Vehicle of the Future/Electric **May 10, 2018** John Arendshorst

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INTRO:

The origin of "Compelling and Extraordinary Conditions" -Brief history of standards for pollution controls.

3-4

The story of electric cars begins with the air we breathe.

Air pollution was a growing post WWII problem. Big US cities were having "pollution attacks" with resultant deaths sometimes in the hundreds.

The problem had been around and intensifying especially in Southern California since the late 1940s. In the 1950s it was officially recognized that dangerous smog was a real health problem.

In 1950s, eye irritation was reported in LA County on a daily basis for more than half the year. The source had been a mystery. Beginning in 1947, LA had reduced sulfur dioxide emissions by banning the use of coal and fuel oils for industrial purposes, but smog continued to increase. Researchers all across California had been trying to figure out the source, without success.

5-6

Cal Tech chemist Arie Jan Hagen-Smit (Dutch) discovered in 1952 that worsening LA smog episodes were caused by photochemical reactions between California's sunshine and nitrogen oxides and unburned hydrocarbons in *motor vehicle exhaust*.

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This soup then incubated in the unique enclosed topography, and with a rapidly growing population, and number of vehicles.

Los Angeles was the first real urban center with concern over auto emissions. It became the *living laboratory* for studying the causes and effects of massive doses of smog.

To its credit, Congress enacted the National Air Pollution Control Act in 1955 to generate research on air pollution and its causes. The Air Quality Act and the Motor Vehicle Air Pollution Act of followed in 1965.

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California's Motor Pollution Control Board - 1961 mandated use of vehicle emissions control technology (PCV valve for crankcases) .

In 1967 the *California Air Resources Board* was established (Gov. Regan) and developed the first vehicle emissions standards in the nation.

The federal government recognized that California's air quality research establishment was likely the best in the world.

What followed, the *first national standards* for car exhaust emissions were made for the 1968 model year cars, and were identical to California's model.

This pattern of California innovation and federal regulators piggybacking on the state's demonstrated success *"iterative (repetitive) federalism"*. This process has been repeated since then.

Vehicle of the Future: Electric

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At the time of the 1901 Olds automobile Curved Dash, the automotive industry in America was made up of small independent firms turning out a few cars. It was only a tiny part of the global economy.

Now automotive manufacturing accounts for trillions of economic output. Nearly 90 million units were manufactured worldwide in 2017. The automobile's importance to growth, trade, innovation, military technology, and the environment is practically immeasurable.

As the world of automotive manufacturing continues to evolve ever more rapidly, the players who are at the top of the heap of all these advances will have dominance over a rapidly expanding share of the international economy, and the global market for vehicle of the future.

The competition will be won by those distancing themselves from the fossil fueled internal combustion engine, with its emissions and greenhouse gas production, toward alternative fuels and propulsion systems. The future of transportation will most likely be the **Fully Electric Vehicle.**

History of the Global Automobile

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The idea of an automobile started happening around 1900.
Steam and electric vehicles were the first.

11-15

Electric vehicles (EVs) were dominant for about the first 10 years, and were produced in larger numbers than the internal combustion engine (ICE) powered vehicles.
In contrast to the ICE vehicles, EV was quiet, did not smell bad, were reliable, and easy and safe to use. Electric taxis were in the major US cities. The EV was by far favored by women motorists.
Even Thomas Edison worked on the development of a competitive EV.

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By 1910, the internal combustion engine vehicle, had *attained dominance.*

-the ICE car became *less expensive* to buy that the Electric Vehicle. (mass production efficiencies
-the increasing availability of gasoline
-the quickness of re-fueling

-the increasing demand for *vehicle range* - no battery then could match the energy density of gas or diesel.
-ICE cars became safer to operate with the invention of the *electric starter.*

All these issues made the ICE vehicle's performance envelope compromise more attractive.

Oil and the Internal Combustion Engine ruled for the remainder of that century.

17-18-19

By 1910, Ford was producing 20,000 cars annually.
By 1924 Ford puts out Ten Millionth Model T
By 1930, automobile production had consolidated to mainly Ford, GM, and Chrysler. Each of these companies attained and persisted in global dominance by harnessing the powers of Oil, the Internal combustion, and economies of scale.

Autos became militarily important.

-WW I saw the development of the tank, motorized troop transports, and other weaponized vehicles.
-The U.S. produced 3.5 million motorized vehicles in 1938.
-Japan, Germany, and Italy combined produced about 437,000 vehicles in 1938,
-The UK, alone 445,000.

After 1941, the US automotive industry became the heart of the "Arsenal of Democracy".The auto industry built over 4 million engines (including 450,000 aircraft engines and 170,000 marine engines), 5.9 million guns, 27,000 aircraft.

