2019 HOUSE ENERGY AND NATURAL RESOURCES

HB 1225

2019 HOUSE STANDING COMMITTEE MINUTES

Energy and Natural Resources Committee
Coteau Room, State Capitol

HB 1225
1/18/2019
31067

☐ Subcommittee
☐ Conference Committee

Committee Clerk:	Kathleen Davis

Explanation or reason for introduction of bill/resolution:

a bill to provide for a legislative management study of future energy innovation and to provide an appropriation

Minutes: Attachment 1,2,3

Chairman Porter: called the hearing to order.

Rep. Steiner: presented Attachment 1,2,3.

13:00

Rep. Mitskog: Your comment, comprehensive plan you mentioned, I believe that's where we need to go looking into the future. I'd be curious in what's the plan?

Rep. Steiner: I don't know if we have a long term strategic plan for energy. I don't think we understand it well enough to develop the plan. We need to have diverse opinions come in and make up our own minds.

Chairman Porter: The SIF fund has a lot of things coming out of it so it puts this concept and bill at risk of going to appropriations and dying a miserable death down there. Did your consideration to working this through the oil and gas research council and EERC to moving it forward?

Rep. Steiner. No. The next 10 years we're good but we need to know what we don't know, and we better know this. I just thought there would be $500k left.

Waylon Hedegaard, president of ND AFL CIO: I have to agree with a lot of what Rep. Steiner said. It's not stranding our assets I'm concerned about. It's that we have a huge amount of human beings who depend on this. I'm from the coal industry, made my living building coal fired power plants and refineries and fossil fuel things and loved that and very proud of what we've done. My eyes are open enough to see the industry is changing and it's going to drastically affect these people, the communities and change to the point I'm not so sure. We just closed down a station and destroyed it in the last couple years and this is going to keep happening. The market forces are inevitable. I urge this study to be done and what are the human impacts. We have little towns like Beulah, Stanton and Hazen that will become

mini Detroits if these plants close. How can we understand what's happening and how can we use this to protect as many people as we can or move into another industry? This study is an excellent idea. We can't go back to the 1970's forever, the world moves on.

Chairman Porter: further support? Opposition? Closed the hearing.

2019 HOUSE STANDING COMMITTEE MINUTES

Energy and Natural Resources Committee
Coteau Room, State Capitol

HB 1225
1/31/2019
31899

☐ Subcommittee
☐ Conference Committee

Committee Clerk: Kathleen Davis

Explanation or reason for introduction of bill/resolution:

a bill to provide for a legislative management study of future energy innovation and to provide an appropriation

Minutes:

Chairman Porter: opened the hearing on HB 1225 regarding future energy innovations. If we're going to do this as a legislative study, we need to amend it a bit. Then we have the issue of appropriation and discussing with Rep. Steiner, there were groups such as EmPower that would take this up because of their mission inside of the code. If this committee leans, we will have an amendment drafted and would offer this for discussion.

Rep. Lefor: I agree, if EmPower is willing to take it up at no cost, I would favor the amendment.

Rep Bosch: How would EERC fit into this?

Chairman Porter: I would say they wouldn't be looking to do it, they would need a funding source at UND. You have all the leaders of all the sectors of energy on EmPower and would be best suited to do this and report back to the Energy and Transmission Committee. They report to them in the interim anyway. So we'll have an amendment worked up on this.

Closed the hearing.

2019 HOUSE STANDING COMMITTEE MINUTES

Energy and Natural Resources Committee
Coteau Room, State Capitol

HB 1225
2/1/2019
31974

☐ Subcommittee
☐ Conference Committee

Committee Clerk:	Kathleen Davis

Explanation or reason for introduction of bill/resolution:

a bill to provide for a legislative management study of future energy innovation and to provide an appropriation

Minutes: Attachment 1, 2

Chairman Porter: opened the hearing on HB 1225. I passed out a proposed amendment, Attachment 1, and the Christmas tree version, Attachment 2.

Rep. Keiser: I move the adoption of the amendment.

Rep. Ruby: Second.

Chairman Porter: We have a motion to adopt the amendment to HB 1225 and a second. Discussion? Seeing none, all those in favor say aye, opposed (voice vote). Motion carries.

We have an amended bill.

Rep. Keiser: I move a do pass as amended on HB 1225.

Rep. Eidson: Second.

Chairman Porter: We have a motion for a do pass as amended and a second. Discussion? The clerk called the roll. 13 yes 0 no 1 absent. Rep. Eidson is carrier.

DP 2/1/19

19.0910.01001
Title.02000

Adopted by the Energy and Natural Resources Committee

February 1, 2019

PROPOSED AMENDMENTS TO HOUSE BILL NO. 1225

Page 1, line 1, remove "legislative management"

Page 1, line 1, after "innovation" insert "by the empower North Dakota commission"

Page 1, line 2, replace "an appropriation" with "for a report to the legislative management"

Page 1, line 4, replace "**LEGISLATIVE MANAGEMENT**" with "**EMPOWER NORTH DAKOTA COMMISSION**"

Page 1, line 4, after "**FUTURE ENERGY INNOVATION**" insert "**- REPORT TO LEGISLATIVE MANAGEMENT**"

Page 1, line 5, replace "legislative management" with "empower North Dakota commission"

Page 1, line 8, replace "legislative management" with "empower North Dakota commission"

Page 1, line 8, remove "report its findings and recommendations,"

Page 1, remove line 9

Page 1, line 10, replace "legislative assembly" with "provide a report to the legislative management by June 30, 2020, regarding the results and recommendations of the study"

Page 1, remove lines 11 through 15

Renumber accordingly

Date: 2-1-19
Roll Call Vote #: 1

2019 HOUSE STANDING COMMITTEE
ROLL CALL VOTES
BILL/RESOLUTION NO. 1225

House Energy and Natural Resources Committee

☐ Subcommittee

Amendment LC# or Description: 19.0910.01001

Recommendation: ☒ Adopt Amendment
☐ Do Pass ☐ Do Not Pass ☐ Without Committee Recommendation
☐ As Amended ☐ Rerefer to Appropriations
☐ Place on Consent Calendar

Other Actions: ☐ Reconsider ☐ _____

Motion Made By Rep Keiser Seconded By Rep Ruby

Representatives	Yes	No	Representatives	Yes	No
Chairman Porter			Rep. Lefor		
Vice Chairman Damschen			Rep. Marschall		
Rep. Anderson			Rep. Roers Jones		
Rep Bosch			Rep. Ruby		
Rep. Devlin			Rep. Zubke		
Rep. Heinert					
Rep. Keiser			Rep. Mitskog		
			Rep. Eidson		

Total (Yes) _____ No _____

Absent _____

Floor Assignment Voice Vote passes

If the vote is on an amendment, briefly indicate intent:

Date: 2-1-19
Roll Call Vote #: 2

2019 HOUSE STANDING COMMITTEE
ROLL CALL VOTES
BILL/RESOLUTION NO. 1225

House Energy and Natural Resources Committee

☐ Subcommittee

Amendment LC# or Description: _____

Recommendation: ☐ Adopt Amendment
☒ Do Pass ☐ Do Not Pass ☐ Without Committee Recommendation
☒ As Amended ☐ Rerefer to Appropriations
☐ Place on Consent Calendar

Other Actions: ☐ Reconsider ☐ _____

Motion Made By Rep Keiser Seconded By Rep Eidson

Representatives	Yes	No	Representatives	Yes	No
Chairman Porter	✓		Rep. Lefor	✓	
Vice Chairman Damschen	✓		Rep. Marschall	✓	
Rep. Anderson	✓		Rep. Roers Jones	✓	
Rep Bosch	✓		Rep. Ruby	✓	
Rep. Devlin	AB		Rep. Zubke	✓	
Rep. Heinert	✓				
Rep. Keiser	✓		Rep. Mitskog	✓	
			Rep. Eidson	✓	

Total (Yes) 13 No 0

Absent 1

Floor Assignment Rep Eidson

If the vote is on an amendment, briefly indicate intent:

REPORT OF STANDING COMMITTEE

HB 1225: Energy and Natural Resources Committee (Rep. Porter, Chairman) recommends **AMENDMENTS AS FOLLOWS** and when so amended, recommends **DO PASS** (13 YEAS, 0 NAYS, 1 ABSENT AND NOT VOTING). HB 1225 was placed on the Sixth order on the calendar.

Page 1, line 1, remove "legislative management"

Page 1, line 1, after "innovation" insert "by the empower North Dakota commission"

Page 1, line 2, replace "an appropriation" with "for a report to the legislative management"

Page 1, line 4, replace "**LEGISLATIVE MANAGEMENT**" with "**EMPOWER NORTH DAKOTA COMMISSION**"

Page 1, line 4, after "**FUTURE ENERGY INNOVATION**" insert "**- REPORT TO LEGISLATIVE MANAGEMENT**"

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Page 1, line 8, replace "legislative management" with "empower North Dakota commission"

Page 1, line 8, remove "report its findings and recommendations,"

Page 1, remove line 9

Page 1, line 10, replace "legislative assembly" with "provide a report to the legislative management by June 30, 2020, regarding the results and recommendations of the study"

Page 1, remove lines 11 through 15

Renumber accordingly

2019 SENATE ENERGY AND NATURAL RESOURCES

HB 1225

2019 SENATE STANDING COMMITTEE MINUTES

Energy and Natural Resources Committee
Fort Lincoln Room, State Capitol

HB 1225
3/1/2019
Job Number 33036

☐ Subcommittee
☐ Conference Committee

Committee Clerk: Marne Johnson

Explanation or reason for introduction of bill/resolution:

A bill to provide for a legislative management study of future energy innovation and to provide an appropriation.

Minutes: 2 Attachments

Chair Unruh: Opened the public hearing. All members were present.

Representative Vicky Steiner, District 37, introduced the bill (1:00-11:15) please see attachments #1 and #2. We are looking for diverse opinions, things that we are not familiar with, things we may not agree with. I'm not happy to say the natural resource markets are changing. I've always been proud of the natural resources of North Dakota, but as I traveled last year, it became apparent that we're standing on shaky ground. Yes, we can have the Empower Commission bring in their people, and we may get some of what we're looking for. I don't think it's the best option, if you want to try the Empower Commission, I hope you give the bill a do pass to gather the research as we can. We're moving towards developing a strategic energy plan for 2050 eventually. Before you develop your strategic plan, you have to understand the powerful energy drivers that are out there. California is a big one, when it demands all electric vehicles, it affects North Dakota. You also have big trucking companies moving to CNG (compressed natural gas), the you need to have CNG fueling stations, North Dakota will grapple with that, because these are cross county routes. There's a lot going on, we can't assume everything will be the same in 20 years.
It has been brought to my attention, you might need to amend this, Empower is not called Empower in statute, it's called Energy Policy Commission, maybe legislative council should let you know if that's an issue.

Chair Unruh: Are you happy with the switch to Empower, do you want it to go to legislative management as you proposed?

Representative Steiner: I hadn't thought about it that way, if we gave it to Empower, I think it would be helpful if they had some money to bring in some diverse opinion, it's kind to offer for free, they have people that can bring information like this, we can give it a go and try it, and then next session maybe then we pursue outside experts; I'd be willing to go either way. I'm concerned that without some money to bring in divergent opinions, that you may not get

a diverse group of opinions. I'm trying to see if the state can bring in wide range of thought as the digital revolution flips.

No opposition testimony.
No neutral testimony.

Chair Unruh: Closed the hearing

2019 SENATE STANDING COMMITTEE MINUTES

Energy and Natural Resources Committee
Fort Lincoln Room, State Capitol

HB 1225
3/15/2019
Job Number 33813

☐ Subcommittee
☐ Conference Committee

Committee Clerk: Marne Johnson

Explanation or reason for introduction of bill/resolution:

A bill to provide for a study of future energy innovation; and to provide for a report to the legislative management.

Minutes: No Attachments

Vice-Chair Kreun: Is that to be changed to energy policy commission rather than Empower North Dakota?

Chair Unruh: I think that was suggested, but I had some conversation with some Empower members, I believe their wishes are to not have to do this study.

Senator Schaible: I don't think we need a study; there is a lot of information out there. I understand the rationale; but I think industry alone deals with worries about where we are going with renewables. Industry already ahead of that, and provides that information. I don't see a benefit.

Senator Cook: I move do not pass.
Senator Roers: I second.

A roll call vote was taken.
Motion passes 6-0-0.

Senator Schaible: Will carry.

Chair Unruh: Closed committee work.

Date: 3/15
Roll Call Vote #: 1

2019 SENATE STANDING COMMITTEE
ROLL CALL VOTES
BILL/RESOLUTION NO. 1225

Senate Energy and Natural Resources Committee

☐ Subcommittee

Amendment LC# or Description: _____

Recommendation: ☐ Adopt Amendment
☐ Do Pass ☒ Do Not Pass ☐ Without Committee Recommendation
☐ As Amended ☐ Rerefer to Appropriations
☐ Place on Consent Calendar

Other Actions: ☐ Reconsider ☐ _____

Motion Made By Sen. Cook Seconded By Sen. Roers

Senators	Yes	No	Senators	Yes	No
Senator Jessica Unruh	X		Senator Merrill Piepkorn	X	
Senator Curt Kreun	X				
Senator Donald Schaible	X				
Senator Dwight Cook	X				
Senator Jim Roers	X				

Total (Yes) 6 No 0

Absent 0

Floor Assignment Sen. Schaible

If the vote is on an amendment, briefly indicate intent:

REPORT OF STANDING COMMITTEE

HB 1225, as engrossed: Energy and Natural Resources Committee (Sen. Unruh, Chairman) recommends **DO NOT PASS** (6 YEAS, 0 NAYS, 0 ABSENT AND NOT VOTING). Engrossed HB 1225 was placed on the Fourteenth order on the calendar.

2019 TESTIMONY

HB 1225

January 18, 2019

Rep. Vicky Steiner, District 37, Dickinson.

Chairman Todd Porter

Thank you, Chairman Porter and Members of the Energy and Natural Resources committee

Vicky Steiner, District 37, Dickinson, ND

A few days ago, Chairman Porter discussed a bill on the floor about refusing to pay for the higher costs of forcing renewables in the electricity rates. I voted for it because I wanted to tell Minnesota corporations that we don't support their agenda. We all know North Dakota cannot be an island. We sell to the world and their market demands impact our future. But Rep. Porter made an important point- renewables are changing the cost and renewables are disrupting markets.

Today and probably for at least 10 years, I believe the Bakken will see a strong market. I've enclosed a "rosy" report from a McKenzie county commissioner from another hearing for your information. It's a good snap shot of today in the Bakken oil region if you are not familiar with it.

We are in a digital revolution. Our health may be monitored in the future by this small computer we call a cell phone. We can already control a furnace in our home from our phone. Economists say it's compares to the industrial age, this digital revolution- it's how the combustion engine changed America in 40 short years. It begs the question- in 40 years- where is the market for the Bakken? Today, we receive $2 billion a year in tax revenue. How long do you think this type of revenue will continue? 20 years at best? Perhaps we need to find flaring solutions and drill faster.

This bill funds a comprehensive natural resources and energy study- ND Energy in 2050- recognizing the current disruption of energy markets and the need for a long-term strategic energy plan. North Dakota has billions of dollars at stake as the country transitions to new forms of energy. We certainly must continue our quest for clean lignite coal, but environmental groups are moving to nuclear

power and have begun discouraging natural gas consumption. We also have yellow cake uranium potential in the Belfield area.

The Dept of Mineral Revenues had reported a few years ago that by 2055, ND may become more of gas producing state than oil. Will there be a gas market?

I've attended NCSL Energy Supply Taskforce meetings the past two years in which the discussion has been more focused on the rapid growth of wind, natural gas peaking plants, microgrids and solar power in west and east coast states. A Maryland senator complained that Maryland needs to get its own wind power because it's too expensive to keep buying it from North Dakota. How much wind is sold or traded to the east coast and when will they expand their own wind supply? Floating wind turbines can operate 29 miles off shore on east coast states in shallow waters that will not be visible from shore. Just as the taxi industry was upended by Lyft and Uber, the energy industry will be disrupted.

In November 2018 issue of Environment and Climate News from Heartland Institute, the headline was California billionaire Tom Steyer paid to put a renewable energy measure on the Nevada ballot. Tom Steyer hoped voters across the country will agree with his agenda. Nevada passed the bill requiring utilities to have portfolios of 50 percent of renewables of wind, solar and hydro by 2030. Nevada is just one of the states he targeted, other states are on his list. He spent $6 million for this initiative. If North Dakota is next, what is at stake long term?

Hobbled by renewable energy mandates, FirstEnergy Solutions Corporation announced it will deactivate in 2021 and 2022 four fossil fuel powered electric plants in Ohio and Pennsylvania. They also have deactivated their nuclear plant. It's estimated in Pennsylvania there will be 11,400 jobs eliminated. Pennsylvania's renewable portfolio standard mandates 18 percent of all electricity be renewable at an estimated cost of $700 million dollars.

How much wind power will our state likely have in 2045? We have 41 wind farms in ND currently. How many more will there be in 20 years and what will the landscape look like?

2045 is the year that California has a mandate to be 100% renewable energy. Although, technically, experts say you'll always need a fossil fuel or nuclear plant running in the background to support renewables, their goal will be difficult to attain. Currently, rooftop solar and community solar systems are all the rage in their state. Community Choice Aggregation (CCA) allowed to form under California law demand renewables in their power mix. Cities or counties, under this law, are allowed to purchase and/or generate electricity for their residents. These CCAs go out on the market to meet their residents demand but it is impacting reliability on the west coast grid. Washington hydro power has been their back up when demand is high. However, it's expensive when they demand it at peak times.

