OPINION

OPINION

Why carbon pricing is not sufficient to mitigate climate change—and how "sustainability transition policy" can help

Daniel Rosenbloom[a,1], Jochen Markard[b], Frank W. Geels[c], and Lea Fuenfschilling[d]

Carbon pricing is often presented as the primary policy approach to address climate change. We challenge this position and offer "sustainability transition policy" (STP) as an alternative. Carbon pricing has weaknesses with regard to five central dimensions: 1) problem framing and solution orientation, 2) policy priorities, 3) innovation approach, 4) contextual considerations, and 5) politics. In order to address the urgency of climate change and to achieve deep decarbonization, climate policy responses need to move beyond market failure reasoning and focus on fundamental changes in existing sociotechnical systems such as energy, mobility, food, and industrial production. The core principles of STP can help tackle this challenge.

Carbon Pricing Critique

Realizing deep decarbonization at the pace necessary to mitigate the worst impacts of climate change has emerged as a pressing challenge for policymakers (1). As a result, the debate about appropriate policy responses has intensified. Many experts and societal actors see carbon pricing as the primary way forward (2–4). Some even use it to argue against other policies, such as fuel efficiency standards. Viewed as the most efficient approach to cut greenhouse gas (GHG) emissions, carbon pricing incentivizes actors to seek the lowest-cost abatement options for their specific circumstances. Consequently, many economists argue that carbon pricing should be the cornerstone of a climate policy response.

We question this reasoning. Carbon pricing faces five major issues that limit its use for accelerating deep decarbonization. First, carbon pricing frames climate change as a market failure rather than as a fundamental system problem. Second, it places particular weight on efficiency as opposed to effectiveness. Third, it tends to stimulate the optimization of existing systems rather than transformation. Fourth, it suggests a universal instead of context-sensitive policy approach. Fifth, it fails to reflect political realities.

Given these limitations, we propose an alternative approach that targets fundamental transformations of existing sociotechnical systems, such as energy, mobility, or food (i.e., "sustainability transitions") (5). STP entails a mix of contextually and politically sensitive policies that simultaneously drive low-carbon innovation and the decline of fossil fuels.

Many are eager to take more substantive policy steps to address climate change, but pricing carbon pricing alone won't be sufficient. Image credit: Shutterstock/Shawn Goldberg.

Market Failure versus System Problem

The underlying rationale for carbon pricing is appealing in its simplicity: GHG emissions are viewed as a negative externality because the social costs flowing from climate change impacts are not reflected in the market price of carbon-intensive goods and services (6). Climate change is framed as the consequence of a market failure that can be corrected by placing a price on carbon so that actors also pay for the social cost of

[a]Department of Political Science, University of Toronto, Toronto, ON M5S 3G3, Canada; [b]Department of Management, Technology, and Economics, ETH Zürich, 8092 Zürich, Switzerland; [c]Alliance Manchester Business School, University of Manchester, Manchester M15 6PB, United Kingdom; and [d]Centre for Innovation, Research and Competence in the Learning Economy, Lund University, 221 00 Lund, Sweden

The authors declare no competing interest.

Any opinions, findings, conclusions, or recommendations expressed in this work are those of the authors and have not been endorsed by the National Academy of Sciences.

[1]To whom correspondence may be addressed. Email: daniel.rosenbloom@utoronto.ca.

First published April 8, 2020.

their carbon-intensive activities and reduce their demand for such goods and services.

Framing the climate challenge as a market failure, however, fails to seriously appreciate its scope and depth. Indeed, the climate challenge has been referred to as a "grand challenge" (7) or "super wicked problem" (8) that has thus far resisted traditional policy approaches.

We argue that climate change can be more appropriately understood as a system problem. Core societal functions, such as heating or mobility, are met through large and deeply entrenched sociotechnical systems made up of interconnected technologies, infrastructures, regulations, business models, and lifestyles (1). Over many decades, these systems have become increasingly locked into the combustion of fossil fuels and the associated release of GHG emissions. Consider, for instance, how the design of cities has developed alongside the diffusion of the gasoline-powered personal automobile; how norms about comfort and attire have become entwined with energy-intensive indoor temperature regulation; and how important political and economic interests have become entrenched with fossil fuel-based resource development or electricity provision.

