

VOLKSWAGEN'S DIESELGATE

PART ONE: HOW TO BUILD A CATASTROPHE



FALL LINE SYSTEMS INC.



OVERVIEW

“If men were angels, no government would be necessary.”

– James Madison¹, one of the main authors of the United States Constitution.

Men and women are flawed and so are the organizations they build. As a result we install checks and balances into organizations and the industries in which they operate.

Sometimes these balancing mechanisms miss the mark. When this happens, organizations and people can fail spectacularly. The Volkswagen Group (VW)’s Dieselgate catastrophe is a recent example. From 2007 to 2015 VW sold 11 million diesel automobiles designed to trick government emissions tests. Each of these vehicles performed flawlessly in lab-based tests but during normal operations released many times the regulated limits of dangerous chemicals into the atmosphere. The resulting smog endangered the health of urban populations around the world.

U.S. regulators did not discover VW’s cheating for seven years, even though the real world emissions were 4000% above the U.S. limits for nitrous oxides. This is not a small omission. The regulators’ testing systems had not anticipated sophisticated deception from one of the world’s leading automobile manufacturers.

At the same time VW’s corporate values and risk management systems were not robust enough to counter the temptations of porous regulatory controls. VW’s people found it easier to design ways to cheat emissions tests than it was to build effective emissions controls. And they almost got away with it.

Men are not angels. Our organizations need solid internal controls to ensure people work safely, ethically and within the law. Corporations are not angelic. Industries require skillful regulators to ensure companies do not harm the public good.

The story of Dieselgate reveals what can happen when internal and external controls are too weak to counter the baser instincts of people and corporations.

 **To comment on this article contact the author:**

George Campbell, President
Fall Line Systems Inc.
george.campbell@fall-line.ca
(403) 228-6623

For additional research on preventing catastrophe see:
www.fall-line.ca/preventing-catastrophe

¹ Quoted in Mathews, Richard (1995). *If Men Were Angels*. University Press of Kansas, Lawrence, KS.

HOW TO BUILD A CATASTROPHE: VW'S DIESELGATE

By George Campbell, Fall Line Systems Inc.

On February 10, 2017 The Volkswagen Group (VW), one of the world's premiere corporations, pled guilty in the U.S. to criminal conspiracy to commit fraud and obstruction of justice. VW's employees had installed software code ('defeat devices') into its engines designed to cheat U.S. emissions tests, and they had maintained and improved that software over nearly a decade.

The defeat devices turned off emission controls for nitrous oxides (NO_x) when VW's passenger diesels were driven on the road, enabling the vehicles to emit up to 40 times the U.S. limit for NO_x pollution. Emission controls worked perfectly well during lab-based government emissions tests.

VW had been confronted about its vehicles' emissions by U.S. regulators in early 2014. VW's response made their legal problems much worse. At first, VW denied the emissions existed, saying it was really a measurement problem. Once forced to acknowledge the reality of the emissions, VW committed to fix the problem during an upcoming recall. During the recall they upgraded the engine control software but left the defeat devices intact. The regulators uncovered the false repair by testing a few of the supposedly upgraded vehicles on the road. Apparently VW hadn't expected this.

The regulators then threatened to withhold certification to sell the upcoming model year's vehicles. With this VW finally had to admit that its U.S. passenger car diesel engines were designed to cheat emissions testing. They also admitted they had sold 11 million similarly equipped cars world-wide. VW continued to sell its heavily polluting vehicles into the U.S. market for the year and a half (2014-15) that they stalled the regulators. VW did not stop sales until ordered to do so.

In what quickly became dubbed Dieselgate, the U.S. Environmental Protection Administration (EPA) announced VW's admission of the defeat devices and excess NO_x pollution on September 23, 2015. So far it has cost VW about \$25 billion U.S. to address claims from owners, regulators, states and dealers for the 600,000 offending vehicles in the U.S.² More charges and more costs are expected. VW's reputation has been badly damaged, and Dieselgate has ruined the prospect for passenger diesel engines in the U.S. and started their decline around the world.



So far it has cost VW about \$25 billion U.S. to address claims from owners, regulators, states and dealers for the 600,000 offending vehicles in the U.S. More charges and more costs are expected.

² (March 10, 2017). VW Pleads Guilty to U.S. Emissions Charges. BBC. <http://www.bbc.com/news/business-39235598>



Many things had to come together for VW to produce Dieseldgate. This report details how VW built the conditions that allowed this catastrophe to fester for almost a decade. The hope is that other modern, highly technical organizations can learn from VW's experience and thus avoid hosting their own similar crisis.

Dieseldgate is a catastrophe for VW, as it has seriously damaged its reputation and its balance sheet. It is also an environmental catastrophe, causing serious lung ailments and deaths.

This catastrophe rumbled on below the surface for a decade. A host of people were directly involved in designing, installing, maintaining and hiding the defeat devices and many more were active in the attempted cover up once the real-world emissions were discovered by U.S. regulators. VW's senior executive may or may not have been involved in the criminal activity. They certainly assembled the cultural components that allowed emissions test cheating to become a feature of engine design and that kept people silent about it for years.

■ ■ ■ ■ VW'S BUILDING BLOCKS FOR THE DIESELGATE CATASTROPHE

Production Pressure

Production pressure by itself is not enough to create catastrophe. In fact, high expectations and strong ambition are the hallmark of successful companies. However when it is not tempered with respect for environmental protection, personal safety, financial stewardship or other ethical restraints production pressure can be very dangerous.

Dieselgate was formed during the intense buildup for the release of VW's next-generation diesel engine in 2008. The first model of this new engine, the E189, contained so many improvements over their previous diesels that VW was sure it would create an almost unassailable competitive advantage. It was decided to market the revolutionary new motor as 'Clean Diesel.' The engine development team were told that the future of VW depended on the engine's success and that failure was not an option.

It was decided to market the revolutionary new motor as 'Clean Diesel.' The engine development team were told that the future of VW depended on the engine's success and that failure was not an option.

Very late in the game, in 2007, a corporate decision was made to replace the NO_x emissions control system on the E189 with a simpler system than what had been previously approved. The new emissions control unit, a Lean NO_x Trap (LNT), had never been used to reduce NO_x to anything approaching the very strict U.S. limits. The engineers could not make the LNT work in the limited time available. Instead they designed and installed a 'defeat device' to cheat the U.S. emissions testing system.³

VW was a hard-driving company and this drive had led to a great deal of success. For those developing the E189 engine VW's pressure was turned into a drive to succeed – at any cost.

Diluted Accountability – It's Not My Fault

Martin Winterkorn, CEO for the entire Dieselgate Era (2007-2015), resigned once the EPA made Dieselgate public in September 2015 saying, "I accept responsibility for the irregularities that have been found in diesel engines." But then he added, "I am not aware of any wrongdoing on my part."⁴

This appears to be a concise statement of the VW model of accountability: Take your punishment, but don't admit you were wrong in any way.

³ See Appendix I for a detailed account of the decision to use the LNT.

⁴ Ewing, Jack. (Sept. 23, 2015). Volkswagen C.E.O. Martin Winterkorn Resigns amid Emissions Scandal. NY Times. <http://nyti.ms/1L62qHN>



Following Mr. Winterkorn’s lead, VW’s senior executive and board spent the following six months trying to portray themselves as surprised, innocent victims who were blindsided by Dieseldgate. But real accountability does not work this way.

Dieseldgate operated inside VW from 2007 to 2015. The CEO, the senior executive and the board members are accountable for building a culture that prevents massive cheating. It is their job to make sure people talk about and act to manage risks that have the potential to put the company under.

People all through the ranks at VW followed the “It’s not my fault,” version of accountability modelled by the senior executive. In this model, accountability flows downhill and if things go wrong you find someone to blame. As a result it was safer for everyone to pretend that NO_x emissions controls worked on the new diesel engine than to stand up, be truly accountable, and speak the truth.

