Columbia | SIPA
Center on Global Energy Policy

Paris COP21 Commentary

December 18, 2015

***

Following the historic Paris Agreement last weekend, the Columbia SIPA Center on Global Energy Policy collected commentary on the agreement from several of our scholars and Faculty Affiliates across Columbia University.

***

Scott Barrett, Lenfest-Earth Institute Professor of Natural Resource Economics at the School of International & Public Affairs, explores the strengths and weaknesses of voluntary pledges, building on his own research. (Page 2)

Jason Bordoff, Professor of Professional Practice in International and Public Affairs and Founding Director of the Center on Global Energy Policy at Columbia SIPA, emphasizes that energy innovation is a key part of what made Paris a success. (Page 5)

Michael Gerrard, Director for the Sabin Center on Climate Change Law at the Columbia Law School, explores the legal implications of the provision in the Paris Agreement that calls on countries to "achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century." (Page 8)

Geoff Heal, Donald C. Waite III Professor of Social Enterprise at the Columbia Business School, highlights the importance of recent cost declines in renewable energy and energy storage technologies. (Page 11)

Vijay Modi, Professor in the Department of Mechanical Engineering, highlights the role of science and technology in expanding energy access while meeting our climate goals. (Page 13)

David Sandalow, Inaugural Fellow at the Columbia SIPA Center on Global Energy Policy, explores the importance of Paris in the context of a broader set of recent climate diplomacy achievements that highlight the need for continued optimism and determination. (Page 18)

Global Consensus on Climate Change Is a Good Start

By Scott Barrett [1]

***

The new Paris Agreement on climate change is a remarkable diplomatic achievement – remarkable mainly for representing a consensus among 195 states. But is it a true breakthrough or was a consensus possible because the agreement asks countries to do very little?

The world doesn't typically negotiate agreements by consensus. But the rule for decision-making on climate change was sealed in 1995, when the parties to the United Nations Framework Convention on Climate Change could not agree on another decision rule – and consensus was the default. Given this, the outcome of COP21 is significant: The world's people agree on little, and in Paris, countries agreed that climate change is a real threat and that every country must play a role in addressing it.

Had these negotiations failed to secure consensus, the UNFCCC process for a global approach to climate change may have come to an end in Paris. The process nearly ended in Copenhagen in 2009, when countries attending COP15 could not agree on how to strengthen the Kyoto Protocol. What saved the Copenhagen conference was a decision, made on the spot, to abandon the idea of a "top down" agreement with negotiated emission reductions and replace it with one in which reductions were pledged voluntarily. To rally countries around the cause of limiting climate change, the legally non-binding Copenhagen Accord set a collective target of limiting global mean temperature change to 2 degrees Celsius. Nationally determined emission limits were to be offered voluntarily and publicly, allowing every country to see what others had pledged and whether the total could possibly achieve the collective goal. The Paris Agreement essentially formalizes the approach taken so unexpectedly in Copenhagen.

The voluntary approach corrects for Kyoto's biggest mistakes: first, singling out the rich countries as being responsible for acting, with poor countries allowed to develop as the rich countries had done previously, an arrangement that legitimized development around fossil fuel energy, and second, to negotiate strict emission limits without providing a means for enforcement.

People who cheer the Paris Agreement see it as reducing emissions relative to a forecast of "business as usual." Critics see the agreement as being unable to achieve the collective goal of limiting climate change. But business as usual is never observed – so we can't easily tell whether Paris will improve on what countries would have done anyway. My reading of an analysis prepared by the UNFCCC's secretariat suggests that the only way the voluntary contributions pledged thus far could achieve the collective 2-degree goal is if a miracle occurs around 2030, some technological

[1] Scott Barrett is the Lenfest-Earth Institute Professor of Natural Resource Economics at Columbia University's School of International and Public Affairs and Earth Institute.

Note: this piece originally appeared on the YaleGlobal website on December 15, 2015. It is reprinted here with permission.

breakthrough forcing global emissions to plummet. Even then, the chances of staying within the 2 degree goal are no better than 50-50.

My research, especially laboratory experiments done jointly with Astrid Dannenberg of the University of Kassel in Germany, explores the behavioral effects of this kind of negotiation process. It shows that groups choose a goal that is too weak relative to what's required to make them as well off as possible, individual pledges fall short of the group goal, and individual contributions fall short of pledges. The UNFCCC analysis assumes that countries will fulfill their voluntary pledges, but over the past 25 years, many countries have made similar promises and failed to meet them.

Far from representing a radical break from the past, the Paris Agreement embodies the same approach tried again and again – setting targets and timetables for emission limits at the national level. The approach has problems: One is that countries haven't adopted policies that limit their emissions directly. Instead, they have adopted policies like carbon taxes and renewable energy targets that cause emissions to be limited indirectly. Another problem: The emissions of individual countries don't matter; only global emissions matter. Because of globalization, when one country acts to limit emissions, prices for commodities like fossil fuels change, usually causing other countries' emissions to increase. It's easy for an agreement structured this way to move emissions around rather than limit emissions overall.

In 1995, when negotiators first agreed that only the rich countries had to act, little concern was expressed about China's emissions. China's emissions have since gone through the roof, and the government's pledge to begin limiting its overall emissions by around 2030 was seen as a major breakthrough. Perhaps, though, we should be more concerned today about other emerging economies, the countries that will become tomorrow's big emitters. India, for example, is planning to double coal consumption over the next decade or so – an outcome that the Paris Agreement will not stop.

The biggest challenge with agreements to limit countries' emissions is enforcement. This is not only because countries are tempted to free ride. It's also because each country may be unwilling to reduce emissions without assurances that other countries will do likewise. Only global emissions will determine whether the collective goal of limiting climate change is achieved.

