Globalization, Environmental Sustainability and Green Growth by Intensifying the Use of Electric Vehicles under the One Belt One Road Initiative

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Abstract **– This paper explores the potential for fostering globalization, environmental sustainability, and green growth by expanding the adoption of electric vehicles (EVs) within the framework of China's One Belt One Road (OBOR) initiative. The future of electric mobility is shaped by a complex interplay of technical, economic, and political factors, with ongoing debates surrounding the environmental and economic implications of EVs-particularly related to battery production and charging methods. This study reviews contrasting perspectives from scholars such as Y. Erofeev, T. Skrúcaný, R. Orvis, D. Weißbach, and C. Buchal. Using a benchmarking method that integrates political, economic, and geographic considerations, proposed is a model whereby China, leveraging its industrial leadership, can pilot a modular battery approach in selected OBOR regions. A favorable combination of these interrelated factors could enable electrification to be implemented at a sufficiently large scale and over a prolonged period.**

Keywords **– Electric vehicles, battery technology, green growth, political economy, modular battery systems.**

DOI: 10.18421/TEM144-18
https://doi.org/10.18421/TEM144-18

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Received: 02 January 2025.
Revised: 03 July 2025.
Accepted: 19 August 2025.
Published: 27 November 2025.

1. Introduction

In recent times, the transition to passenger electric vehicles (PEVs) has become imperative in most highly developed countries. According to a report by the International Energy Agency (IEA), a Paris-based global energy sector analysis organization, published in April, 2023, sales of PEV having grown to over 10 million units. China has the largest share of this market (around 60%), followed by highly developed countries in Europe (14%), where one in five passenger cars sold in 2022 is electric. PEVs sales are growing fastest in the US, with a 55% increase in 2022. Outside these three large markets, volumes are negligible, with countries such as India, Thailand and Indonesia reaching a total of 80,000 for the same year [1].

The imposition of PEVs in highly developed countries is leading to a historic transformation in the automotive industry and is the result of targeted policy. Shanghai for instance, with population around 20 million, has banned the sale of new cars with Internal Combustion Engines (ICE), the UK is planning to stop selling such cars and vans by 2030, the European Union (EU) is considering a similar measure by 2035, as is California, the most populous US state, with a population of nearly 40 million. The reasoning behind this policy is environmental.

However, the success of such efforts is not guaranteed. The problems surrounding the partial transition to electric vehicles have not yet been satisfactorily resolved. Due to a number of circumstances, China as a leading producer and consumer can deliver answers to many questions in this regard.

This article analyses the controversies and obstacles to the use of Electric Vehicles (EV) using the benchmarking method. The controversy around the economic and environmental impact of their use continues. The most doubts are linked with the energy source - the battery and how it is charged. The article takes into account divergent, even opposite views of several scientists. The method used examines their theses in terms of a combination of political, economic, political and geographical factors. The main factors that determine the penetration of a new technology in life are discussed in combination. The question is whether a good combination of these factors is possible to ensure sustainable development of the transport electrification. In view of the favourable combination of these factors in China, a model is proposed by which this country can test optimal solutions for the emerging revolution in passenger transport.

1.1. Key Factors Influencing the Adoption of Electric Vehicles

The adoption of any significant technological innovation-such as the electric vehicle-requires more than just a breakthrough in engineering. Its widespread implementation is shaped by a combination of interrelated factors: technical capabilities, economic viability, and political or regulatory support. These three dimensions do not act independently but rather influence and reinforce each other in determining how and when a new technology is integrated into everyday life.

1.2. Technical Factors

Scientific and technical progress is the driving force of innovation, growth and improvement of the quality of life of modern society. It covers the development of new technologies, the improvement of existing ones, as well as the application of scientific discoveries in practical aspects of life. Here are some of the main driving forces of scientific and technical progress, in the context of modernity:

- Information and Communication Technologies (ICT): The development of ICT has changed the way people communicate, work and learn. The Internet, mobile technology, and cloud services are examples of innovations that have a profound impact on society.

- Biotechnology: Developments in the field of biotechnology including genetic engineering, cloning, development of new drugs and therapies. These discoveries have significant potential for treating disease and improving quality of life.

- Sustainable Energy and Environment: Scientific and technical progress in the field of sustainable energy, such as solar, wind and hydrogen energy, is key to addressing climate change. Innovations in this area help reduce dependence on fossil fuels and protect the environment.

- Artificial Intelligence (AI) and Robotics: AI and robotics are transforming industry, medicine, transportation and even domestic life, creating opportunities for automation, increasing efficiency and developing intelligent systems that can analyze large amounts of data.

- Space Research: Developments in space technology not only help us better understand the universe, but also develop technologies that have applications on Earth, such as satellite communications and Earth observation.

- Electromobility: Electric mobility is the use of electrically powered vehicles, which include cars, buses, trucks, airplanes, motorcycles, scooters and bicycles. This concept fits with environmental policy as it produces much less or no direct carbon emissions, which is particularly important to reduce air pollution in urban areas and to combat climate change; The development of electromobility is driving innovation in battery technology, which includes improving energy density, reducing charging times and increasing battery life. These innovations are important not only for the automotive industry, but also for other areas such as mobile phones, portable computers and energy storage. The integration with renewable energy sources means that electric vehicles can be powered through solar and wind power, further reducing their carbon footprint and supporting the transition to more sustainable energy systems.

The development of electric vehicles often goes hand in hand with the integration of intelligent technologies such as autonomous driving, intelligent navigation systems and interaction with urban infrastructure, which improves transportation efficiency and safety. As economic and social changes are concerned, electromobility is driving changes in the automotive industry, creating new jobs and business opportunities while also causing changes in traditional patterns of car ownership and use.

Scientific and technical progress is an integral part of the modern world and continues to develop at an accelerated pace, causing continuous changes in society, the economy and people's daily lives.

