Innovation, Deep Decarbonization and Ethics - **Critical Review Essay**

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Abstract: Deep decarbonization—slashing global greenhouse gas emissions to net-zero—now dominates global climate policy. Two recent books assess feasible routes to achieve deep decarbonization. Bill Gates' How to Avoid a Climate Disaster explains in depth why deep decarbonization requires significant innovations in tech, and Danny Cullenward and David Victor's Making Climate Policy Work emphasizes the importance of policy innovation (beyond carbon pricing) for driving clean tech breakthroughs. In this critical review essay, I summarize and assess both books. In the final section, I raise several normative questions which the pair of books might lead us to.

Gates, Bill. *How to Avoid a Climate Disaster: The Solutions We Have and the Breakthroughs We Need*. Knopf, 2021.

Cullenward, Danny, and David G. Victor. *Making Climate Policy Work*. John Wiley & Sons, 2020.

Deep decarbonization—slashing global greenhouse gas emissions to net-zero—now dominates global climate policy.[1] Two recent books assess feasible routes to achieve deep decarbonization. Bill Gates' *How to Avoid a Climate Disaster* explains in depth why deep decarbonization requires significant innovations in tech, and Danny Cullenward and David Victor's *Making Climate Policy Work* emphasizes the importance of *policy* innovation (beyond carbon pricing) for driving clean tech breakthroughs.

In the next two sections, I will summarize and assess Gates' contribution, and then Cullenward and Victor's. I conclude by raising several normative questions which the pair of books might lead us to.

The Hard Stuff

How to Avoid a Climate Disaster provides a sobering view of the specific technical challenges to decarbonizing a range of sectors, from heavy transport to manufacturing to the world's electricity generation system. Collectively Gates refers to these challenges as "the hard stuff". I outline the technical challenges Gates highlights in Table 1.

Table 1. Technical challenges for decarbonizing the hard stuff

Type of hard stuff	Technical challenges for decarbonization (per Gates)
Heavy transport: (Trucks, Aviation, Shipping)	• Batteries are not nearly energy-dense enough to power heavy vehicles efficiently over long distances. • Biofuels are inefficient, expensive, and land-hungry
Steel manufacture	• Electricity doesn't easily generate enough heat to melt iron ore • CO_2 emitted during chemical process of steelmaking
Plastics	• CO_2 emitted from chemical process of making plastics • CO_2 emitted when plastics biodegrade
Cement manufacture	• Electricity doesn't generate enough heat for cement kilns. • CO_2 emitted in chemical process of turning calcium carbonate to calcium oxide for cement.
Animal Agriculture	• Methane emissions from ruminants can be reduced but not eliminated. • Meat-like substitutes currently expensive and some (lab-meat) mistrusted.

[1] See, for instance International Energy Agency (2021)

Emissions from fertilizer	• N_2O emissions (a potent greenhouse gas) are a central byproduct of artificial fertilizer use. • Technology to capture N_2O from the air is currently non-existent.
Electricity (storage)	• Storing large amounts of electricity to cover local seasonal fluctuations in wind and sun is very costly.
Electricity (transmission)	• Underground power transmission creates enough heat to melt metal cables. (New over-ground power transmission lines politically difficult)

These technical challenges are not just on the margins of deep decarbonization. Gates implies, rightly, that hard stuff represents a huge chunk of greenhouse gas emissions. The last two rows of Table 1 underscore that decarbonizing the electricity sector involves significant hard stuff. But even a fully decarbonized electricity grid will do very little to impact the other tough-to-electrify sectors, such as manufacturing steel, plastic, and cement; agriculture; and heavy transport. For reference, heavy transport currently amounts to around 8% of global GHG emissions (Ritchie, 2020), cement production another 8 % (International Energy Agency, 2020a) and steel a further 5%.[2] On the agricultural side N_2O emissions, largely from nitrogen fertilizer count for 6% [3], and methane from ruminants' digestive tracts 4%[4]. Emissions from all these sectors are projected to grow in developing countries. With net-zero as a goal, the hard stuff is a big deal.

As well as outlining the nature of the technical challenges, Gates surveys the state of possible solutions. Through five central chapters, focusing on manufacturing, electricity generation, agriculture, transport, and heating/cooling, Gates goes through possibilities for dealing with the hard stuff – from capturing carbon and injecting it into concrete itself, to molten-oxide electrolysis for producing pure iron ore, to introducing nitrogen-fixing bacteria to soils.

