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Technology Decision Analysis (TDA): Cummins' Path to a Zero-Emissions Future: An Analysis of Hydrogen Fuel Cells and Market Trends

Roopak Ingole[1], Ashish Gupta[2]

[1,2]Student – Master of Business Administration, W120-U723: Strategic Management of Innovation and Technology – Winter 2020 (Professor Jeffery Covin) Kelley School of Business – Indiana University Bloomington, IN USA

*roopak.ingole@gmail.com, ashish5000@gmail.com

ABSTRACT

In the pursuit of a zero-emissions future, Cummins Inc. has strategically navigated through the disruptive wave of electrification, aligning its focus towards the Hydrogen Economy and Fuel Cell technology. This paper presents a comprehensive Technology Decision Analysis (TDA), critically evaluating Cummins' response to electrification and its commitment to hydrogen fuel cells as a cornerstone for sustainable transportation. Through a detailed analysis encompassing current technological investments, a SWOT analysis, and an exploration of market trends, the paper scrutinizes Cummins' transition from traditional diesel engines towards green alternatives. The assessment leverages Cummins' internal strengths and market opportunities while addressing external threats and weaknesses, illustrating a coherent path to zero-emission vehicles (ZEVs). By juxtaposing hydrogen fuel cells against the backdrop of industry demands and regulatory pressures for reduced greenhouse gas emissions, this study underscores Cummins' strategic positioning and readiness to lead in the emergent hydrogen economy. Moreover, it highlights the challenges and prospects of adopting hydrogen as a pivotal energy vector, offering insights into Cummins' strategic initiatives and future directions in advancing toward a carbonneutral footprint.

Key words: Technology Decision Analysis, Hydrogen Fuel Cells

INTRODUCTION

The transition towards a sustainable and carbon-neutral future represents one of the most significant challenges and opportunities for the automotive and energy sectors. As global awareness and regulatory pressures concerning environmental degradation and climate change intensify, companies are compelled to innovate and adapt to the evolving landscape of energy consumption and emission standards. Cummins Inc., a stalwart in the field of power technology, finds itself at a critical juncture, where the paths of tradition and innovation intersect, demanding strategic foresight and decisive action towards a zero-emissions future.

Cummins, historically renowned for its robust and efficient diesel engines, has embarked on a transformative journey, venturing beyond the realm of internal combustion engines (ICEs) to embrace the potential of hydrogen as a fuel and other renewable energy technologies. This pivot not only reflects Cummins' response to the electrification disruption but also underscores its commitment to spearheading the transition to a Hydrogen Economy—a vision characterized by the utilization of hydrogen as a clean, versatile, and sustainable energy carrier.The introduction of hydrogen technology as a fuel into Cummins' strategic portfolio signifies a bold step towards aligning with global environmental goals and meeting the stringent emission standards set forth by governments worldwide. However, this transition is fraught with complexities, necessitating a nuanced understanding of the technological, economic, and regulatory landscapes that shape the hydrogen economy.

This paper, through a Technology Decision Analysis (TDA), delves into Cummins' strategic maneuvering amidst the electrification shift, scrutinizing the company's investment in hydrogen technology against the backdrop of market trends, regulatory environments, and competitive dynamics. It aims to dissect Cummins' strategic rationale, examining the alignment of its hydrogen initiative with internal capabilities and external market conditions. Furthermore, the paper evaluates the potential of hydrogen as a disruptive technology capable of redefining the future of transportation and power generation.

In doing so, the paper embarks on a comprehensive analysis, weaving together Cummins' current technology landscape, a SWOT analysis to elucidate strategic positioning, and an exploration of industry trends that highlight the trajectory towards reduced CO2 emissions and a greener future. Through this analysis, the paper seeks to offer insights into the challenges and opportunities that lie ahead for Cummins, as it navigates the transition from a diesel-dominated past to a hydrogen-fueled future, marking its contribution to the global pursuit of zero emissions.

ANALYSIS OF CUMMINS SOLUTION

In the report "Technology Decision Analysis (TDA):

Cummins Inc. and the Shift Toward Electrification in Commercial Trucking" [1] authors discussed Cummins' decision to shift focus toward Electrification. Continuing that, in this section, we will analyze Cummins' response to electrification disruption and determine if they have made the right choice to move in the direction of Hydrogen Economy and Fuel Cell technology [2].