Addressing the climate challenge, therefore, involves fundamental changes to existing systems, referred to as "sustainability transitions" (5). These transitions entail profound and interdependent adjustments in sociotechnical systems that cannot be reduced to a single driver, such as shifts in relative market prices. In mobility, for example, a low-carbon transition might encompass interacting developments around new vehicle technologies (e.g., autonomous electric cars), infrastructures (e.g., vehicle charging stations and high-speed rail), business models (e.g., mobility as a service and intermodal transport), and regulation (e.g., emission performance standards) but also changes in city planning (e.g., reduced urban sprawl) and lifestyles (e.g., telework and local vacations). The market failure framing fails to appreciate the broad scope of the climate challenge and the sweep of system elements that must undergo change. And so, the resulting solution orientation is far from sufficient.

Efficiency versus Effectiveness

Carbon pricing strategies are often considered to be the most efficient means of reducing carbon emissions (4, 6). They do so by affording heterogeneous polluters (e.g., firms from different industries) the flexibility of responding to the carbon price signal in a least-cost fashion, selecting the level of abatement and specific abatement options that are most cost-effective for their circumstances. Abatement options are then adopted in a stepwise manner in line with the carbon price. Under a series of assumptions (e.g., economic rationality, perfect information, credibility, and broad coverage), the result is that "a given level of abatement is met at least global cost" which "no other instrument than pricing is able to realize" (2).

We question whether efficiency should be an overriding priority of climate policy. If we are to limit global warming to less than 1.5 °C, there is little time remaining to reach carbon neutrality (9). The negative impacts of climate change are already undermining human prosperity and the cost of inaction will escalate the longer we wait (10). Despite the urgency of the problem, carbon pricing places considerable weight on seeking low-hanging fruit and, according to Patt and Lilliestam, fails to appreciate that "we must eventually pick all of the apples on the tree" (11). Furthermore, as of 2019, existing carbon pricing schemes only cover about 20% of global emissions and more than two-thirds of these have prices below $20 United States dollars (USD) per ton of CO_2 equivalent.* This is far too low to be effective and increasing coverage and prices presents serious challenges, which we return to below.

Efficiency considerations must, therefore, be tempered by an immediate need to realize carbon neutrality through whatever means actually work. This implies moving beyond lowest-cost solutions to stimulate a diversity of mitigation options, including those that have considerable immediate reduction potential (e.g., phasing out coal or restoring peatlands) and others that may fundamentally transform systems in the longer term (e.g., mobility-as-a-service or biobased materials).

Optimizing versus Transforming

By increasing the relative price of carbon-intensive goods and services, carbon pricing is understood to incentivize the adoption of existing low-carbon technologies and (indirectly) stimulate the development of low-carbon innovations (2). Investments in low-carbon alternatives are not only encouraged through present carbon prices but also through expectations about future carbon price increases.

It is, however, unclear how strong such innovation effects actually are and whether carbon pricing can generate more than incremental changes. Tvinnereim and Mehling (12), for instance, review the record of several prominent carbon pricing strategies and find that they have, to date, helped realize limited opportunities for innovation and system-wide transformation. Rather, current trajectories and emission reductions deviate little from business-as-usual scenarios, even in the case of Sweden's $140 (USD) carbon price for the transport and building sectors. Others have observed similar patterns (13–15). This suggests that, in practice, carbon pricing strategies tend to promote the optimization of established business models and technologies but neglect more fundamental system change necessary for deep decarbonization.

While optimization remains important, it does little to confront carbon lock-in, encourage radical innovation, or avoid dead-end paths (16). Indeed, research indicates that investments in long-lived, carbon-intensive infrastructures, such as natural gas, are still ongoing, even in jurisdictions with prominent carbon pricing regimes (12, 17). Retiring these investments prematurely in order to align with deep decarbonization pathways will be

*Data are drawn from The World Bank Group's Carbon Pricing Dashboard.

