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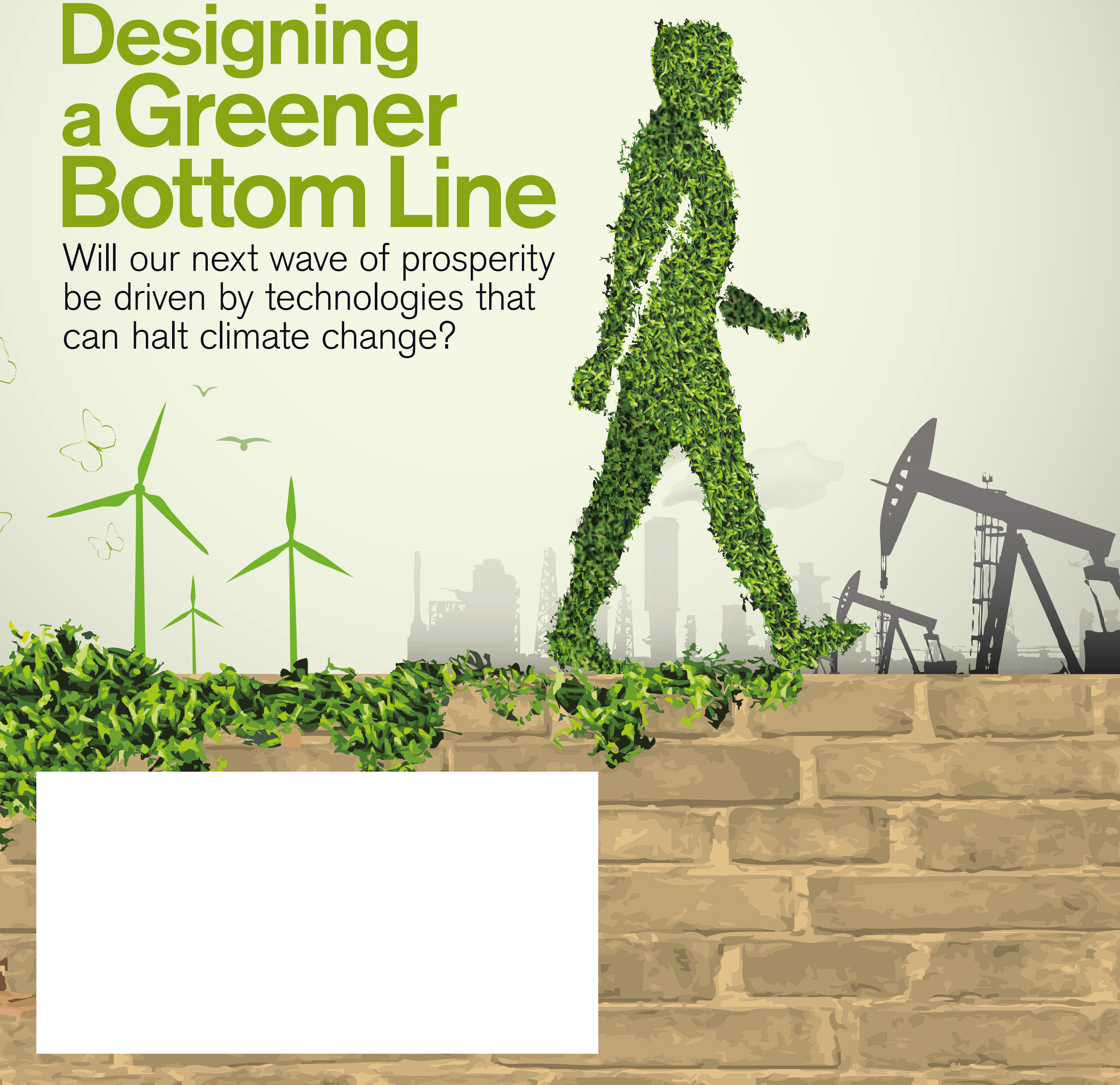
Designing a Greener Bottom Line

Will our next wave of prosperity be driven by technologies that can halt climate change?