After WWII the market for automobiles boomed. The Federal Interstate system was started.

20-21

Ralph Nader's 1965 *Unsafe at Any Speed:The Designed-In Dangers of the American Automobile* caused a stir, pointing out the dangers of all these modern cars. This symbolized the *beginning of the battle between auto producers and regulators* - in safety, efficiency, emissions, and quality.

The most serious new problem with all this growth in numbers and use of the automobile, reiterated by Nader, was *emissions*.

(((The Environment had by then become a major public concern. The overall lack of effect, and lackluster implementation by the states, of the existing laws led to Nixon's 1970 National Environmental Policy Act.

He declared: "…the 1970s *absolutely must* be the years when America pays its debt to the past by reclaiming the purity of the air, its waters, and our living environment. It is literally now or never."

The *Clean Air Act of 1970* set national automobile emission standards., and also the establishment of the EPA. **)))**

The Path to the Electric Vehicle

New Beginnings: Challenges to US Auto Industry: Japan , GM's EV1, the Prius
22-23
In the 1970s, at the Big Automakers, quality control began to go lax. An early 70s car went out the door with more than two dozen defects on average.

Also, with more awareness of the negative environmental and health impact of car emissions, people became more interested in smaller, gas efficient, lower cost (and for the auto makers lower profit-margin) cars,

Japanese imports, for the same reasons, were gaining momentum.
The Japanese cars of 1975 were a real threat to American auto makers.

-better quality than the US equivalent.
-about $1,000 less expensive.
-Japanese automakers were 50% more productive than American counterparts.

They also recognized that if they could meet California Air Resource Board (CARB) emission standards, they would also meet all standards for the remainder of the U.S.

Japan's regulators believed they had to meet these goals to export to America. So…those regulations considered "unreasonably" strict by U.S. automakers, steered Japan's entire auto industry to make changes that ended up putting it a decade ahead in their understanding of emissions control technology.

They learned that keeping ahead of the regulatory curve in fuel efficiency and emissions could be a comparative and competitive advantage.

This was the new future of pushing far beyond what regulators required, later including hybrids and electric cars.

By 1980, less than 10% of small cars in the US market were American. Japan had become America's largest source of automotive imports.

24-
The ZEV and the EV1

In January 1990, GM chairman Roger Smith demonstrated the *Impact*, an electric concept car, at the 1990 LA Auto Show. The car had been developed by electric vehicle company AeroVironment, using design knowledge gained its role with GM in participation in the 1987 World Solar Challenge, a trans-Australia race for solar vehicles, with the Sunraycer, which went on to *scorch* the competition.

Alan Cocconi of AC Propulsion designed and built the original drive controller electronics for the Impact, and the design was later refined by Hughes Electronics.

It utilized an array of stunning innovations:including -An electric motor drive, and regenerative braking.

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The, *Impact,* with silent operation, no tailpipe, went "further and faster than any previous production-oriented electric vehicle".
On April 18, 1990, GM announced that the Impact would become a production vehicle.

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Well….for the CARB regulators, this was proof-of-concept that a zero emission vehicle (ZEV) was technically possible and incentivize the auto manufacturers into making progressively lower emissions vehicles.

This supported CARB's goal of including their regulatory target of *Zero Emission Vehicles. Zero-Emissions* vehicles would require an entirely new collection of hardware and software, as demonstrated in the IMPACT.

CARB's new rule stated that by 1998, 2% of new vehicles would be required to be ZEVs, up to 10% ZEVs by 2003.

The intent of the mandate was the development and deployment of *Electric Cars.*

The automakers said the mandate was overly ambitious, unreasonable, and punitively expensive. But they had no real option, as CARB's influence was not only nation-wide but international.

In 1996, CARB agreed to postpone the 1998 mandate deadline until 2003. In exchange, the ZEV percentage of the fleets went to 10% (from2), with no ramp-up period.

So, when California started to loosen its regulations, GM decided to *end its EV1* program..dramatically. by 2002 they were all recalled, put in parking lots, "unceremoniously crushed". (other car manufacturer's EV attempts were similarly shredded).

Rumors abounded as to the auto manufacturer's reasoning…and there was a widespread and vocal outcry - documentary *Who Killed the Electric Car…*

The list of possible culprits behind the EV demise idea:

-Car companies
-Oil industry
-Party politics - Republicans were increasingly positioning themselves as opponents of new environmental technologies and alternatives to oil/gas based transportation.
-CARB itself - recalibrating regulations when it became apparent that the mandate was not working out as planned.
-EV costs were high,
-Battery technology development had stalled
-Range remained a problem for the present EV to satisfy consumers.
-There was also concern about the need to back fuel cell development (which Washington was pushing heavily).