In this sense, electromobility could provoke a major change, similar to transformations like: the use of sailing ships, the appearance of railways in the 17th century and the transition to steam-powered ships, the introduction of internal combustion engine, the development of aviation and pipelines.

Infrastructure also develops parallel with transport and communications, for instance motorways, gas-stations and so on. The development since 1885 of wheeled transport with its ability to carry goods 'door to door' stimulates the growth of modern megacities.

1.3. Economic Factors

Costs associated with transport include also the infrastructure, including the production, storage and delivery of the energy needed for propulsion. Except for the costs of insuring the means of transport and cargo, all other costs are of technical origin. From this point of view, the sharp reduction of technically determined costs is a major driver for the globalization, which manifests itself as the unification and merger of local and regional commodity markets into a single global market. In this sense, the local origin of a certain commodity is far from guaranteeing a competitive advantage in the market related to the shortest possible delivery route. This finding is relevant both to the first wave of globalization in the late 19th and early 20th centuries and to the current wave that began in the 1990s. e.g. the competition between rail and wheeled transport depends very much on the aggregate costs that societies pay for the service provided.

1.4. Political and Administrative Factors

According to market-oriented theories, if only free competition is practiced in the given market, then transport costs should be determined only by the interaction of the two sets of factors mentioned above. Unfortunately, in most cases, political considerations always impose additional restrictions related to the realization of certain goals and policies. Widespread recent environmental considerations, the so called “global warming” or “climate change”, are already imposing administrative solutions that some researchers call a new revolution in transportation. This involves at least a partial shift towards vehicles powered by electricity, including that produced from alternative and emission-free, at least during the period of operation, energy sources.

However, the prevalence of the political factor at present means that the combination of the three sets of factors is not optimal; optimizing this combination is a process that also needs its own test fields, such as China can offer.

By 2023, passenger electric vehicles PEVs have reached a technological maturity that allows economic considerations to come into play in solving explicit and implicit political tasks: protecting the environment and combating “global warming”, disempowering geopolitical rivals relying on large reserves of traditional fuels, etc.

The political tasks may be controversial, but have already in many places created a legal framework for the mass production and use of PEVs like the European Green Deal [2]. Given the importance of road transport, this really means a revolution with major implications for societal development.

An intermediate solution is the production of hybrid cars that use two or more sources of energy to move around. In 2022 more than 2,9 million hybrid electric vehicles have been sold worldwide compared with 60 000 in 2012 [3]. Under certain conditions, these vehicles might have a good future, but this article explores the issues facing pure electric models, which have the highest hopes of replacing ICE vehicles. The comparison is only with gasoline-powered vehicles. Despite their many advantages, diesel-powered cars, including trucks and buses, are already subject to a number of restrictions, especially in the cities of Western Europe, and an objective comparison with their electric competitors is becoming less possible.

Electric cars are powered entirely by electricity and, unlike hybrids, do not have an internal combustion engine. In 2020, electric cars accounted for 0.7% of the world's available vehicles. At the same time, electric vehicles accounted for around 2.2% of all cars produced, meaning that there was only one electric vehicle for every 250 standard models. It is currently forecast that nearly 14 million electric vehicles will be sold globally in 2023, with more than 2.3 million already sold in the first quarter of the year [4].

Goldman Sachs Research forecasts that PEVs sales will grow to 73 million units in 2040. Meanwhile, the share of PEVs in global car sales is expected to grow from 2% to 61% over this period. The share of PEVs sales is expected to exceed 80% in many developed countries [5]. These expectations are presented by Figure 1:

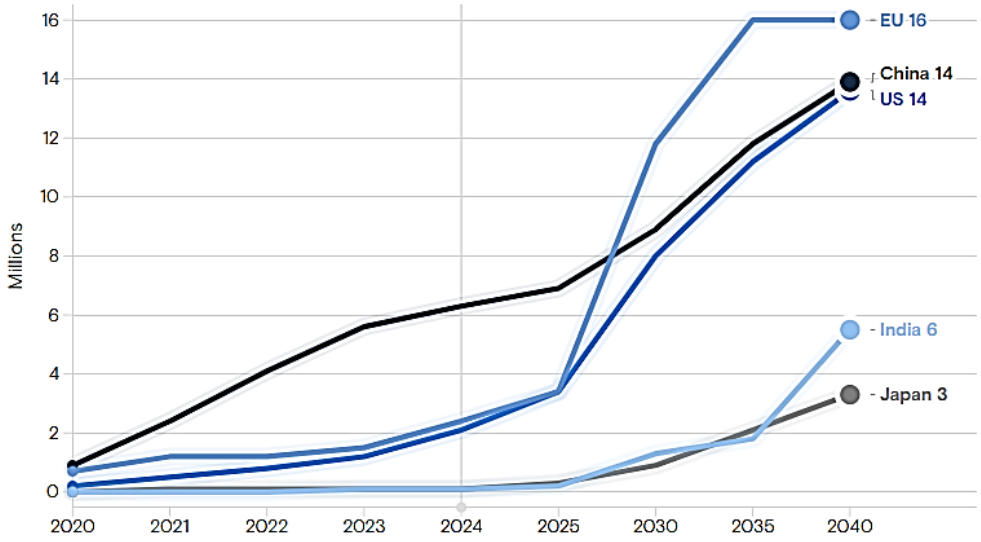

Figure 1. Electric vehicle sales, incl. forecast
Source: IHS Global Insight, Goldman Sachs Research

However, the sustainability of this trend depends on the action of the above-mentioned groups of factors, as follows:

