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The Living Space Analysis in the Battery Leasing Business

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Abstract

The paper analyzes the living space of the battery leasing company in the business model “vehicle and battery separated, battery leasing”, and its effected factors such as the battery price, the battery life cycle, the gasoline price, as well as battery type and vehicle type. The results have shown that leasing battery cannot get profit under the current battery price, life-cycle, gasoline price, and the financial subsidies. However, with the decrease of the battery price and the increase of battery cycle life and the gasoline price, the battery leasing company is possible to get the living space. Micro EVs give the battery leasing company an upper bound 10 percent higher than that of the compact EVs in the same situation. To make the living space of the battery leasing company just exist, the financial subsidies should be at least 5000 RMB/kw.h. The application of lead-acid battery will help the battery leasing company gain the living space. The lower bound corresponding to the lead-acid battery is only 23 percent of that corresponding to the li-ion battery.

Keywords: battery leasing, business model, living space, electric vehicle

1 Background

With the rapidly growing number of conventional vehicles (CV) and ever-worsening problems such as energy crisis and greenhouse gas (GHG), the application of electric vehicles (EV) becomes one of the most effective ways to release the pressure of “energy saving and emission reduction” [1].

In recently years, China has invested countless manpower, material resources and financial resources on the development of EVs. Also, there are special programs on EVs in the “10th Five-Year Plan” and the “11th Five-Year Plan”. The long-term input of scientific research has promoted great progress on EV technology. The demonstration of the EVs at the Beijing Olympic Games and the participation of various EVs in the “Ten Cities& Thousand Units” Plan have proved the achievement China has made on the technology of EV [2].

However, at the initial stage of the development of EV, there are problems such as short drive range per charge, long charging period and high acquisition costs [3]. The existence of these problems has become the bottleneck of the development of EV. In order to solve these problems, we need to turn to new business models apart from reinforcing technological research and development [4].

The remaining high cost of battery has kept the price of EV at a high level. If an EV is sold with battery, the cost of the battery will be half of the EV’s selling price, which is the same cost of a comparable CV. For instance, the price of a B grade EV (battery included) is 200,000 RMB and the battery of it will cost approximately 85,000 RMB. Therefore, the battery excluded selling model- “vehicle and battery separated, vehicle sales without battery”- becomes one of the best choices for the current time [5].

“Battery leasing” therefore becomes a necessary

supplement of the “vehicle and battery separated, vehicle sale without battery” business model [4]. Battery switch is the commonly used way in the business model of battery leasing. The battery leaseholder plays an important role in this model. On one hand, he has the ownership of the batteries, recharge and manage them; on the other hand, he makes profits by leasing recharged batteries to his consumers. This business model has a series of advantages: provide fast battery switch services to its consumers; extend the working life of batteries by recharging them properly; bring down the possible risks of over heat and fire during the recharging process by centralizing the process of recharging; etc [5].

This paper, using the method of living space analysis, gives a comprehensive analysis of the leaseholders’ battery purchase cost, electricity purchase cost and their consumers’ purchase intention, diagnoses whether the battery leasing company would get profits from this “Battery Leasing” model and provides a scenario analysis of different situations with different EVs, different types of batteries and financial subsidies.

2 The Living Space Methodology

2.1 The Definition of Living Space

The EV consuming process consists of three parts: the EV manufacturer, the battery leasing company and the consumer. Unlike the CV consuming process, the battery leasing company is a newcomer.

Where the shoe pinches in the implementation of the business model of battery switch is to ensure the benefit of each role. To ensure the benefit of the EV manufacturers, non-commercial ways of restricting or squeezing EV prices should be prohibited; to keep the battery leasing company’s benefit, a reasonable service price should be made so to make the business profitable as well as popular with the consumers; to guarantee the consumer’s benefit, the costs of acquisition and use of an EV should not be higher than those of a CV.

