

The influence of recent low interest rates on the estimated prices of OTEC fuels

William H. Avery (Ph.D)
Johns Hopkins University
Applied Physics Laboratory (ret.)¹

An important goal of OTEC commercial development is to produce vehicle fuels that can be a cost-effective, sustainable alternative to gasoline. If OTEC methanol was available now in commercial quantities it could replace gasoline made from crude oil, particularly that imported from the Persian Gulf region. **Major benefits in National security and defense expenditures would result from adopting this technology.**

The estimated prices of OTEC fuels are dependent on the cost of the OTEC plant, and depend directly on the interest that must be paid on the capital investment. The low interest rates now available for plant investments make the estimated prices of OTEC methanol (CH₃OH) fuel below the price of gasoline, for the same road mileage. Therefore, OTEC methanol could be an economically attractive replacement for gasoline. OTEC methanol could be produced in ample amounts to replace gasoline derived from crude oil imports, and could potentially replace all gasoline supplies.² The data in Tables 1 and 2 show that commercial production of OTEC methanol to replace gasoline would be a highly profitable venture for entrepreneurs.

Although commercial development of OTEC technology would add an important new sustainable energy resource to the world economy, OTEC development will not take place without the support of the automobile industry and the suppliers of fuels.

There is now evidence that carbon dioxide (CO₂) added to the atmosphere by combustion of gasoline in motor vehicles is a cause of global warming. The automobile and oil industries have strongly resisted past attempts to impose restrictions that would require them to produce smaller, lighter cars with lower fuel consumption, which would reduce carbon dioxide emissions, because it is clear that the public does not want cars with lower performance and carrying capacity. Fortunately, there is a new technology being developed for motor vehicles that would achieve much smaller fuel consumption without degrading vehicle performance. It uses fuel cells combined with regenerative braking and computer controlled operation, to provide engine power. Cars and trucks of current designs equipped with such "hybrid" systems are forecast to reduce energy consumption per mile of road travel by 50% to 70%. The option appeals strongly to industry and government energy planners and is receiving substantial funding.³ The conversion of U.S. motor vehicle production to "hybrids" would reduce U.S. gasoline consumption enough to satisfy the international demands for reduction of carbon dioxide addition in the atmosphere to values below those in 1990.⁴

Fuel cells that would use hydrogen as a fuel have been proposed for future automobiles. However, if automobiles are to use hydrogen, it must be stored at high pressure in tanks, or as liquid hydrogen in Dewar vessels, or as a metal hydride. None of these options is attractive although all have received funding support from government and industry. A better approach that is now recognized is to use a fuel that can be packaged in present automobile designs. This option is recommended, for example, in recent publicity by oil companies and car manufactures describing their R & D programs on fuel cells.³

Gasoline and methanol are both being seriously considered for use in motor vehicles equipped with fuel cells. Gasoline can be "reformed" to produce hydrogen (by partial combustion with air) prior to entering the fuel cell. Methanol can be a direct input to fuel cells. The two fuel types appear to be comparable in estimated fuel cost per mile of travel, and in packaging requirements to carry enough fuel to go 300 miles.

The gasoline option is attractive because it can use the vehicle fuel storage equipment, distribution and infrastructure now in place, but the requirement to accommodate the reforming equipment in the engine space is a drawback. Methanol avoids this difficulty. It can be a direct input to automobile fuel cells and is an optimum fuel for hybrid vehicles. The costs to modify the gasoline distribution infrastructure for methanol use in transportation will be affordable, much less than for options being studied that would use molecular hydrogen in the fuel cell.

. Capital cost estimates for a 200- MWe methanol commercial plant were developed by Brown and Root Development, Inc. (BARDI) under technical supervision of the Johns Hopkins Applied Physics Laboratory (JHU/APL). Full details of the methodology are presented in section 7.3.1 of the book by Avery and Wu². Prices of methanol fuel produced by OTEC and delivered to U.S. ports are computed by use of the financial analysis method developed by Mossman⁵. The analysis provides an estimate of the required plant investments, as dependent on the number of plants deployed, and the price at which an OTEC fuel must be sold if investments in OTEC plant construction and deployment, and delivery of methanol to on land facilities are to be profitable.

. Data on the estimated OTEC plant investments, delivered methanol prices and the potential financial returns to investors in OTEC methanol fuel production to replace gasoline in internal combustion engines are presented in Table 1. The data pertinent to the analysis are listed for interest rates of 5%, 7%, 9%, 11% and 13% in the 14 columns of Table 1. The headings are self-explanatory. The refiners price of gasoline for resale averaged \$1.011/gal in January-June 2003.