- Technical capabilities: The passenger electric car as a technical solution is older than the ICE car. After the invention of the battery by Alessandro Volta and the first collector direct current (DC) electric motor by William Sturgeon in 1832, the first developments appeared – by Robert Anderson (1832 - 1839), Gustave Trouvé (1881), Thomas Parker (1884), etc. After the invention of the ICE by Nikolaus Otto in 1876 and its subsequent application by Karl Benz (1885) and Gottlieb Daimler (1885, 1886), the ICE car won the competition with the electric car, despite the latter having a simpler and easier to manufacture design - with up to 10 times fewer moving parts. The electric car has three relatively simple main modules: a battery, an electric motor and a controller. The controller controls the flow of electricity from the battery to the electric motor, thereby regulating power and acceleration. PEVs are notable for their quick acceleration, quiet operation, instant torque and smooth acceleration. Electric vehicles demonstrate high efficiency, with energy conversion rates reaching up to 90% from the battery to the engine [6]. Operating costs are lower compared to conventionally fueled vehicles, and electric motors demand less maintenance than internal combustion engines. Additionally, no emissions are produced during operation, making them environmentally preferable.

The main drawback of the electric car remains the energy source. Despite the progress the batteries used today remain heavy and expensive to produce, provide low range and are slow to charge. If the extraction of raw materials used for the production of the batteries is taken into account, as well as the recycling, the environmental effect falls into doubt. These are energy-intensive processes that pollute water and soil.

Economic factors have long been in favour of the ICE cars, and only sporadic sharp increases in the price of oil have awakened interest in the electric cars. In fact, the price of oil continues to influence consumer attitudes even now.

- The political factors only emerged after 2006 with the sudden upsurge of the environmental movement triggered by Al Gore's film “An Inconvenient Truth”. The sharp spike in the price of oil in 2008 - up to $178 per barrel of West Texas Intermediate (WTI) crude oil in May, and the subsequent high levels up to 2014, along with sustained and resultant pressure from environmentalists, drove major investment in two directions: improving alternative energy sources and increasing efficiency and reducing battery weight and cost, along with improving charging methods. There is also reason to suspect that the pressure to abandon fossil fuels, which the EU is also trying to exert globally, comes from the fact that the EU is the most deprived of these fuels compared to its main competitors (excluding Japan) and is thus trying to erase their competitive advantage.

Either way, the official view in the EU is that so-called "greenhouse gases" are a major threat to the climate balance. Studies show that, for EU countries, around 12% of total CO_2 emissions (the most important “greenhouse gas”) are attributable to cars. The “Green Deal” foresees the EU becoming “climate neutral” by 2050. To achieve this goal, CO_2 emissions from transport must be reduced by 90% and energy for electricity generation must be increasingly switched to renewable sources such as solar and wind [7]. However, the optimistic forecast for EV sales in the EU, as presented in Figure 1, appears to be overly optimistic and remains subject to critical evaluation based on current trends and constraints.

- Economic factors are currently very difficult to analyse, as calculations are often characterized by wishful thinking - e.g. downward trends over time in the prices of important production components, both batteries and alternative energy sources, are assumed to be irreversible. At present, the purchase of electric vehicles is massively subsidised with the promise that the aforementioned trends will soon make subsidies redundant. There is controversy around this, together with the controversy around some unsustainable technical solutions, which form the core of the discussion that follows.

2. Discussion Around the Feasibility of the Electric Vehicle

Currently, the share of PEVs is small but growing. Comparisons between the best-selling electric models and comparable petrol models highlight different advantages depending on the perspective, which is often not scientifically based.

2.1. Technical Maturity of Batteries

The main issue with the electric vehicle remains the power supply - the battery itself and more broadly the associated energy - generation, storage and efficiency of electricity use.

The invention of Volta has undergone a major development aimed at higher efficiency, durability (number of discharge/charge cycles), charging time, resistance to temperature fluctuations, lightweighting and lowering cost. Recently, environmental considerations have also come into play.

Various metals are used for production today, including relatively rare ones, which raises the question of securing the necessary quantities. In the firstplace lithium, cobalt, manganese and neodymium are concerned. Lithium-ion batteries are currently proving to be good. Most often the anode is graphite. For the cathode, as opposed to the originally used titanium disulfide (TiS2), the following are now used: layered oxides (e.g. lithium cobalt oxide); polyanionic materials (e.g. lithium iron phosphate); or lithium manganese oxide. This type of battery has the highest energy-to-mass ratio, does not suffer from the "memory effect" and loses its charge very slowly when not in use. Self-discharge depends on the storage temperature and charging rate. At a temperature of 25 °C and 100% charge, the self-discharge rate is about 1.6% per month. The most commonly discussed problems with lithium-ion batteries are:

- Flammable if charged incorrectly or if mechanically damaged;
- Can be damaged by overcharging;
- Losing capacity at too low temperatures. Norway, has the highest EV use per capita in the world, but this is because of Norway's targeted and very generous policy for EV subsidies - free electricity, Value Added Tax (VAT) reduction, etc.;
- Lithium-ion batteries require high-purity lithium - to produce one ton of lithium, 100 tons of ore must be processed;
- Waste is poisonous.

Lithium iron phosphate (LiFePO4, LFP), a variety of lithium-ion battery, offers the best solutions to the above problems. It uses LiFePO4 as the cathode and a graphite-carbon electrode with a metal substrate as the anode. Due to its lower cost, high safety, low toxicity, long lifetime and other factors, LFP batteries have recently found widespread use in vehicles, stationary batteries and for backup power. LFP batteries do not contain cobalt. Replacing it with phosphates avoids the high cost of cobalt and environmental problems resulting from its release into the environment. As of September 2022, the market shares of LFP batteries for electric vehicles reached 31%, of which 68% was accounted for by Tesla and Chinese electric vehicle manufacturer BYD alone. Chinese manufacturers currently have a near monopoly on LFP battery production due to a favorable combination of several groups of factors - their own deposits of the necessary metals, government support, etc.