Six months after Dieseldgate became public, when it was clear the financial penalties would be more than \$15 billion, Mr. Winterkorn, the senior executive and Board members received full bonuses for their 2015 performance. Accountability is seriously diluted when it flows only in one direction.

People all through the ranks at VW followed the “It’s not my fault,” version of accountability modelled by the senior executive. In this model, accountability flows downhill and if things go wrong you find someone to blame.

Black Elephants Nurtured

It was an open secret in many parts of VW that Clean Diesel was a myth. Dieselgate grew out of this 'Black Elephant,' which is defined as "a cross between a 'black swan' – a rare, low-probability, unanticipated event with enormous ramifications – and 'the elephant in the room'."⁵

Black Elephants exist in organizations because the senior executive does not want to hear about them. Senior leaders don't have to send memos to signal what is not discussable. They nurture Black Elephants by acting deaf to signals that they exist and by reacting badly when people speak up directly. It would have taken considerable energy to remain in the dark about the defeat devices on 11 million vehicles – consider the many possible sources of information:

- VW had based its corporate and technical strategies on the success of the E189 passenger diesel engine. The engine had been under development for about a decade and was considered revolutionary in the automotive world. This engine would have undergone test after test after test on every aspect of its performance and these test results would have been poured over by very high ranking VW officials.
- The U.S. restrictions on NO_x emissions were by far the toughest in the world. VW based its decision to re-commit to the U.S. market, building one plant in Mexico and another in Tennessee, on its ability to meet these standards. Emission performance was of material value to VW's ability to recover its capital expense.
- VW made a radical change to the emissions control for NO_x in the E189 engine one year before it went to market. The early technology had been developed jointly with Mercedes and Bosch and the change was very controversial within VW. Performance of the new emissions control, using a Lean NO_x Trap, would have had many eyes on it.
- VW owns the world's largest proving grounds for automobiles called Ehra-Lessien. It was built in 1965 in a no-fly zone near the East German border. The people here would notice a 4000% increase in NO_x emissions on the test track compared to their lab tests.
- The European Commission committed in 2008 to supplement its emission lab tests with what is now called the Real Driving Emissions (RDE) testing process. Under RDE every diesel would be tested for emissions while driving on the road as well as in the lab. All manufacturers knew this was coming and in 2011 the European Automobile Manufacturers Association (Acea) began a vigorous lobby campaign to delay and restrict implementation. Every European auto manufacturer would have conducted on-road tests on all their vehicles to assess the compliance costs for RDE tests.

⁵ Friedman, Thomas (2016). Thank You for Being Late: An Optimist's Guide to Thriving in the Age of Accelerations. Farrar, Straus and Giroux. New York, NY. Quoting Adam Sweidan's description of Black Elephant Events.

Normalized Deviance

It has been normal practice in Europe for about 20 years for VW's diesels to have vastly different emissions performance in government testing labs than on the road. In fact, it appears that no passenger diesel in Europe is compliant with NO_x emissions standards on the road, although they all pass emissions lab tests. None of this is illegal under EU rules.

So what appears to us and to the U.S. regulators as cheating is normal practice in VW's primary market. VW has been exceeding emission limits in Europe for years and so some people may have seen the installation of defeat devices as just an extension of the same game. Excess emissions, and tricking the regulator, became normalized and not worth speaking about.

The depth of this normalization was stunningly displayed during a 2013 warranty problem in the U.S. Engineers noticed parts were wearing out prematurely in the NO_x emission control units. Their analysis showed that the parts were wearing out because they had been designed to operate only during emission tests, not during the majority of time when the vehicles were driven on the road.



VW fixed the warranty issue by updating the Engine Control Module software to more accurately recognize when the cars were being tested for emissions. With this change the emission controls operated less often during normal driving thus reducing the likelihood that they would wear out.

The fix also meant that the cars emitted up to 40 times the allowed limit of NO_x more often during normal driving. The warranty work was completed at the same time that VW was being investigated by U.S. regulators and was denying that their vehicles produced any excess emissions.

IT TOOK A VILLAGE TO PRODUCE DIESELGATE

It took a village of people within VW to create and maintain the fiction of the Clean Diesel for more than a decade – from engine development, performance testing, marketing, regulatory affairs, risk management, senior management, the Supervisory Board, and other areas. The tragedy is that no one stood up to stop the cheating and get VW back on track. As a result, people in cities all around the world suffered, and continue to suffer, diminished health and shortened lives.

VW's senior executive denied the broad involvement in Dieseldate, just as they had denied the existence of excessive NO_x emissions. Michael Horne, CEO of Volkswagen America testified before a U.S. House subcommittee a few weeks after Dieseldate became public. Mr. Horne said, "This was a couple of software engineers who put this in for whatever reason. To my understanding, this was not a corporate decision. This was something individuals did."⁶

Mr. Horne was arguing that over a period of more than seven years no one at VW, other than the couple of software engineers, noticed that 11 million of their vehicles were emitting up to 40 times the U.S. limit of NO_x. Mr. Horne was strongly challenged during the hearings and he admitted, "I agree it is very hard to believe⁷."

***"This was a couple of software engineers who put this in for whatever reason. To my understanding, this was not a corporate decision. This was something individuals did."*⁶**

The Black Swan Defense

Even though the rogue employee theory was implausible, VW stuck with it well into 2016. The number of rogue employees grew in the explanations from a couple to six, then ten, then 15 or 16. The main storyline was that VW and its senior executive were innocent victims, deceived just as much as the customers and regulators had been. Like Mr. Winterkorn and Mr. Horne, the remaining executive could see no wrongdoing on their part.

VW described Dieseldate in terms that fit a Black Swan Event⁸: Events that are so far outside the realm of regular expectation they are essentially unpredictable; have extreme impacts; and after they occur they seem as if they could have been predicted. Essentially what the senior executive were claiming was, "We could not possibly have known about this, but if we had known we certainly would have acted quickly to prevent the problem."

⁶ Quoted in Puzanghera, Jim & Hirsch, Jerry (October 8, 2015). VW Exec Blames 'A Couple' of Rogue Engineers for Emissions Scandal. Los Angeles Times. <http://www.latimes.com/business/autos/la-fi-hy-vw-hearing-20151009-story.html>

⁷ Ivory, Danielle (2015, October 6). VW's U.S. Chief Tells Congress of a Wait to Fix Diesel Cars. NY Times.

⁸ Taleb, Nassim Nicholas (2007). The Black Swan: The Impact of the Highly Improbable. Random House, New York, NY.

Genuine Black Swan Events do occur and Nassim Nicholas Taleb's work on this matter is an important contribution to the study of risk. Taleb emphasizes that many events with very big consequences are not predictable and because of this our organizations and societies need to build in resilience so that we can survive the aftermath.

The big international banks have made extensive use of the Black Swan Theory to isolate responsibility for what they call 'rogue traders.' The courts are beginning to frown on this practice. For example, a French court has just ordered Société Générale to pay its 'rogue' trader Jérôme Kerviel nearly \$510,000 for unfair dismissal because "[The bank] could not pretend it hadn't long been aware of the unauthorized trades conducted by Mr. Kerviel. The bank therefore can't argue that Mr. Kerviel was at fault when it 'previously tolerated similar practices.'" The court made this ruling even though Mr. Kerviel's trades cost the bank somewhere between \$5.6 billion and \$7.2 billion.⁹

The courts are seeing Dieseltgate in the same light. The judge for the VW criminal case, Sean Cox, called Dieseltgate a "deliberate and massive fraud¹⁰," adding that more blame should be placed on the company's top management and supervisory board. The senior executive's blindness to their contributions to Dieseltgate points to a crisis of governance at VW, even if criminal charges do not make it up to their level.

