



# Constraining fossil fuels based on 2 °C carbon budgets: the rapid adoption of a transformative concept in politics and finance

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## Abstract

This article traces how the notion of finite limits to emissions based on 2 °C carbon budgets was applied to increase the credibility of a carbon-constrained future in two very separate realms, social movements contesting fossil-fuel development and the financial sector—a process yet to be described in the relevant political and financial literatures. For each realm and sub-areas within them, we apply a three-wave taxonomy to trace the application of 2 °C carbon budget based concepts—including stranded assets, the carbon bubble, divestment, and anti-pipeline campaigns—from the fringe to the mainstream in under 10 years. We do so by drawing on relevant primary documents and peer-reviewed literature, complemented by a quantitative textual analysis of relevant discourse from news sources. The article establishes how, in efforts to shift expectations, climate proponents used 2 °C carbon budgets to frame a stark choice between a safe climate with strict carbon constraints and growth-oriented fossil-fuel interests. The article also demonstrates that these concepts, and efforts inspired by them, contributed to constraints on fossil-fuel developments and interests, arguably further enhancing the credibility of a carbon-constrained future. We conclude with a discussion of the potentially self-reinforcing nature of such expectation dynamics and by highlighting overlapping implications for actors across finance, where investors reorient risk assessment around climate, and social movements, where activists disrupt states' entrenched commitment to fossil-fuel expansion.

**Keywords** Carbon budgets · Fossil fuels · Social movements · Climate justice · Financial sector · Fossil-fuel divestment · Carbon bubble · Stranded assets · Climate politics

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## 1 Introduction

The early decades of debate over climate policy focused on reducing emissions—who should reduce them, when, and by how much (Randalls 2010)—and placed the question of cumulative limits to emissions (Meinshausen et al. 2009) in the background. However, as global emissions continued to increase, the notion of a global carbon budget (Le Quéré et al. 2018)—a ceiling on emissions that can be released into the atmosphere within a specified warming limit, like 2 °C—gained prominence. This new emphasis on finite limits has significant implications. Perhaps most notably, given that all emissions need to be eliminated within decades (Rogelj et al. 2018), the majority of economically proven fossil-fuel reserves cannot be developed (Meinshausen et al. 2009). This contrasts sharply with the continued financing of new fossil-fuel developments in the hundreds of billions a year (Mercure et al. 2018). Clearly, proponents of 2 °C limits have yet to firmly establish the credibility of a “carbon-constrained” future in which most fossil fuels are not extracted. However, such credibility is critical to influencing the course of decarbonization in a non-linear fashion because expectations of the future can be self-reinforcing (Arthur 1989), for example, when expected future oil demand shapes today’s investments and strategic decisions.

It is surprising, then, that several relevant literatures say little regarding the use of 2 °C carbon budgets to influence the credibility of a carbon-constrained future. The literature on the climate movement has established that this movement’s focus on injustice caused by fossil-fuel damage grew from historical local resistance to fossil fuels in developing regions like Nigeria (Benedikter et al. 2016) to newer opposition in response to more polluting unconventional developments like heavy oil and hydraulic fracturing in industrialized states (Aykut et al. 2017; Le Billon and Carter 2012; Grady-Benson 2014; Carter and Eaton 2016). However, this literature overlooks climate-movement actors’ own descriptions of their anti-fossil-fuel strategies as based on the implications of 2 °C carbon budgets (see Dietz et al. 2014; Caniglia et al. 2015; Bergman 2018; an exception is Yona and Lenferna 2016).

Similarly, while the financial literature on stranded assets (capital that becomes unviable and must be abandoned) does consider carbon budgets as a framework for understanding the scope of potential losses (e.g., Caldecott et al. 2014), this literature has not examined the process by which 2 °C carbon-budget framings came to influence the financial sector. To this point, our textual analysis of the literature on carbon budgets (see Section 2.2.) showed that since 1987, out of our sample of 128 articles on “carbon budget” or “cumulative emissions” and variations of “2 °C,” the abstracts of the 63 articles featuring financial or social terms do not address how the use of 2 °C carbon budgets influenced the credibility of a carbon-constrained future.

Thus, this article considers the last decade of efforts by climate proponents in social movements and energy finance to establish the credibility of this finite limit. We ask: what was the process and strategic logic by which 2 °C carbon budgets were leveraged in efforts to increase the credibility of a carbon-constrained world, and what has been the progression by which this concept’s influence grew? We trace the process by drawing mainly on primary documents produced by key proponents of 2 °C carbon budgets and peer-reviewed analyses of their influence on discourse and fossil-fuel growth, then supplement these sources with a quantitative textual analysis of relevant discourse from news sources.

Our findings show an emerging shift in expectations towards a carbon-constrained future and a remarkable progression of 2 °C carbon budget framings from fringe to mainstream over the last decade. Our findings also strongly suggest that climate proponents self-consciously

built on 2 °C carbon budgets to shift expectations: in the climate movement, activists developed campaigns to “keep it [fossil fuels] in the ground” (KIIG) by targeting fossil-fuel supplies and industry “enemies”; in the financial sector, climate proponents quantified the risks of fossil-fuel investments and business operations in a 2 °C-compliant world (Leaton 2012). We also show that these strategies contributed to constraining political and financial facts on the ground (e.g., delayed pipelines), which gave climate-agnostic actors reasons to view increased constraints based on 2 °C limits as credible. These results have implications for many actors, suggesting that the competition between the dominant expectations of profitable fossil-fuel expansion and the expectations of carbon constraints has entered an unpredictable phase where expectations can shift with surprising speed.

Below we describe the emergence of the 2 °C target and carbon budget, then discuss our methodology (Section 2). Section 3 summarizes the basis of KIIG concepts and the broad pattern of their spread across politics and finance. We then trace the progression of proponents’ once-fringe ideas towards the mainstream, considering the climate movement and finance in turn (Sections 4 and 5). We end by exploring key trends from the findings including the overlap between politics and finance, and the implications of these findings for actors in both realms (Section 6). Note that the analysis focuses on 2 °C as the animating target during the period in question. However, we use the inclusive “below 2 °C” because new evidence supports the value of keeping warming below 1.5 °C (Rogelj et al. 2018). We also recognize the limitations of temperature targets and carbon budgets (Knutti et al. 2016).

## 1.1 Background: the emergence of the 2 °C target and carbon budgets

The 2 °C target and associated carbon budgets that followed from it represent a framework emphasizing finite limits. This framework rivals the previous framework that emphasized incremental emissions reductions without reference to finite limits. The latter was evident in the negotiations by the time of the Kyoto Protocol (COP3) in 1997 (Randalls 2010): that agreement was based on emission reductions compared with a 1990 baseline rather than some cumulative emissions limit. This approach built on the 1990 Intergovernmental Panel on Climate Change (IPCC) report that focused on “controlling emissions rather than the global thermostat,” and did not use temperature outcomes to summarize scenarios (Randalls 2010, p. 600).