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It turned out, apparently, that at that time, EV technology was not merely a challenge, it was not ready/possible. The lead acid or metal hydride batteries did not have enough energy density, and were extremely expensive.

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Prius

Meanwhile, Japan knew their companies at the time were the best in the world at combining price, quality, and fuel economy.

In 1994, Toyota's leadership decided to respond to these challenges and build "the car of the future", a car built to survive a changing power-resource environment and with reduced emissions.

The result - the *Prius.*

The Prius was a car developed completely from scratch. The resultant computer-linked combination electric motor and brand-new highly efficient engine was brilliantly engineered. The first Prius was designed and the first version on the roads in 1997.

The 2004 introduction of the second generation Prius was very successful. Toyota was selling the hybrid Prius well:

-better overall design,
-improved motor-engine interface,
-improved *Lithium Ion* batteries and range.
-The Japanese government was subsidizing the development of hybrid technology, which helped Toyota get through the first slow, revenue-losing years of the initial development program

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Greenhouse Gas (GHG) Slide:

-Clean Air Act 1970
National Emissions Standards & EPA established
-Corporate Average Fuel Economy (CAFE) standards 1975
-Clean Air Act Amendments 2004-2009
-National Highway Traffic Safety Administration establishes (NHTSA) new CAFE standards
-EPA establishes new GHG emission regulations
-2007 - CO_2 ruled a Greenhouse Gas and proportional to miles/gallon
- NHTSA and EPA updates emission targets
CAFE = CO_2 = Greenhouse Gas

The Return of the EV

The EV Re-emergence in America

30-34

Tesla Motors, named for Nikola Tesla, the prolific electronics inventor, began when engineer Martin Eberhart wanted to build the best, most fuel-efficient sports car.

He and had visited Alan Cocconi of AC Propulsion, who designed and built the original AC drive controller electronics for the I*mpact*, and was demonstrated in AC P's experimental car, the *TZERO.* He used this as the basis for the new Tesla drivetrain.

After a leadership reorganization, with Elon Musk now the company head, and out-of-control start-up costs, and sanity challenges, what emerged the *Tesla Roadster*.

It was an expensive, very sheik, very high performance production electric car.

So, with the Tesla Roadster, in America the electric vehicle was back! Emerging from a Silicon Valley start-up, not Detroit.

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GM, also being out-chased in the efficiency/clean arena by Toyota's Prius, decided once again to make an EV.

The Chevy *Volt* was first shown as a concept car at the 2007 Detroit Auto Show. The reception was so strong, that GM then had to actually make and market the actual car!

The Volt's development team, by 2008 was huge and on a huge budget. The "range extended EV" had a small IC engine to top off the batteries for the electric drive train. Development had many pitfalls and it looked for a while like GM just couldn't get the product going. The Volt was first offered to consumers as MY 2011.

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All this was amidst the Crash and Bailout (The Great Recession) scenario of 2008-9.

As an important caveat of the bailout was partial ownership of GM and Chrysler which gave the government massive and direct regulatory leverage over the US auto sector.

The result was that EPA and DOT Standards were an accelerated application of the fuel economy goals from the *2007 Energy Independence and Security Act.* In 2009, these goals were revised for 2009-2016 phase, and for the 2017-2025 phase. Resulting targets:

-35mpg by 2016
-54.5 mpg by 2025
-Tax subsidies for EVs. Up to $7,500 for the first 200,000 cars sold by a manufacturer.
-Funds for infrastructure deployment. Federal incentives (tax rebates) were available for installing EV chargers.

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By 2012, *Japanese Electric Vehicles* had become dominant in the EV market of Japan, Europe and North America.

The Japanese government's industrial policy and state-corporate collaborations were allowing EVs to flourish, and slowly move its transportation sector away from fossil fueled transportation. The Japanese government helped this program also by granting generous subsidies to EV purchasers.

New technology enabled a *vastly improved* EV system.

-The heart of the new EV technology was the new *Lithium-ion batteries' performance and range*.

-More compact, powerful, and efficient *electric motors made with rare earth elements* also made a huge difference.

Nissan bought NEC, a battery company, and brought the whole package to market as the "Leading Environmentally-Friendly Affordable Family Car" - the *LEAF*.

LEAF sales did very well. Nissan also spearheaded infrastructure, installed 800 fast chargers in its dealerships. Japan's government, collaborating with Nissan, deployed and supported a massive network of charging stations.

38-40

The next big EV event in the story of the world EV: *Tesla Model S*

Tesla launched its Model S in June 2012. It was a full-sized sedan. It had acceleration and handling of a super performance car. It had the best safety rating ever. Consumer Reports called the Model S the best car it had ever driven.

In 2013 it was the luxury car segment car to get. Style, substance, technology, and sizzle all in one package.

