The Impact of Electric Vehicles on Electricity Consumption

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Abstract

This paper tries to estimate the magnitude of load increase in Turkey due to a possible electrification of cars. Two different methods are used to estimate the amount of energy usage. Based on this energy demand, the power requirements are then calculated. The issue of electric vehicles is highly speculative, thus the results are conditional. However, since there are only few alternatives, each needs to be analyzed thoroughly to increase awareness and preparedness.

1. Introduction

It is argued that the end of oil is near. If that would be the case so might be the internal combustion engine. We might stop burning oil because we simply ran out of it; we may be forced to quit burning up fossil fuels altogether to prevent a global boiling. But even before the wells dry-up we might give up oil just because there are alternatives that are simply better and cheaper.

The age of nuclear energy may be dawning - once gain. Apparently it is no longer the enemy number one to the greens. Although some people still walk the streets to increase awareness in people against nuclear, old (and wise) green leaders started to embrace nuclear energy in an era of global warming. Meanwhile solar, wind, wave, tidal energies are in line to be utilized as alternatives to fossil fuels for electricity generation. Nuclear fusion is the most desired energy source, but it still is, as it has always been, four decades into the future. All these methods though has a common point: energy collected by either source, has to be converted into electricity to be used.

Hydrogen as a fuel, on the other hand, has to overcome obstacles and problems with cryogenic storage and distribution. Hydrogen sources are limited as well. One cannot find it by drilling holes in the ground; instead it has to be produced – mainly using electricity.

Other alternatives are a nightmare for alternative seekers such as bio-diesel (which happens to be a major threat to the global food supply) and oil producing bacteria which help internal combustion engines (ICE) to stay.

To wrap up - with a very speculative statement - we basically have two alternatives: one is we will produce a range of chemicals which we'll use in ICE, and second is we'll use electricity generated by any conventional or alternative method to power up our vehicles. For the latter case, it will be for the battery-electric vehicles (BEV).

Electric vehicles have been around since the beginning of the last century. BEVs had sold out ICE once. They were preferred by women as they were cleaner, silent and much easier to use. Electric trains, trolleybuses and trams all use electricity. Although in many ways electric propulsion had its advantages, storage has been a problem. Advances in battery technologies driven by mobile devices and new power management electronics made electric vehicles feasible once again.

We use the term battery-electric to cover any electric rechargeable device. These include all rechargeable batteries, super capacitors; basically any electric storage device. Although technically speaking super capacitors are not batteries, functionally they are super fast charging batteries that can only hold small amounts of charge and therefore can be treated as such.

If battery electric vehicles are to be the most used method of land transportation in place of ICE vehicles (which the author strongly believes so but the discussion is irrelevant for the purpose of this paper) we have to analyze its impact on our electric generation scheme.

We look at the effects of battery electric vehicles if they become the future form of transportation. The motive of this study is we suspect that if that would be the case, then the demand for electricity will increase significantly. The question therefore becomes how much additional energy and power will be drawn from the current network by BEVs. This paper, as the title suggests, is about forecasting electric demand and consumption which is quite essential in planning power generation and distribution. If we are to use a lot more electricity, we will better prepare our power generation and distribution systems for an increase in demand.

2. Estimating Additional Energy Demand

Estimating the demand for electricity is already a tough problem. It is very much related to fluctuations in the economy, income, growth rate, changes in people's habits and shifts in technology trends.

In estimating the demand the Turkish Electricity Transmission Company – responsible for demand and supply forecasts – uses MAED (Model for Analysis of Energy Demand). It is a powerful tool that performs long-term energy and electricity demand forecasting. MAED is scenario based and projects demands for specific activities. [1]

In the 2008 report for Ten Year Electricity Generation Projection Report, for example, the effects of Compact Fluorescent Lights (CFL) and increase in tourism are discussed. However there is no mention of BEVs.[1] [2]

These scenarios are important to show the effects of socio-political and technological factors. The advance in battery technologies is expected to cause a major technological transition in the transportation sector. This coupled with green movements, introduction of emission control policies and high

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[1] This paper by no means tries to criticize the MAED model nor the work of TEIAS. We simply emphasize that for a country like Turkey where electricity supply has historically fell behind the demand, BEVs might cause the supply to fall short again.

oil prices make room for BEVs. All these factors need to be included in any forecasting model as well as MAED scenarios.

In order to raise awareness on the effect of BEVs no precision estimation is necessary; crude estimates of energy usage will be sufficient. Thus this work will not use any complicated model. Instead we'll estimate the magnitude of the impact of BEVs. Even then one should expect errors as this is rather a highly speculative subject.

There may be many ways to calculate the additional demand by BEVs. One is to calculate energy usage based on vehicle types and the number of new electric vehicles to be registered. We need to define vehicle types, find out average energy consumption per mile, estimate average mileage for each type and predict the number of new vehicles.

A second method is to take total energy usage for road transportation and estimate electricity equivalent and predict a conversion ratio from ICE to BEV.

Either calculation will be based on power and energy consumption of BEVs. We will therefore briefly discuss the efficiency of electric propulsion and compare various efficiency measures.