Micro-grids are forming to take advantage of battery storage. A good example is San Diego State University. They run independent of San Diego as their own micro grid, experimenting with new battery storage ideas, using groundwater to cool their computer buildings. They have public electric car chargers that they invite the public in to use along with university fleet.

The former MDU refinery, now owned by Marathon, mentioned by the Governor in his State of the State speech, is being converted to make renewable diesel with soybeans. This product will be shipped to California by train. To me, this is a red flag. Why not diesel made from Bakken oil which is in supply so close?

Jeremy Rifkin, an economist who spoke at NCSL in Los Angeles in July, said " The legacy fossil fuel industries, and the countries that depend on them, will suffer. I've included his white paper. I recommend you read it sitting down. **According to a recent study by Citibank, the energy industry and power and transmission companies today are sitting on potentially $100 trillion in stranded assets**. You'll find that on page 8. He also predicts that, in 40 years, energy will be nearly free, widespread abundance, smaller nimble companies will collaborate in a hybrid capitalistic economy, cost of sensors will drop so low they will be embedded allowing machines to work for us, young people will have much leisure time.

At a Legislative Energy Horizons Institute meeting in Washington, D.C., Peter Trelenberg, Manager, Environmental Policy & Planning, Exxon Mobil said their

corporation is moving into biomass because that's their "specialty" is how he worded it. I asked him if they plan to strand their oil and gas assets. He said no, they have an 18 year drill out plan and do not plan on stranding anything. However past 2050, the path is not defined as it is now. It's more uncertain, he said.

We are flaring gas at record levels. By the time we have adequate pipelines to take the product to markets south of here, what will its value be? Should we store it to use later or push it out faster?

A speaker in Boston at another Energy Supply Taskforce meeting in 2017, Dr. Chandra V. (Visweswariah) said there are 4 disruptive trends. 1- availability of data with large data centers 2-pace of solar and wind adoption and declining cost (wind and sun don't ask for cost of living increases) 3-advent of heat pumps-so efficient 4) battery storage and electric vehicles-eventually you won't be able to buy a gas fueled car. Dr. Chandra is President and CEO of Utopus Insights. He is a strong believer in economic and environmental forces that will create a clean energy future. He said it will be a "veritable energy utopia."

China owns most of the rare earth minerals used in cell phones, TVs and wind turbines, military aircraft. The Dept. of Energy asked North Dakota to search for their own sources. Slope county has the greatest concentration of rare earth minerals but is it marketable?

There are so many unanswered questions about North Dakota's vast energy stores. Before we can develop a plan, we need much more information on how this digital revolution impacts N.D., changing consumer demand, and fossil fuel market disruptions.

1225

I would ask for a Do Pass on this bill to solicit expert and diverse opinions as we will need to gather information that could be used to develop a strategic energy plan for 2050 for our state.

Thank you and I stand for questions.

Testimony of Doug Nordby, McKenzie County Commissioner and WDEA Board Member
Support for Infrastructure Funding – HB 1066
House Finance and Taxation Committee
January 15, 2019

Good morning Chairman Headland and members of the committee. My name is Doug Nordby and I am a McKenzie County Commissioner and a Board Member for the Western Dakota Energy Association. Today I am here to address the importance of HB 1066 and the critical need to continue a reliable distribution of the Gross Production Tax to oil producing counties in western North Dakota. This will allow political subdivisions the ability to plan, and in turn, help the entire state succeed.

When talking with people outside the area, they ask what is happening now that the boom is done. My response to them is that statement is not completely true. The industry has responded with enhanced oil recovery technology to increase production and lower costs for drilling. Today's rig can drill a well in less than two weeks, and fracking technology is able to extract 12% to 16% of oil, up from 4% to 5 % in recent years. The 66 active drilling rigs currently in the State are up from 36 in 2017. These rigs produce more oil than when there were nearly 170 rigs drilling in the Bakken, and what was once a $14-$20 million per well cost, has decreased to $5-$6 million per well with less than half the time to complete. In the past, this level of development in any community in North Dakota would have been considered a boom. This is the new norm for us in the oil producing communities in the west where the entire Bakken continues to experience activity and traffic impacts.

Oil and gas companies have invested billions of dollars into North Dakota and the Bakken, with $100 billion invested into wells drilled and completed, another $11 billion in wells drilled but not yet completed, and $15 billion in gas processing facilities and pipelines. In McKenzie County alone, an additional $2.2 billion has been committed to investments in new and expanded gas plants by 2020. This level of investment has created an economic engine that benefits the State of North Dakota. Over $16 billion dollars of oil and gas taxes have been

dispersed throughout the state since 2010 in the form of transportation funding, property tax relief, support for our schools and education, and critical water infrastructure.

Transportation infrastructure is the main priority for counties in the Bakken. Roads and transportation within the oil producing counties are the life blood of the oil industry. Counties in the Bakken spend between fifty and sixty percent of our budgets on maintaining and rebuilding roads and bridges. The volume and weight of oil industry traffic, where it takes 2300 truck trips to complete a well, is unmatched by any other industry in the state. The Badlands topography in western North Dakota makes it more expensive and time consuming to build and repair roads. We cannot afford to wait for problems to show up on our roads before addressing them. Regular maintenance and planning are essential in order to continue providing the industrial infrastructure required for oil development. The major oil producing counties, and others, have a five-year road improvement plan that is reviewed annually in order to be responsive to the dynamic changes that are inherent in the exploration and development of oil.

In October 2018, another record was broken with 15,344 wells in production in western North Dakota. This level of activity produces revenue for the State, but it also requires a workforce to maintain and operate. It is estimated that McKenzie County will need an additional 8,000 production jobs by 2025 and could increase to as many as 22,000 jobs by 2045. In the four major producing counties, future employment numbers in oil and gas careers could easily exceed 63,000 jobs. This does not include the additional services that are needed for new families moving to work in the Bakken. The most recent NDSU Bakken study estimated that each oil and gas job creates at least one additional non-oil job in the service industry and retail sectors.

According to ND Director of Mineral Resources, Lynn Helms, the challenge to fill these jobs could be a big factor in slowing the growth of the industry. To address this challenge and the future demand for workers, McKenzie County has invested in a program called the Skills Initiative. Together with the Industry, we have partnered with Watford City High School, Williston State College, Train ND, and the University of Mary, to develop targeted programs for growing the skilled workforce needed in the future.

Chairman Headland and Committee members, I ask your support for the allocations of Gross Production Tax proposed in HB1066 without a sunset. This provides a reliable funding source and the certainty counties need in order to continue to be responsive to infrastructure and workforce needs so that we can do our part in making sure that statewide benefits from the oil and gas industry are maximized.

strategy+business

ISSUE 89 WINTER 2017

The Thought Leader Interview: Jeremy Rifkin

The influential economic theorist looks ahead to a world of virtually free energy, zero marginal cost production, widespread abundance, and a desperate race against climate change.

BY ART KLEINER AND JULIETTE POWELL

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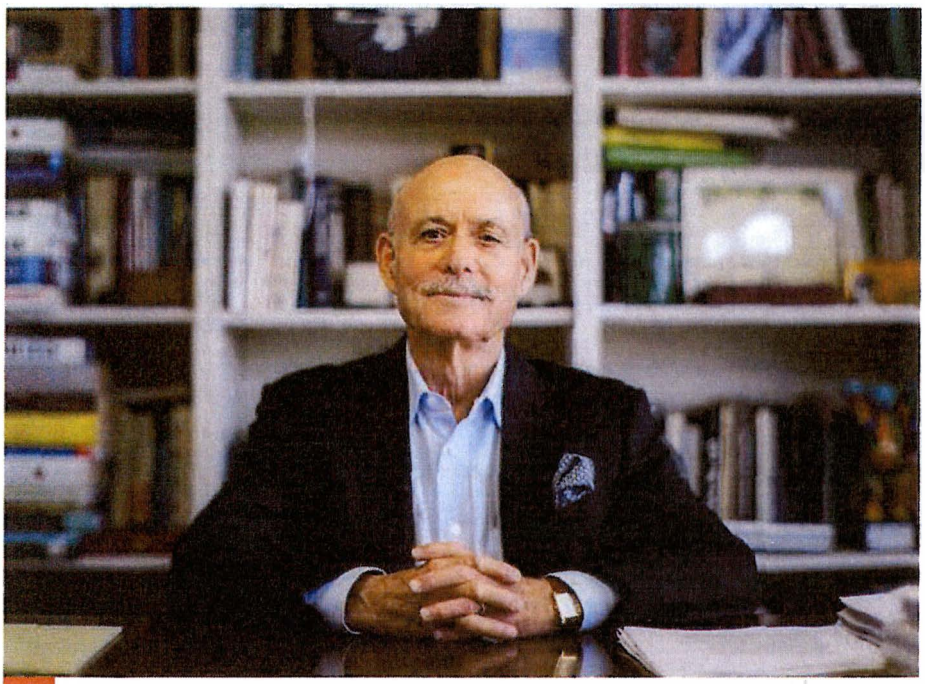
The Thought Leader Interview: Jeremy Rifkin

The influential economic theorist looks ahead to a world of virtually free energy, zero marginal cost production, and widespread abundance, and to a desperate race against climate change.

BY ART KLEINER AND JULIETTE POWELL



Photograph by Hector Emanuel

Most people in the business world are aware of the convergence of computer and communications technology, the shift in energy from fossil fuels to renewables, and the movement toward self-driving vehicles and robot-driven manufacturing. But only a few people are thinking intensively about how all these technological changes will fit together — along with changes in advanced manufacturing, water systems, agriculture, healthcare, and education — to generate rapid, widespread growth accompanied by a dramatic reduction in ecological footprint.

This systemic approach to the industrial future is the domain of economic theorist Jeremy Rifkin. Rifkin, 72, is a longtime commentator on economic and technological issues and a lecturer in the executive education program at the University of Pennsylvania's Wharton School of Finance. He is a consultant to heads of state (including the top leadership of Germany, the president of the European Commission, and the leadership of the People's Republic of China), along with many companies (including PwC, the publisher of *strategy+ business*). And yet his logic is controversial in many business circles. He argues, for example, that both capitalism and the fossil fuel industries are hitting limits that stem from the laws of thermodynamics. Investor-based capitalism, which focuses resources for immediate returns, will inevitably be replaced by a more distributed and streamlined network-based capitalism, alongside a sharing economy governed by a high-tech global commons.

According to Rifkin, this new hybrid economic system will be made possible through the provision of solar, wind, and other renewable energy on demand, facilitated by innovations such as the Internet of Things and blockchain. In the world he envisions, the costs of producing and delivering an increasing array of goods and services will dwindle to near zero, and economies will have to learn to manage abundance — and the use of shared goods and services. These shifts will happen during the next 40 years or so, he says, unless they are cut short by the exponentially increasing dangers of climate change and species extinction.

Rifkin outlined his thesis in three successive books: *The Empathic Civilization: The Race to Global Consciousness in a World in Crisis* (Penguin, 2009); *The Third Industrial Revolution: How Lateral Power Is Transforming Energy, the Economy, and the World* (Palgrave Macmillan, 2011); and *The Zero Marginal Cost Society: The Internet of Things, the Collaborative Commons, and the Eclipse of Capitalism* (Palgrave Macmillan, 2014). His ideas were featured in a 2017 documentary film, *The Third Industrial Revolution* (Vice Media). Two massive initiatives for which he is an advisor — the E.U.'s "Smart Europe" and China's "Internet Plus" — are, in a sense, manifestations of his world view.

Even those who do not agree with Rifkin's theory that capitalism is in the midst of a fundamental transformation must respect the exponential power of the forces he is tracking. Intelligent technology, in particular, is expanding at an ever-increasing rate, lowering costs, replacing human labor, tracking human activity, and making many new things possible — which could be the "dark net" of authoritarian surveillance or a broadening of wealth and quality of life. Rifkin sat down with *strategy+business* in late August at the Bethesda, Md.–based headquarters of his primary organization, TIR Consulting Group, to explain his arguments in greater detail.

> "It had been clear, even before the dot-com bubble collapsed in 2000, that the digital revolution was forcing down costs."

S+B: The "zero marginal cost society" concept suggests we're heading into a time of abundance that will radically change the way people live. How did you come to this idea?

RIFKIN: In the early 2000s, I was teaching in the advanced management program (AMP) at Wharton Executive Education. It had been clear, even before the dot-com bubble collapsed in 2000, that the digital revolution was forcing down fixed and marginal costs in information and communications technology in an exponential way, as described by Moore's Law.

Marginal costs are the costs of taking a product to scale, and these had already gone to near zero in media and software. Once you've paid the fixed costs to record a song, the marginal cost of streaming the music is virtually zero, whether you stream a thousand or a million copies. Newspapers, television, record labels, and the film industry discovered that they could no longer rely on their old business models, especially if they involved advertising.

S+B: But this applied only to digital media.

RIFKIN: At the time, yes. But we saw that this might soon apply to other parts of the economy as well. One major signal, for us, was the pressure IBM felt, starting in the mid-1990s. [Then CEO] Lou Gerstner, at a retreat with the company's top executives, said out loud that they had a problem. Their cash cow was the big

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mainframe computer. But as competition increased, and the price of computers continued to plummet, where would their profits come from? That led them to shift, in part, to managing information services.

In our AMP classes, I introduced the idea that the digital revolution, and dropping of marginal costs down to near zero, represented the ultimate success of capitalism. But it would also force a radical shift in the nature of the capitalist business model.

S+B: By capitalism, you mean market-based economies, governed by the laws of supply and demand, without government controls.

RIFKIN: By capitalism, I mean a particular type of market economy where the investors, owners, managers, workers, and consumers are all separate people. Capitalism of this sort is only 200 years old.

Let's step back for a moment and consider how the great economic transformations in history occur. There have been a number of them in world history, and they all have a common denominator. At a single historic moment, the same three defining technologies emerge and converge to create a new general-purpose technology infrastructure. They fundamentally change the way society manages, powers, and moves economic activity. The three technologies are new communication systems that manage economic activity more effectively; new sources of energy that power the activity more efficiently; and new modes of mobility that move the economic activity more rapidly. This changes society's spatial temporal orientation, its business models, its forms of governance, and even people's cognition and consciousness.

> "There have been a number of great economic transformations in world history, and they all have a common denominator."

For example, consider the first Industrial Revolution, which took place in the 19th century. Before then, there were very few large businesses. Most merchants owned the tools they used — the means of making, delivering, and trading goods. Then came new technologies for communications, energy, and mobility. The steam-powered printing press, which made possible cheap newspapers and mass-produced books, transformed communications. This enabled more widespread literacy; with textbooks, there could be compulsory public school systems. The invention of the telegraph annihilated space and compressed time, making possible national and even global markets. The coal-based steam engine, a new form of energy, made it possible to manage production at a much larger scale. That engine was then put on rails, giving rise to a national system of locomotive-based transportation, further speeding up the managing, powering, and moving of economic activity and the geographic expansion of markets.

These technological changes were so broad and complex that they required a new form of manage-

ment. Railroads became the first modern capitalist business corporations, with thousands of employees, vertically integrated operations, and shareholders separated from the business. Once all three technologies were in use, around 1860, modern capitalism rolled out quickly around the world. By 1900, in less than 40 years, the world had been transformed.

A second industrial revolution followed in the early 20th century. This involved the invention of the telephone and, later, radio and television; the widespread use of fossil fuels; the laying out of electricity grids; and the introduction of the internal combustion engine for road, rail, water, and air transport. The second industrial revolution's juvenile infrastructure was put in place in the United States and elsewhere between 1905 and 1929. Its growth was interrupted with the coming of the Great Depression and World War II, and it finally matured in the second half of the 20th century across the industrial world.

S+B: And by the early 2000s, you were saying that way of life was obsolete.

RIFKIN: We saw that the productivity potential of the second industrial revolution technology infrastructure had run its course. Meanwhile, a dramatic reduction in fixed and marginal costs had already occurred in computers and communications, and would probably occur elsewhere as well. And as this happened, it would change the economy so that neoclassical economic theory would no longer suffice to describe it.

The world was entering a third industrial revolution — a digital revolution. [Note: Although the numbers differ, what Rifkin calls the third industrial revolution and the broad technological shift known as "Industry 4.0" are roughly the same movement.] In a digitally connected society, the marginal costs of an increasing number of goods and services would fall to near zero. This would force a fundamental change in prevailing business models: from markets to networks, from ownership to access, from workers to "prosumers" [individuals who produce as well as consume goods and services distributed on the Web], from sellers and buyers to providers and users, and from consumerism to sustainability — and the second industrial revolution's economies of scale would no longer apply. The communications part of it had already happened: Inexpensive computers and the Internet existed, and the smartphone had just been invented. It took a while to see that the same phenomenon could occur in the world of atoms, and dramatically reduce the cost of energy, mobility, and other goods and services.

The Next Infrastructure

S+B: So when you say "third industrial revolution," what change are you referring to?

RIFKIN: A new technological infrastructure is gradually coming together, brought on by digitization. The process began with the maturation of the communications Internet over the past 25 years. Now this is converging with a second Internet, this one for renewable energy. It's a new digital power grid, stretching across continents, which allows millions of people to produce their own wind and solar electricity and send their excess power generation back into the system. Both of these Internets will converge, during the next decade, with an emerging digitized mobility Internet composed of increasingly autonomous electric and fuel-cell vehicles operated by near-zero marginal cost renewable energy on smart road, rail, water, and air systems. These three systems will allow people to share communication, energy, and mobility partially in the capitalist market and partially in the emerging sharing economy.