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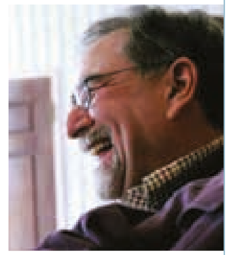

Lee Goldberg, Editor

I woke up earlier than usual to follow the spectacular end hours of the Cassini Saturn probe's 17-year mission. Incinerating the craft in the planet's atmosphere made sense. It would protect Saturn's moons against possible contamination while yielding a precious close-up glimpse of the mysterious gas giant. Nevertheless, as I listened to the laconic chatter of the flight ops team preparing the spacecraft for its incandescent dive, I found myself near tears and awash in memories of another spacecraft's death that occurred more than 20 years ago.

Attachments

Mars Observer was a much less sophisticated spacecraft, launched in 1992 to resume the task of studying the red planet that had come to a halt after the Viking probes went silent about a decade earlier. It had been conceived to fulfill the "Faster, Better, Cheaper" philosophy that NASA had adopted at the time and was intended to be built on a relatively tight budget with as many off-the shelf components from existing commercial spacecraft as possible. Weighing about a fifth of Cassini's 12,000 pounds, it still managed to carry eight scientific payloads that would provide new insights on the geology and atmosphere of Mars. I was lucky enough to be part of the team at GE Astrospace who were responsible for making sure those payloads fit on the spacecraft, survived the journey to Mars, and were able to execute their mission once they arrived.

Since making the science payloads "comfy" aboard the spacecraft involved so many aspects of its design and testing, my job gave me a chance to work with nearly every engineering team on the project. In the process, I learned a great deal about things like how objects gain and lose heat in a vacuum, the arcane workings of attitude control and hypergolic propulsion systems, and how the craft's limited supply of solar-electric power was distributed to the flight electronics and the payloads.

As fascinating as the technology was, the people I worked with were the most rewarding part of my job. Mars Observer was the first interplanetary mission our company had worked on since we built some of the early Ranger lunar probes in the early 1960s, so we all took special pride in being a part of it. Some of my work involved providing the thermal engineers with the information they'd need to keep the instruments at an even temperature in a deep space environment. At other times, I'd watch as the mechanical engineers translated the payload interface requirements I'd developed into small, 3-dimensional poems, written in carbon and titanium.

After four years of assembly and testing, most of the team headed down to Cape Canaveral in the spring of 1992, where we spent several months preparing Mars Observer for launch and integrating it with its Titan III launch vehicle. It took a lot of double shifts and weekends to maintain a pace that would have the craft tested, fueled, and ready to meet the 3-day launch window that opened up in late September, but we still managed to have some fun along the way. I'll leave those stories, which include spending the night in a bunker directly under the launch vehicle, midnight encounters with wild pigs on the Cape's back roads, and kissing the rocket's nosecone for another column.

When launch day arrived, we watched the Titan burn its way into the sky. We held our breaths for 17 minutes while we waited for the first telemetry signals from our bird to tell us that it was doing fine and ready to head to Mars. I wasn't married at the time, and had no children, but the feelings of relief, pride, and deep joy we all felt gave me a preview of what I'd experience at the birth of my daughter a few years later.

With the launch behind us, most of the tribe I'd spent the last six years with began to move on to other assignments, leaving a small team who would operate the craft during its two-year journey to Mars. Most of us kept in touch with the flight ops team to see how "our baby" was doing. It was one of those old friends who called me a few days before Mars Observer was scheduled to arrive to let me know they had lost communication with our spacecraft.

I returned to GE to serve on the team that tried to figure out what happened and to regain contact with the craft. We spent two weeks attempting various recovery plans before we ran out of things to try. It was just a machine but, for many of us, it felt as if we had lost a dear friend, a fellow traveler to the stars.

Some 23 years later, I felt echoes of that heartache as Cassini's flight team reported the craft's attitude control system was struggling to maintain stability as it descended into Saturn's atmosphere. Soon after that, the telemetry stream disappeared, replaced by the hiss of static.

I am glad that Cassini had a dramatic and fitting end to its amazing 20-year mission. I'm also grateful that GE determined the problem with Mars Observer and built a second vehicle that launched in 1996 and successfully delivered its payload to Mars.

Nevertheless, part of me is still lost in the stars, along with the emissary I helped to build.

Is there something you worked on that stole your heart? If you'd like to share it with me, or your fellow readers, write me at lee.goldberg@advantagemedia.com.

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Designing a Greener Bottom Line

Will our next wave of prosperity be driven by products and technologies that can halt climate change?

