MYTH *v.* FACT

Before we can embrace appropriate energy policies, we have to face the hard truths about the technologies available to us.

BY JOHN REILLY AND ALLISON CRIMMINS

John Reilly is a senior lecturer at the Sloan School of Management at the Massachusetts Institute of Technology in Cambridge, and co-director of the Joint Program on the Science and Policy of Global Change. Allison Crimmins is a communications officer with the Joint Program.

The way we power our homes and cars and factories is one of the most important choices our society faces. Perhaps it's the push of climate change, air pollution, resource depletion, and national security. Or maybe it's the pull of new technologies and newfound energy supplies that may be cheap and clean. Either way, most experts expect that we are heading toward a virtual revolution in the power and energy industries over the next few decades.

But whether we can revolutionize our energy infrastructure—and how, exactly, we would do it—is not simply a question of technology. Economics will play a deciding role in what unfolds. For alternative technologies to be chosen among the mix of energy sources, they must be able to compete in the energy market. The future costs of energy technologies and the ever-changing price of conventional energy sources will determine the success of alternatives over conventional, fossil fuel-powered technologies.

To better understand competition among conventional and alternative energy technologies and their implications for the environment, researchers at the Massachusetts Institute of Technology are using a comprehensive framework to model climate response and analyze policy proposals. The Joint Program on the Science and Policy of Global Change developed the MIT Integrated Global System Modeling framework, which integrates natural and social science to simulate global change and to assess the effects of policy proposals—like the one regarding alternative energy technology policy.

What makes the research at the MIT Joint Program unique is the systemic approach of combining economics, science, and policy to look at the probabilities, risks, and impacts of climate change. The IGSM models the interactions and feedbacks between the Earth systems, such as the ocean, atmosphere, and land, and human activities such as economic development and emissions. The modeling of human activities, using a component of the IGSM called the Emissions Prediction and Policy Analysis model, is of particular use to representing future global energy resources and the economics of alternative energy technologies.

These tools can shed light on the economic factors determining the role of renewables and other alternatives in the future energy market. Though these issues are complex, several consistent themes have emerged from MIT's results, some of which confirm some long-held truths and others that expose some damaging myths. The bottom line is that while existing technologies can get us started on a path of emissions reductions, it's vitally important to select cost-effective policies to ensure a brighter, cleaner energy future.

Before examining the different possibilities for future energy supply, we need to understand just how much energy the world will demand in the future. Using the MIT EPPA model, researchers can project future global energy demand under a business-as-usual scenario. This scenario assumes that global activities continue without policy measures that could raise the price of fossil fuels.

TRUTH: Without significantly higher energy prices, energy demand will continue to grow—especially in developing countries.

Under business as usual, model projections show global primary energy use more than doubling by 2100, from around 480 exajoules in 2010 to 1,100 EJ by 2100. Energy use is closely related to income, and the rapid economic expansion of developing countries such as China and India will drive the steep increase in energy use. That economic growth will exceed anticipated efficiency improvements in end-use energy technology. The effect is so strong that even with policy measures that would increase energy prices, and thus provide enough incentive for conservation and efficiency to reduce projected energy use by as much as one third, the world would still need a 50 percent increase in energy supply by 2100.

Of the supply needed to meet that increased demand, what portion of the future energy mix will be made up of alternative technologies, and what portion will continue to be made up by fossil fuels? A common myth is that the world is running out of fossil fuels and thus a shift to a fuel mix dominated by cleaner alternatives is inevitable.

MYTH: The world is running out of fossil fuels.

According to the MIT projections, conventional technology supported by fossil fuels will continue to dominate under a business-as-usual scenario. In fact, absent climate policies that would impact energy prices, fossil fuels will supply nearly 80 percent of global primary energy demand in 2100. Alternative energy technologies will expand rapidly. Non-fossil fuel use grows from 13 percent to 20 percent by 2100, with renewable electricity production expanding nearly tenfold and nuclear energy increasing by a factor of 8.5. But those sources currently provide such a small share of the world's energy that even rapid growth is not enough to significantly displace fossil fuels.

In spite of the growth in renewables, the projections indicate that coal will remain among the least expensive fuel sources. Non-fossil fuel alternatives, such as renewable energy and nuclear energy, will be between 40 percent and 80 percent more expensive than coal. Some renewables may be even more expensive, as the intermittent nature of energy technologies like wind and solar require back-up capacity or storage to address variability of supply.