Importantly, Gates notes there are some key breakthroughs that would unlock many of the problems at once. One is developing a decarbonized energy-dense fuel to rival fossil

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[2] The International Energy Agency estimates that iron and steel production accounts for 8% of global energy sector CO_2 emissions (International Energy Agency, 2020b). Since energy sector CO2 emissions equate to around 75% of total greenhouse gas emissions, this means iron and steel production accounts for around 5% of total greenhouse gas emissions.

[3] Using 3.06 Gigatons emissions of N_2O in CO2e in 2018 and global emissions of 48.9 GT CO2e, from the CAIT database (available at https://www.climatewatchdata.org).

[4] Gates, 2021, p. 117, using a radiative forcing measure for methane of 28.

fuel. This could power long-haul transport, solve the intermittency problems with the grid and provide the high heat needed for heavy industry. Gates raises as contenders "advanced biofuels" (made from non-food crops which do not need fertilizer or arable land) and "electrofuels"[5] (various artificial fuels from green hydrogen). Another key breakthrough would be increases in the cost-effectiveness of direct air capture of CO2. This, in combination with cost-effective carbon storage networks, would allow the world to directly offset the emissions from much of the hard stuff. (Peacock, 2021).

As Gates and Cullenward & Victor both recognize, the trouble is not (in most cases) that the technologies to decarbonize the hard stuff don't exist, but they are currently prohibitively expensive. Gates illustrates some of the costs via the useful concept of a "Green Premium". This is an estimation of how much *more* a zero-carbon alternative to a current technology currently costs, typically over the life-cycle of the technology. It's a rough estimation of course, and Gates is frustratingly opaque on his methodology for estimating Green Premiums, but they are useful for getting a sense of the scale of how far we need to move for each of the "hard sectors".

Some of the most dramatic of Gates' green premiums are for decarbonized fuels: they range from a 106% markup if one switches from gasoline to advanced biofuels, to a 601% markup comparing ship's bunker fuel to current electro-fuels. Gates also uses the concept of green premiums to powerful effect when illustrating the difficulty of using batteries to store power on a seasonal basis. Factoring in the cost of financing a grid-scale battery, he figures that storing electricity this way raises the effective cost of electricity by 300% for overnight storage to 10,000% if stored in a windy summer to use in a calm winter.

Since fully decarbonized processes for producing steel, plastic and cement are still theoretical, Gates estimates the green premiums for these by counting the cost of capturing the amount of CO_2 emitted in production and storing it. That is, estimates the price increase of these materials if the emissions were offset using direct air capture at current prices (Gates uses values of $94-175 per ton). This gives a Green Premium for green ethylene plastic: 9-15%, for steel: 16-29%, and for cement: 75-140%). While double-digit green premiums might be something that wealthy citizens in the developed world might be willing to pay, Gates points out they will be difficult for firms that compete with each other on cost to voluntarily shoulder. Furthermore, Gates recognizes that

[5] Also known as P2X (power-to-X) technologies. One thing Gates does not make clear: electrofuels have the advantage of making renewable energy more cost-effective. When there is *more* sun or wind then needed renewable capacity can be directed to making precious electrofuels.

asking developing countries to pay twice as much for cement as they currently do, given its ubiquity in construction, is unrealistic and would constrain global development.

While *How to Avoid A Climate Disaster* is not a book primarily on policy, it does contain some policy recommendations for the US context. Gates calls for a price on carbon, but also a 500% increase in US government R+D investment in clean tech, as well as government provided loan guarantees, subsidies, and targeted government procurement policies that focus on clean tech.[6] But the worth of the book is not primarily in its links to policy. Rather, it functions as an excellent handbook for the layperson of the challenges of decarbonizing our current system of technology. Gates draws on his rather unique set of experiences: as an engineer, CEO, global philanthropist, and venture capitalist. He has a knack for communicating the complexity of technical problems and their possible solutions—from liquid metal batteries to the Haber-Bosch process—in clear and succinct ways. Gates also has something of an insiders' perspective on some of the political barriers that might be inhibiting many of these nascent technologies, such as the struggles of green concrete manufacturers to meet old building regulations that specify the exact chemical composition of concrete, or the role of 1970s US energy efficiency laws delaying the uptake of heat pumps.

