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Short and Long-Term Cost Efficiency Analysis of Fossil Fuel versus Alternative Energy Vehicles

Mitchell Ng, Princeton University

Abstract
Electric and hybrid-electric vehicles have long been seen as the answer to the economic and environmental problems created by traditional fossil fuel vehicles. In addition to the ability to reduce carbon emissions and reduce negative environmental externalities, they have the potential to end the current dependence on limited fossil fuel reserves and thus enhance energy security. However, the facts that electric and hybrid-electric vehicles have not attained widespread use within a free-market economy like that of the US points towards an overarching problem with alternative energy vehicles: cost-inefficiency. This paper aims to investigate and quantify the extent to which alternative energy vehicles are not as cost-efficient to the average US consumer as traditional fossil-fuel based vehicles. To accomplish this goal, a mathematical model was created to quantitatively measure the microeconomic effects affecting the short and long-term prices of driving an electric or hybrid car, taking into account such factors as baseline prices in vehicles, power costs, changes in the interest rates, and gasoline prices over the span of a decade. Overall, the data points towards the fact that, in addition to the substantially larger short term costs of alternative energy vehicles, the long-term energy savings of purchasing an electric or hybrid-electric car still do not compensate for the initial price difference between conventional fossil-fuel cars and alternative energy cars to the average US consumer at this time. This, however, assumes a totally laissez-faire model with automobile and energy prices set by the free market alone. In reality, it is likely that government policies aimed at supporting the alternative energy vehicle market will not only continue to be implemented but also grow in importance within the coming decade, and this paper also examines some of the macroeconomic effects that the government policies could potentially introduce to lower the costs and improve the economic efficiency of alternative energy vehicles.

Keywords**:** Alternative Energy Vehicles, Breakeven Time, Hybrid Car, Electric Car, Fossil Fuel Vehicles, Cost-efficiency, Car Loan Interest Rates, Gasoline Prices, Economies of Scale.

Introduction

The past decade has seen increased investment in alternative energy-based modes of transportation by the world's leading economies (Harder 2010). Specifically, there have been hopes that automobiles that utilize alternative energy sources will come to replace the current fossil-fuel based vehicles (Kyle 2008). The two main reasons such a solution has been sought are 1.) The expectation that alternative energy vehicles will reduce carbon emissions and promote environmental friendliness and 2.) the hopes that widespread adoption of alternative energy vehicles will decrease economic reliance on fossil fuels and in an era of ever-increasing oil prices (2011).

For major oil-consuming economies like that of the United States, the second reason, of rising oil prices rather than environmental concerns, has been most responsible for the recent increase in interest in developing alternative energy vehicles (Kyle 2008). Based on data extrapolation, this paper examines, quantitatively, the current economic feasibility of the two alternative energy vehicles with the largest share of the automobile market: hybrid-electric and electric cars. This was done by comparing the short and long term costs of driving a typical fossil-fuel based car, a mid-size sedan, against its electric and hybrid-electric counterparts on the current automobile market. Specifically, the first objective of the research was to measure the degree of the cost-inefficiency of using an electric car and a hybrid car as opposed to a fossil-fuel based car. This was done primarily on a microeconomic scale from the perspective of an average American consumer, using the Chevrolet Volt, the Toyota Prius, and the Honda Civic as the electric, hybrid and fossil-fuel car standards respectively (2011).

After compiling baseline cost data, this paper used additional mathematical modeling to systematically determine which other variable affects the short and long-term cost efficiency of alternative energy vehicles. It became evident that the interest rates and gasoline prices were the two dominant factors which most determined the long-run feasibility of either electric or hybrid-electric vehicles, while the short-run cost-efficiency was primarily determined by the initial cost of the purchased vehicle.

Finally, once a full quantitative analysis of the short and long-term cost efficiency of hybrid versus electric cars is given, the paper offers potential solutions to address the current predicament of higher long-term and short-term costs consumers face when purchasing an alternative energy vehicle. These potential solutions are based on potential future macroeconomic factors, such government policies to support alternative energy vehicles (in the form of subsidies or tax breaks), and increasing economies of scale for alternative energy vehicles in the future.

Quantitative Analysis of Cost-Efficiency of Fossil-fuel Cars to Hybrid and Electric Cars

This section examines the current cost-efficiency of the fossil-fuel car when compared to the alternative energy vehicles like the hybrid and electric car. To achieve this end, several cars were chosen to represent these three types of car. The fossil-fuel car, hybrid car, and electric car are represented by the Honda Civic, Toyota Prius, and the Chevrolet Volt respectively (2011).