2.1. The Efficiency of Electric Vehicles

Electric propulsion is efficient due to various reasons. Beyond all, electric motors themselves are quite efficient[1] (80-95% vs 25-40% ICE efficiency[2]); they do not have to run idle in urban traffic and can produce high torque at low revs so either drivers go easier on the throttle or can be driven at higher gears (if the vehicle would have any gears at all). Electric vehicles are capable of capturing kinetic energy while breaking (called regenerative breaking) which can save some 15%. Meanwhile storing electricity (i.e. the batteries) amount almost %20 energy losses.

From environmental point of view one might consider well-to-wheel efficiencies. In order to see the effect of the method of propulsion one needs to look at say carbon emissions, air quality, and issues like global warming. From such a perspective, the well-to-wheel efficiencies are comparable – 20-30% for both BEVs and IECs for highway driving. Note that slow, stop-and-go type urban traffic efficiency figures differ significantly with BEVs having the edge.

The method of electric generation is also important when comparing the two. If electricity is to be generated by burning coal (which is very carbon intensive), the net benefit of replacing gasoline or LPG burning vehicles (which has lots of hydrogen in it) is negligible.[3] We'll see net benefits, on the other hand, if nuclear and/or renewable energy sources are to be utilized instead.

Although we believe every design must take environmental issues into consideration, this paper is limited only to engineering and planning problems of the supply of electricity. That is, we'll limit ourselves only to the energy or loads at the mains (net demand) or at power plant output levels (gross demand). In order to calculate the effect of EVs on electric demand (net or gross), we need to use vehicle efficiency (from mains-to-wheels) and not the overall well-to-wheel efficiency.

2.2. Energy Consumption Ratio

BEVs overall energy consumption is quite low as compared to ICE powered vehicles. Of the electric cars in production, Tesla is claimed to use 13 KWh of electric energy per 100 km, whereas a typical 2 lt roadster (BMW Z4) might use 6 lt gasoline per 100 km, which is approximately 58 KWh/100 km.[4] This means almost 3-4 times higher efficiency.

US EPA and DOE, on the other hand, uses a value of 21.68 KWh/lt for the conversion energy units while calculating BEV mileages, which makes electric cars at least twice as efficient as ICE powered cars. MIT "On the Road 2020" study uses a value of 0.29 for energy usage of electric vehicles as compared to reference ICE vehicles.[5] For long haul and higher efficiency diesel vehicles such as buses and trucks, we'll assume this value to be 0.50. [5]

Typical medium load mileages are 20-30 lt of diesel/100km (200-300 KWh equivalent) for buses and 30-40 lt/100km (300-400 equivalent) for trucks.

The overall energy consumption of electric vehicles is therefore 10-30 KWh/100km for cars, 100 KWh/100km for buses and may well exceed 200 KWh/100km for trailer trucks – all depending on speed, load and whether this is urban or highway driving.

2.3. Total Energy Usage Method

According to State Statistics Agency, 352 million liters of gasoline and 2,310 million lt of diesel oil were consumed for transportation in 2005.[6] The total energy equivalent of fuel consumtion is approximately 110 TWh. Adjusting for the efficiency of BEVs (1:2), if all the ICE vehicles were converted to BEVs today than the total energy demand would be 55 TWh.

In the coming years, the economy is expected to grow quickly as it gets out of global crises. If we assume a typical 5% growth rate, then in the next 10 years the consumption of total energy for transportation will roughly increase by 63%. Adjusted for growth, if all vehicles converted to BEVs, the total energy consumption will be around 90 TWh by 2019.

The cost of electric propulsion is approximately one fourth the cost of driving on gas. In economic terms, this will have positive income and substitution effects. That is people will be riding more as riding gets cheaper as compared to other goods (substitution) and consume more of all the goods as they have more money left in their hands (income effect). In order to calculate the magnitude a deeper economic analysis is needed, however from the theory predicts that the net effect will be positive.

With today's figures, every 1% of vehicles converted to electric propulsion requires 0.55 TWh per year (plus the growth rate). If electrification of land vehicles occurs at a rate of 5% a year, then each year 2.75 TWh/year extra electric energy will be needed. If this rate occurs around 10%, then you would need extra amount of 5.5 TWh for that year.

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[1] Electric motors meeting NEMA standarts have around 90% efficiency for smaller (<10KW) motors and 95% for large (>100 KW) motors. [3]

[2] Gasoline engines driving cars have 25-30% efficiencies, whereas diesel engines have up to 45%. Theoretical maximum diesel efficiency is around 55% and diesel engine efficiency can be incresed by introducing 6-stroke engines.

[3] A study by Johnson found carbon footprint of LPG forklifts are in fact smaller than electric.[4]

[4] Very roughly 1 lt of gasoline contains 9-10 KWh of energy depending on the octane number

[5] Low speed diesel engines on highway will have beter fuel efficiencies and thus have a beter ratio against BEVs and yield the previously mentioned higher end %45 efficiency.