. The table shows the number of OTEC methanol plant ships needed to supply enough methanol to replace gasoline made by refining crude oil, in amounts sufficient to eliminate the need to import oil from the Persian Gulf, or to replace all imported crude oil, or to replace all U.S. gasoline made from fossil fuels. The numbers of plants needed to supply hybrid cars, that deliver twice the miles per gallon, to replace present automobiles that have internal combustion engines are shown in Table 2.

The tables list in the last two columns the returns on investment (ROI) and returns on equity (ROE) as dependent on interest rates, and on the number of OTEC plants deployed. The estimated financial returns are attractive and should interest potential entrepreneurs. The estimated plant investments are approximations. Accurate values will not be available until a pilot plant is built and deployed. However, the dependence of costs on interest rates is not debatable.

CONCLUSION

The government and energy industry should recognize that OTEC methanol could become an ample, sustainable and economical source of motor vehicle fuels. Production of OTEC methanol to replace gasoline would provide great benefits in national security and in the economy. In the future, as shown in reference 2, OTEC liquid ammonia could provide a practical way to produce, store and transport hydrogen to form a totally non-polluting automobile fuel in ample amounts to replace all gasoline used in U.S. transportation.

Development of OTEC systems to become a new national energy resource will depend not on their economic status or environmental benefits, but on creating strong support from established political and financial institutions.

I wish express my thanks to Drs. Michel Gauthier, Joseph Vadus, Don Lennard and Patrick Takahashi for helpful comments and suggestions and to Ms. Jin Chung for editorial assistance.

1. Present address: 60 Daley Terrace, Orleans MA 02653
2. William H. Avery and Chih Wu, 1994, *Renewable Energy from the Ocean The Case for OTEC* " Oxford University Press p373
3. See, for example, the ExxonMobil web page, at www.exxonmobil.com, and the DaimlerChrysler web page at www.methanol.org/fuelcell/fact/mfcv.efmT
4. In the first eight months of 2003 gasoline consumption in the U.S. averaged 8.42 Mbbbl/d. In 1990 it was 6.96 Mbbbl/d. A 50% reduction by fuel cells would lower the amount used to 4.41 Mbbbl/d. The atmospheric pollution caused by gasoline consumption will be reduced in the same proportion as the reduction in gasoline consumption. If all vehicles used fuel cell power plants that reduced fuel consumption by 50% the reduction in atmospheric pollution would satisfy the United Nations requirement for reduction of emissions to a value below the 1990 level (U.S. DOE/EIA-0035 (2003-09)).
5. Reference 2, p 7.3.1

Table 1. Returns to investors producing OTEC methanol (ME) fuel to replace gasoline made from crude oil. .
 Equity 20%, Plant life 25 years, Debt interest 5%.7%,9\$,11%,13% Plant construction 2 1/2 years at 9% interest, Income Tax Credit (ITC) 0 %
 5 year PI payback Delivered methanol price set to make APV = 0
 Plant investment based on DOE funded 1984 pilot plant estimate corrected for inflation av 1984 to av Jan-Jul 03.