Unfortunately, the international system is particularly bad at enforcement. It is sometimes argued that an agreement must be "legally binding" to be effective, but the Kyoto Protocol was "legally binding," and that didn't stop the United States from declining to participate or Canada from withdrawing once its compliance was in doubt. Sovereignty finds ways to wrangle out of legally binding obligations. To be effective, enforcement provisions must be built into an agreement.

The Paris Agreement is self-enforcing because it is a voluntary agreement. But to limit climate change, emissions must be reduced by much more than countries pledged in Paris.

How to enforce a more ambitious agreement? Recent research by William Nordhaus of Yale University shows that a club of likeminded countries could enforce more demanding obligations using a generalized tariff. However, the use of such a tariff could spark retaliation. Even if a trade war is avoided, Nordhaus's analysis shows that a tariff loses its effectiveness once the cost of reducing emissions rises to the level needed to bring about a transformation in the global energy system.

Paris doesn't foreclose parallel options that are designed strategically. One such approach is already underway: an effort to amend the Montreal Protocol, an agreement to protect the ozone layer, to limit HFCs, a potent greenhouse gas. This approach will work because Montreal is enforced by an effective but limited trade restriction. We need to develop more agreements focused on individual sectors and gases, such as ones that limit the emissions from aluminum manufacture and international aviation and shipping. Often, these agreements rely on technical standards.

Unfortunately, even this approach is not enough to stabilize concentrations. To be sure we can do this, a coalition of willing countries should undertake joint research into "game-changing" technologies, including the only true backstop technology for reducing emissions – removing CO2 directly from the air. Such a technology would likely be expensive, but the collective action needed to develop and apply it on a large scale is potentially easier than trying to change behavior worldwide.

The Paris Agreement won't achieve much just for existing. If the agreement is really to pay off, countries need to invest in its implementation. We should also work to build parallel agreements like an amended Montreal Protocol and similar efforts targeted at specific sectors and gases. But unless a miracle technology appears unexpectedly, making fossil fuels uncompetitive, stabilization of the climate will ultimately require more radical approaches – enforcement mechanisms like trade restrictions and new technologies like industrial air capture. The problem of climate change is unprecedented. Addressing it fully requires actions that go beyond the measures that negotiators have so far dared to contemplate.

Energy Innovation is a Key Part of What Made Paris a Success

By Jason Bordoff [2]

***

The Paris climate summit is rightly being hailed as a historic achievement. That is largely because of the new Paris Agreement, a landmark accord that provides a foundation for both developed and developing countries to curb emissions through increasingly ambitious domestic climate policies over time. The attention paid to the accord struck on the summit's final day, however, has risked obscuring the significance of the summit's first day, when philanthropist Bill Gates unveiled the world's largest clean energy research and development partnership, and a group of nations including the United States agreed to double their clean energy R&D budgets.

Mission Innovation and the Breakthrough Energy Coalition

The historic research commitments in Paris make the national targets and policies that form the Paris Agreement more credible, and will enable more aggressive emissions reductions over time. Deep carbon reductions will require new breakthroughs in clean energy, not merely increased use of wind, solar or even nuclear power. To succeed, the new negotiating framework of national plans to reduce emissions, therefore, will need to be accompanied by a dramatic increase in clean energy R&D in both the public and private sectors.

Unfortunately, to date, the trend has been the reverse. US government investment in energy innovation has declined for decades, with energy research funding smaller than in other sectors like biotech or than in other industrialized nations.

A vast economics literature recognizes that the private sector underinvests in early-stage R&D because it is able to capture only a small share of the social value of such breakthrough innovations. Government funding is therefore needed to target long-term, high-risk R&D efforts, such as the sort pursued by the Department of Energy's Advanced Research Projects Agency—Energy (ARPA-E). Examples might be advanced batteries, fusion, or nanotechnology. This is why Mission Innovation is so important, through which the United States commits to double R&D spending—an increase of nearly $5 billion per year—along with commitments from 19 other nations to double clean energy R&D as well.

Government spending can only go so far, however. Private capital is going to fund much of the new technology breakthroughs, and certainly the very large amounts of capital that will be necessary for their deployment in the energy system. As entrepreneur (and Columbia University Center on Global Energy Policy Advisory Board member) Reid Hoffman put it, in explaining why he was joining Bill Gates and other business leaders to create the Breakthrough Energy Coalitions, "Technologies are pioneered in lab settings, but tested, improved, and mainstreamed in commercial markets."

[2] Jason Bordoff is a Professor of Professional Practice in International and Public Affairs and Founding Director of the Center on Global Energy Policy at Columbia SIPA.

Through the Breakthrough Energy Coalition, many of the world's wealthiest individuals have committed to deploy not only their resources, but their business skills and commercial savvy to help the most promising clean energy technologies pass the daunting "Valley of Death" that has challenged many new technologies that require large capital deployments to scale.

As Hoffman noted: "Promising technologies that are ready for real-world testing and iteration but are not yet mature or risk-free enough to attract traditional investors cannot find the funding they need to survive this key stage of their development."

The Paris Agreement

All this exciting new technology will only be viable, of course, if national policies create markets for them—and that is where the Paris Agreement comes in.

The Paris Agreement moves away from the Kyoto Protocol, which prevailed for the last 20 years of climate negotiations and attempted to encourage through international law mandatory emission-reduction obligations for developed countries.