S+B: Where will this shift happen first?

RIFKIN: It's already happening in some places. Germany has been quietly building out the necessary infrastructure for the past 10 years. When Angela Merkel became chancellor in 2005, she asked me to advise her on growing the German economy. She and I discussed the potential of transforming Germany into a third industrial revolution paradigm. Almost immediately, she and her colleagues resolved to be-

come world leaders in the third industrial revolution.

Since then, Germany has been working on all three fronts: the digitization of communications, renewable energy, and mobility. I have been working closely with senior government officials there, including president Frank-Walter Steinmeier and vice chancellor and economy minister Sigmar Gabriel. Under the plan they put in place, one-third of German electricity is now produced through renewable energy, at near-zero marginal costs. Installing solar and wind technologies is tremendously labor intensive, at least during this transition. Germany has created hundreds of thousands of net jobs this way, and now there are more jobs in renewable energy than in the rest of the energy industry combined.

On a parallel track, I have worked with three presidents of the European Commission — Romano Prodi, José Manuel Barroso, and the current president, Jean-Claude Juncker — in the conception and deployment of a smart digital third industrial revolution across all 28 member states of the European Union. In February 2017, I joined Maroš Šefčovič, the vice president of the European Commission in charge of the E.U. Energy Union and Smart Europe, and Markku Markkula, the president of the European Committee of the Regions, in announcing the launch of the Smart Europe initiative. A €631 billion [US$744 billion] kitty for investment — the Juncker Fund — will now be partially available for its deployment.

The other center of activity is China. When President Xi and Premier Li came into office, Premier Li published his official biography, which mentioned that he had read [my book] *The Third Industrial Revolution* and had instructed the central government to pay close attention to the narrative and proposals outlined in the book. President Xi and Premier Li realized that their country had been locked out of the first Industrial Revolution and much of the second, and they didn't want to lose out on the third. Shortly after the first of several formal visits I had with Chinese leaders, the chairman of the national electric power grid announced an [US]$82 billion commitment to digitize the state electric power grid in the current Five-Year Plan. Millions of Chinese people can produce their own solar and wind power, and use it locally or sell it back to the grid. With the Belt and Road project, they're moving the same technologies to other countries. China calls this digital transformation the Internet Plus revolution, which is similar to the Smart Europe initiative. Of course, China is still one of the world's largest users of fossil fuels, but that is rapidly changing.

Parts of the U.S. are also moving in this direction, without much government involvement: California, Oregon, Washington state, New York, New England, and the San Antonio–Austin area in southeastern Texas. There are wind farms in the prairie states and many large companies and small entrepreneurial startups, all hoping to lead the transition.

The payback for renewable energy is much more rapid than people think. The fixed costs — materials and installation — have gone down exponentially. In 1979, the fixed cost of producing one watt of solar electricity was $79. As of August 2017, it's 55 cents. By 2020, it will be 35 cents. The viability of the technology is just now reaching a tipping point. As for the marginal costs, there aren't any. The sun and wind haven't sent us a bill.

S+B: What about mobility and communications?

RIFKIN: Already, millions of people use car-sharing networks as their primary mode of transportation. Millennials don't want to own automobiles. They want access to mobility in car-sharing networks. Meanwhile, the marginal costs of autonomous, self-driving electric vehicles operating with near-zero marginal cost renewable energy will plummet. Drones will also operate with near-zero marginal costs. Today, there are about a billion cars, buses, and trucks, and they are the third major cause of global warming emissions, after buildings and beef production and consumption and related agricultural practices. We'll likely eliminate 80 percent of vehicles in the world in the next two generations as we shift to car and truck sharing [via] provider–user networks.

The cars and trucks that are left will become, in effect, rolling, mobile distributed data centers outfitted with sensors that pick up and share information on traffic, weather conditions, warehouse availability, and logistics. Daimler has already quietly outfitted more than 400,000 of its motor trucks with sensors. This will increase aggregate efficiency and productivity, while dramatically reducing ecological footprint.

> "In 1979, the fixed cost of producing one watt of solar electricity was $79. As of August 2017, it's 55 cents. By 2020, it will be 35 cents."

The Key to Productivity Growth

S+B: Doesn't this contradict what people like Robert Gordon and Erik Brynjolfsson have been saying about productivity growth — that it is not likely to pick up again?

RIFKIN: They haven't taken aggregate efficiency into account. Aggregate efficiency is the ratio of potential work to the actual useful work that gets embedded into a product or service. The higher the aggregate efficiency of a good or service, the less waste is produced in every single conversion in its journey across the value chain.

A few economic researchers, like physicist Reiner Kümmel at the University of Würzburg and economist Robert Ayres at INSEAD, have reconsidered productivity in recent years. Traditional economics says you increase productivity by investing more capital in better machines and by providing better-performing workers, all of which reduces the fixed and marginal cost of production. But these factors account for only about 14 percent of productivity. Much of the rest of productivity is accounted for by the improvement in aggregate efficiency in the managing, powering, and moving of economic activity.

Aggregate efficiency works the same way in economic production as it does in nature. When a lion chases down an antelope and kills it, only about 10 to 20 percent of the entire energy in the antelope gets embedded into the lion; the rest is heat lost in the transition. So the lion's aggregate efficiency is only 10 to 20 percent. If it could consume more of its prey's energy, or use less of its own in the hunt, the lion would gain productivity as a predator.

Economists are now learning that aggregate efficiency is a critical determiner in productivity growth. In the past, economists have missed this because they have not been trained in thermodynamics; chemists, engineers, biologists, and architects get it.

When the second industrial revolution began around 1905, there was about 3 percent aggregate efficiency in the U.S. production of goods and services. Mass production methods dramatically improved this level, and productivity rose as a result. But there were limits to the efficiency of 20th-century telecommunications, fossil fuel–based energy systems, and internal combustion–driven transportation. By the beginning of the 21st century,

the U.S. was up to around 13 percent aggregate efficiency; Germany had reached 18.5 percent; and Japan led the world at 20 percent aggregate efficiency. That was the ceiling, and productivity growth stagnated. Businesses that plug into the second industrial revolution infrastructure can no longer significantly increase their aggregate efficiency and productivity in managing, powering, and moving their goods and services through their value chains.

Now, with the digital third industrial revolution more fully under way, aggregate efficiency is about to rise again — perhaps exponentially this time. Two factors are the vastly reduced costs of communication, energy, and transport that we talked about. Another is the Internet of Things. The cost of sensors and identification chips is, for the first time, dropping low enough to allow us to embed them in trillions of devices: thermostats, assembly lines, appliances, warehouse equipment, and more, all gathering data. With the IPv6 protocol, those devices can be interconnected through the Internet. When intelligent technology is embedded in homes, offices, factories, and infrastructure, everyone will have a transparent picture of all the economic activity flowing through the economy, with the ability to mine it and use predictive analytics to improve thermodynamic efficiency and productivity while reducing the ecological footprint of economic activity.

The impact will be immense. For instance, an improvement of just 1 percent in aviation engine fuel efficiency, which GE posits as a baseline for its new systems, would save $30 billion over 15 years. The intelligent value chain would be continually learning how to create, use, upgrade, recycle, and reuse physical goods at an ever lower cost. We'll have an economy of partial abundance, full of many nearly free products and services provided at near-zero marginal cost.

S+B: What would living in that economy of abundance be like?

RIFKIN: We're witnessing the birth of a new economic system: a hybrid of the existing capitalist structure and the sharing economy. Most of the goods and services that [make up our] quality of life will be much less expensive. It will be easier to broaden prosperity, without having to fight over scarce resources, in part because it will be much easier to make the most of the resources we have.

Cooperatives, free services, and app-based resource-sharing enterprises will crowd out some — but not all — of the incumbent corporations that depend on fixed-cost business models. We already saw this with digital communications. Whole industries were disrupted: music, television, newspapers, publishing, magazines, educational media. But new businesses emerged, and not just the major platforms like Facebook, Google, and Amazon. Millions of individuals are producing and selling or sharing virtual goods, like music, videos, and writing, at near-zero marginal production cost, using blogs and social media to find audiences. Millions of students are taking massive open online college courses and getting college credits. The most notable is Jimmy Wales's experiment with Wikipedia: It's the sixth-largest website in the world, operated with $50 million in donations a year. For the first time in history, the knowledge of the world is being democratized: People from all walks of life have constructed it in a peer-reviewed platform, with accuracy at least equal to that of top-down encyclopedias. When anyone puts something up on Wikipedia, there are people crawling all over it within hours, checking

their sources or amplifying their text with additional information.

Investor capitalism won't disappear; it will live side by side with the sharing economy. In the emerging era, the cooperative form of business is being reinvigorated because of the lateral scaling advantages made possible by a digitally interconnected global economy with near-zero marginal cost. There were already successful cooperatives around the world, many of them dating back to the early 20th century. A billion and a half people work in them, in industries like agriculture, food production, housing, banking, and energy. They have new life now that there are IT-based tools, such as blockchain, that make it easier to collaborate, and because of the scaling advantages made possible by the digitally interconnected global economy.

> "We're witnessing the birth of a new economic system: a hybrid of the existing capitalist structure and the sharing economy."

The four largest German power companies — EnBW, RWE, E.ON, and Vattenfall — dominated the power and electricity market for years. But together, they own only about 5 percent of all installed capacity of renewable energy in the country. The rest is generated by small companies and cooperatives: democratically managed enterprises in which the profits go to the members. At least two of the big four power companies in Germany are becoming distributors and aggregators of renewable energy that the small players generate across the country. These new electricity cooperatives — some representing farmers, others run by small business groups or urban neighborhood associations — have received low-interest loans from the banks and put up solar and wind generation installations. None of these companies defaulted on their loans. Instead, they sold their extra energy back to the power grid. Cooperatives scale more efficiently than the large incumbent power companies. There are similar electric power cooperatives in the United States.

Abundance and Its Discontents

S+B: What effect will this have on today's energy and transportation industries?

RIFKIN: The legacy fossil fuel industries, and the countries that depend on them, will suffer. According to a recent study by Citibank, the energy industry and power and transmission companies today are sitting on potentially $100 trillion in stranded assets. These include exploration rights, leases, and infrastructure for the extraction of fossil fuel that will be underpriced by renewables. Countries like Saudi Arabia and the Emirates, with oil-based economies, see the disruption coming. So do some of the major oil companies. Other players in the energy industries are simply in denial. But for those that are willing to adapt, there will be some time. We're not leaving the second industrial revolution entirely tomorrow morning. This is a

30- to 40-year transition stretching over two generations.

In the end, the economy may no longer be controlled by a small group of centralized, global, vertically integrated companies. The first and second industrial revolution infrastructures were centralized, proprietary, and vertically scaled because the communication, energy, and transport technologies worked best that way. By contrast, the coming infrastructure of 5G communication, renewable energy, and automated mobility works best if it's distributed, open, transparent, crowd-sourced, and laterally scaled. The more users on the network, the more everyone benefits. With any attempt to monopolize, control, or centralize it, the infrastructure loses aggregate efficiency and productivity. Even today's giant Internet platforms, if they become too centralized, will be vulnerable to others coming in and taking their place.

We'll see a similar kind of change in education. The public school system was a great leap forward in the 19th century, but it was introduced to prepare a generation for the first industrial revolution of factory and office employment, and then was only slightly upgraded for the second industrial revolution. A school designed for that time is a microcosm of a factory. The teacher instructs, and the students are supposed to memorize the knowledge and recite it back. Every 50 minutes a bell rings and they move to the next spot on the line. They're being trained to be efficient automatons operating machines. If the students share information, and help each other, it's called cheating.

Today, millennials have an alternative. Outside the classroom, they're all learning together on their smartphones. They're crowdsourcing, playing online games together, and sharing their knowledge. We need to move toward a new kind of school that recognizes this collaborative interconnectivity.

One model for this change is in Hauts-de-France — the rust belt of France, where its coal, steel, and auto industries are based. Beginning in 2010, our global consulting team began working with the region to revitalize its economy, working alongside the government, the business community, and civil society, with several thousand people participating in scores of committees and projects. They are transforming old mining towns, retrofitting them with solar and wind power sources, and starting entrepreneurial enterprises.

The region brought together seven universities and more than 250 secondary schools in a consortium to think in terms of digital education. They didn't eliminate departments, but all the departments now teach in an interdisciplinary fashion, with multiple perspectives. The students work in teams, and they have to teach one another, with the faculty operating as guides. They also ratcheted up service learning, so that students at all levels work outside in the communities, and have to teach and learn collaboratively with the community businesses and neighborhoods. There is a robust level of social entrepreneurialism involving students, teachers, and their neighborhoods in ways that generate more positive community value.

> "In the end, the economy may no longer be controlled by a small group of centralized, global, vertically integrated companies."

S+B: You've portrayed the upside, but what about the downsides?

RIFKIN: Although the digital third industrial revolution could bring about a more democratic and ecological era, it is by no means guaranteed. I'm not a utopian in regard to technology. Indeed, I've been critical of some technologies over the years. There are going to be many political struggles along the way. For example: How do we ensure data privacy when everyone's connected?

How do we prevent cybercrime and cyberterrorism? And how do we prevent Internet companies, the big ones, from monopolizing the platform for commercial purposes and exploiting the information they gather? Increasingly, members of the millennial generation are aware that their personal information is commodified and sold to third parties, which incorporate it into algorithms and use it for marketing and other purposes. Authoritarian governments can use that same information to control what people do politically.

These are qualitatively big issues. In Europe now, policymakers are recognizing that these issues of the dark net are as formidable as the possibilities are bright, and they will have to spend at least 50 percent of their regulatory capacities managing them. It's naive to think that companies like Google, Facebook, Amazon, and Twitter can maintain their current practices without regulation. The battles over this have already started.

And the biggest shadow in the room is climate change. Most scientists had thought that we had another 100 years before facing a significant crisis, but we didn't fully anticipate the feedback loops brought on by global warming emissions — the more the Earth warms, the more the process of climate change accelerates. We probably have less than 30 years to effectively exit a carbon-based civilization.

The most recent indicators of change have scared the living daylights out of me. For every one degree rise in the temperature of the planet brought on by global warming emissions, the atmosphere is absorbing 7 percent more precipitation from the ground and the oceans, leading to more concentrated precipitation in the clouds and more extreme and unpredictable water events — blockbuster winter storms, dramatic spring flooding, prolonged summer droughts and wildfires, and category three, four, and five hurricanes. Our ecosystems cannot catch up to a runaway exponential curve in the water cycles and are collapsing in real time, taking us into the sixth extinction event of life on Earth over the course of the next half century. Even in a world of abundance, climate change is the dark shadow that could foreclose opportunities for present and future generations and for life itself on Earth.

Fortunately, the third industrial revolution is based on post-carbon technology. Moreover, it's inclined toward a highly diverse and distributed infrastructure. The more diverse, redundant, and distributed the networks and systems are, the more resilient the infrastructure is, and the less vulnerable it is to cybercrime, cyberterrorism, or natural disasters from climate change.