The car was also being shipped to Europe, Japan and China. The company also established a network of "superchargers" across the US, Europe, and China.

The EV today…and the Future:

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The technology of EVs: What compromises and Electric Vehicle

Its heart is the *Induction Motor.*

AC power input creates a rotating magnetic field which induces current on the central rotor bar to make it turn. Very powerful rotation is created by the AC power supply. Induction motors as a result have a huge power to weight advantage over IC engines.

The battery pack delivers DC power which must be converted to AC by an *Inverter*.

The inverter is also the AC frequent controller to modulate resultant motor speed. It also modulates the AC amplitude, thus controlling the overall power of the motor. Thus the Inverter acts as the brain of the electric car drivetrain.

The *Battery pack* is a collection of Lithium-Ion cells with a temperature control coolant system. The battery pack is commonly in the lowest possible position in the vehicle to keep the center of gravity low. That improves car stability and handling, generates interior space and gives the car structural integrity in side collisions.

Transmission - a single speed gear box as the motor's power/speed curve is very flat. Its purpose is only for motor-to-wheel speed reduction gearing, and for torque multiplication functions.

Regenerative Braking system - this system saves the kinetic energy of the car as electricity rather than wasting it as heat. This braking comes into action any time the accelerator pedal is released. Magnetic field drag on the rotor speed slows the car down.

The same induction drive motor then acts as an electrical generator and replenishes the battery pack.

EV Ownership Benefits

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1) Electric Cars Pleasant and Fun

1. Love that Torque - throws you back into your seat. Formerly took huge engine
2. Silence -
3. Always full - habit of plugging in at night, unplugging in am
4. Very smooth in all traffic conditions - no clutch, no gear changes, just rest you foot on the accelerator, and , like those big electric trains, go oh! we're moving !
5. Heat and air instantly even with engine off, e.g. waiting at "idle" somewhere
6. No/little maintenance. No oil changes, no tune-ups, ..tire rotation maybe
7. Cold weather warm-up - nope, instant warm from the vents..think of a space heater
8. Clean garage
9. No Smell - imagine NYC in 1900. Horse crap all over, with around the clock team to attempt to control the pollution and smell. EV cabs were a perfect solution even back then!

43-46

2) Electric Car is Less Polluting

To really compare the pollution and c*limate-change emissions* of an Electric Vehicle with an Internal Combustion vehicle, the vehicle's *life-cycle basis* needs to be considered.

That includes every phase from manufacturing the vehicle and battery, the vehicles operation, maintenance, and material disposal/re-use. Each phase is linked with carbon dioxide and other greenhouse gas emissions.

Both IC and EV begin with the extraction, refinement, transportation, and manufacturing of the *parts that are assembled* into the complete car body.

Batteries, now Lithium-ion technology, are especially material and energy-intensive to produce. So the global warming impact of the Electric Vehicle at that stage is relatively much higher than an IC vehicle.

The overall effect changes as the actual driving and use part of the life-cycle takes place. Battery electric cars *make up for* their higher manufacturing emissions in about the first year of use (shorter range batteries in less than 6 months), and continue to outperform the IC car from then on

The climate change emissions created buy driving on electricity depend on where you live, reflecting the primary electricity generation methods of that area.

The electric vehicle continues to improve over IC cars as the grid gets gleaner, as we continue to shift away from coal and add more renewables. Thus existing EVs can get even cleaner over time. The EVs sold years ago can now run much cleaner that where they were purchased.

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The recent (Feb. '18) data also shows that EVs are cleaner for most drivers in the US.

On average, an EV driving on electricity in the US today is equivalent to a conventional gasoline car that gets 80mpg, up from 73mpg in 2017.

75% of folks now live where EVs are cleaner than a 50 mpg IC car. Where people have already bought an EV, the advantage is comparable to an 80 mpg IC. car.

47 SLIDE Ownership Benefits:

3) EV Progressively less expensive

- Initial cost of EV higher
- Battery cost drives EV manufacturing cost
- Battery technology evolves: improving rapidly
- Priority research goal = lower cost, more power-dense battery
  - Power density increasing: Li-ion -> Li-silicon -> metal-air (ultimate)
  - Battery evolution happening even faster than anticipated = rapidly decreasing costs
- EV costs coming down - prices now nearly equal to similar ICE car
  - less expensive battery = lower electric car pricing
  - longer battery range: Range Anxiety -> Range Confidence
  - Federal Income Tax Credits for EV - up to $7,500 for first 200,000 sold of a model.

48-50

Battery Manufacture

Read slide

In 2014, plans were initiated to build a Tesla (in partnership with Panasonic) lithium-ion Gigafactory in Nevada. It idea was to become also a major battery manufacturer, with projected output exceeding the present total global production of lithium-ion batteries.

