
BETTERING
HUMAN LIVES
LIBERTY

ENERGY MATTERS!

Liberty's mission is to **better human lives**.

Liberty is a **technology pioneer** of the shale revolution and has driven enormous improvements in both human well-being and environmental quality.

Liberty management and board are aligned with our owners and our communities.

Liberty partners with our customers to deliver **low-impact, low-cost, reliable energy** (and we're proud of it!).

Liberty sees **three global energy challenges**:

- Energy poverty
- Secure supply of reliable, affordable, and clean energy
- Climate change

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PREFACE

INTRODUCTION

It is simply not possible to discuss the environmental and social impacts of our industry without considering the environmental and human impacts of the *absence* of our industry.

As with all complex issues, Liberty strives to learn first, define a thoughtful plan, and then act. *Bettering Human Lives*, our annual Environmental, Social, and Governance (ESG) report, is intended to share our journey with you. We aspire to go far beyond a narrow focus on our company to look at the bigger picture of the world in which we live and the industry in which we operate. *Bettering Human Lives* strives to answer the often-asked question "would the world be better off without fossil fuels?" Our answer is emphatically "No." Because the broader issues around energy, poverty, and the environment are so important — and so often misunderstood — we will explore and explain them in depth.

Part 1 of this report tackles the big-picture issues that provide the proper context for our business. Sections provide overviews of energy, energy poverty, climate change, climate change economics, geopolitics, food production, and the four critical materials — cement, steel, plastics, and fertilizer — without which there would be no modern world. We believe that a basic understanding of these issues is critical for successfully engaging with today's three global energy challenges: 1) energy poverty, 2) secure supply of reliable, affordable, and clean energy, and 3) climate change. There is no reason that we can't master all three challenges. But doing so requires honest assessment, rational evaluation of tradeoffs, continued technology advancement, and the will to get it right.

Since the oil and gas industry began in the second half of the 19th century, global life expectancy has doubled, extreme poverty has plummeted, and human liberty has grown tremendously. The timing here is no coincidence. The surge in plentiful, affordable energy from oil, gas, and coal enabled this progress in the human condition.

Energy poverty is today's most urgent challenge and this report explains why the longer, healthier, opportunity-rich lives in the modern world are simply not possible without oil and gas. Borrowing Thomas Hobbes' words, life for most everyone throughout history was "nasty, brutish, and short" when human liberty was scarce and energy was supplied only by human toil and draft animals. Liberty's mission is to bring modern energy to the one-third of humanity that still lacks access, and to help energize the world with a secure supply of affordable, reliable, clean energy. Even in wealthy nations, rising energy prices pose significant economic and health threats to lower-income people.

The World Health Organization (WHO) estimates over three million premature deaths occur each year from indoor use of traditional biomass fuels, which generate copious particulate matter during combustion. WHO attributes several million additional deaths from outdoor air pollution predominantly from the same source: particulate matter, or $PM_{2.5}$ — one of the world's most deadly pollutants. Transitioning from traditional biomass fuels to modern fuels and implementing appropriate industrial pollution controls are the keys to reducing outdoor concentrations of $PM_{2.5}$, malnutrition, and preventable diseases. Combined with a lack of access to clean drinking water and basic education, collectively these issues account for over 10 million premature deaths each year. Bringing affordable, reliable energy to the world's poor is essential to eradicating these scourges.

The third global energy challenge, climate change, has become so politicized and emotionally charged that rational, calm, fact-based decision-making is too often displaced by well-intentioned but hasty and counterproductive measures. The unfolding global energy crisis is significantly caused by politically-driven policy decisions that have forced up energy prices, made power grids less reliable, and grown energy poverty without making any meaningful progress on climate change. The imposition of these burdens has given humanity no significant reduction in climate change — a long-term challenge requiring broad-based actions and significant technological advancements. Liberty is proud to be playing a role here too.

To put the global energy challenges in context, Figure 1.1 shows an economic analysis of the staggering lost economic output resulting from the major afflictions of the world since 1900. Although we have seen over a century of progress, air pollution, disease, malnutrition, and other serious issues continue dwarfing climate change in urgency. Solving these challenges is intimately tied to raising the poorest third of the world population out of dire energy poverty. Figure 1.1 overlays, on a like-for-like basis, the economic impacts of climate change as projected by the Nobel Prize-winning economist, William Nordhaus.

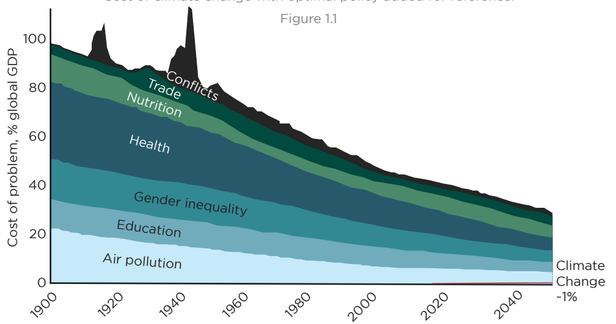
Part 2 of this report covers actions specific to Liberty. We are a proud passionate family that wants to spread liberty and opportunity to those born in less fortunate circumstances. We do this through many avenues, including educational scholarships, anti-poverty programs, criminal justice reform, and hiring practices that cast a broad net from returning veterans to formerly incarcerated individuals who had a truly tough start in life. We also cover our steps to maximize the benefits of our services and to lead the industry into a new era of technology and stewardship. At Liberty, we view ESG principles as foundational to our business strategy, expanding beyond our four walls to ensure that the work we do benefits our families, our communities, and the world. We work passionately to better the process of bringing hydrocarbons to the surface in a clean, safe, and efficient fashion.

Liberty's ESG report covers critical issues important to our business today. Information is provided by Liberty's subject matter experts, approved by our leadership team, and reviewed by the Liberty board of directors. Data in the report cover our 2021 calendar year unless otherwise indicated. The report is prepared in accordance with Sustainability Accounting Standards Board (SASB) standards and uses several other ESG standards to inform our discussion. In developing our report, we have identified opportunities for expanded reporting in subsequent years as we continue to drive improvement.

HOW MUCH RICHER WOULD THE WORLD BE HAD WE SOLVED DIFFERENT ISSUES, 1900-2050

Cost of climate change with optimal policy added for reference.

Figure 1.1



BETTERING HUMAN LIVES BY ADVANCING ENERGY ACCESS

MESSAGE FROM CHRIS WRIGHT, CHAIRMAN AND CEO

"It was the best of times, it was the worst of times" opens Charles Dickens' classic novel *A Tale of Two Cities*. In the year since we published the inaugural *Bettering Human Lives* report it has been the best of times for Liberty with great progress in our business, culture, technology, community efforts and our broader goal to better supply the world with energy. However, for the global energy system and the world's citizens who depend critically on it, it is among the worst of times. We are seeing the greatest threats in many decades to energy security, reliability, and affordability. This is not due to any shortage of available resources. It is due to years of underinvestment in hydrocarbons and related infrastructure. The deeply unfortunate underinvestment in hydrocarbons over the last eight years — in significant part driven by damaging and naive political, regulatory and investor pressures — has led to an energy crisis that is also precipitating a global food crisis.

This report covers both stories. Liberty had a year of tremendous progress across the board. It is a story of human passion, innovation and startling progress. Globally, unfortunately, the story is quite different. It is a story of suffering, insecurity and danger. It is the best of times, it is the worst of times.

Last year's report focused on the critical role that hydrocarbons play in lifting people out of poverty and the huge challenges that remain with billions still living in energy poverty. We listed energy poverty as the top global energy challenge. That has not changed. My letter last year summarized the climate change economic work of Nobel Prize winner William Nordhaus that helps put climate change in the appropriate context of energy poverty. Nordhaus' work and the issue of tradeoffs is contained in this year's report, as well as in both the Introduction and the sections on Energy Poverty, Climate Change and Climate Economics, which are updated in this year's report.

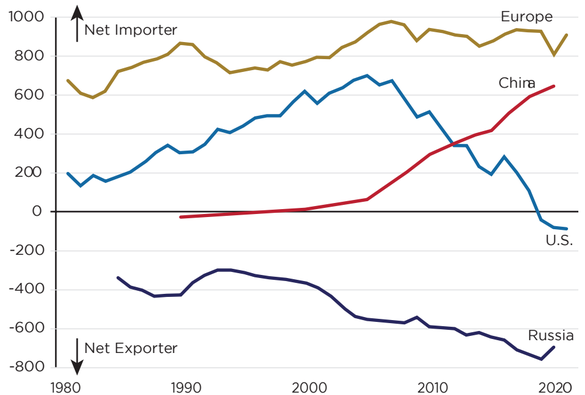
In last year's *Bettering Human Lives* letter I discussed the "growing belief that our industry soon will be, and should be, gone." What a difference a year has made. Now the equally strident clamor is quite contrary. Our industry is now accused of withholding production to "price gouge" even though U.S. oil and natural gas production have both grown significantly over the last 12 months. Production today is mostly limited by available surface resources including frac spreads, drilling rigs, frac sand, and available infrastructure such as pipelines and natural gas export terminals. This is the difference between an oversupplied market with depressed prices and an overly tight market with growing fears of demand outrunning supply.

This year's report expands to include more about our second-ranked global energy challenge: secure supply of reliable, affordable, and clean energy. The crisis today surrounds energy. The first alarm bells came last fall with a severe shortage of Liquified Natural Gas (LNG). The LNG crisis has not abated and, unfortunately, it gave Vladimir Putin's Russia tremendous leverage over Europe, likely influencing the timing of his long-held ambition to invade Ukraine. Without Russian gas, Europe's lights go out, its homes freeze and its factories close. Wealthy, free, democratic Europe has become overly dependent on Russia for natural gas, oil and coal — the critical substances that enable the modern world.

Energy security equals economic security and national security. This year's *Bettering Human Lives* report elaborates on the connections between hydrocarbons and the modern world, from food production to the material building blocks of our world, to geopolitics. We do this not as shameless cheerleaders for oil and gas — I began my energy journey working on fusion, solar and geothermal — but as believers that **energy realism is a precondition for humanism**.

NET IMPORTS OF OIL, NATURAL GAS, & COAL IN MILLION TONNES OF OIL EQUIVALENT, 1979-2021

Figure 1.2



The Liberty family, from our field crews to our board of directors, is committed to a simple mission: build a successful enduring business that will help better human lives inside our homes, workplaces, families, communities and the world. We can say this without hyperbole as the energy that we help supply is foundational to everything that humans do. Everything. We chose our name, Liberty, because we believe in human liberty: everyone should have the freedom, energy, and opportunity to pursue their dreams. This ethos permeates our diverse workforce, hiring policies, employee benefits — the new lives made possible by Liberty's IVF benefit (page 81) is a perfect example — community involvement, and our mission to help energize the world.

The world has changed more dramatically in the last 200 years than during any period in human history. In the last several generations, as dire poverty has rapidly declined, global life expectancy at birth has doubled, human rights and liberty have grown enormously, and the modern world has expanded today's life possibilities beyond even the wildest imagination of our ancestors. Harnessing coal, oil, and natural gas to empower human action combined with the rise of human liberty (bottom-up social organization) have completely transformed the human condition. These basic facts about recent human history are little known and even less appreciated. This has allowed a well-intentioned drive to improve corporate behavior in three broad areas — Environment, Social, and Governance — to often stand in opposition to the very transformative forces that enabled the modern world: hydrocarbons and bottom-up social organization.

Hydrocarbons, like everything else, have downsides (air pollution, climate change) as well as upsides (longer, more opportunity-rich lives, forest preservation, reduced need for cropland, ability to deliver clean water). There is no such thing as "clean" energy or "dirty" energy. All energy sources have positive and negative impacts on humans and their environment. Evaluating the tradeoffs in energy systems requires thoughtful analysis in the context of local conditions, values, and needs. Today's highly-politicized and sometimes adrift-from-reality energy dialogue clearly has not been conducive to sober decision making. We're now paying the price through higher energy costs and lower energy security. This year's *Bettering Human Lives* contains additional sections covering the critical role of hydrocarbons in the modern world as part of our efforts to grow energy literacy and, hence, energy sobriety. These additional sections in Part 1 that help put our business in its broader context include: The Four Pillars of the Modern World: Cement, Steel, Plastics and Fertilizer; Food and Hydrocarbons; and

Geopolitics and Hydrocarbons. Before closing I would like to point out a few Liberty highlights and our role in the shale revolution:

1. We have recently fully integrated two strong teams from our acquisitions of Schlumberger's OneStim® business and PropX, a leading provider of proppant delivery solutions. These teams bring a wide variety of things to Liberty including technology, equipment, customer relationships and, most importantly, high-performing ethical, passionate people fully committed to our mission to better human lives.

2. We are in the midst of commercially launching our breakthrough frac fleet technology, digiFrac™, which will deliver a new level of performance, reliability, and longevity to drive the next level of performance in the shale revolution. Not only will we deliver higher quality fracturing services to our customers, we will power this with 100% natural gas. Natural gas is far more abundant than oil, lower cost, cleaner burning, and with significantly lower Greenhouse Gas (GHG) emissions.

3. The shale revolution has led to an explosion of North American propane production, which has grown far more than even North American oil and natural gas production. The U.S. today supplies nearly 50% of global propane exports, with Liberty-fractured wells providing roughly 15% of the North American total. Propane is my favorite hydrocarbon because it provides clean cooking fuel today for over 2 billion people. An additional 2.5 billion people aspire to have propane cook stoves. Those aspiring to cook with propane are currently burning wood, charcoal, dung, and agricultural waste. The World Health Organization estimates over three million annual deaths from indoor air pollution among those still lacking clean cooking fuel. We're proud that **Liberty-fractured wells currently supply clean cooking fuel to approximately 100 million people!** Hundreds of millions more still aspire for the same. We are committed to keeping the hammer down!

4. When the shale revolution was just starting to hit its stride in 2005, the U.S. was the world's largest importer of both oil and natural gas. Although an industrial powerhouse, we had a large and rapidly growing need for imported energy. At that time China produced roughly an equal amount of energy as they consumed. Over the last 17 years the U.S. has grown our energy production so significantly that we now produce more total energy than we consume. The U.S. is now the largest global exporter of LNG, and the world desperately needs more. China, by contrast, has become a massive net energy importer and the largest importer of LNG (see Figure 1.2). What would the global energy landscape look like without the shale revolution? Where would energy prices be? How different would geopolitics be?

The Liberty family is passionate about our company and our mission to energize the world and better human lives. We strive every day to improve our business and our communities. Thank you for joining us on the journey.

To Bettering Human Lives,

Chris Wright
Chairman and CEO
Liberty Energy

GLOBAL IMPACTS FROM U.S. PROPANE EXPORTS IN 2020[1]

Using the assumption of 50% of exported LPG is consumed in household cooking

285,300 LIVES SAVED, 391 MILLION PEOPLE SUPPLIED WITH CLEAN COOKING FUEL

65 MILLION HOUSEHOLDS CONVERTED FROM SOLID FUELS/BIOMASS

17.3 BILLION HOURS SAVED FROM GATHERING FUEL AND TENDING COOKING FIRES

PROPANE: MY FAVORITE HYDROCARBON

Propane — also known as liquefied petroleum gas or LPG — has provided the bridge out of poverty for over a billion people, with another 2.5 billion people aspiring to cross that bridge as soon as possible. There is a big gulf between the wealthy world, with infrastructure to deliver natural gas via pipeline and reliable electricity at scale and the emerging world where 2.5 billion people still cook burning wood, dung, charcoal, etc. Propane is *the* critical fuel for everyone emerging from poverty or simply living away from infrastructure.

- Propane can help prevent over three million annual deaths from indoor combustion of solid fuels and biomass.
- Propane can be widely distributed without pipeline infrastructure, delivering clean burning energy for countless applications to well over a billion people.
- Propane is transported under pressure as a liquid, but is combusted as a very clean burning gas.
- Propane is essential to feeding the world. It is used to power farm houses, equipment, and crop drying.
- Propane is a major feedstock for critical petrochemicals.
- Propane bridges the gap between the gaseous hydrocarbons (methane and ethane) and liquid hydrocarbons like butane, condensate, and oil. Hence it is in the sweet spot for shale production.
- Half of the surging propane production in the U.S. is exported to better human lives around the world.

The United States has reshaped energy markets both domestically and around the world. The United States is a cornerstone of global energy security.[2]

Dr. Fatih Birol, IEA Executive Director

THE SHALE REVOLUTION

The American shale revolution has transformed world energy markets and driven a significant drop in GHG emissions, particularly in the U.S. The shale revolution has enabled the U.S. to produce more energy than it consumes for the first time since the 1950s, making our country a net exporter of energy, with import benefits for the trade balance and the geopolitical calculus.

Liberty was founded 11 years ago inspired by a strong desire to drive further growth and improvements to the shale revolution. Our focus remains the same today, although it is expanding in scope as we see additional opportunities for Liberty's services, technologies and expertise. Part two of this report covers Liberty-specific efforts and operations. However, fully judging Liberty's impact requires a holistic view of the ESG impacts of the industry as whole.

The shale revolution has positively impacted several key factors in the energy system: increasing energy density, cutting energy costs, reducing pollutants and greenhouse gas emissions intensity, as well as diversifying global supply sources.

The next several sections cover specific areas of Liberty's business, all in the service of bettering the shale revolution. Liberty is shrinking our environmental impact and working in harmony with the communities in which we operate. Later you will also read about our commitment to building a strong, diverse, and ethical workforce and how our exceptional independent Board of Directors is working to ensure that corporate governance is aligned with both our shareholders and the communities in which we operate.

MAJOR ESG IMPACTS OF THE SHALE REVOLUTION[3]

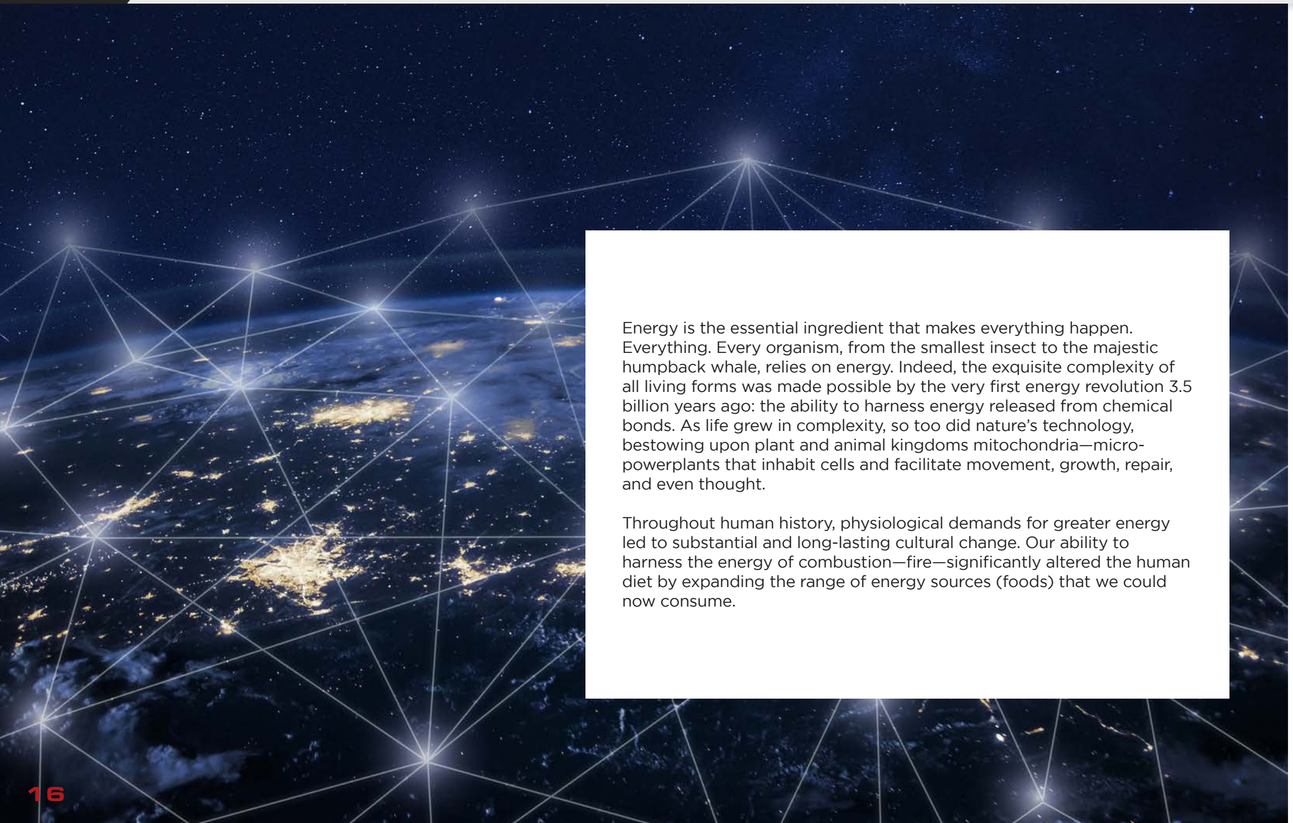
- Surging growth in oil, natural gas, and natural gas liquids production has driven down global energy prices, saving energy consumers over $1 trillion annually.
- U.S. is again a net energy exporter for the first time since the 1950s.
- Rapid rise in global propane (and other NGLs) supplies, lowers the cost and increases the availability of this key clean cooking fuel. Potential to save millions of lives annually as wood, dung, charcoal and agricultural waste are displaced.
- Lowering geopolitical tensions via greater diversity of oil and gas suppliers.
- Natural gas drilling rig count is down by ~90% from 15 years ago, yet the U.S. has gone from the world's largest importer of natural gas to one of the top exporters.
- Improving U.S. air quality, most importantly $PM_{2.5}$, to the best in generations.
- Largest contributor in reducing U.S. GHG emissions to the lowest level in nearly 30 years, and on a per capita basis to the lowest in over 60 years.[2]
- Added 8x more energy production in the U.S. than the combined output of heavily subsidized wind and solar.
- Enormous growth in well-paying (~$100K) blue collar jobs in rural U.S. and Canada, areas with severe economic stress over the last decades as urbanization progresses.
- Dramatic increase in energy produced per acre of land disturbed, evidenced by North Dakota's Bakken oil field using less than 2% of surface land with minimal impact on local farms and ranches.

PART ONE

LIBERTY'S BUSINESS IN GLOBAL CONTEXT

LOW-COST ENERGY AS AN AGENT OF HUMAN WELL-BEING

1.1 ENERGY



Energy is the essential ingredient that makes everything happen. Everything. Every organism, from the smallest insect to the majestic humpback whale, relies on energy. Indeed, the exquisite complexity of all living forms was made possible by the very first energy revolution 3.5 billion years ago: the ability to harness energy released from chemical bonds. As life grew in complexity, so too did nature's technology, bestowing upon plant and animal kingdoms mitochondria—micro-powerplants that inhabit cells and facilitate movement, growth, repair, and even thought.

Throughout human history, physiological demands for greater energy led to substantial and long-lasting cultural change. Our ability to harness the energy of combustion—fire—significantly altered the human diet by expanding the range of energy sources (foods) that we could now consume.

ENERGY IS THE ESSENTIAL INGREDIENT THAT MAKES EVERYTHING HAPPEN. EVERYTHING.

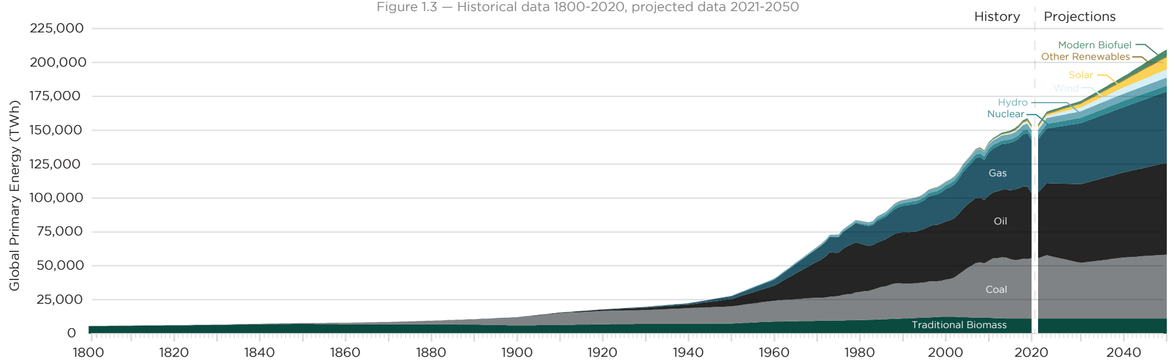
Roughly ten thousand years ago, humans experienced a second energy revolution with the development of agriculture. We quickly learned about, planned the use of, and produced vast quantities and varieties of energy sources (vegetables, fruits, and grains). The soaring production of energy from agriculture led to a substantial rise in global populations, giving rise to further cultural change. At each step, greater cultural efficiencies in producing and delivering food, artifacts, and information, freed up unused energy for the further advancement of human well-being and civilization.

This long history has led us to the third energy revolution, the harnessing of fossil fuels. These buried deposits of plant and animal species from millions of years ago, provide a concentrated and highly potent source of energy that makes much of our daily lives possible. Fossil fuels today support billions of people in lifestyles that were simply unimaginable only a few generations ago. Planes, trains, and automobiles changed the game of human mobility, facilitating trade and expanding social communities beyond local neighborhoods. Likewise, communications and the internet have made possible the accumulation of knowledge like never before. And modern medicine and technologies have increased the lifespan, health, and well-being of millions. The expansion of our technologies due to fossil fuels means that people today enjoy greater freedom — to choose what to eat, where to live, with whom to interact, and how to live.

Figure 1.3 shows the rapid and overwhelming increase in energy supply made possible by the addition of fossil fuels. The figure shows how in the second half of the 19th century fossil fuels drove the industrial revolution, enormously increasing human productivity, in a process that economic historian Deirdre McCloskey called the Great Enrichment.

GLOBAL PRIMARY ENERGY CONSUMPTION 1800-2050

Figure 1.3 — Historical data 1800-2020, projected data 2021-2050



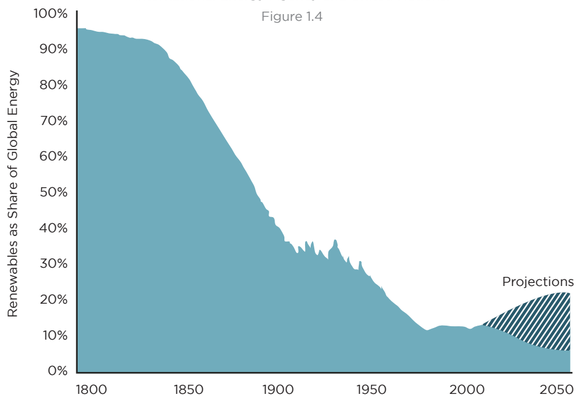
By the year 1900 over half of global energy was supplied by fossil fuels. It was not until after World War II, however, that the Great Enrichment began to spread in the world's lesser developed countries. But spread it did. The decades after WWII saw billions of humans lifted out of poverty. This revolution is still far from done, but has boosted living standards like never before. Figure 1.3 shows a 30-year projection from the EIA using aggressive assumptions for growth in renewables. Fossil fuels are still projected to dominate global energy supply in 2050.

After dominating human energy supply throughout history, renewable energy's percent of global energy bottomed out in the 1970s/1980s at around 13%. Since then, it has crept up to around 15% today as the continued gradual decline in market share of traditional fuels like wood, dung, and agricultural waste is being offset by the heavily subsidized use of solar, wind, and industrial scale biofuels. Solar and wind today make up about 2-3% of global primary energy supply. Also shown in Figure 1.4 is the wide range of future projections for renewables market share from the International Energy Agency and U.N. out to 2050. Of course, projections are just projections. Figure 1.4 shows that changing the global energy system is a gradual process. It moves slowly even when significantly more abundant, higher quality, cheaper, and cleaner

RENEWABLE ENERGY AS A PERCENTAGE OF TOTAL GLOBAL ENERGY

Data from 1800-2018. The hatched funnel shows the spread of scenarios from the International Energy Agency and United Nations.

Figure 1.4



fuels lead to consumer pull, as in the case of hydrocarbons displacing older, lower quality energy sources.

In addition to the continued displacement of traditional fuel sources by hydrocarbons, there is a strong and growing force for change in today's energy system: concerns about climate change. Climate change is covered in more detail in a subsequent section.

