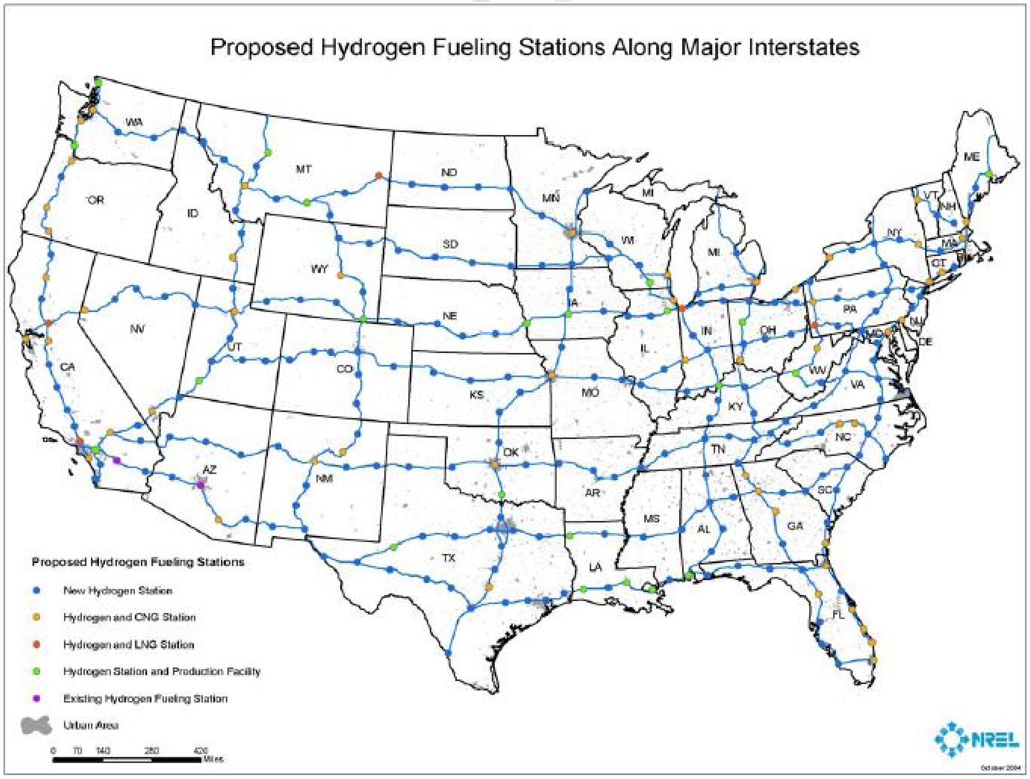
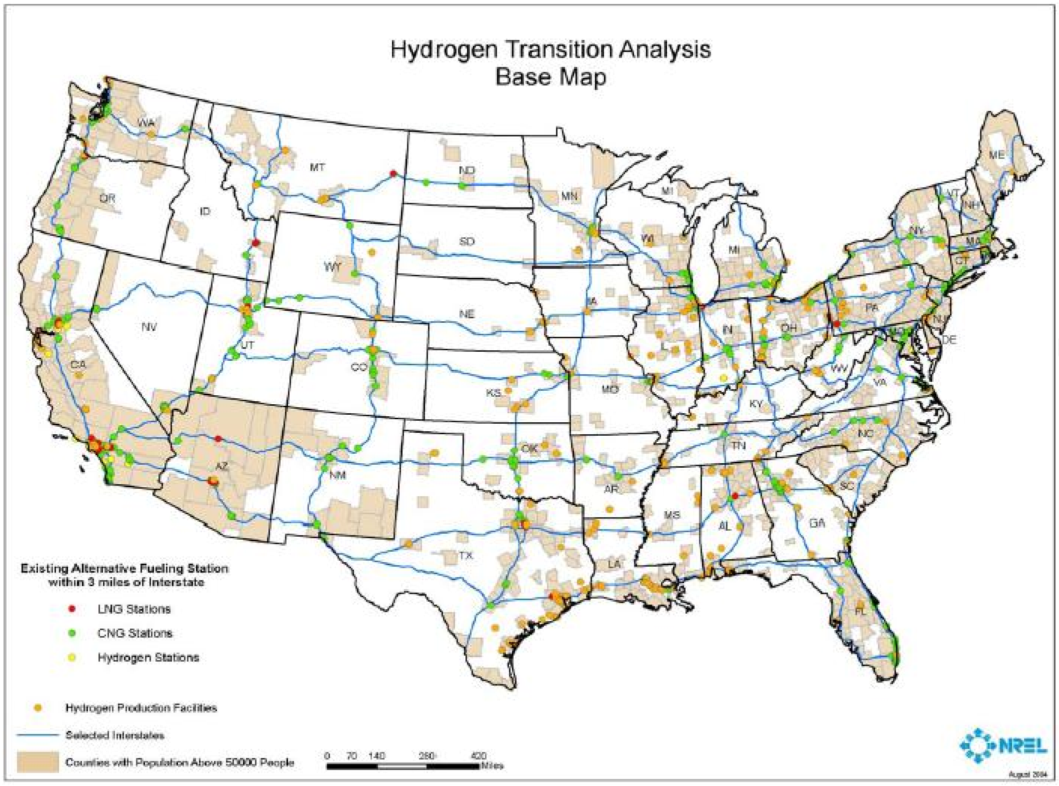
[*] Diesels are a significant source of black carbon an emission that contributes to global warming.