The credibility of this framing came into question as emissions continued to rise and industry actors delayed action (Supran and Oreskes 2017). Environmental non-governmental organizations (ENGOs), in particular, began rejecting the COP process, shifting from a pre-2000 focus on engaging negotiations (Lipschutz and McKendry 2011) to a more antagonistic posture, especially after COP negotiations collapsed in 2009 (Nulman 2016). That year, cooperative ENGO engagement with negotiators peaked and street protests grew much larger thereafter. Protests also began confronting fossil-fuel interests directly, including targeting the United States’ Keystone XL pipeline starting in 2011 (Tokar 2014; Dietz et al. 2014). This reorientation—which also emphasized grassroots tactics and justice for marginalized groups (Lipschutz and McKendry 2011; Martinez-Alier et al. 2016)—created an opening for the emphasis on finite limits offered by carbon budgets based on the 2 °C target.

A temperature target emerged during the 1990s as just one approach to assessing progress in addressing climate change. Within a public policy context, the 2 °C target was first successfully promoted within the EU, for example following Rijsberman and Swart (1990) and related advocacy by the Stockholm Environment Institute (Randalls 2010; Jaeger and

Jaeger 2011). The target was subsequently adopted for the first time by the European Community environment ministers in a 1996 declaration. Temperature ranges began entering IPCC reports in 1995, lending credibility to degree-based warming limits as benchmarks (Randalls 2010). The target was not mentioned in the Kyoto Protocol, however, and European attempts to insert it into G8 communiqués were blocked by the US Bush administration (Randalls 2010). It was finally accepted in 2009 by President Obama (Jaeger and Jaeger 2011), and the 2010 COP agreement committed governments to “hold the increase in global average temperatures to below two degrees” (UNFCCC 2010). Institutional actors followed this lead. The International Energy Agency (IEA), for example, shifted its climate-safe scenarios from a “450 ppm” scenario to a 2 °C scenario (IEA 2008, 2009, 2010).

Many saw the 2 °C target as a more compelling public frame. The 2 °C target was taken up by climate advocates to convey urgency prior to COP15 in 2009 (Randalls 2010). Likewise, a pre-COP joint editorial by 56 newspapers around the world argued, “The world needs to take steps to limit temperature rises to 2°C, an aim that will require global emissions to peak and begin falling within the next 5–10 years” (Guardian 2009). According to IPCC co-chair Thomas Stocker, “The power of the 2°C target is that it is pragmatic, simple, and straightforward to understand and communicate, all important elements when science is brought to policymakers” (Carbon Brief 2014). Thus, while there is scientific complexity surrounding the translation of the 2 °C target into carbon budgets, the target and budgets made it easy to articulate failures to stay within limits, such as the gap between the Paris Agreement’s goal and the sum of national emissions reduction pledges (leading to ~3 °C of warming). This built on the IPCC’s work characterizing carbon budgets for various temperature limits (Collins et al. 2013). In Paris, the target was also modified to a 1.5–2 °C range, and the IPCC Special Report on Global Warming of 1.5 °C (Rogelj et al. 2018) increased the emphasis on the more constraining carbon budget required to keep warming below 1.5 °C.

## 2 Methodology

To conceptualize shifting expectations towards a carbon-constrained future, we draw on “lock-in” theory and trace the rise of KIIG and related concepts through a three-wave progression, drawing on primary and peer-reviewed sources. We corroborate this narrative with a textual analysis of financial and political media discourse.

### 2.1 Theoretical lens

The impact of trends like fossil-fuel divestment can be indirect and thus difficult to measure (Bergman 2018). Hence, we apply a broad, nonlinear theoretical lens: we conceptualize the impact of KIIG and related ideas on the credibility of a carbon-constrained future by drawing on the theory of technological lock-in—specifically, the role of “adaptive expectations” (Pierson 2000)—in determining a competition between incompatible options (Arthur 1989). This approach also facilitates examining political and financial trends together. “Adaptive expectations” refers to a self-reinforcing expectations-commitment feedback cycle, when actors make a zero-sum bet on one of two incompatible future options, such as choosing between Beta or VHS video formats. The commitments involved (e.g., stores selling only VHS) reinforce the viability of the option they choose, leading others to deem that future more probable and to accelerate change by adapting their expectations and actions to the assumption

that this future is winning out (Arthur 1989). This dynamic applies in politics (Pierson 2000), where elected officials are concerned with backing winners. In finance, as the world's largest pension funds and insurers take actions that align with 2 °C, other investors read this as a negative signal for the future of fossil fuels, and react (Dordi and Weber 2019). Not incidentally, this framing aligns with KIIG proponents' strategy: they seek to make carbon constraints a winner like VHS over Beta, to convince the world that most economically proven fossil reserves are nearly worthless—because we would greatly exceed a 2 °C carbon budget if they are burned (Meinshausen et al. 2009)—rather than worth trillions. Indeed, as much as \$100 trillion USD in fossil-fuel assets are at risk of being stranded if emissions are kept within a 2 °C carbon budget (Channell et al. 2015). Of course, KIIG and related concepts can plausibly reshape expectations thanks to their prominence as the official Paris Agreement target and use of carbon budgets to measure the progress of national contribution (Jaeger and Jaeger 2011).

## 2.2 Analysis and sources

To organize the progression of KIIG and related concepts towards the mainstream within finance and climate movements and their sub-areas, we use a three-wave taxonomy that Ansar et al. (2013) applied to divestment: a progression from early promoters of the idea (wave 1), to a set of legitimizing backers (wave 2), to uptake by mainstream actors (wave 3) (see Fig. 3). To flesh out this taxonomy, we created a database of relevant events and populated Fig. 3 with notable examples, mostly those discussed in Sections 3 through 5. We focus on actors and trends that are important to this progression to illustrate the systemic shift rather than to be comprehensive (e.g., in reporting and disclosure, we focus on the oil majors).

We relied on a variety of sources: primary documents (e.g., articles/reports) created by proponents that convey their views of their strategies; we used primary documents (e.g., shareholder resolutions and oil companies' responses), and peer-reviewed sources that trace the growth and fossil-constraining impact of these strategies and discourses, supplemented by financial gray literature and news accounts. At the mainstream level, we establish systematic relevance by focusing on leading actors (e.g., the world's largest insurance companies).