Table 1: Prices and Fuel-Price Efficiency for Typical Fossil Fuel, Hybrid, and Electric Vehicles

	Honda Civic LX Gas	Toyota Prius Hybrid	GM Volt Electric
Initial Price (in $)	18,655	22,000	40,000
Miles per gallon (mpg)	32	50	N/A
Fuel price / distance (in cents / mile)	400/32 = 12.50	400/50 = 8.00	2.2

To achieve this end, statistics were compiled on these three vehicles. When comparing cost-efficiency, the main factors affecting a consumer's mindset are the purchasing price of the vehicle and the cost of the driving the vehicle due to the price of fuel. Table 1 above outlines the initial price and the cost of driving each vehicle in cents/mile. Note that the fossil-fuel vehicle has the smallest purchasing price although its fuel costs are the highest, while the electric vehicle has the highest purchasing price and the cheapest fuel costs.

Due to this discrepancy between initial price and the cost of driving each vehicle, the fundamental question refers to whether or not the savings per mile of the alternative energy vehicles will be able to compensate their initial higher price tag when compared to the Honda Civic. The Toyota Prius Hybrid is $3345 more expensive than the Honda Civic while the GM Volt Electric is $21345 more expensive.

The initial assumptions to compare the short and long-term costs are that 1.) the typical American car buyer can borrow at an interest rate of 6% per year to finance the additional price tag of the alternative energy vehicles and 2.) 12,000 miles are driven per year. This was calculated by assuming there are 20 working days per month, and 40 miles per working day – this gives 800 miles driven per month. Adding in 200 miles per month of weekend driving makes the total monthly driving distance 1,000 miles. When compared to the Toyota Prius Hybrid, the Volt will save $58.00 per month by saving 5.8 cents savings per mile.

Putting the above pieces of information together, the decision to choose between these three vehicles boils down to the length, in months, the per month savings of driving the more fuel-efficient alternative energy vehicles will breakeven with the initial purchasing price difference. Since the average American purchases a car using loans from a bank, the 6% interest rate per year an average bank charges for the car loan is factored into the long-term cost efficiency of the vehicle (Solheim 2011).

Basic compounding-discount arithmetic requires us to solve for the unknown T, the breakeven number of months, in the model below. P represents the initial price difference while the fuel cost savings per month is depending on fuel cost savings / mile * 1000 miles/month. The interest rate is assumed to be at 0.5% per month, from an average of 6% per year.

$$P = FuelCostSavings / month * \left[\frac{1 - \frac{1}{(1+i)^T}}{i} \right]$$

Table 2: Time to Breakeven when Purchasing a Hybrid Car over a Fossil Fuel Car (in years)

	$2.00	$2.50	$3.00	$3.50	$4.00	$4.50	$5.00	$5.50	$6.00
0%	1239%	9.9111	8.2593	7.0794	6.1944	5.5062	4.9556	4.5051	4.1296
1%	1329%	10.4894	8.6634	7.3791	6.4265	5.6918	5.1079	4.6327	4.2384
2%	1438%	11.1563	9.1172	7.7096	6.6790	5.8918	5.2707	4.7681	4.3531
3%	1572%	11.9380	9.6324	8.0768	6.9553	6.1080	5.4451	4.9123	4.4746
4%	1745%	12.8737	10.2250	8.4884	7.2595	6.3430	5.6328	5.0661	4.6033
5%	1980%	14.0253	10.9175	8.9548	7.5970	6.5999	5.8357	5.2309	4.7403
6%	2334%	15.4979	11.7438	9.4900	**7.9748**	6.8824	6.0559	5.4081	4.8864
7%	2984%	17.4914	12.7567	10.1140	8.4021	7.1955	6.2964	5.5995	5.0428
8%	6137%	20.4584	14.0459	10.8563	8.8915	7.5454	6.5607	5.8071	5.2108
9%	NPB	25.8260	15.7811	11.7634	9.4609	7.9405	6.8532	6.0336	5.3922
10%	NPB	49.5535	18.3430	12.9135	10.1366	8.3924	7.1797	6.2822	5.5888
11%	NPB	NPB	22.9170	14.4535	10.9600	8.9171	7.5479	6.5571	5.8031
12%	NPB	NPB	41.6748	16.7120	12.0003	9.5385	7.9684	6.8636	6.0382

Based on these results, it takes 7.9748 years for a consumer who purchased a hybrid car to breakeven with the opportunity cost lost if a fossil-fuel car had been purchased instead. This is based off the assumptions that the gas price is $4.00 with a 6% interest rate per year. The acronym "NPB" stands for "never pay back." This outcome refers to the fact that the monthly savings will never pay back the initial purchasing price difference. For a numerical example of this occurrence, see Table 4.

