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## **To produce or convert: A case for large scale electric motorcycle conversion in Singapore**

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### **Abstract**

This paper explores the economic viability of the electrical conversion of motorcycles in Singapore. The vehicle market is regulated through Certificate of Entitlement (COE)<sup>1</sup> and road tax. These mechanisms do not cover converted electric motorcycles yet. Large-scale conversion allows for the production of 2500 motorcycles per year with an estimated workforce of 20 people. Electric motorcycles are cheaper to run compared to ICE motorcycles and these cost savings can recoup the price of the motorcycle in a short period. A policy innovation in this area could further spur large scale electric motorcycle conversion and make it a viable business.

*Keywords:* Conversion,

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### **1 Introduction**

Substantial research has been done in the area of design and manufacturing brand new electric motorcycles from scratch. However, little attention has been paid to the possibility of large scale conversions of Internal Combustion Engine (ICE) motorcycles into electric motorcycles. Conversion rather than manufacturing from scratch is preferred as it allows bike frames which would have been otherwise scrapped at the end of their service life to be reused. Our team has converted a second hand CBR 400 to test its feasibility as well as to anticipate possible hurdles if the process is conducted on a large scale. The CBR 400 was selected as it is the most common sports motorcycle on Singapore roads and therefore it will serve as an appropriate representative of future mass conversions.

This paper will discuss the possibilities of EV infrastructure in Singapore, feasibility of conversion of motorcycles, a possible mass conversion plan and the various economic and legal considerations for consumers and the government.

### **2 Possibilities and Problems of Conversion**

A common complaint with electric motorcycle is the comparatively low range. However, this low range is acceptable for touring around the city state of Singapore. Electric motorcycles are perfectly suited for Singapore and other cities of similar size. As can be seen from Table 1, the converted CBR 400 is able to travel 35 km which is close to the daily average distance travelled by Singaporean motorcyclists<sup>2</sup>.

Table 1: Comparison of specifications between a CBR400 ICE, a converted CBR400 (lead acid and Li-Polymer version)

	CBR400 engine	IC	CBR400 Lead Acid Battery Version	CBR400 Li-Polymer Battery Version
Top Speed	210 kmph		100 kmph (estimated)	100 kmph (estimated)
Efficiency	20%		85%	85%
Engine/Electric Motor size	59 horsepower max power		72 V 8hp cont. 19 hp peak	72 V 8hp cont. 19 hp peak
Range			35 km	64km
Maintenance Cost	High		Low	Low

In order for EVs to thrive in Singapore, the infrastructure for EVs must also be conducive for its uptake. This infrastructure depends on the availability of charging methods that are convenient for the end user, ample government interest and the robustness of the electricity grid in order to handle the additional load.

Electric motorcyclists face an additional problem of charging. For ICE motorcycles, there are plenty of petrol kiosks but the same cannot be said for electric motorcyclists. This problem can be amended by setting up “ATM-like” fast charging stations. Such products already exist in the market. Swiss engineering company ABB and Eaton already have such products that conform to the SAE’s (Society of Automotive Engineers) EV charging standards. Moreover EVs can be designed specifically to facilitate battery swapping in order to cater for customers that are in a hurry. The combination of battery swapping and fast charging stations can cater to EVs customers with different time constraints with ease and convenience.

As of this moment, the Energy Market Authority (a Singapore government body) has a test bed for EV vehicles which aims to find an “optimal way to operate and deploy charging infrastructure”, look at “consumer behaviour on charging and range anxiety”, test the “robustness of EV battery systems” and “general performance of EVs on Singapore road conditions”. While the results of this study are not out yet, it indicates considerable interest on the Government’s side

for EVs. Government support and endorsement is crucial for the EV infrastructure to succeed.

Another study<sup>3</sup> done by the research group at TUM CREATE’s Center for Electromobility analyzes the impact of EV integration into the Singapore grid. In their study they concluded that the “overall systems effects on costs and emissions are relatively small even with 600,000 EVs” in operation. They assumed the EVs to be cars and therefore the actual number can be even higher if we were to consider a combination of electric cars and motorcycles.

Therefore with the convenience of existing charging methods, the significant amount of government support and the robust capability of the grid to handle the additional load, we can conclude that the existing infrastructure has potential for EVs to run in Singapore.

