Transitions to Alternative Transportation Technologies; a Focus on Hydrogen

Presentation of Results

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Committee on Assessment of Resource Needs for Fuel Cell and Hydrogen Technologies

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Goals of the Statement of Task

- Establish as a goal the *maximum practicable number* of vehicles that can be fueled by hydrogen by 2020
- Determine the *funding*, public and private, to reach that goal
- Establish a *budget roadmap* to achieve the goal
- Determine the *government actions* required to achieve the goal
- Consider the role that hydrogen's use in *stationary electric power* applications will play in stimulating the transition to hydrogen-fueled hybrid electric vehicles
- Consider whether *other technologies* could achieve significant CO2 and oil reductions by 2020

Analytical Approach

Estimate HFCV **maximum practical penetration rate**, assuming

- Technical goals are met
- Consumers accept HFCVs
- Oil prices remain high (EIA high oil price scenario used as reference case)
- Policies are in effect to support HFCVs and hydrogen production.

Analytical Approach, continued

Three HFCV scenarios

- Hydrogen Success, not a projection but possible if above assumptions are met, based on DOE scenario and extended to 2050 by committee
- Hydrogen Accelerated, possible if goals are exceeded or strong policies enacted
- Hydrogen Partial Success, possible if goals not completely met

Committee adopted Hydrogen Success as most plausible **maximum practicable penetration rate.**

Analytical Approach, continued

Alternative Technologies

- Continued improvement of ICEV efficiency past 2020
- Rapid development of Biofuels
- Also considered these two plus HFCVs together

CONCLUSIONS

Lower-cost, durable fuel cell systems for light-duty vehicles are likely to be increasingly available over the next 5-10 years and, if supported by strong government policies, commercialization and growth of HFCVs could get underway by 2015, even though all DOE targets for HFCVs may not be fully realized.

- **Hydrogen from distributed technologies can be provided at reasonable cost to for the maximum practicable case transition.**

- **Hydrogen from coal gasification is cost competitive now, but sequestration needs demonstrated. Carbon policy needed**

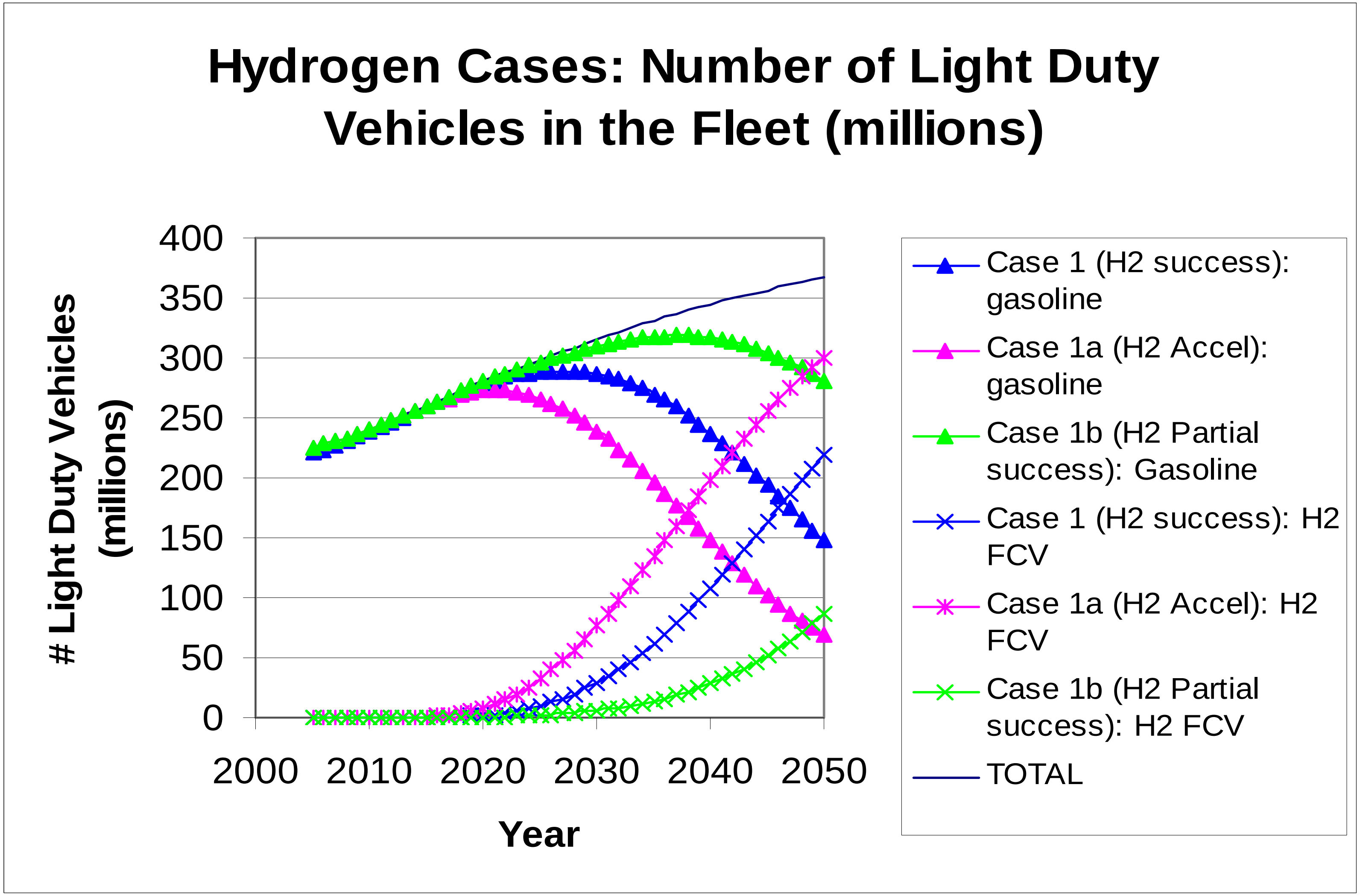
- **Hydrogen from biomass gasification technology is developing rapidly.**