Lithium-iron-phosphate batteries have a life of 10-20 years, approximately 1500-3000 charge-discharge cycles. Discharge near the lower voltage limit, 2 V, can reduce their life, but such discharge is easily preventable in use. The load current and stable discharge voltage make them particularly suitable for electric vehicles. Very low self-discharge rates, resistance to low temperatures, and the capability to charge at temperatures as low as 0°C are characteristic features. Safe charging is possible when specific conditions are met, which are more easily ensured in controlled factory environments. Even under harsh operating scenarios, lithium iron phosphate batteries do not emit gases, are non-explosive, and are highly resistant to ignition.

This type of battery is widely used as a buffer device for energy storage in autonomous energy systems using wind turbines and solar panels, as well as in in-plant and warehouse electric transport and, most importantly, in electric cars and electric buses.

For the mass use of PEVs, charging/discharging modes are decisive. Until recently, massively used batteries lasted 600 charge-discharge cycles before their capacity dropped to 80%, with a minimum fast charge time of 1 hour. The use of LFP batteries increases the number of cycles as shown above. There are currently three charging modes developed:

1. Charging via a simple 120 V AC household outlet. Level 1 chargers can take over 40-50 hours to charge an electric vehicle to 80%;
2. AC charging with 240V voltage for charging at home, workplace and public places. The chargers can charge a PEV to 80% in 4-10 hours;

3. DC fast charging (DCFC) at special installed stations in public places. DCFC equipment supplies 400 V - 1000 V DC, typical output power of 50 - 350 kW and can charge a PEV to 80% in only 20 minutes to 1 hour.

In this case, the problem to be solved has to do with range anxiety, one of the biggest challenges facing electric vehicle owners. Electric vehicles have a limited range and many charging stations are needed to charge them. The availability of charging stations varies widely, and in some areas charging infrastructure is limited or non-existent.

2.2. Economic Considerations

-Production costs: The most expensive part of an electric vehicle is the battery. Its cost has fallen from €605 per kWh in 2010, to €170 in 2017 and to €100 in 2019 [8]. As with other industrial production, cost optimization is directly linked to quantities.

- Total cost of ownership: In the EU and the US, the total cost of ownership of PEVs is estimated to be lower than that of equivalent gasoline vehicles due to lower fueling and maintenance costs [9].

The greater the distance travelled per year, the more likely it is that the total cost of owning an electric car will be lower than that of an equivalent ICE car. The equilibrium point varies from country to country depending on taxes, subsidies and different energy costs. Plug-in electric vehicles (PEVs) are subsidised in most regions through both direct and indirect measures, such as purchase incentives, tax exemptions, and restrictions or bans on internal combustion engine (ICE) vehicles. In certain cases, indirect support is also provided via subsidised electricity prices. Not only national governments but also local authorities, for instance in the UK, are introducing incentives to reduce the purchase price of electric vehicles. This is the result of the political interference in the market. Without subsidies, PEVs will hardly catch on for now.

Subsidies can also apply to batteries only, to the same effect. From 2020, the battery of an electric car is up to 40% of the total value of the car. Purchase prices are expected to fall below those of new ICE vehicles when battery costs fall below $100 per kWh, which is projected to happen by 2025 [10]. Since China is the largest producer of electric vehicles and batteries, the growth of PEVs sales is primarily driven by subsidies in the Chinese economy, which is controlled at the government level.

According to the Washington-based Center for Strategic and International Studies, in 2019 the total amount of subsidies - loans and land sales at below-market interest rates, tax breaks and capital provided by sovereign wealth funds and banks, ranges between $248 billion and $407 billion, depending on how exchange rates are accounted for.

This figure amounts to 1.73% of China's gross domestic product in 2019, well above the same figure compared to other highly developed countries promoting industrial policy [11]. South Korea comes in second with 0.67% of Gross Domestic Product (GDP). In addition to China's industrial policy, the social policy of the state must also be taken into account, which, through the provision of state-funded social services, keeps the cost of labor low compared to competitors, which is why economic estimates affecting the production and use of PEVs have no firm basis and are far from pure market pricing.

A more detailed comparison of electric and internal combustion engine (ICE) vehicle pricing and ownership costs is provided in Table 1, which illustrates the significant price differential between comparable models under current economic and policy conditions.

Table 1. Comparison of EV and ICE vehicle prices

Gasoline	$	Electric	$
Hyundai Kona SEL	24 745	Hyundai Kona Electric SEL	35 245
Hyundai Kona Limited	29 845	Hyundai Kona Electric Limited	43 745
Ford F-150 XL	31 685	Ford F-150 Lightning Pro	41 669
Kia Niro EX Premium	33 600	Kia Niro EV EX Premium	45 865

Source: „Most electric vehicles are cheaper to own off the lot than gas car", Robbie Orvis, May 2022.

Also a price comparison between the most advertised 2019 Tesla Model 3 ($40,240) and its matching-parameter and quite successful Hyundai model, the Avante/Sixth generation ($15,838-$28,763), should be added [12].

According to Robbie Orvis' methodology, electric vehicles are cheaper than gasoline-powered vehicles due to their lower total lifetime costs, with fuel and maintenance savings outweighing the differences in purchase price. The implication is that consumers focus on how much is paid to own and operate the vehicle each month rather than how much the vehicle will save them over its lifetime. According to Orvis, most new PEVs are cheaper to own from the day they are purchased, even when the price is significantly higher, especially in view of the electric car incentives currently on offer [13].

However, there are other assessments. In a June 2022 report by Alix Partners, the raw material costs of an average electric vehicle rose from $3,381 in March 2020 to $8,255 in May 2022. The reason for the cost increase is mainly due to the appreciation of lithium, nickel and cobalt [14]. This means that the use of PEVs depends on the movement of the metals' stock prices in the same way that ICE car sales are affected by oil prices.

