Comment

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Temporary mitigation off-ramps could help manage decarbonization headwinds

Sam Uden & Chris Greig

Compressing global energy and industrial system decarbonization into less than three decades creates unique social, technical, financial and political risks. Here we introduce 'off-ramps' as one potential approach to manage these whilst still driving rapid emissions reductions.

The pace of clean energy deployment required to meet ambitious mitigation targets, such as global net-zero emissions by 2050, is astonishing. The rapid and complete diffusion in solar, wind, batteries and clean firm options (geothermal, nuclear, etc.) as shown in energy models defies all historical precedent on how quickly energy systems transform[1]. New technologies to decarbonize hard-to-abate sectors, like aviation and materials manufacturing, are only in the early stages of development. Still, global emissions have yet to peak.

While there are reasons for optimism, such as the rapid growth and cost-declines in renewables[2] and the potential for significant demand-side mitigation[3], we cannot discount that multiple countries are and may continue to periodically fall behind on their emissions targets[4]. Considering how best to manage this future is warranted. For example, should countries fall behind simply ratchet their mitigation policies? From the viewpoint of Intergovernmental Panel on Climate Change scientists and diplomats, the boldest climate pledges are also the most credible[5]. But this may be an overly optimistic view, with growing real-world evidence of emergent bottlenecks, cost escalation, and similar dynamics leading to backlash movements seeking to reverse ambitious policies. Recent examples include the gilet jaunes protests in France demanding lower fuel taxes[6], efforts in Texas to stymie wind and solar growth through stricter permitting rules[7], farmer protests in the Netherlands to proposed nitrogen reduction policies[8], and opposition in Germany to a world-first heat pump mandate that led to a substantial watering down of the proposed law[9].

Political scientists have identified incremental and 'low-visibility' policies as means to backlash prevention[10]. But with less than three decades to transform energy and industrial systems these approaches are unlikely to be sufficient. Other techniques such as real options analysis can be helpful, but in this case are of limited value given the irreducibility of the uncertainties involved[11,12]. Here we introduce off-ramps as an alternative policy strategy that could provide aggressive mitigation while still seeking to avoid or limit mitigation target overshoot. We note that a level of caution is warranted and more research is recommended to understand the strategy's potential risks and effectiveness.

The imperative—and risk—of ambitious mitigation

An ever-shrinking carbon budget to avoid dangerous global warming requires a serious and rapid effort to reduce greenhouse gas emissions[13]. Recent climate policy research has focused on identifying proven policies for near-term (2030) progress[14], broader approaches for enabling long-term mitigation such as green industrial policy[15], as well as policy innovations that could amplify mitigation by combining multiple policies together to create a self-reinforcing loop[16] or targeting specific leverage points in the economic or political systems[17].

But less attention has been paid to the potential risks that accompany, and could ultimately undermine, economy-wide transitions to 100% clean energy resources. These could include periods of, for example, grid insecurity from a rapid integration of renewables, volatile or inequitable energy prices rises, stranded assets leading to financial losses and potentially a more systemic financial crisis, transitional unemployment as (often heavily subsidized) fossil fuels give way to clean alternatives, as well as public opposition to rapidly changing landscapes to develop utility-scale renewables projects[18]. Any one of these issues, as well as other unforeseen geopolitical or economic disruptions[19], could contribute to hasty, knee-jerk responses that lock-in carbon-intensive assets[20] and set a given country back further from its net-zero target than if it had taken a pre-planned approach to refreshing its mitigation strategy.

A plan to review and reset ambitious mitigation targets and policies in a future where the above issues manifest may thus be more beneficial than trying to maintain them. One obvious option would be for a country to defer its net-zero target–say, from 2050 to 2070. Whilst this might relieve immediate pressure, a clear downside is that it would forego an emissions target aligned with a global 1.5 °C or well below 2 °C outcome. By reducing the required pace of reductions, it may also limit the ability of a country to credibly ratchet up mitigation later[21], for example, in response to renewed international efforts to avoid dangerous warming. Another option could be for a country to reduce its emissions reduction efforts and rely more heavily on carbon dioxide removal (CDR) to achieve net-zero emissions. Although CDR is anticipated to play a key role in net-zero portfolios[22], this strategy comes with a risk that the relatively new technologies cannot be scaled quickly enough to avoid significant target overshoot.

Being cognizant of both the imperative and risk of rapid decarbonization, an alternative strategy would provide the option—but not the obligation—to relax some mitigation policies. In this case, a country would not need to make such a binary trade-off between ambitious mitigation and prudent risk management. If done well, such a strategy would keep open the option to ramp up mitigation, either in the sector subject to the relaxation, or in compensating sectors, with a view to getting back on track towards the original target. Target deferment and/or relying on increased future CDR are unlikely to provide such optionality.

