While the Association does not have the copyright authority to reprint Margo Oge's entire book, we do have permission to provide the following pages that will give you a good sense of the book. You may purchase the book at your local book store or at Amazon or Barnes and Noble.

DRIVING THE FUTURE

COMBATING CLIMATE CHANGE WITH CLEANER, SMARTER CARS

MARGO T. OGE

FOREWORD BY FRED KRUPP

Arcade Publishing
New York

First Edition

Arcade Publishing books may be purchased in bulk at special discounts for sales promotion, corporate gifts, fund-raising, or educational purposes. Special editions can also be created to specifications. For details, contact the Special Sales Department, Arcade Publishing, 307 West 36th Street, 11th Floor, New York, NY 10018 or arcade@skyhorsepublishing.com.

Arcade Publishing® is a registered trademark of Skyhorse Publishing, Inc.®, a Delaware corporation.

Visit our website at www.arcadepub.com.
Visit the author's website at www.margooge.com.

10 9 8 7 6 5 4 3 2 1

Library of Congress Cataloging-in-Publication Data

Oge, Margo T.
Driving the future : combating climate change with cleaner, smarter cars / Margo T. Oge. — First edition.
pages cm
Includes bibliographical references and index.
ISBN 978-1-62872-538-4 (hardcover : alk. paper); ISBN 978-1-62872-691-6 (paperback : alk. paper); ISBN 978-1-62872-771-5 (ebook)
1. Alternative fuel vehicles. 2. Automobiles—Technological innovations. 3. Automobiles—Environmental aspects. 4. Sustainable engineering. I. Title.
TL216.5.O38 2015
629.222028'6—dc23 2014048036

Cover design and photograph by Enrique Florendo and Marisa Oge

Printed in the United States of America

To my husband, Cuneyt, my best friend, whose love, support, and belief in me means the world to me. To my daughters, Nicole and Marisa, who are the greatest gifts in my life. To my mother, Ioanna Tsirigotis, who is my hero.

To all EPA employees, especially my colleagues at the Office of Transportation and Air Quality, whose passion and hard work have resulted in significant improvements to public health and the environment. To all individuals and organizations who are working for a cleaner and more sustainable planet.

"When written in Chinese, the word 'crisis' is composed of two characters. One represents danger and the other represents opportunity."

— John F. Kennedy

CONTENTS

LIST OF FIGURES

INTRODUCTION

8:00 p.m., Beijing, China

On September 30, 2040, a slight woman in jeans and a T-shirt swipes off her e-book and steps out of a silently idling car on a busy street.

"Park Mode," she says and then watches as the empty, single-occupant car pulls down to the entrance of the parking garage underneath her apartment building. The woman doesn't have a license—she normally takes the train and shared taxis around the city—but decided to pay for a car on demand to drive her out of town to a friend's house for the weekend. After pausing for an exiting electric scooter, the driverless vehicle disappears into the lot.

The car's surface still glows in the woman's favorite shade of purple. The color-changing exterior also acts as a solar panel that powers the air conditioning and accessories when the vehicle is idling in traffic. The car's body contains no steel, but is constructed primarily out of aluminum and plastics, weighing in at about 1,650 pounds. The electric engine gets about 100 miles per gallon (mpg), close to the global average, and puts out zero emissions. In 2030, the Chinese capital passed laws that allow only zero emissions vehicles within city limits.

The car's navigation system has helped it travel 120,000 miles without so much as a scratch, but the technology also helps the car quickly find a parking space in the darkened garage. Four low-light cameras integrated into the frame guide it into a cramped space between two other vehicles. The car's exterior fades back to its default blue shade, and it begins wirelessly powering up for the next customer.