OTEC ME PLANT NUMBER	AVERAGE				FIRST HALF								
	OTEC PLANT INVESTMENT (PI) (\$B)	OTEC PLANT INVESTMENT (PI) (\$B)	TOTAL PLANT INVESTMENT (PI) (\$B)	ME PRICE FOR Nth PLANT (\$/GAL)	AVERAGE ME PRICE FOR N PLANTS (\$/GAL)	EQUIVALENT GASOLINE PRICE (\$/GAL)	ME GAL/Y (B)	ME ANNUAL SALES (\$B)	YEAR 2003 GASOLINE AV PRICE w/o TAX (\$/GAL)	SAVING REPLACE GASOLINE WITH ME (\$/GAL)	SAVING REPLACE GASOLINE WITH ME (\$B/Y)	RETURN ON INVEST- MENT %/Y	RETURN ON EQUITY %/Y
(DEBT INTEREST 5% INVESTMENT TAX CREDIT 0%)													
1	1.322	1.322	1.322	0.545	0.545	0.981	0.199	0.108	1.011	0.030	0.006	0.45	2.25
2	1.058	1.190	2.38	0.432	0.489	0.879	0.398	0.172	1.011	0.132	0.052	2.20	11.00
4	0.984	1.087	4.35	0.401	0.460	0.828	0.796	0.319	1.011	0.183	0.145	3.34	16.70
8	0.915	1.001	8.01	0.372	0.431	0.775	1.59	0.592	1.011	0.236	0.376	4.69	23.45
210	0.650	0.705	148.05	0.256	0.374	0.674	41.8	10.698	1.011	0.337	14.1	9.52	47.60
711	0.572	0.623	442.95	0.225	0.291	0.524	141.5	31.835	1.011	0.487	69.0	15.57	77.85
1149	0.544	0.594	682.51	0.213	0.266	0.478	228.7	48.703	1.011	0.533	122	17.84	89.20
(DEBT INTEREST 7% INVESTMENT TAX CREDIT 0%)													
1	1.322	1.322	1.322	0.632	0.632	1.138	0.199	0.126	1.011	-0.127	-0.025	-1.91	-9.55
2	1.058	1.190	2.38	0.516	0.574	1.033	0.398	0.205	1.011	-0.022	-0.009	-0.37	-1.85
4	0.984	1.087	4.35	0.465	0.545	0.981	0.796	0.370	1.011	0.030	0.024	0.55	2.75
8	0.915	1.001	8.01	0.400	0.505	0.909	1.592	0.637	1.011	0.102	0.162	2.03	10.15
210	0.650	0.705	148.05	0.300	0.404	0.727	41.79	12.537	1.011	0.284	11.9	8.01	40.05
711	0.572	0.623	442.95	0.260	0.331	0.595	141.489	36.787	1.011	0.416	58.8	13.28	66.40
1149	0.544	0.594	682.51	0.246	0.304	0.547	228.651	56.248	1.011	0.464	106	15.55	77.75
(DEBT INTEREST 9% INVESTMENT TAX CREDIT 0%)													
1	1.322	1.322	1.322	0.722	0.722	1.300	0.199	0.144	1.011	-0.289	-0.057	-4.34	-21.70
2	1.058	1.190	2.38	0.573	0.648	1.166	0.398	0.228	1.011	-0.155	-0.061	-2.58	-12.90
4	0.984	1.087	4.35	0.531	0.610	1.098	0.796	0.423	1.011	-0.087	-0.070	-1.60	-8.00
8	0.915	1.001	8.01	0.492	0.571	1.027	1.592	0.783	1.011	-0.016	-0.026	-0.32	-1.60
210	0.650	0.705	148.05	0.342	0.495	0.891	41.79	14.292	1.011	0.120	5.015	3.39	16.95
711	0.572	0.623	442.95	0.296	0.387	0.697	141.489	41.881	1.011	0.314	44.4	10.03	50.15
1149	0.544	0.594	682.51	0.280	0.352	0.634	228.651	64.022	1.011	0.377	86.1	12.62	63.10
(DEBT INTEREST 11% INVESTMENT TAX CREDIT 0%)													
1	1.322	1.322	1.32	0.811	0.811	1.460	0.199	0.161	1.011	-0.449	-0.089	-6.76	-33.80
2	1.058	1.190	2.38	0.643	0.727	1.309	0.398	0.256	1.011	-0.298	-0.118	-4.98	-24.90
4	0.984	1.087	4.3	0.596	0.685	1.233	0.796	0.474	1.011	-0.222	-0.177	-4.07	-20.35
8	0.915	1.001	8.0	0.552	0.641	1.153	1.592	0.88	1.011	-0.142	-0.226	-2.82	-14.10
210	0.650	0.705	148.05	0.384	0.555	1.000	41.79	16.0	1.011	0.011	0.474	0.32	1.60
711	0.572	0.623	442.95	0.333	0.435	0.782	141.489	47.1	1.011	0.229	32.4	7.30	36.50
1149	0.544	0.594	682.51	0.314	0.396	0.713	228.651	72	1.011	0.298	68.2	10.00	50.00
(DEBT INTEREST 13% INVESTMENT TAX CREDIT 0%)													
1	1.322	1.322	1.32	0.897	0.897	1.615	0.199	0.179	1.011	-0.604	-0.120	-9.09	-45.45
2	1.058	1.190	2.38	0.710	0.804	1.446	0.398	0.283	1.011	-0.435	-0.173	-7.28	-36.40
4	1.001	1.095	4.4	0.670	0.737	1.326	0.796	0.533	1.011	-0.315	-0.251	-5.73	-28.65
8	0.915	1.005	8.0	0.610	0.673	1.212	1.592	0.97	1.011	-0.201	-0.320	-3.98	-19.90
210	0.650	0.705	148.05	0.424	0.612	1.102	41.79	17.7	1.011	-0.091	-3.82	-2.58	-12.90
711	0.572	0.623	442.95	0.366	0.480	0.863	141.489	51.8	1.011	0.148	20.9	4.72	23.60
1149	0.544	0.594	682.51	0.346	0.436	0.785	228.651	79	1.011	0.226	51.6	7.56	37.80