The overall goal is to drive battery, and therefore EV drive-train costs down to and below the costs of the gas/ICE drivetrain. It would be especially helpful go drive battery prices down in time for their lower cost sedan, the *Model 3*.

Model 3 production, to date, has been the promise of The Affordable Electric Car. It is the most tech-advanced platform and production facility yet by Tesla. There have been several production hiccups early-on. The promise is that later this year they will be close to their 20k vehicle/mo goals. There are more that 500,000 advanced deposits for the Model 3.

51-52 Read Slide

(4) Cheaper to Operate

- Operation of EV > 50% more case effective than gas car
- EV Cheaper to maintain - no gearbox, very few engine moving parts, no Oil changes
- Little or no routine maintenance
- Median savings $800/yr. (e.g. Chevy Bolt chg = $7 vs $23 for 200 mi trip 2018)
- National average electricity costs are stable
  - cleaner power ever more prevalent and progressively cheaper
  - off-peak times cheapest

So, although the initial cost to buy an EV may be higher that a comparable gas-powered car, a crossover point typically occurs within the first year of ownership, and for the life of the vehicle thereafter. This divergence happens much earlier within the luxury vehicle segment.

53-55

Recommendations for drivers considering an EV: **(Union of Concerned Scientists, Inc.)**

-Evaluate the ability to get electric power where you intend to park and EV
-Find out about rate options available for charging an EV
-Research the availability of state local, and electricity -provider incentives for buying an EV or EV charging equipment.

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Charging:

The easy availability of charging will require continued rapid development. Subsidies for public and private charger installations will incentivize this needed rapid growth.

The standardization of the fast-charging infrastructure also needs to be addressed. Fast charging enables an 80% EV battery charge in 15-20 min.
There are presently 4 charger plugs in use:

-The J1772 plug standard (Combined Charging System CCS)-developed by BMW, GM, and Daimler
-CHAdeMO, or Charge de Move, developed by Japanese firms including carmakers Nissan and Mitsubishi

-The Tesla Supercharger - Tesla is building a global network of superchargers powered by solar panels, the idea being that they don't have to wait for any other infrastructure to be built, offering Tesla drivers nearly unlimited range.
-GB/T in China, the world's biggest electric car market.

56 Read Slide

EV Today - Rapid Growth Worldwide

Until now, EV about 1% of the global market
- Range and infrastructure concerns
- Requisite lifestyle/pattern changes - home charging routine, finding charging when traveling
- Presently, 80% of car use within radius of today's average-range EV

57-58-59-60-62 Read Slides

Today Looking Forward: Rapid Growth Worldwide

Now there are a lot more choices. The long range, mass-market EVs (Bolt, Tesla 3) are now here. These address these new concerns of EVs and will likely change how life with and EV would be.

Global sales of EVs are projected to be 2 million by 2019.
China - in 2017 50% of global market share of EVs
Europe - 26% global marke

In the past year there has been a slew of announcements from major automakers about their plans for the EV market.

Most car manufacturers have definite plans to include, if not entirely replace, their future car line-up with EVs. Most of these companies have huge R&D ongoing for EVs, and have roll-out plans for a number of models within a year to 18 mos.

The projection is a potential of 400 models and global sales of 25 million by 2025.

- Porsche - 50% electric by 2023
- Jag/LRover - entirely electric and hybrid by 2020
- GM, Toyota, Volvo - 1 million in sales by 2025
- BMW - 12 EVs by 2025
- Renault Nissan and Mitsubishi - 12 new EVs by 2022

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EV TODAY - Read Slide

Attaining the EPA mandated target of 54.5 ave mpg is a technological challenge. The best path to attain these goals and beyond is the EV

64 Read Slide
The EV is an integral part of a Global Sustainable- Energy Transportation System

65 Global Electric Vehicle: Who Benefits?
Potentially the largest financial beneficiaries of the EV market may be the energy and petrochemical companies. They are committed to expanding charging infrastructure and have started investing heavily in charging stations. (Example: Shell acquired 'The New Motion", the largest infrastructure operator in the Netherlands, with 30,000 stations)

The cost-of-ownership seems clear-cut. Life rhythms getting used to charge-up times will be less of a hurdle with faster charging times, longer battery ranges, and more infrastructure support for charging ease and speed.

New charging technology is developing rapidly.
Next is likely ultra-fast charging and inductive wireless charging. Wireless inductive charging is now possible in some new EVs (MB).

Roadways with integrated charging systems now being tested

So - Will the ownership cost benefit, and the fun of driving, and the altruistic knowledge that your are actually driving a much cleaner vehicle be enough reason to actually make the plunge and adjust your driving life-style to actually do this???

I think so!