Media and political proclamations today calling for massive and rapid changes in world energy systems appear unrealistic. Similar proclamations have been made over at least the last three decades. The recent record illustrates the collateral human damage when attempting to force large-scale change without superior, cost-effective technologies. The early movers like Germany, the U.K., and California used top-down political mandates to drive changes in the energy system without carefully evaluating the tradeoffs. They have all driven significant increases in electricity (and other energy) prices with a resulting economic burden on their citizens, particularly lower-income people who spend a larger percent of their income on energy. Lower-income citizens also skew toward energy-intensive jobs like manufacturing, farming, and transportation and hence disproportionately see their jobs being displaced to locales with lower energy costs. We will cover this issue more in the following section on energy poverty.

Russia's invasion of Ukraine in February 2022 has revealed the costs of Europe's energy insecurity. Over a period of three decades or so, and in spite of repeated warnings, policy makers have deliberately used subsidies to drive in renewable energy such as wind and solar, while simultaneously allowing Europe's domestic oil, gas and coal production to decline. Indeed, European fossil fuel production has fallen so significantly that the European Union is now critically dependent on imports, particularly of natural gas. This is of acute importance since the presence of large fleets of weather-dependent, intermittent generation from wind and solar has rendered Europe's electricity grid increasingly fragile with natural gas as the sole guarantor of security of supply. To make matters worse, the largest source of these gas imports is Russia. Rejecting Russian gas as part of the economic sanctions is far from straightforward, giving Putin considerable leverage, and creating a regional gas supply crisis. Skyrocketing prices for electricity, home heating, and industrial fuels are the result, with serious economic and societal consequences. Businesses struggle to plan their future production, while domestic households face very tight budgets, with

reports suggesting that European households are returning to the burning of wood as a lower cost alternative.

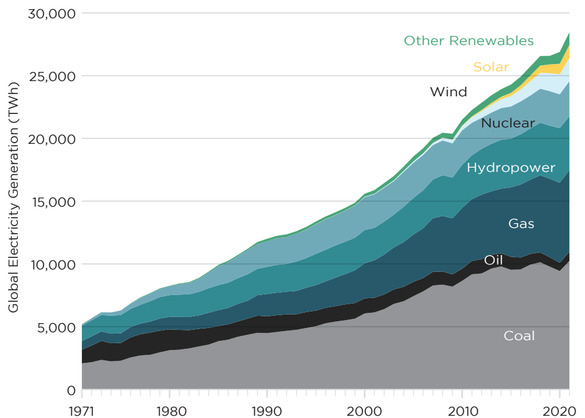
The U.S. Energy Information Administration data in Figure 1.5 gives a sense of the changing global sources of electricity over the last 50 years. The first thing it makes clear is the fact global demand for electricity and energy is rising. Globally, electricity represents only 20% of total energy consumption; however, it dominates the conversation when discussing energy. On a global basis coal is the largest source of electricity, supplying around 36%. Natural gas is second at approximately 23%. Low carbon energy sources — nuclear, hydropower, wind, and solar — combined supply just over 35% of global electricity, a market share that has been roughly flat for the last 35 years but is rising modestly now.

The last ten years have seen the dramatic impact in the United States, and to a lesser extent globally, of the shale revolution. American natural gas production has risen dramatically, which pushed global natural gas prices down, a beneficial trend that continued until last

GLOBAL ELECTRICITY PRODUCTION BY SOURCE, 1971-2021

'Other renewables' includes biomass and waste, geothermal, wave and tidal.

Figure 1.5



year. Today's crisis is not due to a shortage of resources. It is due simply to underinvestment in production capacity, and most critically, underinvestment in infrastructure to move energy via pipelines and export facilities. This underinvestment has much to do with a growing policy and investor "ESG" movement in opposition to hydrocarbons. We are only beginning to see the human costs of this politically-driven opposition to hydrocarbons.

The North American shale revolution brought the world abundant new supplies of oil and natural gas. The most visible impact perhaps has been in the electricity sector where natural gas vaulted to the top, supplying nearly 40% of U.S. electricity. Coal has fallen hard from over 50% of U.S. electricity supply just 15 years ago, to less than 25% today.

This has meant both cleaner air (lower $PM_{2.5}$, SO_X, mercury, and more) in the U.S. and a decline in U.S. GHG emissions on a per capita basis to its lowest level in over 50 years. Well over half of the steep U.S. drop in GHG emissions over the last 15 years is attributable to natural gas displacing coal. The displacement of coal by natural gas has also led oil and gas to their highest-ever market share of U.S. primary energy — nearly 70% in 2019 - 2021. The story is not a surge of hydrocarbons' market share, but instead a shift among oil, gas, and coal. Nuclear energy comes third at nearly 20% of U.S. electricity. The rest comes mainly from hydropower, wind, and solar.

Globally, and in the U.S., hydrocarbons remain approximately 80% of total primary energy supplied as they have been for the last few decades. This is not to say that there are not significant changes happening in the mix of energy sources. Besides natural gas taking market share from coal, we have also seen solar and wind rising rapidly. Nuclear and hydroelectric have not seen meaningful growth even with their status as the two largest sources of very low carbon energy. Hydroelectric struggles with environmental pushback due to the large land footprint and intrusion in waterways. Nuclear is held back by uncertainty around permitting and regulatory challenges due to public fears over nuclear safety. The data does not support the public fears, as nuclear has an outstanding, pack-leading safety record.

The global energy system is and always has been, both complex and critical to human welfare. It is too important to get wrong. In our own time the energy system is just as important as ever, but it is also immense in scale, meaning that rapid change cannot be expected. As Vaclav Smil has reminded us repeatedly, energy transitions take time.

1.2 ENERGY POVERTY

The most urgent challenge with energy today is that one-third of humanity still lacks access to basic modern energy, electricity, and clean cooking fuel, including over 80% of Africans and half of Indians. Over two billion people still cook their daily meals and heat their homes with traditional fuels, typically wood, dung, agricultural waste, or charcoal. Simply for lack of access to a basic stove and an LPG canister, over three million people die every year from the resulting indoor air pollution. This staggering loss of human potential can and must be eradicated.

The World Health Organization (WHO) estimates there are several million additional deaths from outdoor air pollution from the same source: particulate matter, or $PM_{2.5}$, which is one of the world's most deadly pollutants. Transitioning from traditional solid fuels to liquid fuels (or natural gas or electricity) is the key to reducing outdoor $PM_{2.5}$ concentrations just as it is for reducing indoor $PM_{2.5}$ levels.

THE MOST URGENT CHALLENGE WITH ENERGY TODAY IS THAT ONE-THIRD OF HUMANITY STILL LACKS ACCESS TO BASIC MODERN ENERGY, ELECTRICITY AND CLEAN COOKING FUELS, INCLUDING OVER 80% OF AFRICANS AND HALF OF INDIANS.

GLOBAL POPULATION-WEIGHTED $PM_{2.5}$ CONCENTRATIONS, 2019

Figure 1.6

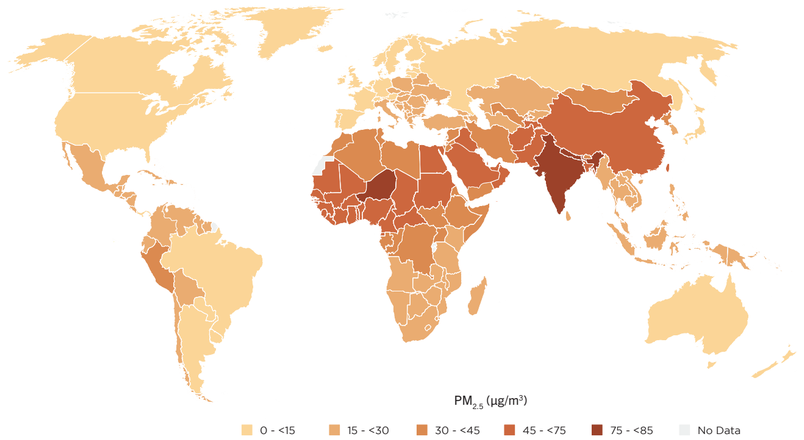


Figure 1.6 shows a global map of outdoor $PM_{2.5}$ pollution. This problem is worst in Africa, south Asia, southeast Asia, and China, the same places where energy poverty drives the indoor air pollution crisis. Wealthy countries have used technology to have both highly energized societies and clean air. Together $PM_{2.5}$, malnutrition, preventable disease, and lack of access to drinking water and basic education collectively cause over 10 million premature deaths each year. Bringing affordable, reliable energy to the world's poorest citizens is essential to eradicating these scourges.

The good news is that tremendous progress is being made. Energy access is increasing globally as hundreds of millions of people have made the transition from traditional cooking and heating fuels to modern fuels — most commonly to liquid petroleum gas (LPG) — over the last 15 years. The U.S. shale revolution has been simply tremendous in lowering the energy cost bar for low-income families to transition from burning solid biofuels to clean-burning LPG stoves fueled by refillable LPG canisters. The U.S. is now by far the world's largest exporter of LPG (dominantly propane) as well as the source of virtually

all the growth in world LPG trade over the last decade. This has brought down LPG prices and significantly grown available supplies. Continuing this trend is essential to bringing everyone clean-burning cooking fuel in the next two decades.

Unfortunately, the admirable progress over the last decade or so is now being reversed as the world enters an energy crisis that is not due to any shortage of energy resources. Instead it is due to a shortage of common sense and humanity behind energy policies in the wealthy world. The irrational energy policies which dismiss the evaluation of tradeoffs between hydrocarbon benefits and risks from climate change in the wealthy world, have led to serious shortages in infrastructure to move Liquified Natural Gas (LNG) around the world, as well as emerging shortages in oil production capacity. Today's energy crisis' roots go back through years of overly restrictive hydrocarbon policies culminating in demand outstripping supply. Russia's invasion of Ukraine surely exacerbates the crisis, but is not the source of the crisis.

The roots of today's energy crisis are most acute in the global supply of natural gas. Many countries count on ship-borne imports of LNG as their marginal supplier of natural gas. As demand crossed available supply in the summer of 2021, LNG prices skyrocketed. Today's LNG prices are several times higher than they were before the crisis and are causing massive dislocations in countries across the world. The most dramatic and tragic impacts are in lower-income countries where unaffordable energy combines with soaring food prices to cause human hardship. Natural gas represents 80% or more of the cost to produce nitrogen fertilizer (ammonia), *the* most important nutrient that limits agricultural productivity. The one-third of humanity living in energy poverty is now seeing much higher energy and food prices. This dire situation illustrates how critical it is to get energy right. At the very least, we must stop the globe's most comfortable and wealthy regions from imposing anti-energy policies that kill the world's least fortunate.

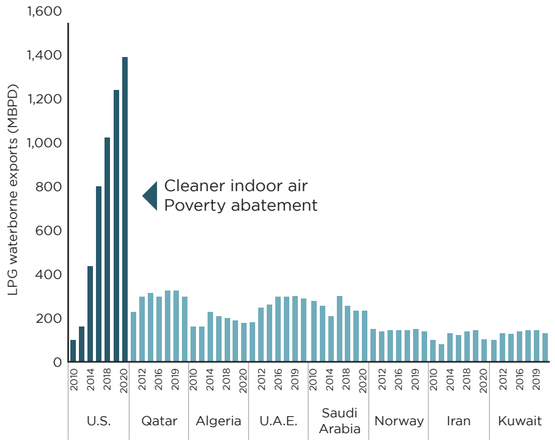
Just how bad these decisions are can be gauged by falling energy consumption in the West. In the United Kingdom, energy use has fallen by 30 percent to quantities not seen since the 1950s, while the rest of Europe has declined 30 years to 1990s levels. British electricity consumption, amazingly, has fallen by about 30% since 2003 and is now back at levels last seen in the 1970s. Even North American energy consumption is showing worrying signs. After 2007, total energy demand in the United States fell substantially and then flatlined. It fell again due to the pandemic, and by 2020 energy demand was down about 13% from the 2007 high. Admittedly, some of that lost demand was restored in 2021, as public health restrictions were lifted, but it remains to be seen whether this recovery will continue.

Faltering or falling energy consumption, particularly electricity, is not an indication of a healthy economy. And it certainly isn't efficiency, which actually increases demand for energy, as we know from the so-called Jevons Paradox.

It is probable that energy demand is falling because of environmental policies, including subsidies to wind and solar. So far, the U.S. has not gone as far down this road, having spent a "mere $125 billion" between 2008-2018. The EU, where the biggest energy collapse is observed, has spent a staggering $800 billion since 2008, a total that has been increasing at $70 billion a year. And the U.K., a country of 65 million people, is shelling out well over $10 billion every year.1 These massive investments have resulted in more costly, and lower reliability electricity and hence, lower demand. Most all energy-intensive activities are displaced to lower-cost energy locales.

U.S. RESPONSIBLE FOR VIRTUALLY ALL GLOBAL LPG EXPORT GROWTH

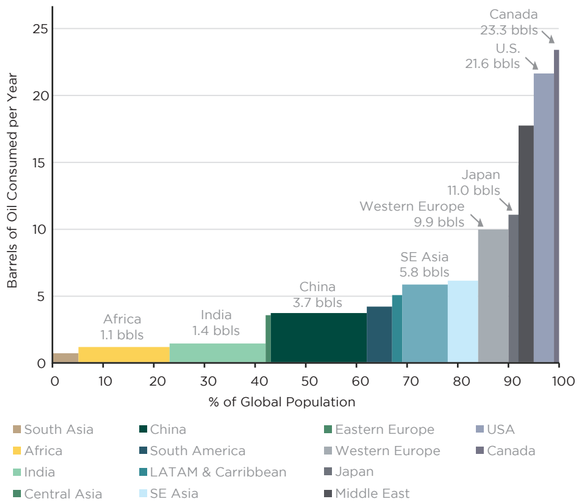
Figure 1.7



PER CAPITA OIL CONSUMPTION (BARRELS/YEAR)

Latest year-end data available as of March 31, 2022.

Figure 1.8



THE TRUE TOLL OF HOUSEHOLD AIR POLLUTION FROM COOKING WITH BIOFUELS[4]

In sub-Saharan Africa, an estimated five out of six people (approximately 900 million) lack access to clean cooking resources.

95%

Almost 95% of that subset of the population rely on solid biomass for cooking in the form of fuel wood, charcoal, or dung. The remaining 5% rely on kerosene or coal.

500,000

Household air pollution stemming from inefficient and polluting cooking fuels was linked to nearly 500,000 premature deaths in sub-Saharan Africa in 2018.

3,000,000+

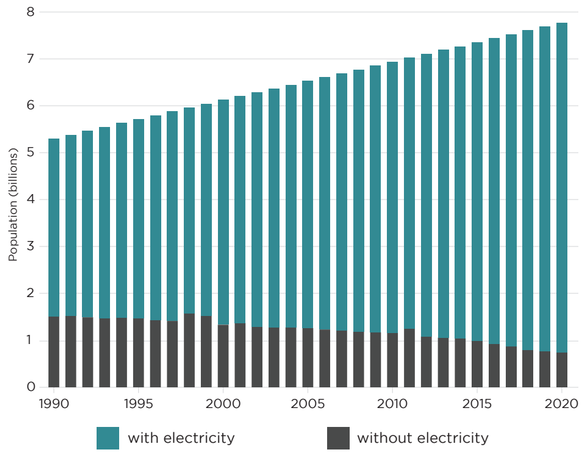
Globally, WHO estimates deaths from indoor air pollution at over 3 million — a figure comparable to the combined death toll of malaria, tuberculosis, and HIV/AIDS in 2018.

ENERGY POVERTY AND ELECTRICITY

The developed world takes electricity access for granted. For hundreds of millions of people, it is a luxury or absent. Today's energy crisis is throwing millions more into energy and electricity insecurity.

PEOPLE IN THE WORLD WITH AND WITHOUT ELECTRICITY ACCESS, 1990-2020

Figure 1.9



Nearly one billion people have no access to electricity. Another billion have only intermittent access — four hours per day — to extremely modest amounts of electricity. This is enough to power a light bulb or charge a cell phone, but not enough to power a water pump or other machinery necessary to raise their productivity and energize significant increases in productivity and income. One billion people received their first access to electricity in the last 20 years — the large majority from hydrocarbons or hydropower.

ENERGY ACCESS = BETTER HEALTH

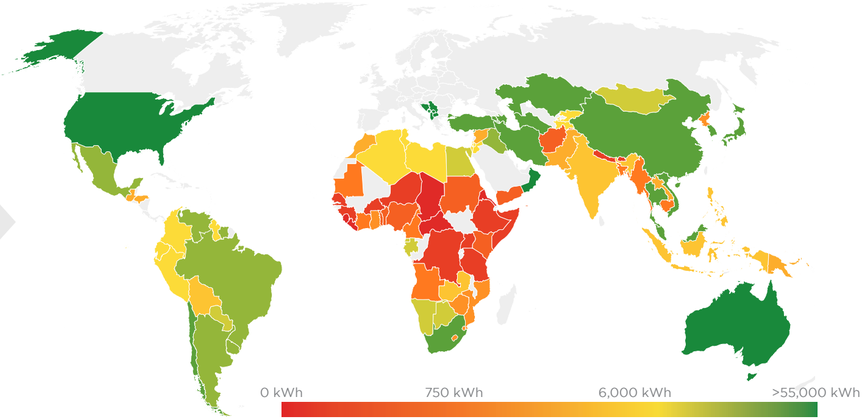
The following page contains side-by-side maps of per capita electricity consumption by country and child malnutrition by country. There is a reason that both maps look quite similar: energy is the prime mover that enables everything else. If you have electricity, your life and that of your family improves beyond description.

Continuing the last several decades of unprecedented progress in the human condition requires massive increases in affordable, reliable energy for the world's poorest countries and the poorest citizens in the world's middle-income and wealthy nations. While long-term progress has been impressive, even prior to today's energy crisis there have been growing headwinds due to the heavy-handed actions of the world's wealthy nations in the name of climate change. The World Bank, European Development Bank, and many large commercial banks are now restricting or simply not offering funding for hydrocarbon-fueled power plants, which are the main source of electricity generation globally, and even more so in developing nations.

ENERGY CHANGES WOMEN'S LIVES: Women in energy poverty spend more than an hour per day gathering fuel wood to cook and an additional hour per day sourcing water.[5] Energy access benefits the welfare of women.

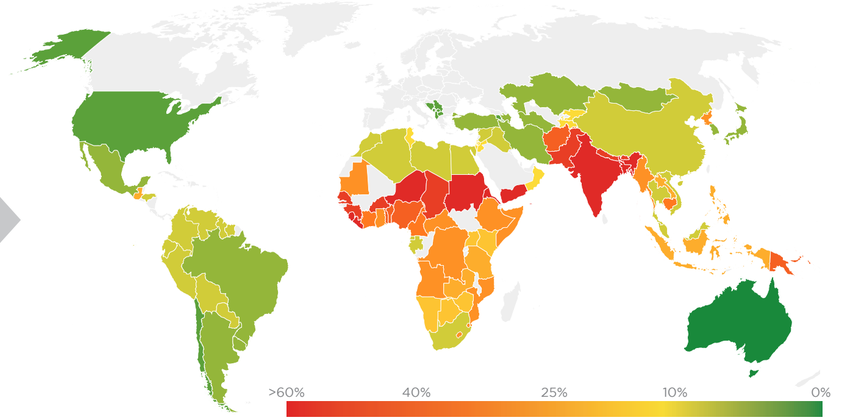
ELECTRICITY CONSUMPTION KWH PER CAPITA

Figure 1.10



PERCENTAGE OF UNDERWEIGHT CHILDREN AT AGE 5

Figure 1.11

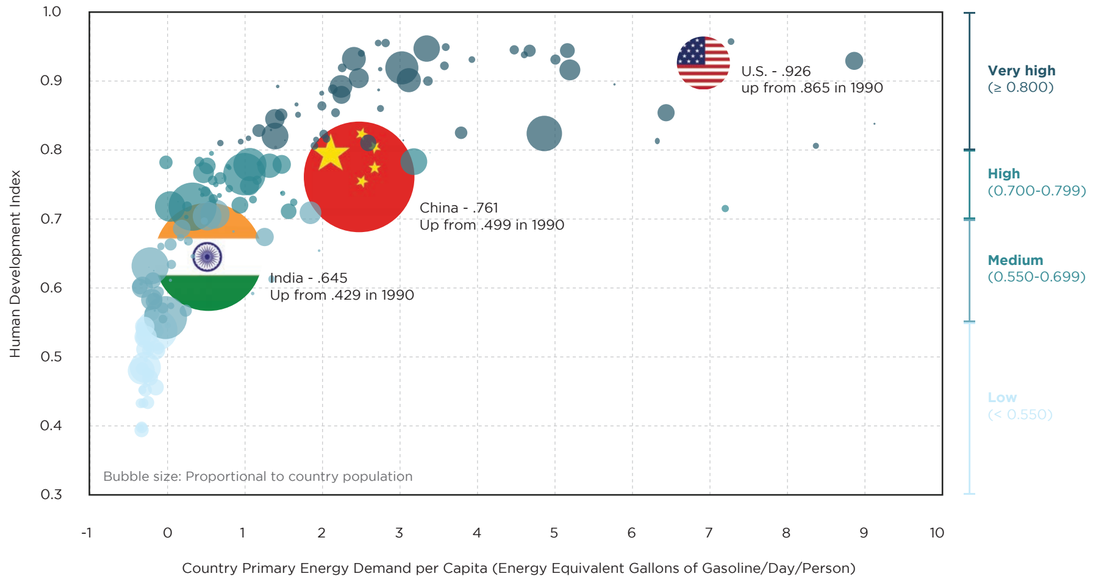


ENERGY ACCESS & THE HUMAN DEVELOPMENT INDEX

The United Nations Human Development Index (HDI) is a good rough proxy for the human condition as it combines life expectancy at birth, years of education received, and per capita gross national product. In 1990, 62% of the global population (5.3 billion) scored "Low" on the HDI. The last three decades have shown tremendous progress as now only 12% of today's larger population (7.6 billion) score "Low" on the HDI. However, 12% is still over 900 million people. As with child mortality, and virtually any index of human well-being, increasing the HDI requires increased energy consumption. This point is illustrated in the two graphs below (Figure 1.12 and Figure 1.13). The first graph shows the relationship between energy consumption per capita and HDI across countries, and the second graph shows the changes over the last thirty years for both China and India where rising energy consumption accompanies rising HDI.

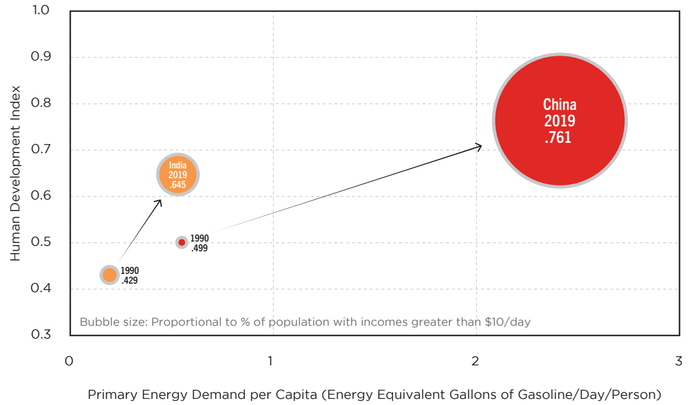
ACCESS TO AFFORDABLE ENERGY IS ESSENTIAL FOR HDI IMPROVEMENT

Figure 1.12



CHINA & INDIA EXPERIENCE RISING ENERGY CONSUMPTION AND HDI IMPROVEMENT IN TANDEM

Figure 1.13



Between 1990 and 2019, India and China have seen a 51% and 52% improvement, respectively, in HDI

INDIA

- Moved from Low to Medium HDI
- Mean education increased 2.2x
- Life expectancy increased 11.8 years
- Energy per capita increased 174%

CHINA

- Moved from Low to High HDI
- Mean education increased 1.7x
- Life expectancy increased 7.8 years
- Energy per capita increased 339%

RISING FROM POVERTY

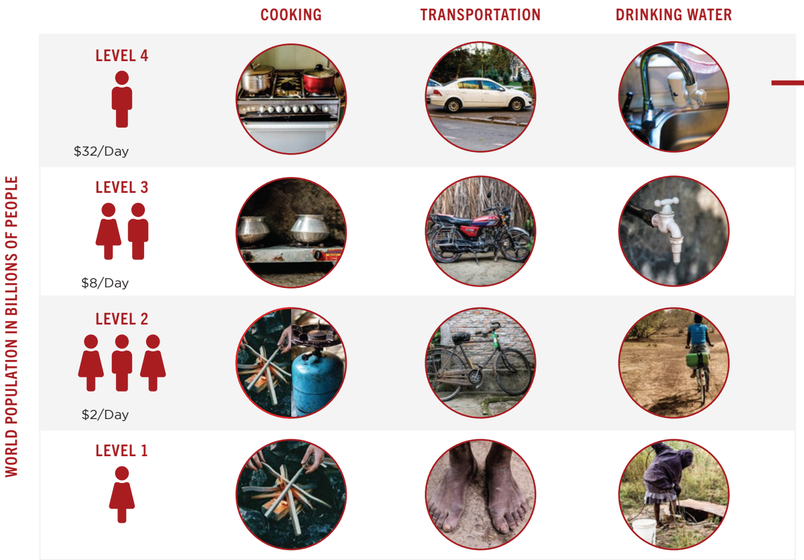
Swedish public health doctor and global data expert Hans Rosling's last work, *Factfulness*, chronicles the enormous progress of humanity over the last several decades based on empirical measures of human well-being. The book also contains an illustrative figure — recreated below in Figure 1.14 — that captures and quantifies the range of today's living conditions. What we often fail to realize is that only about one-seventh of the world's population lives in conditions at all like the readers of this report. Policy, conventional wisdom, and "green" activist agendas mostly focus on that top one-seventh.

Rising from poverty and joining the modern, developed world requires an enormous increase in personal energy consumption. There is simply no other way to rise from poverty.

The modern world was enabled by a surge of available, reliable, affordable energy and all that followed in a highly energized society. The speed at which liberating, energy-rich living conditions can be brought to more people depends on low energy costs that will create rising per capita income. Slower economic growth inhibits the rise out of energy poverty as do rising energy costs. Energy costs matter.

THE RANGE OF LIVING CONDITIONS AMONG THE WORLD'S POPULATION

Figure 1.14



PUTTING IT IN PERSPECTIVE:
Only about one-seventh of the world's population lives in conditions at all like the readers of this report.

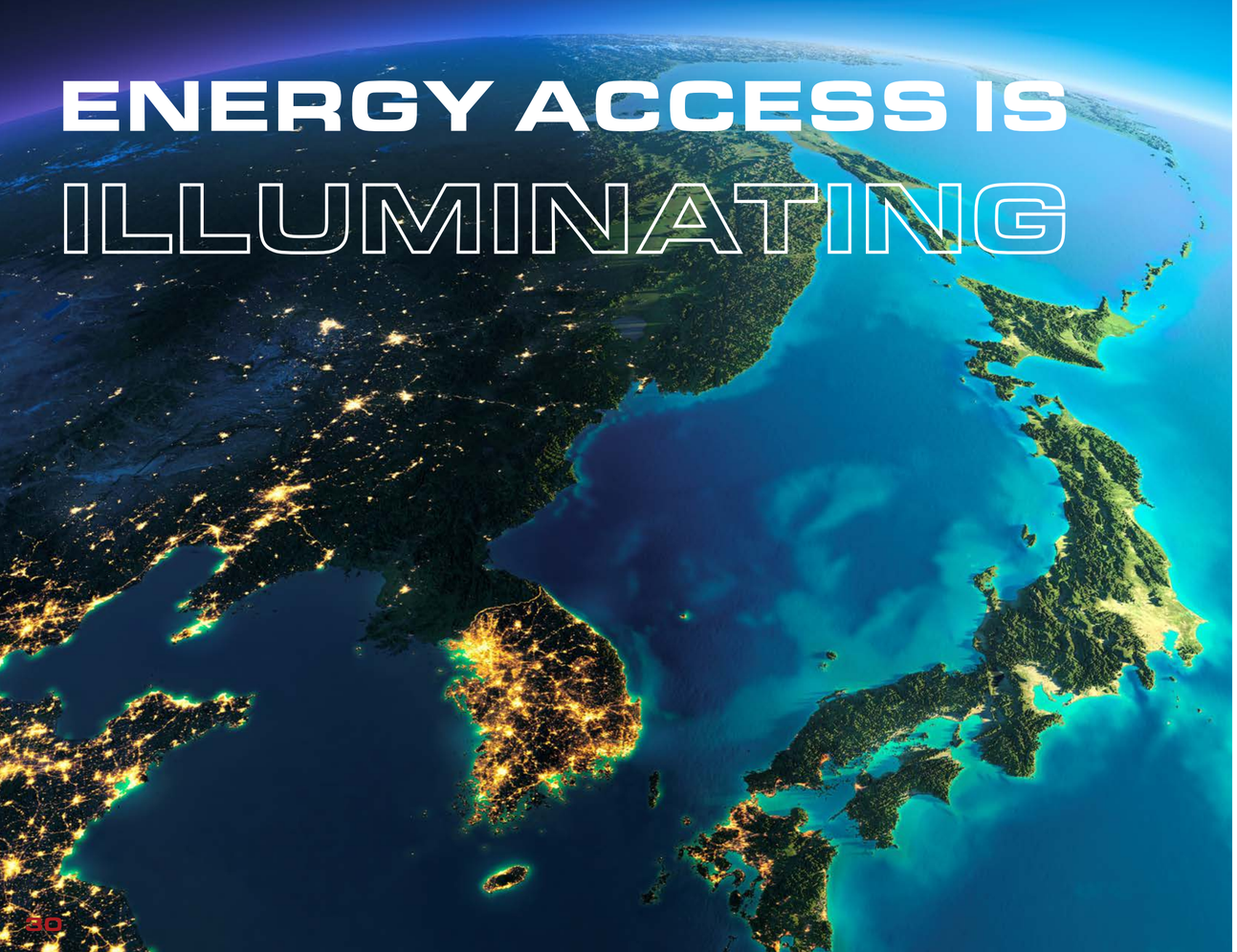
Energy access for the world's least fortunate is not only a social goal for Liberty, it is a driving principle upon which the company was founded. Energy poverty is not just a developing world problem. In 2020, 27% of U.S. households had trouble meeting their energy needs, and 10% of Americans reported keeping their homes at unsafe temperatures in order to balance their budgets.