The new framework is important, in part, because it does away with the rigid distinctions between developed and developing countries with respect to limiting emissions. Nearly every country submitted national targets and policy actions—known as Intended Nationally Determined Contributions (INDCs)—that collectively cover nearly all global emissions (as opposed to the 14 percent of emissions covered today by the Kyoto Protocol).

The Paris Agreement creates a process whereby countries come together every five years to put forward more ambitious targets and policies. And it creates important transparency requirements for monitoring, reporting and verification—a crucial confidence-building measure.

Importantly, but less noticed, are the provisions for international policy linkages through "internationally transferred mitigation outcomes," which lay the foundation for the use of carbon markets to meet the national policy goals.

Currently, the price of fossil fuels like coal is relatively cheap because the environmental damages from using it—what economists call "social costs"—are not reflected in the price. The most cost-effective way to correct such a market failure is by internalizing those social costs through a market-based mechanism like a carbon tax or cap-and-trade system.

As the Environmental Defense Fund's Nat Keohane wrote of the deal, "The role of markets may not be in this week's headlines – but a decade from now, it will be one of the enduring legacies of Paris."

The deal reaffirms the goal of limiting global temperature increase to 2 degrees Celsius (3.6 degrees Fahrenheit), and sets a new aspiration to limit the increase to 1.5 degrees Celsius (2.4 degrees Fahrenheit). While politically necessary, along with additional adaptation financing, to strike a deal with poorer countries, this increased ambition is unlikely to materially affect the stringencies of national policies, which are still very far from being able to achieve even the 2 degree target.

Indeed, critics have seized on this fact—that the national targets in the deal do not keep global temperatures from rising above the 2 degree Celsius threshold adopted by the United National Convention on Climate Change. There are two reasons this should not be perceived as failure, however.

First, even achieving the targets in the deal would bring substantial benefits. The climate change damages that would result from the 2.7 to 3.7 degrees Celsius (4.9 to 6.7 degrees Fahrenheit) of warming these initial cuts would provide, while severe, are still much lower than would result from the 4 to 6 degrees Celsius (7.2 to 10.8 degrees Fahrenheit) of warming expected without them.

Moreover, the Paris Agreement explicitly builds in a mechanism to ratchet up ambition and stringency over time. As confidence builds that the burden of climate action is being shared, and public support for more action builds too, it will become easier for countries to take more aggressive steps. Because climate change is the ultimate tragedy-of-the-commons, free-rider problem—a ton of carbon does the same damage regardless of where it is emitted—countries cutting emissions need to know that others are as well.

There is no legal commitment that compels countries to achieve their targets or ratchet them up in five years—another reason some have criticized the Paris Agreement. But international law has proven to be a rather feckless way to deliver climate action in the past. The new framework recognizes that the biggest obstacle has been mobilizing political support for more robust domestic climate policies. And the new approach relies on public pressure and shame to persuade countries not to become laggards in meeting their obligations, an approach bolstered by the robust and transparent reporting mechanisms.

Conclusion

Amid all the praise for the Paris Agreement, a sober reminder is warranted of just how difficult and dramatic the transformation of the global energy system is going to need to be over the longer term to address the threat of climate change. It is far from clear at this point whether countries will really be willing to take the steps needed to decarbonize the global economy. But with a framework that places new focus on national climate policies that can ratchet up over time, supported by dramatic increases in public and private sector R&D funding for new technologies, the Paris climate talks should rightly be judged a success.

What the Paris Agreement Means Legally for Fossil Fuels

By Michael B. Gerrard [3]

***

The Paris Agreement on climate change reached on December 12, 2015 has a heavily negotiated sentence that, when closely read, seems to call for the virtual end of fossil fuel use in this century unless there are major advances in carbon sequestration or air capture technology. That, in turn, has important legal implications.

Article 4 Par. 1 says, "In order to achieve the long-term temperature goal … Parties aim to reach global peaking of greenhouse gas emissions as soon as possible … and to achieve rapid reductions thereafter in accordance with best available science, so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century."

In other words, what goes up should be taken back down: for every ton of GHGs emitted from a smokestack, tailpipe or chopped tree, a ton should be removed.

The Numbers

According to the Intergovernmental Panel on Climate Change's Fifth Assessment Report (2014), fossil fuel use emits about 32 gigatons of carbon dioxide per year. Other sources, such as methane leakage, cement manufacture, and other industrial processes add another 5-7 gigatons carbon dioxide equivalent. Deforestation and other agriculture, forestry and other land use changes (but subtracting emissions sequestered by forest growth) add yet another 10-12 gigatons a year. This all adds up to about 49 gigatons. However, global carbon sinks remove only about 18 gigatons per year (8.8 to the oceans, 9.2 to land, not including land use changes).

In other words, we would need to end fossil fuel use entirely in order to achieve a "balance" between emissions and sinks.

Assuming that some kind of balance between emissions and sinks can be achieved, would we actually have until 2099 to decarbonize the economy? Not really. Kelly Levin and colleagues at the World Resources Institute provide here an illuminating overview of what is required to achieve the long-term temperature goal in Article 2 of the Paris Agreement ("holding the increase in global average temperature to well below 2° C above pre-industrial levels and to pursue efforts to limit temperature increase to 1.5° C"). As the WRI post notes, a recent paper in *Nature Climate Change* suggests that carbon dioxide from electricity would have to be brought close to zero by 2050, and by then around 25 per cent of energy required for transportation would also need to come from electricity (up from less than one per cent now).

[3] Michael B. Gerrard is Andrew Sabin Professor of Professional Practice and Director of the Sabin Center for Climate Change Law at Columbia Law School, and Chair of the Faculty of the Earth Institute.