- **The maximum practicable number of HFCVs that could be on the road is about:**

2 million by 2020,

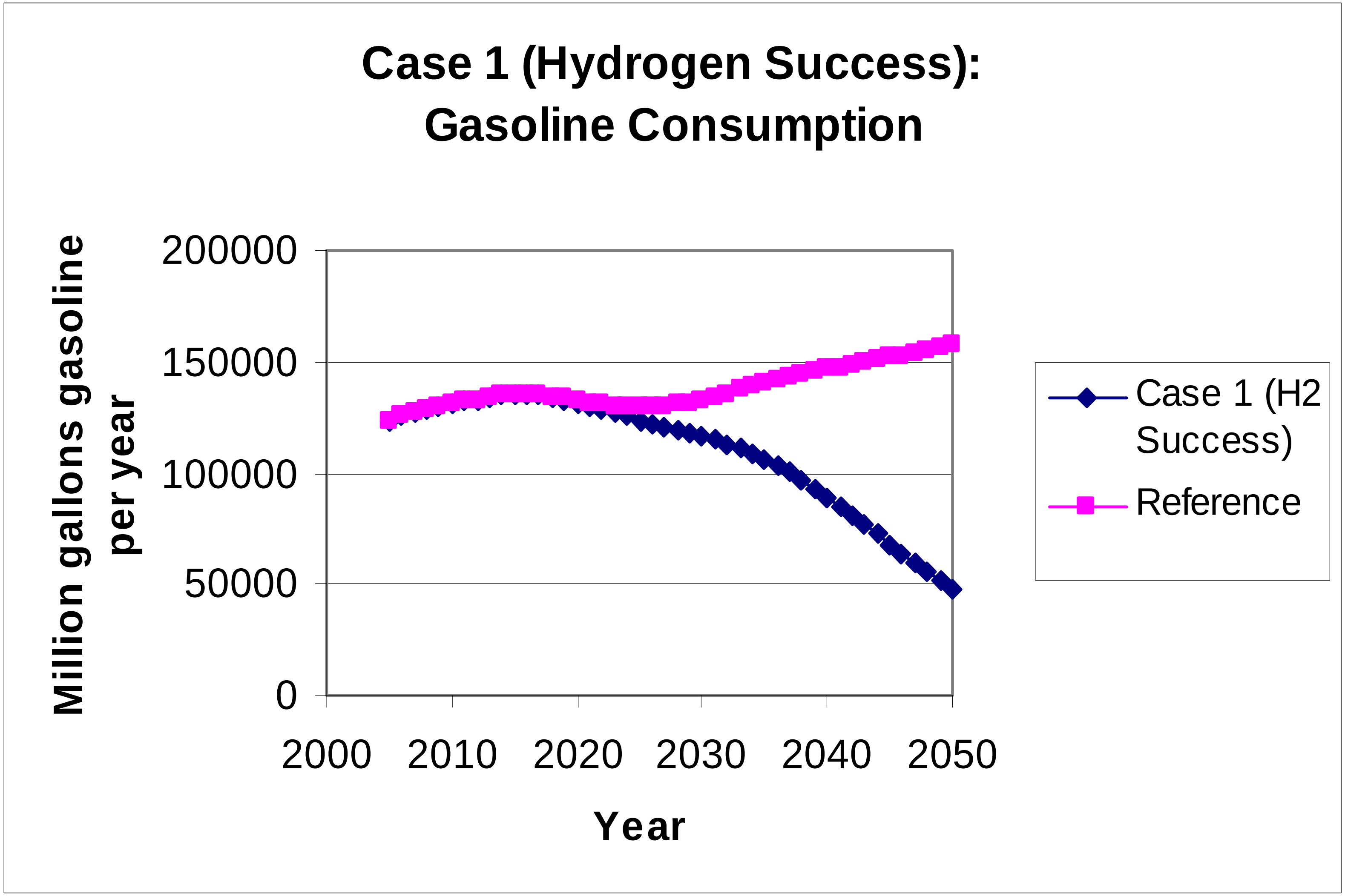
60 million by 2035,

200 million by 2050.