Rich-world policies made to combat climate change can cause more damage than benefits if they don't consider all the world's citizens. Making energy more expensive or impeding access to hydrocarbons is dangerous and crushes opportunity for those struggling to better their lives. Many climate policies also generate poor results in lowering global GHG emissions.

The Korean peninsula starkly illustrates the cost of living without abundant energy. North Korea's darkness reveals the border location — energy access is illuminating (Page 30). Energy access is also green (Page 33). Haiti's extensive dependence on wood for fuel leads to significant deforestation and higher GHG emissions. Haiti has suffered extreme deforestation because so many of its citizens depend on wood for heating and cooking. Meanwhile, its wealthier neighbor with modern-energy, the Dominican Republic, is covered in rainforest.

DID YOU KNOW?:
3 billion people are living with less energy per year than the average American refrigerator.[6]

ENERGY ACCESS IS ILLUMINATING



THE STARK DIFFERENCE IN ENERGY ACCESS BETWEEN NORTH AND SOUTH KOREA

Only **52% of North Korea's population has access to electricity**[7] as compared to 100% of South Koreans.

17X

South Korea has **17 times higher per capita energy consumption** than North Korea, primarily sourced from fossil fuels.

Higher energy consumption means healthy, longer lives. South Koreans are born with a life expectancy 11 years longer than their northern neighbors.

Access to energy has far-reaching effects. **9.3% of North Korean children under the age of 5 are underweight** as compared to 0.9% of South Korean children of the same age.

THE ISLAND OF HISPANIOLA IS SHARED BY HAITI AND THE DOMINICAN REPUBLIC

The national border can be seen in this photo **due to the severe deforestation** in Haiti as traditional biofuels are the primary energy source for much of the population.

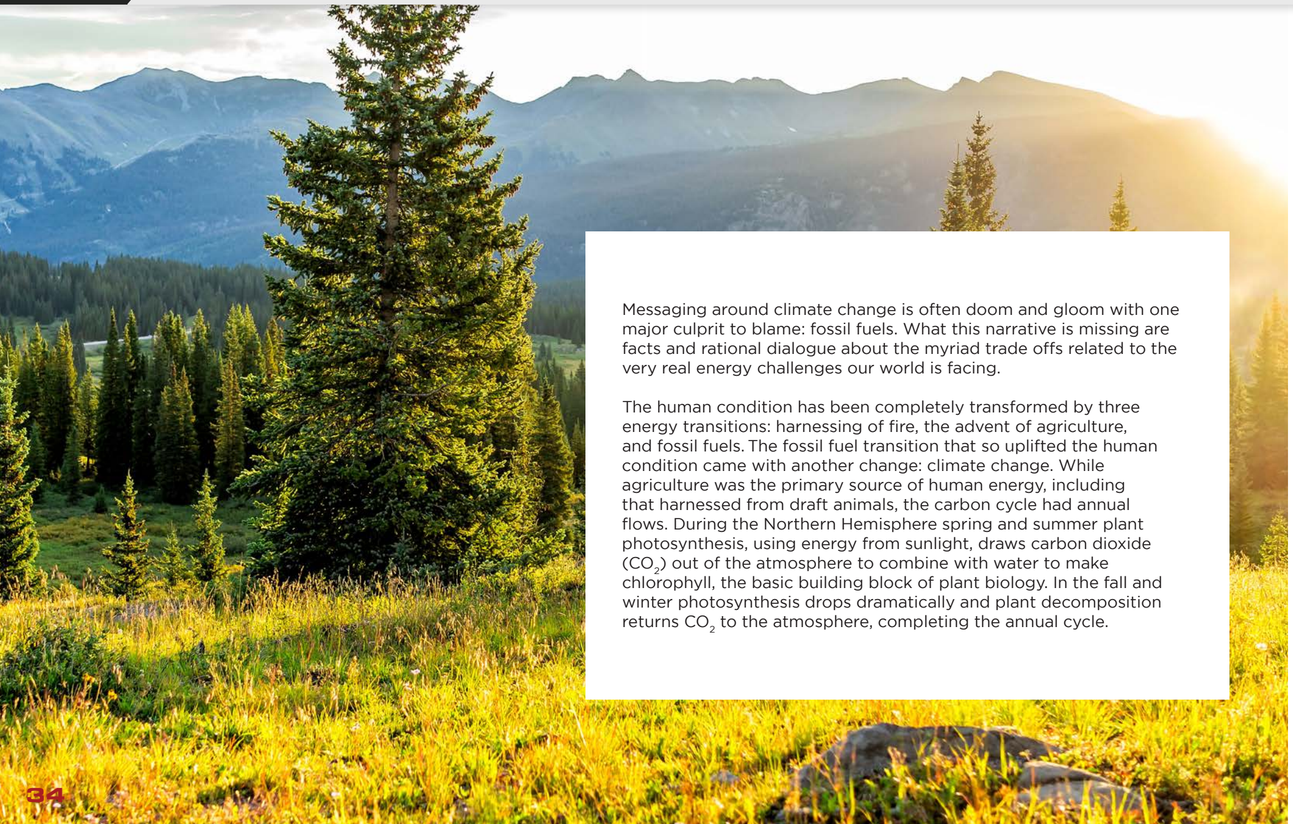
The Dominican Republic, on the other hand, has **8 times higher per capita energy consumption**[8] than Haiti, almost entirely from fossil fuels.

Higher energy consumption means **healthy, longer lives**.

Far fewer people relying on traditional energy sources like wood means **thriving forests and a cleaner environment.**

ENERGY ACCESS IS GREEN

1.3 CLIMATE CHANGE

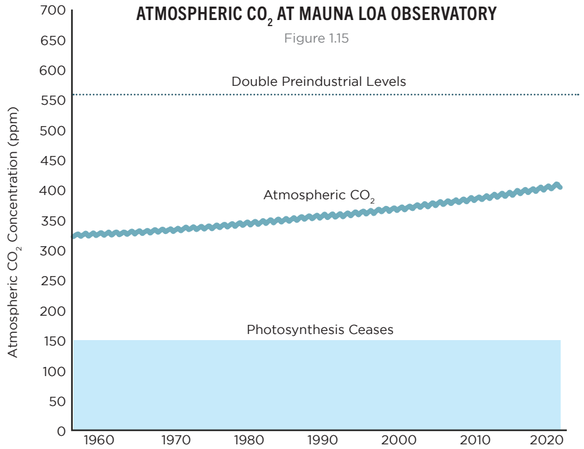


Messaging around climate change is often doom and gloom with one major culprit to blame: fossil fuels. What this narrative is missing are facts and rational dialogue about the myriad trade offs related to the very real energy challenges our world is facing.

The human condition has been completely transformed by three energy transitions: harnessing of fire, the advent of agriculture, and fossil fuels. The fossil fuel transition that so uplifted the human condition came with another change: climate change. While agriculture was the primary source of human energy, including that harnessed from draft animals, the carbon cycle had annual flows. During the Northern Hemisphere spring and summer plant photosynthesis, using energy from sunlight, draws carbon dioxide (CO_2) out of the atmosphere to combine with water to make chlorophyll, the basic building block of plant biology. In the fall and winter photosynthesis drops dramatically and plant decomposition returns CO_2 to the atmosphere, completing the annual cycle.

MESSAGING AROUND CLIMATE CHANGE IS OFTEN DOOM AND GLOOM WITH ONE MAJOR CULPRIT TO BLAME: FOSSIL FUELS. WHAT THIS NARRATIVE IS MISSING ARE FACTS AND RATIONAL DIALOGUE ABOUT THE MYRIAD TRADE OFFS RELATED TO THE VERY REAL ENERGY CHALLENGES OUR WORLD IS FACING.

Photosynthesis requires a minimum threshold atmospheric CO_2 concentration of 0.015% (150 ppm). During the last glacial period (16,000 to 100,000 years ago) atmospheric CO2 nearly breached this level, falling to only 180 ppm. It is estimated that atmospheric CO2 concentration was just below 0.03% (280 ppm) before the industrial revolution and large scale burning of hydrocarbons, or fossil fuels. The hydrocarbon-powered global economic growth since World War II has driven a steady climb (shown in Figure 1.15) in atmospheric CO_2 concentration to slightly above 0.04% (420 ppm in 2021) as humans have been liberating the solar energy stored long ago (over hundreds of millions of years) in ancient plants (coal) and marine phytoplankton (oil and natural gas). Atmospheric CO_2 concentration rises due to the combustion of fossil fuels, which is essentially a reversal of the photosynthetic reaction in which oxygen combines with hydrocarbons.



The equation shown below represents the chemical reaction of burning methane, the simplest hydrocarbon.

$$CH_4 + 2\,O_2 = CO_2 + 2\,H_2O$$

One methane molecule combines with two oxygen molecules to create one CO_2 molecule and two water vapor molecules (the white steam you see rising from power plants) while liberating significant amounts of energy to produce electricity, power industrial processes, heat your house, and more.

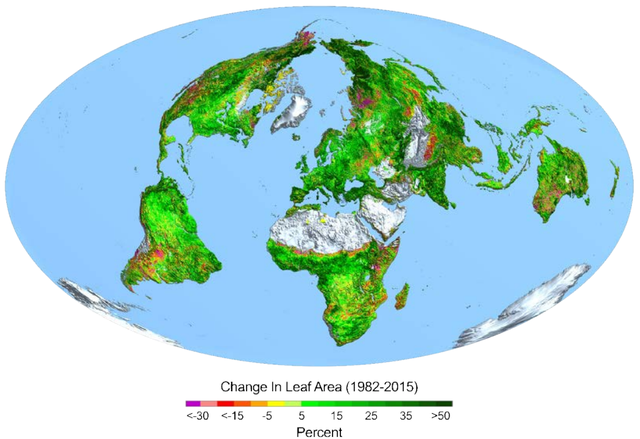
Roughly half of the CO_2 released in this combustion reaction has gone into the oceans or into “greening” the planet as the increased availability of CO_2 (plant food) in the atmosphere has led not only to increased agricultural productivity (why commercial greenhouses enrich their air with CO_2) but also to a significant increase in grasses, trees, phytoplankton, and plant matter of all kinds across the globe. Figure 1.16 shows the significant greening of the planet over the last few decades.

The other half of the released CO_2 has remained in the atmosphere driving the increased atmospheric CO_2 concentration shown in Figure 1.15. It is this increased atmospheric CO_2 concentration that is the source of climate change concerns as CO_2, like water vapor, methane, and nitrous oxide, is a significant “greenhouse” gas. The term greenhouse gas (GHG) is used because these molecules absorb infrared radiation that the earth continually emits into space to balance the incoming heat from the sun. The net impact of increasing GHG concentrations is to warm the average temperature of the earth. The largest warming is expected (and has been measured) in the cold polar areas at night with progressively less warming moving

towards the tropics. Even in the tropics, the warming impact is larger at night than during the day. Estimates from radiation physics predict that doubling pre-industrial times atmospheric CO_2 concentration to 560 ppm (likely by late this century) would result in a 1.3 – 1.4°C average warming of the planet in the absence of feedback effects. A recent empirical study of historical temperature data provides similar warming estimates of 1.2 – 1.8°C in response to a doubling of atmospheric CO_2 levels. There remains significant scientific uncertainty around feedback effects, mainly induced changes in atmospheric water vapor (a more significant GHG than CO_2) and impacts on cloud formation. This is highly technical with myriad research efforts focusing on this critical topic. We will not delve into a discussion of climate feedback in this report. This summary is intended to provide basic understanding and context around climate change and provide a summary overview of key historical observational data for global average temperature, sea level rise, extreme weather events and deaths from extreme weather events.

GLOBAL GREENING FROM CO_2 FERTILIZATION

Figure 1.16



The first two are rising, the third displays no trend, and the fourth is plummeting. These are far from the only areas of climate change discourse, but they are the central ones.

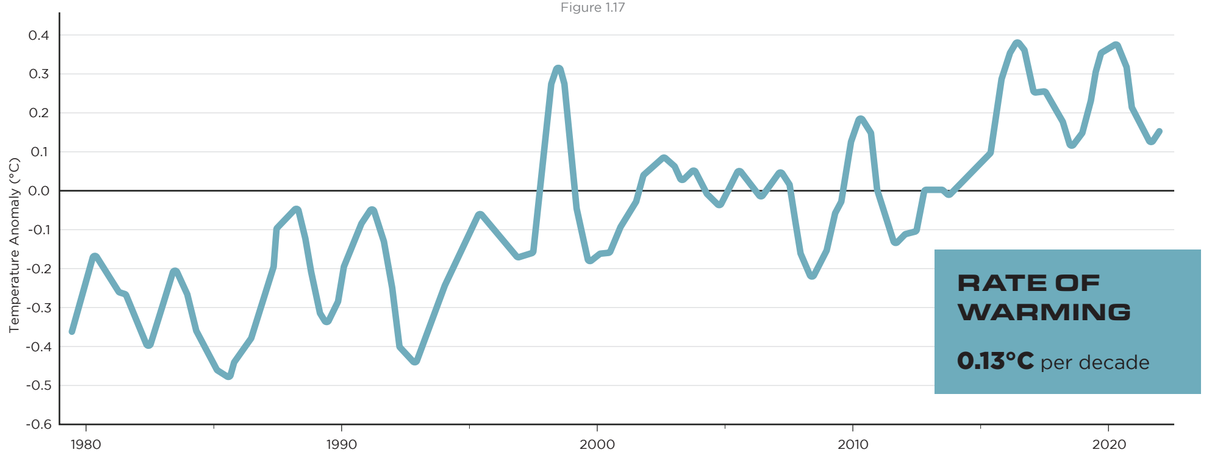
Figure 1.17 on the next page shows the entire atmospheric temperature record, as collected by the University of Alabama Huntsville. We show atmospheric data as this technology allows a more uniform measure across the whole planet, as opposed to land-based sensors that suffer from uneven spatial coverage, changing conditions around measurement locations like urban heat island effects, different temperature sensors employed, continuously evolving "homogenization" techniques, etc. Satellite measurement of global temperatures began in 1979. The full 40+-year record of lower atmospheric temperature shown in Figure 1.17 shows an average rate of warming of 0.13°C per decade. This is down slightly from the 0.14°C per decade warming rate in our last report as we have had two years of cooling due to La Nina conditions. La Nina is the opposite phase of the more famous El Nino Southern Oscillation (ENSO), a cyclic pattern of the surface waters in the eastern tropical Pacific Ocean. During La Nina there is a net transfer of heat from the atmosphere to the oceans, while during El Nino phases the net heat transfer runs the opposite direction.

Remote Sensing Systems also provide global atmospheric temperature measurements that show a somewhat higher rate of warming. Averaging the two raises the observed warming rate to around 0.17°C per decade. This implies that at the rate of warming observed over the past 40 years, we would expect little more than another one degree C of warming by the end of the 21st century. This is in addition to the roughly one degree C of warming that the world has seen over the last century. Climate change impacts are most often estimated by economists based on the total warming from pre-industrial times. We will discuss these projections in the following Climate Economics section.

After increasing global temperatures, sea level rise and extreme weather events are the other climate changes that are most often raised as concerning. We include the data here on sea level rise over

UAH GLOBAL LOWER TROPOSPHERIC TEMPERATURE VARIATIONS (°C) 1979-2021

Figure 1.17



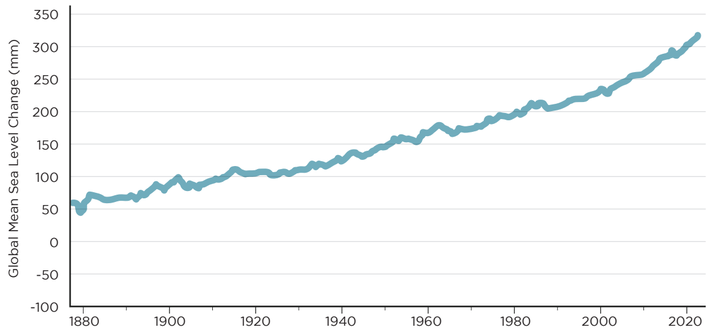
two different time scales and with two different measurement technologies. Tide gauges have the longest direct instrumental (not proxy) record of global sea level rise. Figure 1.18 shows a roughly 150-year record of changes in global average sea level from tide gauges. The modern rise in sea level began in the middle of the 19th century as the Little Ice Age came to an end and the planet started warming. It shows an average rate of rise of a little less than one inch per decade. The quality of the data set is limited by the number of tide gauges included, which is lower in the early years of the record but much better in the more recent years.

Despite this limitation it is worthwhile to view a longer-term perspective on sea level trends. From indirect proxy records, we know that sea levels have risen around 400 feet since the end of the last glaciation nearly 20,000 years ago.

Figure 1.19 shows the satellite record of changes in sea level. The satellite sea level record only begins in 1993. It shows a relatively constant rate of sea level rise over its 29-year record of a little over one inch per decade (1.3 inches per decade). The discrepancy between the rates of rise from satellite and tide gauges remains in the most recent data. It is likely the result of the different measurement mechanism that each employ. However, we have some confidence in knowing that sea levels are currently rising at a global average rate of around one inch per decade or perhaps a bit more, with no observable change in the rate of rise over the last few decades. We must say "global average" as sea level has significant geographical variability due to the uneven rebound of the continental plates (isostatic rebound) in response to the massive ice sheets melting at the end of the last glaciation 10,000 to 20,000 years ago. For example, currently sea level is roughly static near San Francisco and along the U.S. West Coast, while rising at about global average along the U.S. East Coast,

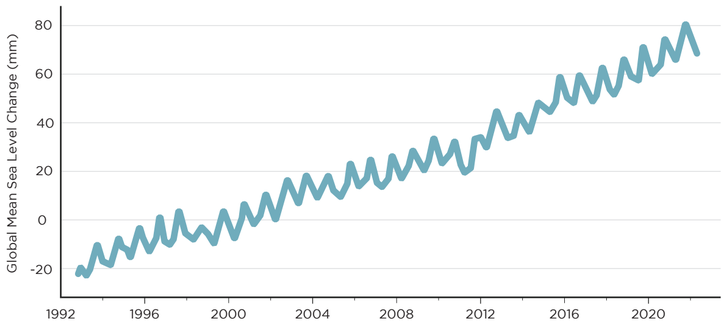
MEAN SEA LEVEL RISE FROM TIDAL STATION AND ALTIMETRY FROM 1880-2020

Figure 1.18



MEAN SEA LEVEL RISE FROM SATELLITE DATA FROM 1993-2022

Figure 1.19



RATE OF SEA LEVEL RISE

Global average of
1 inch per decade

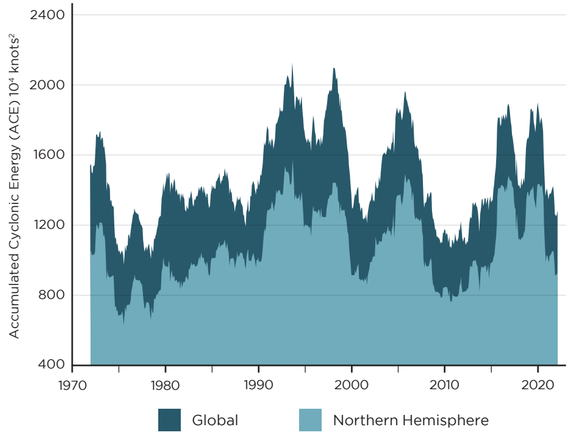
and rising at a much more rapid rate than the global average on Australia's West Coast. Rising sea level presents a threat to coastal cities and their fresh water aquifers, hence it is important to understand what is happening. Extreme weather features prominently in the news perhaps due to the frightening sense of awe inspired by hurricanes, tornadoes, floods and droughts.

Extreme weather has killed millions of people over the years, displacing and impoverishing countless more. Fortunately, to date we have not seen an increase in extreme weather events, and deaths from extreme weather events have been plummeting as a wealthier, more energized world has proven far more resilient than in times past.

Figure 1.20 shows the trend in Accumulated Cyclonic Energy (ACE), a metric that captures together the frequency, duration and intensity of global hurricane activity since 1970. Figure 1.21 shows a different hurricane metric: the trend in the number of global land-falling hurricanes since 1970. Figure 1.22 shows the same metric for the United States dating all the way back to 1900. As one can see from these figures, while there is large annual variability

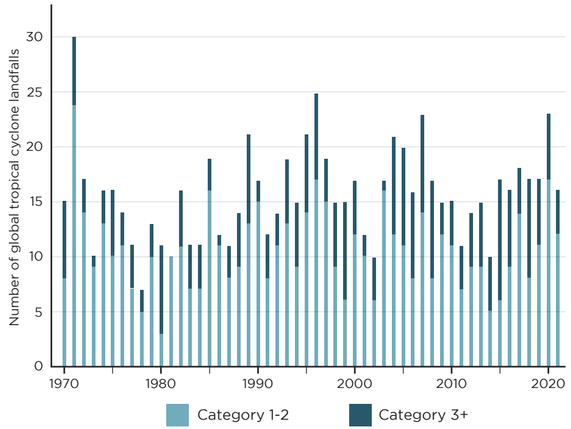
GLOBAL TROPICAL CYCLONE ACCUMULATED CYCLONIC ENERGY 1972-2021

Figure 1.20



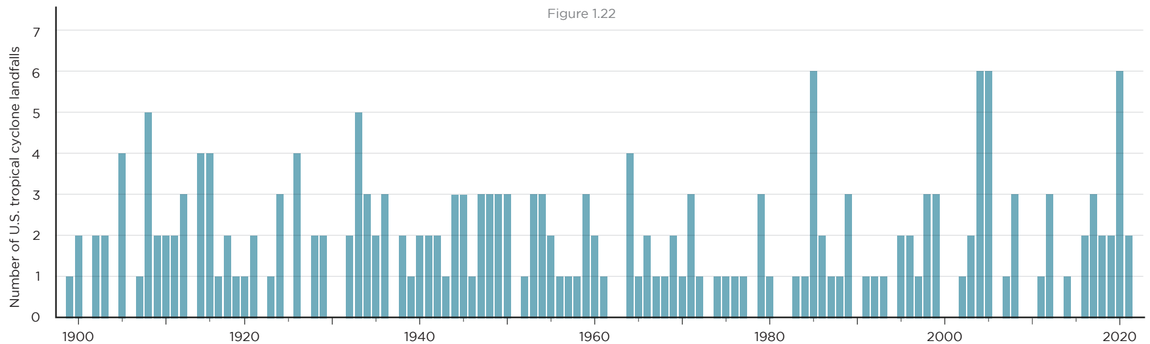
GLOBAL HURRICANE LANDFALLS 1970-2021

Figure 1.21



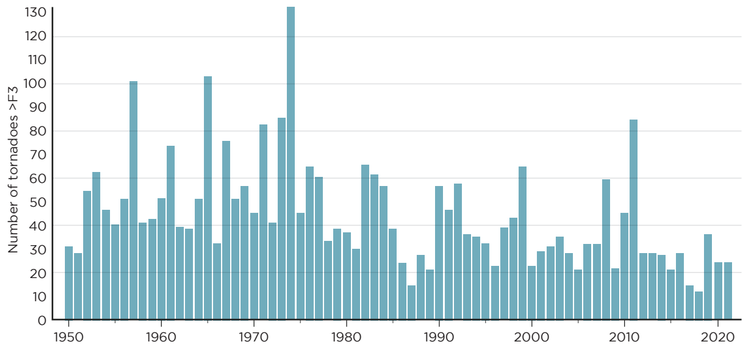
U.S. HURRICANE LANDFALLS 1900-2021

Figure 1.22



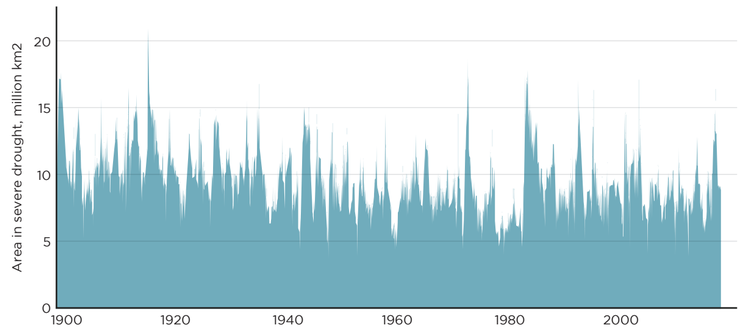
U.S. STRONG TO VIOLENT TORNADOES (>F3), 1950-2021

Figure 1.23



GLOBAL AREA IN SEVERE METEOROLOGICAL DROUGHT, 1901—2017

Figure 1.24



in hurricane activity, the data show no obvious increasing trend. 2021 had the fewest cyclones (called hurricanes in the Atlantic) ever recorded since satellite tracking began over 40 years ago. Curiously, this wasn't newsworthy. More importantly, 2021 was middle of the pack for Accumulated Cyclonic Energy, a better measure of global cyclone activity.

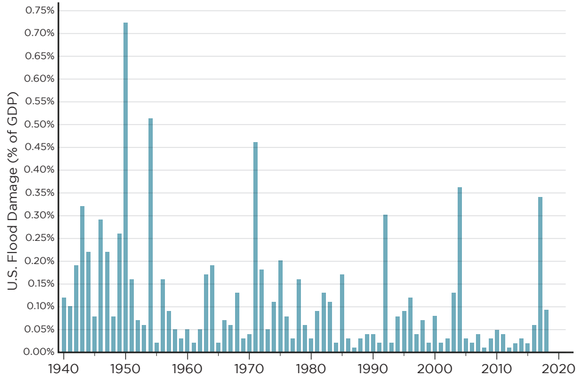
Figure 1.23 shows the frequency of severe tornadoes in the United States starting in 1954. Fortunately, the trend here appears to be downward.

Figure 1.24 shows the percent of the world in extreme level drought since 1900. There appears to be a slight decline in global drought prevalence over the last century, as might be expected as a slightly warmer world implies a slightly wetter world due to increased evaporation. Floods are harder to quantify except in their economic damage. United States annual flood damage as a percent of GDP starting in 1940 is shown in Figure 1.25. Annual flood damage shows a meaningful downward trend, more likely due to better flood preparedness than an actual reduction in floods or extreme rain events. With the availability of abundant, reliable energy, humans have been better able to predict, prepare, and sometimes even prevent these deadly and costly flooding events.