But there may not be enough time to avoid the abyss. The transition would have to take place quickly. We would need to make the shift in 30 to 40 years. As I said, we know it's possible. The second industrial revolution infrastructure was installed across much of the United States in less than 40 years. We could, if highly motivated and passionately committed, do something similar across the world over the course of the next 30 years by using the third industrial revolution to transition into a more just and ecologically sustainable civilization. +

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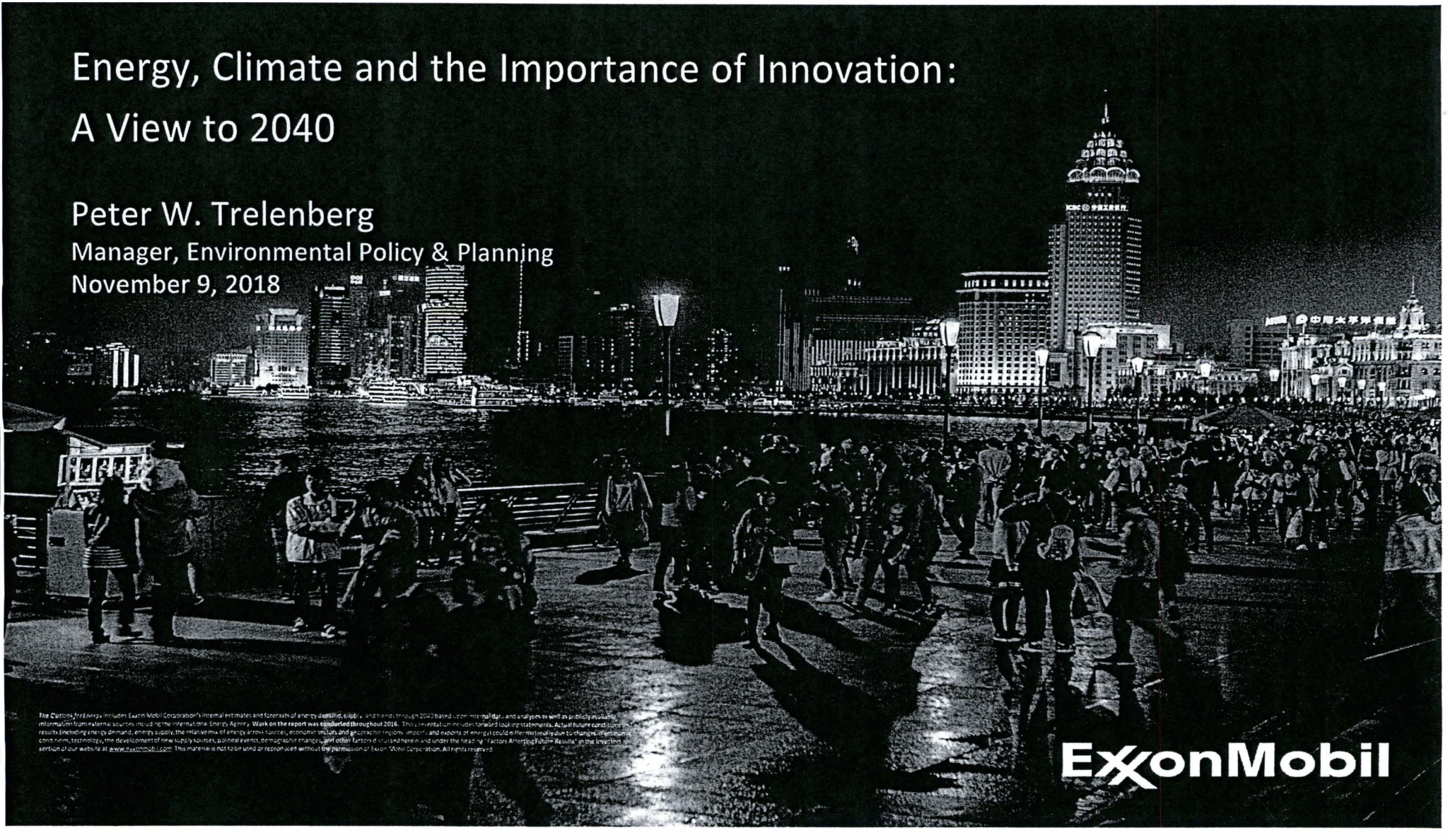
Energy, Climate and the Importance of Innovation: A View to 2040

Peter W. Trelenberg
Manager, Environmental Policy & Planning
November 9, 2018



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Key Messages

- Access to affordable and reliable energy fuels human development
- Growing non-OECD middle class drives energy demand
  (Organization for Economic Cooperation + Development)
- CO_2 emissions peak ~2030, not yet approaching 2°C pathway
- All scenarios require trillions of dollars of oil & gas reinvestment
- Broad cost range for CO_2 reduction options
- Technology provides solutions
- Energy system transitions span decades; pace limited by complexity and scale

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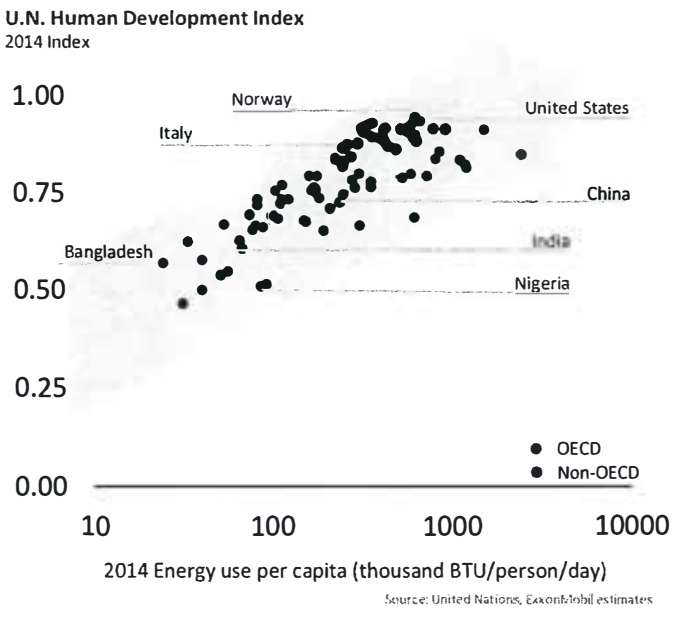
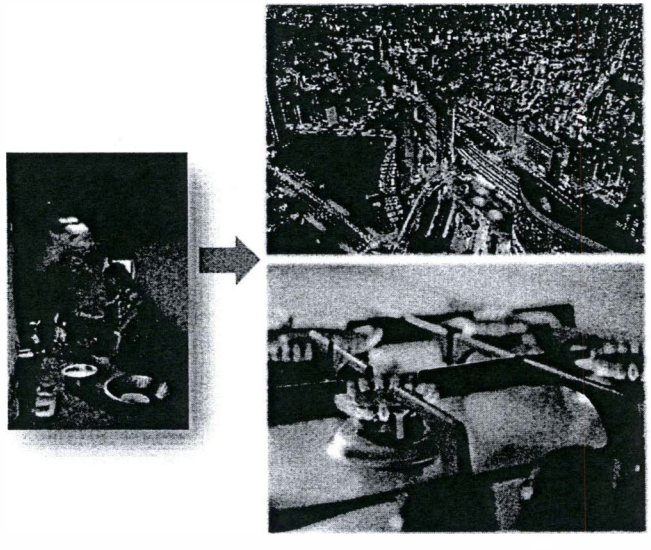
Energy Fuels Human Development





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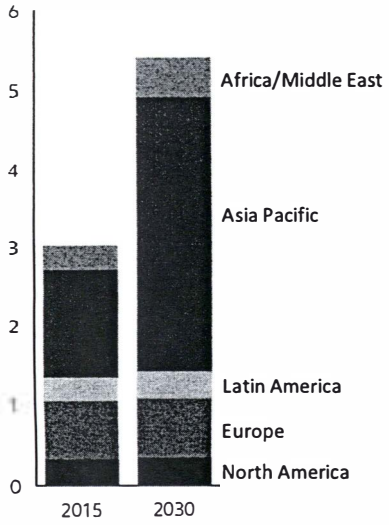
Middle Class Drives Demand Growth, Energy Mix Shifts

Global middle class

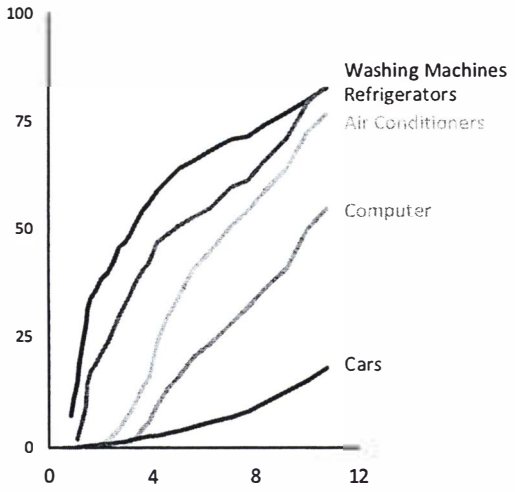
Billion people



Source: The Brookings Institution

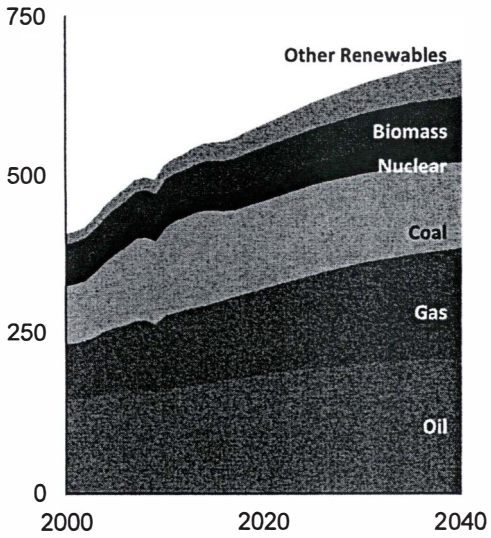
China Durable Goods Ownership

Average Ownership per 100 Households
(1985 – 2012)



Global primary energy demand

Quadrillion BTUs



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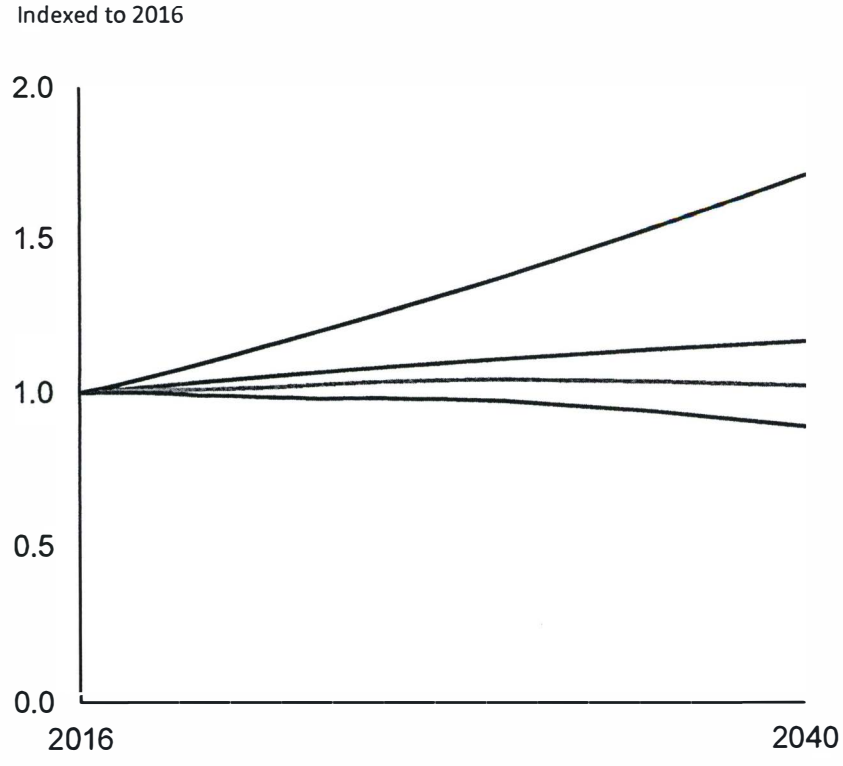
North America Trends



+14 trillion GDP

+80 million people

flat energy demand

-10 percent carbon emissions

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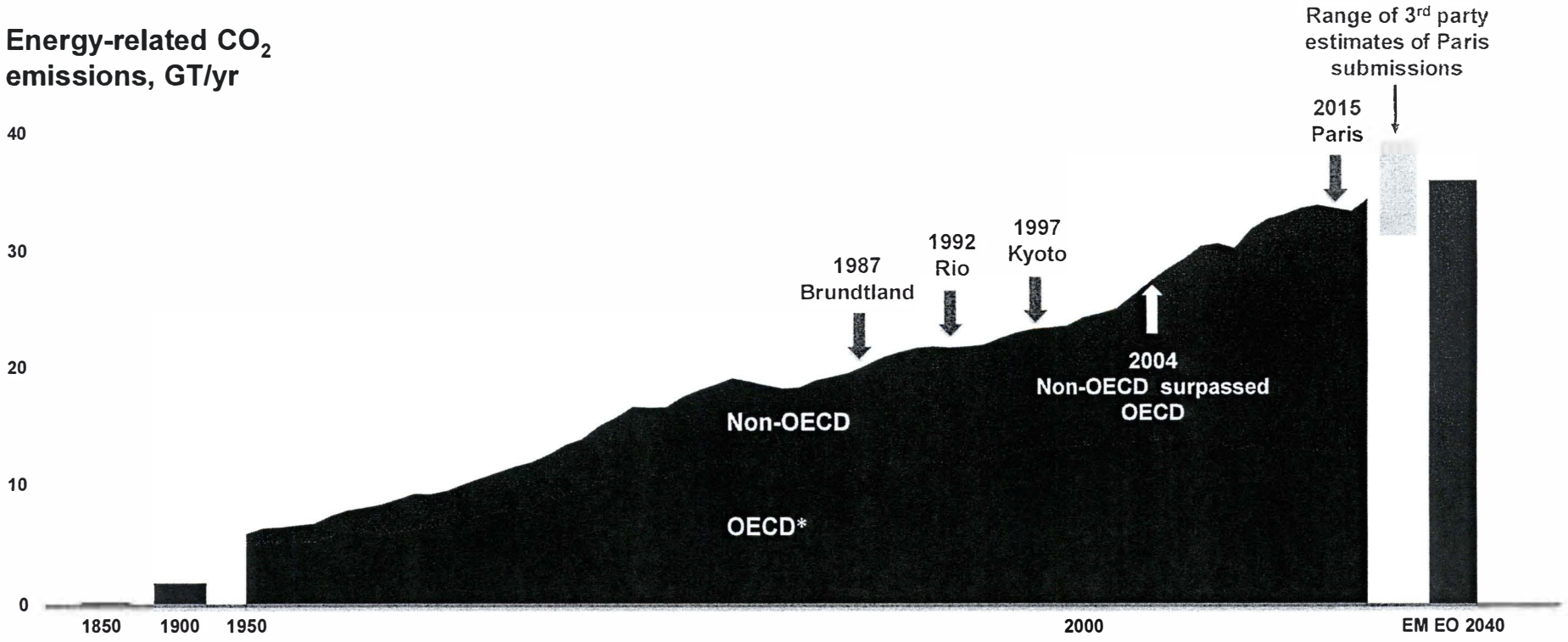
CO_2 Emissions Continue to Rise Despite Mitigation Efforts



* Includes current 36 OECD member countries
Source: energy-related CO_2 emissions: 1850-1969 (CDIAC 2018); 1970-2016 (ExxonMobil Energy Outlook); 2017 (IEA); 2040 (ExxonMobil Energy Outlook); ExxonMobil calculations

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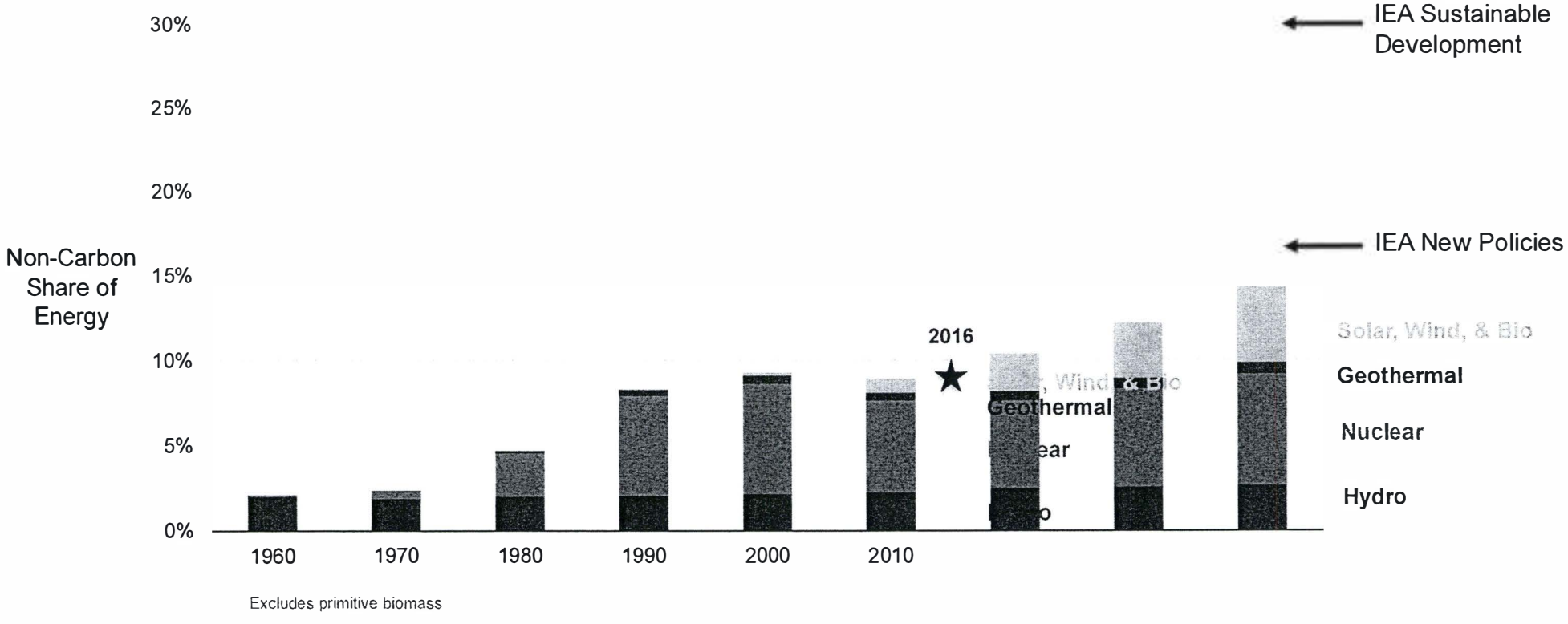
Non-Carbon Share of Energy Flat Since 1990