1:00 p.m., Berlin, Germany

A seasoned German truck driver stops for a lunch break on the outskirts of town. He is almost done with his day's work, transporting motorcycle parts from Frankfurt in his two-trailer, autonomous truck. The truck is the latest generation truck from Daimler and sports a cellulosic, biodiesel hybrid system and is capable of driverless operation. It has been averaging a relatively constant 85 miles per hour (mph), making the 344-mile trip just over four hours, always connected to the "Connected Cloud Drive" system. The driver had been listening a lot of Karl May audiobooks on his trips recently and briefly fell asleep somewhere near Leipzig. But on the dedicated highway for autonomous trucks, his short nap wasn't any more dangerous than a passenger falling asleep on a plane. About fifteen minutes from the shared traffic routes, he had to punch in his driver code and grab the wheel. But he only had to intervene once when heavy rain set off a warning that the visibility of the truck's control cameras might be impaired. Even in that extreme weather, the truck was in continual communication with the vehicles around it as well as receiving information from the road's own traffic warning nodes to keep it on track.

12:00 p.m., London, United Kingdom

A young London City trader walks out of his office on the way to meet his girlfriend for lunch. He pauses to pick out a flower at a stand before pushing the valet app on his smartwatch. He typically does not drive in the city—central London has had a daytime congestion fee for vehicles since before he was born—but he can't resist a quick spin in his company's new executive share car, a shiny black 2040 model fuel cell 911 Targa. As it turns the corner, the car's almost entirely carbon fiber body gleams, but the super-strong and lightweight material encases a vehicle that weighs less than the tiny 1954 Austin Healey coupe his dad used to drive on the weekends.

The Targa glides up, and the man slides underneath a roof made of new generation solar panels with a nanotechnology coating that produces even more electricity from the wind friction generated at higher speeds, refilling the battery packs as he drives. The car can travel a more than 400-mile range on a five-minute quick-fill charge of the solid-state battery pack and hydrogen tank. The fuel cell engine is virtually silent, but with the optional flywheel technology the car can accelerate from zero to 60 mph in around 3.5 seconds.

He forwards his girlfriend's text with the restaurant location to the car's navigation system. The Porsche transmits its presence on the road to the City, which transfers £30 from his company's account to the public transportation network. Then the vehicle pulls out behind a bus on the otherwise quiet street.

7:00 a.m., Atlanta, United States

The Atlanta suburbs are already a humid 90 degrees. As a middle-aged man stands in the shower, his car charges wirelessly in the garage while the air conditioner precools the interior. The vehicle is small, about the size of the Honda Fit he and his wife used to own, and can travel about 100 miles on a full charge of the advanced battery pack, which is the size of a large briefcase. At 7:15, he hops into his car and sees a few crumbs on the passenger seat. The whole windshield is capable of turning into a high-resolution screen; his daughters had snuck out there last night to play video games.

Just for the fun of it, he backs the car out of the driveway himself before allowing the steering wheel to retract. While the car takes him the five minutes to the train station, he has a quick video conference with the sales staff at his low-carbon fuel company. The car drops him off and drives itself home.

At 7:30 the two kids jump into their car, which takes them to school. Their mom is telecommuting today but has an appointment with her personal trainer at 12:30. The gym has a drop-off zone but no parking lot, so, after the woman hops out, the car waits in a designated space two blocks away.

Then, at about 1:00 p.m., the eighth grader calls in. She feels sick and wants to go home. The car texts the mom, asking for permission to pick her daughter up, and then texts the girl. The car knows that the fitness appointment will run another 30 minutes, so it picks up the daughter before returning to the gym. Later in the day, the car also picks up the other child from school, along with her friend who is coming over to study. After charging for fifteen minutes, the car picks up the dad from the train station. Even though the family has three people of driving age, the autonomous car allows them to get around with just a small urban commuter car. That weekend the whole family is taking a trip to the beach, so they'll use some of their lease's contractual "shared vehicle days" for a larger plug-in vehicle.

6:00 a.m., Mexico City, Mexico

A couple that has just moved into a new apartment complex is fast asleep. In the past, their car purchases had been dictated by where they lived. They didn't need one in the crowded center city but decided they wanted a vehicle to get around once they moved to the outskirts. They still use public transport to get to work—the car is mostly for personal use. In this case, however, they chose their apartment because of their car. They save money on their home's power bill by plugging their electric vehicle into their apartment's "green circuit." Right now, during lower use hours, the battery pack is storing the cheaper wind-generated electricity that the local microgrid supplies. During the day, the microgrid switches to solar. Later, when it is sitting unused in the garage during the daytime peak load hours, the battery pack provides lower cost, clean electricity for their apartment.