Wildfires are a different story as forest management practices play a leading role. In August 1910, the "Big Burn" in western Montana and northern Idaho burned an unfathomable 3 million acres in just two days. The "Big Burn" killed 78 firefighters and radically altered the psyche of the U.S. Forest Service, policy makers, and the American public towards an ever-present natural phenomenon of wildfires. This began a strident policy to prevent and fight

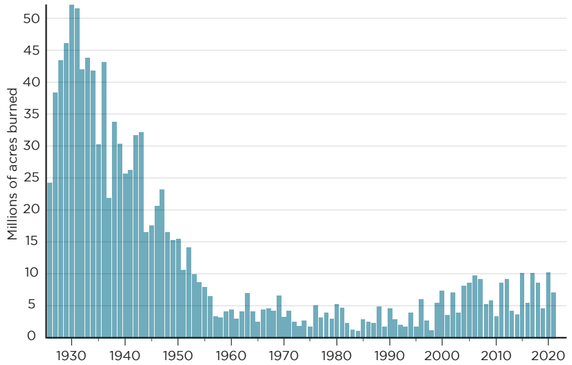
U.S. FLOOD DAMAGE AS PERCENTAGE OF GDP, 1940-2018

Figure 1.25



U.S. FOREST AREA BURNED, 1926-2021

Figure 1.26



wildfires above all else. A leader in conservation recently commented "Bad events create bad policy. Today, more than 100 years after the Big Burn, we are left with our current wildfire paradox: Decades of fire suppression have resulted in accumulated fuels that lead to larger and more severe wildfires that cannot be suppressed."

A study by U.S. Forest Service scientists of Western U.S. Forests concluded that increased "live fuel" due to changing forest management practices were responsible for more than 50% of the recent increase in wildfires. Figure 1.26 shows a hundred years of annual U.S. forest acres burned. In the 1930s wildfires annually burned several times more acres than they do today. The Wildfire Acres Burned graph also illustrates the dramatic impact of the U.S. Forest Service Smokey Bear campaign launched in the 1940s to expand fire prevention by enlisting the public in its efforts to prevent and quickly extinguish wildfires. Multiple regulatory changes from the 1960s onwards made significant changes to forest management practices that made it increasingly difficult to perform basic forest management practices like tree thinning, clearing undergrowth and controlled burns. Fortunately, the political will to address forest management practices

THE BOTTOM LINE ON EXTREME WEATHER

Whether through an actual decrease in event frequency/severity or through better preparedness and management practices enabled by a more advanced culture, **the data shows no obvious increasing trend in any extreme weather events**.

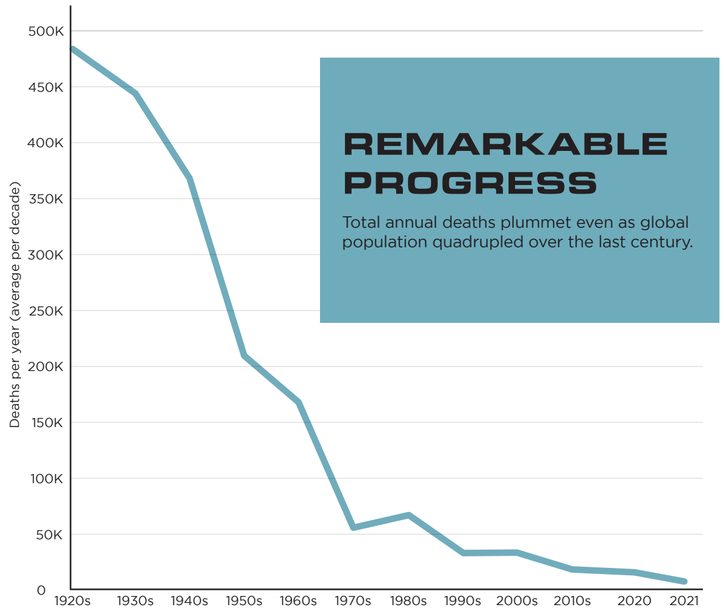
appears to be growing. However, reversing 100 years of mismanagement will take significant time and resources.

By far the most important factor regarding extreme weather is the impact it has on human lives. Here the trend is manifestly positive. Figure 1.27 shows the dramatic decline in the deadliness of extreme weather events. There has been an over 90% decline in annual global deaths from extreme weather during the last century even while the world population has nearly quadrupled throughout the same time-period. The downward trend in deaths from extreme weather continues unabated, with the last few years plunging even further! Wealthier societies with abundant access to affordable energy are simply far safer places to live. The large majority of the remaining deaths from extreme weather are concentrated in poorer nations with high rates of poverty and energy poverty (nearly synonymous). Spreading energy access to those currently in energy poverty discussed in the last section is the key to further saving lives from extreme weather. While climate change is both broad and complicated, familiarity with the basic science and data is highly valuable and, sadly, quite scarce. This brief section is included to provide an introductory overview of the chemistry, physics and empirical data surrounding the central climate change issues. The following section on Climate Economics touches on the work of economists to quantify the potential human impacts from climate change now and into the future.

GLOBAL DEATHS FROM SEVERE WEATHER 1920-2021

Global deaths from floods, droughts, storms, wildfire, extreme temperatures, annual average by decade 1920-2019, per year for 2020 and 2021 (estimated full year)

Figure 1.27



CLIMATE CHANGE ECONOMICS

Climate economics is a rich and relevant topic in the energy industry. There are numerous relevant complexities like territorial GHG emission targets that localize the costs but socialize the benefits across the whole planet. For example, if the U.S. were to rapidly decarbonize its entire economy as many advocate, the costs would be counted in the trillions of dollars and the benefits to the U.S. would be rather modest. United Nations' Intergovernmental Panel on Climate Change (IPCC) climate models predict a less than 0.1°C reduction in global temps in the year 2100 would result from a rapid and complete de-carbonization of the U.S. economy. For the U.S. to realize any material benefits, global emissions must be reduced. This territorial problem is even more stark at the state level, although many states are passing legislation with territorial emission targets. We'll leave this complexity and many others aside and discuss projected impacts on a global scale.

The recent IPCC Assessment Report (AR6) provided — almost certainly incomplete — estimates economic damage from a cumulative 2.0°C of warming from pre-industrial times. The IPCC estimated that global per capita income would decline by somewhere between 0.2% and 2.0% from 2.0°C of global warming. The problematic immensity of predicting the economic impacts of climate in the coming century cannot be overstated! Nevertheless, for discussion purposes we cover the existing estimates from these efforts. The world is estimated to have so far warmed about 1°C since pre-industrial times. At the current observed rate of warming of 0.17°C/decade from averaging the satellite data, we would expect to hit 2°C total warming around 2080.

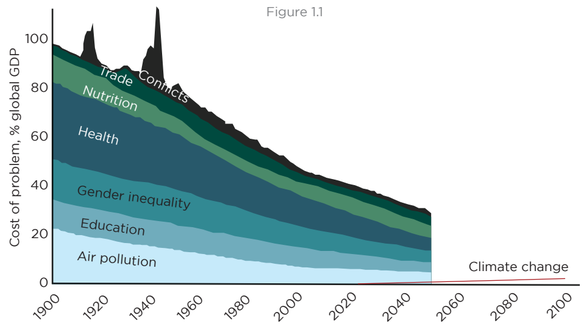
The rate of global warming may increase in the future. Of course, it may also decrease. Scenarios of more significant 21st century warming are also considered. Nobel Prize-winning climate economist William Nordhaus analyzed a scenario on the upper end of the IPCC projections where the rate of warming accelerates significantly and rises to 3.5°C by the end of the century even after his calculated optimal GHG mitigation efforts are undertaken. This is the scenario included in the figure in the Introduction at the front of this report and repeated here (Figure 1.1). Estimated current and future climate economic impacts are plotted together with impacts from the world's greatest current challenges like malnutrition, air pollution, disease, illiteracy, and gender inequality. Nordhaus estimates a less than 1% economic impact from climate change through 2050, rising to over 3% by 2100.

Projected economic impacts from climate change are global and large in gross dollar magnitude, but pale in comparison to today's challenges for the one-third of humanity that still lives in energy/economic poverty. It is very difficult to have confidence in global predictions nearly a century in the future, hence the uncertainties of these predictions are significant. But even the most extreme predictions of climate change from leading climate economists are far lower than those suffered today by people in energy poverty.

HOW MUCH RICHER WOULD THE WORLD BE HAD WE SOLVED DIFFERENT ISSUES, 1900-2050

Cost of climate change shown with optimal policy

Figure 1.1



As discussed earlier, over 3 million annual deaths from energy poverty is a conservative estimate as it only considers impacts from a lack of clean cooking fuels. Despite media proclamations of dramatic threats to human health today from climate change induced rising extreme weather and heat, the climate change impact on mortality so far is likely a modest reduction in annual deaths. The Climate Change section showed the century-long dramatic decline in deaths from extreme weather. Deaths from extreme heat have likely risen, but those deaths are almost certainly far more than offset by a reduction in the number of deaths from extreme cold. Deaths from extreme cold globally are

more than five times larger than deaths from extreme heat. Surely there are significant impacts from climate change today, but they are nothing compared to the magnitude of energy poverty.

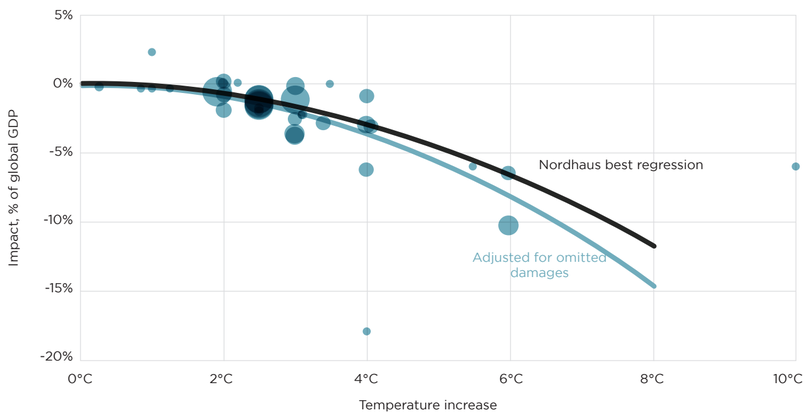
Figure 1.28 is a compilation of work done by climate economists projecting economic impacts over a wide range of possible future warming magnitudes. One thing that stands out is the broad agreement that economic impacts today and over the next few decades are likely to be quite modest. This is exactly the time-period in which energy poverty hits hardest: today and in the near future. In light of the continuing growth in global economies and energy production, it's highly possible we could see a near eradication of severe energy and economic poverty over the next few decades.

These next few decades will likely also see tremendous progress in low-carbon energy technologies, including reliable on-demand (non-intermittent) sources like Enhanced Geothermal Systems, next generation nuclear, improved energy storage, and perhaps economic Carbon Capture Use and Storage (CCUS) and nature-based carbon sequestration. Solving climate change must and can be done with new technologies and systems that do not increase the price or reduce the reliability of energy, as energy is simply critical to human survival, emergence from poverty, and the ability to flourish. Unfortunately, too many efforts to date to address climate change have driven up the price of energy with enormous tolls on human lives.

Greenhouse gas mitigation efforts so far have been mostly in wealthy countries and concentrated in the power sector. Electricity, however, represents less than 20% of global energy and all the projected growth in GHG emissions is in countries not affiliated with the Organization for Economic Co-operation and Development (OECD). Figure 1.29 shows global greenhouse gas emissions over the last 40 years broken down by major world regions/countries. This figure illustrates that the wealthy (OECD) countries have been reducing their GHG emissions for more than 20 years, while non-OECD countries GHG emissions are rising rapidly as they energize their societies and raise the standards of living of their residents. Most GHG reduction efforts to date have been more effective at raising energy prices than at reducing global greenhouse gas emissions. Meaningful global progress hinges on future advances in energy technology, an area of tremendous focus and real promise.

TOTAL IMPACT FROM TEMPERATURE INCREASE MEASURED IN PERCENT OF GLOBAL GDP

Figure 1.28



California, Germany and the United Kingdom have been aggressive early movers in responding to climate change concerns and the results do not appear positive. California has driven their electricity prices up to 50% higher than the U.S. national average, leading some energy-intensive industries to leave the state. California has disproportionately harmed their low-income residents and now has the highest adjusted poverty rate of any U.S. state, according to the U.S. Census Bureau. California's negative impacts were coupled with only modest reductions in GHG emissions and much of those "reductions" were simply exported out of California to other states, and therefore not reductions at all.

Germany's aggressive de-carbonization efforts have doubled their electricity prices, now almost three times higher than the U.S. average, while achieving a smaller percent reduction in their GHG emissions than the U.S. over the last decade. The United Kingdom has achieved a larger reduction in their GHG emissions but at a heavy cost to their residents as they have also driven electricity costs up dramatically. These cost escalations have been multiplied by the onset of today's energy crisis starting in late summer 2021 and Russia's invasion of Ukraine in February 2022. Energy prices matter. A lot.

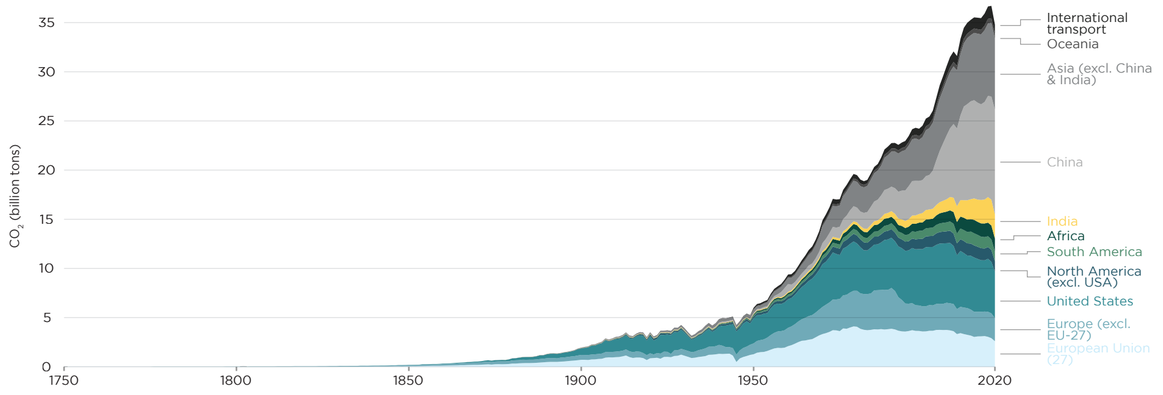
The United Kingdom's emission reductions are significantly overstated as it is now the leading nation in per capita imported GHG emissions. This is an unsurprising result of their territorial efforts to lower emissions leading to large-scale outsourcing of energy intensive industries from the birthplace of the industrial revolution. China illustrates the degree to which energy intensive industries are displaced to countries with lower energy costs. China today produces 50% of the world's steel, 61% of the world's cement, and 31% of the world's plastics.

Our top priority now should be urgently addressing the immense energy poverty challenges. Starting with providing modern energy to the one-third of humanity still cooking with traditional fuels like wood, dung, and agricultural waste. Low-cost LPG cook stoves exist and growing local businesses are providing stoves and LPG canisters to households eager to improve the health and well-being of their families. Another giant target is to energize the billion people who lack access to electricity and at least another billion who lack a sufficient quantity of electricity to drive up their incomes and quality of life. These two large groups are mostly overlapping in lack of access to clean cooking fuels and electricity. A third major concern is the rising grid instability in states and countries that are politically mandating large amounts of intermittent, unreliable electricity on their grids. These actions are increasing energy costs and decreasing grid reliability for reductions in global GHG that are not significantly meaningful.

As the world seeks to reduce energy poverty and improve energy access for all citizens, we can also mitigate the risks of climate change via aggressive, thoughtful investing and innovating to develop low-carbon ways to produce affordable, reliable, clean energy that is so essential for the long, healthy lives made possible by the modern world. Energy matters. A lot.

ANNUAL TOTAL CO_2 EMISSIONS, BY WORLD REGION

Figure 1.29



1.4 HYDROCARBONS ENABLE THE MODERN WORLD

Our need for petrochemicals and hydrocarbons is growing faster than the demand for energy. A little-known fact is that 14% of worldwide oil demand and 8% of natural gas demand go to make petrochemicals, like plastics and pharmaceuticals. This demand is not for energy — it is to provide the essential raw materials that make the modern world possible. Petrochemical demand is growing faster than demand for oil or natural gas. Petrochemicals represent between one-third and one-half of total projected future demand growth for oil and gas.

Skyscrapers, highways, dams, power plants, hospitals, airports, seaports, railroads, factories, and housing — none of our modern world would exist without cement, steel, and plastics.

OUR NEED FOR PETROCHEMICALS AND HYDROCARBONS IS GROWING FASTER THAN THE DEMAND FOR ENERGY.

FOUR PILLARS OF THE MODERN WORLD

Cement

Steel

Plastics

Fertilizer

In 2019, the world used a staggering 4.5 billion tons of cement, 1.8 billion tons of steel, and 370 million tons of plastics. The same year, over 150 million tons of fertilizer, dominantly nitrogen fertilizer, was produced, without which world food production would be immediately cut in half. These are the four pillars the modern world stands upon — all products of hydrocarbons.

Other materials like aluminum, wood, gypsum drywall, metal alloys, and silicon supplement, all rely on the four pillars. Everything of scale hinges upon the four pillars for mining, production, processing, or distribution. All four pillars depend critically on the combustion of fossil fuels for process heat in their manufacture and three of the four use fossil fuel molecules for critical feedstock.

Cement is the only pillar that does not get production feedstock from hydrocarbons, however it requires enormous amounts of process heat from the combustion of coal dust, petroleum coke, and heavy fuel oil. Steel requires coking coal or natural gas as a carbon source to turn iron into steel, along with high-temperature process heat typically from natural gas.

Plastics are custom-designed hydrocarbon chains tailored to specific applications, where natural gas or oil supplies energy and feedstock. Most manufactured products today contain plastics, including two-thirds of global clothing fibers.

Nitrogen fertilizer production uses natural gas as the source of hydrogen and as the processing energy to synthesize ammonia, the critical chemical that makes nitrogen accessible to crops. Nitrogen is essential for crop development and while air is over three-quarters nitrogen, that nitrogen is not directly accessible by crops.

Can you think of anything today that does not directly contain or rely on one of the four pillars? The pillars are among humanity's greatest fortune from hydrocarbons. Today, and for the foreseeable future, there is no scalable, viable way to produce the enormous quantities demanded without hydrocarbons.

Global demand for all four pillars today is at all-time highs and growing. All economic progress, from dire poverty to a wealthy western lifestyle, hinges on the pillars. For instance a basic need in Africa and Asia is to replace mud floor huts with concrete to improve overall hygiene and reduce the incidence of parasitic disease by nearly 80%.

China produced as much cement in two years (2018-2019) as the United States did during the entire 20th century. Slightly less than 20% of global primary energy goes to producing these essential materials, about the same amount of energy as in the entire electricity sector. Attempts to reduce greenhouse gas emissions countrywide have displaced most energy-intensive manufacturing out of wealthy countries with cleaner energy systems and towards lower-income

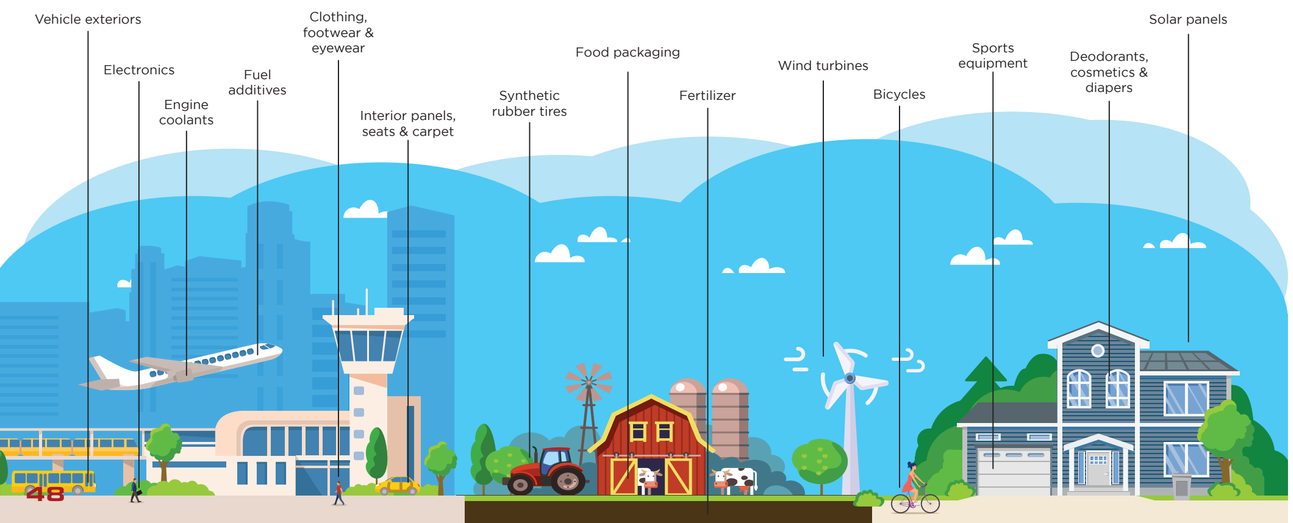
countries with dirtier energy sectors. Displaced manufacturing from the U.S. — where natural gas is our dominant industrial fuel — to Asia's coal-dominant manufacturing sector increases global greenhouse emissions and global particulate matter emissions. While this transfer has reduced the overall production cost of the four pillars and their countless derivatives, its carbon footprint has increased. Everything involves trade-offs, acknowledged or not.

Wind turbines are highly-visible embodiments of hydrocarbons; they demand enormous amounts of concrete, steel, and plastic. The bases that anchor the turbines are made of steel-reinforced concrete. The towers, nacelles, and rotors contain nearly 200 tons of steel per megawatt of capacity. A mid-size turbine blade uses 15 tons of energy-intensive plastic resins.

Too often, the electricity (or power) sector is confused with the energy sector, of which electricity is only a modest subsector. Manufacturing — of everything, not just the four pillars — is the largest consumer of primary energy. Despite increasing efforts to electrify everything, less than 15% of manufacturing energy comes from electricity — the same fraction that it was 25 years ago. Let's celebrate advancements in electricity production, but keep them in perspective as small parts of the global energy system.

Silicon deserves an honorable mention as a pillar of the modern world due to its ubiquitous role in modern computing, communications, and consumer devices. Silicon's impact has been tremendously life-enhancing, but it merits only an honorable mention as everything silicon has brought depends entirely on the four pillars.

WHERE WILL YOU USE HYDROCARBONS NEXT?



FOOD AND HYDROCARBONS

Food is the energy that powers the human machine. It is not optional. Food production has transformed earth's ecosystems to a far greater degree than any other human activity. Roughly one-third of the total non-glaciated global land is utilized today for food production. Over the last century, the land devoted to food production has roughly doubled. However, the global population has increased four-fold while per capita calorie consumption increased by approximately 50%.

In the United States, corn yields per acre have risen from 2 tons in 1920 to over 10 tons today. While this is impressive, the productivity increase per unit of human labor is simply astounding. We can go back even further with wheat farming data. Two hundred years ago, it took 10 minutes on an American farm to yield a kilogram of wheat. Today, it is less than two seconds! Why? A cascading series of innovations, materials, and machines made possible by the rise of hydrocarbons over the last two centuries.

Two centuries ago, over 80% of Americans were farmers, and farming practices were not wildly different than those two thousand years ago in ancient Egypt. The mechanical energy inputs came from humans and oxen. Thermal energy from wood produced metallurgical charcoal for smelting the iron in rudimentary farm equipment like plow plates, sickles, and scythes. With over 80% of Americans working on farms in the early 1800s, the rate of innovation was limited. A lack of energy, wealth, urban centers, and time for risky efforts that may or may not yield success left laborers stuck in inefficient farming practices.

The following century saw tremendous progress as rapidly rising coal consumption allowed steel production and, hence, much-improved farm machinery, such as larger plows pulled by teams of horses. Seed drills arrived, as did railroads and steam-powered locomotives that brought better tools, seeds, and access to markets at harvest time. Large steel silos allowed crop storage, giving farmers flexibility on when and where to transport their crops to market.

The 1900s brought advancement to the industry through machinery and science. Diesel-powered tractors automated crop planting, harvesting, and processing. Farm seed quality, irrigation, farming practices, and hydrocarbon-enabled pesticides increased yield. And a globally significant breakthrough in chemistry introduced industrial-scale synthetic nitrogen fertilizer.

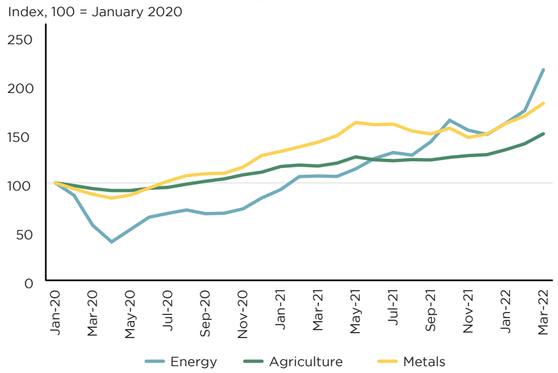
DID YOU KNOW: Elimination of natural gas-synthesized nitrogen fertilizer would cut global food production in half.[9]

In the early 1900s German chemists Fritz Haber and Carl Bosch developed a process to use natural gas as both a source of hydrogen and for high-temperature process heat to produce nitrogen fertilizer on an industrial scale. Before the Haber-Bosch process innovation, nitrogen content in soil was a major constraint on crop productivity. Existing nitrogen sources from bird guano, manure, and rotating cultivation of leguminous crops like peas, clover, and beans supply only limited amounts of vitally needed nitrogen. It is hard to overstate the significance of the Haber-Bosch process to today's world. Elimination of natural gas-synthesized nitrogen fertilizer would cut global food production in half. There is no going back from hydrocarbon-enabled food production.

At the time of writing, in the summer of 2022, tight global LNG markets have inflated prices, curtailing nitrogen fertilizer production globally and posing a measurable risk to the world's food supply. The Russian invasion of Ukraine is further straining global food supplies. A well-functioning global LNG market is critical to the world's food production, enabling transportation and nitrogen fertilizer production.

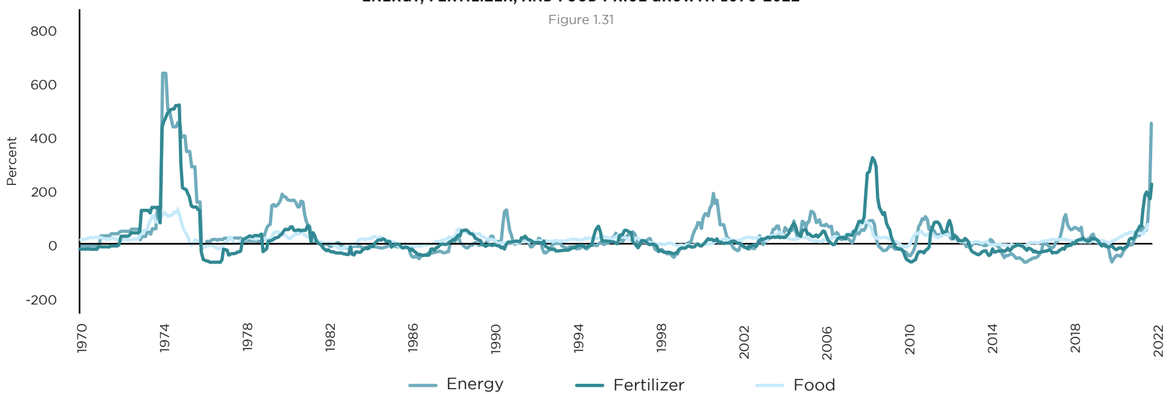
COMMODITY PRICES 2020-2022

Figure 1.30



ENERGY, FERTILIZER, AND FOOD PRICE GROWTH 1970-2022

Figure 1.31



GEOPOLITICS AND HYDROCARBONS

The intimate link between energy security and national security has been underappreciated in recent years. This all changed on February 24, 2022 when Russia invaded Ukraine. Russia's invasion of Ukraine did not cause today's energy crisis. In fact, it's the reverse: Today's energy crisis is likely an important factor in the timing of Russia's invasion. Over the last 20 years, Europe has significantly reduced its hydrocarbon production, becoming more dependent on imported energy, primarily from Russia. Europe has invested massively in wind, solar, and biofuel energy to reduce GHG emissions. These energy sources are far more capital intensive and lower in energy density and reliability. Hence today, Europe is in the unenviable position of heavy reliance on Russia for natural gas, oil, and coal. This energy pivot appears a failure as it has delivered significantly higher energy costs, grave energy insecurity, and relatively modest GHG emissions reductions after factoring in the impact of Europe outsourcing manufacturing emissions to more coal-dependent countries.

A glance back to the history of energy and geopolitics is warranted.

Holland and England led the rise of modern liberal democracy, the rule of law, free markets, free trade, and the tremendous growth of human liberty over the last several centuries. Perhaps the most critical driver of their rapid rise was substantial advantages in energy supply. The Dutch were famous for their thousands of windmills used to pump water and grind grain in the early 1600s. But windmills do not provide process heat to smelt metals, blow glass, make bricks, or refine sugar. Peat, an immature hydrocarbon produced from partially decayed plant matter, was the key energy source that enabled the rise of a small coastal nation into a worldwide leader in agriculture productivity, early manufacturing industries, and global trade. Peat made Holland the most energized nation on earth and the wealthiest per capita. Peat supplied 20 – 100 times more energy than windmills in the Dutch Golden Age.