To corroborate this narrative quantitatively, we conducted separate iterative textual reviews of news articles and scholarly articles as detailed in the [supplementary material](#). We adopt the preferred reporting items for systematic reviews and meta-analyses (PRISMA) method (Liberati et al. 2009) to identify salient scholarly literature. The query of the Web of Science database included peer-reviewed articles on the carbon budget, cumulative emissions, and 2 degrees.<sup>1</sup> This resulted in 128 unique publications, of which 88.2% were published after 2009, which we used to establish the gap in the literature, as described in the introduction. The remainder of this textual analysis was applied to popular discourse represented in media coverage. We replicate the PRISMA methodology within LexisNexis, including additional social and financial words to further scope the selected news articles. We identify 861 unique articles with finance-related keywords and 576 unique articles with social-related keywords.

Within this news article set, we employed two analyses to corroborate some of the major events we traced. Firstly, we assessed the frequency of select keywords (bubble, carbon tracker, divestment, stranded, and pipeline) from 2009 to 2015 (see Fig. 2). Secondly, we

<sup>1</sup> (ALL = (("carbon budget" OR "cumulative emission\*" OR "cumulative carbon emission\*")AND("2 C" OR "2C" OR"2 degree \*"OR "2-degree\*"OR "two degree\*"OR "two-degree\*"))) AND LANGUAGE:(English) AND DOCUMENT TYPES:(Article)

examine several word associations within the articles (based on the number of articles that include the two words being analyzed), where a high association (0.8) between the word's "divestment" and "carbon bubble," for example, corroborates the apparent linkage between these concepts during the period in question.

### 3 The spread and effectiveness of 2 °C carbon budget frames

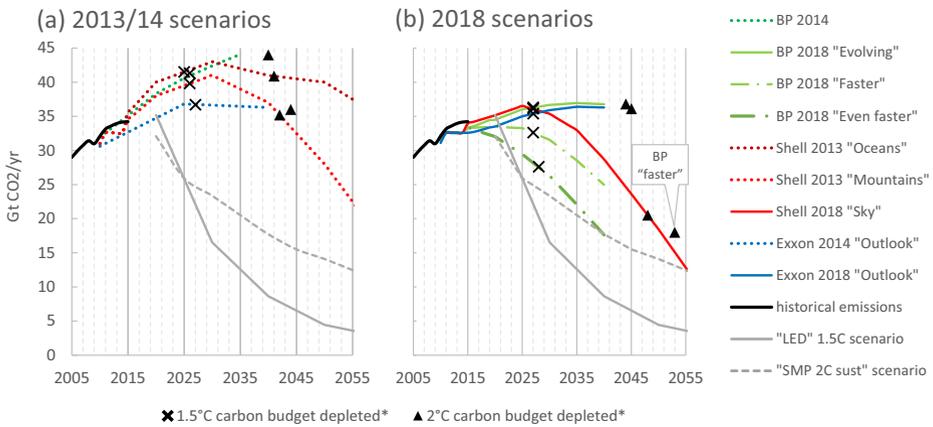
Key proponents using 2 °C carbon budgets to raise the credibility of a carbon-constrained world relied on the concept to frame a zero-sum choice to shift adaptive expectations: either actions can be aligned with temperature-limit targets or new fossil-fuel projects can be developed, but not both. This section summarizes this either-or framing, its emergence, and diffusion.

#### 3.1 Framing a choice between the climate and continued fossil-fuel developments

Proponents of KIIG and related concepts built this either-or premise on a seminal paper published prior to COP 2009 by Meinshausen et al. (2009). It plainly stated the quandary, estimating that staying within a 2 °C target (66% probability) translated into a remaining carbon budget of 565 GtCO<sub>2</sub> while consuming "proven" (i.e., profitable) fossil-fuel reserves would release 2795 GtCO<sub>2</sub>. Further, the discrepancy is increasing in a "carbon crunch": the later emissions peak, the more abruptly we will need to phase out fossil fuels (Figueres et al. 2017), and thus the more the transition will threaten fossil-fuel industries' business models and interests.

One aspect of this framing diverges from the consensus IPCC approach to carbon budgets in a key fashion: it typically excludes negative emissions or carbon capture and storage (CCS) schemes. While these can be reasonable scenario-modelling tools, some climate scientists have criticized them as speculative loopholes that delay accountability for emissions today, dilute the recognition of finite limits, and burden future generations (Anderson and Peters 2016). Additionally, the oil industry uses this framework to argue that even under below-2 °C scenarios, the industry status quo can largely continue and that more substantial emissions cuts will take place after the current business time horizon (see Section 5.2). This concern is validated by the way the massive CCS growth projected by the IEA failed to materialize, while emissions increased rapidly (IEA 2008). Thus, despite the many complexities and uncertainties of carbon budgets that balance carbon sources and sinks, within public-policy discourse, it is credible to ignore speculative or far-off measures (Anderson and Peters 2016) when examining the implications of below-2 °C carbon budgets for the fossil-fuel industry.

To illustrate this either-or frame, in Fig. 1 we show the stark divergence between below-2 °C scenarios and emissions projections from the three largest private oil companies. Building on a comparison by Frumhoff et al. (2015), we analyzed when the latest IPCC carbon budgets (Rogelj et al. 2018) would be depleted in each company's scenario (without negative emissions or CCS), finding that carbon budgets to limit warming to 1.5 °C would be rapidly exhausted (between 2025 and 2028) and 2 °C carbon budgets would be exhausted within the capital lifetime of many projects (between 2040 and 2053), except in BP's "even faster" scenario, which ends in 2040 on an apparent trajectory to keep below the latest 2 °C carbon budget this century. While it is just one way to calculate these dates, this simple, transparent analysis shows most of these scenarios to be consistent with emissions well beyond stringent carbon budgets for below-2 °C.



**Fig. 1** Scenarios of global CO<sub>2</sub> emissions from energy use from the top three oil majors with historical energy emissions (Le Quéré et al., 2018) and energy emissions from reference scenarios for 1.5 °C or 2 °C featuring minimal CCS or negative emissions (“LED” and “SMP\_2C\_sust” from Grubler et al. 2018 and Bertram et al. 2018—see Rogelj et al. 2018 and Huppmann et al. 2018). (a) 2013–2014 projections pre-Paris Agreement, adapted from Frumhoff et al. (2015). (b) Scenarios from 2018 from British Petroleum (2014, 2018) ExxonMobil (2014, 2018) and Royal Dutch Shell (2013, 2018). \*Carbon budget depletion years for each scenario were arrived at starting with the remaining IPCC budget for 2018 of 1170 GtCO<sub>2</sub> and 420 GtCO<sub>2</sub> for 2 °C and 1.5 °C respectively (Rogelj et al. 2018), then assigning 85% of this to an energy-only budget (the current percent of energy emissions) (for Exxon 2014/18 and BP 14/“evolving” depletion years are 5–6 years after the scenario ends based on extrapolating the emission trends and 14 years in the case of the BP “faster” scenario)