A.Cummins Current Technology Analysis:

Cummins continues to invest heavily in developing new generation diesel engines of all sizes. For over a decade, Cummins has been developing the largest diesel engine nicknamed 'Hedgehog' which is a 95ltr engine for use in mining, power generation and locomotive applications and has spent more than a billion dollars on this new platform. Its R&D continues to launch new projects for developing new versions of X15, however, all these projects are launched with their main OEM customer agreements in place. **Error! Reference source not found.** shows a S-Curve for commercial on-highway diesel engines, with all the recent developments, it is clear that after almost 100 years of ruling the semi-truck market, Cummins is now heading to the last phase of the 'S' curve 'Decline'.

Cummins also develops alternative fuels engines that can run on Natural Gas, Propane, digester gas etc. In July 2008, diesel price hit a high of $4.85/gall, these fuels were considered to be the successor of Diesel as they were cheaper and cleaner. However, with the invention of fracking and horizontal drilling, shale oil became abundant and fuel prices fell to a price of around $3/gal. as of Jan 2021. The big challenge with these crude oil-based fuels (diesel, gasoline, natural gas) is that they are 'Carbon' based and not renewable, their combustion produces CO2 which is a Greenhouse gas.

B. SWOT Analysis:

We have conducted a SWOT analysis to see the possible options. Cummins' chosen solution of 'Develop Hydrogen Fuel Cells based powertrain' leverages their Internal Strengths and takes advantage of External Threats. There are few other good options (highlighted in Blue) which are discussed in 'Future Recommendation' section at the end of this case study.

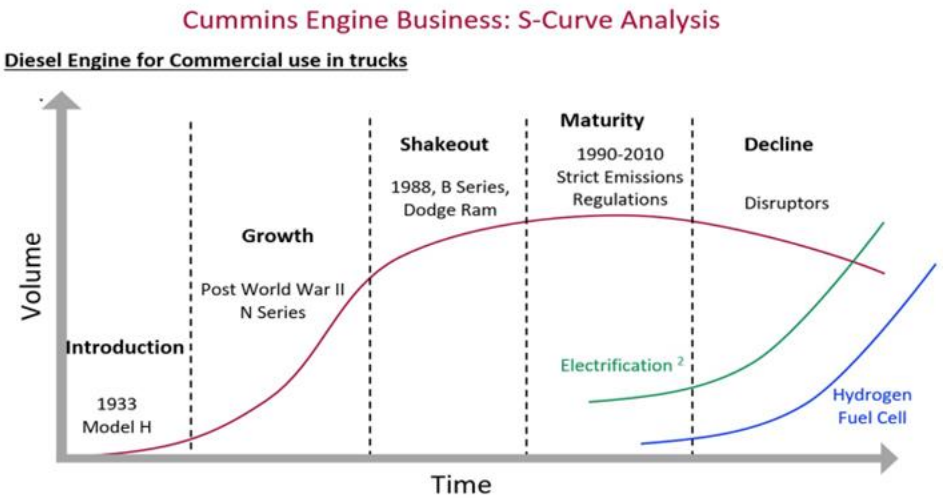

Figure 1: S-Curve for semi-truck powertrains

Table 1: Cummins Inc. Swot Analysis.

Swot Analysis	**External Opportunities (O)**	**External Threats (T)**
	1. Truck manufacturing 2. Electrification powertrain 3. Electrification Components 4. Solution provider to energy business 5. Renewable energy – wind, solar management, components 6. Marine Engines	1. Electrification start ups 2. Alternate Fuels like Hydrogen 3. Climate Change 4. vailability of liquid fuel 5. OEM's making their own powertrain 6. Companies good in IT taking service business away
Internal Strengths (S) 1. R&D capability-people, patents 2. Manufacturing scale 3. Existing electrical component knowledge and manufacturing 4. Global sales and service network 5. Brand Value 6. Cash in hand to invest	SO Maxi-Maxi Strategy Examples 1. (S_&O_)_Get in truck business 2. (S_&O_)_Integrate electrical components with IC engines 3. (S_&O_)_Expand product line 4. (S_&O_)_Invest in making IC engines carbon neutral	ST Maxi-Mini Strategy Examples 1. (S_&T_)_Use manufacturing scale to reduce cost of EV components 2. (S_&T_)_Leverage service network to win business 3. (S_&T_)_Explore other products like power generation for electrification 4. (S_&T_)_Take Digital Transformation to product service and delight customers 5. Develop Hydrogen Fuel Cells based powertrain
Internal Weaknesses (W) 1. Moves slow compared to start ups 2. Does not make	WO Mini-Maxi Strategy Examples 1. (S_&T_)_Invest in Electrification R&D 2. (S_&T_)_Retrain workforce and	WT Mini-Mini Strategy Examples 1. (W_&T_)_Invest in electrification components instead