★ ★ ★

How close will these imaginary scenarios of the future be to reality? For half a century, the promise of futuristic technologies—high-tech computer cars, electric and driverless cars—has been dangled in front of us in magazines and television shows. But a yearly trip to the dealership would show only modest technological improvements in new models.

Today, those promises are finally being realized. In 1970, for example, there were zero mass-produced hybrid electric vehicles. The same number of hybrids was available to drivers in 1980 and the early 1990s. By 2000, there were two hybrid models. Today there are over fifty.

Even more amazing are the growing number of pure electric cars and hydrogen fuel-cell vehicles that use no gas at all. Several of these vehicles already get as much as 100 mpg today, a number that, until recently, would have seemed ripped from the pages of science fiction. Increasingly smart and interactive vehicles with functions like lane change assist are already available in multiple production models. Several prototypes for driverless cars are being road tested. The automobile market has changed dramatically and irrevocably. The future is now.

This transformation is far from over, though. Over the next decades, the proliferation of alternative fuels and powertrains will make cars many times quieter, cleaner, more efficient, and smarter than they have ever been. In the near future, we will see automobiles that not only are high efficiency or emissions free but also completely reimagine personal transportation. More and more people will get around via automobiles that have more in common with cell phones or airplanes that our traditional concept of a steel box with a gas-burning engine. In short, we are in the early stages of a transportation revolution bigger than any since Henry Ford began mass production of his Model-T. But just as remarkable is why this sea change in automobile design is taking place now.

The conventional automobile is one of the twentieth century's great success stories. But this same petroleum-burning technology that radically increased personal mobility came with a huge cost. By the 1940s and 1950s the automotive exhaust in American cities was sickening citizens and darkening skies. By the 1960s, the smog in Los Angeles had become a poster child of rampant pollution for the nascent environmental movement. By the early 1970s, this environmental consciousness pushed the federal government to begin cleaning up conventional pollutants in automobile emissions with new technologies and improved fuels. By 2010, new technology and fuels had resulted in cars that emitted 99 percent fewer conventional pollutants. But today's revolution in automobiles is designed to face down our biggest environmental challenge yet, climate change.

In addition to foul-smelling exhaust, cars—along with trucks, boats, planes, and trains—have been releasing a threat that is undetectable to our senses. The powertrains of the transportation sector run almost exclusively on petroleum. And every gallon of gas or diesel that they burn emits carbon dioxide, the greenhouse gas that accelerates climate change. As a result, about a third of the total greenhouse gas emissions in the United States are from the transportation sector. Globally, the sector accounts for about a quarter of greenhouse gases, but transportation is also the fastest growing contributor to overall greenhouse gas emissions.

This growth has many factors, but among the most important is the purchasing power of an Asian middle-class swelling from about 500 million in 2012 to around 1.75 billion people by 2020, a 3.5 times increase in only eight years. In 2013 the Chinese consumer alone bought more than 22 million vehicles, and in 2020 they are expected to buy more than 30 million vehicles. That is 10 percent more than the 2013 combined sales in North America and Western Europe. To avoid a climatic catastrophe, the enormous number of new cars on Chinese roads alone must be significantly cleaner. The good news is that China, like other major economies, is moving aggressively to reduce transportation emissions. The global efforts to rein in greenhouse gas emissions in the transportation sector have been much more successful than most other international treaties targeting the existential threat of climate change.

⋆ ⋆ ⋆

Over the past three decades, the dangers related to climate change have become increasingly clear and immediate. Ocean levels and surface temperatures have been rising, and each of the last three decades has been successively warmer at the earth's surface than any preceding decade since 1850. In the form of devastating droughts, extreme flooding, heat waves, and fires, the earth got a taste of the destructive changes that would become increasingly common as climate change accelerated in the near future. While climate scientists don't like to connect any one event to global warming, their modeling conclusively shows that humans can expect more of the same weather as an unprecedented growth of greenhouse gases in the atmosphere continues to drive global warming.