There seem to be only three ways to continue to use fossil fuels for electricity in the second half of the century:

1) Capture the carbon before it escapes into the air, and sequester it;
2) Devise, and deploy on a massive scale, technologies to remove the carbon from the air, and sequester it; or
3) Create new sinks, such as through the immediate halt to deforestation and a worldwide program of tree planting.

All three of these raise a question of how long the carbon will be stored; we do not know how long carbon will stay in reservoirs, and we do know that trees do not live forever, and when they burn or die they release their carbon. Moreover, the technologies of carbon capture and sequestration, and of removing carbon from the ambient air, are developing slowly and are nowhere near large scale deployment. (A price on carbon would create an economic incentive to develop and use these technologies, but politicians in most places are unwilling to impose such a price. A large-scale government-funded research effort, such as the ones that put human beings on the moon, could also produce the necessary innovation, but there has been little visible support for such an effort.) Most of the industrial carbon sequestration that now occurs goes toward "enhanced oil recovery" – squeezing oil out of depleted reservoirs – but extracting more oil is not compatible with stopping fossil fuel use.

So meeting the demands of society for energy means a combination of aggressive energy efficiency and conservation programs, the installation of renewable energy (and, perhaps, nuclear), and the substitution of electric or hydrogen vehicles for those using petroleum at an unprecedented pace. The Deep Decarbonization Pathways Project has set forth the colossal amount of new facility construction that would be required worldwide to achieve this.

Legal Implications

The Paris Agreement calls on all countries to strengthen their pledges to reduce GHG emissions, and to monitor their progress and report it to the world. It also states "all parties should strive to formulate and communicate long-term low greenhouse gas emission development strategies" (Article 4 Par. 19). That looks like strategies under which every country must show how it is controlling its fossil fuel use.

These provisions are not legally enforceable. However, many domestic laws are, and they will become a powerful tool to force early planning, or at least disclosures. The securities disclosure requirements for publicly traded companies are high on the list of laws that can produce meaningful results. On January 27, 2010, the US Securities and Exchange Commission issued guidelines for the disclosure of climate-related risks. They specifically call on companies to "consider, and disclose when material, the impact on their business of treaties or international accords relating to climate change." The Paris Agreement is clearly such an accord, and (if it is implemented) it will have material impact on many companies in the business of extracting, processing and using fossil fuels, or making things that rely on fossil fuels (such as motor vehicles, ships and airplanes). The SEC's guidelines make clear that management's discussion and analysis should explore known trends and uncertainties concerning climate regulation. This includes regulation outside the US that can affect the operations abroad of US companies. Therefore disclosure can be expected of the effect of severe restrictions here or in other countries on fossil fuel use, including the possibility that most fossil fuel reserves will need to stay in the ground.

Climate disclosures have received increased attention since it was reported in November that New York Attorney General Eric Schneiderman is investigating ExxonMobil under the New York securities law, the Martin Act, over its statements about climate change, and had reached a settlement with Peabody Energy.

This is not necessarily limited to US-registered companies. For example, in April 2015 the G20 finance ministers and central bank governors asked the UK Financial Stability Board for advice on the financial stability implications of climate change. In November 2015 this Board proposed the establishment of a disclosure task force to develop voluntary disclosures for several climate-related risks, including "the financial risks which could result from the process of adjustment towards a low-carbon economy."

Going forward, impact review of energy projects under the National Environmental Policy Act and its counterparts in many states and most other developed countries should consider the Paris Agreement's plan to phase out fossil fuels. For example, a proposal to build or finance a coal mine, a coal-fired power plant, or a coal port should consider whether the facility would need to be closed before the end of its otherwise useful life, and whether the project would be inconsistent with the Agreement.

Systematic analysis and disclosure of these risks will lead responsible boards of directors to undertake serious planning to effect an orderly transition to the low-carbon world that 188 countries agreed to in Paris. These disclosures will also help investors decide what companies will thrive in such a world (such as developers of technologies for renewable energy and efficiency), and what companies are failing to prepare for the transition and thus will themselves become fossils.

Perspectives on Paris

Geoff Heal [4]

***

The Paris agreement is a major and frankly unexpected development. The much-heralded meeting achieved more than I had expected, which is encouraging. Good news on the climate is scarce. But we should not be carried away by our enthusiasm: under the Paris agreement all countries agree in principle to reduce their greenhouse gas emissions, or reduce the rate at which they are increasing, but the targets they talk about are not legally binding, and even if they were, would not be sufficient to solve the problem. However we are all agreed on the goal and are moving towards it, which is real progress.

There is further good news, actually much more important than the Paris agreement. This is that here in the US we can now produce electricity from wind at between 3 and 4 cents/kWh, and from the sun for between 4 and 5 cents. This compares with 5 cents and up for natural gas and 6 cents and up for coal.[5] In the right locations, renewable energy is now less costly than fossil fuels. Many politicians in Paris spoke of the financial burden of using renewable energy rather than coal: they clearly had not seen these figures. The cost burden is with coal now, not renewables, particularly when we take into account the external costs, the devastating impacts of coal pollution on health. This is why so many utilities in the US are using wind and solar power for much of their new capacity, and even before the Clean Power Plan none were using coal: it just makes good business sense.

Of course there is a catch: renewables are intermittent, so we need something to back them up and provide electricity on windless nights. Fortunately we are seeing striking progress there too: electricity storage is a fast-moving field, with nearly $20 billion of venture capital money invested recently. Batteries big enough and cheap enough to store electricity for use in the grid will be available within years. Meanwhile we can continue what we are doing today, which is using gas-fired plants to back up our intermittent clean energy sources.