A similar mathematical analysis was performed when comparing fossil-fuel cars to electric cars:

Table 3: Time to Breakeven when purchasing an Electric Car over a Fossil Fuel Car (in years)

	$2.00	$2.50	$3.00	$3.50	$4.00	$4.50	$5.00	$5.50	$6.00
0%	43.91975	31.69265	24.79094	20.35765	17.26942	14.99473	13.24953	11.86822	10.74773
1%	57.86275	38.131161	28.50172	22.77191	18.96598	16.25246	14.21936	12.63897	11.37507
2%	105.4367	50.277872	34.26951	26.16273	21.20331	17.84107	15.40643	13.56004	12.11077
3%	NPB	100.50693	45.4406	31.48867	24.36315	19.94321	16.90925	14.6893	12.99106
4%	NPB	NPB	119.7996	42.16151	29.39117	22.93224	18.90601	16.12283	14.0724
5%	NPB	NPB	NPB	NPB	39.90726	27.7625	21.76764	18.03653	15.44937
6%	NPB	NPB	NPB	NPB	**NPB**	38.41954	26.47612	20.80382	17.29734
7%	NPB	NPB	NPB	NPB	NPB	NPB	37.59092	25.45295	19.99673
8%	NPB	NPB	NPB	NPB	NPB	NPB	NPB	37.43609	24.64201
9%	NPB	NPB	NPB	NPB	NPB	NPB	NPB	NPB	38.14522
10%	NPB	NPB	NPB	NPB	NPB	NPB	NPB	NPB	NPB
11%	NPB	NPB	NPB	NPB	NPB	NPB	NPB	NPB	NPB
12%	NPB	NPB	NPB	NPB	NPB	NPB	NPB	NPB	NPB

As evident in the table, the most common answer in the above table is NPB which stands for "never pay back." Taking these results and the results listed in Table 1.1 into consideration, one can effectively rank the cost-efficiencies of the cars. The fossil-fuel car costs the least initially and is cheaper for 8 years and forever when compared to a hybrid or electric car. The following section analyzes the current cost efficiency of hybrid versus electric cars.

Current Cost Efficiency of Hybrid versus Electric Cars

Based on a 2009 financial report in the *Wall Street Journal*, the General Motors Company's Chevrolet Volt is expected to get 230 miles per gallon versus Toyota's Prius 51 miles per gallon in city driving (Terlep 2009). This segment analyses the financials of both cars and based on realistic assumptions for the average middle-class American who drives everyday. The Volt is expected to sell at around $40,000 apiece (Terlep 2009). Assuming the $7,500 tax credit can be fully deducted in the same year of the purchase, instead of having it amortized equally over a few years, will still leave the Volt at a price disadvantage of $10,500 over the Prius which can be had for $22,000.

It is reported that the Volt's lithium-ion battery pack can deliver a range of 40 miles before it is recharged at 88 cents per charge (Terlep 2009). The 40-mile range seems applicable since 80% of Americans commute fewer than 40 miles a day. That yields a mileage efficiency of 2.2 cents per mile.

If we assume regular unleaded gasoline sells for $4.00 per gallon, the Prius's mileage efficiency will be at 8 cents per mile. At this efficiency, driving the Volt has an advantage or savings of 5.8 cents per mile over the Prius.

Due to this discrepancy between initial price and the cost of driving each vehicle, the fundamental question refers to whether or not the savings per mile of the alternative energy vehicles will be able to compensate their initial higher price tag when compared to the Honda Civic. The Toyota Prius Hybrid is $3345 more expensive than the Honda Civic while the GM Volt Electric is $21345 more expensive.

