As I've discussed the earlier three posts in this series, it is possible to imagine a cycle of positive feedback, in which the history of past climate efforts increases the likelihood of future ones and even draws more jurisdictions into the effort. But it is also possible to imagine that bottom-up efforts might not catch hold, fading away over time. In that scenario, the initial sparks might simply die out rather than taking fire. Under what circumstances might we expect a growing cascade of efforts rather than a fading one?

In thinking about the prospects for self-sustaining growth among climate initiatives, an analogy may be helpful. As of 1990 or so, the world had a very well-developed and stable energy system based on fossil fuels, and governance systems to go with it. We can think of this as an ecosystem of sorts, in which producers and consumers adapted to each other and thrived – though at the expense of fouling their environment with waste products. That ecosystem has now been invaded by new species of energy producers such as solar and wind generators, along with new types of energy policy. Many invasive species fail; others flourish and even drive out the natives. Normally, we regard that as an undesirable outcome, but in this case, we are hoping the new energy and policy "species" ultimately drive the existing incumbents to extinction.

In a sense, this is a simple question about whether the invaders' reproduction rate exceeds their death rate, leading their expansion to continue. (And correspondingly, whether the natives have a higher death rate than replacement.). Sometimes this can happen simply because individual members of the invading species outcompete the natives. The counterpart for energy would be that renewable energy just gets cheaper and more appealing, driving out less efficient fossil fuels. We've actually started to see this in the United States, with renewables and natural gas combining to push coal out of the market. Whether this continues at the global level is still unknown. Part of the answer depends on the cost curve for mitigation methods. The more rapidly that costs fall over time, the better. This dynamic requires that the bottom-up efforts are sufficiently widespread and sufficiently ambitious to provide markets for increased production efficiency and for innovation. Some of this depends on characteristics of technologies that may not be known at the outset. But other factors include whether jurisdictions are willing to invest in research and development to improve mitigation technologies and whether there is a sufficiently large initial core of committed jurisdiction – enough of a critical mass to get the process going.

The invasive species can succeed in another way, however, not just by one-on-one superiority. They can modify the environment in a way that is more favorable to them than to the natives – perhaps by causing habitat modifications or changes in prey/predator relationships. The more invaders there are, the stronger this process becomes. Human beings are really good at this. We're individually weaker than many other species, but we're

good at modifying the habitat to our benefit, and we do so more readily as we can population and access to resources.

This is exactly the process discussed in this series of posts, whereby the growth of renewable energy and of climate policies go hand in hand to foster the further their own further spread. It's also the subject of a new paper that I've just posted online.

What I like about the ecosystem analogy is that it captures both the complexity of the energy/policy system and the highly diverse types of interactions that take place. There are many channels for policy decisions to affect the energy mix, and vice versa, and for actions at one time and place to have ripple effects throughout the system. Of course, we are (often) intelligent actors who adjust our behavior according to available information, which makes the ecosystem analogy inexact, but it still captures something about the way the system works.

I'm actually optimistic that we will ultimately succeed through these processes in making the transition to a zero-net carbon society. What worries me, though, is the element of time. The longer the process takes, the greater the legacy of carbon that we leave behind, and the harder our descendants will suffer from severe disruption of the climate system.

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