By Lee Goldberg, Editor

Introduction

Although the recent series of unusually violent hurricanes and tropical storms strengthened the consensus that global climate change poses a genuine threat to civilization, there has been less agreement as to what we can we do about it. Some respected experts believe the human-induced changes in the Earth's thermal equilibrium have passed the point where they could have been stopped, while others think that the heroic efforts needed to reduce greenhouse gas emissions to a survivable level would require us to return to a pre-industrial economy.

A recent study prepared by the Rocky Mountain Institute (RMI), a forward-looking think tank, dedicated to creating market-based environmental solutions, provides convincing arguments a third path is available that leads to a vibrant, sustainable future.

Figure 1. It will take a combination of new technologies, agricultural and land use practices, business strategies, and policies to create the framework for a vibrant, sustainable economy.

According to Mark Grundy, RMI's Director of Communications, halting the Earth's temperature rise to well below 2 C° is technically feasible and economically do-able. In an interview with PD&D, Grundy said, *"The scenarios described in our study rely not simply on mandates or hoped-for inventions but on current capabilities implemented by business-led, market-driven, and often highly profitable solutions."*

While the study does not promise these scenarios will lead to a so-called "climate boom", it is clear that many of tomorrow's opportunities for designers, manufacturers and other technologists will be in the sectors that create the tools, products, and services that enable the transition to an economy that puts green into the environment as well as investors' pockets.

This article explores some of the roles technologists and designers will play in realizing this vision, and the technologies they use to do it.

A Contrarian Perspective

There is now a strong consensus that climate change primarily a function of human activities, most notably, the ones that produce large amounts of CO2, methane, and other so-called greenhouse gases. Recently, it has also become apparent that the warming process is being further accelerated by damage to the parts of biosphere (deforestation, ocean pollution, factory farming, etc…) that might otherwise moderate the carbon emissions' effects.

Since current global economy depends on many of the things that cause climate change, efforts to halt it have been slow, and the outlook for our future has become increasingly grim. One of the most well respected studies, the *UN Emissions Gap Report*[1] concluded that, even if all the signatories to the Paris Agreement met their emissions reductions pledges, the world could still expect to see a temperature rise of 2.9–3.4 C° before 2100, far above 2 C°, the generally agreed upon maximum acceptable increase.

Figure 2. Solar electricity will play a key role in the green economy, eventually producing 60% of the world's power.

These grim projections have been challenged by a recent study, titled "*Positive Disruption*[2]," published by the Rocky Mountain Institute (www.rmi.org). The study uses generally accepted findings to predict how CO2 and other greenhouse gasses will affect the global average temperature, but employs a market-based analysis to challenge many of the current assumptions about how quickly their production can be reduced.

RMI's researchers suspected that that previous climate studies had severely underestimated the potential impact of climate-moderating technologies for several reasons. Those earlier studies had assumed that solar and wind power, biomass, and other key technologies would continue to displace older "dirty" technologies at roughly their present rate of adoption. In contrast, RMI observed that most of the technologies needed to de-carbonize the global economy are subject to the same market forces that drove the rapid adoption of other technologies, including computers, cell phones and automobiles. See the sidebar "*Solar Hits the Tipping Point.*"

The study also identified several principles, driven by economic mechanisms and technical trends that affect how we generate and use energy. One of these principles, referred to as "*Cascading Systemic Effects from Converging Changes across Technologies,*" identifies the self-reinforcing virtuous relationships that sometimes occur between two or more technologies (See Figure 3). A passage from Positive Disruption provides the following example:

The falling cost of batteries simultaneously encourages faster electric vehicle deployment, increases renewable energy penetration on the grid, and allows greater flexibility in energy use. In turn, more electric vehicles mean cheaper batteries, implying distributed solar everywhere; faster coal and nuclear power displacement; and a distressed natural-gas industry. Improvements in the cost and performance of the information technologies in electric vehicles also contribute to better functioning and faster deployment.