Natural gas should also remain abundant. Recent advances in technology that allow for access to and extraction of tight gas, coal bed methane, and shale gas have significantly expanded the economic resource base of natural gas. In the not-too-distant future methane hydrates, which today are locked in frozen sediments beneath permafrost and the seafloor, could become an immense source of future fossil fuel reserves.

The scenarios also project something surprising: Oil does not "run out." Global production of oil from conventional sources may well peak soon, but unconventional sources are economical or nearly so today. Oil sands, shale oil, and coal-to-liquids are abundant and can be competitive if crude oil prices are in the $80 to $150 per barrel range.

Unfortunately, unconventional sources of oil and coal-to-liquids technologies are quite greenhouse-gas-intensive, releasing more carbon dioxide and other greenhouse gases in their processing and use than conventional crude oil. Even if the carbon dioxide emissions from processing these fuels were captured and stored, these synthetic fuels (aside from hydrogen) are just as damaging to the climate when burned as conventional gasoline or diesel.

Can renewables solve that problem? It is tempting to see renewables as a sort of energy and economic panacea: Besides benefiting the environment, expansion of renewable energy has been touted as a means to develop a new technology sector, create jobs, and boost the economy. But renewable energy shouldn't necessarily get a free pass in terms of environmental impacts.

MYTH: Renewable energy generation technologies are free from environmental concerns.

Renewable energy sources are not necessarily free of environmental risks. For example, researchers from the MIT Joint Program used the same IGSM model to show that deployment of wind turbines over a scale large enough to meet 10 percent or more of global energy demands in 2100, which would require installation of turbines over 58 million square kilometers of land, could result in the stagnation of surface air. This can create a localized warming effect of about 1 °C that may also lead to broader climate impacts, such as altered precipitation patterns.

In another example, biomass energy can lead to indirect emissions of carbon dioxide and other greenhouse gases when an increasing amount of land area is cleared. Biofuels also have implications on water use and food security. Even cellulosic biofuels may create large indirect emissions through land use change. Though renewable energy technologies are often considerably cleaner than fossil fuels, they have shortcomings as well as advantages and deploying them will involve some tradeoffs.

Even so, continued reliance on fossil fuels for energy poses many environmental risks. Burning fossil fuels results in emissions of conventional air pollutants, such as precursors to ozone and particulate matter, which have negative consequences for human health, agriculture, and natural ecosystems. And of course, the emissions of greenhouse gases have significant impacts on climate change.

TRUTH: Continued reliance on fossil fuels is altering Earth's energy balance. The risks of extreme temperature changes and subsequent impacts will grow substantially unless concrete actions are taken.

MIT Joint Program research demonstrates that by following the business-as-usual trajectory without any major climate policy, the probability of the globally averaged temperature increasing by 5° C or more by 2100 is about 50 percent. Fifty-fifty odds aren't all that promising, considering the catastrophic impacts many scientists suggest will occur with even 3 °C or 4 °C of warming. Most federal and international agreements are aimed at maintaining a threshold of 2 °C to limit dangerous climate impacts. Because greenhouse gases remain in the atmosphere for decades and even centuries after they are emitted, immediate action to reduce current emissions is urgently needed to avoid higher temperature increases.

Halting climate change is a daunting endeavor that will require dramatic modifications to the future global energy mix. But this does not necessarily imply that miraculous revolutions in technology are the only solution. And it certainly does not mean that we are incapable of action without their invention.