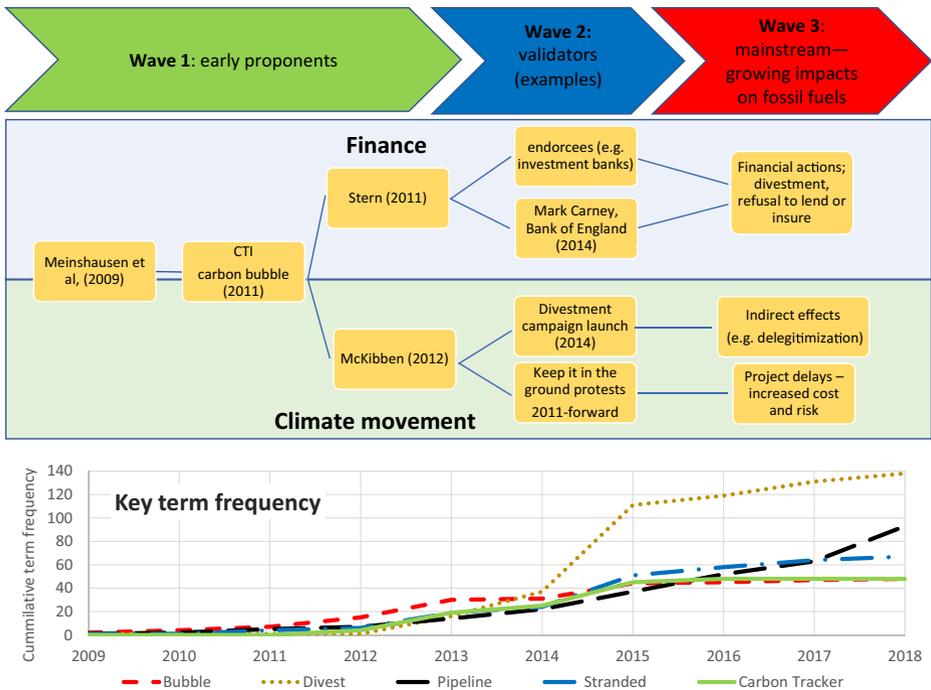
Industry projections are not merely scenarios: they are an extension of demand-projections long-used to guide investments to meet that projected demand. ExxonMobil’s document begins, “The Outlook for Energy is ExxonMobil’s view of energy demand and supply through 2040. We use the Outlook to help inform our long-term business strategies and investment plans.” (ExxonMobil 2018, p. 2). While BP kept the business-planning role of its 2018 outlook vague, the 2017 version featured only one scenario identified as “most likely” and as useful to “ensure we are able to continue to meet the energy needs of a changing world”: the highest-emissions “evolve” scenario (British Petroleum 2017, p. 4).

The key implication is that below-2 °C pathways and these business-planning scenarios diverge sharply within an investment-relevant timeframe, so that many new investments meant to meet industry demand scenarios must be stranded if these targets are met. These are two incompatible futures. The bulk of research on capital tied to “unburnable carbon”—those reserves beyond the 2 °C budget—supports this view. Several studies found that as of 2017, existing infrastructure, especially coal plants, would produce at least 2 °C of warming if operated through their lifetime (Guivarch and Hallegatte 2011; Davis and Socolow 2014; Pfeiffer et al. 2016); and, in line with the carbon crunch, if emissions do not peak soon, the financial stakes committed to overshooting 2 °C would grow rapidly (Bertram et al. 2015). At a minimum, significant portions of global fossil-fuel capital will have to be retired early if the industry implements current expansion plans worth hundreds of billions (Mercure et al. 2018; Cui et al. 2019). Based on this perspective, climate-agnostic actors are confronted with a very difficult choice regarding which expectations to plan around: do they expect fossil fuels to be developed well beyond 2 °C, or do they expect climate policy to succeed in constraining emissions below 2 °C?

### 3.2 Overview of the growing influence of finite limits to carbon development

In climate politics and financial realms, the salience of KIIG based on 2 °C carbon budgets grew from the fringe to the mainstream. By 2011, proponents in both realms were drawing specifically on the finding in Meinshausen et al. (2009), which had yet to garner significant attention in either realm (see Fig. 2). First, financial analysts who formed the Carbon Tracker Initiative (CTI) translated the contradictions identified by Meinshausen et al. (2009) into financial terms, coining the term “carbon bubble” to describe the pool of overvalued carbon assets in a world committed to staying below 2 °C (Campanale and Leggett 2011). Then, key actors in the climate justice movement (e.g., McKibben) picked up on CTI’s accessible and financialized framing as a conceptual foundation to argue for KIIG, a vernacular framing of the implications of finite carbon budgets. This link from CTI to the climate movement is corroborated by our LexisNexis document term matrix: “Tracker” is mentioned with “McKibben” very often (an association of 0.55) while “carbon bubble” is mentioned very often with “keep it in the ground” (an association of 0.45).

In both realms, the originally fringe framing attracted additional legitimizing backers (wave 2), and then reached the mainstream status required to exert meaningful pressure



**Fig. 2** Simplified schematic of the progression in the climate movement and finance sector of KIIG and the 2 °C carbon budget frame (below) cumulative term frequencies (i.e., mentions are added to those from previous years) from our LexisNexis sample of articles mentioning “carbon budgets” and “2 °C,” showing the use of key terms rising in 2012 and especially in 2014–2015, generally consistent with this schematic progression and results in Sections 4 and 5

on fossil-fuel interests (wave 3). A simplification of this overarching progression is depicted in Fig. 2 (Fig. 3 offers more detail). Figure 2 also shows that relevant terms like “bubble” gain frequency post-2011 within our LexisNexis matrix of news articles relating to carbon budgets and 2 °C. Next, we describe the progression in each sphere.