avoids releasing 5-7 tons of greenhouse gas emissions into the atmosphere annually[53] whereas today's fuel cell powered bus avoids the release of 94-95 tons of greenhouse gas emissions annually compared to its diesel-powered counterpart.[54] As conventional light duty vehicles and diesel transit buses to improve their efficiencies in the coming years it is likely that these relative advantages may shrink slightly. Despite this, fuel cell vehicles will still yield significant reductions in the release of GHG emissions. These significant reductions can be expected to grow exponentially when vehicle volumes begin to climb as more automakers place fuel cell vehicles on the road.

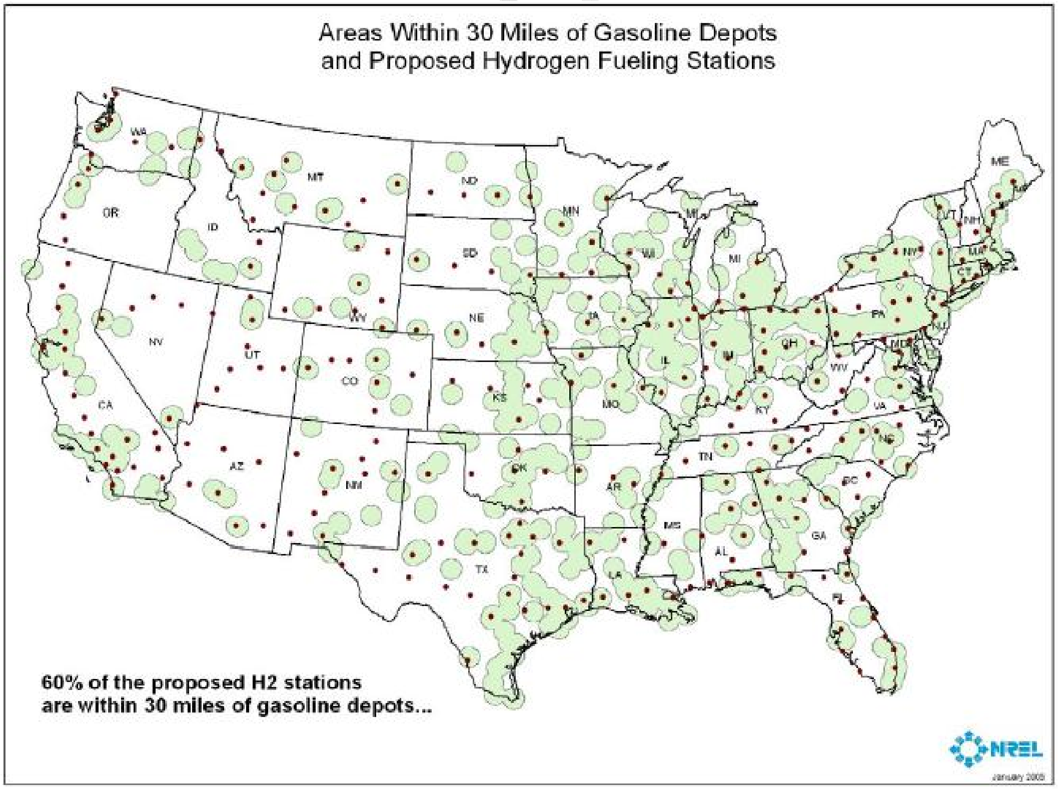
However, in order for this to occur the necessary supporting fuelling infrastructure also needs to develop. Indeed there is already a great deal of practical commercial experience that exists for producing, transporting and using hydrogen, and there are current methods for the production of hydrogen that are cost-competitive with today's gasoline production. With further improvements more cost-competitive methods could soon be available.[55] Because hydrogen has the advantage that it can be flexibly produced from a variety of domestic energy resources, as previously mentioned, it is possible for each region to produce hydrogen from its most abundant domestic resource. What remains is for the coordinated deployment of infrastructure.