### 3 To Produce or to Convert: A market overview

Cost consideration has been done on the applicability of the many models of motorcycles in Singapore, with differing variation of sizes ranging from 200cc to those above 1000cc, with each having different price ranges according to their sizes. Even though it is possible to make the conversion unit applicable to motorcycles of various sizes, there are several factors working against the marketability and economic viability of targeting the small motorcycle market. Unlike the larger motorcycles, smaller motorcycles already have off-the-shelf models that are produced in China, widely available and competitively priced. Most are rated around 1 hp range and cost around 450 USD (around 560 SGD) that cater to their travelling needs of short distance transport in congested routes. Due to the economies of scale, the low cost of buying these motorcycles off the shelf makes the cost of conversion large in comparison.

Table 2: A price comparison of Honda motorcycles with electric motorcycle variants using CC to horsepower comparison.

Honda Motor cycle Model	Price (\$\$)	EV equivalent	Price (\$\$)	Feasibility (Y/N)
Honda Wave 125	5,500	No equivalent	No equivalent	N
Honda CBF 150	5,980	Zero XU	10,002 [7,995 (USD)]	N
Honda Tiger 200	8,100	Brammo Inertia Plus	13,755 [10,995(USD)]	N
Honda CB 400	16,600	Brammo Empulse	21,261 [16,995(USD)]	Y
Honda CBR 600RR	20,300	Saietta R	27,455 [13,975 pounds]	Y
Honda CBR 1000RR	29,550	Mission R	37,529 [29,999(USD)]	To be researched
Honda VFR 1200	34,400	No equivalent	No equivalent	To be researched

From Table 2, we can see that the largest jump in price for both electric and ICE motorcycles lies between the 200 and 400cc motorcycles. When compared to the cost of conversion which may lie between 3000 to 6000 SGD, with variances depending on the motor performance, the economies of scale and number of battery packs needed, this jump in price of around \$8000 SGD allows the cost of conversion to become a fraction rather than the majority of the converted motorcycle's cost. Hence, conversion of motorcycle is economically viable for larger motorcycle classes than small motorcycle classes.

## 4 Mass Conversion Plan

### Mass Conversion process (> 2500 motorcycles)

#### Stage 1:

Experienced mechanics will be hired to remove the IC engine and related components, hence requiring approximately 8 hours. Lowering of the

engine will be mechanised and lowered using a crane to improve safety, given the weight of the engine.

**Estimated Time taken: 8 man-hours**



Figure 1: Honda CBR400 after undergoing Stage 1 of the conversion

#### Stage 2:

The battery mounts should be pre-fabricated prior to conversion. This allows the conversion process to move seamlessly from stage 1 to stage 2. As this process would be new even to experienced mechanics, we can hire untrained mechanics and teach them how to install the mount and motor initially. We would expect the rate of conversion to improve as they gain experience.

**Estimated time taken: 16 man-hours (initially) - 8 man-hours(experienced).**



Figure 2: Honda CBR400 after undergoing Stage 2

## 4. Price Considerations for Consumers

Despite the greater consumer awareness about green products such as electric vehicles, economic rationality continues to have a dominant role in the decisions made by consumers. Therefore a strong economic case is crucial to convince motorists to convert to electric powered motorcycles. Using the unconverted CBR 400 as the basis of comparison, we calculate the years needed to recoup the price of conversion for the consumer.

The monthly cost of running the ICE CBR 400 is roughly S\$121.11 whereas the monthly cost of an Electric motor CBR 400 is S\$ 29.43 resulting in significant savings for the consumer.

Moreover the maintenance cost for the electric motorcycle is significantly lower than the IC engine motorcycle largely due to the reduced number of moving parts. With the exception of the regular battery checks, it is almost maintenance free.

From our “proof of concept” conversion the price of conversion amounted to SGD 4,000 without any economies of scale. This figure does not take into account labour and overhead costs due to paucity of information available. Assuming a profit of SGD 1000 per unit, the selling price of the converted motorcycle will be SGD 5000.

Based on these figures, the initial investment on conversion can be recouped within 5 years which falls within the 10 year COE period. The user will be able to save on fuel costs for 5 years once the conversion cost has been paid for by the comparatively cheap electricity.