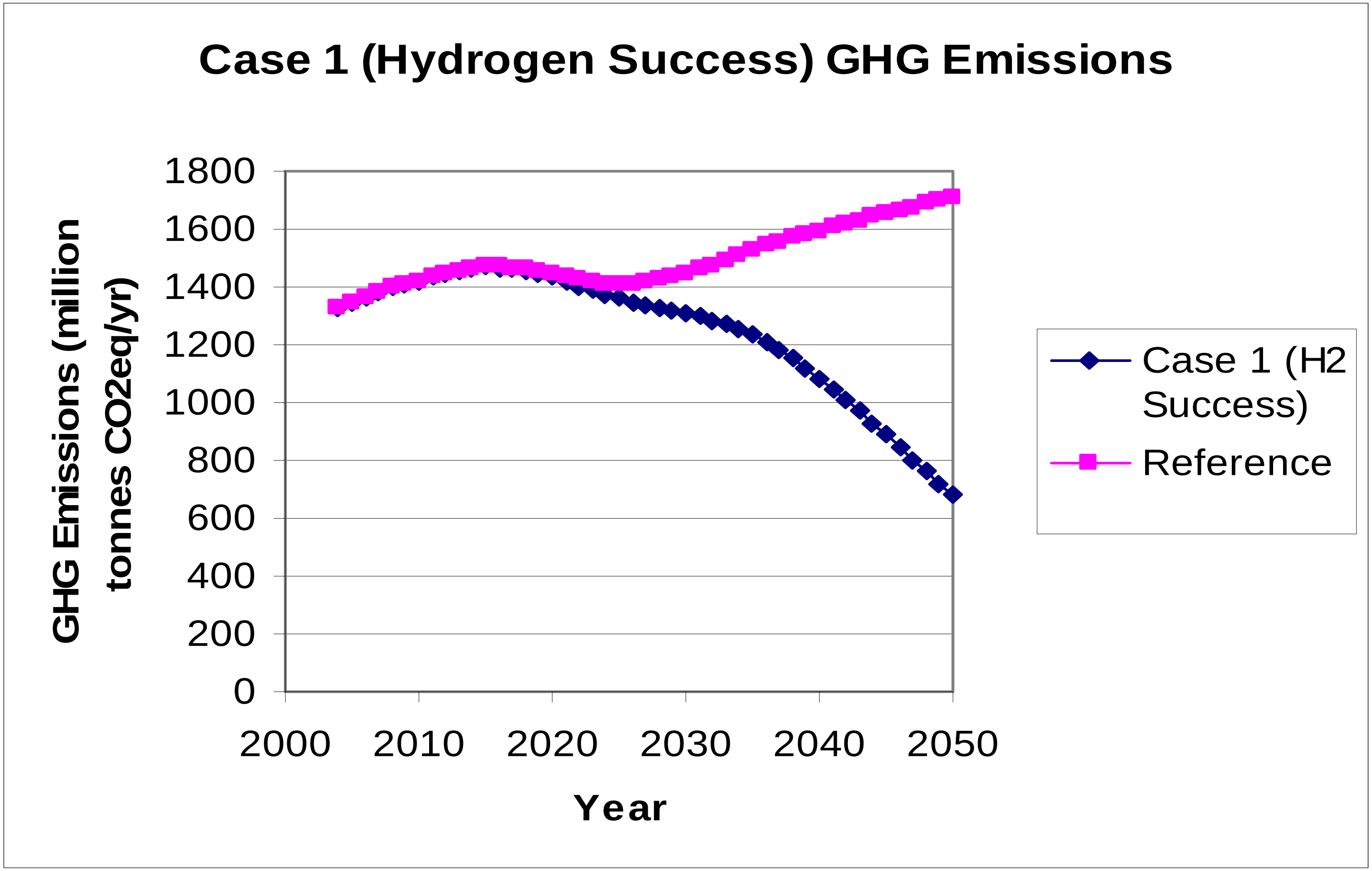


Hydrogen Cases: Number of Light Duty Vehicles in the Fleet (millions)
Light Duty Vehicles (millions)
400
350
300
250
200
150
100
50
0
2000
2010
2020
2030
2040
2050
Year
Case 1 (H2 success): gasoline
Case 1a (H2 Accel): gasoline
Case 1b (H2 Partial success): Gasoline
Case 1 (H2 success): H2 FCV
Case 1a (H2 Accel): H2 FCV
