OPINION

Climate policy needs more than muddling

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More than half a century ago political scientist Charles Lindblom (1) argued that a policy of "muddling through" with incremental steps is frequently superior to attempting to design and implement comprehensive policy solutions. After decades of talk the world is finally showing signs of muddling its way toward a range of policies to reduce emissions of carbon dioxide. The recent Paris accord will require nations to regularly report on their emissions and plans, and hence take more seriously the need for abatement (2). Incremental steps toward reducing emissions in the United States include the switch to natural gas and the implementation of the Clean Power Plan for existing power plants (www.epa.gov/cleanpowerplan/what-epa-doing). Outside the United States, the ongoing efforts of the European Union, the agreement between the United States and China (3), and efforts to limit emissions from aircraft and ocean shipping (4), are also promising incremental steps.

Muddling through, however, has serious repercussions. Among them: investing in short-sighted technology and policy approaches that do not scale up. This could occur, in part, because most future emission reductions will proceed nation-by-nation and sector-by-sector. Although such a bottom-up approach can be a good thing (5, 6), without careful foresight it can also lead to solutions that actually impede rather than facilitate deeper emission cuts. Unlike schemes such as emission fees, caps, carbon portfolio standards, or even performance standards, like corporate average fuel economy (CAFE) (all of which can be designed to become more stringent over time in a predictable way), many of the complex systems that result from difficult negotiations may complicate the achievement of future deep emission cuts. Once they become firmly established, complex regulatory systems, the bureaucracies that have been created to enforce them, and the emergence of interest groups with a stake in continuing their operation (think corn ethanol), can be extremely difficult to change.

If climate policy is ultimately to be successful, "muddling" will need to be combined with some longer-term "visioning." Modest first steps that reduce emissions of greenhouse gases are wonderful, but to stabilize the climate the world must ultimately reduce emissions of greenhouse gases by at least an order of magnitude (7). It is not too soon to start thinking about how to avoid getting stuck with policies that do not scale up: how to avoid regulatory lock-in and move past early incremental steps to achieve much deeper reductions.

If climate policy is ultimately to be successful, "muddling through" will need to be combined with some longer-term "visioning." Image courtesy of Shutterstock/Calin Tatu.

Patchwork Approach

In the United States, once the Senate failed to pass the Waxman-Markey bill (8) that would have implemented a national trading system that could have scaled up, the White House made the reasonable choice to proceed incrementally, using Section 111 of the Clean Air Act (3). The Environmental Protection Agency's (EPA) plan rests on three building blocks: (*i*) make fossil fuel power plants more efficient, (*ii*) use more low emission natural gas power plants, and (*iii*) build more solar and wind.

Under the United States federal system, states or groups of states will each develop their own implementation strategies. Hopefully litigation will not derail this effort, and the United States will achieve the

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Author contributions: M.G.M. wrote the paper.

Any opinions, findings, conclusions, or recommendations expressed in this work are those of the authors and do not necessarily reflect the views of the National Academy of Sciences.

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www.pnas.org/cgi/doi/10.1073/pnas.1601167113

EPA's goal of a 32% reduction in emissions from 2005 levels by 2030. However, 32% is only a fraction of what will be needed over the coming decades (7). Unless approaches based on regional or national trading emerge as the dominant strategy, it could prove very challenging to overcome a complex patchwork of state-by-state regulatory solutions and to move beyond that first 32%.

Regulatory complexities that jeopardize future deep cuts are also emerging internationally. For example, a committee of the International Civil Aviation Organization has developed a "strawman" proposal to reduce aircraft emissions (4). Rather than a simple performance standard or an emission charge, a differential approach is being developed that imposes lower demands on new, small, rapidly growing airlines. If adopted, the result would involve a set of complex formulas that impose different requirements on different carriers, making it increasingly difficult to scale up as the industry works to meet its own aspirational target of cutting emissions to 50% below 2005 levels by 2050 (4).

Beyond Baby Steps

There are strategies that can help to minimize the difficulties of achieving much deeper reductions. They include: (*i*) adopting a total-system perspective on energy efficiency; (*ii*) sustaining and encouraging all sources of energy that do not release carbon dioxide to the atmosphere; (*iii*) developing ways to remove carbon dioxide from the atmosphere (9); and (*iv*) undertaking analysis to identify and avoid pathways that could slow progress on any of the preceding strategies, or that could lead to future "dead ends," namely getting locked in to technologies that don't scale, regulatory systems that become almost impossible to change, or the dictates of interest groups that successfully lobby against future change.

Adopt a Total-System Perspective on Energy Efficiency. To date, most attention has gone to improving the end-use efficiency of buildings and appliances. Although that is important and should continue, we need to look more broadly. Only about 40% of the primary energy consumed in the United States ends up providing useful end services, such as lighting, heating, cooling, computing, communication, and transportation. The rest is rejected as "waste heat" (for example, for the case of the United States see the Lawrence Livermore National Laboratory energy flow charts available at https://flowcharts.llnl.gov/content/assets/images/energy/us/Energy_US_2014.png). The situation is not dramatically different in most other countries. We can do much better. For example, when natural gas is used to make electricity 45% or more of the input, energy is rejected as waste heat. As both China and the European Union have demonstrated, distributed combined heat and power (CHP) systems can improve this efficiency by using that "waste" heat. However, because CHP systems involve economies of scale, they are much more cost-effective if they can be deployed as part of microgrids that serve several customers (10). At present, most US states have laws that prevent private operators from developing and running microgrids and impede the rapid deployment of such systems. Legislators and regulations should work to identify and remove legal and regulatory barriers to improving total-system energy efficiency.