Appendix One
A Brief Note on the Hydrogen Fuel Cell

The Bush administration then, with the administration's ubiquitous use of Freedom precursor, came up with the description of his Freedom Car. Its description carried the Bush administration's thinly cloaked perspective on energy and transportation policy. The Freedom Car program was to embrace the concepts:

-freedom for Americans to choose the kind of vehicle they want to drive
-freedom for Americans to drive where they want, when they want.
-freedom to obtain feel affordably and conveniently

—-all a blast against mandates for higher fuel efficiency and against Electric Vehicles.

This all meant also that federal research programs were to move away from batteries and hybrids, and increasingly focused on incremental improvements to the efficiency of IC engines and a long-term goal of promoting hydrogen fuel cells.

To clarify further; the entire Bush administration program was based on fossil fuels - IC engines run on gas or diesel, Hydrogen refined from natural gas or coal. Fuel Cell research was the new buzz word. The Freedom Car program participants by 2005 also included ExxonMobil, BP, Shell Hydrogen, and ConocoPhillips.

The running joke was that hydrogen was the fuel of the future, always had been the fuel of the future, and always would be the fuel of the future. !

Hydrogen fuel cells are still in the mix for a few.

Infrastructure is a problem for hydrogen. Production, storage and delivery systems would need to be built at tremendous cost. The production of hydrogen fuel generates greenhouse gasses that make its use benefits a marginal gain.

The hydrogen model, is, however, attractive to oil companies who would be refining hydrogen and running refueling stations. Car companies also have some fondness for the platform, as it provides the range similar to a petrol car so they don't need to start consumer education over again. They could also manufacture the fuel cells.

So, there may be some long-term benefits, but with a ton of near-term hurdles.

Appendix 2
April 2018 EPA announces intent to lower Clean Air Act 2025 targets

The *Clean Air Act* empowers the EPA to regulate air pollution from motor vehicles nationwide.

By the time the Clean Air Act was passed, California was already developing laws and standards for handling its unique air pollution problems. So, Congress carved out an *exemption* for California's unique situation.

As long as California's standards to protect public health and welfare were *at least as strict as federal law, and are necessary "to meet compelling and extraordinary conditions"*, the Clean Air Act law requires the EPA to grant California a waiver so it can continue to apply its own regulations.

So California has received numerous waivers as it has worked to reduce vehicle emissions by enacting progressively more stringent standards since the 1960s.

Other states can't set their own standards, but can opt to follow California's motor vehicle emission regulations. Currently 12 states and DC have adopted California's standards.

The origin of "Compelling and Extraordinary Conditions" -Brief history of standards for pollution controls.

Air pollution was a growing post WWII problem. Big US cities were having "pollution attacks" with resultant deaths sometimes in the hundreds.

The problem had been around and intensifying in Southern California since the late 1940s. In the 1950s it was recognized that dangerous smog was a real health problem.

In 1950s, eye irritation was reported in LA County daily for more than half the year. The source had been a mystery. Beginning in 1947, LA had reduced sulfur dioxide emissions by banning the use of coal and fuel oils of industrial purposes, but smog continued to increase. Researchers all across California had been trying to figure out the source, without success.

Cal Tech chemist Arie Jan Haggen-Smit (Dutch) discovered in 1952 that worsening LA smog episodes were caused by photochemical reactions between California's sunshine and nitrogen oxides and unburned hydrocarbons in *motor vehicle exhaust*. This soup then incubated in the unique enclosed topography, and with a rapidly growing population.

Los Angeles was the first real urban center for concern over auto emissions. It became the living laboratory for studying the causes and effects of massive doses of smog.

Congress enacted the National Air Pollution Control Act in 1955 to generate research on air pollution and its causes.

California's Motor Pollution Control Board - 1961 mandated use of vehicle emissions control technology (PCV valve for crankcases) .
In 1967 the *California Air Resources Board* was established (Gov. Regan) and developed the first vehicle emissions standards in the nation.

The federal government recognized that California's air quality research establishment was likely the best in the world.

The *first national standards* for car exhaust emissions (The Motor Vehicle Air Pollution Act of 1965, and the Air Quality Act) were made for the 1968 model year cars, identical to California's model. ,
This pattern of California innovation and federal regulators piggybacking on the state's demonstrated success *"iterative (repetitive) federalism"*. This process has been repeated since then.

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The *Clean Air Act of 1970* set national automobile emission standards., and also the establishment of the EPA.

Corporate Average Fuel Economy (CAFE) standards became a part of the US auto industry since 1975. It instituted as a method to reduce fuel consumption, and dependency on foreign oil after the oil embargo imposed on the US in 1973.
Clean Air Act Amendments in 1990, phased-in progressively more strict standards of emissions, including the required percentage of a manufacturer's fleet for the Zero Emissions Vehicle (ZEV) as had been in place for California.