The competitive position of solar power is even greater than these number suggest in developing countries, as most of them don't have a national electricity grid, or have one that is at best vestigial. Solar electricity doesn't need a grid: it can be generated on the demand site and is perfect for distributed power generation. This cuts out the massive capital costs of the grid, which run about $3 million per mile and can easily double the capital costs of a conventional fossil fuel system.

The transition to renewable energy will not result in higher electricity costs, as the cost figures above show, but it will require massive investment in new generating plants. Replacing our fossil fuel plants by sources of clean energy will take investments of between two and three trillion dollars, and then in addition we will need to invest in storage capacity, possibly about the same sum again.[6] Such a massive mobilization of capital will surely require supportive government policies, which brings us

---

[4] Geoff Heal is the Donald C. Waite III Professor of Social Enterprise at Columbia Business School.
[5] https://www.lazard.com/media/2390/lazards-levelized-cost-of-energy-analysis-90.pdf
[6] Author's calculations.

back to the Paris agreement. This is a signal of governmental support for renewable energy, though governments will still need to enact policies that provide concrete incentives.

It isn't just electricity generation that produces greenhouse gases: it's transportation and also deforestation. There's good news on these fronts too. The progress in battery technologies that I referred to above has also made electric vehicles more competitive. Battery costs are down from $500 per kWh to $150,[7] and battery charge times down from hours to minutes.[8] New vehicles reflecting these new realities will be on the market in 2017, perhaps in 2016. Their prices will be comparable to vehicles with internal combustion engines (ICEs), their running costs lower, and they will be vastly superior in performance and reliability, because electric motors are so much simpler than ICEs. Electric vehicles powered by clean electricity hold out real hopes for a stable climate.

Deforestation contributes about 12-15% of greenhouse gases, and has other acute environmental costs – it is the major driver of extinctions. The Paris agreement has something to say about this too: it[9] "*Recognizes the importance of adequate and predictable financial resources .. as .. incentives for reducing emissions from deforestation and forest degradation*." It supports a system of financial incentives for maintaining the integrity of forests, which stabilizes the climate and also stabilizes the habitat of many threatened species. I am personally particularly pleased with this, as I and two graduates of Columbia Business School (Kevin Conrad and Federica Bietta EMBA 05) have for the last decade been running the Coalition for Rainforest Nations,[10] arguing for support for forest conservation to be built into the successor to the Kyoto Protocol. A decade of hard work has paid off.

Taking all of this together, we can see that there are reasons for real optimism over and above the undoubted diplomatic coup in Paris. We have an agreement on the need for action just as that action becomes economically attractive.

---

[7] http://ecomento.com/2015/10/06/chevy-bolt-battery-to-cost-less-than-145-per-kwh/.
[8] http://www.bloomberg.com/news/articles/2015-12-04/porsche-plans-tesla-car-rival-in-push-to-move-beyond-vw-scandal.
[9] At paragraph 55 of http://unfccc.int/resource/docs/2015/cop21/eng/l09r01.pdf
[10] www.rainforestcoalition.org

Energy Access and Economic Growth: How can Science and Technology Help?

by Vijay Modi [11]

***

COP21 just ended with a much-celebrated acknowledgement and recognition climate change represents an "urgent and potentially irreversible threat to human societies and the planet and thus requires the widest possible cooperation." The Paris Agreement also welcomed the UN resolution on the Sustainable Developments Goals as well as the adoption of the Addis Ababa Action Agenda of the Third International Conference on Financing for Development. An important part of the Paris Agreement was the acknowledgment of the *"the need to promote universal access to sustainable energy in developing countries, in particular in Africa, through the enhanced deployment of renewable energy."* While the Paris Agreement has been rightly hailed as a success, we must expand energy access to the poor as an urgent priority as we pursue our climate goals. Science and technology can help meet this challenge.

For the countries where the nearly 1.2 billion live without access to electricity and nearly twice that without access to clean cooking, the promise of universal energy access to a sustainable energy goal is center-stage. While access to electricity reached much of the world over the course of the twentieth century, the last billion do not want to wait that long. They want access to a range of energy products and services that have enabled modern homes, business, communication, agriculture, and industry, such as cell phones. It is also recognized that many of the other aspirations of the poorer countries (such as eliminating poverty and moving towards fuller employment, universal access to quality health and education) will never be achieved without reliable electrical power.

While the last billion still struggle for their first clean electric light, the first billion that got electricity are so far ahead in their consumption that the greenhouse gas (GHG) emissions from their power generation will have global-scale adverse impacts if the emissions continue unabated. The environment does not care whose emissions these will be. Hence in spite of the large geographic variations in natural and human resource endowments, and the ability to carry out large capital investments in decarbonization, world leaders at COP21 recognized the importance of sharply slowing down GHG emissions through the increased use of renewable energy and energy efficient technologies. Ironically those who are least responsible for this state of affairs, i.e. the poorest or those living in particularly vulnerable geographies of small island states will disproportionately feel the impact from such emissions. So how can science and engineering communities respond so that the poorest countries can help themselves achieve universal access within their political imperatives and their own geographic and economic context.

The science community can be proud of the fact that a combination of basic research, applied engineering and scaled manufacturing of solar photovoltaic (PV) cells has already enabled first

[11] Vijay Modi is a Professor in the Department of Mechanical Engineering at The Fu Foundation School of Engineering and Applied Science at Columbia University.

access to lighting and cell-phone charging for millions of people. Yet, this is a drop in the bucket compared to the larger need. The developing world is also taking a pathway to energy access that could lead the way towards what the developed world might need in the future. Scaled mass production of PV cells was fueled by demand incentivized through feed-in-tariffs. In the developed world, this led primarily to grid-tied installations, either large solar PV farms or grid-connected rooftop systems. However their biggest impact in the poorest countries has been through rapid growth in stand-alone solar-battery systems (all the way from flashlight level lighting from a small PV-battery-LED light to PV-battery systems that are a thousand times larger and can power a 100 square meter home with several appliances).