Sources: 2018 ExxonMobil Energy Outlook; IEA World Energy Outlook 2017

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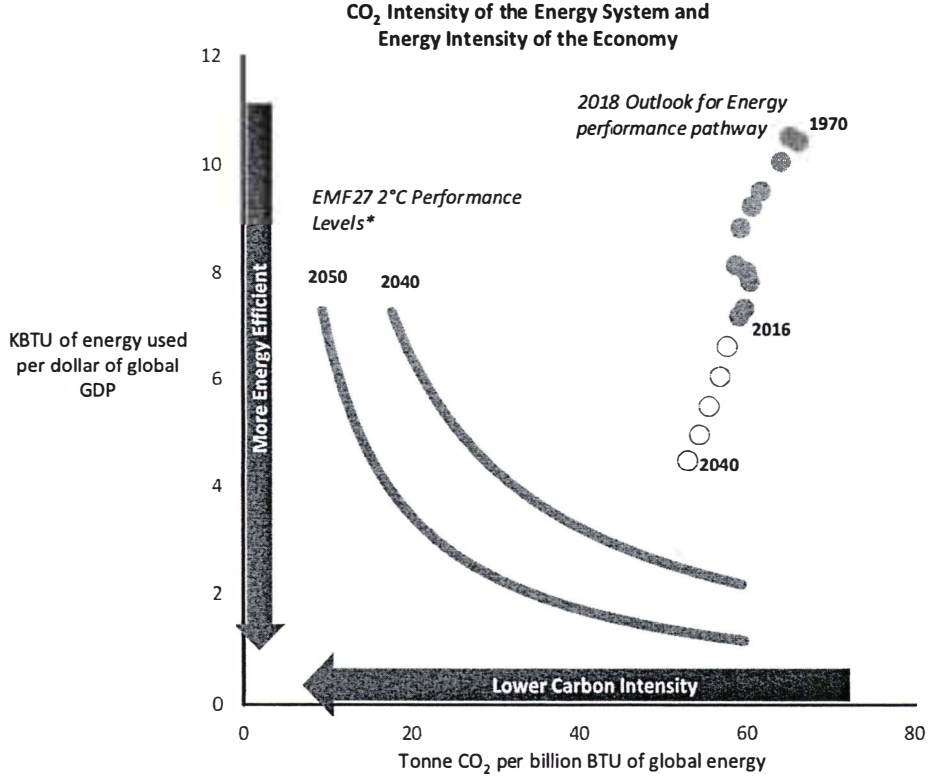
Efficiency and GHG Intensity Reduction Essential for 2°C



*Based on average Stanford EMF27 full technology / 450ppm scenarios' CO_2 emissions (~20 billion tonnes including energy and industrial processes), ExxonMobil GDP assumptions consistent with 2018 *Outlook*

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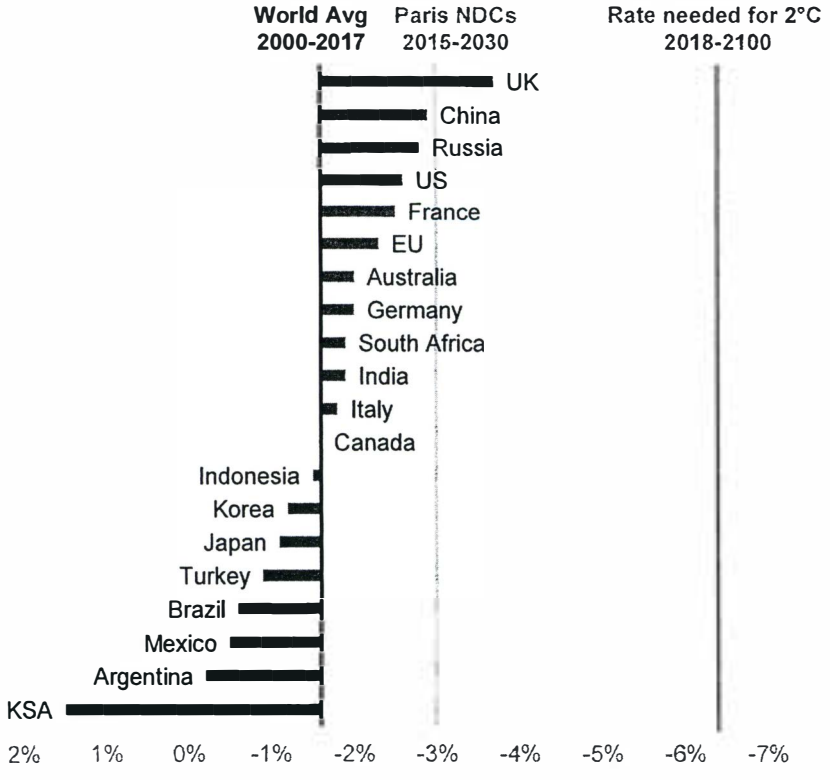
Reduction in Carbon Intensity, Investment Lagging 2°C Requirement

G20 annual average change in carbon intensity of GDP



Pace of investment inadequate to meet 2°C

Investment		Required Annual Additions 2010-2040	Annual Additions 2010-2017	2017 Actual	Calculated Annual Additions 2018-2040
Base Load	Nuclear Plants 1,000 MW	19	1	-1	~24
	Coal and Gas Plants with CCS 500 MW	60	< 1	< 1	~78
Intermittent	Wind Turbines 4 MW	16,600	12,000	~13,000	~18,000
	Solar PV m^2 Panels	385 million	296 million	~628 million	~412 million

Source: PwC the Low Carbon Economy Index 2018
Average investment based on EMF27 full technology / 450ppm scenarios; ExxonMobil calculations

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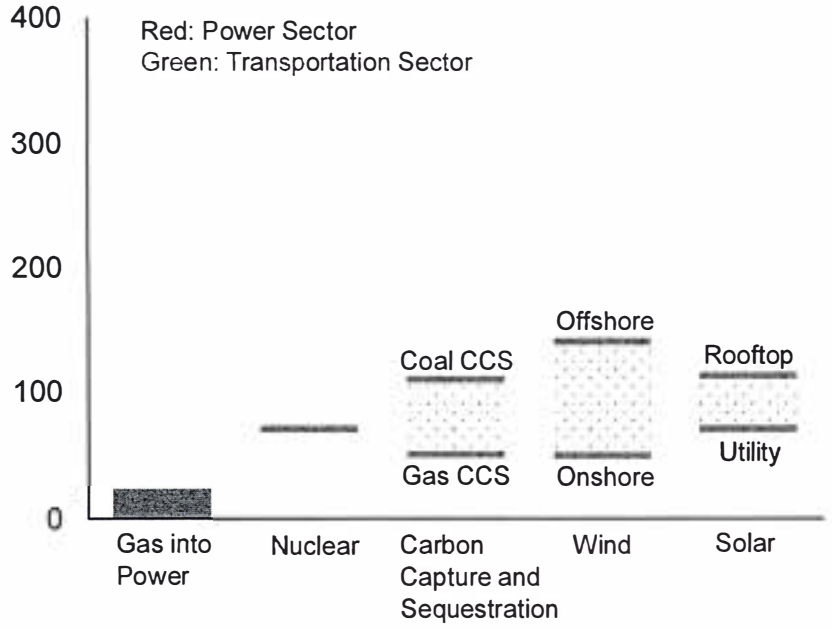
Options to Reduce CO_2 Emissions

Average U.S. CO_2 Abatement Costs

2017 - Dollars per tonne



Source: U.S. Department of Energy, ExxonMobil estimates

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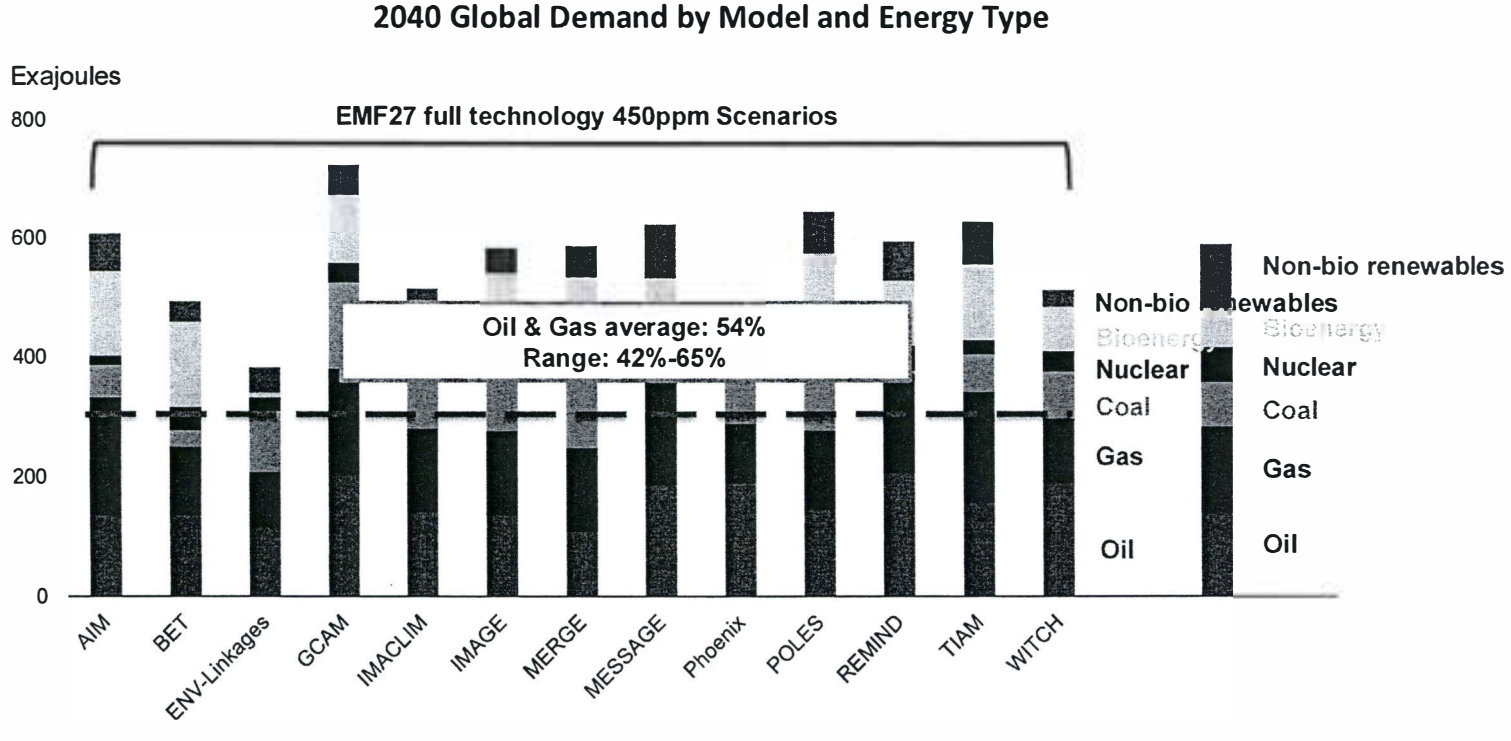
Oil and Gas Still Required in 2°C Scenarios



Based on EMF27 full technology / 450 ppm scenarios (Assessed 2°C Scenarios), CCS components are included in the related primary energy sources.
Sources: EMF27 full technology scenarios data downloaded from: https://secure.iiasa.ac.at/web-apps/ene/AR5DB; IEA World Energy Outlook 2017

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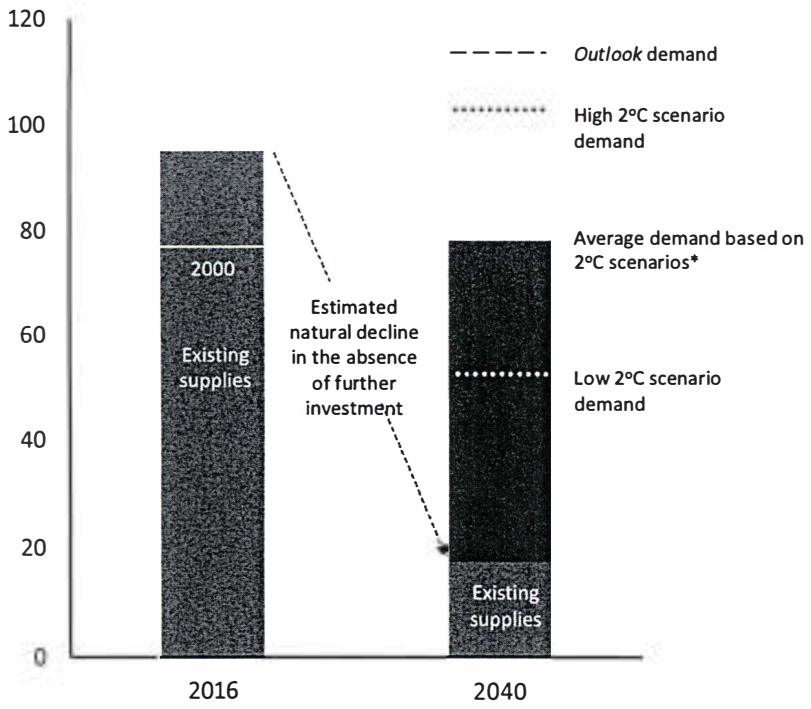
11