We'd like to remind that the effect is cumulative. Once the BEV is registered, it will be used for years to come, so will the new registries every year. After 10 years, the total effect of BEVs would be more than 45 TWh/year assuming 5% electrification every year or total 70 TWh/year assuming 10% electrification and 5% growth.

Thus we can expect a net demand between 45-90 TWh/year demand increase by 2019.

2.4. New BEV Registries Calculation

According to State Statistics Agency, there are more than 6 million registered vehicles in Turkey in 2008. Of the 277,210 new cars registered (2008 make) 142,075 are cars, 6,956 are minibuses, 7,768 are buses, 83,155 are light trucks and 12,549 are trucks.

In order to calculate the energy demand we need to make assumptions on the average trip for each type of vehicle. Cars are typically used 20 km on the average, buses and minibuses are used 200 km, light trucks mostly make 50 urban km, and trucks make some 400 km on the average.

These figures are underestimates as riding on electric power is significantly cheaper than petrol, mileages will be much greater.

With the assumption of 20 KWh/100 km for cars, 40 for minibuses, 50 for light trucks, 100 for buses and 200 for trucks, we can therefore calculate energy demand.

If all new vehicles were BEVs, then total demand would be 5 TWh/year. If only 10% of the new registers were BEVs then the demand would be 0.5 TWh/yr.

2008 Was especially a bad year due to the global economic crises. There are twice as many 2007 make vehicles in Turkey and more than 1.2 million 2006 make vehicles thus making the 10% scenario demand increase 2.5 TWh/year – very comparable to total energy usage estimate.

There are predictions that in 10 years half of all new registries will be BEVs. Even if we start slow and have an erithmetic increse, in 10 years we could expect more than 25 TWh/year additional demand.

3. Additional Power Demand

The total net electric energy consumption for 2008 was 155 TWh. A 2.5 TWh increase in demand atop normal growth rates is quite high already. 25 TWh/year additional demand increase is by no means manageable if you don't plan ahead (such figures are possible at peak conversion rates if you assume an S shaped conversion curve).

By 2017, it is expected that total gross energy demand will be 360-390 TWh (290-310 TWh net). A 90 TWh additional demand will immediately flatten a 30% safety margin.

To give a sense of the magnitude of demand, Hasan Ugurlu hydroelectric plant generates about 1 GWh/year and Ataturk Dam 7-8 GWh/yar. To meet the demand you would have to build an additional power plant every year.

3.1. Charging Hours

BEVs are normally charged overnight. Night charging puts less stress both to the grid and power plants. In fact vehicles plugged in to the grid may even feed back some stored energy during day time to benefit from the differences in electric rates. However, as the technology becomes ubiquitous, charging times may shift to day hours.

The night charging scheme will be limited mostly to cars, light trucks and minibuses. High energy consuming vehicles (trucks and buses) won't be able to adjust their usage according to night charging schemes – unless spare batteries are charged overnight and replaced when needed. Even then, there will be a lot or renegade vehicles.

A 2.5 TWh energy demand is equal to 7 GWh daily demand. If the vehicles were to be charged during night hours (11:00-06:00), then this would create a demand for 7 GW extra capacity.

Even the stickiest overnight charging rules will hardly eliminate the need for new plants.

4. Conclusions

In the next decade we're expecting major shifts in type propulsion systems and the kind of energy used in land vehicles. Although the direction technology will take us to is not yet clear, there's a high chance that BEVs will be roaming the Earth. If that will be the case, then there will be millions of hungry batteries to be fed with juice. That juice can hardly be generated by the existing power plants. At best we will need a mid size plant every year for the next 10-15 years – if not more.

Such demand increase requires not only engineering planning but also huge public financing and public policies such as acceptance of nuclear energy.

5. References

[1] "Model for Analysis of Energy Demand (MAED-2) User's Manual", IAEA, Vienna, Austria, 2006. [PDF]. Available: http://www.adicasupport.com/option,com_docman/task,cat_view/gid,44/Itemid,72.html. Downloaded: 2009, June 10.

[2] "Türkiye Elektrik Enerjisi 10 Yıllık Üretim Kapasite Projeksiyonu", TEİAŞ, Ankara, Turkey, July 2008. [PDF]. Available: http://www.teias.gov.tr/projeksiyon/KAPASITE%20PROJEKSIYONU%202008.pdf. Downloaded: 2009, June 10.

[3] *NEMA Premium Motors and Generators*, NEMA MG 1 – 2006 Rev 1 2007, 2007, Nov 20.

[4] E. Johnson, "Disgreement over Carbon Footprints", *Energy Policy*, vol. *36*, no. *4*, pp. *1569-1573*, Apr. 2008.

[5] M. A. Weiss, et.al., "On the Road in 2020", *MIT Energy Laboratory Report*, no. *00-003*, Oct. 2000.

[6] "Enerji kaynakları ve kullanım alanlarına gore toplam enerji tüketimi", TUIK, Ankara, Turkey, 2005. [Excel]. Available: http://www.tuik.gov.tr/Veriilgi.do?tb_id=11?ust_id=3. Downloaded: 2009, June 10.