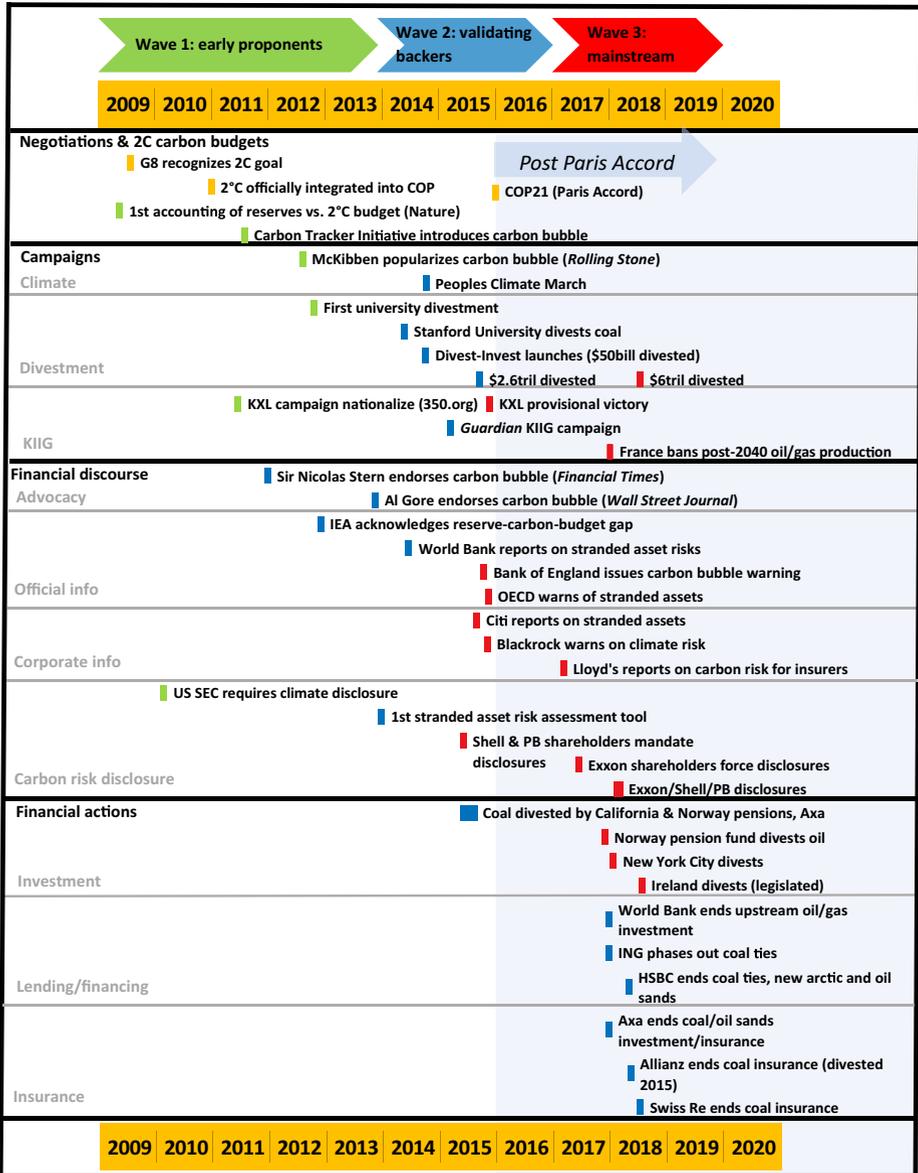


Fig. 3 Comparative progression in the application of the 2 °C carbon budget notion in three waves across the climate movement and within the financial sector

## 4 Adopting 2 °C carbon budgets in the climate justice movement

By 2012, the 2 °C carbon budget frame and carbon bubble concept were being used by climate activists to shape their strategy of treating the fossil-fuel industry as “enemies” by targeting fossil-fuel-supply financing (via divestment) and infrastructure (via protests). Critically, these strategies dovetailed with the increasing focus on justice for marginalized groups and grassroots tactics. The cumulative result was the rapid mainstreaming of a once-fringe perspective.

Two prominent movement individuals, Naomi Klein and Bill McKibben (Dietz et al. 2014), credit the CTI report with convincing them of the value of divestment and a communicable rationale for directly opposing the industry and supply infrastructure. Klein homed in on the (near) zero-sum choice articulated by CTI’s interpretation of the carbon budget and recognized its great potential to shape adaptive expectations. Klein believed the CTI warning that vast reserves are unburnable needed more credibility, since corporations would exert their power to burn their reserves, leaving people stranded, as opposed to fossil-fuel reserves—and she argued activism could help make KIIG a credible future. Klein explained the strategic logic: “If we’re the bubble, how do we flip it? How do we turn them [fossil-fuel companies] into the bubble that’s going to burst? And that’s where the divestment idea comes from. Those are the stakes, that’s really what that research shows: It’s them or us.” (Grist 2015). Similarly, McKibben emphasized, “If they [the fossil-fuel sector] carry out their business plan, the planet tanks” (350.org 2015). Both activists aimed to make a “KIIG and below 2°C” world the more credible of two opposing futures.

### 4.1 Energizing the climate movement with KIIG

To implement this new strategy, McKibben wrote a widely read article in *Rolling Stone* (2012) structured around the carbon-bubble rationale and “three simple numbers” from Meinshausen et al. (2009): 2 °C, 565 GtCO<sub>2</sub> (carbon budget), and 2795 GtCO<sub>2</sub> (carbon in proven fossil-fuel reserves). To drive home Klein’s “us or them” framing, he noted that these fossil fuels, while still in the ground, were already an economic reality that influenced corporate share prices and balance sheets. Thus, he defined the fossil-fuel sector as the enemy of a safe climate, giving the climate movement the clear target it had lacked. McKibben and 350.org, which he founded, also launched “Do the Math” (a tour of university campuses and film by the same name) and a global “Go Fossil Free” fossil-fuel divestment campaign to “revoke the social license of the fossil-fuel industry,” driven by the goal of “keeping carbon in the ground” (350.org 2013, 2015; Schifeling and Hoffman 2017).

McKibben and his colleagues were surprised by the “unprecedented” traction their campaigns received (Nisbet 2013), especially on university campuses (Grady-Benson and Sarathy 2015; Grist 2015). Within the environmental community, McKibben served as a validator of the carbon-bubble concept as well as a translator of its implications for activism (wave 2). His tour booked large concert halls and his *Rolling Stone* article was one of the magazine’s most widely circulated online (Nisbet 2013). Within a few years, the originally radical message of divestment entered mainstream discourse (wave 3) (Schifeling and Hoffman 2017). The KIIG message became part of the slogan of the 2014 People’s Climate March in New York City, which drew an unprecedented 400,000 people, including mainstream figures such as the UN Secretary-General. Finally, in the months before the Paris Agreement, *The Guardian* newspaper, in partnership with 350.org, ran a campaign to publicize 2 °C and the carbon budget, calling for philanthropists like Bill Gates to divest (*Guardian* 2015).

## 4.2 Divestment campaigns

The fossil-fuel divestment movement primarily targets the moral legitimacy of fossil-fuel investments, leveraging the profile and authority of divesting institutions like churches, universities, and pension funds (Yona and Lenferna 2016; Mangat et al. 2018). The targeting of legitimacy is distinct from the financial case regarding stranded assets, but crucially, they are linked: to paraphrase Klein (Grist 2015), delegitimization is designed to make the financial threat of climate action for keeping below 2 °C a perceived reality around which actors orient themselves.