Unfortunately for Holland, England had coal — an emerging source of energy that was far more extensive, energy-dense, and easier to transport. Pre-industrial societies had limited supplies of energy. Forests were rapidly exhausted, and everything else depended on highly variable annual crop yields. Reliable access to affordable energy in quantity has always been the primary constraint on the human condition. Coal transformed England and began the emergence of the modern world.

The rise of coal in England began long ago, playing a significant role even during Shakespeare's time. Coal is estimated to have provided half of England's energy by 1700, principally as thermal energy for heating, cooking, forging metal, and other process heat manufacturing uses. In the 1700s, the invention of steam engines displaced the historical constraint of mechanical energy only coming from human and animal (horse) power. Without the ability to transform thermal energy into mechanical energy with steam engines, most everyone reading this report would still be a farmer.

The rise of the world as we enjoy it today resulted from larger and higher quality energy sources supporting modern transportation, manufacturing, communications, education, healthcare, computing, travel, leisure, and more. No current industry could exist in recognizable form without the energy and materials from hydrocarbons, including electricity production from hydroelectric, nuclear, wind, and solar sources. Energy supply is critical to all modern warfare — as was food and fodder in pre-modern wars — and has often been the origin of the conflicts as well.

The immense rise in global trade in the 20th century brought economic benefits from harnessing different countries' comparative advantages. A relatively peaceful post-WWII order enabled the rapid spread of industrialization via foreign direct investment, global trade agreements, and capital flows. Rising geopolitical tensions over the last decade (at least) are unfortunately exposing the fragility of today's global economic order.

Today over 100 countries across every inhabited continent produce oil and natural gas. Global markets have generally been well-supplied, and, importantly, the inflation-adjusted cost of oil over the last five years has been roughly equal to its average since the industry began in 1860. As the world gets wealthier, the percent of the total income needed for energy costs has been in long-term decline, a positive trend for human well-being. Unfortunately, we appear to be getting off-track recently.

The world energy system requires a meaningful spare capacity to handle inevitable bumps in the road. The last several years have seen this capacity whittled away partly due to insufficient investment during a period of low commodity prices. Excess capacity has also shrunk due to regulatory blockage of critical energy infrastructures such as

pipelines, import terminals, and export terminals. In the U.S., roadblocks for well permitting and leasing on federal lands, low public energy literacy, and ill-informed climate alarmism are stymieing hydrocarbon development. Further constraining investment capital is a corporate Environment, Social and Governance (ESG) movement that has been myopic in environmental concerns regarding hydrocarbons' negative climate impacts without an accompanying appreciation of their necessity for human well-being. The net result is a constrained supply of oil, natural gas, and coal which means higher prices and a greater risk of market dislocations like the one unfolding today. High energy and food price inflation is the cruelest form of tax on the poor.

Unbalanced and unrealistic views of hydrocarbons are driving up the cost of energy for the global population and contributing to geopolitical instability. This is most evident with the grave threat to Europe's economy today, particularly if Russia continues restricting natural gas exports to Europe. Prices for diesel, gasoline, jet fuel, petrochemicals, and other petroleum products are rising due to elevated global oil prices and tight global refining capacity. Perhaps worst of all is the shortage of LNG export capacity to supply an ever-growing demand for natural gas-generated electricity, home heating, petrochemicals, industrial process heat and raw materials, and most alarmingly, nitrogen fertilizer production.

Current undersupplied LNG markets are a primary driver of inflated fertilizer and food costs — the Russian invasion of Ukraine is a significant exacerbating factor. Today's food and energy prices are impoverishing citizens around the world and driving instability in countless countries from Sri Lanka to Peru. Sri Lanka recently couldn't supply the required energy to operate schools across the country, and Pakistan also closed schools due to fuel shortages for school buses. The rising human toll is disheartening.

Now is a time for reflecting on how we got here, how we can rebuild, and how to avoid these costly mistakes in the future. It is not clear how this plays out in the coming years. It is clear, however, that elevated and uncertain energy and food prices are a real and present danger to the world order.

A WARNING FROM SRI LANKA

In April 2021, Sri Lankan President, Gotabaya Rajapaksa, imposed a nationwide ban on the importation and use of natural gas-based, synthetic fertilizer and pesticides, forcing two million farmers to adapt to organic farming.[10] The impact was rapid and brutal:

- **In the first six months of the ban, domestic rice production fell by 20%.**
- **Domestic prices for rice — a staple of the national diet — surged by around 50%.**
- **Sri Lanka was forced to import $450M worth of rice.**
- **The ban also devastated the nation's tea crop, resulting in estimated economic losses of $425M.**

The results of these policies were devastating to humans and the economy of Sri Lanka. Hungry and outraged citizens launched protests, forced the government to resign en masse, and the president to flee the country.[11]

GAS PRICES EXPLAINED

There are several factors that determine retail gasoline prices: the cost of crude oil, taxes, refining costs, and distribution and marketing costs.

Crude oil is, by far, the largest component of retail gasoline prices and the price of crude is determined by a combination of physical market factors — most notably available supply and demand. Increases in U.S. oil production had, until very recently, reduced upward pressure on oil and gasoline prices. Geopolitical tensions and global supply constraints combined with a post-COVID increase in demand have driven up the price of crude oil.

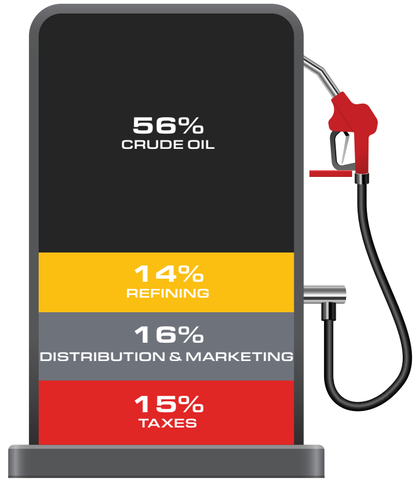
Refining costs, while a smaller percentage of overall cost, are subject to seasonality and available refining capacity. The type of gasoline produced, and the different formulations required by each state also factor into the final refining cost. More recently, declining refining capacity has added to ongoing supply constraints, driving up gasoline and diesel prices.

Typically, gasoline is transported from refineries to terminals, where it is blended with other products like fuel ethanol to meet local requirements for commercial distribution and consumption.

Finally, gasoline travels via tanker to retail gas stations where the price consumers see reflects federal, state, and local taxes, averaging 57.09¢/gallon.

PRICES IMPACTS AT THE PUMP

Figure 1.32



27.6 MINUTES
Average American
One-way commute.

57.09¢/GAL
Average tax on a gallon
Of gas in the U.S.[12]

>50¢ VARIANCE
State taxes vary, from 68.15¢/gal in California to 15.13¢/gal in Alaska.

1.5 BIG PICTURE: EMISSIONS AND AIR QUALITY

THE SPECTACULAR CLEANING OF AMERICAN AIR HAS COINCIDED WITH SIGNIFICANT POPULATION GROWTH, A MORE THAN DOUBLING OF PER CAPITA GDP, AND A LARGE INCREASE IN VEHICLE MILES TRAVELED

The Clean Air Act named six "Criteria Pollutants" that posed the greatest threat to human health: ground-level ozone, particulate matter, carbon monoxide, lead, sulphur dioxide, and nitrogen oxides. Technology and innovation — automobile catalytic converters, scrubbers on coal plants, dramatic improvements in diesel engines, and more have led to a dramatic 78% decline in these six harmful pollutants over the last 50 years. By far the world's deadliest pollutant, particulate matter, is considerably lower in the U.S. today than in all the other OECD countries in Europe and Asia.

The spectacular cleaning of American air has come about coincidentally with significant population growth, a more than doubling of per capita GDP, and a large increase in vehicle miles traveled. Broad-based innovation and (mostly) sensible regulation have enabled this success. A similar path can be followed by the world's emerging economies as their per capita wealth grows. Historically, countries have traveled an enrichment path of necessities first, then improving environmental quality becomes prioritized as captured in the Environmental Kuznets curve. As per capita income rises, they follow similar patterns to the U.S., which has seen at least 50 years of improving environmental quality.

Figure 1.29 tells the story of energy efficiency and market-based de-carbonization. U.S. per capita energy consumption is currently more than 10% below where it was 50 years ago even with increases in personal income. Rising from poverty necessarily involves a significant increase in per capita energy consumption as machines replace human hands in producing life's necessities. Further increases in human wealth become increasingly less energy intensive.

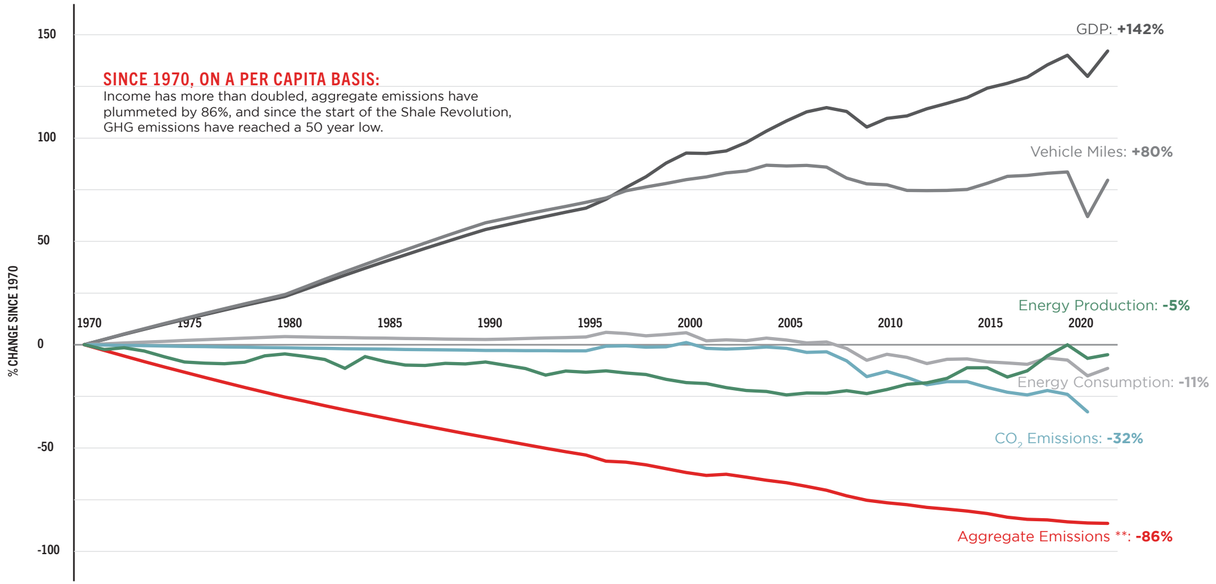
Per capita GHG emissions were relatively flat from 1970 until the shale revolution hit scale. In the years since, per capita GHG emissions have dropped by 32%, significantly driven by natural gas displacing coal as the U.S.'s leading source of electricity. This transition had the additional benefits of reducing energy costs and air pollutants.

Globally, coal is still the world's dominant source of electricity with a market share over one-third. Growing natural gas electricity generation globally could be a major source of greenhouse gas reduction as well as a major factor in reducing air pollution. China, India, Korea and others are all pursuing this strategy. In most countries without significant local natural gas production, coal electricity is still the most cost effective option. An even more urgent energy substitution is to transition the remaining one-third of humanity away from cooking with wood, charcoal, dung or agricultural waste. Propane has been the dominant replacement cooking fuel for people moving out of energy poverty. Surging U.S. exports of propane are increasing availability and lowering the cost to make this critical step out of energy poverty.

Houston, TX

U.S. PER CAPITA GROWTH AND EMISSIONS 1970-2020

Figure 1.33



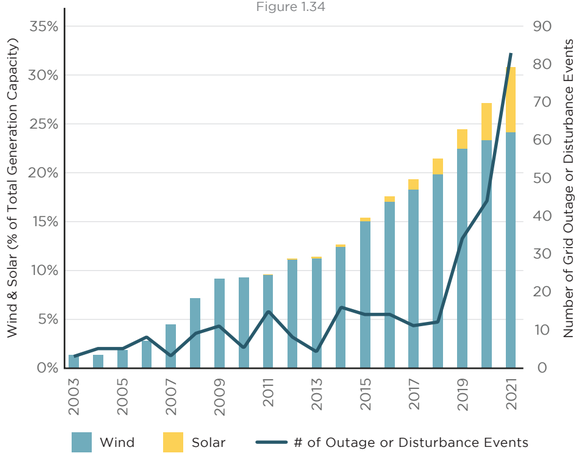
** 6 named criteria pollutants from The Clean Air Act: Ground-level Ozone, Particulate Matter, Carbon Monoxide, Lead, Sulphur Dioxide, Nitrogen Oxides

ENERGY IN TEXAS

Texas not only holds a strong reputation for leading the U.S. in oil and gas production, but the state is also a leading developer of industrial-scale wind generation capacity. The state's wide open spaces, with relatively consistent topography and prime wind resource corridors, give Texas a significant natural wind resource advantage over most states. When coupled with the massive tax subsidies available to developers, very large landowners willing to site nearly 17,000 turbines, and an electricity market structure that perversely provides favor to intermittent power suppliers over those capable of meeting spikes in market demand as they occur no matter the time of day or season of the year, it is no wonder that wind (and more recently solar) has rapidly become a large share of the state's generation portfolio. The rapid buildout of wind capacity in Texas began between 2007 – 2009 and constructed capacity now accounts for 24% of total in-state generation capacity. The state's solar buildout lifted off in 2017 and now accounts for 7% of state generation capacity.

WIND & SOLAR SHARE OF TEXAS POWER GENERATION CAPACITY VS REPORTED POWER OUTAGES

Figure 1.34



Today, Texas is 138% more dependent on wind capacity, 22% more dependent on solar, but has 15% less capacity in baseload or call-up generation (fossil fuel, nuclear, and hydroelectric) on its grid relative to the rest of the U.S.

Unfortunately, as Texas expanded its intermittent wind and solar generation capacities, it retired 5% of its reliable coal and natural gas generation assets when the overall demand for power increased 20% since 2005. The result has been a dramatic increase in recorded power outages and disruptions as the Texas generation stack and its grid have been unable to meet ratepayer needs when conditions are the most desperate and lives hang in the balance.

In 2021, power outages involving the Texas grid accounted for 21% of the total outages reported across the U.S. which is nearly twice its 11% share of U.S. power demand. This is due in large part to the outsized intra-year monthly peak-to-trough variability and coincident timing of trough month production of wind and solar with extremely hot and cold weather. On a combined basis, monthly Texas wind and solar output swings by 40% peak-to-trough which is 1.3x more source volatility than the rest of the U.S. making the state's grid management a massive challenge. The challenge is made even worse as trough month production from wind and solar regularly occurs during periods of extreme heat and cold which require large amounts of energy to survive and reveal in real-time the limitations of weather-dependent power generation sources. Within each of the past ten years, trough month production for combined wind and solar generation in Texas occurred seven times when state power demand peaks during the hottest but lowest wind speed summer months of August and September. And tragically, during February of 2021, the Texas power grid nearly collapsed under the bitter cold, ice, and snow produced by Winter Storm Uri.

Winter Storm Uri became the deadliest and costliest power outage in Texas history as it gripped the entire Midwest and Gulf Coast with brutally cold temperatures of uncommon duration. While the upper Midwest is generally prepared for such a winter storm, the power generation assets in Texas struggled and the grid managed by Electric Reliability Council of Texas (ERCOT) missed a complete collapse only by cutting service to ratepayers during the worst hours of the storm. The impacts of the storm and the failure of market structure to create adequate and viable electricity resources to survive it accounted for 210 deaths connected to power outages, an estimated 4.5 million customers without power for up to four days, and losses to the Texas economy in the range of $80 to $130 billion.

In the four weeks leading up to Uri, the daily ERCOT generation mix averaged 29% from wind, 3% from solar, 33% from natural gas, 22% from coal, and 13% from nuclear. During the depths of the freeze (February 9-17), the mix shifted to average 8% from wind, 1% from solar, 62% from natural gas, 19% from coal, and 9% from nuclear. In terms of absolute changes to output during the storm versus the four weeks prior: wind -62%, solar -49%, nuclear -8%, coal +9%, hydro +68%, natural gas +135% Nearly half the massive increase in the need for life-saving natural gas came from plants that were essentially idle leading up to the storm.

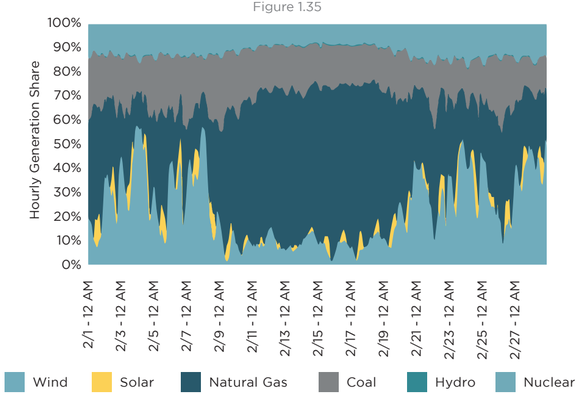
As the storm battered regional infrastructure, the ability to store physical fuels at locations proximate or on-site at natural gas, coal, and nuclear power plants allowed for those assets to maintain relatively stable outputs. In the case of natural gas, in fact, those plants dramatically increased their output to fill the gap created by very low capacity factors at wind facilities as they froze or were plagued by extended periods of low wind speeds. Solar facilities also froze or became incapacitated by the coverage of ice and snow.

Not only did natural gas do more to preserve the Texas power grid than any other generation source, but it also provided life-saving heat to millions of Texans. In fact, demand for natural gas from residential and commercial customers holds priority over demand from the power sector. It is frequently underappreciated that demand from homes and business across Texas and the Gulf Coast increased significantly to combat the bone chilling cold weather. According to Bloomberg commodity flow data, natural gas supplied to Gulf region residential and commercial customers rose from a four-week pre-storm average of 2.1 Bcf/d to an average of 5.0 Bcf/d during the storm (with an all-time record daily peak of 6.9 Bcf/d on February 15).

Liberty is proud to play a critical role in the production of U.S. natural gas which proves time and time again to be a life enhancing and, at the most consequential moments, a life-saving fuel of choice for consumers in Texas and throughout the world.

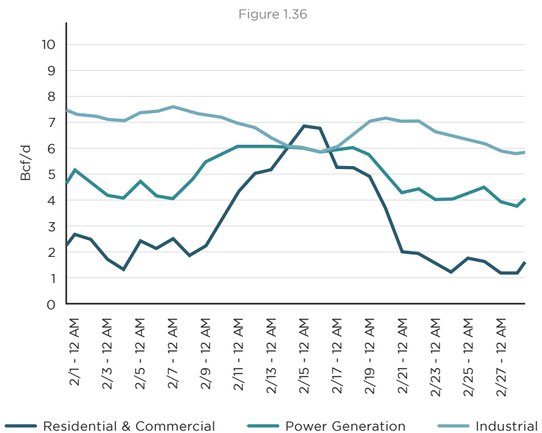
SHARE OF TEXAS POWER GENERATION BY SOURCE, FEBRUARY 2021

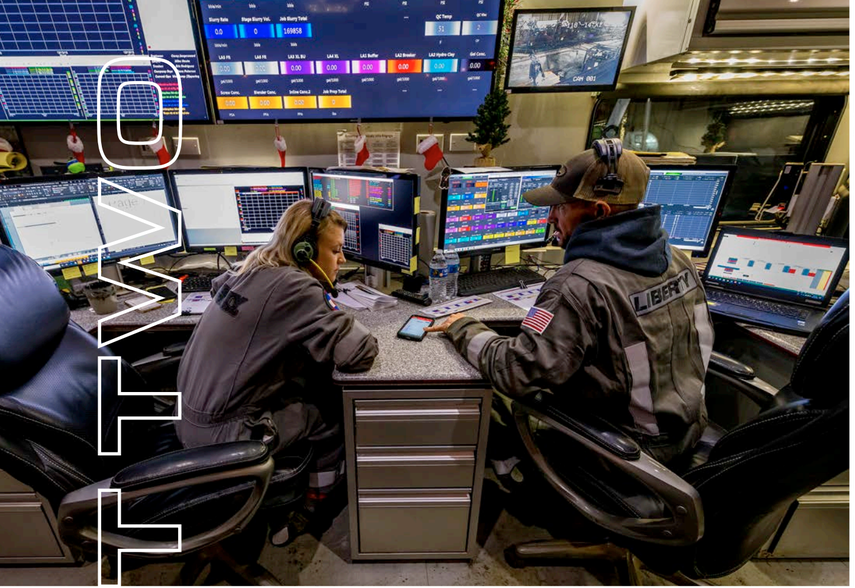
Figure 1.35

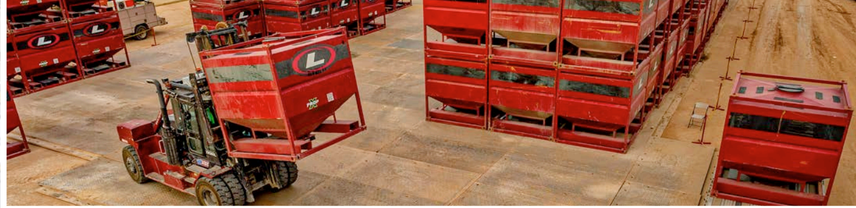


GULF REGION DAILY NATURAL GAS DEMAND BY SECTOR, FEBRUARY 2021

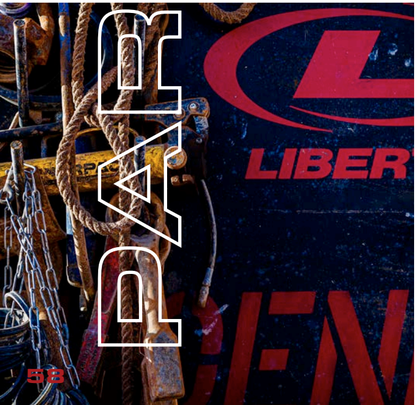
Figure 1.36







PART TWO



LIBERTY TODAY

BETTERING HUMAN LIVES AND REDUCING ENVIRONMENTAL IMPACTS

LEGACY OF SUSTAINABILITY

2011

Assemble industry-first comprehensive database of Bakken petrophysical and completions well data

2012

Slickwater Design — Increasing Bakken oil productivity by 50%

Rolled out first iPads to E&P customers, a key enabler of customer integration

Inaugural frac in North Dakota

2013

Dual Fuel — Liberty's first dual fuel fleet reduces emissions

2014

Containerized Sand — Reduces dust, noise, and truck traffic

2015

Spirit — Fluid system places proppant cheaper and cleaner

2016

Quiet Fleet® — Liberty introduces Quiet Fleet technology

Liberty acquires Sanjel assets

2017

IVF and adoption assistance added as employee benefit

2018

Tier IV DGB Caterpillar Field Test Partnership

First Liberty Women's Summit

ST9 — Acquires ST9 and starts a development program for fully-electric low-emissions fleet

2019

Adopts Ban the Box initiative

2020

Next Gen Frac Fleet White Paper — ESG profile quantified for Next Gen fleets

Deploys Tier IV DGB Fleets

OneStim — Acquires OneStim, Schlumberger's North American onshore hydraulic fracturing business

Liberty adds Wireline and Freedom Proppant businesses

Liberty enters Canada

2021

digiFrac — Liberty launches built-for-purpose electric frac fleet

PropX — Acquires PropX, provider of proppant delivery equipment, logistics, and software solutions

COMMITMENT TO ESG

Liberty has been a force for disruptive change in the service industry. Driven by our mission to deliver the secure, affordable, dependable energy vital to human success, we continue to make advances in providing sustainable solutions for our customers and within our operations.

From day one, our principles have closely aligned with the current market push for ESG. We knew that to be successful as a service business, our people had to come first, and that holds today. The foundation of our team is integrity, talent, and hustle. Investment in our people, from offering variable schedules to recruiting our management from within, strengthens our culture and reputation. We can adapt, innovate, and create best-in-class efficiencies, allowing us to grow into one of the largest North American completions companies.

In 2018, we acquired a start-up company, ST9. ST9's pioneering technologies in frac equipment components led to its novel idea for a next generation frac fleet. With the debut of our first, fully electrified frac pump in 2021, we are now at the forefront of low-emission frac technology. In 2020, we acquired Schlumberger's North American completions business, OneStim, advancing our business with complementary technologies, people, assets, geographic diversification, and vertical integration. In 2021, we completed the acquisition of PropX, a leading provider of environmentally friendly last-mile proppant delivery. The addition of PropX integrates the latest proppant delivery technologies and software into our supply chain and brings advanced, ESG-friendly wet sand technology and expertise to Liberty.

Liberty's commitment to digital technology has been critical to our success and the improvements in environmental performance and shale-well productivity over the last decade. We have adapted our data vans and engineered automated fracturing pump control to optimize fleet horsepower using more natural gas and less diesel. Our teams have successfully used software to automate fleet performance monitoring and enhance personnel safety by mitigating the risk of human error. These achievements build on our past advancements in technology — from the development of the Quiet Fleet®, which reduced noise pollution in nearby communities, to our logistics solution through containerized sand.

As we continue to move forward, our desire is to provide our customers with exceptional service, offer transparency to our stakeholders, and strengthen our communities. We take our responsibility seriously and will continue to hold ourselves accountable with vigorous ethical standards, best-in-class governance, and risk-management controls.

173
STUDENTS RECEIVED SCHOLARSHIPS IN 2021

$1M
RAISED FOR OUR COMMUNITY PARTNERS

0.51 TRIR
OUR SAFEST YEAR IN COMPANY HISTORY

738
EMPLOYEE OWNERS

93%
OF EMPLOYEES CONTRIBUTE TO 401K

42%
OF EMPLOYEES ARE MINORITIES

2.1 ENVIRONMENTAL PERFORMANCE

LIBERTY HAS A STRONG HISTORY OF INVESTMENT IN NEXT GENERATION TECHNOLOGY AND INNOVATIVE SOLUTIONS THAT MINIMIZE THE IMPACT OF HYDRAULIC FRACTURING AND WIRELINE SERVICES.

This past year Liberty took important steps to make measurable strides in environmental performance in many areas of our business.

In the digital space, we focused much of our effort on enhancing the operation and monitoring of our fleet. Our next generation operating system, FracCATX™, together with the StimCommander™ pump control software, provides enhanced control capabilities for the pumps to maximize longevity of components and optimize performance in areas including gas substitution. Liberty's new FracPulse™ software delivers new levels of condition-based asset operation analysis and performance alert capabilities with real-time emissions reporting on our fleet. Together, these digital technologies will ensure we are producing the lowest possible emissions at the highest operational efficiency for each job.

We made tremendous strides in our progress towards the commercial deployment of digiFrac. We completed more than 1,500 hours of testing on the electric pump, both in the yard and on location in both the Permian and DJ basins, with remarkable success under all operating conditions. In parallel, we finalized the engineering design work and began fabrication of our power generation solution for digiFrac, bringing to the mobile world of frac a natural gas motor with thermal efficiencies unmatched by any diesel engine or turbine in the space today.