There are already concerns about the availability of sufficient stocks of these metals, as well as their distribution. The Democratic Republic of Congo currently produces 63% of the world's cobalt. Bolivia accounts for about 24% of the world's total proven reserves of easily mined lithium. Another 20% is found in Argentina. Chile is slightly further down this list at 11%. In fact, three-quarters of the world's lithium reserves are concentrated in Latin America. The three countries mentioned, plus Peru, Mexico and China, are determined to impose state control over the mining and production of the metal and batteries, and are also considering the prospect of creating an Organization of Lithium Exporting Countries, the so-called "Lithium-OPEC." Outside the region, significant reserves exist in Australia, Russia and China.

The small number of lithium suppliers can create market problems. It is not clear what number of PEVs can supply the world's available stocks of cobalt, neodymium and lithium. If the LFP battery (Lithium iron phosphate) solves the issue of possible cobalt shortages, this is not the case with lithium. Earlier studies were optimistic - according to a 2011 study by the Lawrence Berkeley National Laboratory and the University of California at Berkeley, the then-estimated lithium stockpile should not be a limiting factor for large-scale production of electric vehicle batteries, as this stockpile could create the 1 billion lithium-based batteries needed with a capacity of 40 kWh - about 10 kg of lithium per vehicle. The study estimates world stocks at 39 million tonnes and total lithium demand over the 90-year period at 12-20 million tonnes per year, depending on economic growth scenarios and recycling rates [15].

But pessimistic estimations point out that if the UK alone, with its 31.5 million cars, should switched fully to PEVs by 2050, it would consume all the neodymium produced in the world, 3/4 of the world's lithium reserves and at least half of the world's copper production in 2018, and global cobalt production should be doubled [16]. Therefore, replacing 1 billion cars globally seems impossible, or at least competition for these elements will keep battery prices high. According to this study, if alternative substitutes for lithium are not found, then the craze for electric cars could end very quickly. Beyond that, ways to dispose of depleted lithium batteries have yet to be developed and it won't be for free.

The aforementioned optimism about the stocks of needed metals may well be wishful thinking. There are enough historical example of pessimism about oil reserves, very vividly expressed decades earlier. The controversy continues. It is certain that new fields are yet to be found and exploited around the world, so any economic calculations may be inaccurate. The issue comes down to the cost of production of the raw material extracted.

The only thing that seems certain is that the exchange price of the metals will dictate large fluctuations in the electric vehicle market.

2.3. Environmental Considerations

If one adds these considerations, which are at the heart of the attack on ICE cars, the discussion becomes even more complex. The major manufacturers are already succumbing to strong political pressure for a mass switch to PEVs, and without comprehensive estimates of the total cost, including that to be paid for retrofitting the energy infrastructure, for battery production and disposal, etc. Comprehensive estimates could refute hopes for a tangible environmental effect.

Electric vehicle batteries themselves are a major and so far neglected environmental problem. The extraction and processing of the lithium, cobalt and manganese needed is extremely energy intensive and the pollution of the atmosphere is above acceptable limits. It takes up to 200, 000 l of water to extract one tone of lithium carbonate, which is then contaminated [17].

German scientists found that the production of a battery with a lifetime of up to 10 years releases between 11 and 15 tonnes of carbon dioxide. If a car is driven 15 000 kilometers a year, this means that it will emit between 73 and 98 gCO_2/km per kilometer. When electricity is generated by coal-fired power stations, the poisonous substances emitted into the atmosphere range from 156 to 181 g/km of driving, compared with 112 grams per kilometer for a Mercedes C 220 D diesel limousine [18]. As mentioned above, the recycling of depleted lithium batteries has yet to be developed and it is unclear at what cost the tolerable environmental load will be achieved. For now, environmentalists prefer to skip over this topic. And it concerns not only the batteries, but also the production of electricity to power them.

A section of the public firmly believes that electric cars are generally more economical than internal combustion engine cars, calculating that the cost per unit of electricity is lower than the unit of chemical energy produced by burning petrol. This belief is due to several typical errors in thinking, some of them deliberately provoked:

1. It ignores the very production of electricity that should power the batteries. The efficiency of this generation varies, and the final selling price per kWh is not a measure, since in many places this generation is subsidized.
2. The belief that electricity can be produced environmentally friendly from windmills and solar panels does not take into account the pollution due to their production and disposal.

A detailed comparison may show that the overall efficiency of an PEV is the same or lower than that of a conventional ICE vehicle. Again, the controversy moves from the electric vehicles themselves to the source of their energy.

3. Discussion around Power Generation

The main problem is the inefficiency of Renewable Energy Sources (RES), with the major exception of the hydroelectric power stations. Under the influence of the political factor, public opinion is not aware of their low Energy Return on Investment (EROI) - or has a distorted idea of it. This indicator is often confused with Return on Investment (ROI), but the latter is often distorted by subsidies. On the other hand, technical progress changes this indicator over time, so that calculations from 2011 or 2013 no longer give an accurate picture. For a long time, the big problem with solar panels, e.g., was their expiry date. Nowadays this rate reaches 25 years. A gradual degradation in power output is typically observed over time, with solar panels appearing to "burn out" and losing approximately 20% of their capacity after around 10 years. It is difficult to improve this characteristic as it is the inverse of its efficiency. But subsidies in the USA allow the average break-even point for energy savings to occurs six to 10 years after installation [19].

The total power produced by the solar panel during operation is defined by their technical characteristics that are difficult to improve with technological maturity. After reaching nowadays the “technological ceiling” the total power is almost impossible to increase the output and the EROI stays low. On the current technical level, any increase in efficiency leads to a rapid increase in electricity cost and a decrease in EROI eventually. All the announced "breakthroughs" in this field are based on purely financial gimmicks and the EROI of most RES, taking into account the whole life cycle, is low, excepting the hydropower. But in highly developed Western countries, the potential of hydropower has long been stretched to its limit and there are no reserves. The energy potential of water reserves has long been tapped, except perhaps in Canada. The shift to renewables raises the problems described above.