Assuming the typical American car buyer can borrow at an interest rate of 6% per year to finance the additional price tag of the alternative energy vehicles, the assumption is also made that there are 20 working days per month, and 40 miles per working day. That gives 800 miles driven per month (Solheim 2011). Adding in 200 miles per month of weekend driving makes the total monthly driving distance 1,000 miles. When compared to the Toyota Prius Hybrid, the Volt will save $58.00 per month by saving 5.8 cents savings per mile.

Putting the above pieces of information together, the decision to choose between the Volt and the Prius boils down to: how long (i.e. how many months) will it the $58 per month savings to breakeven the $10,500 that we have to borrow upfront from the bank at 6% per year, or 0.5% per month? Basic compounding-discount arithmetic requires us to solve for the unknown T, the breakeven number of months, in the model below.

$$10{,}500 = 58 * \left[\frac{1 - \dfrac{1}{(1+.005)^T}}{0.005} \right]$$

Solving for T, we get T=472.3158 months, or 39.36 years or 39 years, 4 months and 10 days. Next, one can recognize that the gasoline price and the interest rate are the two most volatile variables subject to market-clearing price changes or regulatory intervention. Consequently, we proceed to vary each of the two variables over a reasonable range simultaneously, and find the corresponding breakeven number of years. We present our results in the following table.

Table 4: Time to Breakeven when purchasing an Electric Car over a Hybrid Car (in years)

Interest rate in % per year \ Gasoline price in $ per gallon	$2.00	$2.50	$3.00	$3.50	$4.00	$4.50	$5.00	$5.50	$6.00
0%	48.61	31.25	23.03	18.23	15.09	12.87	11.22	9.94	8.93
1%	66.60	37.48	26.18	20.13	16.36	13.78	11.90	10.48	9.36
2%	179.33	49.08	30.88	22.69	17.97	14.89	12.71	11.10	9.84
3%	NPB	92.54	39.17	26.42	20.11	16.28	13.69	11.82	10.41
4%	NPB	NPB	63.58	32.71	23.16	18.11	14.91	12.70	11.06
5%	NPB	NPB	NPB	48.59	28.13	20.66	16.49	13.78	11.85
6%	NPB	NPB	NPB	NPB	**39.36**	24.71	18.68	15.17	12.82
7%	NPB	NPB	NPB	NPB	NPB	33.10	22.04	17.06	14.05
8%	NPB	NPB	NPB	NPB	NPB	NPB	28.56	19.90	15.71
9%	NPB	NPB	NPB	NPB	NPB	NPB	NPB	25.12	18.15
10%	NPB	NPB	NPB	NPB	NPB	NPB	NPB	51.92	22.43
11%	NPB	NPB	NPB	NPB	NPB	NPB	NPB	NPB	36.76
12%	NPB	NPB	NPB	NPB	NPB	NPB	NPB	NPB	NPB

NPB = never pay back

If interest rate were 0% and gas price remains at $4.00 per gallon, then each of the $58 monthly savings need not be discounted. To find the breakeven number of months, simply divide $58 into $10,500 instead of using the somewhat complicated model above. In doing so, the result is 181.03 months or 15.09 years as shown in the table above.

As evident in the table, the most common answer in the above table is NPB which stands for "never pay back." This means the monthly savings of the Volt will never pay back its extra $10,500 upfront cost at the corresponding gas price and interest rate. To illustrate, one can use the $4.00 per gallon price and 7% per year interest or .5833% monthly interest. The monthly savings remains at $58, but this series of perpetual $58 savings when discounted value at 0.5833% per month amounts to only 58/.005833 or $9,942.86 which is insufficient to cover the extra $10,500 upfront cost of the Volt. At 6% per year or 0.5% per month, the $58 monthly savings begets a total discounted savings of $58/.005 or $11,600. This means if the Volt can last indefinitely without any extensive maintenance, an implausible assumption, its savings over the Prius will be $1,100 which is the difference between $11,600 and $10,500. The breakeven or indifference between the Volt and the Prius occurs at 39.36 years. In other words, when the ownership duration is less than 39.36 years, assuming $4.00 gas price and 6% annual interest, the Prius is cheaper to operate; when the ownership duration is more than 39.36 years, the Volt is cheaper to operate.

The fact that the majority of the table values point to "never pay back" explains quantitatively to what extent utilizing electric cars is economically inefficient to the consumer. Taking 39.3 years for the use of an electric car to breakeven with the opportunity cost of driving a hybrid car is a strong factor dissuading consumers from purchasing electric cars. The following section focuses on potential solutions to make the cost-efficiency of driving alternative energy vehicles more affordable when compared to driving a fossil-fuel vehicle. In particular, the initial price discrepancy between electric and hybrid cars is lessened due to the implementation of a government-based tax.