Case 1b (H2 Partial success): H2 FCV
TOTAL

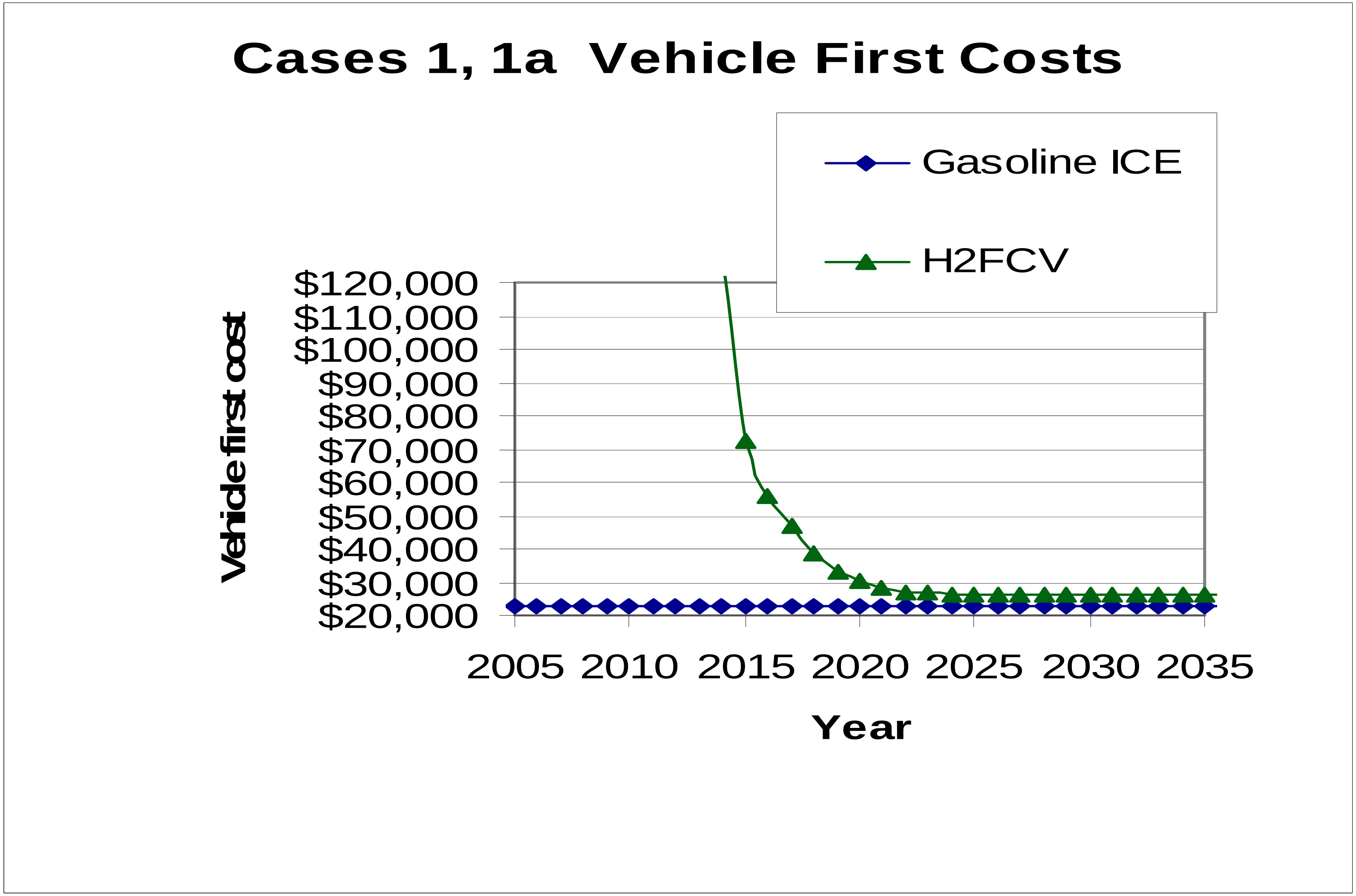
While it will take several decades for HFCVs to have major impact, under the Hydrogen Success scenario, fuel cell vehicles could lead to large reductions in oil consumption. CO_2 emissions will also be greatly reduced if strong carbon control policies are implemented.