The Black Elephant

Corporate risk management systems degrade rapidly once a serious risk is treated as an undiscussable Black Elephant. Unacknowledged risks cannot be managed. For this reason senior management and the board have to ensure that they are neither deaf nor blind to signals of material risk.

Our research into the prevention of catastrophe in organizations¹¹ shows that there is always information about the potential catastrophe available in the organization before the crisis hits. Senior leaders may be blindsided by a catastrophic event, but they get that way through their own actions.

Plenty of people at VW knew about the defeat devices and their cars' real life emissions. James Liang, one of the central figures in Dieseltgate, pled guilty to criminal charges in the U.S. and struck a plea bargain in September 2016. Liang has revealed he "was one of many at Volkswagen" who knew about the components of Dieseltgate.

We expect the senior executive to set up a culture where risks that could lead to a \$25 billion charge are not treated as Black Elephants, but are talked about openly and with urgency.

⁹ Ware, Doug (2016, June 7). Court says 'rogue' trader who nearly crashed French bank fired unfairly, is owed \$510k. UPI.

¹⁰ Vlasic, Bill. (2017, April 21). VW Moves Beyond Criminal Case, but Not Without a Scolding. NY Times.

¹¹ Campbell, George (2014). Preventing Catastrophe in Organizations. <http://www.fall-line.ca/preventing-catastrophe>



Liang was a lead engineer in Germany for the development of the Clean Diesel engine. He transferred to the U.S. in 2008 to shepherd the introduction of this new engine to the American market as head of the Diesel Competence Unit. He was the first senior VW engineer criminally charged in this case. One report observed, “VW Dieselgate engineer sings like a canary¹².” It is likely that Laing is clarifying for prosecutors who knew what by when.

The criminal charges may or may not reach to the top of VW. Accountability for Dieselgate should reach to the top. We expect the senior executive to set up a culture where risks that could lead to a \$25 billion charge are not treated as Black Elephants, but are talked about openly and with urgency. Saying “No one told me,” might be accurate and it might be a defense from a criminal charge but from a governance point of view it is a sign of serious executive failure.

The Compliant Board

Three members of VW’s Supervisory Board found out about Dieselgate more than a month after VW admitted to the EPA that its passenger diesel cars contained defeat devices. Board members Stephan Weil, Prime Minister of Lower Saxony; Olaf Lies, Economy Minister of Lower Saxony and Babette Fröhlich, an official with the IG Metall labour union heard about this catastrophe on the TV news and online, not from VW’s senior executive.

These Board members were surprised by the news on September 18, 2015. No one thought to tell them on August 15 that Volkswagen staff admitted to a senior EPA official that VW had been

¹² Nichols, Shaun. (2016, September 12). VW Dieselgate Engineer Sings Like a Canary: Entire design team was in on it – not just a few bad apples, allegedly. The Register.

deceiving regulators by using a defeat device. Nor was it mentioned that on a September 3 conference call with the EPA and CARB, VW described in detail how their vehicles were programmed to trick emissions tests.

Admittedly the Board was busy during this period. Mr. Winterkorn, the CEO, and the Board were finalizing the terms of a contract extension for the CEO. The Board's Executive Committee, which included Mr. Weil, recommended a three year contract extension to the full board on September 2, 2015. The next day VW had its conference call about the Dieseldate details with the EPA and CARB. Apparently Mr. Winterkorn thought his contract extension was more important to discuss than the Dieseldate Scandal.

■■■■ ROOT CAUSE(S) OF DIESELGATE

From the beginning it was very hard to believe that VW was the victim in Dieseldate, even though their spokespeople argued they had been tricked by a tiny group of rogue employees. The longer VW promoted this untenable story, the more likely it seemed that there was broad corporate involvement.

Two astute industry observers saw past VW's cover story in the first week after Dieseldate became public in September 2015:

- Mike Jackson, Chairman, CEO & President of AutoNation, America's largest auto dealer network said, "This is not a rogue employee. This is not a bad apple. This is not a lapse. This is not negligence. This is a deliberate scheme to deceive customers and regulators."¹³
- Henry Mintzberg, one of the foremost academics on organizational theory, says that the fault may be much larger than VW's malfeasance. He states, "It's not a scandal; it's a syndrome. The Volkswagen affair is just a blatant case of an accelerating trend. Expect it to get worse, because we are living in a world where predatory capitalism is triumphing."¹⁴

Both of these assessments have proven correct. Part One of this report explores VW's direct involvement in producing Dieseldate. Part Two of this report explores Dieseldate as a symptom of the much broader industry and regulatory failure on NO_x emissions in Europe. Dieseldate should make everyone extra cautious about today's pressures for regulatory simplification and self-regulation.

¹³ Belvedere, Matthew (2015 September 23). AutoNation CEO: VW deliberately schemed to deceive. CNBC Autos.

¹⁴ Mintzberg, Henry (2015 September 22). Don't Call it a Scandal: Volkswagen corruption is a syndrome. Globe and Mail.

■ ■ ■ ■ NO_x IS DIFFICULT – DEFEAT DEVICES ARE EASY

Defeat devices are as old as automobile emissions controls. Some manufacturers have always found it cheaper to cheat emissions testing than to actually reduce emissions.

Air Pollution is a Health Risk

Controls of air pollution evolved out of the serious smog-related public health problems that hit California in 1943. Los Angeles has unique weather patterns that trap smog gasses and this combined with the city's expansion of wartime industry and population to create a toxic air mass. When smog is present the working ability of people's lungs can diminish significantly leading to discomfort, illness and death.

Initial action was directed at point sources of pollution such as refineries and factories. But smog continued and it became evident that emissions from automobiles and trucks would also have to be controlled. By 1966 roughly 60% of pollutants discharged into the air in the United States were from motor vehicle traffic.¹⁵

California enacted the world's first emissions controls for vehicles in 1967. These were federally adopted in 1968 by the newly-established Environmental Protection Agency. Subsequently the number of smog alerts in Los Angeles has plummeted even though the number of vehicles expanded massively.

NO_x emissions are not seriously harmful when released from the tailpipe – it is only when NO_x moves into the atmosphere that it transforms into toxic gasses.

NO_x Emissions are Tempting to Ignore and Difficult to Control

NO_x control has always been a challenge for regulators. NO_x emissions are invisible and odourless and so there is no great push by consumers to eliminate them. In addition NO_x emissions are not seriously harmful when released from the tailpipe – it is only when NO_x moves into the atmosphere that it transforms into toxic gasses. NO_x reacts with other substances in the atmosphere to produce dangerous components of smog such as nitrogen dioxide, ozone, and ammonium nitrate.

¹⁵ Melosi, Martin. The Automobile and the Environment in American History. University of Michigan-Dearborn. http://www.autolife.umd.umich.edu/Environment/E_Overview/E_Overview4.htm



Consumers and citizens complain much more about visible smoke, bad odors and particulate matter than they do about invisible pollutants like NO_x and carbon dioxide. This is one of the reasons that VW was able to promote their highly polluting vehicles as clean.

All internal combustion engines produce NO_x during combustion. In gasoline engines, NO_x emissions have been substantially reduced since the introduction of the three way catalytic converters which became compulsory in the U.S. in 1981 and in the EU in 1992. Prior to implementation of these regulations governments had to require the adoption of non-leaded gasoline, as the lead made the NO_x control catalyst inoperable.

Diesel emissions have been an even harder nut to crack. Diesel fuel is less refined and contains much longer hydrocarbon chains and other mystery compounds than gasoline, producing more emissions to control. And to compound the fuel problem, “the temperatures and pressures under which a diesel engine runs the most fuel efficient and the most peppy are also the conditions that will convert the maximum amount of oxygen and nitrogen into NO_x ¹⁶.”

Measures in diesel engines that reduce output of nitrogen oxides, which cause lung ailments, automatically increase production of soot particles, which cause cancer. Reducing soot output requires the use of additional fuel, which increases fuel consumption. These technical trade-offs were generally resolved in favour of the more tangible pollutants. Consumers preferred to avoid the black soot characteristic of old diesels and they loved the low fuel consumption. Gains in these areas led to higher levels of NO_x emissions.