In 2004, *CARB* set rules requiring automakers to begin, starting model year 2009, phasing-in lower-emitting cars and light trucks that will collectively emit 22% fewer GHG than 2002 vehicles by 2012, and 30% fewer GHG in MY 2016. These were adopted also by 12 other states.

For the *second phase of the Clean Air Act Amendments, 2004-2009*, the *national* standards were even more attuned to reducing emissions.

* Department of Transportation's National Highway Traffic Safety Administration (NHTSA) establishes Corporate Average Fuel Economy (CAFE) standards
* EPA establishes national emissions and Greenhouse Gas (GHG) emissions standards.

This covered the fact that existing emissions regulations did not cover a primary vehicle exhaust component, CO2. Since CO2 emissions are proportional to the amount of fuel used, the national CAFE (Corporate Average Fuel Economy) regulations are the primary way in which automobile CO2 emissions are regulated.

In 2009, following the Crash-Bailout, Pres. Obama announced a new national fuel economy and emissions policy that carried forward *increasingly strict* emissions standards, ZEV requirements, *and* greenhouse gas emissions.

It states combined fleet fuel economy for an auto manufacturer of cars and trucks will have to average 35.5mpg, based on the CAFE standards, by 2016. That would be 42mpg for cars, and 26mpg for light duty trucks.

in 2012 the EPA passed legislation to revise CAFE and emission standards for cars sold 2017 - 2025.
The standards were projected to result in an average industry fleet wide level of 163 grams/mile of CO2 in model year 2025, which is equivalent to 54.5 miles per gallon.

This phase was published as a "broadly supported national program which conserves billions of barrels of oil, cuts carbon pollution, protects consumer choice, help reduce costs and regulatory complexity and enables long-term planning for automakers."

It would result in the MY 2025 vehicles emitting one-half of the GHG emissions of a MY 2010 vehicle, representing the "most significant federal action ever taken to reduce GHG emissions and improve fuel economy."

This program was supported by auto manufacturers representing over 90% of US vehicle sales, as well as the state of California.

The EPA's expectations were that the majority of improvements to vehicles to attain the new fleet standards would be: advances to the internal combustion engine, increase in *electric cars*, hybrids, and plug-in hybrids.

These rules would put the US at the forefront worldwide in the manufacture of electric and highly fuel-efficient vehicles.

Given that these regulations were to cover a span of 13 years, changing technology would ultimately come to affect a vehicle's efficiency. So, the rule stated that in 2017, and no later than April 1, 2018, the EPA would re-evaluate existing regulations "to determine if they are appropriate for the changing vehicle market" and have the opportunity to propose new regulatory requirements, also referred to as a "midterm review" clause.

It was reviewed by the Obama administration in January 2017, and concluded the program's goals and path remained fine and needed no changes.
The Trump EPA review, released April 2018, overturned the Obama administrion's midterm review and concluded that the MY 2022-25 was not feasible and that the assumptions behind these rules were "optimistic" and can't be met. The review's 38

pages nearly ignored the purpose of the standards, and the costs of continuing to burn gasoline and emit high levels of GHG. The word “climate” never appears, and “carbon” only appears once.

The current California waiver was approved in 2013 as a part of a “Grand Bargain” between California, federal agencies, and automakers. It covers California’s Advanced Clean Cars program, and includes standards to reduce the “conventional” air pollutants (CO, Nitrogen oxides, particulate matter), as well as the GHG standards jointly developed with the EPA and DOT.

The Trump administration is now threatening to revoke this waiver when it decouples the national GHG vehicle standards from California’s standards. The EPA’s Pruitt says he is re-examining the waiver, saying “ cooperative federalism doesn’t mean that one state can dictate standards for the rest of the country”.

This statement has been viewed as a mischaracterization of how the Clean Air Act works. Other states have *voluntarily* chosen to follow California’s rules because they see benefits in reducing air pollution, its associated health risks, addressing the climate change issue, and saving money though documented reduced fuel expenditures and health care costs.

It also creates an uncertain path for automakers. The EPA is sending the message of choosing to be less stringent on CAFE and emissions requirements, and interested in prolonging the internal combustion engine, and promoting the continued growth of larger, less fuel efficient, higher polluting pickups trucks and SUVs.
The resulting hesitation in the continued implementation of new vehicle technology R&D here in the US will be very costly as the rest of the industrial world carries forward the vehicles of the future, the Electric Car.
This would result in only a short term gain for US automakers. Long term, as global standards of lowering emissions increase, the US will be left in a position of not being able to effectively compete. Japan, China, and possibly India’s market opportunities and offerings will be increasingly competitive at home and abroad.