Some might find Gates' rejection of lifestyle changes and structural change somewhat jarring. While he admits "guilt" about his "absurdly high" carbon footprint, he also defends (inter-continental) mobility as a "form of personal freedom" while the face-to-face contact provided by international air travel enable us to "understand our common goals" (Gates, 2020, p. 15, 133). As to veganism as a solution, he supports eating less meat but cites traditional festivals in the developing world, and France's UNESCO protected "gastronomic meal – including starter, meat or fish, cheese and dessert" to conclude that animal products "plays too important a role in human culture" to disappear in time to allow deep decarbonization, (Gates, 2020, p. 119). Reducing international trade to cut down shipping emissions is a non-starter for Gates, since global trade networks are a "matter of survival for farmers in poor countries", (Gates, 2020, p. 133). Similarly, Gates has a keen sense of the centrality of the demand for concrete, steel and fertilizer for traditional paths out of poverty for developing

[6] Gates notes the irony of his calling for more government intervention in the market, since Microsoft waged one of the largest battles against government oversight in the early 2000s antitrust lawsuit by the US Government. He claims now that the lesson for companies from the anti-trust case is that "we should have been engaging with policy-makers all along" (Gates, 2021, p. 183).

countries. Regardless of the success of these brief defenses, Gates' main point about innovation remains. If the aim is net-zero, then simply reducing the amount of hard stuff that goes on is not sufficient. Even a socialist world of localist vegans still needs some fertilizer, steel, concrete and energy storage. Gates' insistence that we need breakthrough technologies to get to net-zero is apt.

Overall, *How to Avoid A Climate Disaster* is valuable. Even those who disagree with Gates' view of the scope of the hard stuff and his assessments of possible solutions will find his explanations of the problems and the potential technologies worthwhile. Gates has less to say about policy and especially politics, but does very well at the main task he sets out to do. Although the charms of Gates' folksy writing voice might be jaded by recent scandals, the simplicity and directness of the prose is refreshing in a complex and jargon-filled domain.

Technical innovation through industrial policy innovation

Cullenward and Victor take Gates' thesis - the urgent need for technological innovation as a starting point. They draw on an earlier co-authored report (Victor et al., 2019) to suggest we are at the *earliest* stage of technological development for most of the technological breakthroughs a decarbonized world require. Whereas Gates provides clear arguments why driving the "green premiums" for clean tech down is crucial for deep decarbonization, Cullenward and Victor focus on how this might be done. Their position, which I turn to next, is that we can't rely on carbon markets for this task. Instead, they claim we should use "experimentalist governance" to find and adapt sector-specific policies that themselves can be diffused worldwide to drive deep decarbonization.

Cullenward and Victor's justification for experimentalist governance over carbon pricing comes from, in part, their conception of climate policy as a search for political compromises that are acceptable to multiple interest groups. In this case, they refer specifically to dominant incumbent firms, new entrant green firms, the public, politicians, and civil society. According to Cullenward and Victor, *none* of these groups have strong incentives to champion carbon prices particularly vigorously over other policy tools or strategies. Worse, incumbent firms opposed to carbon prices can easily mobilize the public to join them by drawing attention to their visible upfront costs. Incumbent firms also tend to demand over-generous allocation of credits and the ability to "bank" those allocations for future years as price for their acceptance of carbon prices. Other special interests (including forest-focused environmental groups) argue for the ability to include offsets of dubious quality in market-based schemes. Finally, politicians tend to want to direct the modest revenue from carbon markets towards inefficient "green pork".

Cullenward and Victor raise broader, more systemic concerns. Carbon markets and supply-side regulations also do not play well together—efficiency standards or feed-in tariffs reduce overall emissions which depress the carbon price. But perhaps most importantly for this discussion, the carbon prices which are politically feasible in most jurisdictions tend to be too low or volatile to drive the development and early adoption of breakthrough clean tech. "Unless the [carbon] prices are extremely high, market strategies don't have much impact on emergence" (Cullenward & Victor, 2020, p. 156). This statement fits with the details Gates gives about some Green Premiums. By my estimate, a carbon tax of $658 per ton would be needed to make electrofuels competitive with six-times-cheaper bunker fuel.[7] (Currently Sweden has the highest carbon tax in the world, at around $126 per ton).