	trucks		prepare for electrification and alternate fuels		of powertrain
3.	Limited talent in electronics	3.	(S_&T_)_Explore combos of technologies for powertrain	2.	(W_&T_) Create partnerships
4.	Do not manufacture batteries like Tesla	4.	(S_&T_)_Make new product development process faster(currently 5-7 yrs)	3.	(W_&T_)Develop flexible product line
5.	No control over alternate fuel choice / industry	5.	(currently 5-7 yrs)	4.	(W_&T_)Withdraw from low profit products
6.	Employee satisfaction with IC engines				

C. Cummins Path to Zero Strategy:

Cummins developed a strategy to significantly improve to-zero emissions as shown in Figure 2: Path to ZEV (zero its core technologies and make the strategic investments emissions vehicle)**Error! Reference source not found.** With throughout the 2020's that will enable them to achieve path

Zero NOx (oxides of nitrogen) on vertical axis and Zero CO_2 on horizontal axis. Application of Hybrid electrification technology to diesel engines will enable Cummins to achieve strict emissions targets imposed by government agencies around the world in the 2020's. But they plan to use battery technology for mid-range products and fuel-cells technology for heavy duty products. Investments in renewable natural gas (RNG) based technologies will further help accelerate this path.

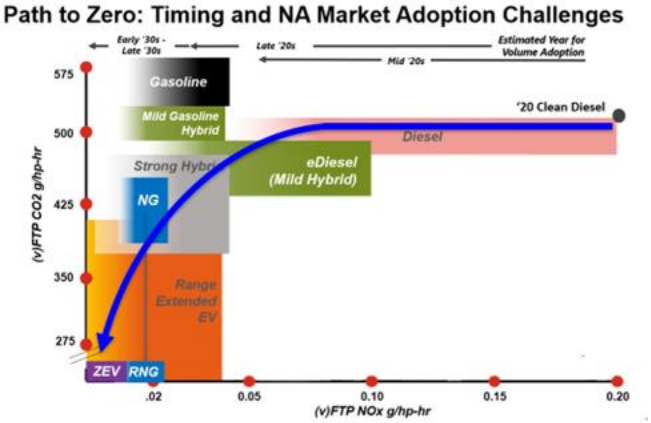

Figure 2: Path to ZEV (zero emissions vehicle)

D. Industry Trends for CO2 improvement:

In line with the report "Reducing Fuel Consumption and Greenhouse Gas Emissions of Medium- and Heavy-Duty Vehicles, Phase Two" published (Figure 3: Greenhouse gas improvement areas.) by The national Academies of Sciences, Engineering and Medicine, Hybridization, vehicle improvements, connectivity features and usage of low carbon fuel will provide the pathway for reducing overall Greenhouse gas emissions [3]. Cummins has been developing and demonstrating these advanced technologies by participating in the U.S. Department of Energy sponsored programs like Super Truck, Super Truck 2 and recently Super Truck 3 [4], NextCAR [5] and co-funded programs like Advanced Platooning with Advanced Driver-Assistance Systems [6].

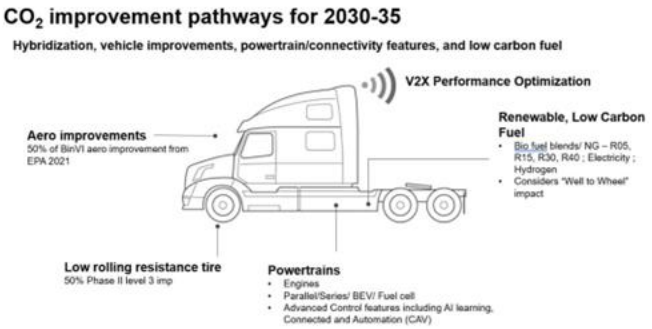

Figure 3: Greenhouse gas improvement areas

DISRUPTIVE TECHNOLOGIES - CATCHING THE WAVE

In their article 'Disruptive Technologies - Catching the Wave' [7], Joseph L. Bower and Clayton M. Christensen prescribes a **four-step guide** to prevent disruptive technologies from slipping through their fingers, established organizations must learn how to identify and nurture innovations on a more modest scale, so that small orders are meaningful, ill-defined markets have time to mature and overhead is low enough to permit early profits. We will analyze and evaluate Cummins' decision to invest in Hydrogen Technology based on this guide.