¹⁶ Ghose, Tia. (2015, September 24). Volkswagen Scandal: Why is it so hard to make clean diesel cars? Live Science. <https://www.livescience.com/52284-volkswagen-scandal-clean-diesel-challenges.html>

Defeat Devices

The basic concept of a defeat device has not changed over the years. A defeat device turns off (defeats) emission controls during normal driving but turns on emission controls during emission tests. As a result a vehicle with a properly operating defeat device will pass government emission tests even though it is a heavy polluter when driven on the road.

In order to succeed, a defeat device must recognize the difference between test conditions and normal driving. It is not hard to imagine doing this. For example cars are tested on a treadmill in the lab. Thus front wheel drive cars could turn on emission control equipment when the front wheels are turning but the back wheels are not. More sophisticated defeat devices could be activated using any of the other parameters of the testing regime. These are all published to make testing consistent and fair. The transparency of the testing protocol also enables the unscrupulous to take advantage.

VW is not alone in using defeat devices over the years but it was one of the first. Here are some early examples¹⁷:

- **Volkswagen 1974:** two temperature sensing switches that deactivated part of the vehicles' emissions controls. 25,000 1973 model VW's. \$ 120,000 fine to the EPA.
- **General Motors 1995:** computer chips in 470,000 Cadillacs (1991-95) allowing the cars to burn more fuel when drivers used the climate control system. EPA penalty: \$11 million fine, \$8.5 million on projects to compensate for excess emissions, \$25 million recall to retrofit the vehicles.
- **Ford 1998:** software that boosted fuel economy and increased NO_x emissions in 60,000 Econoline vans. EPA penalty: \$2.5 million fine, remove the software, \$5.3 million other costs.
- **Honda 1998:** disabled parts of the onboard diagnostic computer that detected engine misfires. 1.6 million vehicles (Accords, Civics and others). EPA penalty: \$17 million.
- **Caterpillar, Mack Trucks, Renault, Volvo and others 1998:** defeat devices enabling three times the legal limit of NO_x emissions in highway driving for these large transport trucks. EPA penalty: \$83.4 million.

By 2008, the defeat device trade-craft had become software based, very precise and extremely hard to detect. The EPA alleges VW's Dieseldate defeat device was almost unbelievably fine-tuned in the Audi, one of VW's brands. EPA states, "A key phase of the standard U.S. emissions test lasts exactly 1,370 seconds. Audi's software, the regulators discovered, was calibrated to emit a legal amount of emissions for precisely 1,370 seconds. When the 1,371st second elapsed the software switched settings, so that the car spewed up to nine times the permitted amount of NO_x."¹⁸

¹⁷ Liawang, Robert (2015, September 25). Volkswagen Isn't the First Car Manufacturer to have been Caught Using Defeat Devices. Financial Post.

¹⁸ Smith, Geoffrey & Parloff, Roger (2016, March 15) Hoaxwagen. Fortune Magazine.

CAUGHT BY A FLUKE, VW SQUIRMED MIGHTILY

VW's emissions problem was not detected by the regulators. Their cars containing defeat devices passed U.S. emissions tests every year from 2008 and VW expected this success to continue. Just prior to the 2013 emissions tests a junior engineer sent a memo to the head of the U.S. Diesel Competence Unit saying, "If this goes through without problems, the function (the defeat device) is probably truly watertight!"¹⁹

VW's cars sailed through the 2013 emissions tests. But later that same year a small non-profit agency called The International Council on Clean Transportation (ICCT) used two VW diesel vehicles in a research project and discovered their real-world emissions levels. The researchers were looking for something completely different but were shocked at the NO_x emission levels. They shared their data with U.S. regulators, the Environmental Protection Administration (EPA) and the California Air Resources Board (CARB).

A small non-profit agency called The International Council on Clean Transportation (ICCT) used two VW diesel vehicles in a research project and discovered their real-world emissions levels.

The regulators then met with VW to work out why their 'Clean Diesel' passenger vehicles were emitting as much NO_x as an 18 wheel transport truck. They anticipated a cooperative problem solving discussion and a reasonably quick resolution. Rather than cooperate, VW stonewalled. A subsequent EPA and Department of Justice lawsuit described VW's response in the 18 months after learning about their cars' emission problems. The suit says that VW "impeded and obstructed" the regulators' inquiry through "misleading information," "concealing facts," and "affirmative misrepresentations."²⁰



VW's Angelic Engineers

VW marketed their Dieseldate automobiles as Clean Diesels. They told their customers that these next-generation diesel engines were a green product that lowered greenhouse gas emissions by its frugal use of fuel and controlled other emissions using revolutionary new technology.

¹⁹ Schoenberg, Tom; Naughton, Keith & Butters, Jamie. (2016, September 10). Engineer Admits Role in VW Emissions Scandal. Calgary Herald.

²⁰ Smith, Geoffrey & Parloff, Roger (2016, March 15) Hoaxwagen. Fortune Magazine.

It wasn't just the regulators that were fooled. VW's Jetta TDI Clean Diesel won the 2009 Green Car Award, and the Audi A3 Clean Diesel won the 2010 Green Car Award.

And VW certainly promoted the virtues of its next generation diesel. In July 2011, they boycotted a major reception in the White House for President Obama's announcement of the new fuel economy and carbon emission targets for the U.S.²¹ VW's absence stood out, as all other major manufacturers were present, but VW was miffed that its Clean Diesels did not get the special fuel economy credits that zero-emission electric cars were receiving. The Toyota Prius did not receive these credits either but that didn't matter to VW as it was sure its diesels were superior to any hybrid electric.

VW capped the campaign promoting itself as an environmental and technological leader with its 2014 Super Bowl ads. Viewers were treated to a display of angel wings popping out of the backs of VW's engineers as customers' vehicles passed 100,000 miles on their odometers. Once Dieselgate hit the press the Green Car Awards were rescinded and the angel wings stopped appearing in TV ads.

A Stroke of Very Bad Luck for VW

VW was tripped up by a \$50,000 research project sponsored by the International Council on Clean Transportation (ICCT). The purpose of the research was to show European regulators that the tighter regulatory structure in the U.S. led to cleaner-running diesels.

“One of the hypothesis (sic) we had was that, because the U.S. regulations on emissions are much stronger than the European ones, the U.S. emissions values would be lower,” says Anup Bandivadekar, ICCT's passenger vehicle program director.²²

In February 2013 technicians from West Virginia University, under contract to ICCT, measured the on-road emissions of three diesel vehicles sold in the U.S. They did not target VW. Passenger diesels are not common in the U.S. and the group acquired what they could find from rental agencies and a private owner. The three vehicles tested were a VW Jetta, a VW Passat and a BMW X5.

All three vehicles were first tested by the California Air Resources Board (CARB) using standardized emission lab tests, and each vehicle passed these tests easily. The road tests, using West Virginia University's Portable Emissions Measurement gear, were a different matter. The BMW complied with emission limits except when climbing steep hills but the VW's produced shocking results. The Jetta emitted 15 to 35 times the permissible levels of NO_x and the Passat 5 to 20 times.

***The Jetta emitted
15 to 35 times the
permissible levels of
NO_x and the Passat
5 to 20 times.***

²¹ Kessler, Aaron (2015, October 6). Volkswagen Sought a Green Seal for its Diesel Cars. NY Times.

²² El Akkad, Omar (2015, Sept. 23). How A Minor Emissions Experiment Put Volkswagen in Hot Water. The Globe and Mail.

The researchers checked their equipment and redid the tests. The results were consistent.

ICCT's \$50,000 research project had uncovered the dark secret of VW's Clean Diesels. Their research project had failed in the sense that they could not show European regulators how much better the U.S. results were. But this chance encounter with VW's emission cheating opened up a world of trouble for VW, including \$25 billion of fines and settlements.