Unfortunately, the world's demand for action on climate has been met with ineffective treaties and half-measures by the global community. Worse, the United States refused to support international treaties and has been unable to pass any federal domestic legislation targeting climate change. For decades, the oil, automobile, coal, and power generation industries took a page from the tactics used by the tobacco industry in the 1980s to cast doubt on the climate science and to scare the public about the economic costs of action. The cost of this intransigence is estimated by the Center for American Progress at US $188 billion in climate-related damage in 2011 and 2012,[1] and it increases by the day. A 2014 White House report suggests that every decade of inaction actually increases the cost of mitigation by 40 percent.

Then, in the first year of the Obama administration, an opening presented itself, and the United States enacted the first greenhouse gas reduction regulations in its history. The 2012–2016 and the 2017–2025 Light Duty Vehicle greenhouse gas and CAFE rules will halve the nation's carbon emissions from cars and double their average fuel economy to 54.5 mpg by 2025. When the *Economist* examined twenty global greenhouse gas reduction actions to combat global warming in the article "The Deepest Cuts" (September 20, 2014), comparing their respective contributions to greenhouse reductions, the United States vehicle rules ranked as the most significant action in the transportation sector to date, worldwide. These same historic regulations are also driving the design of a new generation of cleaner, smarter cars.

A number of factors aligned to create this groundbreaking regulation including a Supreme Court decision, a California state law, a suddenly bankrupted auto industry, and an administration determined to do something about climate change. It was this perfect alignment of events that gave my office at the EPA a real chance to finally rein in the greenhouse gas emissions that gas-powered cars have been emitting into the atmosphere ever since they first hit the road. Just as important, a converging set of emissions and greenhouse gas regulations being implemented across the world's major economies—including Europe, Japan, and China—promises similar reductions by 2025. These global regulations are among the key drivers required to combat climate change by changing the cars we drive.

* * *

The first part of this book tells the story of humans' growing understanding of science behind climate change and how, starting in the 1980s, a collection of corporate interests ferociously beat back national efforts to address the problem. It traces the history of the environmental policymaking in the United States along with automakers' foot-dragging and downright refusal to bring their most innovative new technologies to the marketplace.

Then we follow the efforts of a wide-ranging group of people—from a staunchly Republican Texas hedge fund millionaire to a former California public school teacher to the Georgetown lawyer who prepared the winning argument for a Supreme Court decision on greenhouse gases, to dedicated EPA engineers in Ann Arbor—as they play critical roles in finally breaking through this corporate and political stranglehold. It also describes how government, despite the barrage of negative reporting, can work to save and improve the lives of its citizens.

Next, we examine the primary drivers that are shaping, and will continue to shape, the car of the future while fighting climate change. Many of tomorrow's technologies, from alternative powertrains to lightweight materials to low carbon fuels and driverless car technologies are already in development. We'll explore their possibilities as well as innovative possibilities that sit on a more distant horizon.

In the final section I assess the scale of the challenge ahead for 2050, putting hard numbers on how much greenhouse gas emissions from cars and light trucks must be reduced to avoid the truly catastrophic consequences of climate change. I will lay out the additional policies and innovations in automotive technology that will be required, while sharing some of the lessons I've taken away during my experience with environmental policy over the last three decades.

I consider this book a continuation of my public service, for it brings together the science, policy, and technologies that combat climate change with the cleaner, smarter, safer, and more exciting vehicles that our world needs. For the past forty years, the United States has led the world in innovative clean air technology. I remain optimistic that we will once again successfully confront the major environmental threat of our times—and do it while advancing Americans' health and our national economy. As a mother, I believe we have a moral responsibility to act urgently to protect our children's future.

PART ONE

THE CLIMATE JOURNEY

I

THE DAWN OF AUTOMOBILITY

In August of 1888, a thirty-nine-year-old woman named Bertha rolled to a stop in the center of Wieslen, a small town that sat in the rolling green countryside of southwestern Germany. She and her two teenage sons climbed out of their three-wheeled vehicle, made their way into the local apothecary, and purchased all the ligroin he had, about three liters. Ligroin is a petroleum ether commonly used for painting and decorating, but Bertha had neither of these uses in mind. Instead, she walked over to the carriage and poured the liquid into an engine sitting on the front. She then hoisted herself back into a wooden driver's seat and, to the surprised looks of pedestrians, chugged out of town with her family at the leisurely pace of six miles an hour.