Environmental considerations exclude electricity from coal-fired Combined Heat and Power (CHP) plants, whose thermal efficiency (~80%) should not be confused with the overall electrical efficiency of CHP plants, which reaches a practical efficiency of 36-39%. Despite pressure from environmentalists, the majority of the world's electricity is still generated in coal-fired CHP plants and therefore PEV consumption is ultimately reduced to fossil fuel combustion. Nuclear power plants (NPP) are highly efficient, but their treatment in countries with a strong “green” agenda is controversial.

When delivered to the consumer, some of the electricity is inevitably lost in power lines and in transformers when converting voltages. The average efficiency of the system to deliver electricity to the consumer is 80-85%. When used in an electric vehicle, electricity is lost during the charge and discharge cycles, storage and conversion to mechanical energy in the electric motor and transmission. Thus, the overall efficiency of the electric vehicle itself can drop to 50%. The difference arises from the condition of the batteries, their charging and discharging modes, ambient temperature, etc.

Thus, the overall efficiency for an electric car ranges between 15% and 30%, which means that at best a passenger electric car is no more fuel efficient than a conventional internal combustion engine car, and more often its efficiency is significantly lower. The efficiency of a passenger electric car charged by renewable energy is even lower given the low efficiency of the primary energy source - below 20%, even under optimal conditions, for solar panels and wind engines measured as of 2016 [18]. The low EROI negatively affects the final cost of electricity. The overall EROI of solar panels drops to 1.6 units, and the EROI of wind farms drops to 3.9 units, which is the lowest value among all [20].

On the other hand proponents of the electricity oppose that the question of the EROI of photovoltaic solar energy is secondary and neither energy market participants, nor politicians, nor scientists are interested in it. According to such considerations the "energy yield" of photovoltaic solar energy is high and will continue to grow as the energy efficiency of production increases and the material consumption of the devices decreases [21]. The calculations show an unsubsidized solar electricity price of 1 cent per kilowatt hour and fix it for 25 years, at which point a metric like EROI loses meaning. In fact, the value may increase up to three times compared to the CHP benchmark, primarily due to the reduced consumption of raw materials—whose production accounts for the main energy cost associated with solar energy systems [22]. This study also indicates that the EROI of wind turbines is 35-45% and will increase as the capacity of installations increases and material consumption decreases.

The differences in estimates are obvious and are not just due to improvements in technology of power generation. The efficiency of the electric drive is also dependent on the composition and share of individual energy sources (energy mix) and the efficiency of energy distribution. Obviously the extremely high share of hydropower in Norway's energy mix (92%!) is very favorable for transport electrification [23].

There are large differences in energy production efficiency in different medium to highly developed countries.

The efficiency of electricity distribution in the grid of Central European countries for instance is at levels ranging from 84% (Poland) to 93% (Slovenia). Further, for every 100 kWh of electricity consumed, 324 kWh of energy must be generated from primary sources in Hungary and 158 kWh in Austria [24]. Hence the great differences in the environmental performance assessment of electric vehicles in different countries when the amount of greenhouse gases produced to generate the required electricity from different primary sources in these countries was observed.

Not surprisingly, vehicles equipped with an ICE engine produce less greenhouse gases compared to electric vehicles fueled by electricity produced in Poland, where 69% of the country's electricity in 2022 is from coal. Also, the energy efficiency of an ICE-powered vehicle is higher than that of an PEV, operated in Hungary [25].

Apart from that, with the strong politicization of the topic, deviations from scientific objectivity can not be excluded. There are six factors that affect and make the analysis difficult: life cycle assessment methodology, age of primary data, Photovoltaic Cell technology, treatment of intermittency, equivalence of investment and output forms of energy, and assumptions about actual outcomes. The apparent divergence in research conclusions due to these factors can often be related to differently defined objectives [26].

However, one major drawback of wind turbines and solar panels remains undeniable - their intermittency and the large gap between production and consumption. In California, e.g., in line with the progressive environmentalist attitudes of the wealthy population, solar panels are being installed *en masse* and are becoming the main supplier of energy to the grid. California is a state with favorable conditions for photovoltaic yields, without large climatic amplitudes. Evidence shows that renewable energy is replacing traditional daytime power plants, making them unprofitable without subsidies and leading to their closure. Second, peak generation in the evening is having to be dramatically accelerated while importing electricity from neighboring states. In 2022 California imported 85 gigawatts of electricity against its own generation of 204 gigawatts. 30.9% of the imports were renewables, mostly from hydroelectric power-plants in Washington and Oregon [27].

In summer, on sunny days, at midday the wholesale electricity market price becomes negative as unwanted surpluses occur. These are exported into neighboring Arizona, but with a surcharge for balancing. Shutting down solar panels doesn't happen automatically within seconds either. Thus a ten-year period of preferential buying of electricity from renewables ended up with a partial degradation of traditional generators and a build-up of problems in the management of generation and consumption.

California's existing energy and pricing system is resulting in the closure of back-up facilities that are becoming unprofitable. Thus, between 2011 and 2017, electricity prices there rose five times faster than in the rest of the country [28].

A scheme has been tried in which solar power stations charge batteries with the excess electricity produced between morning and evening peak - the "curtailment" time. However, this means transportation difficulties during the active part of the day, when PEVs should be used *en masse*. The "International J1772 Combo" standard allows charging the battery of electric vehicles to 80% in about 20 minutes, but with constant current that solar power plants can not guarantee. This restriction leads back to dispatch problems. Therefore, storing excess electricity generated by renewables in electric vehicle batteries is not a very good solution from technical, environmental and economic points of view for the time being.