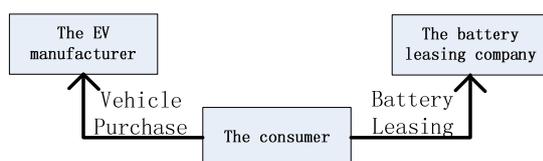


Figure 1: The new business model

Profitableness of the battery leasing company is the decisive factor of the feasibility of the business model, “vehicle and battery separated, battery leasing”. In the cash flow of the battery leasing business, the battery manufacturer and the grid are at the upstream while the consumer is at the downstream, in between stays the battery leasing company. The upstream determines the cost of the battery leasing company, while the downstream determines the revenue of the battery leasing company.

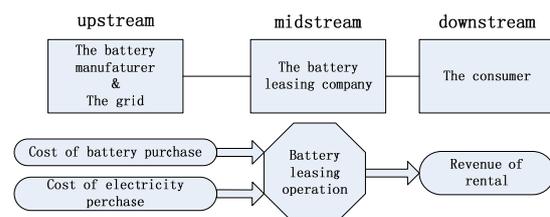


Figure 2: The cash flow through the battery leasing company

When pricing the battery leasing service, the battery leasing company should not make the price too low considering the battery and electricity purchase cost; meanwhile, they should not make the leasing price too high due to the compared use-cost of a CV.

Thus, the price which keeps the revenue equal to the cost is called the lower bound of the living space; the highest price which ensures the consumer’s willingness to purchase is called the upper bound of the living space. And the living space is the price interval from the lower bound to the upper bound.

The living space analysis provides a necessary condition for the business model, “vehicle and battery separated, battery leasing”. If the living space is an empty set, there’s no feasibility; otherwise, the business model may work.

2.2 The Calculation of Living Space

2.2.1 Lower Bound, Determined by the Cost

Cost of battery purchase (C_b):

The batteries used by EV are usually expensive Li-ion battery or Ni-MH battery. The battery cycle life is short under the current technology. Thus, the battery amortized cost for every use of kilowatt hour (kw.h) will be the prime cost of the battery leasing service.

The parameters related to the cost of battery purchase are: Depth of discharge (DOD)(%), cycle life(time), price of battery(RMB/kw.h). It can be calculated by equation (1):

$$Cb = \frac{Pb}{DOD \times Lc}$$

Cb: Cost of battery purchase(yuan/kw.h) (1)

Pb: Price of battery (yuan/kw.h)

DOD: Depth of discharge(%)

Lc: Life cycle

Cost of electricity purchase (Ce):

In the battery switch model, the battery leasing company provides the leasing of recharged battery. Every kw.h charged into the battery, which is from the grid, should be counted into the cost. Unlike the individual consumers, the battery leasing company can charge uniformly at night using the cheap valley electricity. The company can also negotiate with the grid for a lower price as a group user.

To sum up, the cost for a battery leasing company consists of the cost of the battery and electricity purchase. From the perspective of cash flow, the consumer is consuming not only the electricity, but also the battery. The price determined by the cost is defined as the lower bound of the living space.

2.2.2 Upper Bound, Determined by the Compared Cost

In order to make the potential consumers accept the new transportation vehicle EV and the battery leasing business model, the service price should not be too high. The compared use-cost of a CV is a significant reference to the pricing of the battery swift service. The use-cost of an EV should not surpass that of a CV. Especially at the beginning, the use-cost of an EV is expected to be lower. Hence, a coefficient of EV/CV use-cost ratio, less than 1, is introduced in the following calculation.

Specifically, the price determined by the potential consumers is directly related to gasoline consumption per 100km (of a CV) (L/100km), price of gasoline (RMB/L), electricity consumption per 100km (of an EV) (kw.h/100km), and use-cost coefficient of EV/CV. The upper bound then can be expressed in the equation (2).

$$U_{ev} = U_{cv} \times r = \frac{Gc \times Pg}{100km} \times r$$

$$Ps = \frac{100km \times Ue}{Ec}$$

(2)

U_{ev}: use-cost of EV(yuan/km)

U_{cv}: use-cost of CV(yuan/km)

P_g: price of gasoline(yuan/L)

G_c: gasoline consumption per 100km(L/100km)

r: use-cost coefficient of EV/CV

E_c: electricity consumption per 100km(kw.h/100km)

P_s: price of service(yuan/kw.h)

In conclusion, the use-cost of a CV which is also called the compared use-cost of a CV provides an upper bound for the living space.