Cullenward and Victor admit that some jurisdictions with carbon markets, such as the European Union or California, have bent down their emissions curve. However, they argue that the modest successes from carbon markets are due to two factors. First, the relatively mature state of *specific* decarbonization technology (e.g. solar or wind energy) allows even a moderate carbon price to incentivize diffusion and deployment. Second, jurisdictions with carbon prices tend to also have other regulatory instruments driving change in the background. Cullenward and Victor point out that policies such as renewable portfolio standards that dictate amounts of renewable energy in the mix, or energy efficiency standards in given sectors typically predate the appearance of carbon prices, keep carbon prices low, and (they assert) drive the bulk of decarbonization. In this sense, they argue, carbon markets are an illusory overlay of the real policy: "Potemkin markets" like the model Potemkin villages that hid the real state of the economy in Tsarist Russia. Cullenward and Victor only briefly discuss carbon taxes, and are somewhat more lenient on that policy instrument. They suggest that current carbon markets, if retained, should be reformed to be more tax-like. That is they suggest carbon markets should have a strict floor and ceiling on the price of carbon. However, they hold out little hope for carbon taxes as drivers of deep decarbonization. Carbon taxes currently apply to "a tiny portion of global emissions and in a handful of trade-insulated sectors; they are unlikely to scale any faster than markets because their acute

[7] From a cost estimate for electrofuels of $9.05 per gallon, and bunker fuel $1.29 (Gates, 2021, p. XXXX) and CO2 emissions per gallon of bunker fuel of 10.18 kg (Environmental Protection Agency, 2020).

political visibility makes them even more difficult to enact in the first place." (Cullenward & Victor, 2020, p. 149).

Cullenward and Victor don't just critique market-based approaches. They offer an alternative in its place. They briefly mention some political instances: The Green New Deal and European Green Deal, but refer more generally to "industrial policy" and "experimentalist governance". Industrial policy is the deliberate government encouragement of specific kinds of private industrial activity, and experimentalist governance refers to the diverse ways that different specific policies under the broad ambit of industrial policy can be tried, tested, and diffused.

It's worth noting that Gates also, while paying lip service to the importance of carbon pricing, highlights the success of industrial policies in the past. As he points out, solar electricity has become cost-effective in part through early R+D investment from Japan, EU and the US, from Germany's feed-in tariff (that rewards private actors for electricity they return to the grid) and from Obama era loan guarantees. All these industrial policies have succeeded in driving the cost of solar energy to the point it is, in many circumstances, competitive with fossil fuel tech even without government policies. Carbon pricing played little role.

Let us return to *Making Climate Policy Work*. One way in which policymakers can encourage and coordinate experimentation and innovation in policies and technology, Cullenward and Victor argue, is by breaking down problems into smaller sub-problems. Finding a way to reduce N_2O emissions from fertilizer use is quite a different issue from developing a cost-effective electro-fuel. Within those sub-problems, governments and civil society can incentivize technological innovation by offering both carrots and sticks. Carrots might include: providing a market (through introducing standards that require a clean tech product); providing capital (say, loan guarantees or R+D grants); or providing complements (pipeline networks for carbon capture and storage, high-volume electricity transmission systems for renewable energy). Sticks might include loss of reputation and access to markets, which might amount to "existential threats" for incumbent firms (Cullenward & Victor, 2020, p. 158). A particularly interesting and topical incentive Cullenward and Victor (and Gates) discuss are border carbon adjustments. These are trade interventions by which states with strong climate policies place can place special tariffs and subsidies on carbon intensive goods to balance out the price difference due to compliance with green regulations. I discuss some normative questions border carbon adjustments raise later.

By contrast with carbon prices, the winners of industrial policy tend to be clear, and the identity of the losers is more opaque. Thus, by standard theories of political science, industrial policy should be more politically feasible (Matto Mildenberger & Stokes, 2020). Furthermore, Cullenward and Victor explain, once large incumbent firms start to build expectations that a particular regulation will be enforced, they begin to have a vested interest in maintaining and not undermining that standard. Here Cullenward and Victor use the example of California's vehicle fuel efficiency standards, and Obama-era methane leakage standards. In both these cases, many incumbents—large automakers and fossil fuel producers respectively—lobbied to *maintain* the government regulations since they had invested significantly in the meeting those standards (Cullenward & Victor, 2020, p. 40).