Table 1. Comparison of carbon pricing strategies and sustainability transition policy

	Carbon pricing strategies	*Sustainability transition policy*
Conceptual roots	Neoclassical economics	Innovation studies, evolutionary economics, institutional theory
Problem framing and solution orientation	Climate change as a market failure problem: price carbon to correct market signals	Climate change as a system problem: fundamentally transform existing sociotechnical systems
Overriding policy priority	Efficiency: reduce carbon emissions while keeping the economy wide costs at a minimum	Effectiveness: drive down emissions as quickly as possible
Innovation approach	Incremental change, indirect stimulation of innovation	Transformative change, direct stimulation of innovation
Contextual considerations	Universality: carbon pricing for all jurisdictions and sectors	Tailoring: policies should be adapted to local and sectoral contexts
Understanding of politics	Revenue recycling to deal with political realities	Creation of alternatives and formation of supportive coalitions

politically difficult and costly (i.e., due to compensation for affected firms and communities).

In contrast, we argue that incremental change alone is insufficient to pursue low-carbon pathways at the required pace. Established systems are characterized by deep lock-ins (e.g., large sunk costs in infrastructure and cultural conventions underpinning user practices) that encourage movement along established development trajectories (18, 19). Deliberately accelerating transitions, therefore, involves weakening lock-ins (e.g., removing fossil fuel subsidies and banning carbon-intensive technologies) and supporting system building for low-carbon alternatives (e.g., stimulating new innovations, business models, and markets).

Universal versus Context Sensitive Policy

Carbon pricing strategies tend to be predicated on the notion that, eventually, all emissions are covered so that all prices will be corrected such that no economic decision would escape carbon pricing's regulatory impact (2). This means that all jurisdictions and economic sectors should be included, ideally with uniform price signals (6). In the absence of uniform pricing, there is a risk that some nations will free-ride on the efforts of others and that firms will relocate to places with lower or no carbon prices (i.e., "carbon leakage").

Three issues confront this universal approach. First, the required levels of coordination and cooperation are unrealistic, as carbon pricing encounters a fragmented international climate policy landscape (20). In the absence of a global sovereign and considering the great diversity of national circumstances (where countries have different responsibilities for generating the problem, vulnerabilities, and resources to adapt and support mitigation), cooperation or convergence among emission pricing frameworks remain elusive. Second, a universal approach will require well-functioning institutional structures and high levels of regulatory competences and monitoring systems, which do not exist everywhere. Third, carbon pricing strategies tend to ignore that policies need to be tailored to local and/or sectoral contexts in order to address specific sources of lock-in and opportunities for innovation.

Carbon pricing functions well in sectors, such as electricity, with large, fixed-point sources, where alternative technologies are available and polluters cannot easily relocate; it's more difficult to implement in agro-food, transport, and heavy industry (14). Agro-food systems are characterized by manifold commodities, dispersed production (millions of farmers) in highly variable contexts (soil conditions, climate, local communities), and deeply entrenched cultural conventions, such as tastes and dietary habits (21), which all make it extremely difficult to assess the level of an effective carbon price and implement this throughout the system. Existing and proposed carbon prices also face problems in transport, often translating into pennies on the gallon. Such effects fall short of inducing the needed lifestyle changes or even being distinguished from standard oil market fluctuations.

This highlights the major difference between systems across different sectors, scales, and locations. The geophysical resources, infrastructures, actor networks, and availability of low-carbon alternatives diverge markedly from one system to another. Thus, the specific package of policy solutions (e.g., performance standards versus technology mandates) will also vary accordingly. And, given the above-mentioned challenges facing a uniform global response, climate policy will be defined by layered and interacting efforts within and across different contexts (22).

Political Realities

A transparent price signal is often considered to be a core benefit of carbon pricing strategies, as it conveys information about the external costs of greenhouse gases to consumers and firms, allowing them to internalize these costs in their decision-making (6). Market forces, in this view, act as the principal drivers of change. The primary role of government is to "set the right price" and "leave the rest to the market." This, however, fails to acknowledge the substantial contestation around climate policy and the political nature of markets.