2.2.3 The Living Space of the Battery Leasing Company

According to the above calculation, the lower bound and the upper bound provide a price interval for the battery leasing business. The set formed by the two bounds is defined as “the living space” of the battery leasing company.

The living space analysis offers a necessary condition to evaluate whether the new business model “vehicle and battery separated, battery leasing” would make profits. When the lower bound is equal to, or higher than, the upper bound, the living space does not exist, which means that the battery company cannot gain profit. It is impossible for the business to be profitable unless the upper bound is greater than the lower bound.

The living space analysis is only a basic analysis in the battery leasing business model. The key factor taken into account is the cash flow rather than the basic investment and the operation cost. Yet, to those operators who value the scale, cash flow is of extreme importance. Like other operating companies, battery leasing company will have to make a very large initiative investment, but a very considerable profit will be earned when the market grows big and the cash flow is positive. Thus, the existence of living space (a positive cash flow) is fatal to a battery leasing company.

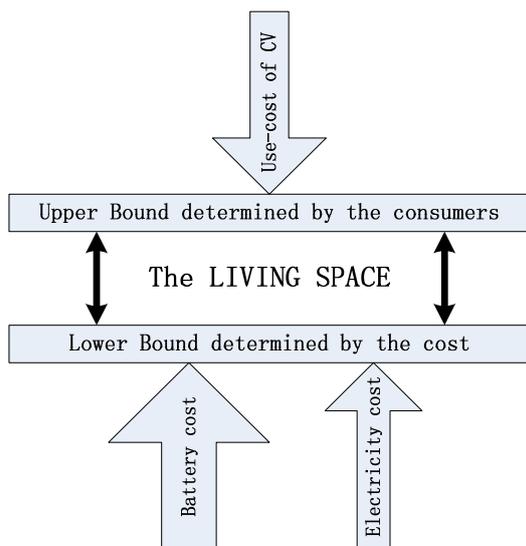


Figure 3: The living space

3 Scenario Analysis

3.1 The Key Factors Related to Living Space

The starting stage is viewed as the incubation period of the new EV value chain, when the market is small, and the living space does not exist. When the market grows bigger, some key factors related to the living space change, which makes the living space grow out from nothing. The key factors are: The price of battery, the cycle life of battery and the price of gasoline.

3.1.1 The price of battery

The price will definitely goes lower by some of the following means: a) The battery cost to the battery leasing company can be reduced by a subsidy act from the government; b) The battery

cost to the battery leasing company can also be lower by adding a secondary or recycle use; c) A large scale of manufacture will directly lower the battery cost; d) The technology research can obviously reduce the cost.

3.1.2 The cycle life of battery

Cycle life must be improved by research. The cycle life and the price of battery both affect the lower bound significantly. If the price of battery can be cut down sharply, the pressure of cycle life improvement will be much lighter.

3.1.3 The price of gasoline

An increase on the price of gasoline will increase the upper bound value, which is good for the business. With the insufficiency of the oil and the pressure of reducing GHGs, the price of gasoline is possible to go higher, leaving an excellent opportunity for the EVs.

3.2 Analysis on Micro EVs

The current living space of the battery leasing company will be calculated via the parameters of a domestic micro EV and its comparable CV in Table 1.

The calculation in Table 1 shows that under current circumstances, battery leasing company cannot obtain living space. However, with the change of the key factors that related to the living space, the upper bound and the lower bound of living space will change as well.

Table 1: The current living space for micro EVs

Basic Data	Lower Bound				Upper Bound			
	Cost of electricity purchase (RMB/kw.h)	Cost of battery purchase (RMB/kw.h)	DOD (%)	Cycle life (cycle)	Price of gasoline (RMB/L)	Gasoline consumption (L/100km)	Use-cost coefficient	Electricity consumption (kw.h/100km)
	0.3	7000	80	1000	6.9	6	0.8	12
Process value					Use-cost of CV (RMB/km)		Use-cost of EV (RMB/km)	
					0.414		0.331	
Result	Total cost(RMB/kw.h)				The highest service price(RMB/kw.h)			
	9.05				2.76			
The living space	As the lower bound 9.05 RMB/kw.h is higher than the upper bound 2.76 RMB/kw.h, there's no living space at present for the company. The difference, negative living space is -6.29 RMB/kw.h.							