Significant Oil and Gas Investment Needed to Meet Demand

Global liquids supply

MBDOE

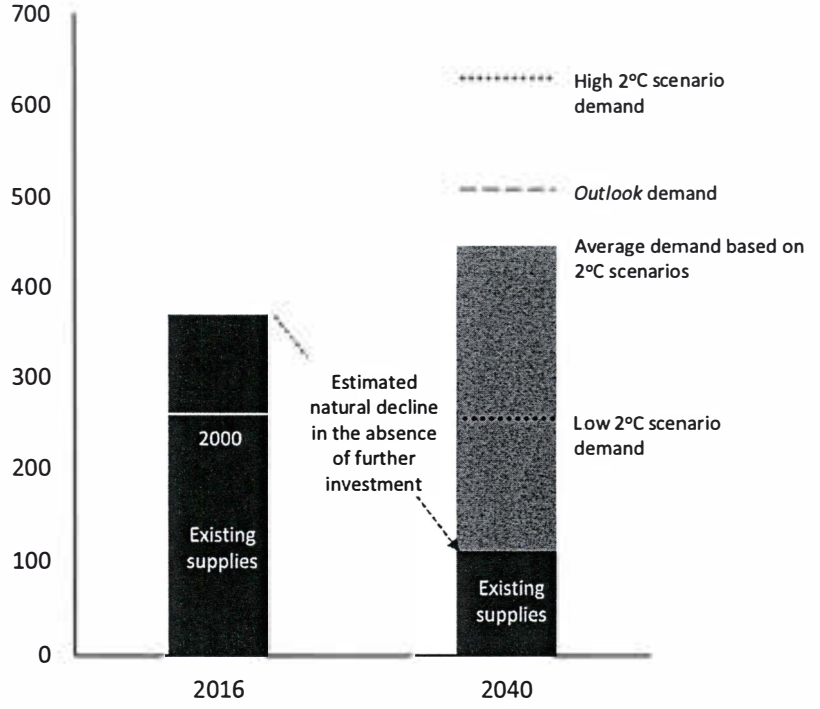


Excludes biofuels

**2°C scenarios based on EMF 27 full technology cases targeting a 2°C pathway*

Global gas supply

BCFD

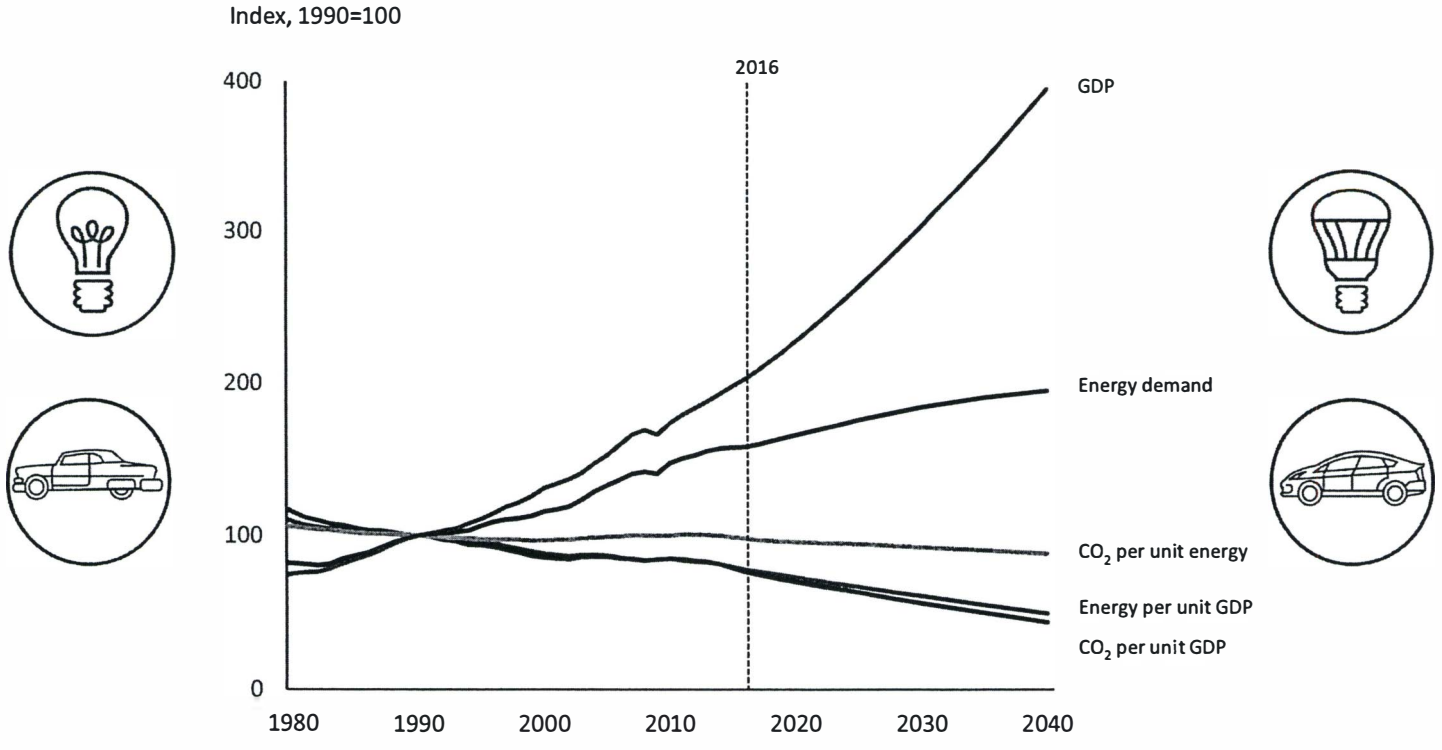


**2°C scenarios based on EMF 27 full technology cases targeting a 2°C pathway*

ExxonMobil

Source: ExxonMobil 2018 Energy Outlook, IHS

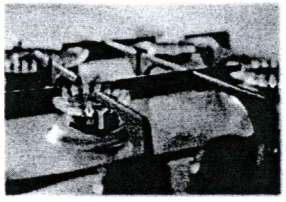
Technology Helps Us Do More With Less



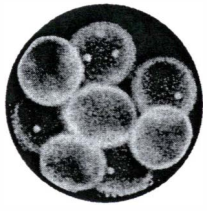
ExxonMobil

ExxonMobil Technologies to Meet the Dual Challenge

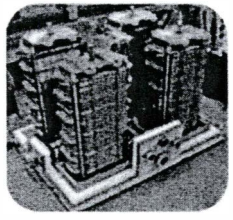
Lower Carbon Intensity



Natural Gas

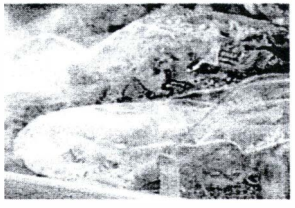


Biofuels



Carbon Capture

Efficiency



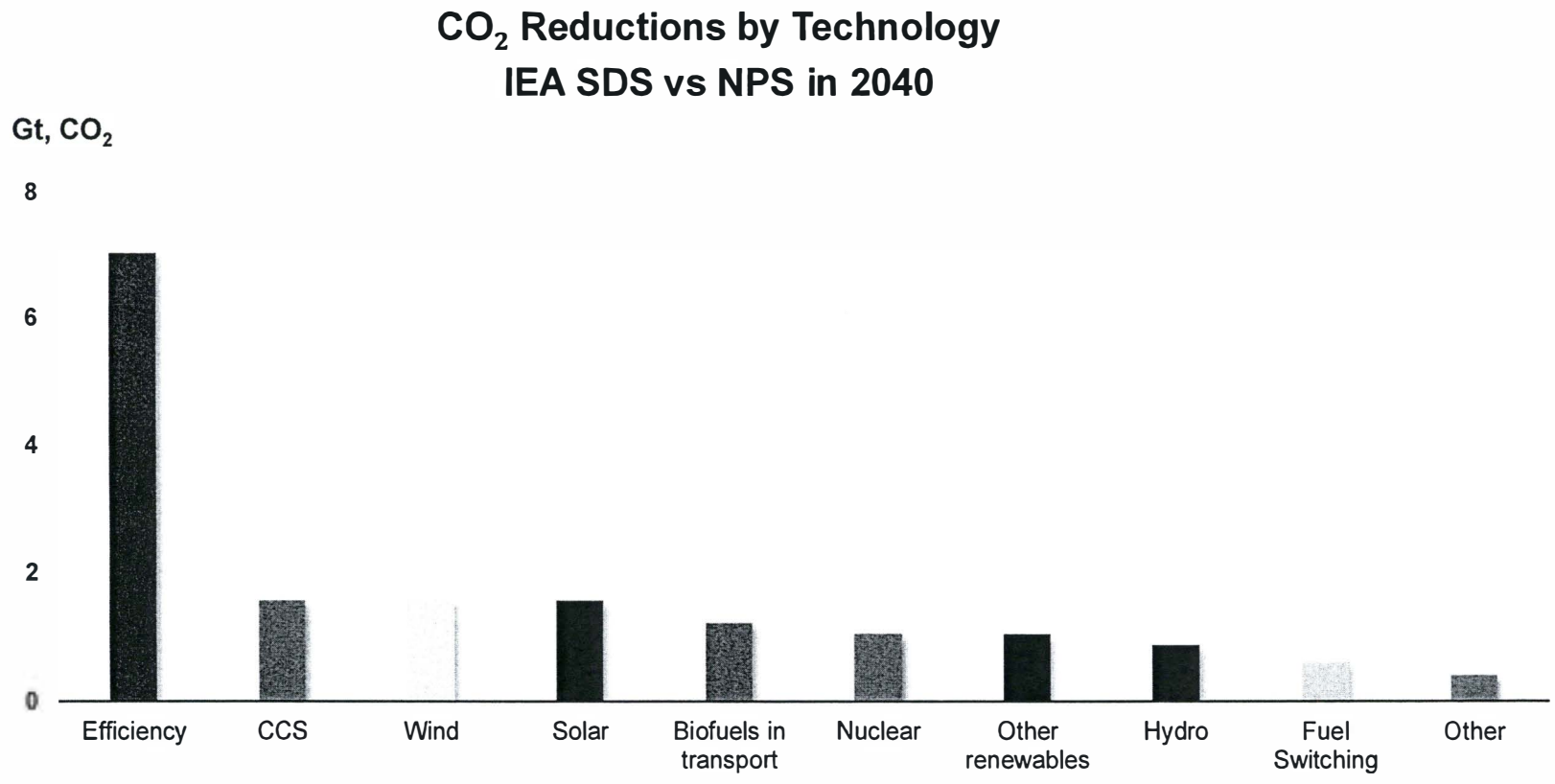
Lightweight Packaging

FUEL TECHNOLOGY Synergy™

Advanced Fuels and Lubricants

ExxonMobil

How important are various technologies to close the 2°C gap?

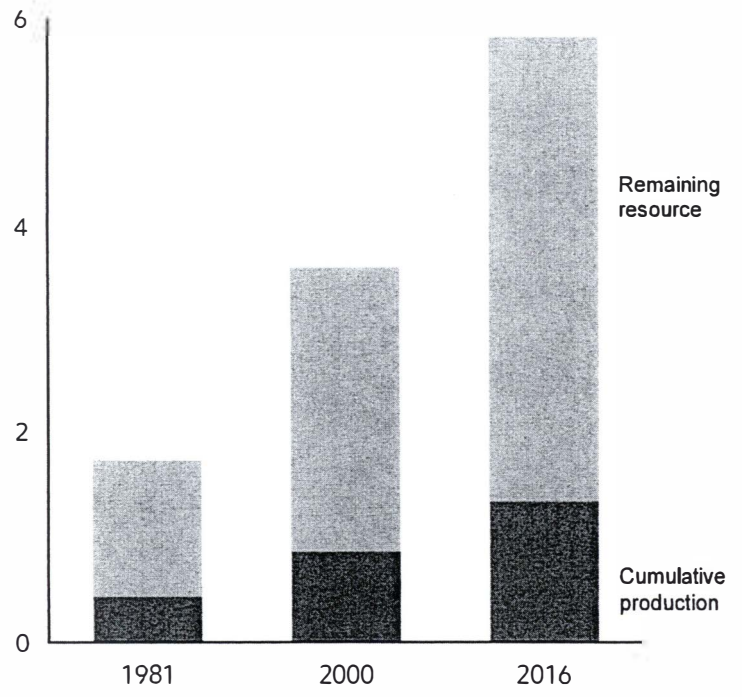


Source www.iea.org/tcep/

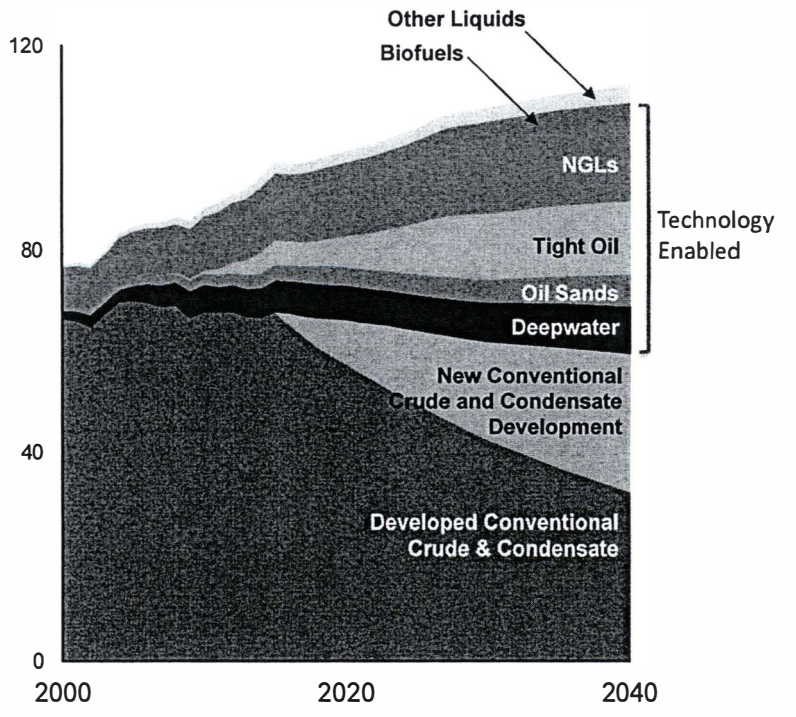
ExxonMobil

Technology Expands Recoverable Reserves

Crude & condensate technically recoverable resources
Trillion Barrels



World Liquid Supply by Type
MBDOE

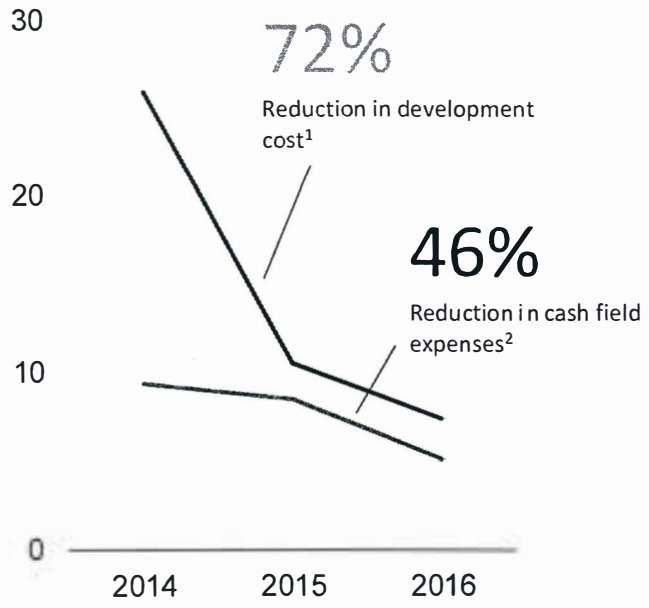


Sources: USGS, IEA

ExxonMobil

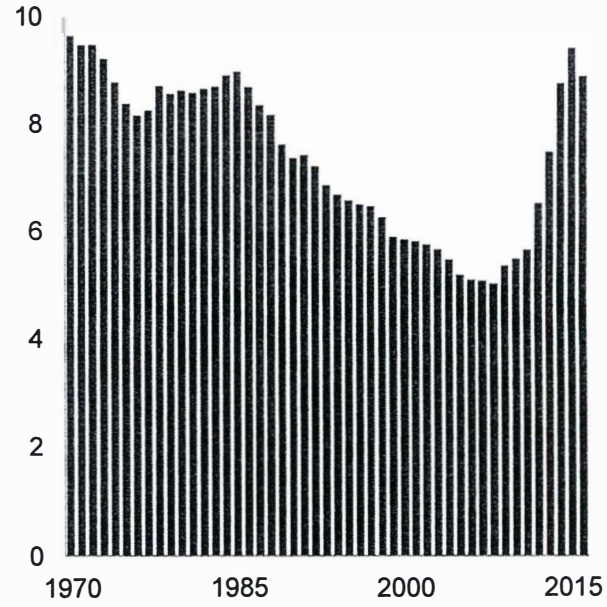
Technology Enabled Production Growth

Permian Basin Drilling & Completion Costs
$/OEB[1]



1 Drilling & Completion cost only; EM operated Midland basin horizontal wells
2 Represents costs associated with field operations and maintenance of wells; excludes energy and production taxes.

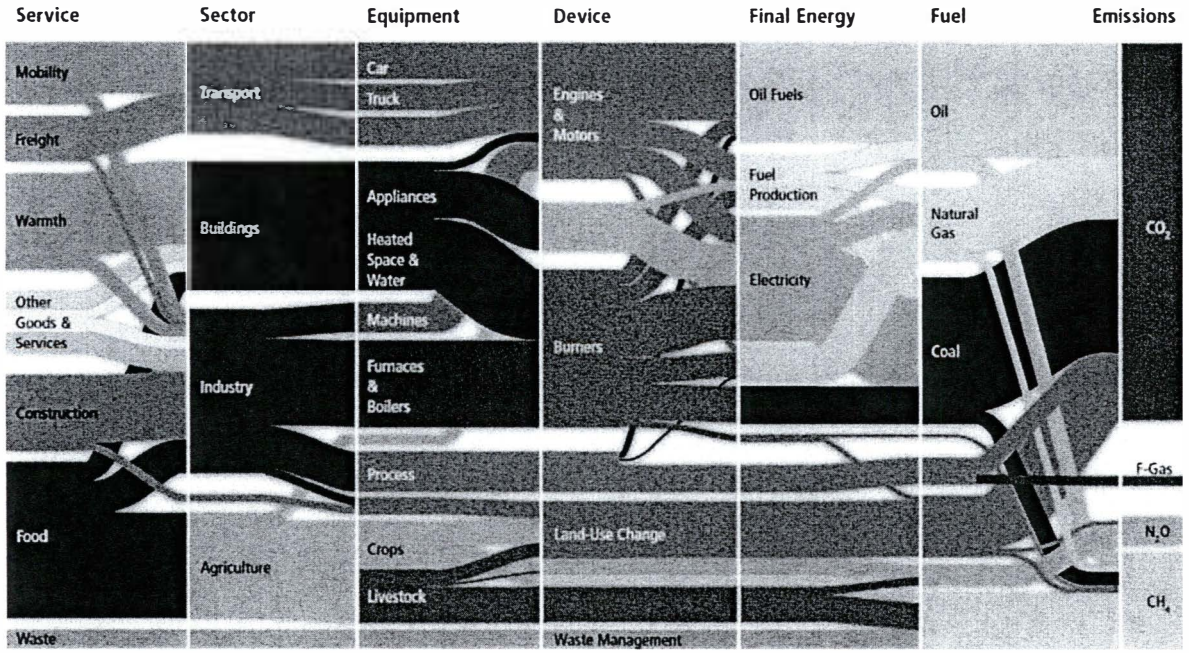
U.S. Crude and Condensate Production
MBDOE



Source: EIA

ExxonMobil

Energy Mix Evolves Slowly Due to Complexity and Scale



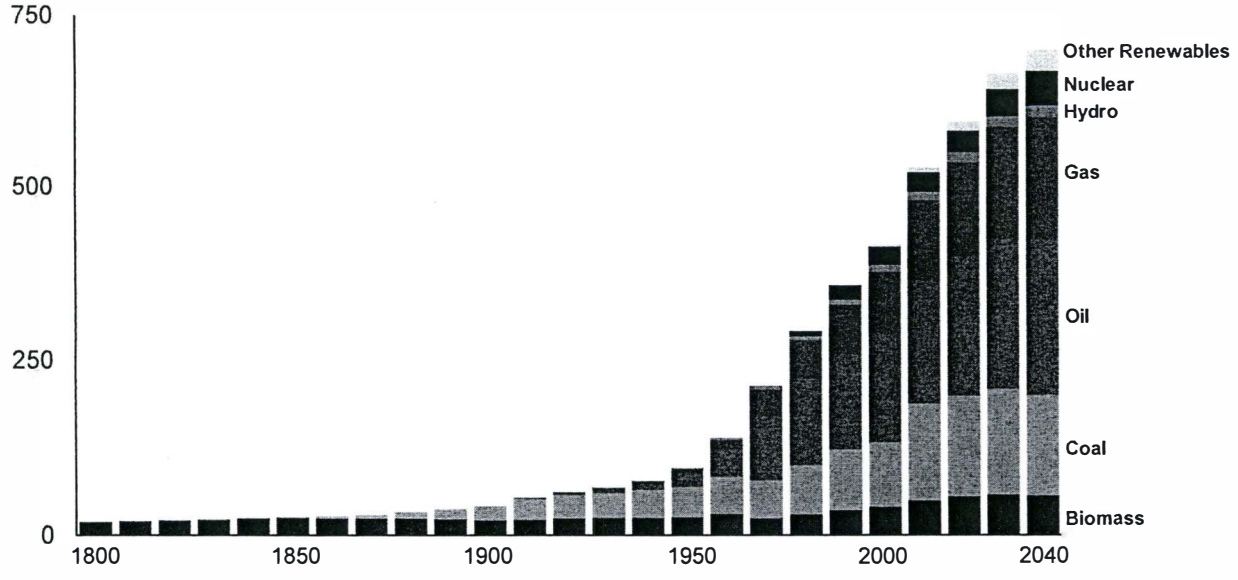
Source: IPCC AR5 WG3, Ch 10 (2014)

ExxonMobil

Energy Mix Evolves Slowly Due to Complexity and Scale

Global Mix of Fuels

Quadrillion BTUs



Source: Smil, Energy Transitions (1800-1960)

ExxonMobil

PROPOSED DUMMY AMENDMENTS TO HOUSE BILL NO. 1225

Page 1, line 1, remove, "legislative management" and ";and"

Page 1, line 2, remove "to provide an appropriation"

Page 1, line 4, replace "legislative management" with "future energy innovation"

Page 1, line 4 replace "future energy innovation" with "report to legislative management"

Page 1, line 5, replace "legislative management" with "Empower Commission"

Page 1, line 5, replace "study" with "consider studying"

Page 1, line 8, replace "legislative management" with "Empower Commission"

Page 1, line 8, replace " report its findings and recommendations" with "provide a report to the legislative management"

Page 1, replace line 9 with "by June 30, 2020 regarding the results and recommendations of the study."