VW Squirms, Delays and Deceives

Standard practice when confronted by a serious pollution problem from your company's products or operations is to shut off the source of pollution, clean up the affected area and then work side-by-side with regulators to prevent similar problems. VW did none of these when asked for an explanation of the excess emissions by the EPA and CARB.

To start, VW simply denied that their cars produced significantly more NO_x emissions on the road than they did in the lab. The real problem, according to VW, was with the design and execution of the road tests.

CARB took the technical lead in the discussions with VW because it had considerable experience with portable emissions measurement systems (PEMS). They met with VW in a series of 10 meetings, each of which produced new concerns from VW about the on-road emissions data. CARB's on-road emissions tests consistently produced results comparable to those uncovered by the ICCT research – VW's passenger diesels produced up to 40 times the allowed limits of NO_x when driven on the road.

After eight months of denial and delay VW finally conceded in December 2014 that there was a problem with real world emissions from their diesel vehicles. It promised to fix this during an upcoming voluntary recall scheduled for an unrelated issue. The regulators agreed to this plan. The recall was completed in the spring of 2015 and VW informed the regulator that they had upgraded the software in the engine control modules and their cars were now compliant. CARB tested a sample of the upgraded vehicles and found that on-road emission performance had improved only marginally. The VW diesels' NO_x emissions were still vastly above the regulated limit.

CARB's engineers then focused on the most likely cause of the huge discrepancy between lab and on-road emissions. They found a way to tweak their test procedures in the lab that signaled to the car that it was on the open road. When this was done the emissions jumped. Clearly there was a defeat device in the car.



By July 2015 the regulators had enough solid data to act. The EPA informed VW that it would withhold certification any of VW's 2016 model year 2.0 liter diesels for sale until it received a credible explanation for the emissions and the defeat device CARB had found. With little choice left, VW's resistance cracked. On August 15, 2015 a Volkswagen official admitted to a senior EPA official that VW had been deceiving regulators by using a defeat device.

In a conference call on September 3, 2015 VW outlined the technical details of its defeat device. At that time a Volkswagen official signed a document that said, "VW admitted ... that it designed and manufactured its 2.0 liter diesel vehicles with defeat devices to bypass, defeat, or render inoperative elements of the vehicles' emission control system."²³

On September 18 the EPA issued a Notice of Violation alleging "model year 2009 – 2015 Volkswagen and Audi diesel cars equipped with 2.0 liter engines included software that circumvents EPA emissions standards for nitrogen oxides. This software is a "defeat device" as defined by the Clean Air Act." With this announcement Dieselgate became known to the worldwide public.

VW continued to sell 2.0 litre diesels containing defeat devices in the U.S. all through 2014 and 2015 while they were being investigated by CARB and EPA. VW stopped the sales only when ordered to by the EPA on September 18, 2015.

²³ Smith, Geoffrey & Parloff, Roger (2016, March 15) Hoaxwagen. Fortune Magazine.

²⁴ 2015, September 18. <https://www.epa.gov/vw>

Meanwhile, Behind the Scenes

VW denied the existence of its cars' excessive NO_x emissions to U.S. regulators March – December 2014. Meanwhile, they brought their most senior technical trouble shooter, nicknamed The Fireman, out of retirement to deal with the emissions problem.

The trouble shooter, Bernd Gottweis, who had retired at the executive level in Germany, arrived in the U.S. in early 2014. Gottweis had been used to sort out the thorniest technical problems in VW during his career. He had a stellar reputation within VW and was well known to the senior executive.

In May 2014 Mr. Gottweis sent a report to Martin Winterkorn, VW's CEO, which stated, "A sound explanation for the dramatically increased NO_x emissions cannot be given to the authorities," it warned. "It can be assumed the authorities will investigate VW systems to determine whether VW has installed a test detection in the engine control unit software (a so-called 'defeat device')." ²⁵

VW has acknowledged that Mr. Winterkorn received the report in May 2014. It pointed out this was included in his "extensive weekend mail." The VW spokesperson added, "Whether and to what extent Mr. Winterkorn took notice of this memo is not documented." ²⁶

"We are not a criminal brand or group. We haven't been that. We have made a huge default, technical default, but there was no intention against customers or authorities." ²⁷

"We Are Not a Criminal Brand"

There are some phrases you do not want to hear from your company's chief executive. Here is one such phrase, from the CEO who replaced Martin Winterkorn. Matthias Müller said in January 2016, "We are not a criminal brand or group. We haven't been that. We have made a huge default, technical default, but there was no intention against customers or authorities." ²⁷

To demonstrate VW's intention to get to the root cause of Dieseldgate in December 2015 the company hired the law firm Jones Day to lead a team of 450 people to conduct a thorough investigation. "We are relentlessly searching for those responsible for what happened and you may rest assured we will bring these persons to account ²⁸," said board chair Dieter Pötsch.

²⁵ Huggler, Justin. (2014, February 14). Ex-VW boss 'aware of emissions cheating for a year' but did nothing, leaked report suggests. The Telegraph.

²⁶ Smith, Geoffrey & Parloff, Roger (2016, March 15) Hoaxwagen. Fortune Magazine.

²⁷ Bomey, Nathan and Snavey, Brent. (2016 January 11). Volkswagen CEO: 'We are not a criminal brand'. USA Today.

²⁸ Ruddick, Graham (2015, December 10). VW Admits Emissions Scandal was Caused by a 'Whole Chain' of Failures. The Guardian.

At the same time Pötsch admitted that Dieselgate involved more than just a few rogue employees. He said, “We are talking here not about a one-off mistake but a whole chain of errors”²⁹

The Jones Day report was to be released for the VW Annual Meeting in April 2016. Prior to the April Board meeting it was announced that the Jones Day report was too risky to release. However, it was declared that the report cleared members of the Board of Management and the Supervisory Board.

“Although the investigation by Jones Day is still ongoing, according to information currently available, no serious and manifest breaches of duty on the part of any serving or former members of the Board of Management have been established that would stand in the way of granting ratification [of the actions of the serving members of the Board of Management for fiscal year [2015] at this time.”³⁰

VW’s legal problems likely are far from over. During trial, John Neal, an assistant U.S. attorney, told the U.S. District Court that Dieselgate was, “a well thought-out, planned offensive that went to the top of the organization.”³¹ The company has not admitted any of its senior management or board members were involved. However, the offices of Jones Day were raided in Germany a week after the U.S. guilty plea was accepted, leading people to speculate that VW’s submission of documents to the court may not have been complete. More legal action is likely.

■■■■ STRATEGIC SUCCESS OR SUCCESS AT ALL COSTS

VW was sucked into the mire of Dieselgate by the allure of a once-in-a-lifetime chance to become a champion company. Its 2007 strategic plan laid out VW’s ambition: to become the world’s number one automaker, “not just in units, but in profitability, innovation, customer satisfaction, everything.”³²

VW was sure it was uniquely prepared to build cars for a fundamentally changed world-wide automobile market. And right at the centre of VW’s competitive advantage was the next-generation Clean Diesel engine that was ready for release after years of development.



²⁹ Ruddick, Graham (2015, December 10). VW Admits Emissions Scandal was Caused by a ‘Whole Chain’ of Failures. The Guardian.

³⁰ Ramey, Jay, (2016, May 13). VW Board Clears Itself of Wrongdoing in Diesel Scandal. Autoweek. <http://autoweek.com/article/vw-diesel-scandal/vw-board-clears-itself-wrongdoing-diesel-scandal>

³¹ Leggett, Theo. (2017, March 10). VW Pleads Guilty to US Emissions Charges. BBC.

³² Smith, Geoffrey & Parloff, Roger (2016, March 15) Hoaxwagen. Fortune Magazine.