As Ansar et al. (2013) noted, fossil-fuel divestment scaled in three waves with unprecedented speed. Before 2012 (wave 1), only a few campus divestment campaigns—linked to the “Beyond Coal” campaign—existed, and only one university had divested (Grady-Benson and Sarathy 2015). The strong response to early validation by McKibben/350.org and Klein, and the associated influx of resources (wave 2) were followed by increasingly credible support. Stanford University announced its divestment from coal (Stanford News 2014). After the 2014 People’s Climate March, the Divest-Invest for Philanthropy organization was launched, announcing that 70 organizations were divesting \$50 billion from the fossil-fuel sector (amounts are the value of the divesting fund, not the value of divested stocks). This announcement was widely reported because of the involvement of the Rockefeller Brothers Fund, heirs to the famous American oil fortune (Grady-Benson and Sarathy 2015; Divest-Invest 2018). By COP21, total divestment (primarily from coal) had reached \$2.6 trillion (Arabella Advisors 2015) and high-profile legitimizers included UNFCCC secretary Christiana Figueres and World Bank president Jim Yong Kim (Gunningham 2017). As Fig. 2 shows, mentions of divestment rose steeply in 2014 during this lead-up to COP21.

By 2019, divestment was arguably mainstream (wave 3), encompassing 1100 institutions managing over US\$11 trillion in assets across 31 countries. They included major pension, sovereign wealth, and insurance funds, churches, foundations, local governments, educational institutions, and even a nation-state, Ireland (Arabella Advisors 2015; gofossilfree.org 2019). Divestment appears to have a multitude of (difficult to measure) indirect effects (Bergman 2018), reducing the spaces in which the legitimacy of fossil fuels is uncontested.

## 4.3 Bolstering the contestation of oil extraction and transport

Alongside the divestment campaigns, longstanding local resistance to fossil-fuel development (Martinez-Alier et al. 2016) expanded during the 2010s. 2 °C carbon budgets became an important source of scientific credibility for targeting fossil-fuel infrastructure and KIIG became a signature rallying and recruiting slogan for anti-pipeline protestors (Hoberg 2017). The movement was legitimized within the environmental community by the successful nationalization of campaigns against the Keystone pipeline (KXL) in the USA, led by a coalition including 350.org (wave 2); the campaign began in 2011 and grew following McKibben’s call to arms.

The surprising success in constraining this pipeline development has been credited with revitalizing and reinventing environmentalism in North America (Hoberg 2017). A first mainstream endorsement (wave 3) might be US President Obama’s 2015 cancellation of KXL due to a combination of this opposition, the fading economic case, and the upcoming Paris negotiations—importantly, he noted that not all fossil fuels could be developed (Wordland 2016). KXL-style opposition has since slowed or blocked many fossil-fuel projects that were once considered routine. In Canada, major bitumen pipelines have been cancelled or withdrawn in part due to

fierce opposition, while the Trans Mountain Expansion proposal has sparked an intense ongoing national controversy (Hoberg 2018). Even when grassroots opposition fails, it can radicalize and draw together movement constituencies for future KIIG campaigns; for example when the Standing Rock Sioux Tribe led the opposition to the Dakota Access Pipeline, this energized Indigenous pipeline resistance across North America (Steinman 2018).

These campaigns have damaged fossil-fuel interests because delays and increased uncertainty can raise project costs, sometimes by billions (Healing 2014), or force project cancellations. Meanwhile, nations are beginning to enact KIIG-like policies to constrain development. Since late 2017, several countries have advanced bans on oil, gas, or coal exploration or extraction including France, Belize, Denmark, Ireland, New Zealand, Spain, Germany, and Iceland (Carter et al. 2019; Lazarus et al. 2019).

## 5 Adopting 2 °C and carbon budget concepts in finance

The progression of the 2 °C carbon budget frame and CTI's carbon bubble concept in the financial sector parallels the progression and adaptive-expectation-logic of the anti-fossil-fuel politics described above. Here, we divided the three-wave progression towards the mainstream into three categories (which overlap with these waves) and consider a more specific three-wave progression for each: financial discourse, particularly regarding the carbon bubble (dominating wave 1); financial reporting and disclosures regarding the risk of stranded assets (beginning in wave 2); and financial actions, such as divestment or refusal of insurance (adopted in wave 3).

### 5.1 The rise of the carbon bubble and stranded asset concepts

When CTI coined the term “carbon bubble” (Campanale and Leggett 2011), they captured the potentially dramatic financial implications of the 2 °C carbon budget. They argued that the short-term valuation models used to price fossil-fuel assets significantly overvalued most reserves and related capital, and they designated reserves outside the carbon budget as “unburnable carbon.” The implication is that investors ought to divest from investments tied to unburnable carbon for financial reasons. This link is shown in our LexisNexis document term matrix: “divestment” and “carbon bubble” are mentioned together extremely often (association of 0.81). Note that while overvaluations in financial bubbles generally have market and policy factors behind them (e.g., US housing bubble), the carbon bubble concept relies on policy in a seemingly novel way: “unburnable carbon” is only overvalued if climate goals are met; there is only a bubble if a consensus emerges that the 2 °C goal will trump fossil-fuel supply and infrastructure valuations. Thus, in advancing these ideas, like Klein and McKibben, the CTI aimed to make the “unburnable” designation a reality in this context by limiting investment in those reserves (M. Campanale, personal communication, September 25, 2018).

The financial sector and energy industries initially dismissed the CTI's arguments as “toxic” (King 2015) and dismissed the 2 °C carbon budget logic behind them (wave 1). The carbon bubble became more legitimate in financial discourse (wave 2) when influential economist Lord Stern summarized CTI's findings in a Financial Times opinion piece, concurring that “there is [...] a profound contradiction between declared public policy and the valuations of these listed companies, based on their fossil fuel reserves” (Stern 2011). Similarly, Gore and Blood (2013) compared the carbon bubble to the subprime housing bubble in the Wall Street

Journal. Soon afterwards, a coalition of investors, politicians, and scientists wrote an open letter urging the Bank of England to investigate fossil-fuel exposure as a risk to financial stability (Caldecott and Leaton 2012). Validation also came from the IEA when it published its analysis of the discrepancy between carbon reserves and 2 °C carbon budgets (International Energy Agency 2012). Like Klein and McKibben, CTI and its allies were surprised by the traction of their 2 °C budget-base strategy, in part attributing its sudden credibility to the crash in coal-stock values and the 2014 oil-price crash (King 2015).

The stranded assets discourse entered the mainstream around the time of the Paris Agreement (wave 3) as agnostic (or conflicted) actors weighed in (also see Fig. 2). Most major investment banks issued warnings or reports to investors on stranded carbon assets and (to a lesser degree) the carbon bubble (see Fig. 3 for examples), as did the world's largest hedge fund, Blackrock. Leading financial organizations that weighed in on both sides of the carbon bubble debate included MSCI (Briand et al. 2015), Towers Watson (2015), and the Organisation for Economic Co-operation and Development (Baron and Fischer 2015). Thus, the direct impact of this new discourse seems to be that it questioned long-standing assumptions regarding financing fossil-fuel growth.