Case 1 (Hydrogen Success):
Gasoline Consumption
Million gallons gasoline per year
200000
150000
100000
50000
0
2000
2010
2020
2030
2040
2050
Year
Case 1 (H2 Success)
Reference


Case 1 (Hydrogen Success) GHG Emissions
GHG Emissions (million tonnes CO2eq/yr)
1800
1600
1400
1200
1000
800
600
400
200
0
2000
2010
2020
2030
2040
2050
Year
Case 1 (H2 Success)
Reference

The unit costs of fuel cell vehicles and hydrogen in the Hydrogen Success scenario decline rapidly with increasing vehicle production, and by 2023 the cost premium for HFCVs relative to conventional gasoline vehicles is projected to be fully offset by the savings in fuel cost over the life of the vehicle.


Cases 1, 1a Vehicle First Costs
Gasoline ICE
H2FCV
Vehicle first cost
$120,000
$110,000
$100,000
$90,000
$80,000
$70,000
$60,000
$50,000
$40,000
$30,000
$20,000
2005
2010
2015
2020
2025
2030
2035
Year

RD&D needed to facilitate the transition to HFCVs totals roughly $16 billion over the 16-year period from 2008 through 2023, of which about $5 billion would come from U.S.(DOE) government sources.

The estimated government cost to support a transition to hydrogen fuel cell vehicles is roughly $55 billion from 2008 to 2023.

$40 billion for the incremental cost of fuel cell vehicles,

$8 billion for the initial deployment of hydrogen supply infrastructure,

$5 billion for R&D.