Off-ramp mitigation policy

Off-ramps aim to balance the rapid decarbonization imperative/risk duality. Off-ramps involves developing an alternate—and less ambitious—

mitigation policy portfolio that could be temporarily adopted in the event of energy transition headwinds. The ability to strategically pause and reset could avoid or limit target overshoot relative to other risk management strategies (Fig. 1). Note that, here, "overshoot" refers to a delay in reaching a net-zero emissions target, and not necessarily a carbon budget overshoot.

Off-ramps is informed by a growing literature in operations research known as "mission abort policy", which identifies when it may be beneficial to abandon a mission to avoid a worse possible outcome[23]. It is commonly applied in a military context. For example, Levitin and Finkelstein[24] identify when it is beneficial for an unmanned aerial vehicle to abandon a surveillance mission based on the risk of aircraft loss, which could become unacceptably high and is considered the worst possible outcome.

Similarly here, it would be beneficial to abandon a steadfast commitment to aggressive mitigation if there develops a sufficiently high risk of policy failure resulting in a large target overshoot. A policy change that provides a temporary relief in mitigation requirements, whether on a sectoral or whole-economy level, can give companies time to resolve supply chain bottlenecks and worker shortages as well as complete key infrastructure construction (transmission lines, carbon dioxide pipelines, etc.) to prevent supply-side inflationary pressures and network connection constraints. It can allow communities to properly review and raise concerns about prospective projects that might otherwise result in long-lasting opposition. It can also provide governments time to engage stakeholders and determine how best to support affected industries, such as via budget reallocations or new policies, as well as develop the necessary strategic alliances and new regulatory frameworks to support an expanded mitigation technology portfolio. Having resolved these blockages, a country can then pivot back to a more ambitious pace of mitigation.

The overall degree of policy revision, duration, and number of off-ramps executed on the course to an economy-wide net-zero target would be variable. For example, Fig. 1 shows off-ramps of horizontal and downward trajectories–reflecting high and moderate policy relaxation, respectively. The off-ramps are also adopted for different time durations. The optimal off-ramp procedure will depend on the social, political, economic, geographic, legal, etc. circumstances of a given country. Table 1 provides examples of off-ramp policies that could be adopted, including for an emissions trading scheme, carbon tax, procurement standards, clean technology incentives and fossil fuel asset retirements.

Assuring that a country can credibly pivot back (or "on-ramp") to an ambitious pace of mitigation is a key and distinguishing feature of off-ramps relative to seemingly similar actions one might see today, such as the UK's recent decision to grant over 50 new oil and gas licenses in the North Sea[25], Germany's decision to develop several new liquefied natural gas shipping terminals[26], or Australia's decision to expand and/or extend the life of four coal mines[27]. Each of these policies were adopted without a clear plan to compensate or otherwise make-up for this new and potentially significant carbon lock-in, causing an increase in climate policy uncertainty, which can reduce mitigation[28,29]. In contrast if these policies were developed as off-ramps—that is, a clear diversion from the path necessary to achieve an ambitious target such as net-zero emissions by 2050—it should make governments more accountable to explain why such actions were undertaken and how they could align with long-term mitigation goals.

One way to achieve this is through a mandate. That is, when an off-ramp portfolio is adopted, whether via legislation or regulation, the same ruling could contain a sunset provision—at which point the ambitious mitigation portfolio is re-adopted. The benefit of this approach is that it is clear and binding. A drawback is that it offers limited flexibility in the event an off-ramp fails to deliver sufficient pressure relief to the system, for example, because it took longer than anticipated to deploy new clean energy assets.

An alternative option could be to tie off-ramp duration to the achievement of certain energy transition milestones, such as installed gigawatts of new zero-carbon generating capacity, secured quantities of critical materials supply, and/or completed construction of key infrastructure such as electric vehicle charging networks. These