Disruptive Change Meshed with VW's Strengths

In 2007 VW was the dominant car maker in Europe where fuel economy requirements had been the toughest in the world for many years (tied with Japan). They were world leaders in passenger diesel technology and had the manufacturing scale, engineering strength and world-wide scope required to meet the needs of a newly carbon-constrained world.

The Kyoto Agreement on Climate Change had come into force in 2005 obligating the 193 signatory countries to take serious action to reduce carbon emissions. Even the United States, which had not signed the Kyoto Agreement, introduced regulations requiring a 40% improvement in vehicle fuel economy starting in 2007. The world auto market was becoming more like Europe's.

Implementation of Kyoto was going to cause massive disruption in the worldwide auto industry. Nearly 100% of road transport was powered by fossil fuels and these vehicles were going to have to get much more efficient in short order. VW was convinced that the requirements of a carbon-constrained world suited its strengths perfectly and so it would ride these strengths to move ahead of all other auto manufacturers.

The Right Technology for a New Age

Success in the auto business requires vast capabilities – in manufacturing, quality control, marketing, design, finance and many others – and VW had enough of these strengths to put it in the top tier of auto manufacturers in the world. To get to the very top though VW needed some luck. As it happened in 2007 the world appeared to need the one technology in which VW stood out as a leader – the passenger diesel engine.

Three engine technologies competed for dominance in the post-Kyoto world in 2007: the gasoline engine, electric drives (hybrids and battery driven) and diesels. VW's analysis put diesel far ahead of the other two as you can see in the following table:

Competing Technology	Diesel's Advantages
<p>The gasoline engine was too mature. Any efficiency improvement would only produce marginal gains.</p>	<p>Diesels were already 15-30% more efficient than gasoline engines and they had far greater upside for efficiency and emission control improvements.</p>
<p>Electric drive vehicles were too immature. Hybrids were too expensive to produce and too complex to maintain. Electric drive vehicles required extensive new infrastructure for charging and great advances in battery technology.</p>	<p>Diesels were proven winners in the European market, which was the most demanding in the world for fuel efficient vehicles. No new infrastructure was required, and diesels had a remarkable track record for reliability and solid performance.</p>

By 2007 diesels had begun to dominate Europe's auto sales, growing from 22.8 % in 1997 to 53.6% in 2007.³³ VW was sure the rest of the world would mirror Europe's path and learn to favour diesels once carbon restrictions began to bite. And it was sure that the advantages of the new generation diesels would encourage even faster adoption of diesels than had been the case in Europe.

The U.S. Market Opportunity

The U.S. had been a tough grind for VW since the popularity of the Beetle collapsed in the late 1960's. By 2007 VW was a marginal player with just 2% of sales. But it needed to become a force in the massive U.S. market to be a true world leader in automobiles.

And in 2007, the U.S. market foundations were shaken by three regulatory changes. Taken together, the new regulations provided VW with the opening it needed:

- **Signing of the U.S. Energy Independence and Security Act (EISA) by George W. Bush in December 2007.** This act increased U.S. fuel economy standards by 40%, reaching an average of 35 miles per gallon by 2020. This was a huge change for the U.S., although the new fuel economy standards were well below European limits.
- **Adoption of 'ultra-low sulphur' diesel fuel in late 2006.** The allowable sulphur content in diesel fuel dropped from 500 ppm (parts per million) to 15 ppm, comparable to the European limit. Prior to this diesel engines designed for Europe could not be used in the U.S., stalling the introduction of modern diesels. VW's new diesels were far better performers than any diesel the U.S. had seen.
- **Reduction in NO_x limits.** The California Air Resources Board (CARB) released the toughest restrictions on nitrous oxide (NO_x) emissions in the world in 2007. These became the de-facto U.S. limits: a fleet average maximum of 0.04 g/km NO_x compared to Europe's limit of 0.18 g/km. No passenger diesel had yet been able to operate at the new U.S. NO_x limits but VW was sure its engineers could work out a solution.

VW was sure that none of the U.S. manufacturers was up to the engineering challenge posed by these three big shifts happening at one time. Americans had never appreciated fuel efficiency, and so their manufacturers had not developed the discipline required to build high quality, fuel sipping vehicles. All their good cars were gas guzzlers. In this changed market VW had a clear advantage as they had a product line filled with vehicles that dominated the very demanding European market.

VW was confident that their Clean Diesel was just the vehicle to crack open the U.S. market. They projected U.S. sales to increase from 235,000 in 2017 to 800,000 in 2018 (up 340%). To support this volume in 2007 VW opened a new plant in Mexico to build the Jetta for the U.S., and began to build a plant in Chattanooga, Tennessee.

³³ <http://www.acea.be/statistics/tag/category/share-of-diesel-in-new-passenger-cars>

The Foundation for Success and Failure was Set in 2007

By 2015 VW became the world's number one auto manufacturer, selling 5.04 million vehicles in the first six months compared to Toyota's 5.02 million. It had achieved one of the most ambitious goals from its 2007 strategy.

VW moved to the front of the pack even though the Kyoto Agreement did not radically disrupt the auto industry and in spite of only moderate success in the U.S. market. VW's hard-driving, product-centered culture helped it push past the industry juggernauts, GM and Toyota, in markets around the world.

Decisions made in 2007 set the stage for winning. Their new diesel engines, released for sale in 2008, were extremely popular and their product quality and innovation built sales momentum. The whole company pulled together with extraordinary effort to move from being far back in 3rd place in 2007 to the number one position in 2015.

But all through the time this victory was being achieved, Dieselpgate bubbled below the surface at VW. In fact, the stage had been set for Dieselpgate in 2007 when their high ambition strategy hit the press. By the end of 2007:

- The Clean Diesel engine's defeat device had been designed, tested and installed in the first production models.
- The inability of the Lean NO_x Trap to control emissions to the U.S. limits had already been established within VW as an undiscussable Black Elephant.
- Engineers, test technicians, designers and suppliers who knew about the excessive vehicle emissions already had chosen to stay silent.
- Senior technical executives had already decided to look away from the nearly magical improvement in the Lean NO_x Trap's performance.
- The culture of delaying, deceiving and pretending to fix technical problems when confronted with test data was already set and practiced internally.
- The senior executive had made it clear that delay or failure of the E189 engine was not acceptable and they would not hear about any problems in this key project.
- Board members had already accepted they would get incomplete information from the corporation about enterprise risk, and they had already accepted their watered-down role in governance.

The whole company pulled together with extraordinary effort to move from being far back in 3rd place in 2007 to the number one position in 2015.

Dieseldate knocked VW's strategy off the rails in 2015 just as it had reached the pinnacle. In January 2016 only 222 diesel-powered cars were sold in all of the U.S.³⁴ VW's stock price dropped precipitously, VW's reputation was decimated and over the next year its balance sheet was very badly damaged by Dieseldate costs.

VW had wanted to stand out from its competitors. In the first half of 2015 it showed how its strong, driving culture could enable it to be the most successful auto manufacturer in the world. In the second half of the same year it showed how the very same culture could make it one of the most corrupt.

■■■■ LESSONS FROM DIESELGATE

Most climbing accidents happen on the way down from the summit, not on the way up. On Everest, 85% of deaths between 1921 and 2006 happened on the descent³⁵.

Climbers get hyper-focused on achieving the summit goal and in doing so they lose sight of the equally important goal of getting off the mountain safely. As a result, they push harder than they should on the way up accumulating a host of small injuries and problems that come together to cause serious danger on the way down.

Industrial catastrophes follow the same pattern. Companies get hyper-focused on achieving very difficult goals and they let go of the longer term needs for sustainability, ethics, reputation and environmental protection. As Tinsley and her colleagues showed in their Harvard Business Review article, "Organizational disasters rarely have a single cause. Rather, they are initiated by the unexpected interaction of multiple small, often seemingly unimportant, human errors, technological failures, or bad business decisions."³⁶

VW did become the world's largest seller of automobiles in 2015. It also built up, piece after piece, the organizational scars and weaknesses that led to the emergence of the Dieseldate catastrophe later in the same year.