The estimated private industry costs is $140 billion from2008 to 2023

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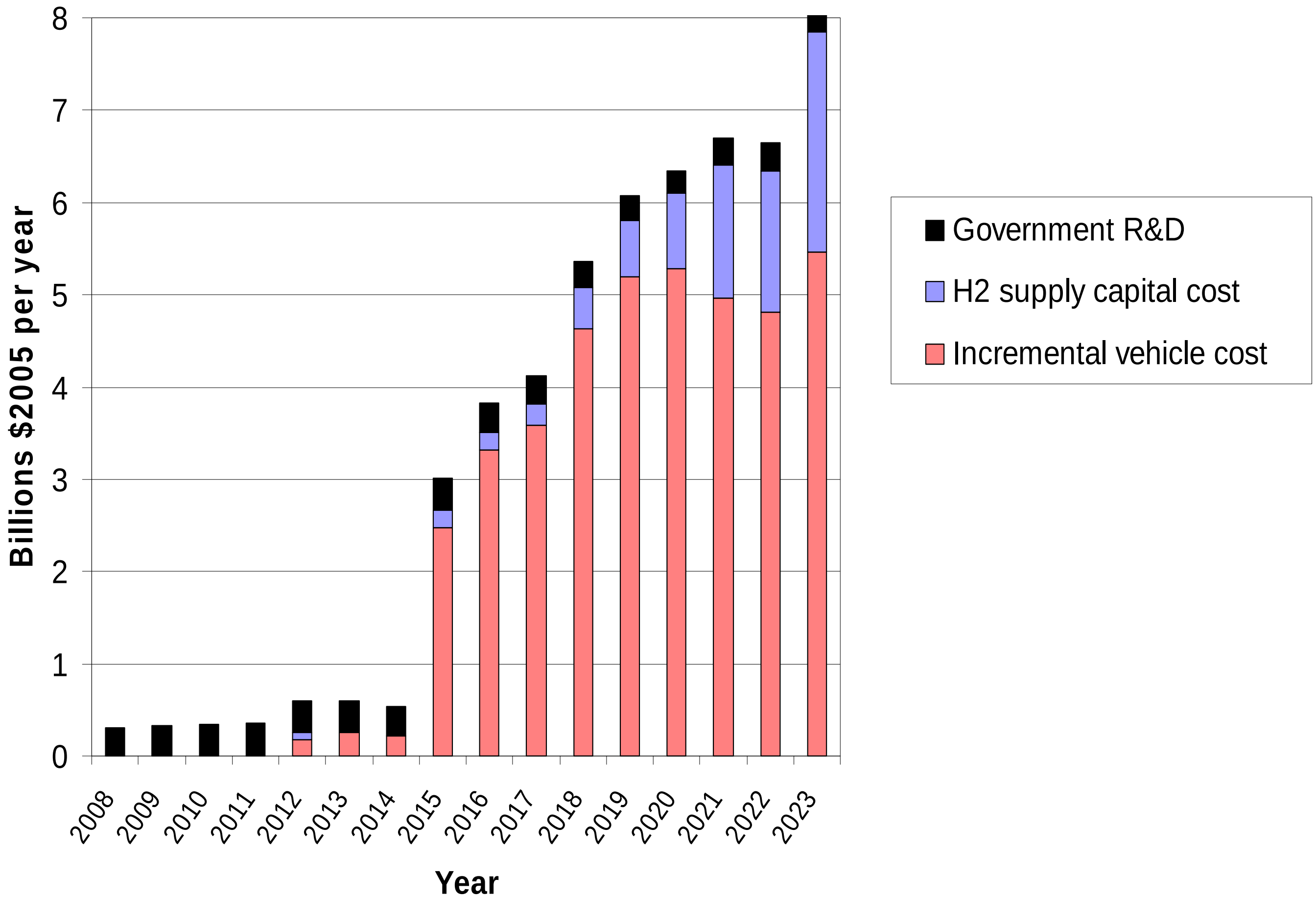
Industry cost for hydrogen infrastructure would be about $400 billion by 2050 to support 220 million vehicles. This would include 180,000 stations, 210 central plants, and 80,000 miles of pipeline.