Still, crafting policies in specific sectors which get enough incumbents (or other powerful actors) on board will be a delicate process, especially since the costs of meeting some regulations are not well known until firms actually try to meet them. Enter the experimentalist aspect. Cullenward and Victor argue for multiple simultaneous attempts in different jurisdictions to get the policy balance right to fix specific kinds of hard stuff. Just as technology can be diffused around the world, so can successful policies. Experimentalism is also not just a top-down process. Since "government and business work together in testing" partnerships between the two are "well positioned to learn what works and adjust accordingly"(Cullenward & Victor, 2020, p. 159, cf Gates 2021, p. 202). Prime examples of experimentalist governance in action, according to Cullenward and Victor, have been the EU's governance of the complex issue of European water pollution, and the Montreal Protocol on ozone depleting substances.[8] Both these examples included the decomposition of complex problems, as well as the exploratory search for the appropriate sticks and carrots.

Cullenward and Victor suggest that complex networks of industrial policy, involving combinations of performance or manufacturing standards, subsidies, R+D grants, along with border carbon adjustments to protect trade sensitive industries, are feasible, necessary and (along with diffusion and deployment policies) sufficient to drive deep decarbonization.

Overall, *Making Climate Policy Work* provides a strong argument for the impotence of carbon prices, and especially carbon markets to drive deep decarbonization. At times, though, Cullenward and Victor over-reach. They frame the UNFCCC process as merely one long failed attempt to create a world-wide carbon market, and ignore the possibilities that the Paris regime holds for being a framework in which some of the aspects of experimentalist governance can unfold. The book would have also been improved by a more through exploration of carbon taxes. As it stands, carbon taxes are dismissed rather quickly, and it is left for the reader to interpret which of their critiques of carbon markets apply to carbon taxes. The citations in the book are also patchy. Some claims are referenced in detail, while other key claims, such as industrial policy temporally preceding carbon markets in most jurisdictions, go largely unreferenced. Similarly, opponents' positions are often alluded to and then rebutted, without the reader ever learning who defends these positions. Finally the positive recommendation – experimentalist governance – is introduced rather briefly, and interested readers would do well to look out for Victor and Sabel's forthcoming monograph on that topic (Sabel and Victor, 2021a). Likewise, those suspicious that Cullenward and Victor's positive approach concedes too much to incumbent firms and political elites will welcome the Boston Review forum which discusses that very question, with Charles Sabel and David Victor arguing that distributional questions of climate politics need not be settled before forging ahead with potentially transformative policies (Sabel and Victor, 2021b).

In all, the book provides a clear and largely convincing argument for experimental governance and industrial policy as the heart of the policy path to deep decarbonization. Cullenward and Victor's approach is constructive, not just adversarial. They include a chapter on how a "right-sized" carbon markets could be designed to provide the marginal incentives that might aid the deployment of existing technology. In all, *Making Climate Policy Work* acts as a clarion call for civil society and other policy actors to pay closer attention to the details of climate policy. It asks us to look at specific regulations, subsidies, standards and tariffs, in particular sectors and jurisdictions, rather than keep aiming for a high carbon price across multiple jurisdictions.

Ethical questions the innovation approach raises

Having surveyed this pair of books on climate innovation, I now want to reflect on why climate *ethicists* should care about such books. Assume, for the sake of argument, that Gates and Cullenward & Victor are right that mutually reinforcing technical and policy innovation is a necessary condition for deep decarbonization. What specific normative issues apart from those mentioned above, does this vision raise?