## 5.2 Reporting and disclosure

As the stranded-assets discourse grew, so did efforts to incorporate these ideas into operations via reporting standards and voluntary disclosures designed to stress-test an individual company or institution against a carbon-constrained future (Monasterolo et al. 2017). This challenged investors' assumptions about the reliability of fossil-fuel growth. 2 °C scenarios and limits set by carbon budgets played an important role here, though subtler than in the climate movement.

By 2014, several voluntary carbon-disclosure pledges (e.g., Climate Disclosure Standards Board, Sustainability Accounting Standards Board) and risk-assessment tools had been introduced (wave 1). For example, Bloomberg launched the first tool to measure “unburnable carbon” risk, citing the early warning (e.g., from CTI) as inspiration (Douglas 2013), but did not use a 2 °C carbon budget metric. On the regulatory front, the SEC first flagged climate risk as a potentially material risk in 2010 (SEC 2010), and later stock markets and indexes, including the Dow Jones Sustainability Index, mandated carbon disclosure—reporting exposure to the potential curtailment of emissions—for trading (see Fig. 3 for examples).

The first set of prominent financial and oil sector actors got involved (wave 2) before the Paris Agreement. Most notably, Bank of England President Mark Carney warned that a popping carbon bubble would pose systemic risk to the financial system, justifying regulation under the Bank of England's mandate (Carney 2015). Carney specifically warned of a financial tipping point due to a rapid shift in adaptive expectations or “Minsky moment”—an unfavourable rush of investors away from fossil fuels as a 2 °C consensus emerges (Carney 2015). Carney's warning was considered a major turning point in legitimizing the carbon bubble and stranded assets concepts, and the divestment movement (e.g., McIntosh 2015).

Concurrently, a coalition of investors holding nearly \$300 billion in assets introduced successful shareholder resolutions calling on Shell and BP to report their carbon risk. The coalition made their case with a heavy focus on stress-testing 2 °C scenarios (mentioning 2 °C 22 times in fourteen pages, and using IEA's 450 scenario as an admittedly weak benchmark of

<sup>0</sup> By contrast, the actual resolution—supported by Shell and BP—never mentioned 2 °C, implying an aversion to the acknowledgement of finite limits.

a carbon-constrained future) (Share Action 2015).<sup>2</sup> Two years later, 62% of ExxonMobil shareholders, including Blackrock, voted against management, specifically calling on ExxonMobil to disclose how its business would fare in a 2 °C scenario (SEC 2017). The resolution was proposed by a coalition holding \$5 trillion in assets (Church of England 2017).

Carbon disclosure may have become mainstream (wave 3) when these shareholder resolutions appeared to be addressed by emission projection reports issued by Shell, BP, and ExxonMobil (plotted in Fig. 1). The ensuing critiques of these reports by the advocate-investors targeted the unconvincing consideration of 2°C carbon budgets. Shell’s “Sky” scenario was criticized for relying heavily on CCS and negative emissions in the distant future to assert compliance with 2 °C, and for projecting incremental change during the investment-relevant next two decades (Share Action 2017). BP’s “even faster transition” scenario was similarly criticized, but so was its devotion of far more attention to the high-emissions “evolving” scenario (British Petroleum 2018), which its 2017 outlook called the baseline scenario for business planning. ExxonMobil was criticized for its vagaries; the company produced a brief box section on a 2 °C scenario, never referencing it in the rest of its energy outlook, yet asserting that 95% of their assets were not at risk under 2 °C (ExxonMobil 2018; also see Carbon Tracker Initiative 2018). Thus, in exerting pressure and expressing skepticism regarding the supposed dearth of stranded asset risks, advocate-investors leaned towards a firmer interpretation of finite limits, though in less than stark zero-sum terms. This new debate over company-level stranded-asset risk creates a new front for constraints: even as many funds remain invested, others have found these disclosures lacking, like the \$1.3 trillion LGIM fund, which divested from ExxonMobil after decades of shareholder engagement (LGIM 2019).

### 5.3 Financial actions

Starting with divestment, large financial institutions and even some countries have begun distancing themselves from financing, investing in, and underwriting the fossil-fuel industry. These actions, which obviously have a more direct impact than discourse or disclosures, can help avoid or limit further fossil-fuel development and the resulting inflation of the carbon bubble. In terms of increasing the credibility of a carbon-constrained world, these financial actions represent agnostic actors making commitments that reinforce the Paris Agreement’s below-2 °C target and the idea that it poses a financial risk to fossil-fuel producers. That is, while most of these actions are motivated by financial factors, they appear to lend credibility to shunning the fossil-fuel industry and shifting expectations towards a world that remains below 2 °C, and to the implied need to strand reserves. We consider the progression of divestment, lending, and insurance in turn.

Most of the total divested before the Paris Agreement was from three massive funds (wave 2): CalPERS (\$476bil), Norway’s pension fund (\$900bil), and Axa (\$576bil), all of which divested from coal (Arabella Advisors 2015). Since then, impactful divestment pledges totalling \$11 trillion (gofossilfree.org 2019) in 2019 include several notable examples (wave 3). The Norwegian trillion-dollar sovereign wealth fund divested from oil, not to align with 2 °C but to avoid betting on oil prices twice, since revenues entering the fund come from the national oil company (Norges Bank 2018). Ireland’s sovereign fund pledged to divest from the fossil-fuel sector as part of “a timely decarbonization process in line with Ireland’s climate

<sup>2</sup> By contrast, the actual resolution—supported by Shell and BP—never mentioned 2 °C, implying an aversion to the acknowledgement of finite limits.

change commitments under Article 2 of the Paris Agreement” (National Treasury Management 2016). New York City did not cite 2 °C or carbon budgets in its \$189 billion divestment announcement but echoed the “enemies” frame by simultaneously announcing a lawsuit against the oil majors for deception on climate change (New York City 2018). Early evidence suggests that financial divestments are being noticed by investors, if not shaping expectations more broadly (Bergman, 2018). For instance, announcements of institutional divestment produce immediate and long-lasting drops in fossil-fuel share prices (Dordi and Weber 2019).