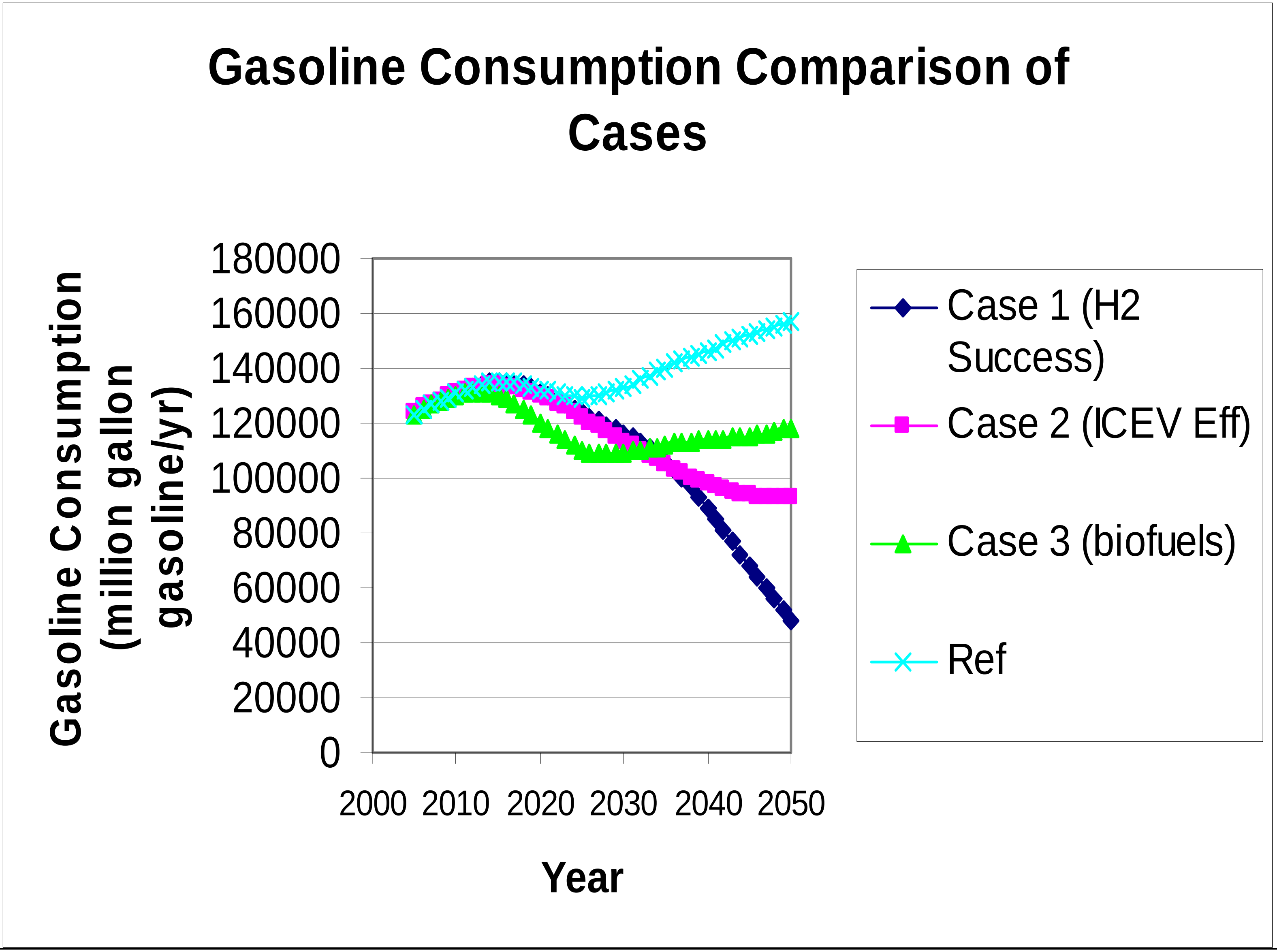
8
7
6
5
4
3
2
1
0
Billions $2005 per year
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
Year
Government R&D
H2 supply capital cost
Incremental vehicle cost

Policies designed to accelerate the penetration of HFCVs into the U.S. vehicle market must be durable over the transition time frame, but should be structured so that they are tied to technology and market progress, with any subsidies phased out over time

At least two alternatives have the potential to provide significant reductions in projected oil imports and CO2 emissions sooner than HFCVs:

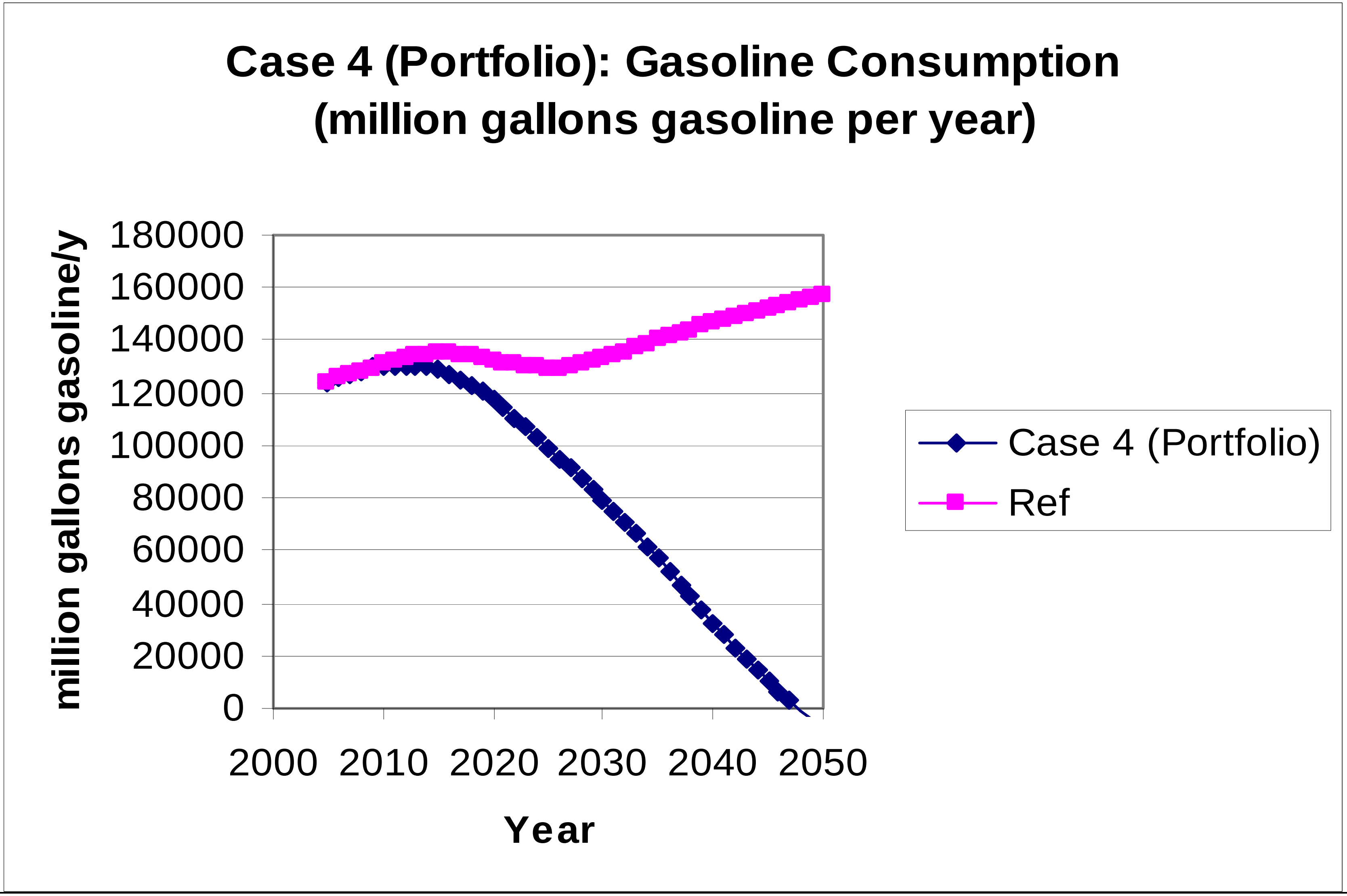
- **Advanced ICE and Hybrid vehicles**
- **Biofuels**

However, their benefits slow after two or three decades, while projected benefits from fuel cell vehicles are still increasing.



Gasoline Consumption Comparison of Cases
Gasoline Consumption (million gallon gasoline/yr)
180000
160000
140000
120000
100000
80000
60000
40000
20000
0
2000 2010 2020 2030 2040 2050
Year
Case 1 (H2 Success)
Case 2 (ICEV Eff)
Case 3 (biofuels)
Ref

A portfolio of technologies including hydrogen fuel cell vehicles, advanced conventional vehicles, hybrids, and use of biofuels has the potential to nearly eliminate oil demand from light-duty vehicles by the middle of this century, while reducing fleet greenhouse gas emissions to less than 20 percent of current levels.



Case 4 (Portfolio): Gasoline Consumption
(million gallons gasoline per year)
million gallons gasoline/y
180000
160000
140000
120000
100000
80000
60000
40000
20000
0
2000
2010
2020
2030
2040
2050
Year
Case 4 (Portfolio)
Ref

Program Area	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*	*Total*
Distributed H^2 Production	12	15	8	8	3	0	0	0	0	0	0	0	0	46
Distributed H^2 Production Demos	0	8	3	2	0	0	0	0	0	0	0	0	0	13
Centralized H^2 Production	28	35	45	50	55	55	50	45	35	30	30	20	15	493
Centralized H^2 Production Demos	0	0	0	15	15	15	15	50	35	20	25	20	0	210
Fuel Cells & H^2 Storage	112	115	115	115	115	110	110	110	110	110	110	110	110	1,452
Fuel Cell Demos	30	40	40	50	40	30	30	20	20	20	15	10	10	355
Safety, Codes and Education	21	21	25	25	25	25	15	10	10	5	5	5	5	197
Systems Analysis	12	10	10	10	10	10	10	10	10	10	10	10	5	127
Science	60	60	60	60	60	60	60	60	60	60	60	60	60	780
Exploratory H^2 from renewables	34	35	35	30	30	30	30	30	30	30	30	30	30	404
Total, 2008-2020	309	339	341	365	353	335	320	335	310	285	285	265	235	4077
Additional, 2021-2023														900
Total, 2008-2023														**4977**