Comment: 1.8 gallons methanol are required to deliver the same road mileage as 1.0 gallons of gasoline, in cars with internal combustion (IC) engines.
 Numbers of OTEC plants to replace gasoline made from daily supplies of oil consumed in the U.S. are: to replace oil imported from the Persian Gulf,210, to replace all imported oil,711, to replace all gasoline used in U.S.,1149

Table 2. Returns to investors supplying OTEC methanol (ME) fuel to hybrid vehicles using fuelcells.

Equity 20%, Plant life 25 years, Debt interest 5%,7%,9%,11%,13% Plant construction 2 1/2 years at 9% interest, Income Tax Credit (ITC) 0 % 5 year PI payback Delivered methanol price set to make APV = 0
 Plant investment based on DOE funded 1984 pilot plant estimate corrected for inflation av 1984 to av Jan-Jul 03.

OTEC ME PLANT NUMBER	AVERAGE				ME PRICE FOR Nth PLANT (\$/GAL)	AVERAGE ME PRICE FOR N PLANTS (\$/GAL)	EQUIVALENT GASOLINE PRICE (\$/GAL)	ME GAL/Y (B)	ME ANNUAL SALES (\$B)	FIRST HALF YEAR 2003 GASOLINE AV PRICE w/o TAX (\$/GAL)	SAVING REPLACE GASOLINE WITH ME (\$/GAL)	SAVING REPLACE GASOLINE WITH ME (\$B/Y)	RETURN ON INVESTMENT (%)/Y	RETURN ON EQUITY (%)/Y
	OTEC PLANT INVESTMENT (PI) (\$B)	OTEC PLANT INVESTMENT (PI) (\$B)	TOTAL PLANT INVESTMENT (\$B)	OTEC PLANT INVESTMENT (\$B)										
0.984 (DEBT INTEREST 5% INVESTMENT TAX CREDIT 0%)														
1	1.322	1.322	1.322	0.545	0.545	0.491	0.199	0.108	1.011	1.011	0.521	0.104	7.84	39.18
2	1.058	1.190	2.38	0.432	0.489	0.440	0.398	0.172	1.011	1.011	0.571	0.227	9.56	47.78
4	0.984	1.087	4.35	0.401	0.460	0.414	0.796	0.319	1.011	1.011	0.597	0.475	10.93	54.64
8	0.915	1.001	8.01	0.372	0.431	0.388	1.59	0.592	1.011	1.011	0.623	0.993	12.40	61.99
105	0.699	0.705	74.03	0.280	0.376	0.339	20.9	5.851	1.011	1.011	0.672	14.045	18.97	94.87
355	0.615	0.623	221.17	0.244	0.309	0.278	70.6	17.237	1.011	1.011	0.733	51.805	23.42	117.12
575	0.585	0.594	341.55	0.232	0.284	0.255	114.4	26.547	1.011	1.011	0.756	86.453	25.31	126.56
0.984 (DEBT INTEREST 7% INVESTMENT TAX CREDIT 0%)														
1	1.322	1.322	1.322	0.632	0.632	0.569	0.199	0.126	1.011	1.011	0.442	0.088	6.66	33.28
2	1.058	1.190	2.38	0.516	0.574	0.517	0.398	0.205	1.011	1.011	0.494	0.197	8.27	41.35
4	0.984	1.087	4.35	0.465	0.545	0.491	0.796	0.370	1.011	1.011	0.521	0.414	9.53	47.66
8	0.915	1.001	8.01	0.400	0.505	0.455	1.592	0.637	1.011	1.011	0.557	0.886	11.07	55.33
105	0.699	0.705	74.03	0.325	0.408	0.367	20.895	6.791	1.011	1.011	0.644	13.452	18.17	90.86
355	0.615	0.623	221.17	0.283	0.350	0.315	70.645	19.993	1.011	1.011	0.696	49.198	22.24	111.22
575	0.585	0.594	341.55	0.268	0.324	0.292	114.43	30.666	1.011	1.011	0.719	82.308	24.10	120.49
0.984 (DEBT INTEREST 9% INVESTMENT TAX CREDIT 0%)														
1	1.322	1.322	1.322	0.722	0.722	0.650	0.199	0.144	1.011	1.011	0.361	0.072	5.44	27.19
2	1.058	1.190	2.38	0.573	0.648	0.583	0.398	0.228	1.011	1.011	0.428	0.170	7.16	35.81
4	0.984	1.087	4.35	0.531	0.610	0.549	0.796	0.423	1.011	1.011	0.462	0.368	8.46	42.28
8	0.915	1.001	8.01	0.492	0.571	0.514	1.592	0.783	1.011	1.011	0.497	0.792	9.89	49.46
105	0.699	0.705	74.03	0.370	0.498	0.448	20.895	7.731	1.011	1.011	0.563	11.760	15.89	79.43
355	0.615	0.623	221.17	0.322	0.408	0.367	70.645	22.748	1.011	1.011	0.644	45.490	20.57	102.84
575	0.585	0.594	341.55	0.280	0.375	0.338	114.43	32.039	1.011	1.011	0.673	77.065	22.56	112.82
0.984 (DEBT INTEREST 11% INVESTMENT TAX CREDIT 0%)														
1	1.322	1.322	1.32	0.811	0.811	0.730	0.199	0.161	1.011	1.011	0.281	0.056	4.23	21.16
2	1.058	1.190	2.38	0.643	0.727	0.654	0.398	0.256	1.011	1.011	0.357	0.142	5.97	29.83
4	0.984	1.087	4.3	0.596	0.685	0.617	0.796	0.474	1.011	1.011	0.395	0.314	7.22	36.12
8	0.915	1.001	8.0	0.552	0.641	0.576	1.592	0.88	1.011	1.011	0.435	0.692	8.64	43.21
105	0.699	0.705	74.03	0.415	0.559	0.503	20.895	8.7	1.011	1.011	0.508	10.617	14.34	71.72
355	0.615	0.623	221.17	0.362	0.458	0.412	70.645	25.6	1.011	1.011	0.599	42.333	19.14	95.70
575	0.585	0.594	341.55	0.343	0.421	0.379	114.43	39	1.011	1.011	0.632	72.331	21.18	105.89
0.984 (DEBT INTEREST 13% INVESTMENT TAX CREDIT 0%)														
1	1.322	1.322	1.32	0.897	0.897	0.807	0.199	0.179	1.011	1.011	0.204	0.041	3.07	15.33
2	1.058	1.190	2.38	0.710	0.804	0.723	0.398	0.283	1.011	1.011	0.288	0.115	4.81	24.07
4	1.001	1.095	4.4	0.670	0.737	0.663	0.796	0.533	1.011	1.011	0.348	0.277	6.32	31.60
8	0.915	1.005	8.0	0.610	0.673	0.606	1.592	0.97	1.011	1.011	0.405	0.645	8.02	40.09
105	0.699	0.705	74.03	0.458	0.615	0.553	20.895	9.6	1.011	1.011	0.458	9.563	12.92	64.59
355	0.615	0.623	221.17	0.398	0.504	0.454	70.645	28.1	1.011	1.011	0.557	39.353	17.79	88.97
575	0.585	0.594	341.55	0.377	0.464	0.417	114.43	43	1.011	1.011	0.594	67.933	19.89	99.45