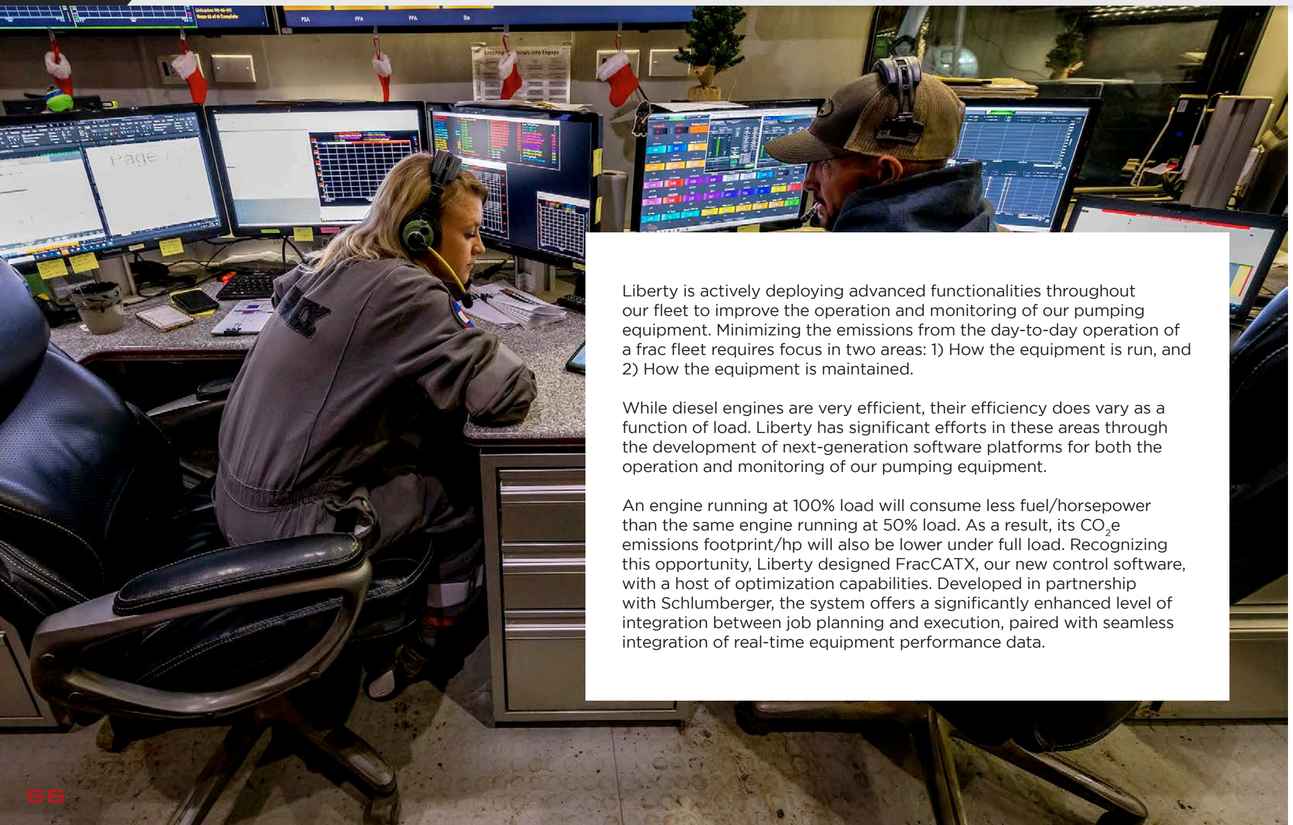
When annual truck trips are measured in the hundreds of thousands, every small gain matters. By centralizing our proppant logistics, we expect to be more efficient with the utilization of every truck we dispatch, meaning less trucks on the road, less idle time at origin and destination and therefore less emissions. Real-time job data, combined with traffic, weather and mine/rail transload wait times provides the Liberty dispatch team with the information to make the best possible decisions on pull point and the routing to the destination.

Our PropX containerized sand system provides the flexibility, given varying Gross Vehicle Weight (GVW) regulations, to maximize the amount of sand hauled in each of our basins. PropX technology also allows us to remove the drying step and deploy of mobile mines closer to frac locations enabling Liberty to utilize wet sand, the latest advancement in proppant use. The removal of the drying process, combined with significantly shorter truck trips, means a large reduction in the emissions associated with sand processing and delivery. It also leads to improved safety due to the reduction in vehicle miles driven and the elimination of silica dust on location.

The Liberty chemistry portfolio is constantly evolving. Our Green Select program, based on global health guidelines, is used by our team to help inform decisions about the best next-generation chemistry, ensuring each new product has less impact than the previous one. We are also moving toward "dry" chemical additives wherever possible. "Dry" chemicals are replacing legacy chemical delivery that uses mineral oil as a carrier fluid to contain the desired chemicals. One truck load of dry additive might replace four loads of the equivalent liquid additive. These dry additives also remove the manufacturing step of slurrying the chemical into mineral oil, further lowering the footprint.

A typical fracture treatment requires millions of gallons of water. Historically, this was all fresh water. Recognizing that we could do better, Liberty continues to work closely with our chemical supply partners and customers to migrate further and further toward alternative water sources, including saline non-potable water and recycled water from previous oil and gas production operations. We have made meaningful progress in this area, allowing our customers to use an ever-increasing percentage of non-fresh or recycled water.

2.2 DIGITAL TECHNOLOGY



Liberty is actively deploying advanced functionalities throughout our fleet to improve the operation and monitoring of our pumping equipment. Minimizing the emissions from the day-to-day operation of a frac fleet requires focus in two areas: 1) How the equipment is run, and 2) How the equipment is maintained.

While diesel engines are very efficient, their efficiency does vary as a function of load. Liberty has significant efforts in these areas through the development of next-generation software platforms for both the operation and monitoring of our pumping equipment.

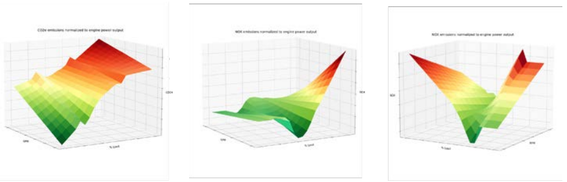
An engine running at 100% load will consume less fuel/horsepower than the same engine running at 50% load. As a result, its CO_2e emissions footprint/hp will also be lower under full load. Recognizing this opportunity, Liberty designed FracCATX, our new control software, with a host of optimization capabilities. Developed in partnership with Schlumberger, the system offers a significantly enhanced level of integration between job planning and execution, paired with seamless integration of real-time equipment performance data.

LIBERTY IS ACTIVELY DEPLOYING ADVANCED FUNCTIONALITIES THROUGHOUT OUR FLEET TO IMPROVE THE OPERATION AND MONITORING OF OUR PUMPING EQUIPMENT

The StimCommander automated pump control system is paired with the FracCATX platform to provide the next level of equipment automation on location. Allowing for fully automated pump control, together with a range of operational optimization capabilities, the combined system will deliver higher daily efficiencies, optimized fuel usage and emission footprint, an improved safety environment and reduced repair and maintenance costs.

Maintenance of the equipment is equally as important as how it is run when thinking about minimizing emissions from frac operations. FracPulse is Liberty's new asset management platform designed from the ground up to provide Liberty employees with focused information on asset health, real-time condition monitoring, and predictive failure analytics. By integrating our Computerized Maintenance Management System with real time data telemetry, we can compile, collate, and deliver information most pertinent to different employee groups. Providing the operations and maintenance teams with clear, concise information in real time offers a path to achieve higher job throughput and equipment longevity. There are several key functions within FracPulse, designed to facilitate a proactive, rather than reactive, response to potential equipment issues. First, the Health Profile prioritizes maintenance events to plan for optimum turnaround times. Second, live equipment alerts notify operators of irregularities with pumps through telemetry data.

To expand on the condition-based monitoring portion of FracPulse, Liberty has been actively pursuing ways to detect failures in earlier stages through high frequency monitoring of key parameters. By monitoring at a higher sampling rate, digital models can be trained to detect anomalies far in advance of what a human operator would be able to achieve. This has led to higher resolution information that can quantify general wear and tear before reaching failure conditions. Liberty is actively deploying this advanced functionality throughout our fleet, using FracPulse as a platform to focus the information and quickly visualize new technology. Our vertical integration strategy, specifically our ST9 pump technology division, allows us to take these learnings and rapidly implement them in next generation pump design for deployment across the Liberty fleet.



FracPulse platform, allowing users to see a real-time view of equipment parameters.

EMISSIONS MODELS & DASHBOARD

2.3 FRAC ENGINES

Liberty built its first frac fleet 11 years ago. At that time, Tier II diesel engines were the best available engine technology on the market. In the years since, large diesel engine technology has evolved through three more generations: Tier II dual fuel (substituting natural gas for some amount of the diesel), Tier IV diesel, and most recently, Tier IV dual fuel. Liberty adopted these technologies early, as they came available, ensuring our customers access to the latest in low emissions frac horsepower.

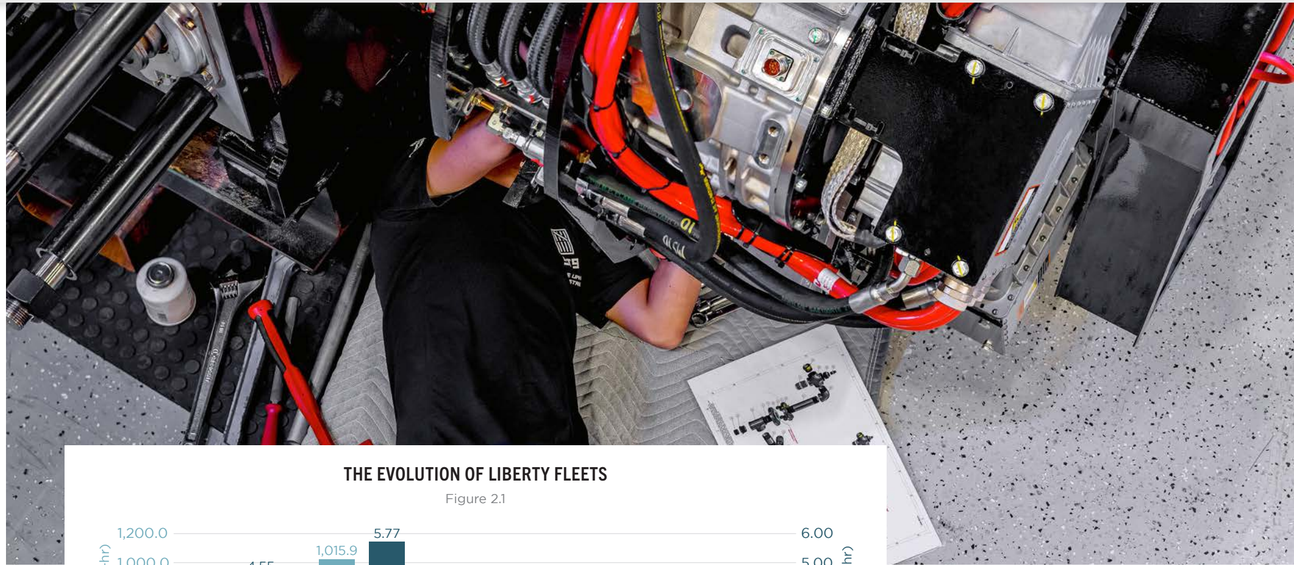
Almost five years ago — driven by our internal desire to be better, together with a strong desire from our customers to take the next step in emissions reduction — we embarked on a journey to develop our next-generation platform for delivering hydraulic fracturing services, an electric frac pump. As E&P operators looked at opportunities to lower the emissions associated with producing a barrel of oil or Mcf of gas, it was clear the completion process represented a meaningful opportunity. Our analysis of manufacturer-provided data showed a potential reduction in CO_2e (CO_2 + methane) of more than 25%.

This journey had two key components — designing a pump driven by electric motors and designing the system for generating electricity. Together, these components would determine the system's success as the next step in Liberty's journey to lower frac operations emissions footprint and improve operational efficiency. While the power generation system received the primary focus when considering emissions reduction, Liberty also seized opportunities to optimize with the pump.

The default approach to electrifying a pump has been to remove the diesel engine and transmission and replace them with one large electric motor. While this approach works fine, it does not offer the best opportunity for optimal operation. The highest current draw for an electric motor occurs during startup, getting from stationary to some rotational speed. Large motors require a larger inrush current to achieve startup. High inrush current means more power generation online at the outset to ensure a successful start. The Liberty digiFrac pump takes a different approach, utilizing 10 smaller motors working in parallel to deliver the same total horsepower as one large motor. This approach provides more flexibility to minimize the inrush current at startup, reducing the power required and emissions emitted during this phase.

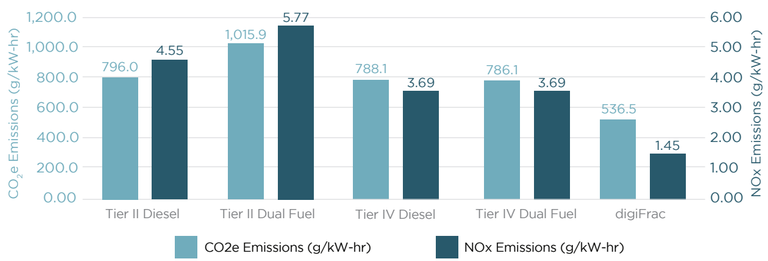
A thorough review of the options for generating electricity on location made it clear that reciprocating natural gas-fueled engines offered the most meaningful emissions reduction compared to existing Tier IV dual fuel units. The Rolls Royce 20V4000 engine is incredibly efficient, with a thermal efficiency of 43%; this compares with a large diesel engine with a thermal efficiency of approximately 35%. Each natural gas generator provides 2.5 MW of power. A typical frac operation would require between six and eight of these generators to power the fleet at peak rate and pressure, but a fraction of that at other times. Rather than one large turbine running inefficiently at part load, the modular approach of multiple smaller generators ensures each is operated at optimal load to maximize efficiency. The combination of high thermal efficiency, cleaner fuel, and modularity will allow Liberty to deliver the next advancement in emissions reduction for hydraulic fracturing operations, our most significant step forward in this area in our history.

LIBERTY HAS ALWAYS BEEN AN INDUSTRY LEADER IN INNOVATION OF NEW TECHNOLOGY, OUR NEXT STEP TO LOWER EMISSIONS AND IMPROVE EFFICIENCY IN FRAC OPERATIONS IS NO DIFFERENT.



THE EVOLUTION OF LIBERTY FLEETS

Figure 2.1



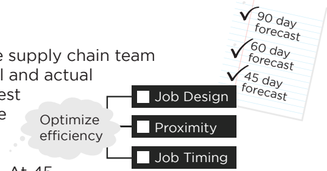
CO_2e is the combination of CO_2 and unburnt methane emissions from an engine. Tier IV engines are slightly more efficient than Tier II engines, leading to reduced CO_2 emissions. Tier IV DGB technology is a dramatic improvement over the older Tier II dual solution, reducing methane slip to basically zero. NO_x emissions are a result of high temperatures in the combustion process. One of the main goals when transitioning from Tier II to Tier IV engines was to reduce NO_x emissions. The manufacturers accomplished this by reducing peak temperatures and pressures within the engine.

2.4 SAND, LOGISTICS, AND SUPPLY CHAIN

THE TRUCKING OF SAND TO FRAC LOCATIONS IS A COMPLEX LOGISTICS OPERATION HAPPENING ON A MASSIVE SCALE. APPROXIMATELY 14,000 TRUCKLOADS OF SAND ARE DELIVERED DAILY TO FRAC LOCATIONS ACROSS THE COUNTRY. MORE THAN 2,000 OF THOSE LOADS WILL GO TO LIBERTY LOCATIONS.

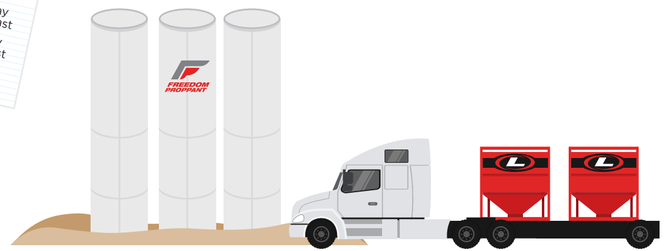
1 Plan & Prep

Starting 90 days out from a job, the supply chain team develops a plan relying on historical and actual customer data, prioritizing the closest rail transload or mine to support the job needs. This plan is reevaluated and adjusted accordingly as the job approaches and factors change. At 45 days, LBRT's teams can expect 90% accuracy.



2 Execute & Adapt

Our teams find solutions to a variety of different factors as they are executing the job. Some of these factors include: change in material cost & availability, third party driver retention and labor shortage, and changes in weather.



Pick up sand from the optimal origin (mine or rail transload)

! Change in material cost & availability

✓ Relationship-based material sourcing

PROPX containerized sand

Optimized box design reduces vehicles on road and maximizes payload

Transport sand to location using route optimization and adjusting for real-time navigation challenges

! Change in weather

✓ Adjust route or product sourcing location

One turn = one driver's journey to deliver a load of sand

! Driver retention & labor shortage

✓ Focus on keeping high quality drivers

Place full sand containers at location and remove empty sand containers

TURN COUNT MATTERS

PRIORITIZE EFFICIENCY & RETENTION

Efficient turns mean less idle time, lower emissions, fewer vehicles on the road, and greater efficiency. Shorter distances increase the number of turns per driver improving pay and job predictability.

Liberty frac crews will pump more than 15 million tons of sand in 2022 — an amount that will require 700,000 truck trips from a regional mine or rail transload to a frac location. Historically, that proppant would come from a northern white sand mine in the Wisconsin/Minnesota/Illinois area or a ceramic proppant manufacturing facility in the southeastern U.S., travel by rail to the basin, and transload into a truck for the last-mile trip to the location. Today, driven by Liberty's engineering team in partnership with our E&P customers, frac design evolution has enabled the use of lower conductivity material without adversely affecting well productivity. This allows for a large percentage of proppant to be sourced locally in the basin, eliminating the 1,000-mile rail trip and the emissions associated with that trip.

Liberty's transition to containerized sand, powered by our PropX division, has been instrumental in changing last-mile hauling and on-site handling of sand. This transition has resulted in more efficient truck utilization, reduced silica dust on location, and reduced emissions due to less truck idle time on location. PropX's next-generation system has enabled another step-change in the proppant space, the use of wet sand. Drying frac sand for ease of handling emits about 200 tons of CO_2 per 10,000 tons of sand dried. Using wet sand eliminates the drying step in some cases and allows smaller "mobile" mines without drying capabilities to be deployed on smaller deposits closer to the well site. Shorter distances between sand and site not only reduce the emissions that come from the drying and transport but also reduce traffic and road wear and improve pay and job predictability for drivers.

With the intent of making the most efficient use of each truck, Liberty has prioritized optimizing sand acquisition, hauling, and delivery. As part of this effort, Liberty has deployed a new software solution built on the PropX PropConnect™ platform that will provide real-time visibility of the status of operations at each Liberty frac location. This data — when combined with the existing visibility on the trucking fleet, current traffic flow en route, and local weather conditions — will enable our new central proppant dispatch team to provide efficient direction to every truck, ensuring the best combination of origin, route, and destination, while maximizing truck utilization.

2.5 FRAC FLUID CHEMISTRY

WE'RE PROUD TO HAVE HELPED REDUCE THE NUMBER AND VOLUME OF CHEMICALS NEEDED TO MAKE TOP-PERFORMING FRAC FLUIDS AND WE CONTINUE TO LOOK FOR SAFER AND GREENER ALTERNATIVES

Liberty has been a pioneer driving frac fluid chemistry forward since our founding. We have focused on the dual goals of increasing production efficiency and therefore lowering the cost of producing natural gas and oil from shale, while also reducing the usage of frac chemicals. Another avenue of improvement has been our drive to develop and use ever-greener chemicals.

Reducing the number and volume of chemicals needed to make top-performing frac fluids is a point of pride for Liberty. Our team has worked hard to go even further by continuously looking for safer and greener alternatives. The most basic functionality of our frac fluid systems can be assembled with ingredients found in a grocery store.

Liberty's GreenSelect program uses Global Harmonized System of Classification and Labeling of Chemicals (GHS) as developed by the United Nations and adopted by OSHA to track health, physical and environmental hazards.

Liberty is committed to the ongoing effort of using safer and greener products in our oilfield operations. We continuously look at ways to improve upon our current applications, and that is why we are implementing a chemical hazard scoring system for each of our products. We will use a product's full GHS classification, along with transport classification, and hazardous disposal information will be used to assign a numerical score.

GHS consists of health, physical, and environmental hazards. Within each type of hazard, there are different categories, ranging from Category 1, which is the most severe, to Category 4, which is the least severe. Our hazard scoring system will assign a weighted numerical score depending on the category, and we factor in a product's transport classification and hazardous disposal information. We work closely with our chemical vendors to obtain all pertinent information on our products to facilitate this endeavor. Each GreenSelect score assists us and our customers in selecting safer and greener products to utilize in oilfield applications. Our industry is subject to state and federal regulations, such as the Safe Drinking Water Act, which has helped to make our industry BTEX-free (no use of benzene, toluene, ethylbenzene and xylenes) since the early 2000s.

It is Liberty's aim to be a good neighbor. Efficiency gains and well economics have driven Liberty to the forefront of efforts to lower the cost to place a pound of proppant (sand) downhole — an effort that has also led to cleaner and safer alternatives. This effort starts from the very launch of our company 10 years ago in North Dakota's Williston Basin, where Liberty championed friction reducer (FR) based fluid systems called "slickwater" instead of the gels commonly being used then. Liberty's slickwater designs are now standard practice throughout the Williston Basin. We played a similar role in driving Colorado's DJ Basin away from expensive, chemical-intensive frac fluid systems to simpler, cleaner fluid systems pioneered by Liberty. Liberty engineers and chemists have deployed sophisticated flow-loops, oscillating rheometers, mass spectrometers, and extensive knowledge to advance the economics of shale gas and oil production while also reducing environmental impacts and risks.

Historically, the lack of transparency in frac fluid composition coupled with the use of myriad chemicals brought about scrutiny from opponents of fracking. Since 2011, E&P operators submit a list of all chemicals and quantities pumped, as provided by their completions service provider, to FracFocus, a public online repository of well data. Liberty welcomes the industry-wide transparency of today. Our engineering teams mine FracFocus data to incorporate within our proprietary FracTrends™ database in an effort to better understand potential production drivers in our MVA workflow.

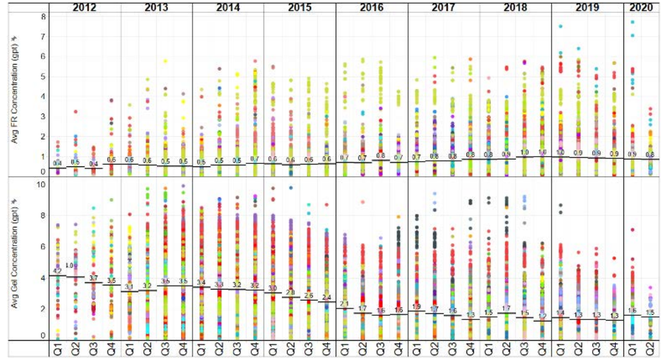
As shown in Figure 2.2, there is a general trend away from more expensive, viscous chemical derivative guar frac fluid systems that dominated for decades. Guar systems are being replaced with simpler, water-dominant, low-concentration friction reducer (FR) based fluid systems called "slickwater." The innovation of low viscosity, water-dominant frac fluid systems was not only essential to cracking the code of extracting oil and gas from shales, it also led to a significant greening of the fracturing process itself. Moving from traditional guar-based viscous frac fluids to slickwater — water plus a FR chemical — led to a dramatic reduction in chemical additives used in fracturing. Certain applications still require a more viscous frac fluid, but advancements in slickwater frac fluid systems continue to gain market share as shown in the plot. Since 2014 an increasing amount of frac treatments employ slickwater, including the heavy sand-laden parts of jobs that previously required more viscous gels. The displacement of viscous gels was made possible by improvements to FR fluid systems, allowing them to transport higher added sand concentrations.

Another benefit of FR systems is they do not need the additional chemical additives such as cross-linkers, buffers and breakers that are required when using guar gel frac fluid systems.

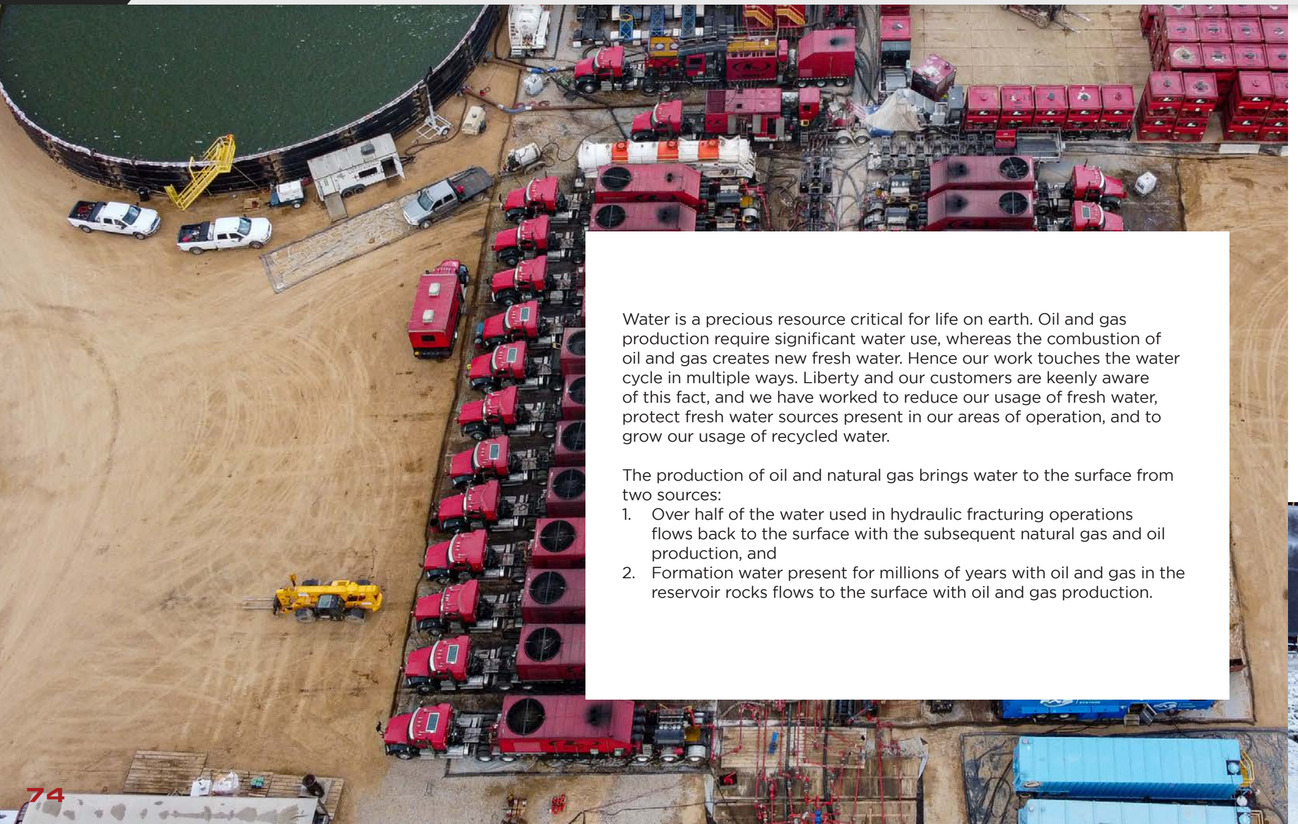
While using 100% water may be an elusive goal for frac fluid composition, the industry has successfully replaced the need for fluid "viscosity" with fluid "velocity" through higher frac pumping rates. Our industry's future will continue driving toward cleaner frac fluids that trend toward the composition of water in a swimming pool — potential future composition of a light FR frac fluid could be made of 99.8% water, with a small fraction of FR, biocide and a surfactant.

HISTORICAL CHANGE IN AVERAGE FRICTION REDUCER AND GEL CONCENTRATION FOR FRACTURE TREATMENTS

Figure 2.2



2.6 WATER



Water is a precious resource critical for life on earth. Oil and gas production require significant water use, whereas the combustion of oil and gas creates new fresh water. Hence our work touches the water cycle in multiple ways. Liberty and our customers are keenly aware of this fact, and we have worked to reduce our usage of fresh water, protect fresh water sources present in our areas of operation, and to grow our usage of recycled water.

The production of oil and natural gas brings water to the surface from two sources:

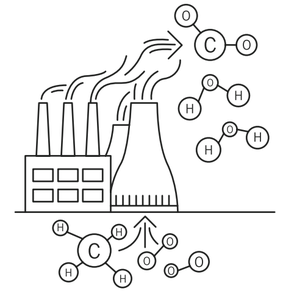
1. Over half of the water used in hydraulic fracturing operations flows back to the surface with the subsequent natural gas and oil production, and
2. Formation water present for millions of years with oil and gas in the reservoir rocks flows to the surface with oil and gas production.

LIBERTY INNOVATIONS ENABLE OUR CUSTOMERS TO RECYCLE WATER FOR FRAC OPERATIONS

Liberty works with our customers to increase the use of recycled water from these two sources in subsequent well-fracturing operations. We do this by developing custom fluid chemistry that is compatible with the highly brine-produced formation water in our customers' area of production operations. Liberty's chemical expertise lets our customers grow their use of recycled water in frac operations.