The most important three factors related to the living space are the price and cycle life of battery, the price of gasoline. As the market and technology develop, the price of battery is going to decrease and the cycle life is expected to be longer. Predictions on the development of battery have been made by many institutes, agencies, firms and universities. Since there is hardly an agreement on the schedule of the development of battery, the above three key factors rather than the period will be the independent variables in the following analysis.

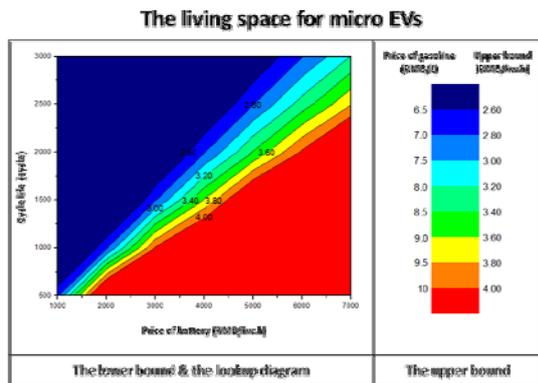


Figure 4: The living space for micro EVs

Fig.4. includes two parts: the right part is “the lower bound chart and the lookup diagram”; the left part is “the upper bound chart”.

The lower bound is determined by both the “price of battery” and the “cycle life”. A curving 3D face is formed through calculations. A contour, which makes reading easier, is plotted in the left part. A specific combination of the price of battery and the cycle life determines a lower bound. So in a specific scenario where the price of battery and a cycle life value are given, the lower bound can be easily obtained through the contour plot.

The upper bound is determined only by the price of gasoline. As a higher gasoline price leads to a higher upper bound, a higher price of gasoline is more likely to give the business model the living space. The price of gasoline is listed on the left of the legend bar, on the right of which is the corresponding upper bound value.

The contour is also the lookup diagram of the living space. The lower bound and the upper bound can be shown in the same graph. Thus, the relationship between the two bounds will be shown clearly. Given a specific price of battery

and a specific cycle life, we can determine a point in the contour, which is the lower bound in the situation. A specific price of gasoline will determine the upper bound, which is shown as a curved line in the contour. The contour shows an obvious increase trend from the top left to the bottom right. If a point representing the lower bound is to the left of the upper bound curve, the living space exists. Otherwise, it is impossible to profit from the battery leasing business.

For example, as shown in Fig.5, when the price of battery is 5,000RMB/kw.h, the cycle life of battery is 1,000 cycles, the lower bound of its living space is point LB, which is above 4RMB/kw.h; if the price of gasoline is 8RMB/L, we can draw from the upper bound chart that the upper bound is 3.2RMB/kw.h, which is curved line UB. The curve shows an increase trend from the top left to the bottom right, so the lower bound is higher than the upper bound. When the price of battery is 5,000RMB/kw.h, the cycle life of battery is 1,000 cycles, and the price of gasoline is 8RMB/L, there is no living space for battery leasing companies.

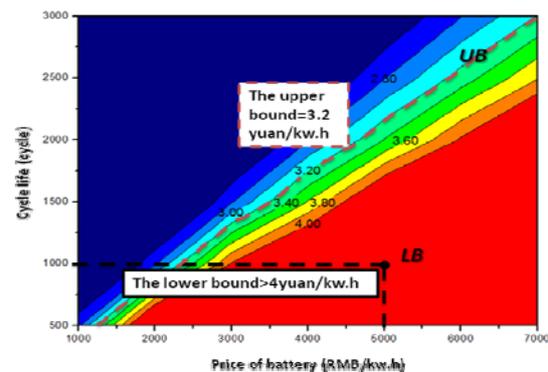


Figure 5: Example - The lookup diagram

3.2.1 Single Factor Analysis

The following analyzes the influence of each of the factors, the gasoline price, battery price and life cycle has on the upper and lower bounds.