Carbon pricing strategies are not politically neutral but normative endeavors (i.e., centered on what constitutes appropriate solutions and why) with major distributional consequences (i.e., who will win or lose). As with the majority of climate policies, they threaten the endowments of incumbent firms and industries. Many of these actors have responded by using their considerable influence to resist and weaken the stringency of carbon pricing measures, such as the European Union's Emissions Trading System (23). Carbon pricing has also attracted political resistance among the broader public, as it is perceived to challenge long-standing practices and livelihoods, such as car-based and suburban lifestyles. Political opponents have been quick to exploit these cleavages around carbon pricing, leading to important electoral victories and climate policy reversals in Canada, France, Australia, and many other jurisdictions (24). While some advocates propose revenue recycling from carbon pricing to encourage public acceptance (3), far more is needed to appreciate the "irreducibly political character" of climate policy (25).

In this way, we argue for more explicit engagement with the politics of climate policy. While politics tends to be regarded as a barrier to climate action, research suggests that well-designed climate policies can also generate self-reinforcing political dynamics that can set in motion transformative processes (26–28). Sequences of policies designed to strengthen supportive coalitions with an interest in low-carbon alternatives (e.g., networks of innovators, communities, and civil society actors) may create conditions for political victories and more ambitious climate policies over subsequent rounds of political debate and policymaking (27).

Sustainability Transition Policy (STP)

Given the limitations of a climate response based on carbon pricing strategies, we offer "sustainability transition policy" (STP) as an alternative (Table 1). Framing the climate challenge as a system problem, STP emphasizes the rapid and effective reduction of emissions, system transformation and radical innovation, the development of context-sensitive responses, and the inherent political nature of decarbonization.

Indeed, STP is predicated on the notion that a low-carbon transition will involve multiple and co-evolving social and technological changes. Many levers will need to be pulled and deliberately aligned to realize change—from supporting emerging innovations and decommissioning existing technologies or infrastructure, to building coalitions of actors and interests, to (re)designing market rules and planning processes, to legitimizing new practices and related social norms. Carbon pricing can be part of this policy mix, but should not be seen as the single best or primary instrument.

Embracing these varied levers, STP is not about a single policy intervention but a coherent sequence of policy decisions—and associated changes in technologies, business models, and practices—that together drive potential decarbonization pathways for sociotechnical systems under conditions of complexity and uncertainty (29). Broadly, STP targets innovation and decline (30). That is, it includes policies to support

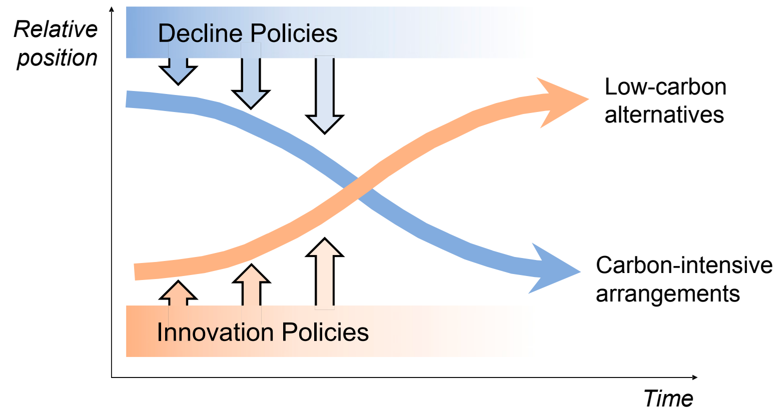

Fig. 1. **To achieve a low carbon future, we need not only policies that encourage innovations such as solar photovoltaics, but policies that discourage carbon-intensive technologies, such as coal. And those policies should enlist a variety of instruments that adapt over time.**

low-carbon innovations and their upscaling, as well as policies to exert pressure on carbon-intensive products, technologies, and practices to eventually stimulate their decline (Fig. 1). Innovation is important to continually develop alternatives. Decline is crucial to break up lock-ins and to signal to producers and consumers that fundamental changes are necessary.