Step1: Determine whether the technology is disruptive or sustaining.

"Hydrogen is today enjoying unprecedented momentum. The world should not miss this unique chance to make hydrogen an important part of our clean and secure energy future."*by Dr. Fatih Birol.* [8] *(Executive Director,* International Energy Agency (IEA)).

According to a report published by the IEA in June 2019, hydrogen has potential to tackle various critical energy challenges, and this is the right time to tap into hydrogen's potential to play a key role in a clean, secure and affordable energy future. Hydrogen is versatile and available in abundance. Technologies are already available today that enable hydrogen to produce, store, move and use energy in different ways. Hydrogen can enable renewable energy sources (wind and solar) to be converted and stored effectively for days, weeks or even months. Though there was a false start for hydrogen technology in the past, due to the versatility of hydrogen, a diverse group of governments and companies has shown stronger interest in it. Industries like renewable electricity suppliers, industrial gas producers, electricity and gas utilities, automakers, oil and gas companies, major engineering firms and local governments are interested in investing and using this technology [8].

Today, hydrogen is used mostly in oil refineries and by fertilizer manufacturers. For it to be adopted by the wider industry, transition to clean hydrogen production is the key. There are various sources for hydrogen to be produced. Figure 4 shows how hydrogen can be produced and utilized in various industries. [9] [10]

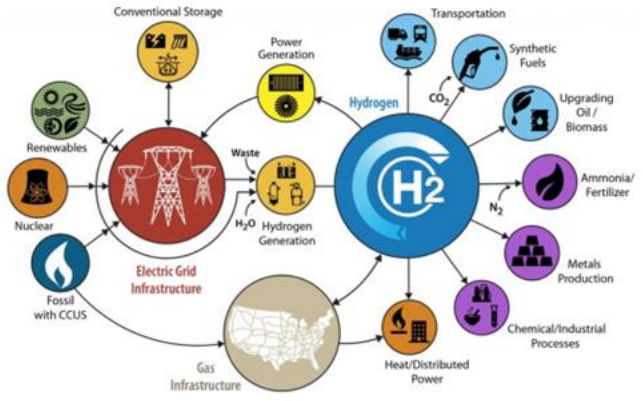

Figure 4: Hydrogen production and utilization. [9]

Based on the source of hydrogen, it is categorized in 3 different types as shown in Table *2*: Types of Hydrogen Based on Source.

Table 2: Types of Hydrogen Based on Source *[11]*

Gray hydrogen	**Natural Gas**	**No Carboncapture**	**High GHG emission**	**$1-$2.1/kg**
Blue hydrogen	Natural Gas	Carbon capture	>95% reduction in GHG	$1.5-$2.9/kg
Green hydrogen	Water & renewable energy	Zero carbon	100% reduction in GHG	$3-$7.5/kg

Today, cost of producing green hydrogen is high, but IEA analysis finds that the cost of producing hydrogen from renewable electricity will fall by 30%. Mass production of electrolyzers, fuel cells and refueling equipment will help to lower this cost further down [9] [10].

Step2: Define the strategic significance of the disruptive technology.

Every 3 - 4 years, government agencies across the world revise the emissions limit for the automotive sector. For the past two decades, engine companies like Cummins were successfully able to meet these targets for diesel engines through innovations in engine and aftertreatment technologies. But from 2024 onwards, it will become extremely difficult to meet the emissions target through engine only solutions. Newer emissions standards are already demanding hybrid electrification solutions. According to the strategic plan to reach 2030 climate targets, through significant investments Germany targets around 7 to 10 million cars and one third of their Freight transportation running on electric engines or electricity-based fuels [12]. Going forward, regulations will become tighter which will force powertrain companies to move towards a partial or full electric solution. 'Battery Technologies' and 'Fuel Cell' technologies will be key enablers.