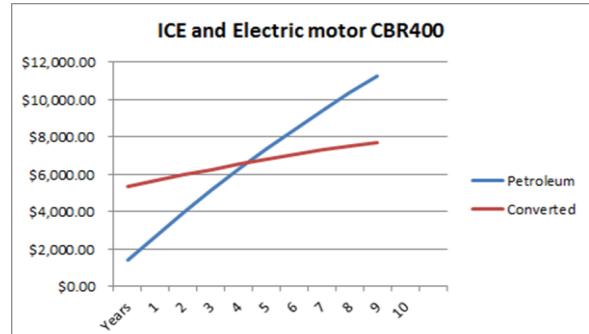


Figure 3: Recouptment period at 5% cost of capital assuming average monthly distance travelled

Based on the graph (figure 4), it is evident that higher crude oil prices are highly likely in the long run assuming the current amount of oil reserves and the level of technology. Moreover it has been stated in BP’s Energy outlook that “at the end of 2011, global proved reserves of oil were sufficient to meet 54 years of current (2011) production; for natural gas that figure is 64 years<sup>4</sup>.” Since the amount of oil is limited, it is only a matter of time before its price rises due to scarcity. Therefore from a consumer point of view, having an electric motorcycle makes sense in the long run as it gives the rider some flexibility to choose which energy source can be used to create the electricity be it renewables or coal or natural gas. Whereas for ICE motorcyclists, they are locked into a system that is inflexible and solely dependent on oil.

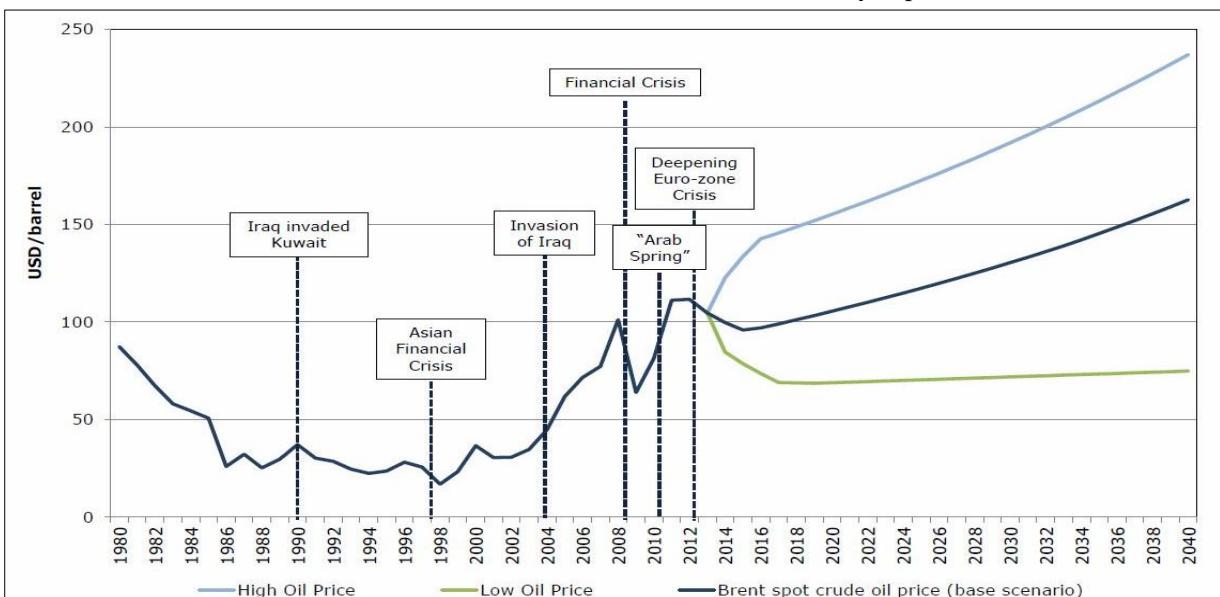


Figure 4: Average annual Brent spot crude oil prices in three cases. Source: Energy Information Administration (EIA)

## 5. Background on Singapore Motorcycle market and Electric Vehicle Policy Situation

As of 2012, 145,680<sup>2</sup> motorcycles were plying Singapore roads. The current vehicle ownership scenario in Singapore is unique in that on top of the existing road tax, owners must procure Certificates of Entitlement (COE), which is issued by the government and sold via regular public auctions. The COE system is designed to limit car ownership to ease traffic congestion in the land scarce island of Singapore. A COE is issued with a maximum time duration of ten years. Beyond this time duration, the owner has to either bid for another COE or scrap or export their vehicle.

However in the case of conversion of motorcycles to electric propulsion, the COE is not an additional cost as the possession of the motorcycle means that the COE is already been paid for. However it can be used as an effective tool to incentivise large scale conversion of motorcycles.