Suggestions to Mitigate the Price Discrepancy

One potential suggestion to resolve the price discrepancy between electric and hybrid cars is taxing or penalizing cars that don't meet efficiency standards through laws which will be effective by 2016 (Terlep and Ramsey 2011). Utilizing this tax and penalty proceeds to "surgically" subsidize electric cars will narrow the $10,500 price difference. For simplicity of comparison, assume the price difference between the Prius and the Volt will then diminish to $5,250. I repeat the same breakeven analysis over the same ranges of gas price and interest rate variables, and I obtain the following results.

Table 5: Time to Breakeven when purchasing an Electric Car over a Hybrid Car with addition of fuel-efficiency based taxes and subsidies (in years)

Interest rate of loan in % per year	Gasoline price in $ per gallon: $2.00	$2.50	$3.00	$3.50	$4.00	$4.50	$5.00	$5.50	$6.00
0%	24.31	15.63	11.51	9.11	7.54	6.43	5.61	4.97	4.46
1%	27.86	17.00	12.24	9.56	7.85	6.65	5.77	5.10	4.57
2%	33.32	18.75	13.10	10.07	8.18	6.89	5.95	5.24	4.68
3%	43.60	21.11	14.14	10.66	8.56	7.16	6.15	5.39	4.80
4%	89.74	24.56	15.45	11.36	8.99	7.45	6.36	5.55	4.93
5%	NPB	30.46	17.18	12.19	9.49	7.78	6.60	5.73	5.06
6%	NPB	46.33	19.61	13.23	**10.07**	8.15	6.86	5.92	5.21
7%	NPB	NPB	23.49	14.56	10.76	8.57	7.14	6.13	5.37
8%	NPB	NPB	31.84	16.38	11.60	9.07	7.47	6.36	5.54
9%	NPB	NPB	NPB	19.14	12.67	9.65	7.84	6.62	5.73
10%	NPB	NPB	NPB	24.34	14.10	10.35	8.26	6.90	5.94
11%	NPB	NPB	NPB	NPB	16.17	11.23	8.76	7.23	6.17
12%	NPB	NPB	NPB	NPB	19.73	12.38	9.36	7.60	6.43

NPB = never pay back

Comparing the two tables, we see that the breakeven time is not linear except when the interest rate is at 0%. That is, halving the price spread from $10,500 to $5,250 reduces the breakeven time from 39 years to 10 years, a mere 25.6% of the original breakeven time using the $4 per gallon and 6% interest rate assumptions. The NPB combinations also decrease from 52 in Table 1 to 20 NPB combinations in Table 2 when the price spread narrows by 50%. This shows economies of scale in reducing the price of the electric Volt is an apparent and viable path to "green" and fossil-fuel independence.

Further Suggestions to Promote Usage of Alternative Energy Vehicles

There are several proposed ways to mitigate the overall cost-inefficiency of alternative energy vehicles when compared to a fossil-fuel car. The first addresses the fact that the initial price difference can be decreased. This has been addressed in the previous section, with taxes on inefficient cars (Terlep and Ramsey, 2011). These taxes can then be transferred as subsidies on alternative energy vehicles to further decrease the purchasing price discrepancy.

Another potential solution addresses the two dominant variables in each of the tables, interest rates and fuel prices. As seen in the Table 2, low interest rates and high gasoline prices are the dominant factors affecting whether alternative energy vehicles will be able to pay back their initial higher cost. Other than compressing the price-tag spread to create the pathway to "green," two other non-mutually exclusive corollary pathways to "green" of my calculations above are: 1.) increase the savings via a decrease in the electric recharge price, and/or increase in the gasoline price hidden as a "green" regulation (Simpson 2006), and; 2.) special zero or low interest loans targeted for purchases of electric cars (2011). These pathways to "green" will take us to the northeast corner of the breakeven table quicker and would promote the use of alternative energy vehicles.

The only potential problem with the widespread implementation of alternative energy vehicles is the possible decrease in fossil fuel prices when many consumers drive electric cars and the demand for fossil fuel declines precipitously (2011). Such price drop will lengthen the breakeven period again, and may recidivate consumer demand for fossil fuel vehicles. The only hope is that by then, the price spread between the electric car and the hybrid vehicle will have dissipated completely, and each propulsion mode will compete based on mileage efficiency alone.