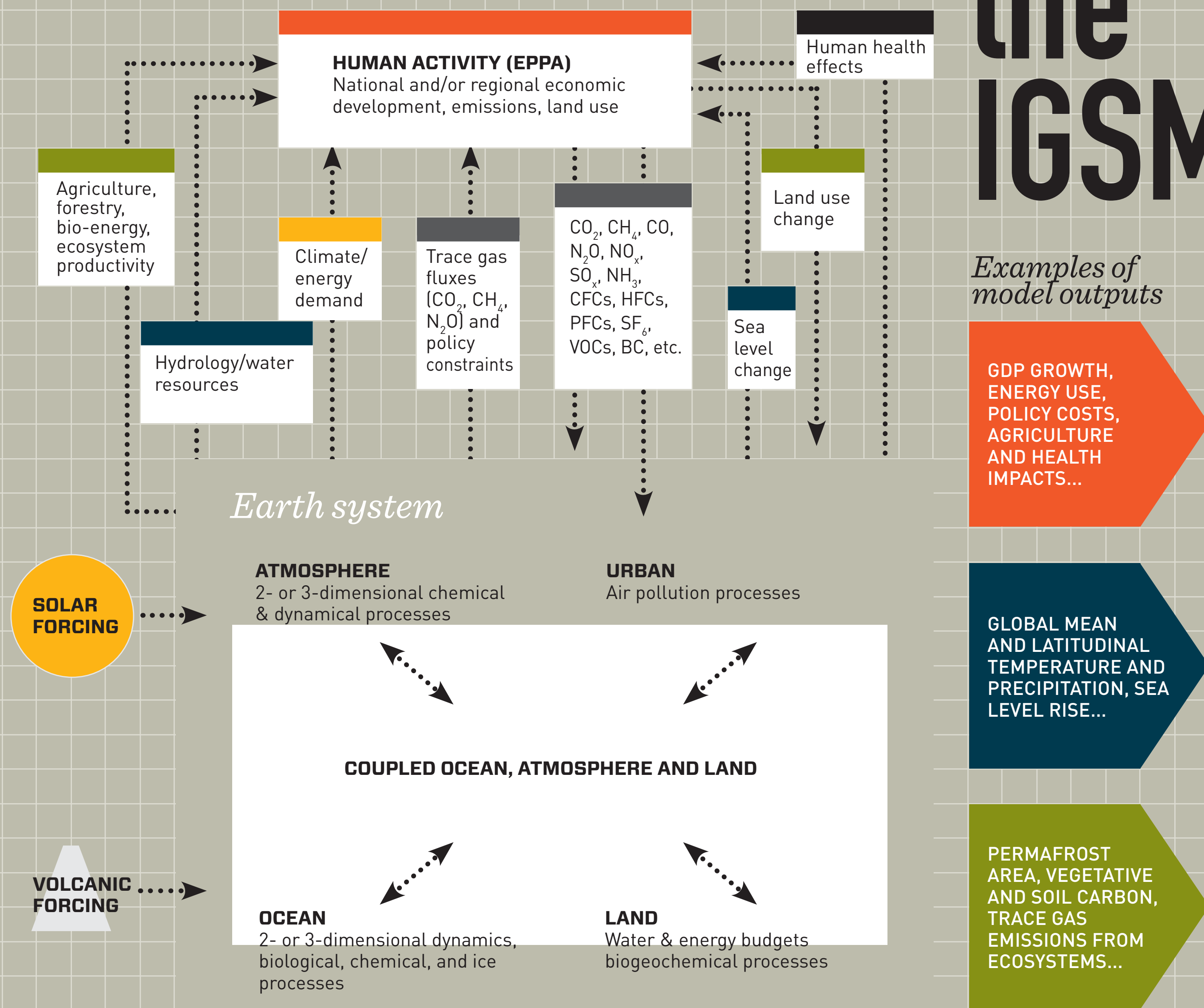
MYTH: Getting started on reducing greenhouse gas emissions will require transformative technologies.

Advanced technology will likely be needed in later years, but significant emission reductions are achievable now, with current technologies. Natural gas, for instance, could be exploited more widely. The properties of natural gas place it somewhere between other fossil fuels, which are cheap but dirty, and renewables that are expensive but mostly cleaner: gas emits carbon dioxide when burned but releases fewer greenhouse gas emissions per unit of energy than coal or oil. Recent advancements in the recovery of gas deposits have made natural gas much more economically competitive.

An interdisciplinary group of faculty, researchers, and students at MIT recently released an interim report titled "The Future of Natural Gas." The report found there was a significant potential in the U.S. for natural gas to replace coal in electricity production. That switch would result in a 50 percent reduction in emissions by 2050 when combined with price-induced gains in efficiency. In that scenario, natural gas acts as a bridge to a low-carbon future; advanced technologies would not be needed before 2040.

However, there would still be a need for research and

the IGSM



LINKED COMPUTER MODELS

The Integrated Global System Model framework, developed by the MIT Joint Program, simulates global change through a linked set of computer models designed to help realize the program's objective of integrated assessment. Rather than looking at only one piece of the puzzle at a time, the IGSM helps MIT researchers conduct "end to end" studies that bring together information on the economy, Earth systems, climate science, technological change, social policy analysis, and uncertainty. By combining models of the Earth system and models of human activities and the economy, the IGSM represents a truly systemic approach to understanding global change issues.