STP also acknowledges that transitions develop through different phases, from early takeoff to later acceleration and consolidation (31, 32). Early-stage innovations, for example, need experimentation in protected spaces (i.e., niches, which shield their development from harsh competitive pressures) (33). Accelerating low-carbon innovation requires diffusion and deployment policies that aim at embedding and scaling niche experiments beyond their initial boundaries, targeting, for example, the creation of new networks, entrepreneurial activities, and standards, as well as education and training.

There is a similar phase-logic with respect to decline. Destabilization and weakening lock-in mechanisms can create windows of opportunity for new practices, business models, and technologies (34). Policy instruments for destabilization include divestment strategies, removal of fossil fuel subsidies, carbon pricing, or stronger environmental standards. To accelerate decline, policy also has a role to play in implementing phaseouts. Otherwise, problematic technologies can persist for decades. Phase-out policies have, for instance, targeted incandescent light bulbs, coal-fired power, and nuclear power.

STP also appreciates the central place of policy and politics. Climate or transition policies are layered on top of existing institutional frameworks, which means that policy formulation and implementation is a complex, messy, and often piecemeal process that resists optimal solutions. And, in the face of political conflict and resistance, it is crucial to generate societal and business support for climate policy responses. This is why stimulating low-carbon innovations and associated supportive coalitions with a material interest in these innovations is of critical importance. Over subsequent cycles of policy-making, climate policies, low-carbon innovations, and supportive coalitions can mutually reinforce one another to drive low-carbon pathways. In general, STP calls for new modes of governance that are better-suited to the context of transformative change. Such an approach recognizes the importance of continually adapting specific measures in response to new developments and learning but also acknowledges that the overarching directionality of policy (commitments, resources, etc.) should be stabilized in order to drive a transition (28).

In summary, the dominant logic of contemporary climate policy, in which carbon pricing is the central policy response, is deeply flawed. Given the aforementioned shortcomings, carbon pricing should not be the primary policy strategy to combat climate change. Instead, carbon pricing should be used as part of a policy mix that promotes innovation and decline, accounts for political dynamics, varies between sectors and over time, and aims at profound system change.

Acknowledgments

D.R. would like to acknowledge the financial support of the Social Sciences and Humanities Research Council of Canada. J.M. acknowledges the Swiss Competence Center for Energy Research, financially supported by Innosuisse under Grant No. KTI 1155000154.