The particular services that the poor tend to pay for first are lighting and information communication technology (ICT) broadly, including cell-phones/smart phones use, television and DVD players. The most successful have been stand-alone systems in which solar PV provide the generation source and a battery provides storage (where the batteries are primarily lead-acid or lithium-ion), with financing and distribution models that are either outright purchase or some form or rent to own or pay as you go models. The systems that have scaled rapidly in the energy access arena are those which have first costs ranging from $50 to $300. Entrepreneurs providing such systems commercially do not charge per kWh tariffs, but instead try to recover capital through some form of a recurrent payment plan or a pay as you go plan. If one computes the prices per kWh of electricity for these systems, they are at least an order of magnitude higher than conventional grid-power. This high cost is primarily due to three reasons: 1) inherently high cost of battery storage and associated electronics; 2) inability to fully utilize electricity that can be potentially produced each day, (a stand-alone system cannot benefit from the aggregation of diverse demands unlike a grid); and, 3) high transaction cost of financing and servicing such stand-alone systems.

The fact that the poor are willing to pay what amounts to several US dollars per kWh is simply a manifestation of the even more expensive, inconvenient and sometimes unsafe alternatives (disposable batteries, candles, kerosene) that they otherwise have to rely on. When they do have access to a small PV/battery system, in order to stay within their household budgets the poor limit their consumption to around one kWh per month and use that first kWh for lighting, cell-phone charging and small electronics. The systems are generally sized to provide this level of service. While for brevity and illustrative clarity, it comes across as if all poor have one common demand level, which is not at all the case. There are a range of systems in the marketplace from those that provide a fraction of a kWh per month to those that provide a few kWh per month.

The poor would of course like to use electricity for other uses too because of the tremendous convenience and ecosystem of appliances that electricity provides. These uses at home would include cooking, refrigeration, thermal comfort, lifting water as well as a multitude of communication, computing, learning and entertainment services that electronics provide today. Residential consumption is just one vector of demand. Studies show that to lift a home, a village, or a region out of poverty one needs to create opportunities for income generation and accelerate those that exist. Such broader economic benefits of energy services derive from powering agriculture, irrigation, agro-processing, storage or drying; powering small businesses and industry; powering even the most basic shopkeeper and the artisan. Costs of stand-alone PV-battery systems are such today that it would be prohibitively expensive to meet these demands. Yet it is these activities that are likely to lead to income and economic growth. While the poor may be willing to pay $3/kWh for the first kWh or two, but for the level of consumption that they aspire to, they cannot afford $3/kWh. If grid power is provided to the same poor, say at a price of say 10 cents to 20 cents/kWh, their consumption increases to nearly 30 to 50 kWh/month.

It is worthwhile contrasting this situation to that in the developed world. If indeed one had a rooftop system with a grid connection—with the ability to buy power and sell power during times of surplus as well as access to low interest finance instruments—one could offset grid consumption and potentially come out ahead if grid power costs exceeded 20 cents/kWh. The scaling up of rooftop deployments in the developed world through net metering and through feed-in-tariffs is happening because of the grid-connected nature of these systems. So *grid parity* in the developed world implies per kWh solar PV prices for each marginal kWh that are comparable to each marginal kWh of grid power. For the poor who are not connected to the grid, a PV+battery system is not at grid-parity. In fact it is costing them 10-fold per kWh more than those consumers in their country lucky enough to be connected to the grid.

A grid connection to the poor may cost $1200 per household when one accounts for all the capital costs associated with generation, transmission and distribution. Lacking other options, electricity providers are furiously trying to finance such infrastructure for the number of households their governments can afford to connect each year, but leaving a significant number unconnected for now. Put bluntly, those lucky enough to have a grid connection pay $0.20 per kWh. Those who do not have a grid connection in effect pay more than $3/kWh. If indeed the longer-term public policy goal is to provide for the ability to server higher demand levels of 30 to 50 kWh/month, the least-cost approach for the government would inevitably imply access through a grid-connected system for all but the most remote populations. One also needs to recognize that the actual loads in a community the size of a small town of several thousand households can be nearly twice purely residential loads.

The poor themselves recognize the advantages of lower cost power and the additional advantage that a grid-based system provides, which is the ability to flexibly increase (or decrease for that matter) consumption as ability to pay or generate income grow. This latter feature of the grid as opposed to a PV-battery system is underappreciated since in developed countries the first use of electricity was through the grid. In fact large grid systems leverage to their technical and commercial advantage the spatial diversity of loads (e.g. difference amongst customers) and temporal diversity (growth in consumption over years and varying consumption during different times of the day) across a very large number of consumers. Hence the poor who lack electricity access are pushing their government representatives hard to provide grid connectivity even when governments are offering subsidies and discounts on off-grid systems.

It was through a quest that emerged out of these constraints that our own work in Africa led us to deploy 16 pilot systems in Mali and Uganda five years ago. We tested a micro-grid concept that we hoped would adapt to many of the constraints of the poor and yet provide electricity both a lower price point per kWh than a stand-alone system, and at a lower capital cost than a grid connection. Moreover the system would try to emulate the features of the grid that the poor valued most, i.e. the flexibility of use. The capital costs per customer would be limited to $400 so that a poorer country could deploy three times as many such connections as a $1200 connection. If one would leverage the higher kWh willingness to pay of the poor for the first few kWh then some of the capital could be recovered through a tariff. The most important findings over time was that consumption increased in spite of high tariffs and that income generation activities led to load diversity.