The trip on the curious carriage was hardly trouble free. Along the way Bertha pulled over at a blacksmith's to fix a chain and a cobbler's to have him attach some makeshift leather brake pads. She'd had to solve other issues herself, using a hatpin to clean a clogged fuel pipe and a garter to insulate a wire. But, just before dusk, she pulled up outside of her mother's house in Pforzheim and, after unloading her sons, sent a telegram back to her husband in Mannheim. The message told him that she had stolen his prototype vehicle, had safely completed the sixty-six-mile journey, and would return home the next day.

The trip back was relatively uneventful, but the sight of the engine-powered vehicle still surprised and alarmed observers—exactly the reaction Bertha wanted. The trip's main purpose was to promote the automobile into which she and her husband, Karl Benz, had invested enormous amounts of money and time.

Or so the story goes. Over time, the legend of Bertha Benz's inaugural trip has been told and retold, embellished and celebrated by German drivers who retrace her journey every year. What is certain is that Karl Benz invented the first practical gas-powered vehicle, that Bertha's trip was arguably the most successful automobile promotional campaign to date, and that the Benz's internal combustion vehicle still faced stiff competition from other propulsion techniques.

At the turn of the twentieth century, popular automobiles were also powered by electricity and steam. Each technology had its own upsides as well as major shortcomings. Electric cars were quiet and easy to operate, but they were heavy, their distance was limited, and their recharge time was unbearably long. One of the most popular vehicles at that time was the Columbia Runabout, which could go forty miles on a single charge and run at speeds of up to 12 mph. Steam-powered cars accelerated fine once you got them going, but they took a long time to harness enough power to start. They also had limited capacity to store energy on long trips and were prone to explosions. Gas-powered vehicles were relatively quick starting and could run for long distances without refueling. But they were noisy, complicated to operate, and often broke down. By the early 1900s, there were nearly four thousand steam, electric, and gas-powered cars traversing America's roads. Which machinery would win out in the end was still anyone's guess.

Then, twenty-six years after Bertha's journey, Henry Ford's factory took automobile production to the next level. By 1914, his factories were churning out a boxy, black, gas-powered Model T every ninety-three minutes, completing six vehicles in roughly the time it had taken Bertha to go sixty-six miles. By 1918, the assembly-line manufacturing had also brought the car's cost down to $450, a price even within the reach of Ford's factory workers—and well below the $2,000 for electric vehicles. The Model T was so popular that Ford didn't buy any advertising for years. By the 1920s, electric and steam vehicles were left in the petroleum-reeking exhaust of the now-dominant internal combustion engine.

⋆ ⋆ ⋆

Of course, the popular availability of cars did much more than make Henry Ford rich. The automobile pushed horse-drawn carriages to the wayside and forced cities to pave roads—if not completely redesign them. It created the sprawling suburbs of 1950s America. It rapidly changed social mores and became one of the most desired consumer goods in the world. It also pushed a century-old revolution in personal mobility to a new zenith.

Over the past two centuries, while the earth's population has increased seven times and global GDP has increased a hundred times, personal mobility has increased a thousand times.[1] In 1800, people primarily got around by walking, riding horses, or using boats. The vast majority never ventured far from their homes or did so rarely. By 1950, millions of people could almost effortlessly travel hundreds of miles in a day. The internal combustion engine was the most important technology in this transformational increase in personal mobility.

Unfortunately, this agent of personal freedom was also a source of an enormous amount of air pollution. Beginning in the 1940s, people in urban areas throughout the United States experienced waves of then-unexplained pollution that caused teary eyes, headaches, nausea, asthma attacks, and other reactions. School children in Los Angeles were kept indoors during high-risk days. The filthy air that factories and power plants emitted was well known, but the smog that enveloped America's cities was not a sooty black; it had a brownish, yellowish tinge, which was due to the nitrogen oxide in auto emissions. The problem worsened until the popular disgust over pollution rattled American politics and eventually spilled over into one of the nation's largest grassroots demonstrations.