For pure electric vehicles, Lithium-Ion batteries are used as energy sources. Though there are various advantages with this battery technology, there exists significant barriers for them to be adopted for heavy-duty trucks. The industry needs significant technology innovation in battery chemistry - improving its energy density, cost, weight, range, charging time, temperature variations, thermal management and life. These factors are the inhibitors for its adoption in heavy-duty long-haul trucks [3].

Hydrogen fuel cell provides the best alternative for continuous source of clean electricity. Cummins's acquisition of 'Hydrogenics' provides the best hydrogen production and fuel cell capabilities. Hydrogenics' electrolyzers will enable Cummins to shape the infrastructure for hydrogen refueling and fuel cells will provide the energy to its powertrains and / or charge the batteries on the go. Cummins has committed to invest in clean electricity production technologies through their 'Power Systems' business unit by means of establishing 'micro grids' where fuel cells will be one of the energy sources. This technology will help to generate clean electricity by managing optimal combinations of renewable and non-renewable energy sources and reducing CO_2. Packaging electrolyzers and micro grids help Cummins to achieve their path to produce green hydrogen and zero-emissions products. [2] [13]

Step3: Locate the initial market for the disruptive technology.

Hydrogen Market Trend: According to IEA, the current annual global demand for hydrogen is 70M tons. The demand for hydrogen is going to increase worldwide due to growing support around the world. With the policies favoring investments in hydrogen technology, it is projected that hydrogen demand will grow up to 500M tons by 2050. This demand will be generated primarily due to increased use of hydrogen in transportation, residential use, and power generation apart from existing industrial use. [8]

Hydrogen Council projects seven key application areas (**Error! Reference source not found.**) where hydrogen can offer economically viable and socially beneficial solutions. Council projects that by 2050, hydrogen can power a global fleet of more than 400M cars, 15 to 20M trucks and around 5M buses, which constitute on average 20-25% of their respective transportation segment. In the power generation sector, hydrogen could provide roughly 1,500 TWh of electricity and 10% of the heat and power jointly required by household and industry sectors [14] [15]. With the initiatives from IEA, Hydrogen Council and the U.S. DOE, current uses of hydrogen as industry feedstock can be decarbonized. Cummins has joined the Hydrogen Council and partnered with Air Liquide to be part of the next $2.5 trillion Hydrogen Economy [16].

H2@Scale is an initiative by the US Government Department of Energy (DOE). According to DOE current US demand for Hydrogen is 10M tons and this demand is going to increase as H2@Scale initiative. DOE will invest in R&D various industries to boost the production of green hydrogen and use the Hydrogen based technology in various applications. This will help the US meet its clean energy needs domestically and meet Planet 2050 goals [15].

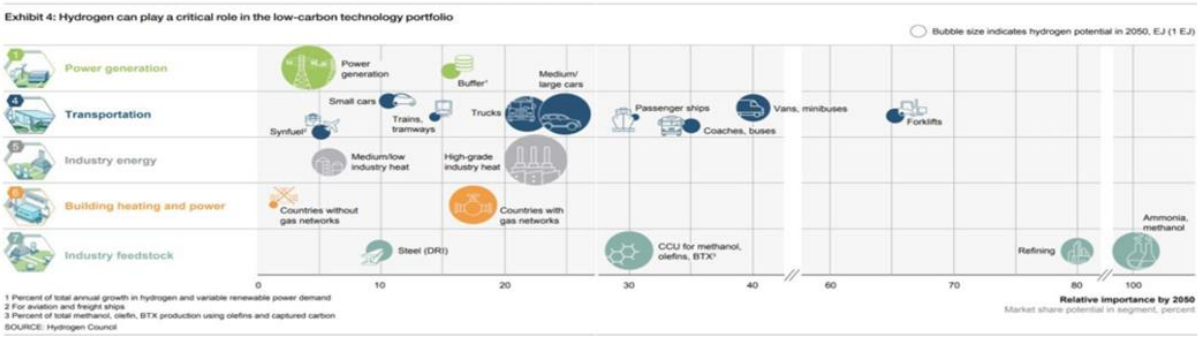

Figure 5: Role of Hydrogen in low carbon technology portfolio. [14] [15]

Like IEA and Hydrogen Counsel projected various use cases for Hydrogen, Cummins sees growing demand for electrolyzers in the traditional industrial market to replace gray hydrogen with green. To tap the full potential of Hydrogenics, Cummins plans to launch fuel cell based powertrains for buses, trucks, trains, boats and off-highway. For stationary power generation use cases, Cummins has partnered with big data centers to provide micro grid solutions [16].