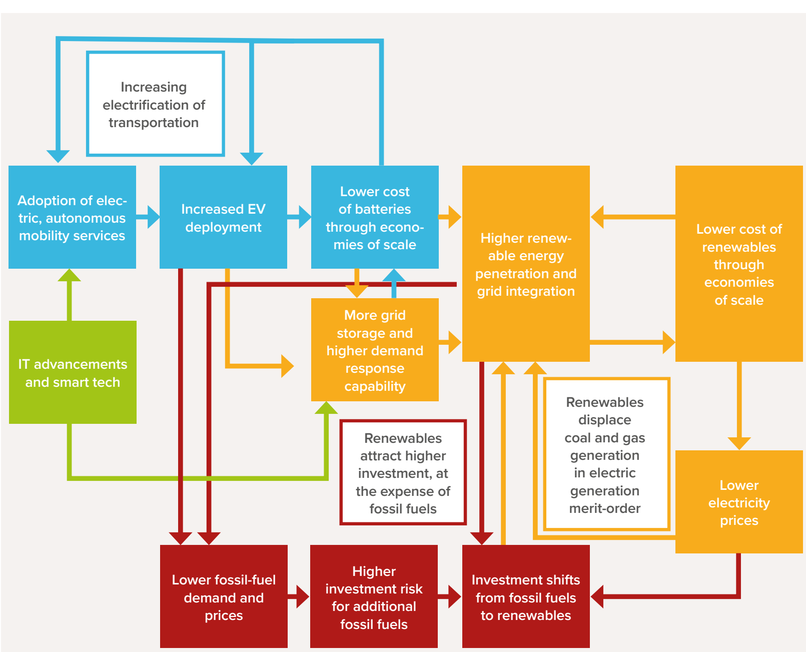

Fig.3, Some technologies compliment each other to create reinforcing feedback loops that amplify their economic benefits and accelerate their adoption. This flow chart illustrates some of the interactions between key energy technologies and their applications that will help accelerate the transition to low-carbon energy sources. Source: RMI

The study also identified three other principles that will help accelerate the integration of new technologies into the global economy:

1. Exponential improvement of core technologies
2. S-curves in market diffusion of disruptive technologies
3. "Leapfrog Opportunities" in developing countries where new infrastructure needs to be installed

A complete description of these principles is available in pages 18-24 of "Positive Disruption[2]."

Six Scenarios

Using these principles, RMI created five scenarios in which key technologies for clean energy production, energy management, conservation, and use were deployed at different rates. A sixth, business-as-usual (BAU), scenario was created which assumed that current trends in energy generation, use and conservation would continue along their current trajectories. Simulations based on each scenario predicted how they would affect CO2 levels (Figure 4) and the resulting average temperature (Figure 5) over the next 80 years.

The most aggressive scenario assumes that solar power will continue to expand at a rapid pace and eventually meet 60% of global energy demand. Most of the remainder would be supplied by wind-generated electricity that would account for 39% of production in developed economies and 25% in emerging economies by 2050. The most conservative scenario assumes that solar PV systems will supply slightly less than 40% of the world's electricity by 2050, with wind providing roughly 35%, and fossil fuels (mostly natural gas) supplying the remainder.