We wish we had access to a petrol or diesel or biofuel powered "dream machine" that would be capable of providing up to a maximum of one kW of power at any point in time, whose fuel consumption would linearly reduce with lower loads, a machine that could operate 24-7 without maintenance issues endemic of small engines, and provide a fuel to electrical conversion efficiency of 25%. The capital cost of such a one kW machine would ideally be $1000, the same per kW cost or similar much larger systems. This innovation would have been truly "contextual" and remains a challenge for the world. This machine could have provided reliable, scalable, flexible grid-like electrical power at 50 cents per kWh. Indeed such a dream machine does not exist today.

So we relied on the same basic technology, i.e. solar PV plus battery but through innovative battery management, demand and supply management, increasing utilization lowering electronics, installation, maintenance and financing costs through shared capacity and automation, allowing pay as you go metering and largely unattended operation over multiple years, we are now able to drive the cost of pay-as-you-go service to $1/kWh (with no additional fixed monthly costs to the consumer). If governments were willing to finance the initial capital costs of say $400/customer (about one-third of the capital cost of a grid connection) then the poor could obtain grid-like service for the first 5 to 10 years before the grid arrives. Such options would provide an additional degree of freedom beyond grid connectivity to rapidly and cost-effectively reach the universal electricity access targets.

In the process they could become pioneers in the kind of innovations today that the developed world might need tomorrow. They could provide the initial market demand for the next generation of power systems that will inevitably need smart meters, wireless communication, lower-cost storage, electrical and electronic controllers/drives, super efficient appliances, DC distribution and improved micro-grid operating systems that manage diverse loads, supply and storage as a system. Numerous different innovators, start-ups have adopted the same approach and the space of micro-grids is now moving from a curiosity to a state of many young entrepreneurs with governments and multi-lateral banks taking notice.

It is however equally if not more important to recognize that we do not today have off-grid or micro-grid technologies that can power both the homes as well as social and commercial demands of the poorer countries at price points that allow them to power agriculture and industry. The one exception to this is small-scale hydropower where a year round reliable stream-flow is available.

For now, power levels commensurate with needs for economic growth still rely on interconnected grids fed by mostly dispatchable electricity generation (usually fossil, large hydro or nuclear). The challenge for humanity and especially for scientists and engineers is that variable sources such as wind and solar alone (without affordable means to make them dispatchable) cannot meet the aspirations of all those that gathered at COP21. To fully decarbonize our economies and do so affordably, we will need to develop one or more of the following technologies: safe modular nuclear power, ultra efficient (on land and water) biofuels, electrical, thermal and grid-scale storage such as compressed air or pumped hydro systems, and simultaneously drive towards extreme efficiency in material processing/use, transportation, buildings, electrical equipment and appliances. Some of these technologies combined with smart operation and management of demand, supply and storage will also allow us to drive increased penetration of variable sources such as wind and solar power. Hence science and technology will have a vital role to play in the future that we all want and need.

The Power of Optimism: The Paris Agreement and Road Ahead

by David Sandalow [12]

***

"I am an optimist. It does not seem too much use being anything else." –
Winston Churchill

Pessimism and defeatism come easily when considering climate change. Yet two diplomatic triumphs in the past year highlight the power of optimism and determination.

US-China Climate Agreement

Consider first the US-China climate agreement announced by President Barack Obama and President Xi Jinping in Beijing in November 2014. In the run-up to their summit, odds were poor that the world's two largest producers of heat-trapping gases could reach a deal to limit emissions. The two countries view each other with deep mutual suspicion. They disagree sharply on many issues, including cyber-security, currency values and the South China Sea. They bring starkly different perspectives to the issue of climate change, with US officials emphasizing the importance of limiting China's emissions growth and Chinese officials emphasizing the United States' historic responsibility for the problem.

Yet officials from both countries identified a potential strategic convergence. They persevered through months of challenging negotiations. In the end, these officials and their leaders produced an agreement with the most ambitious commitments either country had ever taken to limit emissions. Both countries followed up, in the months after, with important policies to implement their commitments.

An agreement of this kind can be explained in several ways. Such a deal would not be possible without a strong alignment of interests between the two countries. Yet that alignment alone is not sufficient for a diplomatic breakthrough. Such a deal also requires individuals within each government who believe an unlikely outcome is possible and are willing to take risks to achieve it. The optimism and determination that reflects are essential for the deal.

Paris Agreement

Next consider the agreement adopted last weekend at the 21st Conference of Parties to the UN Framework Convention on Climate Change (UNFCCC) in a suburb of Paris. An agreement of the UNFCCC requires unanimous or nearly unanimous approval by more than 190 countries – an absurdly difficult task. Every nation – rich and poor, fossil fuel importers and fossil fuel exporters, big polluters and small island nations at threat of extinction – must agree on a text. In the US Senate frustrations often run high because 60 out of 100 Senators must agree before an action is taken. The

---

[12] David Sandalow is the Inaugural Fellow at the Columbia SIPA Center on Global Energy Policy.

challenge in the UNFCCC is an order of magnitude greater. Before this weekend, the UNFCCC had not produced a landmark, widely hailed agreement for 18 years.

Yet officials from around the world saw a strong common interest in reaching agreement, despite their widely varying backgrounds. They persevered through years of difficult negotiations. Thanks to their belief a deal was possible and tireless efforts, the Paris Agreement was adopted Saturday in Le Bourget, just over 10 miles from the Eiffel Tower.