The IGSM can, for instance, simulate global environmental changes that arise as a result of human activities or policies—and then show the impact of these environmental changes back on human activities and economies. What makes integrated assessment powerful, though, is that researchers can do more than make predictions: they can understand the probabilities, risks, costs and benefits, and uncertainties associated with policy proposals and the impacts of global changes. In this way, integrated assessment pushes the boundaries of how to consider questions with a wider, more linked view.

development into alternative energy technologies. After all, if natural gas is a "bridge" technology, there has to be something waiting on the other side. "In the very long run, very tight carbon constraints will likely phase out natural gas power generation in favor of zero-carbon or extremely low-carbon energy sources such as renewables, nuclear power, or natural gas and coal with carbon capture and storage," said Ernest Moniz, director of the MIT Energy Initiative and co-chair of the natural gas study. "For the next several decades, however, natural gas will play a crucial role in enabling very substantial reductions in carbon emissions."

Although funding for research is still needed to make these future technologies economical, the fact that future low- or zero-carbon technologies are not yet fully proven should not undermine urgently needed mitigation measures today.

New supply-side capacity isn't the only way to meet future energy demands. Price-induced policies can actually reduce overall energy demand in the U.S. in tandem with gains in efficiency.

TRUTH: There are opportunities to greatly reduce energy intensity through gains in efficiency. These gains could be made by both technological advances and price-induced substitution.

Using integrated systems modeling to assess similar climate policies on a global scale shows that significant improvements in efficiency are possible. Though energy intensity—the units of energy use per unit of GDP—would vary substantially across different regions, it decreases by 75 percent to 90 percent around the world by 2100. Put another way, a broad price on carbon could improve efficiency such that one dollar's worth of economic output could be produced with one-quarter to one-tenth as much energy as today, depending on the region of the world. For a country like the U.S., this would mean lowered total energy use; for economically developing regions, energy use will still likely increase but efficiency will be greatly improved.

If emissions can be greatly reduced by gains in efficiency and without waiting for transformative technologies, does that mean that conventional fuels will be swamped by ever-improving renewable energy technologies?

MYTH: There is little room for improvement on fossil energy technologies—fossil fuel extraction, internal combustion engines, and so on. Therefore, only small advances are needed before alternative energy technologies are competitive.

In fact, internal combustion engine technology continues to make improvements. Advancements in these and other fossil technologies make it much more difficult for alternative energy systems, such as electric vehicle or hydrogen vehicle alternatives, to compete. Another instance of this can be seen in the advancements in the extraction of shale gas: The technologies that enable carbon-intensive shale gas, and possibly gas hydrates, to be economical lower the competitive price that all other alternative energy systems must meet. Our future energy mix will be determined by the price of both conventional and alternative energy sources, and those in turn will rely in part on legislation of mitigation policies that put a price on carbon.

The question, then, is not whether the cost of cleaner alternatives can come down, but whether they can come down faster than the advances keeping the cost of fossil fuels low and making unconventional sources economical. To some, the number and type of different renewable energy generation sources implies that they may already be outpacing fossil fuels.

MYTH: Explosive growth in renewable fuels in recent years is evidence that these alternatives are economically competitive with traditional fossil fuels.

Much of the growth in renewable energy sources in the United States has been due to non-market forces. Government-mandated renewable portfolio standards stipulate that a minimum percentage of electricity supply must come from renewable energy sources. The cost of an RPS is rolled into the average cost of electricity bills. Therefore, if the percentage of required renewables dictated by the RPS is large enough to have a significant impact on emissions, it will also have a large impact on electricity bills. Subsidies and tax exemptions can help reduce electricity bills, but when consumers do not see the full cost of energy sources they have little incentive to use them efficiently.

What's more, such subsidies are paid for by tax incentives—and energy consumers are also taxpayers. Thus while tax incentives, subsidies, and other regulatory requirements may make renewable energy technologies economical, they hide the true cost of these policies.

TRUTH: Subsidizing renewable energy generation doesn't lower the cost of alternative energy; we simply pay the cost in other ways—and at the expense of cost-effective market-based policies.