Moves to limit lending to certain types of fossil-fuel development (coal and heavy oil in particular) have also been partially validated by prominent financiers (wave 2). Major actors including BNP Paribas, the World Bank, ING, and HSBC all made variations of such commitments. BNP Paribas and HSBC explicitly cited the Paris Agreement’s 2 °C target, while ING’s narrow decision to restrict coal financing by 2025 exemplifies a more piecemeal approach (HSBC 2018; BNP Paribas 2017; ING group 2015). While the impact of these recent moves is unclear, financing is already an important choke point for some developments, especially those that also face uncertainty due to political opposition, like the Canadian Trans Mountain pipeline (purchased by the federal government in 2018 when the private developer was ready to abandon the project) or the Australian Carmichael coal mine.

In 2017, some of the world’s largest insurance groups committed to stop insuring some or all new coal projects (wave 2). They are motivated by both their unique interest in long-term risk management and the threat of climate impacts on their underwriting business (Kousky and Cooke 2009). While no insurer has ceased to underwrite all fossil-fuel technologies, Swiss Re (the largest reinsurer) and Axa (the largest insurer) are moving away from the oil sands and Arctic drilling. In their announcements, insurers Zurich (seventh-largest), Allianz (second-largest), and Swiss Re explicitly cite their responsibility to achieve a 2 °C target as a rational business decision (Swiss Re 2018; Axa 2017; Zurich Insurance Group 2017; Allianz 2018). The impact will likely be that fossil-fuel projects face higher insurance costs or fail to obtain insurance, which would entirely derail them.

Broadly, while each type of action has the potential to constrain fossil fuels if taken up by enough actors, there may also be a powerful cumulative effect signalling that financial ties to fossil fuels are growing increasingly risky.

## 6 Conclusions and discussion

Above we illustrated how KIIG proponents in the climate movement (Dietz et al. 2014) used 2 °C carbon budgets as a strategic framework to frame a zero-sum confrontation with the fossil-fuel “enemy,” helping build effective divestment and protest campaigns against supply-side investments and projects. We also show that KIIG proponents in finance used similar, though more nuanced concepts to pressure investors over the looming risks for the growth-oriented fossil-fuel sector in a 2 °C world (Leaton 2012), and show that even the biggest financial actors are reducing their ties to fossil fuels. This evidence supports the case that KIIG and related concepts (a) were promoted to make this limit credible, (b) became mainstream over a decade, and (c) have contributed to constraints on fossil-fuel interests and developments. Building on Fig. 2, Fig. 3 summarizes the remarkable decade of progression with illustrative examples of the three-wave progress across each of the sub-areas discussed.

While we do not establish a direct causal link between proponents’ efforts and the increasing prominence and credibility of KIIG, it is a reasonable inference that these efforts

played a substantial role. We also note that these trends are part of a much broader picture that includes, for example, environmental justice (in the climate movement) or competitive pressure on coal from renewables (in finance).

## 6.1 Potential implications for shifting expectations regarding carbon constraints

We applied an adaptive expectations lens derived from technological lock-in to frame the progress of KIIG and related concepts in terms of expectation-commitment feedback cycles, cycles in which alignment with carbon constraints increases expectations of future constraints, creating increased pressure to further this alignment, including by raising the credibility of stranding fossil-fuel assets. This broad perspective is helpful since many relevant effects are indirect and difficult to track (Bergman 2018), and feedback-driven change in such contexts is easily underestimated. We highlight three key insights from this perspective.

First, commitment-expectation feedbacks are not only relevant in both climate politics and energy finance but the clear overlap between them suggests that commitment-expectation feedbacks probably work in synergy across these fields to raise the credibility of a carbon-constrained future. This may be surprising, given some climate activists' antagonism to capitalism, and investors' profits-first orientation. The potential for synergy can be seen in the case of divestment: organizations that divest for ethical reasons must typically prove to stakeholders that it is financially prudent, thus helping strengthen the financial case for divestment; meanwhile, massive funds that divest for primarily financial reasons have nonetheless touted the climate dimension of their actions, arguably boosting the ethical legitimacy of divestment. Similarly, project-delaying protests have altered the business case for many fossil-fuel infrastructure projects, increasing costs by billions and making completion uncertain. In turn, lenders and investors must now consider the costs and risks of protests and legal actions when evaluating the viability of carbon developments. This potentially powerful overlap is important to consider when assessing the further progression of KIIG as a credible paradigm.

Second, adaptive expectations highlight the potential power of an apparent shift from KIIG discourse towards action by large players like nations or top-tier financial actors. Within expectation-commitment feedbacks, actions naturally do more to shift expectations than words, and bigger actions matter more. This is analogous to technological lock-in, when a major video-rental chain decides to carry only VHS tapes, this commitment shifts expectations more than individual customers' choices. Thus, it is plausible that major financial divestments, refusals to insure, pipeline blockades, and national KIIG policies will intensify the credibility—and likelihood—of a carbon-constrained world.

Third and finally, lock-in contextualizes the rising credibility of KIIG and related concepts within a world where government, corporate, and financial actors still organize their activities around the expectation that humanity will burn far more fossil fuels than is possible under stringent, below-2 °C scenarios. Blackrock, for example, pressured oil companies yet continues to invest in fossil-fuel expansion. In this context, a more even contest between competing visions can be destabilizing. Similarly, at one point, consumers may have owned both VHS and Beta players as they waited to see which option won out. Thus, if actors become increasingly uncertain whether certain oil reserves are worth trillions or close to zero (for example), the door opens for an abrupt shift towards expecting carbon constraints, as the Bank of England warned (Carney 2015)—and as can happen when commitment-expectation feedback passes a tipping point and firmly establishes one future vision over another (Arthur 1989).

## 6.2 Implications for relevant actors

The implications of expectations shifting towards a carbon-constrained world are enormous. Already, there are a growing number of political and financial spaces where fossil-fuel extraction is unwelcome, and much about the fossil-fuel status quo can no longer be taken for granted, including the value of trillions in new carbon investments and supposed assets. This shifting landscape has major implications for the climate movement, the financial sector, and for policymakers and political leaders.

This article suggests that climate advocates' strategy of identifying enemies and turning limits on paper into credible threats has been successful, and that the underlying theory of change—and tactics—is worth pursuing farther. The overlap between social movement and financial shifts suggests there are ways to leverage synergies by creating facts on the ground that align with 2 °C. In the financial sector, while carbon risk is already increasingly considered, investors should consider the trajectory of KIIG concepts as well as the compound risk of unpredictable combinations of financial and political shifts. Bubbles can pop suddenly, while protest movements can quickly reshape political contexts. Meanwhile political leaders and policymakers stand to benefit from considering the implications of the zero-sum climate-or-carbon framing. Most notably, it will be increasingly difficult to credibly claim that fossil-fuel expansion aligns with climate targets. While it remains conventional wisdom that finding oil means striking it rich, governments may find that ground shifting beneath them. As the climate crisis intensifies, carbon expansion could become increasingly associated with intractable conflict and escalating financial risk, turning once-lucrative fossil-fuel development into a political and economic liability.

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