Step4: House the disruptive technology in an independent entity

Cummins has a corporate research group which reports directly to the CTO (Chief Technical Officer), most of the early electrification research was conducted within this group. This included demo projects, govt. funded research work and smaller projects for a small customer like an airport converting its transit buses to EV. There was initial discussion about placing these new technologies under 'Component Business Unit' as they would be sold as standalone systems. However, with the developments in the industry Cummins made the right decision to form a new business unit in 2017 called 'New Power' [16].

This business unit is at par with other businesses with its leader, a company vice president reporting directly to the COO (Chief Operating Officer) of the company. The employee's pay and salary grades are the same and the bonus is averaged (same) for all business units of the company (by country), which is similar to the recommendation in the article.

An old plant that used to manufacture X15's older version has been repositioned for 'New Power'. Between 2019 and 2020, net sales grew from $38M to $72M. However, losses increased from 148M to 172M. Cummins continues to support this Business Unit as an investment in its future.

CONCLUSION

Considering all the information and evidence, we can conclude that **Cummins has chosen the right strategy**. Doing nothing and relying on Diesel Engine is not a practical strategy, a lot of companies have gone that path and demised. Even though Internal Combustion Engines have ruled for the last century, it is evident that disruptors will make their way from automotive to commercial applications. Cummins is lucky that it has got some time due to battery limitations, this also means that some kind of engine or source needs to power or charge the batteries on the go. As of today, it seems like Hydrogen to be disruptive technology, but it may change in the near future.

Cummins has been late to Digital Transformation; and yet to realize Digital as a business opportunity. There are similar traits in 'New Power' - rather than taking an aggressive approach, it seemed to move slower than competition. In diesel engine technologies, Cummins has been shaping the market. However, for new disruptive technologies they have not been able to come up with a differentiating product. They need to be very agile and move quickly in this changing environment.

RISK & MITIGATION

These new technologies come with a lot of uncertainty; this is a disruption that Cummins has not experienced in its 102 yr. history. It must evaluate risks and be ready with an action plan or risk others leapfrogging it quickly.

1. **Full EV's are able to power a heavy-duty semi-truck and Hydrogen fuel cells are not required:** Continue to invest in full EV technologies and keep a close eye on the competition.

2. **Hydrogen fuel cells are not able to provide power at the same level as a diesel X15:** Create a flexible product portfolio as this technology continues to improve. Evaluate alternative fuels that are cleaner than diesel but less complicated and lower cost.
3. **Hydrogen storage seems a challenge and the cost of thick and heavy cylinders continues to deter the customer due to the high initial cost of the truck:** Consider participating in investing in Hydrogen infrastructure in the early stages of adoption.
4. **A new technology that may act as a source of 'on the go charging' emerges:** Cummins can adopt parallel play strategy to monitor new developments in the industry. Continue to invest in R&D of other alternatives and partner with government agencies, universities, and research groups.
5. **Workforce morale:** It takes a long time for an employee to gain proficiency with diesel engine development, the company should actively start retraining their workforce for new technologies so that they can be redeployed quickly without much disruption.
6. **Loss of interim revenue:** Cummins is a Fortune 500 company with a dividend higher than its competitors leading to a higher stock price. They need to stay transparent with the stockholders of the company for possible challenges.

FUTURE RECOMMENDATION

It is possible that despite all the above plans, they may still not get large OEM business and suffer an exponential business loss. They should start a separate strategy project to evaluate a backup plan, that will probably bring about a "Transformational Change' but will be required to survive. From our SWOT analysis, some of the things they can evaluate could be:

1. Becoming an OEM themselves - i.e. start developing their own commercial vehicles.
2. Repurpose powertrain technology to some other application like clean power generation, power grid management.
3. Target industries that currently use other types of Internal Combustion engines like gas turbines for aviation, marine etc.
4. Become an EV component supplier.

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