The Paris Agreement will not save the world, but it provides an important foundation for the global response to climate change. The fact an agreement was reached – that more than 190 nations put aside differences in the face of a common threat – sends an important signal to businesses and capital markets around the world. (More than 150 heads of state traveled to Le Bourget to open the Paris conference, showing solidarity in the face of both terrorism and climate change.)

At the core of the Paris Agreement is a system of national climate action plans to be submitted by all nations on a regular basis. The first round of these plans were submitted this year by more than 180 nations. Those plans focused leaders in capitals around the world on policies to limit emissions and respond to climate change. In many capitals, the plans were the most ambitious ever developed. Now those plans will be revised on a regular basis, with each plan more ambitious in reducing emissions than the one before it. Procedures for transparent review of those plans will be developed. The Parties will meet regularly to take stock of their progress.

The fact that all countries will submit plans is significant. The Paris Agreement calls on developed countries to "continue to take the lead" in cutting emissions, but does not include the rigid distinctions between developed and developing countries that helped doom the Kyoto Protocol. While recognizing the principle of "common but differentiated responsibilities" set forth in the UNFCCC, the Paris Agreement (in the words of legal scholar Dan Bodansky) "completes the paradigm shift" to a common global framework for addressing climate change.

On the crucial issue of finance, the Paris Agreement calls on developed countries to "continue to take the lead in mobilizing climate finance from a wide variety of sources, instruments and channels." It encourages developing countries to do the same. The text states that amounts mobilized by developed countries should grow in the years ahead. Neither specific amounts nor specific countries are named. These provisions are a sensible compromise that allowed negotiators to resolve one of the most challenging issues in the talks.

The Paris Agreement establishes – for the first time -- a global goal of "enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change." This reflects a recognition that some impacts of climate change are unavoidable and international cooperation can play a central role in helping countries adapt to climate change. Much more attention to adaptation will be required in the years ahead.

The Paris Agreement establishes a new goal: to hold the increase in global average temperatures to "well below 2°C above pre-industrial levels" and "pursue efforts to limit the temperature increase to 1.5 °C above pre-industrial levels." The 1.5°C (2.7°F) goal was a top priority for small island nations, some of which face a risk of complete submersion if temperatures rise higher. It was inspired in part by a study which suggests that a global average temperature rise of 1.5°C (2.7°F) could lead to widespread melting of the Siberian permafrost, releasing billions of tons of methane, a potent heat-trapping gas.

Whether the goal is achievable is unclear. Global average temperatures have already risen at least 0.85°C (1.5°F) since the beginning of the Industrial Revolution. According to the Intergovernmental Panel on Climate Change (IPCC), to have a 66% chance of staying within a 2°C (3.6°F) rise, global emissions of carbon dioxide must not exceed roughly 900 billion tons – roughly 24 years of emissions at current rates. To have a 66% chance of staying within 1.5°C (2.7°F), according to the IPCC, global emissions of carbon dioxide must not exceed roughly 250 billion tons – 6-7 years of emissions at current rates. However global emissions are projected to rise for at least a decade if not more. There is no clear path based on existing technologies and development plans to stay within a rise of 1.5°C (2.7°F).

Does that mean the Parties to the UNFCCC made a mistake in adopting the 1.5°C (2.7°F) goal? Not in my view. If a 1.5°C (2.7°F) rise would create a serious risk of whole nations being submerged or catastrophic melting of the Siberian permafrost, it qualifies (to quote the language of the Framework Convention on Climate Change) as "dangerous anthropogenic interference with the climate system." As part of the Paris Agreement, the 1.5°C (2.7°F) goal will increasingly be a factor in national and corporate decision-making (although the impact of other goals including economic growth will often be far greater). Furthermore, in the past year we've seen outcomes with respect to climate change that seemed unlikely at best. Of course there are many differences between successfully concluding long shot international agreements and transitioning the world's economy to achieve a seemingly impossible goal. But the goal sends an important signal about the change needed, even in the absence of a plan to achieve it. Perhaps the optimism and determination that helped produce diplomatic breakthroughs with respect to climate change will help produce results here as well.

The Road Ahead

The road ahead on climate change is fraught with challenges that can seem insurmountable. New coal plants are being built across Asia. Transitioning the world's vehicle fleets to low carbon energy will take decades. Forest fires are pouring huge amounts of carbon dioxide into the atmosphere each year.

Furthermore, climate change is a "super wicked" policy and political problem. It's caused by invisible, odorless gases. It proceeds at a pace that scientists find alarming but can be difficult to perceive in day-to-day life. Many of its impacts -- including heat waves, severe storms, droughts, floods and forest fires – also occur naturally, making attribution seem difficult. The benefits of cutting emissions are global while the short-term costs are often local.

It would be easy to give up. Yet in the face of these challenges there are reasons for hope. The diplomatic successes discussed above are a start. To name a few more:

1) Global energy-related CO2 emissions stayed flat in 2014 and may have fallen in 2015, even as the global economy grew.
2) Costs of clean energy are falling sharply, led by steep reductions in the cost of solar and wind power in recent years.
3) Twenty nations from around the world just agreed to double their budgets for clean energy research and development in the next five years.
4) Twenty-eight billionaires led by Bill Gates just agreed to deploy billions of dollars of new capital in clean energy innovation.
5) Polling data indicates younger voters support action to address global warming more than their parents and grandparents.

The Paris Agreement sends a strong signal of global consensus about the need to address climate change. It establishes a system for encouraging and supporting national action to do so. Its success will depend upon national policies, technological innovation and many other factors. Optimism and determination will be essential.