Dieseldate did not have to explode on the scene. VW could have downgraded it to a much smaller problem by acting earlier on the accumulating risks. Even if they had waited until the last moment and then told the truth about their emissions cheating when confronted by the U.S. regulators their costs probably would have been reduced from \$25 billion to a few hundred million.

³⁴ Bennett, Jeff (2016, February 18). Diesel Sales Tumble in U.S. The Wall Street Journal.

³⁵ Lite, Jordan (2008, December 10). Death on Mount Everest: The Perils of the Descent. Scientific American.


³⁶ Tinsley, C; Dillon, R & Madsen, M. (2011, April). How to Avoid Catastrophe. Harvard Business Review



For those organizations that want to both reach the summit of exceptional performance and return back safely for long term success, VW's Dieselpgate experience has many lessons:

- There is a fine line between pushing for success and driving toward success at any cost.
 - It is not the push that is a problem. Successful organizations are full of high expectations.
 - Production pressure must be balanced with caution because the higher the pressure to meet performance goals, tight schedules and cost targets, the more likely people are to discount near-miss signals or misread them as signs of good decision making.
- Enterprise risk management systems cannot be effective in organizations that house Black Elephant risks.
 - When people cannot talk about significant risks openly these risks cannot be managed.
 - When senior leaders refuse to act on (or hear about) significant risks, people stop talking about them.
- Employees mirror the level of accountability modelled at the top of the organization.
 - Finding someone else to blame for Dieselpgate seemed to be a main preoccupation of VW's senior management and board.
 - When caught by U.S. regulators, VW denied the emissions problem and tried very hard to transfer blame.

- Boards that do not take governance role seriously expose the company to danger.
 - Members of the Supervisory Board learned about Dieselpgate through the media several weeks after the senior executive were fully briefed. They responded to this outrage as if it was the normal way of doing business at VW.
- The push toward regulatory simplification and self-regulation is dangerous for society.
 - VW, one of the world's premiere auto manufacturers, built devices into 11 million vehicles world-wide that were designed to cheat emissions testing.
 - VW continues to sell its high emitting diesels in markets outside the U.S. in jurisdictions where regulators turn a blind eye to the emissions.
- NGO's are an important part of any regulated industry.
 - Dieselpgate was not discovered, and would not have been discovered, by the U.S. regulators without the work of the ICCT, a small NGO with 40 employees.
 - NGO's have a role in keeping the regulator's enforcement branches sharp and doing their jobs.
- Catastrophes hosted by one company harm the entire industry. As a result of Dieselpgate:
 - All manufacturers selling diesel vehicles in the U.S. are undergoing much more detailed testing.
 - London, Paris, Madrid and other major cities in Europe are starting legislation banning diesel cars from their city core.
 - The European emissions regulator is beginning to toughen up enforcement of diesel emissions.


In Part 2 of this report, to be released in November 2017, we will show what happens to corporate ethics when regulatory enforcement collapses.

■ ■ ■ ■ EPILOGUE: VW'S POST-DIESELGATE STRATEGY

Remarkably VW was not greatly harmed by Dieselpgate in its key markets outside of the U.S. After an initial dip, sales in Europe, Brazil, China, and Australia recovered quickly. VW regained worldwide sales leadership over Toyota in 2016, selling 10.3 million vehicles vs. Toyota's 10.2 million³⁷.

In VW's home market of Europe, customers are not greatly upset that their diesel cars are heavy polluters. They are upset that the American VW owners are receiving significant compensation while European owners receive almost no money.

European governments and regulators have been forced through Dieselpgate to begin to admit that Clean Diesel is more a promotional myth than reality. Governments are talking about eliminating diesel fuel subsidies, major cities are talking about banning diesels from their core and regulators may be prodded into enforcing emission limits with some diligence. The passenger diesel's time will soon be over, even in Europe, where registrations of new diesel engines dropped 15% in April 2017.

Governments are talking about eliminating diesel fuel subsidies, major cities are talking about banning diesels from their core and regulators may be prodded into enforcing emission limits with some diligence.

Sergio Marchionne, Fiat Chrysler Automobiles' chief executive, believes there will soon be no more market for small passenger diesels. He believes any car with an engine smaller than 2 litres will be "priced out of the market" because the cost of installing injectors of urea – a chemical that lowers NO_x emissions – will be too high³⁸.

VW has also decided that the era of the passenger diesel will soon be finished. On June 16, 2016 CEO Matthias Müller announced a new strategy titled, 'Together – Strategy 2025.' Müller called the strategy "the biggest change process in the history of Volkswagen."³⁹

The strategy commits VW to introducing 30 new plug-in electric vehicle models by 2025 and forecasting sales of 2 to 3 million electric vehicles per year by 2025. (Currently only 1.3 million electric cars are on the road worldwide)⁴⁰

³⁷ Schmitt, Bertel (2017, January 30). It's Official: Volkswagen is World's Largest Automaker in 2016. Or Maybe Toyota. Forbes.

³⁸ Campbell, Peter (2016, June 20). European Diesel Car Sales Hit by VW Scandal. Financial Times. <https://next.ft.com/content/94c56a30-3476-11e6-bda0-04585c31b153>

³⁹ Rauwald, Christoph (2016, June 16). Volkswagen Pushes for Redemption with Electric Cars, Robo-Taxis. Bloomberg Technology. <http://www.bloomberg.com/news/articles/2016-06-16/vw-pushes-into-electric-vehicles-sets-margin-target-for-2025>

⁴⁰ Plumer, Brad (2016, June 17). Volkswagen is making a huge shift to electric cars in the wake of its diesel scandal. Vox <http://www.vox.com/2016/6/17/11964206/volkswagen-electric-cars-diesel-scandal>



In 2015 VW produced two electric models, and Audi had none. The new strategy says that by 2025 electric vehicles will be 25% of VW's sales. As part of this plan VW also commits to producing batteries for its fleet and others, and establishing a mobility-solutions business based on ride-sharing, robo-taxis and car sharing.

The strategy requires new investment of more than €10bn. VW will be stretched for funds and will have to catch up to its rivals' competence in electric vehicles for this strategy to succeed. But the biggest challenge for VW will be to win back public confidence.

Matthias Müller stated plainly during the strategy announcement, "Our most important currency is trust⁴¹." It is not certain trust can be won back by VW.

In order to rebuild public trust, VW will first have to shift the working culture inside VW. As Bernd Osterloh, a member of VW's supervisory board, said in a letter to VW staff days after Dieselgate became public, "We need in future a climate in which problems aren't hidden but can be openly communicated to superiors. We need a culture in which it's possible and permissible to argue with your superior about the best way to go."⁴²

⁴¹ (2016, June 16). Volkswagen to Launch More Electric Cars after Diesel Scandal. NY Times.

⁴² Cremer, Andreas & Bergin, Tom (2015, October 10). Fear and Respect: VW's Culture Under Winterkorn. Reuters. <http://www.reuters.com/article/us-volkswagen-emissions-culture-idUSKCN0S40MT20151010>

■ ■ ■ ■ APPENDIX 1: DEVELOPMENT OF THE CLEAN DIESEL ENGINE

'Clean Diesel:' the E189 Engine

The engine causing so much excitement at VW in 2007 is formally known as the E189 diesel. This 'Clean Diesel' was the key to the U.S. market and the basis of a long-term competitive advantage for VW in an increasingly carbon-constrained world.

The EA 189 engine came in 2.0 and 1.6 litre versions, engineered for small passenger vehicles like the Jetta and Audi A3. The engine used common-rail turbocharged direct injection (TDI) and complex engine controls to produce high performance, low fuel consumption and low exhaust emissions. This was a very sophisticated engine. It was going to be tough for others to compete against in the low-margin market for small cars.