Page 1, remove lines 10-15.

Renumber accordingly

HOUSE BILL NO. 1225.

Introduced by

Representatives Steiner, Guggisberg, Hatlestad, Keiser, Meier, M. Nelson, Rohr

Senators Bekkedahl, Unruh

A BILL for an Act to provide for a ~~legislative management~~ study of future energy innovation~~; and to provide an appropriation~~.

BE IT ENACTED BY THE LEGISLATIVE ASSEMBLY OF NORTH DAKOTA:

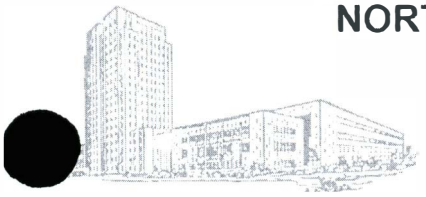
SECTION 1. ~~LEGISLATIVE MANAGEMENT~~ FUTURE ENERGY INNOVATION STUDY - ~~FUTURE ENERGY INNOVATION~~ REPORT TO LEGISLATIVE MANAGEMENT.

During the 2019-20 interim, the ~~legislative management~~Empower Commission shall ~~study~~ consider studying current methods of creating consumable energy and future innovative methods of creating consumable energy, the timetable for implementing new innovations, and the estimated future annual economic impact of new innovations. The ~~legislative management~~Empower Commission shall ~~report its findings and recommendations, together with any legislation necessary to implement the recommendations, to the sixty-seventh legislative assembly~~ provide a report to legislative management by June 30, 2020 regarding the results and recommendations of the study.

~~**SECTION 2. APPROPRIATION.** There is appropriated out of any moneys in the strategic investment and improvements fund in the state treasury, not otherwise appropriated, the sum of $500,000, or so much of the sum as may be necessary, to the legislative council for the purpose of contracting with consultants to study future energy innovations, for the biennium beginning July 1, 2019, and ending June 30, 2021.~~

HB 1225
3.1.19
#1
Pg.1

NORTH DAKOTA HOUSE OF REPRESENTATIVES



STATE CAPITOL
600 EAST BOULEVARD
BISMARCK, ND 58505-0360

Representative Vicky Steiner
District 37
859 Senior Avenue
Dickinson, ND 58601-3755
vsteiner@nd.gov

COMMITTEES:
Finance and Taxation
Government and Veterans Affairs, Vice Chairman

March 1, 2019

Good morning Chairman Unruh and Members of the Senate Energy and Natural Resources committee

Vicky Steiner, District 37, Dickinson, ND

House Bill 1225 is about our state's energy future long term.

North Dakota exports its energy resources to the rest of the country and the world. Our energy companies are responding to market demands that impact future state tax revenues. As you may have read last week, coal plants in N.D. may be closing in the future and renewables are disrupting markets.

Today and probably for at least 10 years, I believe the Bakken will see a relatively strong market.

We are in a digital revolution, an explosion of video on the Internet, a world of collaboration which will lessen the ability of large corporations to integrate entire energy systems as are done today.

Economists say it's like the industrial age- how the combustion engine changed America in 40 short years. It begs the question- in 40 years- where is the market for the Bakken? How long do you think this type of revenue will continue? 20 years at best? The oil and gas industry is forecast to provide $4 billion in revenue in the next two years. How will our revenue stream from the Bakken change over time?

The Dept of Mineral Revenues had reported a few years ago that by 2055, ND may become more of gas producing state. But where are gas markets after 2045?

I've attended NCSL Energy Supply Taskforce meetings the past two years in which the discussion has been more focused on the rapid growth of wind, natural gas peaking plants, microgrids and solar power in west and east coast states. A Maryland senator complained that Maryland needs to get its own wind power because it's too expensive to keep buying it from North Dakota. How much wind is sold to the east coast and when will they expand their own wind supply? Floating wind turbines can operate 29 miles off shore on east coast states in shallow waters that will not be visible from shore. Just as the taxi industry was upended by Lyft and Uber, the energy industry will most certainly continue to be disrupted.

In November 2018 issue of Environment and Climate News from Heartland Institute, the headline was California billionaire Tom Steyer paid to put a renewable energy measure is on the Nevada ballot. Tom Steyer hopes voters across the country will agree with his agenda. Nevada passed s the bill requiring utilities to have portfolios of 50 percent of renewables of wind, solar and hydro by 2030. Nevada is just one of the states he targeted, other states are on his list. He spent $6 million for this initiative. If North Dakota is next, what is at stake long term?

If you look at the last ten years and the ballot initiatives from

[redacted]bbled by renewable energy mandates, FirstEnergy Solutions Corporation announced it will deactivate in 2021 and [redacted]22 four fossil fuel powered electric plants in Ohio and Pennsylvania. They also have deactivated their nuclear plant. It's estimated in Pennsylvania there will be 11,400 jobs eliminated. Pennsylvania's renewable portfolio standard mandates 18 percent of all electricity be renewable at an estimated cost of $700 million dollars.

How much wind power will our state likely have in 2045? We have 41 wind farms in ND currently. How many more will there be in 20 years and what will the landscape look like?

2045 is the year that California has a mandate to be 100% renewable energy. Although, technically, experts say you'll always need a fossil fuel or nuclear plant running in the background to support renewables, their goal will be difficult to attain. Currently, rooftop solar and community solar systems are all the rage in their state. CCA or Community Choice Aggregation allowed to form under California law demand renewables in their power mix. Cities or counties, under this law, are allowed to purchase and/or generate electricity for their residents. These CCA's go out on the market to meet their residents demand but it is impacting reliability on the west coast grid. Washington hydro power has been their back up when demand is high and they can't find enough power.

Micro-grids are forming to take advantage of battery storage. A good example is San Diego State University. They run independent of San Diego as their own micro grid, experimenting with new battery storage ideas, using groundwater to cool their computer buildings. They have public electric car chargers that they invite the public in to use along with university fleet. The former MDU refinery, now owned by Marathon, mentioned by the Governor in his State of the [redacted]tate speech, is being converted to make renewable diesel with soybeans. This product will be shipped to California by [redacted]in. To me, this is a red flag.

Jeremy Rifkin, an economist who spoke at NCSL in Los Angeles in July, said " The legacy fossil fuel industries, and the countries that depend on them, will suffer. I've included his forecast white paper. **According to a recent study by Citibank, the energy industry and power and transmission companies today are sitting on potentially $100 trillion in stranded assets**.

At a meeting in Washington, D.C., an executive from Exxon Mobil said their corporation is moving into biomass because that's their "specialty" is how he worded it. I asked him if they plan to strand their oil and gas assets. He said no, they have an 18 year drill out plan and do not plan on stranding anything. However past 2050, the path is not defined as it is now. It's more uncertain, he said.

We are flaring gas at record levels. By the time we have adequate pipelines to take the product to markets south of here, what will its value be? Should we store it to use later or push it out faster?

A speaker in Boston at another Energy Supply Taskforce meeting in 2017, Dr. Chandra V. (Visweswariah) said there are 4 disruptive trends.

1- availability of data with large date centers
2- pace of solar and wind adoption and declining cost (wind and sun don't ask for cost of living increases)
3- advent of heat pumps so efficient
[redacted] battery storage and electric vehicles - eventually you won't be able to buy a gas fueled car. Dr. Chandra is President and CEO of Utopus Insights.
He is a strong believer in economic and environmental forces that will create a clean energy future. He said it will be a "veritable energy utopia."

China owns most of the rare earth minerals used in cell phones, televisions and wind turbines, military aircraft. The Dept. of Energy asked North Dakota to search for their own sources. Slope county has the greatest concentration of [redacted]e earth minerals but is it marketable?

There are so many unanswered questions about energy and its future use. The Empower Commission members have volunteered to take up the long-term questions with their company experts. Before we can develop a plan, we need much more information on how this digital revolution, changing consumer demand, fossil fuel market disruption, expansion of hydrogen and electric vehicles impact North Dakota's long-range future for its coal, oil, natural gas, wind stakeholders.

Empower Commission has been added when the money was stripped because they've volunteered to do this for free.

I don't think that's the best option but certainly an option. The original bill had $500,000 to bring diverse opinions to the study so do what you can.

I would ask for a Do Pass on HB 1225 to gather research to which we could develop a strategic energy plan for 2050 for our state. Thank you.

HB 1225
3.1.19
#2

strategy+business

ISSUE 89 WINTER 2017

The Thought Leader Interview: Jeremy Rifkin

The influential economic theorist looks ahead to a world of virtually free energy, zero marginal cost production, widespread abundance, and a desperate race against climate change.

BY ART KLEINER AND JULIETTE POWELL

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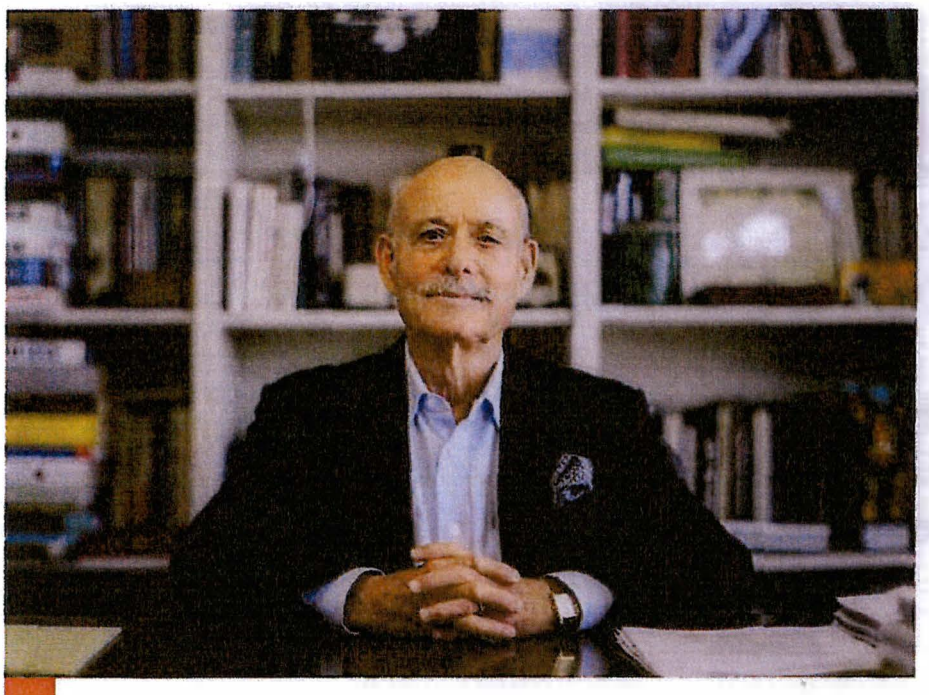
The Thought Leader Interview: Jeremy Rifkin

The influential economic theorist looks ahead to a world of virtually free energy, zero marginal cost production, and widespread abundance, and to a desperate race against climate change.

BY ART KLEINER AND JULIETTE POWELL



Photograph by Hector Emanuel

Most people in the business world are aware of the convergence of computer and communications technology, the shift in energy from fossil fuels to renewables, and the movement toward self-driving vehicles and robot-driven manufacturing. But only a few people are thinking intensively about how all these technological changes will fit together — along with changes in advanced manufacturing, water systems, agriculture, healthcare, and education — to generate rapid, widespread growth accompanied by a dramatic reduction in ecological footprint.

This systemic approach to the industrial future is the domain of economic theorist Jeremy Rifkin. Rifkin, 72, is a longtime commentator on economic and technological issues and a lecturer in the executive education program at the University of Pennsylvania's Wharton School of Finance. He is a consultant to heads of state (including the top leadership of Germany, the president of the European Commission, and the leadership of the People's Republic of China), along with many companies (including PwC, the publisher of *strategy+ business*). And yet his logic is controversial in many business circles. He argues, for example, that both capitalism and the fossil fuel industries are hitting limits that stem from the laws of thermodynamics. Investor-based capitalism, which focuses resources for immediate returns, will inevitably be replaced by a more distributed and streamlined network-based capitalism, alongside a sharing economy governed by a high-tech global commons.

According to Rifkin, this new hybrid economic system will be made possible through the provision of solar, wind, and other renewable energy on demand, facilitated by innovations such as the Internet of Things and blockchain. In the world he envisions, the costs of producing and delivering an increasing array of goods and services will dwindle to near zero, and economies will have to learn to manage abundance — and the use of shared goods and services. These shifts will happen during the next 40 years or so, he says, unless they are cut short by the exponentially increasing dangers of climate change and species extinction.

Rifkin outlined his thesis in three successive books: *The Empathic Civilization: The Race to Global Consciousness in a World in Crisis* (Penguin, 2009); *The Third Industrial Revolution: How Lateral Power Is Transforming Energy, the Economy, and the World* (Palgrave Macmillan, 2011); and *The Zero Marginal Cost Society: The Internet of Things, the Collaborative Commons, and the Eclipse of Capitalism* (Palgrave Macmillan, 2014). His ideas were featured in a 2017 documentary film, *The Third Industrial Revolution* (Vice Media). Two massive initiatives for which he is an advisor — the E.U.'s "Smart Europe" and China's "Internet Plus" — are, in a sense, manifestations of his world view.

Even those who do not agree with Rifkin's theory that capitalism is in the midst of a fundamental transformation must respect the exponential power of the forces he is tracking. Intelligent technology, in particular, is expanding at an ever-increasing rate, lowering costs, replacing human labor, tracking human activity, and making many new things possible — which could be the "dark net" of authoritarian surveillance or a broadening of wealth and quality of life. Rifkin sat down with *strategy+business* in late August at the Bethesda, Md.–based headquarters of his primary organization, TIR Consulting Group, to explain his arguments in greater detail.

> "It had been clear, even before the dot-com bubble collapsed in 2000, that the digital revolution was forcing down costs."

S+B: The "zero marginal cost society" concept suggests we're heading into a time of abundance that will radically change the way people live. How did you come to this idea?

RIFKIN: In the early 2000s, I was teaching in the advanced management program (AMP) at Wharton Executive Education. It had been clear, even before the dot-com bubble collapsed in 2000, that the digital revolution was forcing down fixed and marginal costs in information and communications technology in an exponential way, as described by Moore's Law.

Marginal costs are the costs of taking a product to scale, and these had already gone to near zero in media and software. Once you've paid the fixed costs to record a song, the marginal cost of streaming the music is virtually zero, whether you stream a thousand or a million copies. Newspapers, television, record labels, and the film industry discovered that they could no longer rely on their old business models, especially if they involved advertising.

S+B: But this applied only to digital media.

RIFKIN: At the time, yes. But we saw that this might soon apply to other parts of the economy as well. One major signal, for us, was the pressure IBM felt, starting in the mid-1990s. [Then CEO] Lou Gerstner, at a retreat with the company's top executives, said out loud that they had a problem. Their cash cow was the big

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mainframe computer. But as competition increased, and the price of computers continued to plummet, where would their profits come from? That led them to shift, in part, to managing information services.

In our AMP classes, I introduced the idea that the digital revolution, and dropping of marginal costs down to near zero, represented the ultimate success of capitalism. But it would also force a radical shift in the nature of the capitalist business model.

S+B: By capitalism, you mean market-based economies, governed by the laws of supply and demand, without government controls.

RIFKIN: By capitalism, I mean a particular type of market economy where the investors, owners, managers, workers, and consumers are all separate people. Capitalism of this sort is only 200 years old.

Let's step back for a moment and consider how the great economic transformations in history occur. There have been a number of them in world history, and they all have a common denominator. At a single historic moment, the same three defining technologies emerge and converge to create a new general-purpose technology infrastructure. They fundamentally change the way society manages, powers, and moves economic activity. The three technologies are new communication systems that manage economic activity more effectively; new sources of energy that power the activity more efficiently; and new modes of mobility that move the economic activity more rapidly. This changes society's spatial temporal orientation, its business models, its forms of governance, and even people's cognition and consciousness.

> "There have been a number of great economic transformations in world history, and they all have a common denominator."

For example, consider the first Industrial Revolution, which took place in the 19th century. Before then, there were very few large businesses. Most merchants owned the tools they used — the means of making, delivering, and trading goods. Then came new technologies for communications, energy, and mobility. The steam-powered printing press, which made possible cheap newspapers and mass-produced books, transformed communications. This enabled more widespread literacy; with textbooks, there could be compulsory public school systems. The invention of the telegraph annihilated space and compressed time, making possible national and even global markets. The coal-based steam engine, a new form of energy, made it possible to manage production at a much larger scale. That engine was then put on rails, giving rise to a national system of locomotive-based transportation, further speeding up the managing, powering, and moving of economic activity and the geographic expansion of markets.

These technological changes were so broad and complex that they required a new form of manage-

ment. Railroads became the first modern capitalist business corporations, with thousands of employees, vertically integrated operations, and shareholders separated from the business. Once all three technologies were in use, around 1860, modern capitalism rolled out quickly around the world. By 1900, in less than 40 years, the world had been transformed.