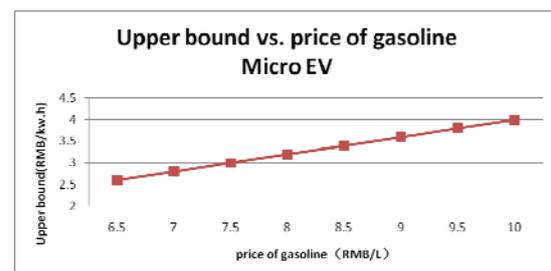


Figure 6: Micro EV: Upper bound vs. price of gasoline

The influence of gasoline price on the living space (Fig.6): the higher the gasoline price, the higher the upper bound. Therefore, it is easier to gain living space with a higher gasoline price.

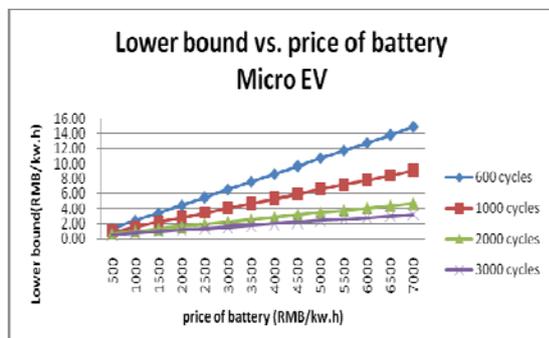


Figure 7: Micro EV: Lower bound vs. price of battery

The lower bound is influenced by the battery price (Fig.7): the higher the battery price, the higher the lower bound. So, the situation of a higher battery price is unfavorable to get living space. With the same battery price, the longer the cycle life, the lower the lower bound. It is easier for the battery leasing company to gain living space with a longer cycle life. With the increase of battery price, the lower bound differences caused by different cycle lives expand.

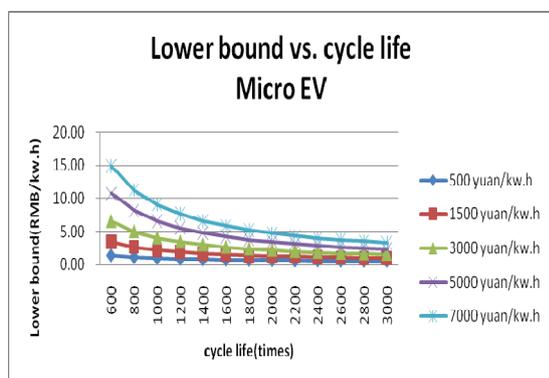


Figure 8: Micro EV: Lower bound vs. cycle life

The lower bound is also influenced by the cycle life (Fig.8): The longer cycle life makes the lower bound lower. The longer cycle life is favorable to the acquisition of living space. The decline of the lower bound and the increase of cycle life are non-linearly related. With the same length of cycle life, a higher battery price leads to a higher lower bound. When the battery price is high, the lower bound is more sensitive to the cycle life than when the battery price is low.

3.2.2 Analysis of Financial Subsidies

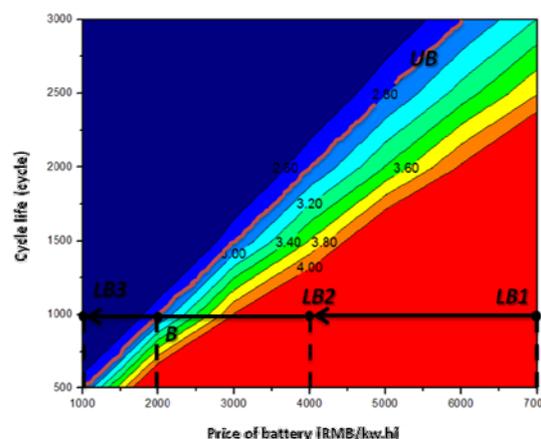


Figure 9: The living space after the subsidy

According to the *Provisional Measures of Financial Subsidy Funds Management on Energy-saving and New Energy Vehicles in Pilot Project* promulgated on January 23, 2009, there will be a subsidy of 3000 RMB/kw.h to those qualified EVs. This means that the cost of battery to the leasing company will decrease from 7,000 RMB/kw.h to 4,000 RMB/kw.h. The cycle life of battery is fixed in a certain period of time. As a result, the lower bound in Fig.9 will move from LB1 to LB2.