The new engine was built on an extremely strong foundation. Its predecessor was VW's venerable 1.9 litre TDI, one of the most frequently built diesel engines in the world. The E189 achieved significant improvements on almost all performance measures and it dealt with the most serious disadvantages of passenger diesels: acoustic performance, cold weather starting, and exhaust gas emissions.

Control of NO_x emissions was a particularly difficult challenge, as NO_x production is a weak spot for all diesels. To make this even more daunting, the new U.S. limits on NO_x, 0.04 g/km, were far below the European limits.

By 2006 VW had mostly achieved a workable solution for NO_x control. They had partnered for several years with Mercedes and Bosch on the development of BlueTec, a urea-based catalytic reduction process. BlueTec worked reliably and kept NO_x emissions well within the new U.S. limits. The only problem with BlueTec is that it required each vehicle to have a tank of urea liquid which needed to be refilled periodically.

The E189 engine was truly an advance in diesel technology for smaller passenger vehicles. VW was sure that its performance would convince formerly reluctant customers to switch to diesel, and it was also convinced that no other manufacturer could build a small diesel engine with anything close to the Clean Diesel's advantages.

The NO_x Trap

But in early 2007, very late in the game, VW made the fateful decision to entirely change the technology for the Clean Diesel's NO_x control system. This decision opened the door to Dieselgate.

VW cancelled its participation in BlueTec because of three reasons. It felt that the extra tank of fluid would take up critical space in the Passat, Jetta, Golf, A3 and other similar models. VW was also sure that Americans would not put up with the need to top up the extra tank of fluid. And finally BlueTec added an additional \$100-200 to the vehicle cost in a very highly competitive market.

To replace BlueTec VW chose the Lean NO_x Trap (LNT), which proved aptly named. The LNT had been around for years, but it had never been used to lower NO_x emission to anything close to the new U.S. requirements.

The Lean NO_x Trap (LNT) is a component of the exhaust system, employing a catalyst that traps NO_x when the engine is running lean. When the trap fills up the engine switches to a richer mixture – the fuel injection system sprays more fuel into the cylinders than is needed to propel the car. The unburnt diesel converts the stored NO_x into nitrogen which is then released into the exhaust. This cycle reduces fuel efficiency and engine torque.

Engineers at VW had less than a year to make it work on the E189 without affecting fuel consumption, torque, reliability or other key attributes of the new engine. They were told the introduction of the vehicles could not be delayed and that technical failure was not an option.

James Liang, the VW engineer who pled guilty to fraud in the Dieseldate case, revealed in his plea bargain how the engineering team responded to the requirement to use the LNT. According to the indictment, “Almost from the beginning of VW’s process to design its new ‘clean diesel’ vehicles, Liang and his fellow co-conspirators designed these VW diesel vehicles not to meet U.S. emissions standards, but to cheat the testing process⁴³.”

In the absence of a real solution, engineers added software to the Engine Control Module (ECM), which controls fuel injection, ignition, emissions control and other functions. This set up the ECM with two modes: one for normal driving and one for operation while being tested. In the testing mode the Lean NO_x Trap operated normally. During normal driving the LNT was turned off and NO_x was emitted by bypassing emission controls.

The method for cheating U.S. emissions tests had been outlined in detail in a 2006 PowerPoint presentation by a top technology executive at VW⁴⁴. It is not yet revealed who saw the presentation at VW, but the method is very clear. It showed that the pattern of the U.S. tests was entirely predictable so that the ECM computer could recognize test situations and then activate emissions controls.

The software cheat got the Clean TDI Diesel to market on time. The new engine was introduced to the U.S. market in a 2008 Jetta TDI Clean Diesel. This model was tested and deemed compatible with California’s Tier 2 Bin 5/CA LEV II regulations, and was thus able to be sold in all 50 states. It was received with rave reviews in the automotive press and it captured green car awards almost right away.

Many people speculate that the intention was to get the defeat device in place in the short term until the Lean NO_x Trap could be perfected. If this was the intention it was never done. The software was upgraded several times and remained a component of the ECM computer until VW was caught in 2015. The uncontrolled emissions of NO_x continued all through this period.

⁴³ Schoenberg, Tom; Naughton, Keith & Butters, Jamie. (2016, September 10). Engineer Admits Role in VW Emissions Scandal. Calgary Herald.

⁴⁴ Ewing, Jack (2016, April 26). VW Presentation in '06 Showed How to Foil Emissions Tests. NY Times. <http://nyti.ms/1T2W9u5>

■ ■ ■ ■ APPENDIX 2: DEFINITIONS AND ACRONYMS

ACEA: European Automobile Manufacturers Association.

BlueTec: NO_x control system for passenger diesel engines jointly developed by Mercedes, Bosch and VW. BlueTec uses a selective catalytic reduction (SCR) system requiring each vehicle to have a tank of urea liquid that requires refilling.

CARB: California Air Resources Board. CARB is the regulator of a broad range of air emissions. It created the world's first regulations controlling emissions from automobiles and trucks.

Catalytic Converter: The three way catalytic converter oxidises carbon monoxide (CO) and hydrocarbons (HC) and converts NO_x to nitrogen, substantially reducing tailpipe emissions from gasoline engines.

Defeat Device: Any device (hardware, software or other) that disables emissions controls under real world driving conditions, and enables emissions controls to perform during formal emissions tests.

ECM: Engine Control Module: The electronic controls that adjust the air-fuel mixture, ignition timing, idle speed and other aspects of engine performance. Also known as the Engine Control Unit (ECU).

EPA: Environmental Protection Agency. The EPA is an agency of the U.S. federal government, created in 1970 to protect human health and the environment. In 2016 the EPA had 15,000 full time employees and its budget was \$8.1 billion.

EU: European Union. A political and economic union of 28 member states in Europe. The EU has developed an internal single market through a standardized system of laws that apply in all member states. 19 of the EU countries have agreed to a monetary union, using the Euro as currency.

Hybrid electric vehicle: A vehicle that combines a conventional internal combustion engine with an electric propulsion system, producing a hybrid vehicle drivetrain.

ICCT: International Council on Clean Transportation. An independent non-profit organization founded to provide unbiased research and technical analysis to environmental regulators. ICCT has an annual budget of about \$40 million and roughly 40 employees.

Kyoto Protocol: The Kyoto Protocol is an international treaty that commits state parties to reducing greenhouse gas emissions. The treaty was negotiated in Kyoto, Japan in 1997 and came into force on February 16, 2005 with 193 signatories (Canada withdrew on December 2012).

LNT: Lean NO_x trap is a device used to reduce NO_x from the exhaust of diesel engines. The LNT uses an adsorbent such as zeolite to trap the NO_x molecules. Once the trap is full it needs to be purged with diesel fuel.

NO_x: Nitrous oxides produced by the combination of nitrogen and oxygen during combustion, particularly at high temperatures. The NO_x components that contribute to air pollution are nitric oxide (NO) and nitrogen dioxide (NO₂).

PEMS: Portable Emissions Measurement System. PEMS are lightweight systems used to measure emissions in real-world applications from cars, trucks, buses, trains, construction equipment, etc.

Smog: Smog is visible air pollution consisting of NO_x, sulphur oxides, ozone, particulates and other substances. Smog is derived from coal, vehicle and industrial emissions. The emission chemicals react in the atmosphere with sunlight to produce secondary pollutants dangerous to human health.

TDI: Turbo-charged direct injection.

VW: The Volkswagen Group. A multinational automotive manufacturing company headquartered in Wolfsburg, Germany. VW sells passenger cars under the Audi, Bentley, Bugatti, Lamborghini, Porsche, SEAT, Skoda and Volkswagen brands. VW has operations in 150 countries and operates 100 production facilities in 27 countries. In 2016 VW was the world's largest automaker by sales.