Effect of Economies of Scale on Automobile Industry and Potential Effect on Alternative Energy Vehicles

The U.S. automobile industry is one of the largest and most mature industries in the nation, directly contributing $375 billion in sales every year, or 3.7% of GDP (Highfill 2004). Being a mature industry that has significantly impacted the American economy since the early 20th century, the current automobile industry has optimized the production and sales of vehicles, reaching economies of scale (Highfill 2004). By far, capital equipment, an average fixed cost, contributes most to the cost of manufacturing an automobile in the U.S.

If alternative energy vehicles, especially hybrid and electric cars, are produced in manners similar to those of traditional fossil fuel vehicles, economies of scale can be similarly reached. Economies of scale would both reduce the average cost of a hybrid or electric car by marginalizing the average fixed cost of producing a vehicle (Husan 1997). The potential effect of economies of scale on alternative energy vehicles is best demonstrated by the current effect of economies of scale on automobiles currently.

Having a high capital cost, or average fixed cost, the automobile industry is well-suited for economies of scale. These capital costs are derived from the need for machinery and other costs related to deploying a factory to produce vehicles. For example, the Honda of Canada facility (HCM) was a $2 billion investment in capital and produces 390,000 units annually (Honda 2011). If alternative energy vehicles were developed on a large scale in similar facilities and sold to a large consumer base, the average cost of alternative energy vehicles, like the Toyota Prius and the Chevrolet Volt, to both the manufacturer and the consumer would be significantly decreased.

Conclusion

Based on the quantitative data obtained, alternative energy vehicles are cost-inefficient when compared to fossil-fuel based ones. Juxtaposing the cost efficiencies fossil fuel cars, hybrid cars, and electric cars, the data demonstrates that alternative energy vehicles are cost-inefficient in both the short and long-term when compared to fossil-fuel based vehicles. The research presented in this paper demonstrates the extent to which fossil fuel vehicles like the Honda Civic are more cost-efficient than alternative energy vehicles like the Toyota Prius or the Chevrolet Volt.

It is ironic that even though both alternative energy vehicles are more fuel-efficient, their initial price difference causes a payback time currently ranging from a decade to four. This cost inefficiency has dissuaded many American consumers from purchasing these more expensive alternative energy vehicles. This problem can be addressed in several manners, all of which relate to lessening the payback time. These solutions are:

1. Decrease the initial purchasing price difference. This can be accomplished by taxing more fuel-inefficient vehicles like fossil fuel cars and subsidizing alternative energy vehicles.
2. Decrease the interest rate for loans, the primary method of car payment in the United States, on alternative energy vehicles like electric cars.
3. Increase the fuel price of gasoline. This can be accomplished by taxing oil companies instead of subsidizing them.

If these suggestions are implemented, the payback time for purchasing an alternative energy vehicle would be decreased. If this payback time could be decreased to the span of only several years, alternative energy vehicles could prove to be not only more fuel-efficient but also more cost-efficient. At the same time, an analysis based solely on market prices is unable to encompass all of the effects of widespread alternative energy vehicle implementation (Ang 2011). Economies of scale will undoubtedly decrease prices as alternative energy vehicles become more widespread. Quantifying the extent of this price decrease depends largely on government and consumer interest. In addition, if alternative energy vehicles were adopted by a large enough consumer base, the savings due to economies of scale would lead to lower retail prices, removing the issue of larger cost which is currently making alternative energy vehicles so cost-inefficient. In any case, if the cost-efficiency problems of alternative energy vehicles are properly addressed by the three direct solutions stated in the above paragraph, the initial goals of 1.) decreasing reliance on fossil fuels in a time of ever-rising prices, and 2.) increasing environmental friendliness and indirectly addressing the problem of climate change, can be achieved.

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Author Biography

Mitchell Ng is currently studying chemistry and mathematics at Princeton University. He has a strong interest in the alternative energy movement, conducting graduate-level research at the Haw Yang Lab. His most recent scientific project deals with the development of bio-orthogonal tags for the cellobiohydrolase 6A in order to more efficiently synthesize cellulosic ethanol, a leading bio-fuel. His strong desire to apply the science of the laboratory to the real-world for practical applications spurred his interest in the economic and financial side of scientific innovations which deal with alternative energy.