★ ★ ★

In 1959, a newly elected Democratic senator began his journey toward becoming the national political face of the new environmental movement. The former governor of Maine, Edmund Muskie, had grown up the working class son of Polish immigrants in the small town of Rumford. At six feet four inches, with a powerful voice, Muskie was soon known in the Senate for both his flashes of temper and his ability to find consensus.

When Muskie arrived in Washington, DC, what we call environmentalism today didn't exist. Hunters and fishermen like Muskie promoted conservationism by protecting their recreational areas. Forestry officials managed logging and mining interests in national parks. But there was very little concern over the effects pollution might be having on public health and the environment. Muskie had experienced the ill effects of pollution firsthand. His hometown was dominated by a paper mill that had been spitting enormous amounts of chlorine, nitrogen, phosphorus, and other pollutants into the water, while spewing sulfur dioxide and other toxins into the sky. Dead fish floated in the water, and the air pollution was so bad that it prevented new businesses from opening in Rumford. The new senator recognized the urgent necessity of protecting birds, frogs, humans, and other living things from pollution.

Throughout the 1960s, Muskie's modern-day environmentalism developed a broad base of support, from scraggly college students to middle-class moms worried about their children's health. Mainstream media's coverage of environmental disasters, like *Time* magazine's 1969 story of a fire on the surface of Cleveland's polluted Cuyahoga River, further galvanized concern. As a result, the first nationwide Earth Day events in 1970 attracted attention from across the political spectrum. Senators and congressman from both parties flew back to their districts to speak at local events in city parks and on university campuses. Meanwhile, Muskie was pushing through a bill designed to satisfy the new environmental concerns.

During the 1960s, a series of laws established increased federal monitoring of pollutants, but none had the authority necessary to begin the real work of cleaning up the country. By 1970, Muskie had created legislation designed to transform America's relationship with its increasingly polluted landscape. His bill also satisfied and incorporated various important political interests. From Tennessee Republican senator Howard Baker he included a commitment to technology-forcing regulations—rules that don't prescribe specific solutions for industry to follow but stimulate the marketplace by creating a demand for new technologies. Muskie also respected Missouri Democratic senator Tom Eagleton's demand for solid deadlines. Finally, Muskie wanted certain health standards to be met. These elements all fused in the creation of the most effective environmental law to date, the Clean Air Act of 1970. The bill locked in the regulatory technique of using technologies to achieve a healthier environment by a certain date. No other federal law combined all these elements—most had none.

A well-known example of the Clean Air Act's application quickly followed its passage. By 1975, new cars were required to meet certain standards for emissions. The regulation would dramatically clean up the air, reducing cases of bronchitis, asthma and more serious health effects including premature death. The requirements had to be met by 1975 model year cars. And it was up to the car companies to figure out what technology would get the job done, prompting a race between multiple companies to supply a device that would win the millions of dollars in contracts from auto companies. That solution, the catalytic converter, is now found in virtually every new car manufactured in the world.

But Muskie wasn't the only one responding to the new environmentalism. Soon after the Clean Air Act became law, President Richard Nixon created the Environmental Protection Agency. A

Republican and no devout environmentalist, Nixon had essentially sat out Earth Day in the 1970s. But he did respect the political importance of the widespread public demand for cleaner land, water, and air. In fact, the EPA may have been strategically created in part to take the environmental card away from Muskie, Nixon's presumed Democratic challenger in the 1972 presidential election. A few months after the creation of the EPA, the Nixon campaign forged and leaked a letter to the press that called Muskie's credibility into doubt, essentially ending the environmentalist senator's presidential ambitions. But whatever Nixon's motivation was, the new agency he created was too powerful to be considered one more political trick. The EPA soon exercised its authority under the Clean Air Act to begin a massive cleanup of the mess that internal combustion–powered automobiles had created over the past half-century.

The EPA's success in this effort is clear when comparing modern cars with those from 1970. Just forty years after the EPA went to work, cars produce over 99 percent fewer emissions than they did in 1970. Between 1970 and 2010, the reductions in levels of soot, smog, and other pollutants from cars, trucks, factories, and power plants have prevented hundreds of thousands of premature deaths, nearly a million cases of chronic bronchitis, and over 18 million child respiratory diseases. Lead reductions have prevented the loss of over 10 million IQ points in children.[2] Americans breathe much cleaner, healthier air than they did in 1970. While our cities' skies may not be pristine, they are remarkably cleaner.