A second industrial revolution followed in the early 20th century. This involved the invention of the telephone and, later, radio and television; the widespread use of fossil fuels; the laying out of electricity grids; and the introduction of the internal combustion engine for road, rail, water, and air transport. The second industrial revolution's juvenile infrastructure was put in place in the United States and elsewhere between 1905 and 1929. Its growth was interrupted with the coming of the Great Depression and World War II, and it finally matured in the second half of the 20th century across the industrial world.

S+B: And by the early 2000s, you were saying that way of life was obsolete.

RIFKIN: We saw that the productivity potential of the second industrial revolution technology infrastructure had run its course. Meanwhile, a dramatic reduction in fixed and marginal costs had already occurred in computers and communications, and would probably occur elsewhere as well. And as this happened, it would change the economy so that neoclassical economic theory would no longer suffice to describe it.

The world was entering a third industrial revolution — a digital revolution. [Note: Although the numbers differ, what Rifkin calls the third industrial revolution and the broad technological shift known as "Industry 4.0" are roughly the same movement.] In a digitally connected society, the marginal costs of an increasing number of goods and services would fall to near zero. This would force a fundamental change in prevailing business models: from markets to networks, from ownership to access, from workers to "prosumers" [individuals who produce as well as consume goods and services distributed on the Web], from sellers and buyers to providers and users, and from consumerism to sustainability — and the second industrial revolution's economies of scale would no longer apply. The communications part of it had already happened: Inexpensive computers and the Internet existed, and the smartphone had just been invented. It took a while to see that the same phenomenon could occur in the world of atoms, and dramatically reduce the cost of energy, mobility, and other goods and services.

The Next Infrastructure

S+B: So when you say "third industrial revolution," what change are you referring to?

RIFKIN: A new technological infrastructure is gradually coming together, brought on by digitization. The process began with the maturation of the communications Internet over the past 25 years. Now this is converging with a second Internet, this one for renewable energy. It's a new digital power grid, stretching across continents, which allows millions of people to produce their own wind and solar electricity and send their excess power generation back into the system. Both of these Internets will converge, during the next decade, with an emerging digitized mobility Internet composed of increasingly autonomous electric and fuel-cell vehicles operated by near-zero marginal cost renewable energy on smart road, rail, water, and air systems. These three systems will allow people to share communication, energy, and mobility partially in the capitalist market and partially in the emerging sharing economy.

S+B: Where will this shift happen first?

RIFKIN: It's already happening in some places. Germany has been quietly building out the necessary infrastructure for the past 10 years. When Angela Merkel became chancellor in 2005, she asked me to advise her on growing the German economy. She and I discussed the potential of transforming Germany into a third industrial revolution paradigm. Almost immediately, she and her colleagues resolved to be-

come world leaders in the third industrial revolution.

Since then, Germany has been working on all three fronts: the digitization of communications, renewable energy, and mobility. I have been working closely with senior government officials there, including president Frank-Walter Steinmeier and vice chancellor and economy minister Sigmar Gabriel. Under the plan they put in place, one-third of German electricity is now produced through renewable energy, at near-zero marginal costs. Installing solar and wind technologies is tremendously labor intensive, at least during this transition. Germany has created hundreds of thousands of net jobs this way, and now there are more jobs in renewable energy than in the rest of the energy industry combined.

On a parallel track, I have worked with three presidents of the European Commission — Romano Prodi, José Manuel Barroso, and the current president, Jean-Claude Juncker — in the conception and deployment of a smart digital third industrial revolution across all 28 member states of the European Union. In February 2017, I joined Maroš Šefčovič, the vice president of the European Commission in charge of the E.U. Energy Union and Smart Europe, and Markku Markkula, the president of the European Committee of the Regions, in announcing the launch of the Smart Europe initiative. A €631 billion [US$744 billion] kitty for investment — the Juncker Fund — will now be partially available for its deployment.

The other center of activity is China. When President Xi and Premier Li came into office, Premier Li published his official biography, which mentioned that he had read [my book] *The Third Industrial Revolution* and had instructed the central government to pay close attention to the narrative and proposals outlined in the book. President Xi and Premier Li realized that their country had been locked out of the first Industrial Revolution and much of the second, and they didn't want to lose out on the third. Shortly after the first of several formal visits I had with Chinese leaders, the chairman of the national electric power grid announced an [US]$82 billion commitment to digitize the state electric power grid in the current Five-Year Plan. Millions of Chinese people can produce their own solar and wind power, and use it locally or sell it back to the grid. With the Belt and Road project, they're moving the same technologies to other countries. China calls this digital transformation the Internet Plus revolution, which is similar to the Smart Europe initiative. Of course, China is still one of the world's largest users of fossil fuels, but that is rapidly changing.

Parts of the U.S. are also moving in this direction, without much government involvement: California, Oregon, Washington state, New York, New England, and the San Antonio–Austin area in southeastern Texas. There are wind farms in the prairie states and many large companies and small entrepreneurial startups, all hoping to lead the transition.

The payback for renewable energy is much more rapid than people think. The fixed costs — materials and installation — have gone down exponentially. In 1979, the fixed cost of producing one watt of solar electricity was $79. As of August 2017, it's 55 cents. By 2020, it will be 35 cents. The viability of the technology is just now reaching a tipping point. As for the marginal costs, there aren't any. The sun and wind haven't sent us a bill.

S+B: What about mobility and communications?

RIFKIN: Already, millions of people use car-sharing networks as their primary mode of transportation. Millennials don't want to own automobiles. They want access to mobility in car-sharing networks. Meanwhile, the marginal costs of autonomous, self-driving electric vehicles operating with near-zero marginal cost renewable energy will plummet. Drones will also operate with near-zero marginal costs. Today, there are about a billion cars, buses, and trucks, and they are the third major cause of global warming emissions, after buildings and beef production and consumption and related agricultural practices. We'll likely eliminate 80 percent of vehicles in the world in the next two generations as we shift to car and truck sharing [via] provider–user networks.

The cars and trucks that are left will become, in effect, rolling, mobile distributed data centers outfitted with sensors that pick up and share information on traffic, weather conditions, warehouse availability, and logistics. Daimler has already quietly outfitted more than 400,000 of its motor trucks with sensors. This will increase aggregate efficiency and productivity, while dramatically reducing ecological footprint.

> "In 1979, the fixed cost of producing one watt of solar electricity was $79. As of August 2017, it's 55 cents. By 2020, it will be 35 cents."

The Key to Productivity Growth

S+B: Doesn't this contradict what people like Robert Gordon and Erik Brynjolfsson have been saying about productivity growth — that it is not likely to pick up again?

RIFKIN: They haven't taken aggregate efficiency into account. Aggregate efficiency is the ratio of potential work to the actual useful work that gets embedded into a product or service. The higher the aggregate efficiency of a good or service, the less waste is produced in every single conversion in its journey across the value chain.

A few economic researchers, like physicist Reiner Kümmel at the University of Würzburg and economist Robert Ayres at INSEAD, have reconsidered productivity in recent years. Traditional economics says you increase productivity by investing more capital in better machines and by providing better-performing workers, all of which reduces the fixed and marginal cost of production. But these factors account for only about 14 percent of productivity. Much of the rest of productivity is accounted for by the improvement in aggregate efficiency in the managing, powering, and moving of economic activity.

Aggregate efficiency works the same way in economic production as it does in nature. When a lion chases down an antelope and kills it, only about 10 to 20 percent of the entire energy in the antelope gets embedded into the lion; the rest is heat lost in the transition. So the lion's aggregate efficiency is only 10 to 20 percent. If it could consume more of its prey's energy, or use less of its own in the hunt, the lion would gain productivity as a predator.

Economists are now learning that aggregate efficiency is a critical determiner in productivity growth. In the past, economists have missed this because they have not been trained in thermodynamics; chemists, engineers, biologists, and architects get it.

When the second industrial revolution began around 1905, there was about 3 percent aggregate efficiency in the U.S. production of goods and services. Mass production methods dramatically improved this level, and productivity rose as a result. But there were limits to the efficiency of 20th-century telecommunications, fossil fuel–based energy systems, and internal combustion–driven transportation. By the beginning of the 21st century,

the U.S. was up to around 13 percent aggregate efficiency; Germany had reached 18.5 percent; and Japan led the world at 20 percent aggregate efficiency. That was the ceiling, and productivity growth stagnated. Businesses that plug into the second industrial revolution infrastructure can no longer significantly increase their aggregate efficiency and productivity in managing, powering, and moving their goods and services through their value chains.

Now, with the digital third industrial revolution more fully under way, aggregate efficiency is about to rise again — perhaps exponentially this time. Two factors are the vastly reduced costs of communication, energy, and transport that we talked about. Another is the Internet of Things. The cost of sensors and identification chips is, for the first time, dropping low enough to allow us to embed them in trillions of devices: thermostats, assembly lines, appliances, warehouse equipment, and more, all gathering data. With the IPv6 protocol, those devices can be interconnected through the Internet. When intelligent technology is embedded in homes, offices, factories, and infrastructure, everyone will have a transparent picture of all the economic activity flowing through the economy, with the ability to mine it and use predictive analytics to improve thermodynamic efficiency and productivity while reducing the ecological footprint of economic activity.

The impact will be immense. For instance, an improvement of just 1 percent in aviation engine fuel efficiency, which GE posits as a baseline for its new systems, would save $30 billion over 15 years. The intelligent value chain would be continually learning how to create, use, upgrade, recycle, and reuse physical goods at an ever lower cost. We'll have an economy of partial abundance, full of many nearly free products and services provided at near-zero marginal cost.

S+B: What would living in that economy of abundance be like?

RIFKIN: We're witnessing the birth of a new economic system: a hybrid of the existing capitalist structure and the sharing economy. Most of the goods and services that [make up our] quality of life will be much less expensive. It will be easier to broaden prosperity, without having to fight over scarce resources, in part because it will be much easier to make the most of the resources we have.

Cooperatives, free services, and app-based resource-sharing enterprises will crowd out some — but not all — of the incumbent corporations that depend on fixed-cost business models. We already saw this with digital communications. Whole industries were disrupted: music, television, newspapers, publishing, magazines, educational media. But new businesses emerged, and not just the major platforms like Facebook, Google, and Amazon. Millions of individuals are producing and selling or sharing virtual goods, like music, videos, and writing, at near-zero marginal production cost, using blogs and social media to find audiences. Millions of students are taking massive open online college courses and getting college credits. The most notable is Jimmy Wales's experiment with Wikipedia: It's the sixth-largest website in the world, operated with $50 million in donations a year. For the first time in history, the knowledge of the world is being democratized: People from all walks of life have constructed it in a peer-reviewed platform, with accuracy at least equal to that of top-down encyclopedias. When anyone puts something up on Wikipedia, there are people crawling all over it within hours, checking

their sources or amplifying their text with additional information.

Investor capitalism won't disappear; it will live side by side with the sharing economy. In the emerging era, the cooperative form of business is being reinvigorated because of the lateral scaling advantages made possible by a digitally interconnected global economy with near-zero marginal cost. There were already successful cooperatives around the world, many of them dating back to the early 20th century. A billion and a half people work in them, in industries like agriculture, food production, housing, banking, and energy. They have new life now that there are IT-based tools, such as blockchain, that make it easier to collaborate, and because of the scaling advantages made possible by the digitally interconnected global economy.

> "We're witnessing the birth of a new economic system: a hybrid of the existing capitalist structure and the sharing economy."

The four largest German power companies — EnBW, RWE, E.ON, and Vattenfall — dominated the power and electricity market for years. But together, they own only about 5 percent of all installed capacity of renewable energy in the country. The rest is generated by small companies and cooperatives: democratically managed enterprises in which the profits go to the members. At least two of the big four power companies in Germany are becoming distributors and aggregators of renewable energy that the small players generate across the country. These new electricity cooperatives — some representing farmers, others run by small business groups or urban neighborhood associations — have received low-interest loans from the banks and put up solar and wind generation installations. None of these companies defaulted on their loans. Instead, they sold their extra energy back to the power grid. Cooperatives scale more efficiently than the large incumbent power companies. There are similar electric power cooperatives in the United States.

Abundance and Its Discontents

S+B: What effect will this have on today's energy and transportation industries?

RIFKIN: The legacy fossil fuel industries, and the countries that depend on them, will suffer. According to a recent study by Citibank, the energy industry and power and transmission companies today are sitting on potentially $100 trillion in stranded assets. These include exploration rights, leases, and infrastructure for the extraction of fossil fuel that will be underpriced by renewables. Countries like Saudi Arabia and the Emirates, with oil-based economies, see the disruption coming. So do some of the major oil companies. Other players in the energy industries are simply in denial. But for those that are willing to adapt, there will be some time. We're not leaving the second industrial revolution entirely tomorrow morning. This is a

30- to 40-year transition stretching over two generations.

In the end, the economy may no longer be controlled by a small group of centralized, global, vertically integrated companies. The first and second industrial revolution infrastructures were centralized, proprietary, and vertically scaled because the communication, energy, and transport technologies worked best that way. By contrast, the coming infrastructure of 5G communication, renewable energy, and automated mobility works best if it's distributed, open, transparent, crowd-sourced, and laterally scaled. The more users on the network, the more everyone benefits. With any attempt to monopolize, control, or centralize it, the infrastructure loses aggregate efficiency and productivity. Even today's giant Internet platforms, if they become too centralized, will be vulnerable to others coming in and taking their place.

We'll see a similar kind of change in education. The public school system was a great leap forward in the 19th century, but it was introduced to prepare a generation for the first industrial revolution of factory and office employment, and then was only slightly upgraded for the second industrial revolution. A school designed for that time is a microcosm of a factory. The teacher instructs, and the students are supposed to memorize the knowledge and recite it back. Every 50 minutes a bell rings and they move to the next spot on the line. They're being trained to be efficient automatons operating machines. If the students share information, and help each other, it's called cheating.

Today, millennials have an alternative. Outside the classroom, they're all learning together on their smartphones. They're crowdsourcing, playing online games together, and sharing their knowledge. We need to move toward a new kind of school that recognizes this collaborative interconnectivity.

> "In the end, the economy may no longer be controlled by a small group of centralized, global, vertically integrated companies."

One model for this change is in Hauts-de-France — the rust belt of France, where its coal, steel, and auto industries are based. Beginning in 2010, our global consulting team began working with the region to revitalize its economy, working alongside the government, the business community, and civil society, with several thousand people participating in scores of committees and projects. They are transforming old mining towns, retrofitting them with solar and wind power sources, and starting entrepreneurial enterprises.

The region brought together seven universities and more than 250 secondary schools in a consortium to think in terms of digital education. They didn't eliminate departments, but all the departments now teach in an interdisciplinary fashion, with multiple perspectives. The students work in teams, and they have to teach one another, with the faculty operating as guides. They also ratcheted up service learning, so that students at all levels work outside in the communities, and have to teach and learn collaboratively with the community businesses and neighborhoods. There is a robust level of social entrepreneurialism involving students, teachers, and their neighborhoods in ways that generate more positive community value.

S+B: You've portrayed the upside, but what about the downsides?

RIFKIN: Although the digital third industrial revolution could bring about a more democratic and ecological era, it is by no means guaranteed. I'm not a utopian in regard to technology. Indeed, I've been critical of some technologies over the years. There are going to be many political struggles along the way. For example: How do we ensure data privacy when everyone's connected?

How do we prevent cybercrime and cyberterrorism? And how do we prevent Internet companies, the big ones, from monopolizing the platform for commercial purposes and exploiting the information they gather? Increasingly, members of the millennial generation are aware that their personal information is commodified and sold to third parties, which incorporate it into algorithms and use it for marketing and other purposes. Authoritarian governments can use that same information to control what people do politically.

These are qualitatively big issues. In Europe now, policymakers are recognizing that these issues of the dark net are as formidable as the possibilities are bright, and they will have to spend at least 50 percent of their regulatory capacities managing them. It's naive to think that companies like Google, Facebook, Amazon, and Twitter can maintain their current practices without regulation. The battles over this have already started.

And the biggest shadow in the room is climate change. Most scientists had thought that we had another 100 years before facing a significant crisis, but we didn't fully anticipate the feedback loops brought on by global warming emissions — the more the Earth warms, the more the process of climate change accelerates. We probably have less than 30 years to effectively exit a carbon-based civilization.

The most recent indicators of change have scared the living daylights out of me. For every one degree rise in the temperature of the planet brought on by global warming emissions, the atmosphere is absorbing 7 percent more precipitation from the ground and the oceans, leading to more concentrated precipitation in the clouds and more extreme and unpredictable water events — blockbuster winter storms, dramatic spring flooding, prolonged summer droughts and wildfires, and category three, four, and five hurricanes. Our ecosystems cannot catch up to a runaway exponential curve in the water cycles and are collapsing in real time, taking us into the sixth extinction event of life on Earth over the course of the next half century. Even in a world of abundance, climate change is the dark shadow that could foreclose opportunities for present and future generations and for life itself on Earth.

Fortunately, the third industrial revolution is based on post-carbon technology. Moreover, it's inclined toward a highly diverse and distributed infrastructure. The more diverse, redundant, and distributed the networks and systems are, the more resilient the infrastructure is, and the less vulnerable it is to cybercrime, cyberterrorism, or natural disasters from climate change.

But there may not be enough time to avoid the abyss. The transition would have to take place quickly. We would need to make the shift in 30 to 40 years. As I said, we know it's possible. The second industrial revolution infrastructure was installed across much of the United States in less than 40 years. We could, if highly motivated and passionately committed, do something similar across the world over the course of the next 30 years by using the third industrial revolution to transition into a more just and ecologically sustainable civilization. +

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