Furthermore, there are corresponding local subsidies. For example, Shenzhen has enacted the same amount of subsidy as that of the national one. This can be viewed equivalently as the battery cost decreases from 4,000 RMB/kw.h to 1,000 RMB/kw.h, which means the lower bound moves from point LB2 to point LB3 in Fig.9. From calculation, we know the lower bound is 1.55 RMB/kw.h.

Suppose the gasoline price is 7 RMB/L, the upper bound should be 2.8 RMB/kw.h, as is shown in curve UB in Fig.9. With both the state subsidy and local subsidy, the lower bound has moved from point LB1 to point LB3. Point LB3 is to the left of curve UB, so the lower bound is lower than the upper bound. Consequently, after the double subsidies from the state and the local subsidies, government, battery leasing companies can get a living space of 1.25 RMB/kw.h.

If the battery leasing company can just get the living space (the lower bound equalized the upper bound) with subsidies, then the lower bound point B should be on the curve UB. The price to point B is 2,000 RMB/kw.h. Therefore, to make the

battery leasing company just get the living space, the total subsidies should be amount to 5,000 RMB/kw.h, which can reduce the cost of battery from 7,000 RMB/kw.h to 2,000 RMB/kw.h to the leasing company.

3.2.3 Analysis of Different Battery Types

Lead acid battery enjoys the longest application history. Though it has low energy density, high self discharge rate and short cycle life, it is still widely used in low speed vehicles in north America because of its mature technology and low cost [6][7].

Table 2: Parameters of both Li-ion batteries and Lead-acid batteries and the living space (gasoline=7 RMB/L)

	Price of battery (RMB/kw.h)	Life cycle (cycle)	Lower bound (RMB/kw.h)	Upper bound (RMB/kw.h)
Li-ion	7000	1000	9.05	2.80
Lead acid	700	500	2.05	2.80

The above data of battery price and cycle life is from a domestic lead acid battery and a domestic Li-ion battery:

From calculation, the lower bound for Li-ion battery is 9.05RMB/kw.h, the lower bound for lead acid battery is only 23% of that of Li-ion battery, which is 2.05RMB/kw.h; the upper bound of both is 2.80RMB/kw.h(gasoline price 7RMB/L), shown in Fig.10. So the use of lead acid battery can enable the battery leasing company to get living space while the Li-ion cannot.

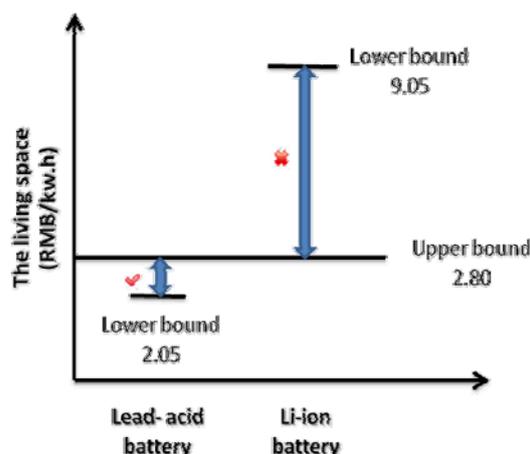


Figure 10: The living space comparison between lead-acid battery and li-ion battery

3.3 Comparative Analysis on Compact EVs

The calculation in Table 3 is based on the parameters of a domestic compact EV and its comparable CV. The living space of a battery leasing company for Compact EV will be drawn and it will also be compared to the living space of battery leasing company for micro EVs.

The living space of battery leasing companies for compact EVs and for micro EVs varies mainly due to the change of the upper bound. The elements related to the lower bound will not be affected by different types of vehicles. However, the upper bound changes with different types of vehicles as the upper bound is influenced by the gasoline consumption per 100 kilometers and electricity consumption per 100 kilometers.