4. Possible Solution to the Problem in China

A partial solution to the problem can be found, but under technological and administrative-legal conditions different from the current ones. China can offer them.

The combination of several groups of factors allows this country to carry out a pilot project to partially solve some of the problems associated with the production and operation of electric vehicles. It is a logistical scheme that increases, at least a little, energy efficiency and, at the same time, reduces the inconvenience of charging batteries, and even partially solves the recycling issue. Some of the questions of the above discussion may be answered.

The circumstances that allow China to carry out a large-scale pilot project to guide the production and operation of an electric vehicle are as follows:

- China's economy is already the largest in the world measured by Purchasing Power Parity (PPP), and it is high-tech. There is no longer any industrial sector that does not use its own know-how. The country has the largest number of highly educated specialists. The economy is controlled by the state directly through state-owned enterprises and indirectly through tax policy, subsidies, etc.

The advantages of the private initiative are combined with strategic planning and at least minimum security guarantees - credit, government procurement, protection against unwanted competition. The state is able to finance and guide risky pilot projects in strategic directions. The political system allows for long-term central planning and the intersection between economic and political considerations.

- Progress on the policy priorities is impressive. There is widespread public support for environmental policies and China is the world leader in renewable electricity generation, with more than three times the output of the second-ranked country, the US - 1.161 to 352 GW [29]. China's renewable energy sector is growing faster than fossil fuels and nuclear power and is expected to contribute 43% of global renewable energy capacity growth. The country aims to have 80% of its total energy mix coming from non-fossil sources by 2060 and to achieve a combined capacity of 1,200 GW from solar and wind by 2030 [30].

- China's electric vehicle industry is also the largest in the world, accounting for about 57.4% of global electric vehicle production and about 500,000 export units in 2021. In 2021, the China Association of Automobile Manufacturers (CAAM) reports that China sold 3.34 million PEVs, consisting of 2.73 million battery-only electric vehicles and 0.6 million plug-in hybrid electric vehicles, representing 53% share of the global market of 6.23 million "new energy" passenger vehicles [31]. According to International Energy Agency (IEA) studies, over 50% of electric vehicles are on the roads of China. According to the same source, China's share of the 10 million PEVs sold in the global market in 2022 is estimated around 60% [32].

Thanks to the technology mastered and the raw materials secured, six Chinese companies - CATL, BYD Co., CALB Co., Gotion High Tech, Sunwoda and Farasis Energy, are on the list of the world's top ten electric vehicle battery suppliers in 2022. The six companies shipped a combined 313 gigawatt-hours of batteries in 2022, capturing 60% of the global market [33].

Finally, China's Belt & Road Initiative (BRI) offers scope for the implementation of such risky pilot projects. Being fundamentally a transport project, it is aligned with the environmental agenda. Many low-carbon technologies - from solar and wind power to battery energy storage and electric vehicles, have been judged to be technologically feasible and commercially viable. Their development fits into the strategic project, whose overall objective is the development of Emerging Market and Developing Economy.

The Green Investment Principles for the BRI were launched in 2018 by the China Finance and Banking Society and the City of London to accelerate green finance flows to address the infrastructure finance gap and "tackle the grand challenge of decarbonizing investment along the Belt and Road" [34]. These principles are transforming to a global platform for action, with 41 signatories owning or managing more than $49 trillion in total assets and providing significant financing for BRI projects [35].

The north of China has the right mix, suitable for testing “green investment”: great wind and solar potential in a sparsely populated region - Xinjiang, through which the main section of the BRI to Kazakhstan passes, as shown on Figure 2.

Figure 2. The Eurasian Landbridge
Source: Xinhua News Agency, May 2014

A pilot project optimising the use of wind and solar power and the use of batteries could be implemented there. In fact, along the entire section of The Eurasian Landbridge, including up to Turkey, favorable natural conditions prevail for electricity generation from solar panels - DNI over 1400 Kwh/m2, and from wind turbines - wind speeds over 7 m/sec. Sparsely populated regions, poorly connected to major urban centers, should be added. Hence the successful solutions from the pilot model in Xinjiang can be immediately applied along the Eurasian Landbridge and help other countries to choose the optimal solution for themselves – a step-by-step approach.

Battery problems in passenger electric vehicle use could be eased if the sourcing scheme is changed. In densely populated cities, there is little opportunity to charge from one's own power grid at night - not every user has his own permanent parking space, let alone his own garage. Charging from public stations like current petrol stations, even via pulse power, takes at best 20 minutes, which in urban traffic conditions does not seem a good solution. Apart from that, not so many models of electric cars are currently suitable for fast charging, even if only from a price point of view.

A good solution may come from the new concept in passenger electric vehicle design, offered in the Chinese Cao Cao 60 EV model with replaceable batteries and a range of 415 km per charge. This is a standard modular design - batteries replaceable at charging stations, where the battery is not owned by the vehicle owner. When charging, the owner gives away the depleted battery and receives another charged battery. This implies a design different from today's more mainstream PEVs.

Technically, it is very easy to move to the production of standard size and shape batteries in several classes and to a vehicle design allowing easy and quick battery replacement, similar to the tyres change by teams in Formula One racing. Thus, public charging stations will be a secure warehouse where users leave their discharged batteries and receive a ready-charged batteries in return within a few minutes. The discharged batteries accumulated in the warehouse during the day can be recharged at night using the free capacity of the NPP.

Outside the city, some public stations may benefit from proximity to intermittent sources of electricity such as wind engines and solar panels. Charging from these solves, at least in part, the problem of storing excess off-peak generation. In some cases, this solution reduces, albeit slightly, grid losses (up to 15%) at power plants remote from cities. Such out-of-town stations can also be equipped as recycling plants for end-of-life batteries, a problem that is still growing and looking for solutions. The conditions of the relatively sparsely populated Xinjiang Uygur region allow for such a solution.