Court battles are in process with the suggested “freeze” of present CAFE and GHG standards trajectory to the 2025 targets.

The Future:
EV Answer
The world is building a new energy economy. The investment in capital that would have gone to fossil fuel extraction and imports fossil fuel may be re-directed toward new areas of electric vehicle manufacturing and electrical power distribution infrastructure.

So, globally, the Electric vehicle (EV) stands to be a part of a much larger economic transformation.
It is nearly the perfect answer to present transportation challenges..

Appendix:

China and the EV Today

One version of development and deployment of The Future of the Electric Vehicle can be seen in fast-forward mode in China.

Chinese urban internal combustion-fueled smog is world famous. In addition to reducing coal burning, and moving the industrial sources farther from urban centers, they are successfully removing millions of ICE cars from the streets.

Despite early failed attempts at making a world competitive electric cars, China is now a major player in the EV world.

This is happening as a result of realized limitations, clear definition of need, strategic regulatory directives, strategic deployment of subsidies, and local market opportunities.

They realized that they did not need to necessarily compete with the Teslas of the world in size and range, but rather make vehicles for the masses concentrated in urban areas. The goal of these designs would be smaller, shorter range, and less expensive cars. The EV was the perfect vehicle for the urban commuter and for most rural motoring needs.

Assisting in these efforts was the intentional drive by the Chinese government to rapidly develop and for the population to rapidly adopt the EV as the vehicle of choice.

Government subsidies and tax incentives have been applied to *reduce the purchase price of the cars* since 2014 as part of measures to reduce emissions. Again, the strategy was to have a chosen segment of the EV line for initial subsidy, fade that one out and then subsidize another segment.

The past few years that has led to the rapid growth of the small, shorter range vehicle segment. This is now going to taper off and instead the longer range higher priced EVs will receive government help.

Infrastructure also received governmental help. An extensive public charging station network has been rapidly developed and become operational. 214,000 by the end of 2017, an increase of 50% for the year, and still lagged behind demand. The aim for 2020 is 500,000. Private chargers, often purchased with the car, also has and continues to receive healthy subsidies. 232,000 private charging stations were installed in 2017.

The goal is for to link 3 million charging stations, or “Piles” to the Sate Grid’s intelligent-vehicle online platform by 2020.

China has become a global leader in the development of NEVs (New Energy Vehicles, including electric, hybrid, and some fuel cell vehicles). In 2017, a total of 777, 000 NEVs were sold in the Chinese market, an increase of 53%, and slightly faster than the 2016 growth. The Chinese government expects NEV output and sales to be 2 million annually by 2020.

Over a short period of time the EV has grown. 2017 saw a 30% increase in EV sales.

There are now over 1.7 million EVs on the road in China. In the bigger cities of China, finding a charger is easy and convenient. Running an EV is about one-sixth the cost of a gasoline vehicle there.

Appendix:

***Recommendations for policy makers and electricity providers*:**
-Access to lower-cost electricity rate plans are key to making EVs a reliable and affordable alternative to gasoline vehicles
-Access to reliable and public charging, especially fast-charging stations, are needed for those drivers who cannot charge at home and those who must drive long distances
-Making separate rates for EV and household electricity available could lower the cost for EV charging for more consumers
-Rate plans, pricing mechanisms, and smart-charging technologies that encourage the coordination of EV charging with the availability of renewable electricity sources will decrease charging costs and rather reduce heat-trapping emissions.

***Recommendations for Policymakers and Automakers*:**
-Federal snd state purchase incentives are vital to making EVs and affordable and competitive option
-Incentive programs for lower-income households to adopt EVs will bring the economic benefits for lower fuel costs to communities an demographics the need itht most but currently lack the ability to ingest in an EV.
-Public policies that encourage manufacturers to product higher volumes of EVs and encourage a greater diversity of electric-drive models and sizes will lower purchase prices for EVs.

(((Future Perspective of the Global Auto Industry

An image of the future of vehicles, was displayed in the Shanghai World Expo 2010.

The GM/SAIC (Shanghai Automotive Industrial Corporation) pavilion was set up to explore the farthest reaches of the futuristic vision of the EV.

The Chinese automaker's goal was to come in as a recognized late comer in the automotive world, albeit with the world's largest automotive market, and leapfrog Japan and America toward the car of the future, the Electric Vehicle.

The IMAX movie/virtual reality presentation displayed that, by 2030, urban China would be a living network of safe, efficient, zero-emission electric pod/vehicles in constant communication with each other and the environment. What was demonstrated was a machine as big as a city with watch-like intricate precision.

"The exhibit is a vision of future driving that is free from petroleum, free from emissions, free from crashes, free from congestion, and at the same time fun and fashionable."
The concept was expanded in the award winning 2013 Mobilant design. **)))**