Let us begin with international ethics. The two books call for bringing down costs of clean tech in many developed countries, in order to allow less ambitious or simply poorer countries to decarbonize more easily. But making decarbonization less expensive for countries like Nigeria or Indonesia is not framed as a *moral* imperative. Gates for instance stresses reasons of national self-interest for fostering breakthrough clean tech. He closes his book with italics, repetition and emphasis, claiming that moving first and reducing the green premiums is not "just a favor to the rest of the world" (Gates, 2021, p. 216). Rather, it is an "opportunity" to reap first-mover benefits in a burgeoning clean tech industry (Gates, 2021, p. 216). Cullenward and Victor make similar claims, referring only to the self-interest of incumbent and new-entrant firms, not any moral imperative. However, some might argue that, due to their historical emissions, wealth, or lack of timely action on climate change, developed countries and their firms have a duty both drive down the cost of clean tech and donate intellectual property for breakthrough solutions to poorer countries. This mirrors an argument over whether pharmaceutical companies should be required to give up the intellectual property of their life-saving drugs and vaccines to enable low-cost generic copies of life-saving medicines in poor countries.[9] One familiar counterargument in both instances would be that insisting on such a practice reduces the financial incentives for actors to develop the breakthrough technologies in the first place. Unpacking the empirical side of this argument certainly involves social science, but ethicists play a role when appeals to fairness and desert are also being made in this context, as they are likely to.

Both books also advocate a controversial international instrument: border carbon adjustments (BCAs). BCAs can be used to protect trade exposed industries, like steel manufacturing, from being overcome by dirty competitors when a jurisdiction enacts significant decarbonization standards. With a BCA, exports are subsidized and imports penalized in a way that is intended to (at least roughly) reflect the extra cost of meeting the climate change regulations in the jurisdictions where the good is produced.[10] The design of BCAs will have to be precise in order to adhere to World Trade Organization (WTO) rules (Mehling et al., 2019). Climate clubs of high-ambition countries aiming to introduce BCAs on goods from those outside the club thus face a choice. One approach would be for a club to ignore WTO rules and levy stringent or broad tariffs. (Nordhaus,

[9] This argument for "technology transfer" used to feature centrally in the UNFCCC negotiations. Scholarly attention is being paid to the legal aspects of these issues much more than the ethical (Zhou, 2019) and (Rimmer, 2018).

[10] The Biden Administration has stated it is "exploring and developing market and regulatory approaches to address greenhouse gas emissions in the global trading system…. this includes consideration of carbon border adjustments." (United States Trade Representative, 2021, p. 3)

2015). Another would be to design BCAs to fit the norms of the current trade regime. One's approach to this issue might just reflect whether one thinks the current norms of free trade are a precious example of genuine global cooperation, or part of a pernicious neoliberal hegemony. But for those not in the grip of either ideology, interesting work beckons to ascertain the appropriate trade strategy to support decarbonization, perhaps in concert with specialists in international law. There is then the further question of procedural legitimacy of a climate club: who should decide which countries are clean enough to levy a BCA on others, and how?

Moving from the international to domestic context, more questions arise. Both books call for fostering and developing the right kinds of industrial activity and extinguishing the wrong kinds. In this vision, government, the general public, civil society organizations and firms all have roles to play. It is common, at least among progressives, to decry all corporate input into politics as a corrupting influence. But given the complexities of the task at hand, it seems some input from firms (especially clean tech firms) will need to filter into the regulatory process somehow. As Gates puts it: "Governments and industry will need to work together to overcome barriers and speed up the innovation cycle" (Gates, 2021, p. 202). Cullenward and Victor similarly see new entrant firms and incumbent firms as vital interests that must be engaged with, not just dictated to by the state. Of course, any public-private cooperation on regulations comes with significant risks of corruption, rent-seeking and corporate capture. My point is that if a zero-tolerance approach to corporate political activity is foolish or naïve, we desperately need a theory of proper and improper corporate political activity: to divide the sheep from the goats, as it were. And such a theory seems non-existent in current political philosophy (Norman & Ancell, 2018).

Finally, we might ask what role the innovation approach plays in a civil society coalition for climate action. The approach of these two books is far from the only vision of the road to deep decarbonization. The Green New Deal shares the emphasis on industrial policy, but for many of its proponents the Green New Deal holds much less room for private firms. That is, many Green New Dealers see government as not just an enabler, but a producer of clean tech. One question is theoretical. Putting aside ideology, how might we decide which role for government is best in this case? And how should champions of deep decarbonization proceed when we disagree?

These two books put forward an approach to decarbonization that is both empirically informed, and realistic about the ability of lifestyle-based or purely political solutions to get us to net-zero emissions. Philosophers often talk about non-ideal theory in the abstract. An innovation-centered approach provides a chance for philosophers to practice non-ideal theory, especially by working in tandem with social scientists, lawyers and even technologists and political actors. These two books provide an excellent place to start.

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