This scheme, presented on Figure 3, is technically easy to implement for all manufacturers following the example given by Geely - in light electric vehicles the battery is located in the floor between the two axles, a space free from other units, and it should not be a problem for manufacturers to model standard niches for several types of batteries in different classes of PEVs.

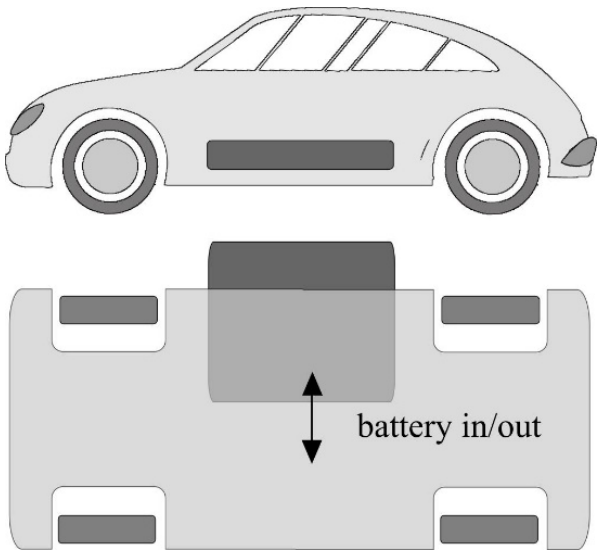

Figure 3. Principle scheme of charging a PEV
Source: own development

Standardized battery production should be made even easier. Large Chinese manufacturers can presumably easily access project credit for such production that does not require a major technical breakthrough.

This modular scheme assumes that the car owner does not own the battery itself, but pays its cost through the total cost of the charging service, which includes the cost of electricity.

This also solves to some extent the problem of the initial cost of the passenger electric vehicle. As can be seen from the table above, it is higher for an PEV than for an ICE and deters buyers, despite suggestions that over the course of the PEV's lifetime it becomes more profitable and the higher initial investment pays for itself. Without a calculated battery cost, the purchase becomes more attractive and the savings calculations become easier. The electric vehicle thus created is initially intended for Cao Cao Mobility, a ride-sharing platform under the leadership of Geely Holding. But this scheme, with a reduced starting price, also allows leasing.

This also solves another problem - the high cost of batteries tempts manufacturers to offer cars whose life cycle matches that of the battery, so that the consumer will opt for replacing the entire car rather than buying a whole new battery - a phenomenon seen in the smartphone industry. Frequent vehicle replacement proves profitable for manufacturers by accelerating turnover; however, this practice raises environmental concerns that should be addressed through appropriate policy measures. Long-lasting cars made with high quality materials, independent of battery life, are a good solution from both an economic and an environmental point of view. Centralized economic policy in China is able to strike a balance between the various considerations. Targeted social support for the region in the framework of the BRI can fit the pilot project described here into an overall strategy for accelerated technological and social development. The good results can be copied by other countries along the Road and Belt leading a focused industrial and social policy devoid of the excesses of market fundamentalism and „environmentalism“. For instance the "pro-market approach" imposed by the European Commission - exchange pricing and short-term contracts, led to sharp jumps in the price of natural gas and to energy crisis in 2021. At the same time, Germany decided to close its last three nuclear reactors for environmental reasons. Between January 2021 and January 2023, energy prices in the EU more than doubled.

5. Conclusion

Vehicle electrification has been a major trend in the automotive industry over the past decade. However, the economic and environmental feasibility continues to seem controversial, and this makes the process uniquely dependent on the political conjuncture, which is so far its main driver. Due to its complex nature, China's Belt and Road project offers a favorable combination of political, technological, economic and geographical factors that allow this electrification to be modelled on a sufficiently large scale and for a sufficiently long time. The project can also serve as a testing ground for new technologies.

The possible testing of a pilot model in Xinjiang, where there is a combination of favorable conditions, could be facilitated by the green investment plans of the One Belt One Road project. If the model demonstrates successful solutions, these could be applied and tested in other countries along The Eurasian Landbridge with suitable conditions. The step-by-step approach may eventually lead to a globally applicable solution. This approach will save unnecessary over-spending in the search for the optimal combination of technological, environmental and economic requirements in the transition to electric passenger cars.

Electromobility plays a key role in the transition toward more sustainable transport systems. However, its widespread adoption continues to face several interrelated barriers that hinder its development. One of the primary challenges remains the high initial cost of electric vehicles, which continues to deter many potential users despite their lower maintenance expenses. In addition, limited driving range—though gradually improving—still lags behind that of traditional petrol or diesel vehicles, and this limitation is further compounded by an underdeveloped charging infrastructure, particularly outside major urban centers. The absence of a standardized system for replaceable batteries also contributes to user hesitation. Another significant concern is the lengthy charging time, which is considerably greater than the refueling time of conventional vehicles. Furthermore, the production of EV batteries requires substantial quantities of rare minerals, raising serious environmental and social concerns related to extraction and supply chains. These factors, combined with the lack of effective battery recycling systems, explain why many traditional automotive manufacturers remain cautious in transitioning to full electric models, as doing so would necessitate major transformations of their production processes and business models. Overcoming these obstacles will require strong political support and coordinated efforts among governments, car manufacturers, energy providers, and consumers.

Strategic investments in charging infrastructure and the promotion of technological innovation through pilot projects—such as the one proposed in this article—are crucial steps toward accelerating the shift to electric mobility.

Acknowledgments

This publication is part of the "China's One Belt One Road Initiative in the Black Sea Region: analysis of opportunities and risks for Bulgaria" project, funded by The Bulgarian National Science Fund (BNSF), contract KP-06-N55/15.

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