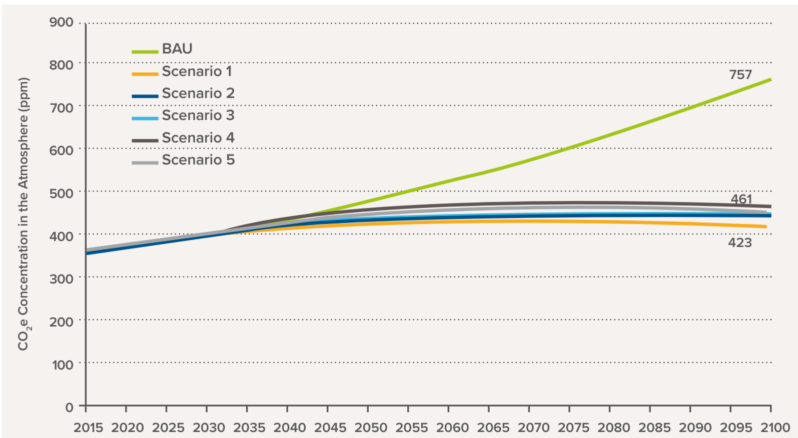

Figure 4. Atmospheric CO2e concentration under different scenarios. Source: RMI

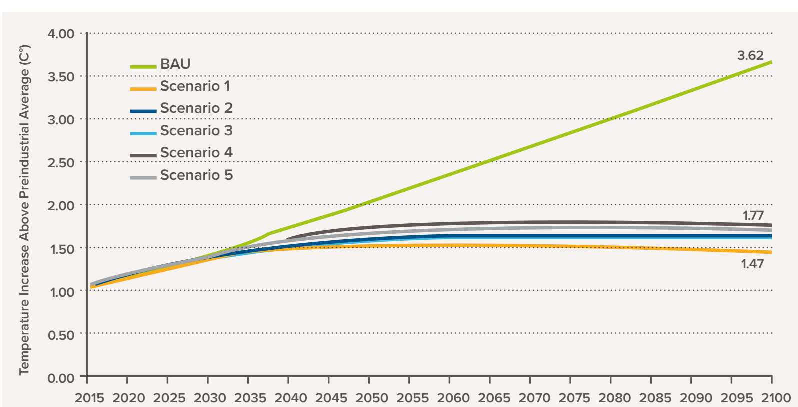

Figure 5. Global average temperature change above the preindustrial era under different scenarios. Source: RMI

Each of the scenarios also assumed that the necessary energy conservation measures, and climate-mitigating agricultural and land use practices would be implemented. Referred to as agriculture, forestry, and other land-use behaviors (AFOLU), RMI's Mark Grundy told PD&D, *"these include increasing forest cover and avoiding conversion of forests to other land uses, integrating trees into farming, farming without disturbing the soil through tillage, adopting permaculture practices, managing wetlands, and using rotational grazing techniques that amplify [the effects of] soil carbon sequestration."*

The scenarios provided the inputs for simulations that calculated the resulting CO2 levels and global average temperatures (Figures 4 and 5) over the next century. Although they are based on very different adoption levels for different technologies and have varying degrees of effectiveness, RMI found that all five strategies resulted in temperatures that stabilized "well below" 2 C°. The most aggressive scenario (#1), which includes measures to reduce fluorinated greenhouse gas (F-gas) emissions as well, limits global temperature change to 1.47 C° by the end of the century. Even the most conservative scenario (#4) predicts a higher, but acceptable, rise of 1.77 C°.

Revolutionary Opportunities

The level of effort and investment required to achieve even the most conservative scenario recommended by RMI will be a massive undertaking, perhaps greater in scale than the transformation of America's economy during World War II. From a technical perspective, the transition to a green economy will include integrating renewable energy and distributed generation systems more deeply into the grid, a transition to more efficient, responsive "energy demand" technologies (HVAC systems, lighting, industrial processes, etc...) and the extensive use of electric vehicles.

While some older industries may suffer during this transition, far more will emerge and grow to meet the demand for advanced energy generation, distribution, and storage systems, new forms of transportation, energy-efficient buildings and new agricultural tools that enable more sustainable food production. Some of the most obvious beneficiaries will be companies involved with clean-energy technologies like solar PV, wind turbines, electrical distribution equipment, batteries, electric vehicles, and advanced building materials, but many others who supply the materials, components, and services to these industries will also thrive.

The RMI study does not make specific claims about the economic stimulus the initiatives will produce but a recent report, published by the Blue/Green Alliance, provides a few data points that hint at what a green economy might look like. Entitled *"Making the Grade 2.0: Investing in America's Infrastructure to Create Quality Jobs and Protect the Environment*[4]," the report analyzes the job creation impact and environmental benefits of improving America's infrastructure in a variety of sectors, including power and the electrical grid, roads and transit systems, water systems, schools, and other public resources.

Sidebar: Solar Hits the Tipping Point

For nearly 20 years, the cost of photovoltaic panels had declined at a slow but steady rate as slowly rising demand made greater economies of scale possible. Somewhere in early 2007, solar hit a price point that triggered a surge in demand that in turn drove the cost reduction curve sharply downward (Figure A). As a result, the cost of solar panels plunged from over $2/Watt to around $1/Watt in roughly a year, and eventually to $0.50/W or less (Figure B). In the process, other PV system components (inverters, mounting brackets, etc…) were driven to undergo similar price reductions. The trends in PV system pricing documented in the recent National Renewable Energy Laboratory (NREL) report[3] provide an excellent example of this process. During the year of 2016, NREL recorded nearly a 30% reduction in the cost of electricity generated by utility-scale solar PV systems, bringing it down to between 4.4 and 6.6 cents/kWh. This trend, and similar declines in the cost of wind- and biomass-generated electricity, have already put renewable energy at or near cost parity with conventional sources in many areas.