Table 3: The current living space for compact EVs

Basic Data	Lower Bound				Upper Bound			
	Cost of electricity purchase (RMB/kw.h)	Cost of battery purchase (RMB/kw.h)	DOD (%)	Cycle life (cycle)	Price of gasoline (RMB/L)	Gasoline consumption (L/100km)	Use-cost coefficient	Electricity consumption (kw.h/100km)
	0.3	7000	80	1000	6.9	9	0.8	20
Process value					Use-cost of CV (RMB/km)		Use-cost of EV (RMB/km)	
					0.621		0.497	
Result	Total cost(RMB/kw.h)				The highest service price(RMB/kw.h)			
	9.05				2.48			
The living space	As the lower bound 9.05 RMB/kw.h is higher than the upper bound 2.48 RMB/kw.h, there's no living space at present for the company. The difference, negative living space is -6.57 RMB/kw.h.							

From calculation, the three key factors related to the living space of compact EVs are also the cycle life of battery, the battery price and the gasoline price, and the relationship among them are shown as Fig.11.

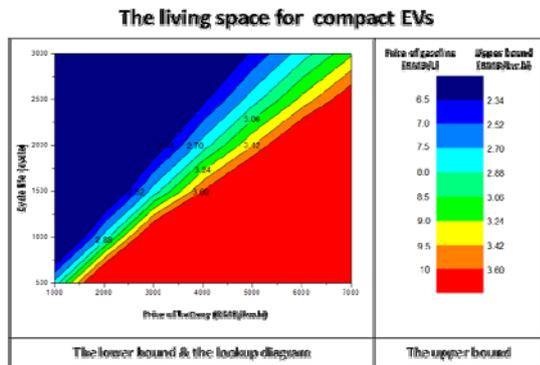


Figure 11: The living space for compact EVs

This figure should be read in the same way that is use in Fig.4.

Through analysis, the lower bounds of both parts are the same. The differences remain in the lookup diagrams and the upper bound charts.

3.3.1 Single Factor Analysis

Because the vehicle type is irrelevant to the lower bound, the influence of battery price and cycle life on the living space is the same as the influence of those two factors on the micro EVs.

The difference between compact EVs and micro EVs is reflected in the influences exerted on the upper bound determined by the gasoline price.

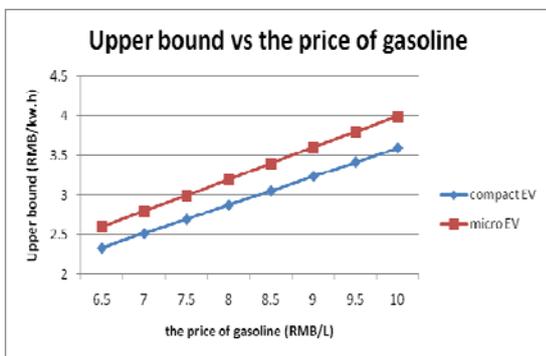


Figure 12: Compact EV comparison: Upper bound vs. price of gasoline

By comparative analysis in Fig.12, with other conditions unaltered, the upper bound for the

micro EV is higher than that for the compact EV. The promotion of micro EVs is favorable to the gaining of living space.

When the gasoline price is 6.5RMB/L, the upper bounds for compact EV and micro EV are 2.34RMB/kw.h and 2.60RMB/kw.h respectively; when the gasoline price is 10RMB/L, the upper bounds for compact EV and micro EV are 3.60RMB/kw.h and 4.00kw.h. Thus, as the gasoline price rises, the upper bounds for compact EV and micro EV increase at the same time. The upper bound for micro EV is 10% higher than that of compact EV.

3.3.2 Analysis of Financial Subsidies

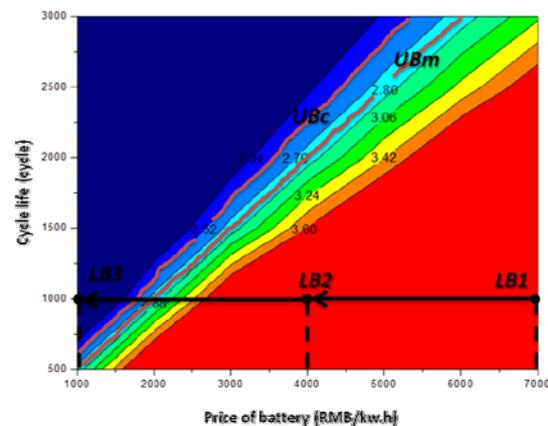


Figure 13: Compact EV comparison: The living space after the subsidy

The state and local subsidies influence the living space by changing its lower bound. Therefore, after the two-stage subsidies, the lower bound still moves from point LB1 to point LB3 via point LB2.