Recent climate policy proposals in the U.S. have often combined a market-based cap-and-trade system, considered by many economists to be the most cost-efficient means of reducing greenhouse gases, with regulatory instruments like renewable portfolio standards. To better understand the implications of proposed climate legislation, the MIT Joint Program looked at the impacts of three potential policy outcomes: a cap-and-trade program, a cap-and-trade program combined with RPS, and an RPS-only policy.

The study found that combining increasingly stringent renewable portfolio standards with a cap-and-trade policy would result in decreasing carbon prices but substantial rises in welfare costs, or the total costs of the policies to society. In other words, combining the two different climate policies resulted in higher costs than just the cap-and-trade policy by itself.

In addition, the RPS-only policy would not significantly reduce emissions. The total cost of the combined policies would be greater than the cost of just a cap-and-trade policy because the RPS requires the use of renewables. Requiring renewable energy sounds like a good thing, but mitigating emissions by stipulating a certain percentage of energy come from renewables means that some other, less costly options would not be utilized.

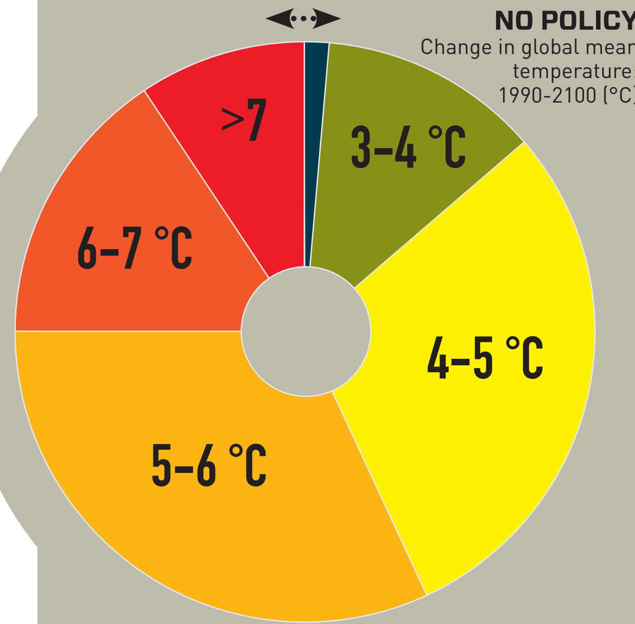
> **TRUTH:** The true costs and benefits of available alternative technologies are highly uncertain. Therefore we should all be careful about predicting technology "winners."

Regulatory policy instruments pick technology "winners," with the eventual success and cost of those policies depending on whether bets were placed correctly. These measures are often heavily influenced by lobbyists for different technologies, with little concern for costs to taxpayers and electricity consumers. Instead supporters of specific technologies, such as biofuel, solar, wind, nuclear, or carbon capture and storage, contend for market viability. Rather than assuring investment in the most cost-efficient options, regulatory policies can be very expensive, particularly if bets placed on alternatives prove to be more costly than expected or fail to encourage efficiency.

The risks of climate change and broader environmental damages associated with continued reliance on fossil fuels are great. Nations—both developed and developing—must find ways to reduce emissions without sacrificing economic growth.

This should not be done in haste, but neither can we delay. Waiting for a silver bullet solution or allowing the perfect to be the enemy of the good will only result in an inexorable increase in emissions and investment in dirty technologies that will remain in operation for decades. In fact, existing technologies can get us started on a path of emission reductions if a price of carbon is reflected in everyday decisions about energy use and fuel choice. The market has the power to provide that clear signal and let individual choices and creativity find solutions, without depending on centralized decisions that target specific technology choices.

In the rush to transform the global energy system, it is important to be informed on the true costs of renewable energy generation. Because a cleaner energy system is likely to be more expensive than today's energy system, it is all the more important to pursue the most cost-effective policies, such as broad pollution taxes or cap-and-trade systems, to reach emission reduction goals. ■



the GREENHOUSE GAMBLE

Projections of future temperature change due to global warming have a level of uncertainty built into them. These charts provide one way to think about the range of potential outcomes in two different scenarios. In a business as usual scenario in which no major greenhouse gas controls are enacted, temperatures are most likely to rise by between 4 °C and 7 °C, with a small probability of larger or smaller rises. In a scenario with strong action on climate change, the temperature rise will most likely be limited to between 2 °C and 3 °C.