Sustain and Grow All Energy Sources That Do Not Emit Carbon. Successfully decarbonizing the energy system will require a portfolio of everything we've got. Although wind and solar can make important contributions, especially if undertaken at continental scale combined with long-distance transmission (11), it is most unlikely that they alone will ever be sufficient. Two other technologies will be essential: carbon capture with deep geological sequestration (CCS) on both coal and gas plants, and a new generation of safer and more cost-effective nuclear plants that can be deployed in both the developed and developing world (12, 13).

We have spent decades talking about CCS (14), but because fossil fuel power plants have been able to freely emit carbon dioxide to the atmosphere, progress in the development of commercial scale CCS has moved at a snail's pace. Through strategies such as a direct or indirect price on emissions of CO_2, tax breaks, or direct subsidies, legislators and regulations should find ways to make it attractive for private firms to invest in commercial scale CCS.

Today in the United States, just under 20% of all electricity comes from carbon-free nuclear plants (amounting to 60% of our power that involves no CO_2 emissions). However, in parts of the United States, nuclear plants are being closed because they are not cost-competitive with cheap natural gas. This may make short-term economic sense, but from a longer-term societal perspective, shutting down reliable base-load power plants that emit no CO_2 is counterproductive. Legislators and regulations should find ways to continue the operation of nuclear plants that are otherwise viable.

In the long run, if nuclear is to play a serious role, existing light-water nuclear plant designs will need to be replaced by more advanced designs that are safer, more cost-effective, and limit the generation of long-lived waste. In the United States, the advanced reactor research program of the Department of Energy should be revitalized and expanded. National and international nuclear regulatory bodies need the flexibility and increased technical ability to evaluate and efficiently license factory-produced small modular reactors and advanced reactor designs.

Develop Ways to Remove Carbon Dioxide from the Atmosphere. Although the Paris accord (2) calls on the world to hold "the increase in the global average temperature to well below 2 °C" and to pursue efforts "to limit the temperature increase to 1.5 °C" above preindustrial levels, virtually every serious scenario designed to achieve such an outcome requires negative emissions: that is, removing carbon dioxide from the atmosphere. Some of this can be done through the use of biomass energy (BE) combined with CCS (BECCS), because growing biomass takes CO_2 out of the

atmosphere, and sequestration would keep it out. However, for biomass systems in which life cycle costs and reduced emissions are attractive (for example, those using cane or switchgrass), logistics and land use constraints will almost certainly limit BECCS to less than what is needed. Of course, advanced biological methods might be developed. Strategies to directly scrub CO_2 from the atmosphere (DAC) will likely be needed. There has been only limited private development of DAC technology (see for example, carbonengineering.com). Governments around the world need to add the aggressive development of advanced BECCS and DAC to their existing climate abatement research portfolios.

Avoid Future Dead Ends. In parallel with the strategies outlined above, academic and other analysis groups should conduct studies to identify and minimize the risks of regulatory and technological dead ends. For example, if distributed CHP systems that use natural gas become widespread, how might they be replaced with systems that have zero emissions later in the century? Would it be possible to convert them to hydrogen or would it be more practical to change them out for other systems such as ground-source heat pumps?

Here are three examples of the sorts of questions analysis should address: (*i*) If market discount rates are used in making investment decisions, planners may not think as far into the future as prudent climate policy requires. Should declining discount rates be used for long-lived capital investments (15)? (*ii*) Should emission fees be linked in some way to anticipated infrastructure lifetime? (*iii*) How might strategies based upon the use of real options (investments today that make future upgrades possible) be used to provide public funds or tax incentives to cover the incremental costs of laying the groundwork for conversions that may be needed many decades in the future?

In designing abatement policies, care should be taken to align incentives, both with the objective of continuing to reduce emissions and with the realities of the underlying economic sector. For most stationary sources, emission fees, cap and trade, or carbon emission portfolio standards, each promulgated with a clear indication of how they will be tightened over time, would be appropriate and effective strategies. The same would be true for motor vehicles if we could afford to wait decades or if high carbon prices were politically feasible today. However, because a carbon price of $1/ton translates to just a penny a gallon at the gas pump, politically feasible carbon prices will not induce the needed change. Given the urgent need for action on all fronts, a performance standard such as CAFE, that becomes progressively tighter over time, is a more appropriate way to kick-start the needed transformation of the vehicle fleet.

Muddling through may be the best we can do in the short-term to get started on policy to reduce CO_2 emissions. However, the community of policy analysts should begin to work now on identifying and avoiding strategies that might lead to regulatory dead ends and find ways to promote strategies that will scale up to the ≥90% emissions reductions that will be needed to stabilize the climate.

Without some longer-term "visioning" of how to gracefully move past short-term strategies to address the longer-term need for major emission reductions, progress could stall. The success of today should not become the burden of tomorrow.

Acknowledgments

Much of the work on which this piece is based was supported in part through a cooperative agreement SES-094970 between the National Science Foundation and Carnegie Mellon University. The views expressed are those of the author alone.

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