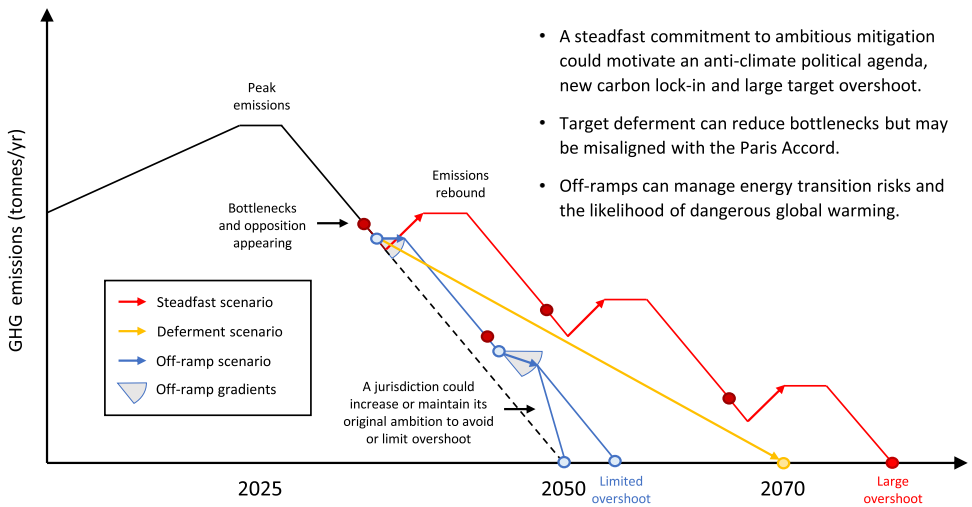

Fig. 1 | Stylistic representation of off-ramp mitigation policy at the economy-wide scale. Diagram compares three mitigation strategies to achieve a net-zero target in a future where clean energy deployment headwinds occur. The steadfast scenario (red) involves no policy change–resulting in social backlash and large target overshoot. Deferment scenario (yellow) involves pushing a mitigation target back to, e.g., 2070. Off-ramp scenario (blue) involves temporary diversions to less ambitious mitigation paths with the potential to avoid or limit target overshoot.

Table 1 | Examples of off-ramp mitigation policies

Mitigation policy	Off-ramp adjustment
• Emissions trading scheme	• Maintain same emissions cap for the off-ramp period (horizontal trajectory) • Reduce annual emissions cap by an amount less than the ambitious path requirement for the off-ramp period (downward trajectory)
• Carbon tax	• Maintain same carbon tax (horizontal) • Increase carbon tax by an amount less than the ambitious path requirement (downward)
• Procurement standard (e.g., Renewable Portfolio Standard, Buy Clean initiatives, etc.)	• Maintain same procurement standard (%) (horizontal) • Ratchet procurement standard (%) by an amount less than the ambitious path requirement (downward)
• Clean technology incentives (e.g., R&D grant programs, tax incentives)	• Establish or redirect a portion of incentives to support more mature technologies to stabilize electricity grids and keep energy prices in check. For example, this could include providing incentives to ensure the availability of dispatchable natural gas or safely extend the life of certain nuclear power plants.
• Fossil fuel asset retirements	• Delay planned retirement and/or extend the life of all operating fossil fuel assets (horizontal) • Delay planned retirement and/or extend the life of a portion of operating fossil fuel assets relative to the ambitious path requirement (downward)

milestones should be targeted to "debottleneck" the problem sectors and issues that created the need for the off-ramp in the first place. One benefit of this approach is that can promote decarbonization pathways centered on direct emissions reductions as opposed to carbon offset schemes that may not provide reliable mitigation[30]. It could be enabled by a requirement that, for the duration of the off-ramp, some small percentage of a country's budget is dedicated to achieving the deployment milestones. A drawback is that incumbent energy companies seeking to progressively shift away from fossil fuels could have a financial incentive to delay their transition to zero-carbon energy production.

Managing risks and trade-offs

Although the motivation for off-ramps is to help manage decarbonization headwinds, we firmly acknowledge the downside: which is that softening mitigation policies is likely to create its own new set of risks. For example, even with a clearly specified off-ramp strategy and duration, some clean energy developers could still delay their projects, citing an uncertain policy environment. Institutional investors could demand higher returns for the same reason. Arguably the most severe risk is that special interests could seek to exploit off-ramps for their own gain, including through delay tactics and lobbying.

A key message, therefore, is that the decision to develop an off-ramp should not be taken lightly. A jurisdiction should, at the least, possess credible interim mitigation targets and policies and a strong legal framework that authorizes regulators to enforce meaningful penalties in the event of non-compliance with off-ramp sunsets. A sufficiently competent civil service to actively manage and inform stakeholders (private companies, advocacy organizations, etc.) of changes to policy and/or potential reporting obligations is also essential. These baseline requirements should help to minimize any loss of clean energy developer and investor confidence in the lead up to, and during, the off-ramp period.

Further guardrails are likely needed to prevent special interests from co-opting the policy development process, especially if the elected officials that decide on whether or not to deploy an off-ramp are also responsible for designing it. One approach would be to establish an independent body, similar to a Royal Commission in the UK or Australia, that would assess the need for, and if required, design, an off-ramp policy. This review could be automatically triggered in the event mitigation progress falls short of a predetermined interim target. Elected officials would vote on, but not be able to amend, the proposal.