Comment: 0.9 gallons methanol used in hybrid vehicles will deliver the same road mileage as 1.0 gallons of gasoline, in cars with internal combustion (IC) engines.

.Numbers of OTEC plants to replace gasoline made from daily supplies of oil consumed in the U.S. are: to replace oil imported from the Persian Gulf,105, to replace all imported oil,355,to replace all gasoline made from crude oil 575 to replace all gasoline used in U.S.,575 Investment per OTEC plant deereases with numbers produced as discussed in reference 4.

Comment: 1.8 gallons methanol equal road mileage of 1.0 gallons of gasoline in cars with internal combustion (IC) engines. In fuel cell hybrid cars, 0.9 gallons of methanol match gasoline mileage in IC cars.

Numbers of OTEC plants to replace daily supplies of oil imported from the Persian Gulf(210),of all imported oil(711), of all gasoline used in U.S.(1149).

Hybrid cars with methanol fuels will reduce by 50% or more the number of OTEC plants needed,e.g. 105, 350, and 56

Equity 20%, Plant life 25 years, Debt interest 5%.7%,9%,11%,13% Plant construction 2 1/2 years at 9% interest, Income Tax Credit (ITC) 0 % 5 year PI payback Delivered methanol price set to make APV = 0

Plant investment based on DOE funded 1984 pilot plant estimate corrected for inflation av 1984 to av Jan-Jul 03.