⋆ ⋆ ⋆

When I joined the EPA in 1980, it was my first professional experience with environmentalism. I had arrived in the United States from Athens, Greece, twelve years earlier, as the environmental movement was becoming a powerful political force. When I got to America my English was limited, but, after a summer-long crash course, I started an engineering program at the University of Massachusetts in Lowell.

At that point my knowledge of environmental issues was also pretty limited. Growing up in Athens, a crowded and polluted city that is home to a third of the entire country's population, I was constantly surrounded by atmospheric pollution from carbon monoxide, sulfur oxides, nitrous oxides, and dust. I watched Athens' air pollution coat the 2,500-year-old marble pillars and statues of the Parthenon in soot. I had seen and read about how the beautiful marble underneath the soot was being eroded by pollution, which made the future of the monument questionable.

After receiving my MS degree, I went on to a job at a Connecticut-based consulting firm for the chemical industry. It wasn't until I started at the EPA's Office of Toxic Substances that my work as a chemical engineer became exciting. I joined the EPA team evaluating the toxicity level of new chemicals before they entered the marketplace. Now my engineering skills weren't just academic; they were preventing toxins from harming people and the environment.

In 1985, I secured a one-year detail to work for Senator John Chaffee, a Republican representing Rhode Island. Chaffee, the powerful chairman of the Senate Environment and Public Works Committee, helped me to author a bill that made plastic rings for six-pack beverages biodegradable. At the time, every six-pack of soda or beer was held together by plastic-ring packaging. A lot of these rings found their way into the ocean, where they trapped and killed marine life. The bill I worked on became part of a Superfund amendment in 1986. It was my first experience with the process of lawmaking.

From the Senate, I returned to the Office of Toxic Substances as a deputy director. As a manager, my first project was the toxic release inventory initiative, which became better known as the "Community Right-to-Know Program." For the first time, the program ensured that public could learn about the type and amount of toxic substance releases from facilities in their community. Several years later, I took on the job of directing the Office of Radiation and Indoor Air. Among my responsibilities was helping to establish the first repository for nuclear waste in Carlsbad, New Mexico. I also worked to make radon gas and other indoor pollutants' health impacts known to the public. With my team, I also managed the publication of the first scientific study about the health impacts of secondhand smoke, which completely changed the policies for smoking in public places.

Then, after moving from various positions over my first fourteen years at EPA, I found a home leading the Office of Transportation and Air Quality. It was here that I directly confronted the legacy of innovators like Henry Ford and Karl Benz. Starting in 1994, I spent the next eighteen years working with my team to reduce the air pollutants that caused premature death and respiratory illness from cars, commercial trucks, and buses. We reduced cancer-causing substances like benzene in gasoline and sulfur in diesel and gasoline fuels. We also developed rules compelling locomotives and boats to reduce their soot- and smog-forming pollutants that impacted the health of millions of Americans.

But while my team successfully pushed forward our agenda to clean up and reduce conventional air pollutants up to 99 percent since the seventies, a mostly odorless, invisible threat was rapidly building up all around us, greenhouse gases. Throughout the 1980s and '90s, as Americans became more familiar with this threat, several things became clear. First, human-produced greenhouse gases were causing the planet to heat up rapidly. Second, along with other greenhouse gases, one of the major culprits in this process was carbon dioxide, a byproduct of burning fossil fuels like diesel, gasoline, and coal. Third, greenhouse gases were streaming out of the tailpipe of just about every car and truck in America. In fact, the transportation sector—the sector my office was responsible for cleaning up—was producing almost a third of the greenhouse gas emissions in the United States, second only to the power generation sector.

Despite all of our efforts at EPA, an unregulated, life-threatening gas was still streaming out of vehicles across the country. Over its first forty years, the EPA accomplished much of its original purpose.

But it turned out that our greatest challenge still lay ahead: the global threat of greenhouse gas–driven climate change. This phenomenon was a complex beast with a global reach—and a problem so politicized that it had been dangerously ignored by our government for decades.