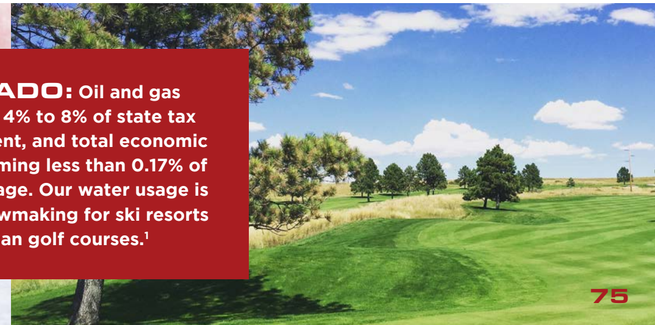
Fracturing new wells consumes significant quantities of fresh water — increasingly being offset by recycling. However, fresh water vapor produced from natural gas and oil combustion at power plants, industrial operations, exhaust pipes, and more likely exceeds the total water used in drilling new oil and gas wells. This is a little-known fact.

A two-mile long Haynesville Shale natural gas well in Louisiana consumes around 30 million gallons of water during drilling and fracturing operations. Combustion of that natural gas chemically combines oxygen with methane yielding water vapor, carbon dioxide and a significant energy release. The same two-mile Haynesville natural gas well yields about 20 billion cubic feet (20 Bcf) of natural gas which produces 70 million gallons of new fresh water when combusted, roughly twice the water used to drill and frac the well. Bakken and Permian oil wells generally use smaller quantities of water in their construction and yield smaller quantities of water when the oil, gas and natural gas liquids are combusted. However, they also ultimately produce more new fresh water than they consume. The created water volume is very small compared to total atmospheric water vapor and most all will be returned to the surface as rain.



The fact that oil and gas production produces more fresh water than it consumes does not take away from our desire to minimize our consumption of local fresh water sources. The new fresh water produced during combustion may be hundreds or many thousands of miles away, wherever the products are consumed. Fortunately, our industry is a highly efficient user of fresh water.

IN COLORADO: Oil and gas represent between 4% to 8% of state tax revenues, employment, and total economic activity while consuming less than 0.17% of Colorado's water usage. Our water usage is a bit larger than snowmaking for ski resorts and bit less than golf courses.[1]



2.7 ECOLOGICAL IMPACT

OUR GOAL IS TO LEAVE THE LOCATION CLEANER THAN WHEN WE ARRIVED, OUR MINDSET IS ALWAYS ON HOW WE CAN GET OUR JOBS DONE WHILE MINIMIZING ECOLOGICAL IMPACT

The Liberty family is full of outdoor enthusiasts, including hikers, climbers, cyclists, skiers, hunters, fishers, and wilderness explorers. Our CEO is a long-time board member of an environmental group, Property and Environment Research Center, and our mindset is always on how we can get our jobs done while minimizing our ecological impact.

Our efforts to lessen ecological impact from routine operations and mitigate risk of serious failures are wide ranging, many of which are covered in more detail in this report. Our efforts to minimize impacts on nearby residents — efforts that include our Liberty Quiet Frac Fleets, keeping all sand sealed in containers to reduce dust and noise, and Uber-for-Sand to minimize truck traffic and waiting times — also bring significant ecological benefits.

Liberty's 11-year effort to build the industry's leading database of unconventional wells coupled with multivariate (Big Data) analytic tools and leading physical modeling tools have helped drive the tremendous progress in getting more oil and gas out of the ground with fewer wells and minimal waste. Efficiency is eco-friendly. In Liberty's history we have seen a nearly two-fold increase in average well productivity and a more than two-fold decrease in the time required to drill and frac a well, which combine to shrink by a factor of four the time required to produce a set amount of oil and gas.

The story of U.S. natural gas production nicely illustrates this "Efficiency is Eco-friendly" point. From 2005 - 2008, the U.S. averaged over 1,000 rigs drilling for natural gas, yet we were the largest natural gas importer in the world. Today the U.S. has only about 150 rigs drilling for natural gas, but we are now the world's largest natural gas producer and the largest LNG (natural gas) exporter! The greatest global fuel shortage today is in LNG, which in turn has meant higher global energy and food prices. It is in this climate of tight global energy markets that Russia chose the timing of its Ukraine invasion. Further increasing U.S. LNG exports is likely the biggest piece of Europe's solution to their over-dependence on Russian gas. This will take time.

There is more. Surging U.S. natural gas production has kept US natural gas prices below half the cost of oil on an energy equivalent basis, and several times lower in the U.S. than in Europe or Asia. This blunts the impact on American citizens of the current global energy crisis. Today's energy crisis will not be over until energy becomes secure, reliable and affordable across the world. Continued growth in US natural gas exports will be a key part of the solution.

Additionally, U.S. greenhouse gas emissions have been on a strong downward trajectory and air quality continues to improve as natural gas displaces coal in the U.S. electricity grid. Liberty was an early adopter of deploying sealed containment across our locations so that incidental spills from fracturing operations do not even touch the ground. They are captured within containment and immediately cleaned up. Fortunately, this practice has now spread throughout our industry.

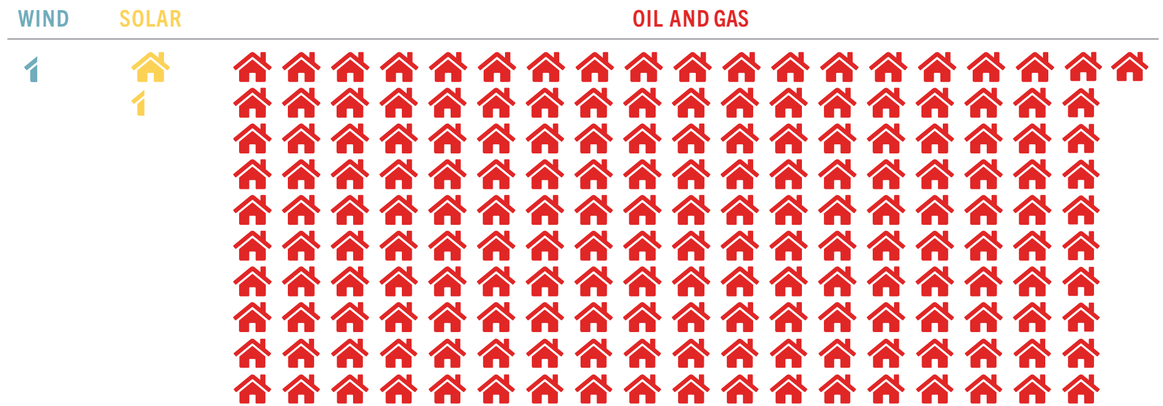
Liberty has been a major innovator driving the "greening" of frac chemicals throughout our 11-year history. We have also developed a suite of novel friction reducers that can work with recycled produced water, enabling our customers to displace more and more freshwater usage with water recycling, driving down any pressure on local fresh water sources.

A theme throughout our ecological efforts is always to be open and transparent. Our operations are run by humans. We are all fallible. Liberty is proud of always being transparent when mistakes happen and rectifying whatever went wrong to the fullest-extent possible. This culture of transparency not only is good for our business, but it is also good for our ecological efforts with our customers, communities, and local governments.

Energy density is a key metric for both environmental impact and on long-term economic viability of various energy sources. The high energy-density of shale natural gas and oil means that our terrestrial footprint is small. The American shale revolution has dramatically increased the amount of energy that can be produced per acre of impacted land. Flying over the massive Bakken oil field in western North Dakota, only farm and ranch activities are immediately visible. Although the Bakken field produces more than a million barrels of oil per day, nearly 10% of total U.S. oil production and more than several OPEC nations, less than 2% of the immediate land is disturbed. Small well pads are constructed along roads that each contain several wells that go down two miles to the Bakken shale and then either two miles north or two miles south of the well-pad location. This allows producing Bakken oil from throughout the field with only modest surface land use. After accounting for the land used for transportation via pipelines, processing, and refining into final products, in addition to the land impacted by drilling wells, oil and gas can provide enough energy to supply 180 homes for every acre of land employed. One acre of solar can supply enough energy for about 1.5 homes and for wind it is far less than even a single home. The star of energy density is nuclear, which can provide for over 1,500 homes per acre of land employed.

HOW MANY HOUSEHOLDS DOES AN ACRE OF ENERGY SERVE?

Figure 2.3



2.8 SAFETY

Michael Tuomi, Lesley Williams, and Michael Shankweiler are joined by representatives from Samsara as they accept the 2022 Samsara Connected Operations Award for "Operations Innovator."

We began 2021 with the OneStim acquisition and welcomed more than 2,000 new employees throughout the year. With time, we blended our employee and safety cultures to achieve one of the best safety performance years on record. During this time, we modified and improved our Field Safety Representative (FSR) program to cover the additional crews and the new service lines.

In 2017, we deployed our Mobile Safety Trailer, a mobile classroom that allows us to meet our employees on location. This traveling training room enables us to provide quick training sessions before the start of a shift, and Liberty trainers can offer in-person instruction on a chosen focus area, such as a revised maintenance practice, to reinforce or update previous classroom training. In 2021, we revamped these trailers to provide more comfortable learning space and hosted a quarterly meeting for every Liberty crew.

SAMSARA PARTNERSHIP

We put millions of miles on our fleet of vehicles every year, making driving the highest-risk activity we undertake.

Liberty was an early adopter of technology that has helped us maintain a strong safety record on the road. We were early to adopt electronic logs, camera-based monitoring, and driver coaching in the cabs of all our heavy vehicles. These efforts have helped Liberty maintain strong Department of Transportation (DOT) scores. Our Motor Vehicle Accident Rate (MVAR) for 2021 was 0.28, more than 80% below non-compliance levels. We remain in full compliance with all other DOT scoring areas and continue to seek ways to keep our drivers — and every driver on the road — as safe as possible.

Our drive for continuous improvement and desire to connect data and technology led us to Samsara, the pioneer of the Connected Operations Cloud. This partnership pushed us to be a leader in safety, efficiency, and technology. Development and implementation of our numerous integrations won us the 2022 Samsara Connected Operations Award for "Operations Innovator," an accomplishment we are proud to share.

DIGITAL ADVANCEMENT IN THE FIELD

Liberty's advance towards the digital age continued in 2021 with the development and integration of an app for our Behavior Observation Cards (BOCs). BOCs are a critical tool for our crews in the field to use behavioral observation techniques and help us stop accidents before they happen. Moving the reporting and data collection process to an app has driven engagement from our crews, with tens of thousands of cards submitted in 2021. Data collection in the app also improved our efficiency in detecting trends and creating actionable intelligence to improve field safety.

PRIORITIZING TRAINING

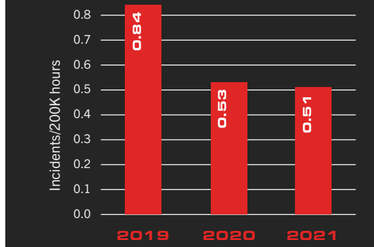
Liberty employees are afforded access to a wide variety of training programs, ensuring they are prepared in any scenario.

- AFEX system training for operations
- Access to employee exposure and medical records
- Basic safeland
- Bloodborne pathogens
- CMV driver basics
- CMV pre/post-trip
- CPR/first aid/AED
- Explosives Awareness LVL1
- Fit test respiratory protection
- Forklift training
- Hazard communications
- Hazards materials handling general awareness and security awareness
- Hot work
- Hours of service
- H2S awareness training
- Loads securement
- Lock out tag out training
- Manlift training
- Portable fire extinguishers
- Pressure Awareness LVL1
- Radiation awareness
- Telehandler forklift
- Basic safeland
- Drug and alcohol policies
- Working in extreme temperatures

18.3 ANNUAL AVERAGE HOURS OF TRAINING PER EMPLOYEE

*Total Recordable Incident Rate (TRIR) is a metric depicting an organization's past safety performance by calculating the number of recordable incidents per 100 full-time workers during a one-year period

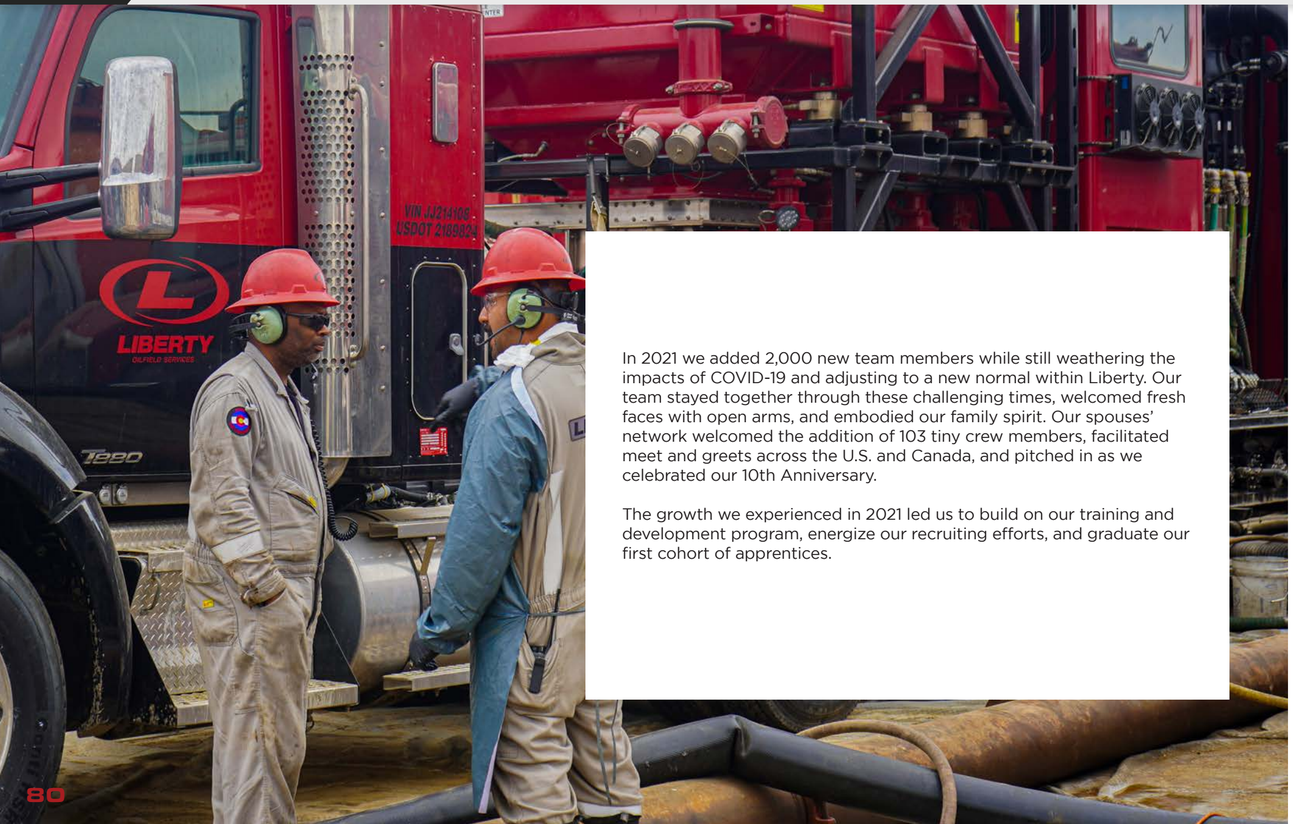
TRIR



We ended 2021 with a Total Recordable Incident Rate (TRIR) of 0.51, a more than 25% improvement over the end of 2020. From our equipment operators to the executive team, the Liberty family remains focused on improving our workplace safety every day, ensuring everyone gets home safely to their families at the end of every shift.

2.9 PEOPLE & CULTURE

OUR MISSION, TO BE THE BEST, IS ONLY ACHIEVABLE BECAUSE OF OUR PEOPLE



In 2021 we added 2,000 new team members while still weathering the impacts of COVID-19 and adjusting to a new normal within Liberty. Our team stayed together through these challenging times, welcomed fresh faces with open arms, and embodied our family spirit. Our spouses' network welcomed the addition of 103 tiny crew members, facilitated meet and greets across the U.S. and Canada, and pitched in as we celebrated our 10th Anniversary.

The growth we experienced in 2021 led us to build on our training and development program, energize our recruiting efforts, and graduate our first cohort of apprentices.

BENEFITS

In 2021 we introduced several new benefits based on the needs of our Liberty employees and their families. This is on top of our affordable healthcare, dental coverage, IVF benefit, spouse's groups, and voluntary benefits. Here at Liberty, our culture of care extends through our total benefits package to address the physical, mental, and financial well-being of our entire team, spouses and children included.

Some of the exciting benefits we now offer include:

- On demand mental health services through LiveHealth Online program.
- Financial Wellness tools and courses.
- Unlimited Speech, Physical, and Occupational Therapy.
- Mammogram Ultrasounds are now covered at 100%.
- Identity Theft Protection.
- Discounted fitness memberships through Active & Fit Direct.

We finished 2021 with the launch of our new benefits website, which enables Liberty employees and their families to conveniently view all of their benefits in one place. To follow, we are planning the release of our Liberty Mobile App in the coming year to further assist our employees in utilizing their benefits.

LIBERTY IVF BABIES





EMPLOYEE ENGAGEMENT, TRAINING AND DEVELOPMENT

Liberty is proud to offer unique educational opportunities for all employees. Recognizing the diverse backgrounds of our team, we work to provide educational experiences that enhance personal and professional growth continually.

Over the past year, Liberty has worked to overhaul our training and development program and provide our team with opportunities to improve themselves personally and professionally. To accomplish this, we have leveraged internal expertise to build a new, cross-functional team dedicated to creating and implementing a technical training and professional development program.

This team is equipped with expert knowledge and offers detailed career development opportunities for our field personnel starting on day one. We believe that a strong culture comes from within, and we want every employee to feel like they are part of the family — whether they are brand new or a legacy member of the team. Our new training program includes classroom instruction, webinars, and an online platform that allows employees to work at their own pace. Clearly defined competency paths help employees quickly identify growth areas and outline the steps necessary to succeed in their personal and professional growth.

In addition to job-specific training, our tech and engineering teams put together monthly classes to share their knowledge on all things frac and wireline. These classes are offered in-person and virtually, so all Liberty employees can attend. Offering technical education has created a stronger understanding of our mission across all business units and strengthened alignment between our technical and corporate teams.

RECRUITING AND RETENTION

At Liberty we believe in bringing your skills and your best true self to work every day. This shared belief laid the perfect foundation to build a recruiting team assembled just this past year. Our young and ambitious group is honored to have the opportunity to tell the Liberty story every day and explain why similarly motivated and driven people want to join our committed, authentic family.

INTERN PROGRAM/TRADE SCHOOL PARTNERSHIPS

Liberty developed the Summer Apprentice Program to create a path for Diesel and Electronics students to experience the oil and gas industry. This opportunity allows students from all over the country a chance to explore industry opportunities outside of their area. Most of the candidates that participate in the program come from rural areas where the job market is limited or non-existent

MONTHLY TOWN HALL & QUARTERLY NEWSLETTER

A favorite tradition at Liberty, our monthly town hall meetings, bring everyone together for company updates and networking, as well as to ensure that employees receive direct communication from our executive team. We also keep in close contact with our field teams via our dedicated HR Generalists for each area.

CULTURE CLUB

Culture has been ingrained in our company since day one. We've always embraced bonding together whether in the office or exploring our surrounding communities. In order to cultivate this, Culture Club was founded in 2016 with the mission to not only unite every department but every employee. Culture Club is made up of one volunteer from each Liberty department who then serves a two-year stint representing their department. As a group they plan activities and outings such as going to a Rockies game, Liberty Kids Night, a summer BBQ, office Thanksgiving and many food and toy drives. This effort has been so incredibly successful, we are working to launch similar initiatives in other Liberty districts.

738
EMPLOYEE OWNERS

156
FAMILIES RECEIVED FERTILITY TREATMENT ASSISTANCE

93%
OF EMPLOYEES CONTRIBUTE TO 401K

3
FAMILIES RECEIVED ADOPTION ASSISTANCE

103
LIBERTY BABIES BORN IN 2021

37%
WOMEN AT CORPORATE HEADQUARTERS

2.10 COMMUNITY ENGAGEMENT

"OUR NAME LIBERTY COMES FROM CELEBRATING THE GROWTH IN FREEDOM AND OPPORTUNITY THAT CREATED THE MODERN WORLD. WE WANT TO EXPAND OPPORTUNITY AND LIBERTY TO THOSE IN OUR COMMUNITIES." — CHRIS WRIGHT



Since Liberty was founded in 2011, we have become deeply rooted in our communities. Every community is different, and since we are unable to address every need, Liberty has chosen three core focus areas:

EDUCATION

Education is the catalyst for bettering one's life. At Liberty, we support organizations that provide and improve upon educational opportunities for children of all ages and walks of life:

- ACE Scholarships
- Montana Tech Liberty Scholars
- Energy Day
- Tennyson Center for Children
- Colorado School of Mines
- Books Between Kids

ALLEVIATING POVERTY

We believe in human liberty. Everyone should have the opportunity and the freedom to follow their dreams. To encourage those dreams, Liberty supports organizations dedicated to lifting people out of poverty by providing opportunities for individuals to find their own definition of success:

- Energy Outreach CO
- Houston Food Bank
- Habitat for Humanity
- United Way of Midland
- Food for Thought
- Denver Rescue Mission
- Food for Hope
- Red Cross

MILITARY SERVICES

We thank all the courageous men and women who have stood up to protect our country, our rights, our families, and our freedom. Through the most challenging conditions, America's veterans have willingly served with distinction, self-sacrifice, and devotion to our country and to one another. They represent true character at its best. To show our support, Liberty partners with organizations that provide support and opportunities for veterans, first responders, and active military personnel:

- Freedom Service Dogs
- Samaritan House
- Infinite Hero Foundation
- Paws of War

IMPACT BEYOND OUR PILLARS

While our core focus remains on these three pillars, we recognize there are many other opportunities in our surrounding communities that need our attention:

- Bike MS
- Rocky Mountain Down Syndrome Association
- Hope for Three: Golf Fore Autism
- Women's Foundation of Colorado
- Hydrocephalus Association
- Special Olympics Colorado
- Carusoe Family Charities

Love, LIBERTY

Recognizing the need to expand outside our focus areas, we launched the Love, Liberty donation matching program to support causes important to our employees and help maximize their impact in the communities where they live and work.

CANADA COMMUNITY OUTREACH

Upon Liberty's expansion into Canada, we began working tirelessly to develop our culture of community involvement.

Canadian Council for ABORIGINAL BUSINESS

In 2021, Liberty initiated working through the Progressive Aboriginal Relations (PAR) certification. The PAR certification program is the only Corporate Social Responsibility program emphasizing Aboriginal Relations. Liberty will complete phase one of the PAR certification during 2022.

ONE YEAR. BIG IMPACT.

- **1,204** TOTAL HOURS
- **$1,013,232** TOTAL RAISED
- **30** DIFFERENT ORGANIZATIONS

COMMUNITY FEATURE: ACE SCHOLARSHIPS

We are proud to support organizations that provide educational opportunities, which is why we have partnered over the years with ACE Scholarships to provide **770 scholarships** in our 11-year history.

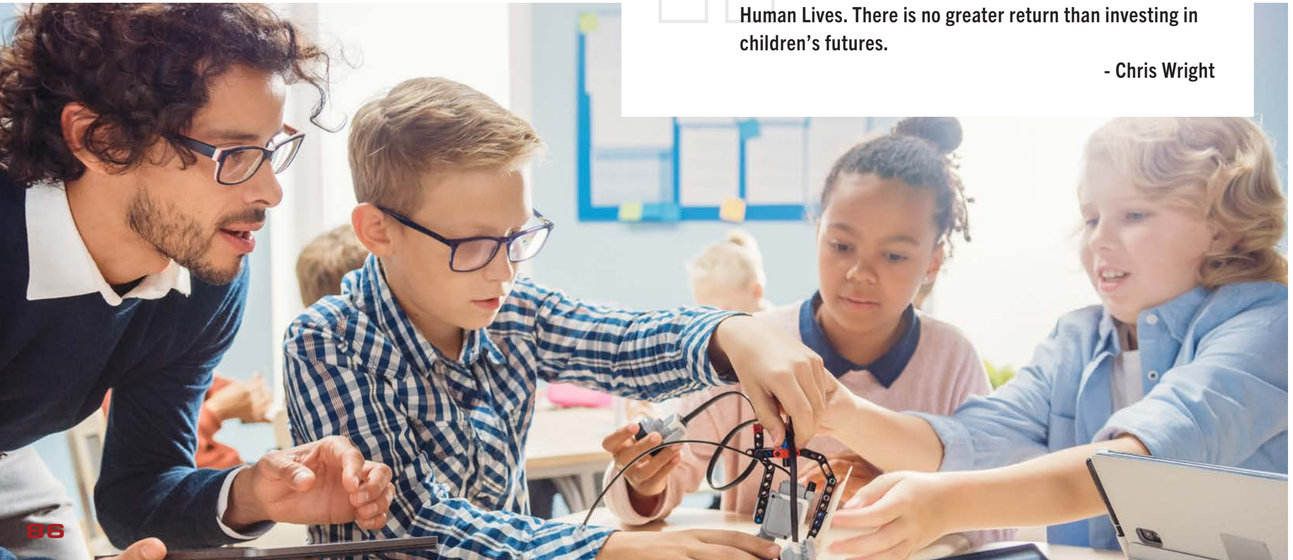
ACE Scholarships is committed to helping low-income parents provide a great education for their children. Their mission is to provide children of low-income families with scholarships to private schools in grades K-12, and to advocate for expanded school choice.

ACE was founded in Colorado by a group of friends with a passion for education. They realized there were a lot of kids from low-income families failing in their current schools, and there were a lot of great schools with extra capacity. They saw independent schools operating with their own philosophies and teaching styles. Yet, as different as they all were, each excelled with the type of students they served. The problem wasn't that there weren't enough good schools, but that low-income families didn't have the resources to access these schools. ACE decided to change that.

ACE is not-for-profit and raises money from generous donors and then awards financial scholarships to students from low-income families so they can attend the school of their choice. ACE Scholarships has quickly become an educational success story.

ACE Scholarships is Liberty's longest community partner. Our mission is well-aligned with ACE: Bettering Human Lives. There is no greater return than investing in children's futures.

- Chris Wright



90%

Schools attended by ACE students that serve inner-city communities

10

States around the country where ACE supports families

93%

Graduation rate of ACE scholars, most of whom go on to college

173

SCHOLARSHIPS PROVIDED IN 2021

$1,922,802

LIFETIME DONATIONS BY LIBERTY

MEET CHARLENE:

A single mother of five ACE Scholars and a member of the ACE family for the past thirteen years.

Our local school, a place where just recently three students were shot by three other students, could not offer what my family needed to succeed. I knew that there had to be better options, and this is when I decided that I was not going to allow my zip code to limit my children. I could have never accomplished this without the education opportunities and resources offered to me by ACE Scholarships. **My children now have these dream jobs and opportunities because someone cared enough about us all to give our family a chance to rise above limitation of our local school.** Someone stepped up and said I will make a difference.

- Charlene

WHERE ARE THEY ARE NOW:

- Jordan is a Project Manager for Mortinson Construction
- Amanda is a Manager of a Local Business and enlisted in the Rocky Mountain College of Art and Design
- Jarrett is a Hardware Quality Engineer for Ball Aerospace
- Joshua is a Land Acquisition Analyst at KB Homes
- Jayce is studying Biomedical Engineering at CU Boulder

CORPORATE GOVERNANCE

Good governance fortifies our commitment to acting ethically, thoughtfully, and responsibly in the pursuit of value creation. As we work to support societal needs for reliable, affordable energy, our team continually finds ways to enhance our service offering and deliver value to our stakeholders. Our dedication to economic, environmental and societal leadership and performance is an integral part of our corporate strategy, leading to a track record of strong cash returns over the lifespan of our company. Liberty's Board of Directors provides independent judgment that strengthens accountability and promotes the long-term interest of our stakeholders. Our senior management team further utilizes rigorous governance practices to ensure that our risks and opportunities are effectively managed for the continued vitality and sustainability of our business in a responsible and ethical manner.

7/9
INDEPENDENT BOARD OF DIRECTORS

2/9
DIRECTORS ARE FEMALE

8
TIMES BOARD FORMALLY MET IN 2021

ADOPTED STRINGENT INSIDER TRADING POLICIES, INCLUDING ANTI-HEDGING AND ANTI-PLEDGING

ALL BOARD COMMITTEES COMPRISED ENTIRELY OF INDEPENDENT DIRECTORS

BOARD OF DIRECTORS

Liberty's directors have a unique set of leadership experience and perspective that fosters productive dialogue and decision-making when carrying out strategic and oversight responsibilities. Our Board has adopted Corporate Governance Guidelines* in accordance with New York Stock Exchange (NYSE) rules within which our Board and committees operate, including the practices and policies that relate to the Board's structure and composition, membership criteria and qualifications, director responsibilities, evaluation of management and succession planning, and interaction with external constituencies. We continuously assess our corporate governance principles to ensure they are effectively supporting a culture of the highest ethical standards.

