The reflections published since the death of Barry Commoner a few days ago – including here by Dan Farber, and in many other places – have appropriately celebrated Commoner's huge contributions to environmental science, and to raising public and political awareness of the gravity of environmental risks and the need to reduce them.

But these reflections have largely overlooked other points of Commoner's argument and advocacy – about diagnosing the causes of environmental problems and identifying how to respond to them – that are quite problematic, and in important ways wrong.

This is a shame – particularly because Commoner's errors were more interesting, perhaps more important, than all the ways he was right. And they are certainly of greater relevance for understanding what to do about the environmental challenges we face today. To identify Commoner's errors conveys no disrespect to all his important contributions. Every scientist knows that a claim that is big, bold, clearly stated, and wrong, can do more to advance knowledge than one that is timid, incremental, and right. So it is with Commoner's thought. He was so bold, courageous, and forceful in his views, that his errors are big, illuminating, and helpful in understanding the nature and severity of the challenges we face – as much as, perhaps more than, the ways in which he was right.

The key issues concern the role of technology in contributing to environmental damage, and what to do about it. On these questions, Commoner was the antagonist of Paul Ehrlich and John Holdren in one of the most important environmental controversies of the 1960s: what is the most important human driver of environmental harm, and thus what is the most effective corrective? Ehrlich argued that the fundamental driver, and the most potent point to intervene, was human population growth; Commoner argued that it was destructive technology. Ehrlich's subsequent reflection on the argument, joined by Holdren in a famous 1971 essay in Science magazine, provided the basis for the "IPAT Identity" – the accounting identity that decomposes any measure of a society's environmental burden (or *Impact*) into separate factors for *Population* (how many people are there), *Affluence* (how much economic value does the average person consume), and *Technology* (how much environmental burden does the average unit of economic value impose).

Commoner's view – which he expressed most compactly in his 1987 article in The New Yorker – was that despite the importance of other factors, technology choice was the predominant source of environmental destruction. He railed against the environmental burdens, seen and foreseen, of multiple technologies then expanding rapidly in the post-war economic boom: e.g., PCBs, pesticides, and other synthetic chemicals; nuclear power; and Chlorofluorocarbons (CFCs).

Commoner never compressed his arguments on causes and solutions into a vivid compact scheme like his four environmental "laws." But his arguments on these matters had a characteristic clarity and cogency that make it easy to pull out an equivalent core structure to his argument. This would go roughly as follows:

- The most basic cause of environmental deterioration is the expansion of environmentally harmful technologies.
- An alternative set of more benign technologies is available to meet the same human needs. (Note that in this respect, Commoner anticipated key points of arguments later advanced by both E.F. Schumacher, in "Small is Beautiful," and Amory Lovins in "Soft Energy Paths").
- We can identify the destructive and benign technologies, and can make collective choices to pursue the good ones and limit or prohibit the bad ones (presumably in advance, before they are deployed at scale).
- But society is afraid to face this choice, because of some combination of psychological unwillingness to face moral choices that impose cost or difficulty, and political inability to overcome vested interests in the continuance and expansion of the destructive technologies.

Every one of these propositions is, to at least a very substantial degree, wrong.

The most basic reason for this is that technologies – specific ones, and technological innovation in general – are usually ambiguous in their environmental effects. They impose some harms, often (or usually) as they mitigate others.

Two of the technologies Commoner attacked, CFCs and nuclear power, illustrate the variety of ways this ambiguity can play out. CFCs were developed in the 1930s as ways to reduce the grave health and safety harms (and environmental ones, though these didn't get much attention in the 1930s) posed by the chemicals previously used as refrigerants. Because of their extreme chemical inertness they were uniformly believed to be harmless: for a pollutant to do any harm, it has to react with something, right? This remained the case until 1973, when Molina and Rowland identified a new, previously unknown, mechanism by which they caused a severe and novel environmental harm – transport to the stratosphere, where the high-energy sunlight present there split apart their molecules and the resultant reactive fragments catalytically destroyed ozone.

For its part, nuclear power can bring either environmental harm or environmental benefit,

depending on how the system is designed, built, operated, and regulated, and – crucially – by what alternative sources and technologies we would use instead if we didn't have it. The grave risk of climate change has turned many environmentalists – including me – from strong opponents to nuclear power in the 1970s to cautious proponents of its expansion today.

So technologies do not come separately bundled into good ones and bad ones: it depends on a ton of details concerning how they are implemented, in what context, and relative to what alternatives. Moreover, the details of any particular technology's benefits and burdens are hard to see, and rarely assessed accurately, in advance. Environmental policy is thus repeatedly forced to play catch-up, attempting to limit technologies, activities, or resultant harms that were either neglected or actually believed to be benign, as expansion of their scale or scientific advance reveal previously unidentified or unobserved harms.

And all of these issues are moving targets – the set of available and anticipated technologies, how they are deployed and used, in what context, with what knowledge of their environmental harms or benefits. As a result, policy choice is almost never about separating the good from the bad and choosing the good. Rather, it is about trying to anticipate uncertain bundles of harm and benefit, encouraging development and deployment of seemingly better choices while discouraging seemingly worse ones, going back to correct the worst errors we made previously, while attempting to look ahead to anticipate new opportunities – all at the lowest feasible cost, and consistent with all the other valued principles and goals of democratic policy-making. We have a little knowledge and experience about how to do this, but not nearly enough – and to have a hope of effectively managing the harder set of environmental problems that are in front of us now and coming up, we will have to get much better at it.

Finally, on the claim that society ignores the environmental dimension of technology choice because it is too painful or contentious, it strikes me that nearly the opposite is the case. Almost all debate about resolving environmental problems is about technology, because it is so much easier to agree on the desirability of environmentally beneficial innovation (particularly if it comes cheaply and easily) than it is to consider tradeoffs and constraints that might follow from environmental limits – particularly if these require looking at the other, much harder factors of the IPAT identity – how many we are, and how much we consume.