1 F. W. Geels, B. K. Sovacool, T. Schwanen, S. Sorrell, Sociotechnical transitions for deep decarbonization. *Science* **357**, 1242–1244 (2017).
2 A. Baranzini *et al.*, Carbon pricing in climate policy: Seven reasons, complementary instruments, and political economy considerations. *Wiley Interdiscip. Rev. Clim. Change* **8**, e462 (2017).
3 D. Klenert *et al.*, Making carbon pricing work for citizens. *Nat. Clim. Chang.* **8**, 669–677 (2018).
4 J. E. Stiglitz *et al.*, *Report of the High-Level Commission on Carbon prices* (World Bank, Washington, DC, 2017).
5 J. Markard, R. Raven, B. Truffer, Sustainability transitions: An emerging field of research and its prospects. *Res. Policy* **41**, 955–967 (2012).
6 W. D. Nordhaus, *The Climate Casino: Risk, Uncertainty, and Economics for a Warming World* (Yale University Press, New Haven, CT, 2013).
7 W. V. Reid *et al.*, Earth system science for global sustainability: Grand challenges. *Science* **330**, 916–917 (2010).
8 K. Levin, B. Cashore, S. Bernstein, G. Auld, Overcoming the tragedy of super wicked problems: Constraining our future selves to ameliorate global climate change. *Policy Sciences* **45**, 123–152 (2012).
9 Intergovernmental Panel on Climate Change, *Global Warming of 1.5 °C* (Intergovernmental Panel on Climate Change, Geneva, Switzerland, 2018).
10 O. Hoegh-Guldberg *et al.*, The human imperative of stabilizing global climate change at 1.5°C. *Science* **365**, eaaw6974 (2019).
11 A. Patt, J. Lilliestam, The case against carbon prices. *Joule* **2**, 2494–2498 (2018).
12 E. Tvinnereim, M. Mehling, Carbon pricing and deep decarbonisation. *Energy Policy* **121**, 185–189 (2018).
13 J. Ball, Hot air won't fly: The new climate consensus that carbon pricing isn't cutting it. *Joule* **2**, 2491–2494 (2018).
14 J. Ball, "Why carbon pricing isn't working: Good idea in theory, failing in practice." *Foreign Affairs* July/August 2018.
15 M. Jaccard, Want an effective climate policy? Heed the evidence. Policy Options, 2 February 2016. https://policyoptions.irpp.org/magazines/february-2016/want-an-effective-climatepolicy-heed-the-evidence/. Accessed 4 September 2019.
16 M. G. Morgan, Opinion: Climate policy needs more than muddling. *Proc. Natl. Acad. Sci. U.S.A.* **113**, 2322–2324 (2016).
17 I. G. Wilson, I. Staffell, Rapid fuel switching from coal to natural gas through effective carbon pricing. *Nat. Energy* **3**, 365–372 (2018).
18 A. T. Dangerman, H. J. Schellnhuber, Energy systems transformation. *Proc. Natl. Acad. Sci. U.S.A.* **110**, E549–E558 (2013).
19 G. C. Unruh, Understanding carbon lock-in. *Energy Policy* **28**, 817–830 (2000).
20 R. O. Keohane, D. G. Victor, Cooperation and discord in global climate policy. *Nat. Clim. Chang.* **6**, 570–574 (2016).
21 C. C. Hinrichs, Transitions to sustainability: A change in thinking about food systems change? *Agric. Human Values* **31**, 143–155 (2014).
22 D. G. Victor, *Global Warming Gridlock: Creating More Effective Strategies for Protecting the Planet* (Cambridge University Press, Cambridge, United Kingdom, 2011).
23 J. Wettestad, EU energy-intensive industries and emission trading: Losers becoming winners? *Environmental Policy and Governance* **19**, 309–320 (2009).
24 B. G. Rabe, *Can We Price Carbon?* (MIT Press, Cambridge, MA, 2018).
25 J. Meadowcroft, What about the politics? Sustainable development, transition management, and long term energy transitions. *Policy Sciences* **42**, 323 (2009).
26 J. Markard, M. Suter, K. Ingold, Socio-technical transitions and policy change—Advocacy coalitions in Swiss energy policy. *Environ. Innov. Soc. Transit.* **18**, 215–237 (2016).
27 J. Meckling, T. Sterner, G. Wagner, Policy sequencing toward decarbonization. *Nat. Energy* **2**, 918–922 (2017).
28 D. Rosenbloom, J. Meadowcroft, B. Cashore, Stability and climate policy? Harnessing insights on path dependence, policy feedback, and transition pathways. *Energy Res. Soc. Sci.* **50**, 168–178 (2019).
29 D. Rosenbloom, Pathways: An emerging concept for the theory and governance of low-carbon transitions. *Glob. Environ. Change* **43**, 37–50 (2017).
30 P. Kivimaa, F. Kern, Creative destruction or mere niche support? Innovation policy mixes for sustainability transitions. *Res. Policy* **45**, 205–217 (2016).
31 D. Loorbach, N. Frantzeskaki, F. Avelino, Sustainability transitions research: Transforming science and practice for societal change. *Annu. Rev. Environ. Resour.* **42**, 599–626 (2017).
32 J. Markard, The next phase of the energy transition and its implications for research and policy. *Nat. Energy* **3**, 628–633 (2018).
33 A. Smith, R. Raven, What is protective space? Reconsidering niches in transitions to sustainability. *Res. Policy* **41**, 1025–1036 (2012).
34 B. Turnheim, F. W. Geels, Regime destabilisation as the flipside of energy transitions: Lessons from the history of the British coal industry (1913–1997). *Energy Policy* **50**, 35–49 (2012).