Moreover the road tax structure in Singapore offers some incentives for electric motorcycles in Singapore as there is a 10% rebate in Additional Registration Fee (ARF) for electric vehicle when they register their motorcycle for the first time. This means electric motorcycles owners only pay 5% of their Open Market Value (OMV) as opposed to 15% for a conventional electric motorcycle under the Green Vehicle Rebate Scheme.<sup>5</sup> This rebate, however applies only to electric motorcycles bought from the open market and does not include motorcycles which undergo conversion to become electric.

Since there are no policies currently existing for converted motorcycles, there is ample opportunity to offer recommendations to the government in this area. Since there are no policies currently existing for converted motorcycles, there is ample opportunity to offer recommendations to the government in this area. Instead of recommending the Government to offer subsidies to electric vehicles, a better strategy would be to “penalise the fossil fuel alternatives”<sup>6</sup>. This can be done by offering rebates on COEs and extending ARF rebates to converted motorcycles. Thus the fossil fuel alternatives would be “penalised” in comparison to converted motorcycles. As of this moment, the complete cost of converting a motorcycle including COE renewal is S\$6780. Assuming a COE rebate of S\$1000 and an ARF rebate of S\$1000 the cost of the conversion reduces to S\$4780 which is even cheaper than the basic conversion price of the motorcycle. This would further reduce the time taken to recoup the price to roughly 3 years as illustrated in Figure 5.

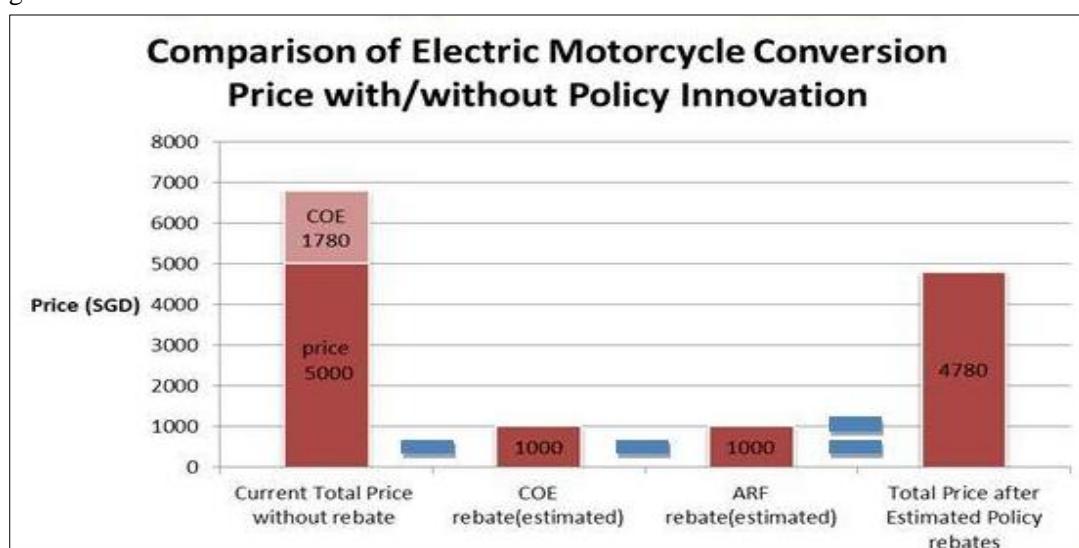


Figure 5: Estimated Price figures after implementation of suggested rebates

## Conclusion

There are still numerous hurdles for electric vehicles to overcome before they become commonplace on public roads. While the charging stations are commercially available, there is a need for greater collaboration between the Government and the EV industry to set up the charging infrastructure. Though policy innovations in the form of COE rebates and ARF rebates provide substantial cost reductions, it remains to be seen whether the government accepts these recommendations. The estimate of producing 2500 motorcycle per annum with a workforce of 20 people can be improved by conducting a pilot phase. Such a pilot phase would require more funding and support than currently available. The associated cost savings of converting from an ICE motorcycle for certain motorcycle class sizes provides strong case for this business model as well as a compelling case for customers to switch to electric motorcycles. Moreover this model can be replicated in other cities as well. Thus, incentivising electric motorcycle conversion by penalising ICE alternatives would allow the Singapore government to take a more proactive approach rather than reactive approach to EV technologies and spur mass conversion.

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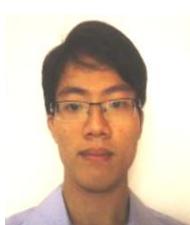
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