Through its ongoing guidance, the board protects the interest of its shareholders, and believes those interests are best served by combining the roles of Chairman and CEO with a strong and independent lead director. Our board believes a combined Chairman and CEO role allows the company to more effectively execute its strategy, especially where our chairman's deep industry expertise, technical leadership and company knowledge can be leveraged in a cyclical industry. The combined Chairman and CEO role, coupled with a strong and independent lead director, has enabled the Board to be responsive to challenges and opportunities as they continue to arise. Liberty is fortunate to have William Kimble serving as the lead director. The lead director has many critical duties, including conferring with the chairman on board agendas, serving as a liaison between the chairman and non-management directors, and presiding at executive sessions of non-management directors and other Board meetings at which the chairman is not present. Our Board believes that this structure, combined with our corporate governance policies and processes, creates an appropriate balance between strong and consistent leadership and independent oversight of the business.

AUDIT COMMITTEE

The Audit Committee oversees, reviews, acts on and reports on various auditing and accounting matters to our Board, including: the selection of our independent accountants, the scope of our annual audits, fees to be paid to the independent accountants, the performance of our independent accountants and our accounting practices.

COMPENSATION COMMITTEE

Our Compensation Committee assists our Board in establishing salaries, incentives and other forms of compensation for officers and other employees. Our Compensation Committee also assists the Board with the administration and oversight of our incentive compensation and benefit plans.

NOMINATING AND GOVERNANCE COMMITTEE

Our Nominating and Governance Committee identifies, evaluates and recommends qualified nominees to serve on our Board, subject to the terms of the stockholders' agreements the Company has entered into with certain stockholders related to the appointment of directors.

The board provides robust oversight through three fully independent committees: Audit, Compensation, and Nominating & Governance. Kimble, Mr. Peter Dea and Gale Norton serve as chairperson for the respective committees. Each director has a background particularly relevant to the committee's oversight.

The board has worked to bring fresh viewpoints to its work. In the past two years, Liberty added three new directors, one female who joined in 2021 and two added in connection with the 2020 OneStim acquisition. Our Board values diversity in gender, geography, skill set, experience and thought, with two female directors, one director of French and Lebanese citizenship, and directors from a wide variety of backgrounds in technology, energy, public policy, finance and accounting, and international business. Liberty maintains an independent Board in accordance with NYSE rules and our Corporate Governance Guidelines. Seven of our nine directors meet the qualifications of independence, and all directors are serving staggered three-year terms. Liberty also joined the National Association of Corporate Directors (NACD) in 2021 to provide our directors with additional governance insight.

The Liberty team's commitment to integrity and excellence translates into a strong reputation of trust with our employees, customers, supplier partners, policy makers, communities, and shareholders.

BOARD COMMITTEES

Name	Audit Committee	Compensation Committee	Nominating and Governance Committee
Peter A. Dea		C	M
William F. Kimble	C		M
Gale A. Norton	M		C
Ken Babcock		M	
Cary D. Steinbeck	M	M	

C = Chairperson M = Member

*A current copy of our Governance Guidelines can be found on our website, www.libertyfrac.com.

ESG: FOUNDATIONAL TO OUR BUSINESS

Liberty believes that access to life-enhancing modern energy presents the most pressing global energy challenge. The Liberty team works passionately to better the process of bringing hydrocarbons to the surface in a clean, safe and efficient fashion and views ESG principles as foundational to our business. The board and its committees provide oversight of risks and opportunities associated with the company's ESG initiatives, with ongoing review by the full board of ESG strategy and challenges at each regular board meeting. Various aspects of ESG are also handled in each of our committees depending on the topics, which include technology innovation, human capital management and enterprise risk management, among other areas. For example, the Audit Committee is monitoring and assessing Liberty's preparedness for meeting potential mandatory sustainability reporting under consideration by the SEC.

The board assesses investment decisions through the lens of risk and opportunities associated with corporate ESG principles. At the heart of investment is whether the deployment of capital resources towards new or leading-edge technology, mergers and acquisitions, or other areas aids the company's ability to maintain top tier service and efficiency for our customers while minimizing the social and environmental impacts of our business. Liberty is uniquely positioned to take a leadership role with continuous innovation and investment in subsurface engineering and equipment design and optimization, to improve operational efficiency and reduce emissions. Of note, our digiFrac electric fleet investment coupled with technology upgrades to dual fuel equipment provides customers the power to choose what works best for them. These technologies serve the dual purpose of lowering emissions and providing fuel cost savings, providing an economically viable opportunity for customers to pursue ESG-focused strategies.

LEADERSHIP ACCOUNTABILITY: PAY FOR PERFORMANCE

The Liberty team has been aligned with shareholders since our founding. Our pay-for-performance compensation philosophy strategically uses incentives that align employee behaviors with their responsibilities to drive better business outcomes. This persists across all areas of the company, from our employees in the field managing efficiency and safety to our sales team's ability to improve profitability outcomes. At the helm, our executive team has a compensation program with a high percentage of variable compensation that is designed to reward the long-term interests of the Company and our shareholders. Incentive compensation includes a focus on pre-tax earnings per share, return on capital employed (ROCE) and adjusted ROCE against a peer group. Our peer group includes the S&P 500; by measuring our results against the broader market, we believe this creates a further tie to shareholder priorities.

The Compensation Committee reviews shareholder votes and feedback to ensure executive compensation programs align with their interests on an ongoing basis. Additional details on our executive compensation program are available in our 2021 proxy statement.

BUSINESS ETHICS

Our business thrives with robust partnerships we've cultivated with our customers, suppliers and communities over the years. At the foundation of these relationships is a strong sense of business ethics that underscore our reputation and trust we have built with all our stakeholders. Our Corporate Code of Business Conduct and Ethics (Code) and our Financial Code of Ethics together set the stage for how we operate our business: By establishing expectations for our team to maintain a high level of integrity, ethical standards and compliance with all legal requirements.

Liberty's Code includes topics ranging from conflicts of interest, employee practices and compliance with applicable laws. All our employees are required to commit to the Code annually, acknowledging an understanding of our key policies. This includes a strict policy against improper payments or gifts from the Company that benefit any government, labor union, customer or supplier, which is intended to prevent corruption and bribery across the supply chain. To protect our Company, Liberty has a whistleblower hotline and encourages employees to report misconduct. Liberty prohibits retaliation for good faith reporting of violations.

RISK OVERSIGHT

At the core of our business is leading-edge innovation and technology, but that often involves taking measured risks. Risk assessment and oversight are an integral part of our governance and management processes. Our Board is responsible for monitoring and assessing strategic risk exposure and providing oversight of risk management, assisted by the Audit Committee. The Board encourages management to promote a culture that incorporates risk management into our corporate strategy and day-to-day business operations.

Liberty management discusses strategic and operational risks at regular management meetings and conducts specific strategic sessions during the year that include a focused discussion and analysis of material operational and financial risks. The Company also conducts a comprehensive risk management session with the executive leadership team periodically with the help of outside consultants, where key risks are identified, prioritized and documented with mitigation strategies assigned to the appropriate risk owner. Throughout the year, senior management reviews risks with the Board and steps taken to mitigate or eliminate such risks. These ongoing discussions assist us with identifying, monitoring and controlling these exposures, providing assurance that the risks we take are consistent with the Board's risk tolerance.

For a comprehensive discussion of material risks Liberty has identified, please refer to our Form 10-K for the fiscal year ended December 31, 2021.

OPERATIONAL RESILIENCE

Liberty's team has developed and tested plans and procedures to ensure the resilience of our operations in the event of a crisis or an emergency. We have procedures in place to execute response activities for a variety of scenarios, including site-specific incidents and pandemics. The COVID-19 pandemic provided the opportunity to test these procedures on a large-scale. The Liberty team, across all departments, was prepared ahead of time and worked together to respond quickly to this situation. The health and safety of our employees and contractors was of the utmost importance.

EMPLOYEE OWNERSHIP

738 EMPLOYEE OWNERS

Liberty takes pride in fostering an entrepreneurial workplace where employees have the autonomy to take ownership of their work and grow professionally. As a part of our professional development and annual goal setting for our employees, Liberty offers restricted stock units to attract, engage, retain and reward our employees. Employee ownership connects our employees' work to Liberty's strategic decisions, supporting both our long-term business model and our people.

DIGITAL BACKBONE

Liberty continues to make significant investments in our digital backbone. We employ a Cloud First approach to enhance business agility and reduce location dependence on any physical office. Liberty partners with the top cloud providers to leverage best-in-class solutions from Microsoft, Amazon, Google, Oracle, and Tibco. This distributed, geo-redundant architecture allowed Liberty to be Remote Work Ready well before we needed to be. Within 3 days of the stay-at-home orders due to the COVID-19 pandemic, Liberty was fully operational with an entirely remote work force.

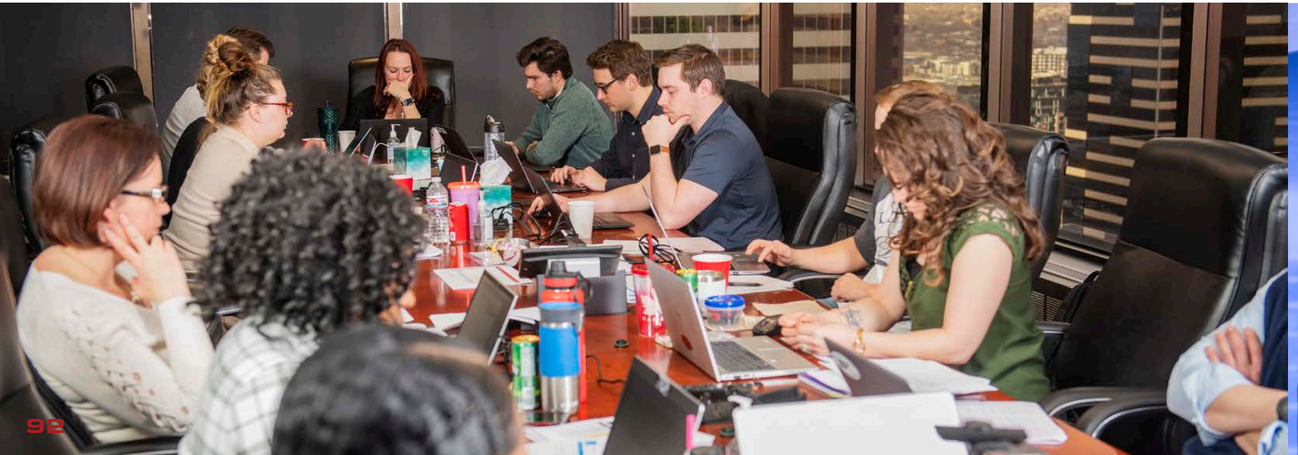
CYBERSECURITY

Liberty recognizes the importance of protecting systems, networks, applications, and data. We are also aware that threats to these have increased in frequency and sophistication over recent years. Liberty utilizes industry security frameworks, such as those from the National Institute of Standards and Technology (NIST) and The Center for Internet Security (CIS). We regularly assess our cybersecurity program against these Cybersecurity Frameworks as part of our audit and governance. We also use assessments to identify any gaps and guide our prioritization of cybersecurity initiatives.

The Liberty cybersecurity program utilizes Defense in Depth, which includes strong endpoint protection; network, cloud, and mobile security; threat detection and incident response. User access to company data and applications is protected using multifactor authentication for on-premises and remote workers. External penetration testing of company systems is done on a regular basis. We also evaluate and monitor our security protocols on an on-going basis. Liberty maintains a cybersecurity strategy that includes industry best practices such as “Defense in Depth” and “Zero Trust” to protect our computing assets, networks, data, and users.

All Liberty personnel with access to Company systems receive mandatory annual training on cybersecurity. This training covers information security best practices and company policies. Phishing simulation campaigns are also conducted throughout the year. In areas of greater risk, certain personnel may be required to take additional security awareness training.

Liberty actively monitors the Microsoft Security Response Center, InfraGard, US-CERT, & CISA for emerging data security guidance to mitigate risks and NIST & CIS to align with developing standards.



BUSINESS AND REGULATORY AFFAIRS

POLITICAL ENGAGEMENT AND TRADE ASSOCIATION INVOLVEMENT

At Liberty we believe when our customers succeed, we succeed. That means working side by side with our customers and industry partners to engage in the legislative and regulatory processes through workgroups and trade associations. The partnerships we have created extend well beyond our location boundaries and our nationwide network of employees are advocates for the industry.

We believe that through collaboration and open communication we can work to adopt policies that put health and safety first, while allowing our industry to continue providing the low-cost energy we all depend on.

KEY METRICS AND DISCLOSURES

FORWARD LOOKING STATEMENT

In order to utilize the 'safe harbor' provisions of the United States Private Securities Litigation Reform Act of 1995 and the general doctrine of cautionary statements, Liberty is providing the following cautionary statement.

This report contains certain forecasts, projections and forward-looking statements – that is, statements related to future, not past events and circumstances with respect to the financial condition, results of operations and businesses of Liberty and certain of the plans and objectives of Liberty with respect to these items. For this purpose, any statement that is not a statement of historical fact should be considered a forward-looking statement. These statements may generally, but not always, be identified by the use of words such as 'will', 'expects', 'is expected to', 'aims', 'should', 'may', 'objective', 'is likely to', 'intends', 'believes', 'anticipates', 'plans', 'we see' or similar expressions; however, the absence of these words does not mean that the statements are not forward-looking.

These forward-looking statements are subject to certain risks, uncertainties and assumptions, including those disclosed from time to time in Liberty's filings with the Securities and Exchange Commission (the "SEC"). As a result of these factors, actual results may differ materially from those indicated or implied by such forward-looking statements.

Any forward-looking statement speaks only as of the date on which it is made, and, except as required by law, we do not undertake any obligation to update or revise any forward looking statement, whether as a result of new information, future events or otherwise. New factors emerge from time to time, and it is not possible for us to predict all such factors. When considering these forward-looking statements, you should keep in mind the risk factors and other cautionary statements in "Item 1A. Risk Factors" included in Liberty's Annual Report on Form 10-K for the year ended December 31, 2021 as filed with the SEC on February 22, 2022 and in our other public filings with the SEC. All forward-looking statements, expressed or implied, included in this report are expressly qualified in their entirety by this cautionary statement. This cautionary statement should also be considered in connection with any subsequent written or oral forward-looking statements that we or persons acting on our behalf may issue.

SUSTAINABILITY ACCOUNTING STANDARDS BOARD (SASB) INDEX

TABLE 1. SUSTAINABILITY DISCLOSURE TOPICS AND ACCOUNTING METRICS

TOPIC	ACCOUNTING METRIC	2020	2021	CODE
Emissions Reduction Services and Fuels Management	Total fuel consumed, percentage renewable, percentage used in: (1) on-road equipment and vehicles and (2) off-road equipment	Off-Road 8,340,600.28 GJ On-Road 339,531.97 GJ	Off-road 20,271,760 GJ On-road 604,165 GJ	EM-SV-110a.1
	Discussion of strategy or plans to address air emissions-related risks, opportunities, and Discussion of strategy or plans to address air emissions-related risks, opportunities, and impacts		Environmental Performance (pg. 64-65), Frac Engines (pg. 68 - 69)	EM-SV-110a.2
	Percentage of engines in service that meet Tier 4 compliance for non-road diesel engine emissions	25.70%	21.00%	EM-SV-110A.3
	Scope 1 Greenhouse Gas Emissions (MTCO2e) calculated in accordance with GHG Protocol		1,427,200	
Water Management Services	(1) Total volume of fresh water handled in operations, (2) percentage recycled		Water (pg. 74-75)	EM-SV-140a.1
	Discussion of strategy or plans to address water consumption and disposal-related risks, opportunities, and impacts		Water (pg. 74-75)	EM-SV-140a.2
Chemicals Management	Volume of hydraulic fracturing fluid used, percentage hazardous	41,078,829 m_3 of frac fluid slurry (includes sand volumes); 0.072% hazardous chemicals	98,063,510 m_3 of frac fluid slurry (includes sand volumes); 0.076% hazardous chemicals	EM-SV-150a.1
	Discussion of strategy or plans to address chemical-related risks, opportunities, and impacts		Frac Fluid Chemistry (pg. 72 - 73)	EM-SV-150a.2
Ecological Impact Management	Average disturbed acreage per (1) oil and (2) gas well site		See footnote 1	EM-SV-160a.1
	Discussion of strategy or plan to address risks and opportunities related to ecological impacts from core activities		Ecological Impact (pg. 76-77)	EM-SV-160a.2
Workforce Health and Safety	(1) Total recordable incident rate (TRIR), (2) fatality rate, (3) near miss frequency rate (NMFR), (4) total vehicle incident rate (TVIR), and (5) average hours of health, safety, and emergency response training for (a) full-time employees, (b) contract employees, and (c) short-service employees	(1) TRIR .53* (2) Fatality rate (0) (3) NMFR .51 (4) TVIR 2.51 (5a) 19.4 (5b) not relevant (5c) not relevant	(1) TRIR .51 (2) Fatality rate (0) (3) NMFR 1.76 (4) TVIR 6.16 (5a) 18.3 (5b)not relevant (5c) not relevant	EM-SV-320a.1
	Description of management systems used to integrate a culture of safety throughout the value chain and project lifecycle		Safety (pg. 78-79)	EM-SV-320a.2
Business Ethics and Payments Transparency	Amount of net revenue in countries that have the 20 lowest rankings in Transparency International's Corruption Perception Index		See footnote 2	EM-SV-510a.1
	Description of the management system for prevention of corruption and bribery throughout the value chain		Corporate Governance (pg. 88-92)	EM-SV-510a.2
Management of the Legal and Regulatory Environment	Discussion of corporate positions related to government regulations and/or policy proposals that address environmental and social factors affecting the industry		Business and Regulatory Affairs (pg. 93)	EM-SV-530a.1
Critical Incident Risk Management	Description of management systems used to identify and mitigate catastrophic and tail-end risks		Corporate Governance (pg. 88-92)	EM-SV-540a.1

*Previously reported 2020 TRIR as 0.66, number in this report is updated using corrected man-hours

TABLE 2. ACTIVITY METRICS

ACTIVITY METRIC	UNIT OF MEASURE	2020	2021	CODE
Number of active rig sites	Quantitative	N/A	See footnote 3	EM-SV-000.A
Number of active well sites	Quantitative	N/A	See footnote 3	EM-SV-000.B
Total amount of drilling performed	Quantitative	N/A	See footnote 3	EM-SV-000.C
Total number of hours worked by all employees	Quantitative	3,927,396 hours	9,797,096 hours	EM-SV-000.D

1. Ecological Impact Management was deemed not applicable, as management of disturbed acreage per oil and gas wellsite is outside of Liberty's operational control.
2. Liberty does not operate outside North America.
3. Number of active rigsites, number of active wellsites, and total amount of drilling performed are not relevant to Liberty's operational control, and have been omitted.

APPENDIX

FIGURE SOURCES

Figure	Figure Name	Figure Source
1.1	How much richer would the world be had we solved different issues, 1900-2050	Lomborg, Bjorn. "Welfare in the 21st Century: Increasing Development, Reducing Inequality, the Impact of Climate Change, and the Cost of Climate Policies." Technological Forecasting and Social Change, vol. 156, 2020, p. 119981.
1.2	Net Imports of Oil, Natural Gas, & Coal in Million Tonnes of Oil Equivalent	BP 2022 Statistical Review of World Energy, NBS China, JP Morgan Annual Energy Paper, 2022
1.3	Global direct primary energy consumption, 1800-2020	Smil, Vaclav. Energy Transitions: Global and National Perspectives, 2017. BP 2022 Statistical Review of World Energy, IEA, EIA 2019 Energy Outlook & Bijou Insights
1.4	Renewable Energy as a percentage of total Global Energy	"International Energy Outlook 2019 - Energy Information Administration." Energy Information Administration, Sept. 2019.
1.5	Global Electricity production by source	BP 2022 Statistical Review of World Energy, EIA, Ember, & Bijou Insights.
1.6	Global Population-Weighted PM2.5 Concentrations, 2019	PM2.5 Exposure | State of Global Air." State of Global Air, 2022
1.7	U.S. Responsible for Virtually All Global LPG Export Growth	IEA and IHS Waterborne
1.8	Per Capita Oil Consumption (Barrels/Year)	Goldman Sachs Asset Management and BP Statistical Review.
1.9	People in the World With and Without Electricity Access	Number of People with and without Electricity Access." *Our World in Data*, 2022
1.10	Electricity Consumption kWh Per Capita	Per Capita Electricity Consumption." *Our World in Data*, 2022
1.11	Percentage of Underweight Children at age 5	"World Development Indicators." *World Development Indicators (WDI)* | Data Catalog, 2022,
1.12	Access to Affordable Energy is Essential for HDI Improvement	United Nations Department of Economic and Social Affairs. "Policy Brief 12 Global Progress Of SDG 7— Energy And Gender." Energy and Gender, 2018, EIA, Bijou Insights
1.13	China & India Experience Rising Energy Consumption and HDI Improvement in Tandem	"World Development Indicators." *World Development Indicators (WDI)* | Data Catalog, 2022, EIA, Bijou Insights
1.14	The Range of Living Conditions Among the World's Population	Rosling, Hans, et al. Factfulness. Rizzoli, 2018.
1.15	Atmospheric CO2 at Manua Loa Observatory	Scripps Institution of Oceanography NOAA Earth System Research Laboratory https://www.e-education.psu.edu/earth103/node/1018
1.16	Global Greening from CO2 Fertilization	Hille, Karl. "Carbon Dioxide Fertilization Greening Earth, Study Finds." NASA, NASA, 25 Apr. 2016
1.17	UAH Global Lower Tropospheric Temperature Variations (°C) 1979-2020	Spencer. "New Reference for Annual Cycle 1991-2020., University of Alabama Huntsville, Apr. 2015, Global Temperature Report." Global Temperature Report: The University of Alabama in Huntsville, 2022
1.18	Mean Sea Level Rise from Tidal Station and Altimetry from 1880-2020	Sea level rise PSMSL Tidal Data 1700-2002 Updated from Jevrejeva et al, 2008, https://www.psmsl.org/products/reconstructions/gslGRL2008.txt
1.19	Mean sea level rise from satellite data from 1993-2020	Nerum, R.S., et al. *Climate-Change–Driven Accelerated Sea-Level Rise Detected in ...* - PNAS. Earth, Atmospheric, and Planetary Sciences, 12 Feb. 2018, "Sea Level." NASA, NASA, 18 July 2022, Jet Propulsion Laboratory. "Satellite Mission Keeps a Steady Eye on Sea Level Change from Space." SciTechDaily, Jet Propulsion Labratory, 15 July 2020
1.20	Global Tropical Cyclone Accumulated Cyclonic Energy (ACE)	Maue, Ryan. "Global Tropical Cyclone Activity: Ryan Maue." *Global Tropical Cyclone Activity* , 2021.
1.21	Global Hurricane Landfalls 1970-2021	Jr., Roger Pielke. Global Hurricane Landfalls 1970 to 2022, The Honest Broker by Roger Pielke Jr., 18 Jan. 2022. ; "2021 Weather, Climate and Catastrophe Insight: Aon." Better Decisions - Commercial Risk - Health - Reinsurance - Wealth.
1.22	U.S. Hurricane Landfalls 1900-2021	"US Hurricane Landfalls." *Atlantic Oceanographic and Meteorological Laboratories*. ; Weinkle, Jessica, et al. "Historical Global Tropical Cyclone Landfalls." *AMETSOC*, American Meteorological Society, 1 July 2012. ; "2021 Weather, Climate and Catastrophe Insight: Aon." *Better Decisions - Commercial Risk - Health - Reinsurance - Wealth*.
1.23	U.S. Strong to Violent Tornadoes (>F3)	"Storm Prediction Center WCM Page." *Storm Prediction Center*.
1.24	Global area in severe meteorological drought, 1901—2017	Lomborg, Bjorn. "Welfare in the 21st Century: Increasing Development, Reducing Inequality, the Impact of Climate Change, and the Cost of Climate Policies." *Technological Forecasting and Social Change*, North-Holland, 24 Apr. 2020.
1.25	U.S. Flood Damage as Percentage of GDP, 1940-2018	Downton, Mary W., et al. "Reanalysis of U.S. National Weather Service Flood Loss Database: *Natural Hazards Review*: Vol 6, No 1." Natural Hazards Review, American Society of Civil Engineers, 1 Feb. 2005. ; *Contribution of Historical Precipitation Change to US Flood ...* - Pnas. ; Jr., Roger Pielke. "Global Disasters: A Remarkable Story of Science and Policy Success." *The Honest Broker Newsletter*, The Honest Broker Newsletter, 14 Jan. 2021.
1.26	U.S. Forest Area Burned, 1926-2020	Parks1, Sean A, et al. "IOPscience." *Environmental Research Letters*, IOP Publishing, 18 Apr. 2018; Lomborg, Bjorn. "Welfare in the 21st Century: Increasing Development, Reducing Inequality, the Impact of Climate Change, and the Cost of Climate Policies." *Technological Forecasting and Social Change*, North-Holland, 24 Apr. 2020,
1.27	Global Deaths from Severe Weather, 1920—2020 (Floods, droughts, storms, wildfires, extreme temperatures)	"EM-DAT: The International Disasters Database." *EM-DAT*, Centre for Research on the Epidemiology of Disasters (CRED). ; Lomborg, Bjorn. "Welfare in the 21st Century: Increasing Development, Reducing Inequality, the Impact of Climate Change, and the Cost of Climate Policies." *Technological Forecasting and Social Change*, North-Holland, 24 Apr. 2020.
1.28	Total impact from temperature increase measured in percent of global GDP	Lomborg, Bjorn. "Welfare in the 21st Century: Increasing Development, Reducing Inequality, the Impact of Climate Change, and the Cost of Climate Policies." *Technological Forecasting and Social Change*, North-Holland, 24 Apr. 2020.
1.29	Annual Total CO2 Emissions, by World Region	Our World in Data based on the Global Carbon Project, ourworldindata.org/co2-emissions.
1.30	Commodity Prices 2020-2022	"Commodity Markets Outlook - World Bank." *World Bank*, World Bank, Apr. 2022.
1.31	Energy, Fertilizer, and Food Price Growth 1970-2022	"Commodity Markets Outlook - World Bank." *World Bank*, World Bank, Apr. 2022.
1.32	Gas Prices Explained	"U.S. Energy Information Administration - EIA - Independent Statistics and Analysis." *Factors Affecting Gasoline Prices - U.S. Energy Information Administration (EIA)*. ; "Gas Prices Explained 'Five Fast Facts About Gasoline Prices.'" *American Petroleum Institute*.
1.33	U.S. Per Capita Growth and Emissions Since 1970	Environmental Protection Agency, Energy Information Administration & Bijou Insights
1.34	Wind & Solar Share of Texas Power Generation Capacity Vs Reported Power Outages	"The February 2021 Cold Weather Outages in Texas and the South Central United States: FERC, NERC and Regional Entity Staff Report." *Federal Energy Regulatory Commission*, 8 Dec. 2021.
1.35	Share of Texas Power Generation By Source, February 2021	"Real-Time Operating Grid - U.S. Energy Information Administration (EIA)." Real-Time Operating Grid - *U.S. Energy Information Administration* (EIA), 2022.
1.36	Gulf Region Daily Natural Gas Demand By Sector, February 2021	Bloomberg.com, Bloomberg Commodity Flows.
2.1	The Evolution of Liberty Fleets	Aune, Roy, et al. "The Shale Revolution: Frac Fleet Emissions." *Liberty Energy*, 14 Apr. 2022.
2.2	Historical Change in Average Friction Reducer and Gel Concentration for Fracture Treatments	Liberty FracTrends Database.
2.3	How Many Households Does an Acre of Energy Serve?	Smil, Vaclav. "Power Density Primer: Understanding the Spatial Dimension of the Unfolding Transition to Renewable Electricity Generation (Part V – Comparing the Power Densities of Electricity Generation)." *Master Resource*, 14 May 2010. ; Smith, Vaclav. *Power Density Primer: Understanding the Spatial Dimension of the Unfolding Transition to Renewable Electricity Generation (Part I - Definitions)*. 8 May 2010.

FOOTNOTES

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4 www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health; https://www.who.int/publications/i/item/9789241511353; https://sustainabledevelopment.un.org/content/documents/17489PB12.pdf

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Find our full list of sources and view the report online:

libertyenergy.com/betteringhumanlivesv2

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BETTERING HUMAN LIVES

LBRT ESG REPORT

ISSUED AUGUST 2022