Hydrogen fueling stations currently exist in support of demonstration fleets. However, it will be necessary to build upon this minimal fueling infrastructure by expanding networks of fuelling stations: first, in the select urban markets associated with the current demonstration fleets and; second, by linking these networks with strategically placed fueling stations along main connecting highway corridors.[56] The National Renewable Energy Lab in the United States has been developing potential infrastructure development scenarios (see three following charts).[57] NREL's work demonstrates how a feasible and cost effective plan can be developed to introduce hydrogen infrastructure in the continental United States if both government and industry are committed to the transition.





Hydrogen Transition Analysis
Base Map



Areas Within 30 Miles of Gasoline Depots
and Proposed Hydrogen Fueling Stations

60% of the proposed H2 stations
are within 30 miles of gasoline depots...

Industry cost estimates for this transition run as low as $10-15 billion in providing fueling infrastructure needed to serve roughly 70% of the population.[58] However, completing the transition to the use of hydrogen as a transportation fuel will take several decades; a fact that is also true for the many other major options outlined. Since each region's energy resource base will likely vary, a hydrogen economy could look different in different regions. A successful transition will require recognition of this fact and require the implementation of an evolutionary approach that initially relies upon current hydrogen production facilities but later relies upon a mix of small and distributed production facilities as well as large centralized production facilities; as appropriate for each region. During the interim the challenge for hydrogen suppliers will be the economic delivery of the hydrogen to the retail locations. Initially this will necessitate delivery by truck, but eventually delivery via pipeline from centralized production facilities will probably be most appropriate in dense urban areas, while distributed on-site production might remain appropriate for more remote locations. Until pipelines can be built to retail locations in urban areas, distributed on-site production will also be used at these sites because this avoids the near-term barriers to the deployment of delivery infrastructure from centralized generation.

Fuel cell and hydrogen technologies are the most comprehensive solution that can be adopted and encouraged in the fight against global warming. This does not mean other technologies should be ignored but instead policy makers should be aware of their limitations, support them selectively, understand how their adoption can facilitate ultimate solutions such as fuel cells and hydrogen and most importantly not minimize support for the real and sustainable solution – fuel cells and hydrogen. And to ensure fuel cell products continue to enter the market and the hydrogen economy continues to develop for other applications, such as light duty vehicles for the automotive sector, governments around the world need to increase their support for the fuel cells and hydrogen sector to ensure its sustainability. For example, government policy and regulations should be targeted towards ensuring that:

1) Market adoption of near term fuel cell and hydrogen applications is encouraged through government subsidy and tax credits (for products and fuel);
2) Regulation continues to encourage the adoption of technologies, like fuel cells and hydrogen, that provide ultimate solutions to both global warming and air quality issues (i.e. true ZEV technologies);
3) Support is targeted to ensure a vibrant and sustainable supply chain continues to develop that will provide the technology solutions to facilitate the market entry of hydrogen and fuel cells products (i.e. fuel cell, hydrogen storage);
4) Infrastructure necessary to economically deliver hydrogen to the retail location is developed.
5) The costs of hydrogen production from renewable energy is supported to make this competitive with current transportation fuels (with the cost of current transportation fuels derived from fossil-fuel resources reflecting all of the relevant externalities)

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~50% estimated current potential according to the CALIFORNIA AIR RESOURCES BOARD, cf: Staff Proposal Regarding the Maximum Feasible and Cost-Effective Reduction of Greenhouse Gas Emissions From Motor Vehicles., July 7, 2004.

[20] Assuming complete market penetration.

[21] National Research Council, 2002. Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards, and related analysis and discussion of NRC in: The California Climate Change Center at UC Berkeley, January 2006. Managing Greenhouse Gas Emissions in California Chapter 4: Technologies for Managing Greenhouse Gas Emissions.

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[27] Will be a function of fleet makeup & rate of tech introduction to market (eg. 35% average across California fleet), based on analysis of NSCCAF as discussed in: The California Climate Change Center at UC Berkeley, January 2006. Managing Greenhouse Gas Emissions in California Chapter 4: Technologies for Managing Greenhouse Gas Emissions.

[28] Assuming complete market penetration.

[29] Based on current US National production target of 7.5 billion gallons by 2012 as set-out in the 2005 EPACT, and current national gasoline consumption levels of 140-150 billion gallons

[30] Based on Life Cycle Analyses in:

- (a) Farrell, A.E., R.J. Plevin, B.T. Turner, A.D. Jones, M. O'Hare, and D.M. Kammen, January 27, 2006. Ethanol Can Contribute to Energy and Environmental Goals. Science VOL 311: 506-508, and (b) subsequent June 23, 2006 exchange in Letters Series "Energy Returns on Ethanol Production" Science VOL 312: 1746-1748, and (c) AE. Farrell Seminar before the California Air Resources Board: "Emissions from Fuel Ethanol: Separating the Confusion From the Uncertainties." May 16, 2006,
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[41] Status and Prospects for Zero Emissions Vehicle Technology: Report of the ARB Independent Expert Panel 2007. April 13, 2007.

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[42] “The future of fuel cells and hydrogen for transportation is directly linked to the automotive industry’s embrace of the technology. The industry, or at least a significant part of it, sees fuel cells as an inevitable and desired future. Fuel cells provide the opportunity to reduce transportation’s environmental impact by eliminating criteria pollutants and greenhouse gas emissions from the tailpipe for the life of the vehicle. In addition, hydrogen fuel cell vehicles may provide extra value to customers. This has not been true of any other non-petroleum vehicle technology. Fuel cell vehicles are quiet, quick to refuel, have smooth, rapid acceleration and potentially lower maintenance requirements. Their electric drive and by-wire systems allow for radically different vehicle designs and give automakers the opportunity to reduce the number of vehicle platforms they must produce to meet the diversity of vehicle needs that today’s automotive consumer demands. Fuel cells are a logical extension of the technological pathway automakers are already following with hybrid vehicles. ” Anthony Eggert, Associate Research Director, Hydrogen Pathways Research Program, Institute of Transportation Studies, University of California, Davis, in TESTIMONY BEFORE THE SUBCOMMITTEE ON NATIONAL PARKS, RECREATION AND PUBLIC LANDS, UNITED STATES HOUSE OF REPRESENTATIVES. MAY 15, 2004.

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