Taking it a step further would involve establishing a new independent government agency, similar to a central bank. Independent agencies are a main institutional option to insulate key public policy decisions from special interests[31]. The benefit of a new agency (e.g., an "Energy Transitions Office") is that it could have a broader purview to track the emergence of headwinds and more readily develop course-correcting policies, of which off-ramps are one option. A drawback is that a new agency with that level of authority is likely to face stiff political opposition to being formed in certain jurisdictions, especially where energy and climate are heavily politicized. California provides an example of such an agency in action, with the state Air Resources Board responsible for an ambitious portfolio of mitigation policies having been granted the authority to regulate greenhouse gases by the state Legislature in 2006. An independent agency also creates added certainty regarding the durability of climate policies.

Addressing a potential argument against off-ramps

Many scientists, climate policy experts and climate advocates may disagree with our assessment on the need to consider off-ramps. A main reason is because they might feel it could undermine existing decarbonization efforts. The same argument has been made on similar issues many times over, including that supporting climate adaptation would undermine mitigation[32], that focusing on reducing short-lived climate pollutants such as methane would undermine efforts to reduce carbon dioxide[33], and that supporting carbon dioxide removal would undermine greenhouse gas emissions reductions[34].

We acknowledge that the off-ramps concept is theoretical and there is no empirical evidence of such a policy working to support climate mitigation. But the argument that off-ramps would necessarily undermine existing decarbonization efforts presents a false dichotomy: a given country could perform both actions at once, and doing so is not a zero-sum game. In fact, as Shindell et al.[33] highlight (in the context of short-lived climate pollutant vs. carbon dioxide mitigation) ambitious action on both could go hand in hand. Similarly, a well-designed off-ramp should minimize a country's cumulative emissions. The alternative, which is to develop no risk management strategy, off-ramp or otherwise, is an all-in bet under deep uncertainty. This is irrational, and should be called out as such.

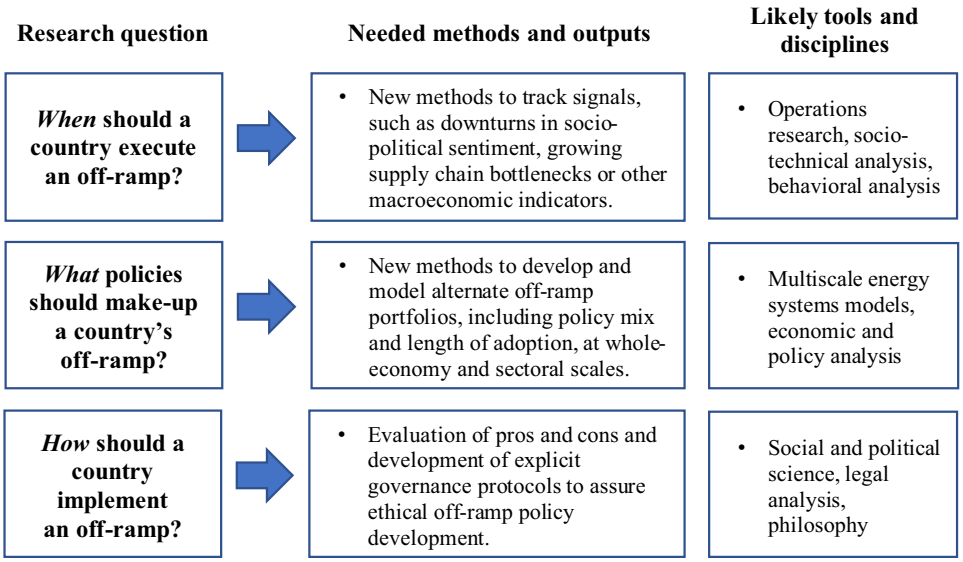

Fig. 2 | A research agenda for off-ramps. Diagram highlights three foundational research questions as well as related methods and likely disciplines to further develop the off-ramp concept.

Analyzing the viability of off-ramp mitigation policy

Backlash to climate policies is growing phenomenon, and we are still only at the "easy" stage of the global energy transition. It is therefore prudent to evaluate policy ideas that could mitigate against this new challenge. One option is off-ramps—and a new research agenda could evaluate its pros, cons, risks and trade-offs, as well as how off-ramps could operate in the real-world as an available policy tool to help governments manage energy transition risks and achieve their emissions targets. We identify three core research questions to guide a new off-ramps research area (Fig. 2). Multiple disciplines will be needed to credibly develop off-ramps, ranging from quantitative modeling to the social sciences.

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S.U. was responsible for conceptualization, investigation, methodology, visualization, and writing. C.G. was responsible for conceptualization, methodology, and writing.

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