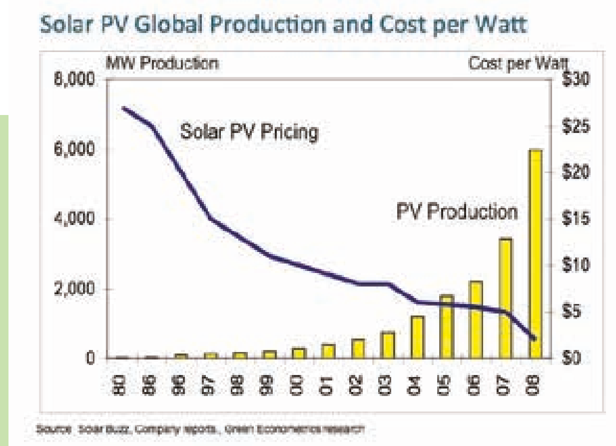

Figure A. A graphic history of photovoltaic panel cost ($/W) and market demand. Image courtesy of Solar Buzz and Green Economics Research.

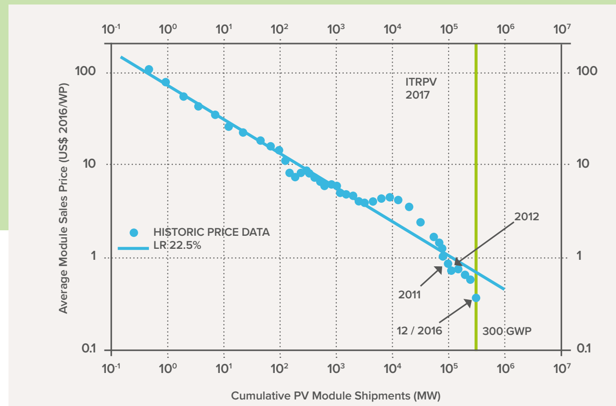

Figure B. Solar prices as a function of cumulative photovoltaic panel shipments. Image courtesy of RMI.

Although the scope of the Blue/Green Alliance report is broader than RMI's, and assumes continued use of some fossil fuels, it provides some useful insights on the need for investments in several key climate-friendly technologies, and the economic benefits they will produce. For example, the section devoted to electrical generation, transmission, and distribution estimates that the $354 billion invested in upgrading the grid will be directly responsible for creating an additional 1.1M job years of employment through 2027. This does not include the many other businesses and institutions not directly involved with the shift to renewable energy which will also benefit as the price of the electricity they use to light, heat, cool, operate equipment, and transport their goods becomes more stable, and even declines over time.

Conversely, the report warns that a failure to invest would result in a less reliable power grid that delivers more expensive electricity and continues to contribute to climate change. Even without factoring in the additional damage done by extreme weather conditions, the report calculated that a sclerotic, fossil-fueled electric grid would put a drag on the economy that would lead to an $819 billion decrease in the U.S. GDP and 102,000 fewer jobs by 2025.

A Third Way Beckons

If the RMI study's findings prove to be correct, we no longer have to choose between a healthy environment and a healthy economy. A third way beckons us towards a more prosperous, sustainable future and the engineers and entrepreneurs who lead the way will be the ones who reap the biggest rewards. PDD

References

1. The Emissions Gap Report 2016: A UNEP Synthesis Report, United Nations Environment Program, November 2016, http://wedocs.unep.org/bitstream/handle/20.500.11822/10016/emission_gap_report_2016.pdf

2. Abramczyk, Marshall, Martha Campbell, Aman Chitkara, Mia Diawara, Aileen Lerch, and James Newcomb. Positive Disruption: Limiting Global Temperature Rise to Well Below 2 C°. Rocky Mountain Institute, 2017 https://www.rmi.org/insights/reports/positive_disruption_limiting_global_temperature_rise/

3. The U.S. Solar Photovoltaic System Cost Benchmark: Q1 2017 https://www.nrel.gov/docs/fy17osti/68925.pdf

4. Making the Grade 2.0: Investing in America's Infrastructure to Create Quality Jobs and Protect the Environment. The Blue/Green Alliance, 2017 http://www.bluegreenalliance.org/wp-content/uploads/2017/09/MakingTheGrade-2.pdf