When the gasoline price is 7RMB/L, the upper bound for compact EV is 2.52RMB/kw.h, so the upper bound curve changes in Fig.13. As shown in the figure, curve UBc displays the upper bound for compact EV, and curve UBm displays the upper bound for micro EV.

The ultimate lower bound LB3 is to the left of both the two upper bound curves, which means that with state and local subsidies, both compact EV and micro EV can help the battery leasing company gain living space. Yet, the distance between point LB3 and curve UBc is shorter than that between point LB3 and curve UBm, the living space brought by compact EV is smaller, so is the room for profits.

Table 4: Parameters of both Li-ion batteries and Lead-acid batteries and the living space

	Price of battery (RMB/kw.h)	Life cycle (cycle)	Lower bound (RMB/kw.h)	Upper bound (RMB/kw.h) Micro EV	Upper bound (RMB/kw.h) Compact EV
Li-ion	7000	1000	9.05	2.80	2.52
Lead acid	700	500	2.05	2.80	2.52

3.3.3 Analysis of Different Battery Types

The same lead acid battery and Li-ion battery used in former analysis is listed in Table 4.

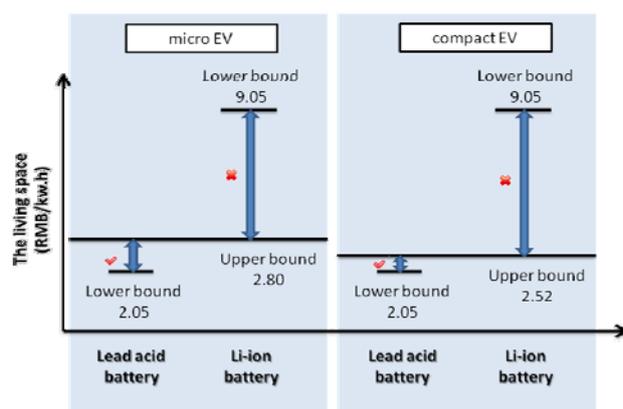


Figure 14: The living space comparison between different batteries and vehicles

As shown in Fig.14: the lower bound with lead acid battery is much lower than that with Li-ion battery, but the number does not change for different vehicles types. The upper bound for compact EV is 2.52RMB/kw.h. By using lead acid battery, the compact EV can earn a living space of 0.48RMB/kw.h for the battery leasing company. It is only 64% of the living space earned by micro EV which is 0.75RMB/kw.h.

4 Conclusions

1. At this stage, the battery leasing company cannot get profit via the business model, “vehicle and battery separated, battery leasing”. However, with the decrease of the battery price and the increase of battery cycle life and the gasoline price, the battery leasing company is possible to get the living space.

2. Promoting micro EVs rather than compact EVs will be more advantageous for the battery leasing company to get the living space. Micro EVs give the battery leasing company an upper bound 10 percent higher than that of the compact EVs in the same situation, which is good for gaining the

living space.

3. The current financial subsidies can help the battery leasing company gain the living space. With the total subsidy of 6000 RMB/kw.h from both the central and local government, the battery leasing company will have a living space of 1.25RMB/kw.h. To make the living space of the battery leasing company just exist, the total subsidy should be 5000 RMB/kw.h.

4. The application of lead-acid battery will help the battery leasing company gain the living space. The lower bound corresponding to the lead-acid battery is only 23 percent of that corresponding to the li-ion battery.

5. The living space methodology can effectively analyze the scenarios of different types of vehicles, batteries and the financial subsidies, and as a necessary condition, it can also diagnose whether the battery leasing company can get profit.

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