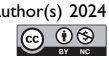
*Research Article*

EV

Environmental Values
2024, Vol. 33(6) 606–625



DOI: 10.1177/09632719241255857
journals.sagepub.com/home/env


# A Dynamic Collapse Concept for Climate Change

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**Abstract**
Despite growing interest in risks of societal collapse due to anthropogenic climate change, there exists no consensus about how collapse should be understood. In this article, we critically examine existing definitions and argue that none adequately address the challenges for conceptualizing collapse that climate change presents. We therefore propose an alternative conception, which regards collapse as a *reduction of collective capacity resulting in a pervasive and difficult-to-reverse loss of basic functionality*. Our conception is dynamic in that it focuses on the interrelations of constituent subsystems. It also distinguishes collapse from transformations needed to address climate change and provides insight into the relationship between collapse and sustainability.

**Keywords**
Civilization collapse, climate catastrophe, climate collapse, climate ethics, climate justice, collective capacity, Florida, sustainability, state capacity, Small Island Developing States

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## Introduction

Continued growth in global greenhouse gas emissions along with increasingly severe and frequent climate change impacts have prompted concerns among scientists, public figures, journalists, philosophers, and others that human societies might be at risk of collapse (Brozović, 2023; Lenton et al., 2023; Lynas, 2020; McKinnon, 2022; Mittiga, 2024; Mulgan, 2011; Steel et al., 2022). Yet climate change poses distinctive challenges for conceptualizing and defining "collapse." Some define "collapse" as large-scale societal transformation (Butzer & Enfield 2012). However, mitigation and adaptation to climate change also entail fundamental transformations of deeply entrenched socioeconomic systems. In addition, climate change presents difficulties for understanding "collapse" as decentralization (Renfrew, 1979) or as a loss of sociopolitical complexity (Tainter, 1988). Centralization and complexity are sometimes dysfunctional, and in such cases, decentralization or simplification might enhance societal sustainability and reduce risks of collapse. This is relevant here because addressing climate change requires transitioning to a more sustainable society (Ritchie, 2024), wherein energy decentralization, for instance, may play an important role (Brinker & Satchwell, 2020). So, a concept[1] of societal collapse better suited for climate change is sorely needed.

In this article, then, we propose a novel collapse concept focused on *collective capacity*. We maintain that a system collapses when it undergoes *a reduction of collective capacity resulting in a pervasive and difficult-to-reverse loss of basic functionality*. For example, a system of trade collapses when it suffers a widespread and long-lasting inability to support exchanges between buyers and sellers. Our conception of "collapse" is *dynamic* insofar as it emphasizes interactions among systems within a society. We suggest that risks of collapse to one system often provoke adaptations in others, some of which may result in general improvements while others may erode key bases of resilience and sustainability. *Societal collapse* is an example of the latter situation: it occurs when failure in one or more systems in a society leads to a broader cascade of collapses, to the extent that meeting the basic needs of the population becomes impossible.

Our proposal has several advantages. First, it explains the difference between societal collapse and a green transition. A collapsed agricultural system would threaten basic population needs, while the displacement of fossil fuels by renewable energy would not. Second, it explains the connection between sustainability and collapse avoidance. We understand collapse as a reduction of collective capacity that undermines basic functionality, whereas a sustainable society possesses the capacity to maintain central functions over the long term (Salas-Zapata & Ortiz-Muños, 2019). From this perspective, collapse and sustainability are opposite sides of the same coin. Finally, our dynamic conception draws attention to how complex interactions among societal systems can shape collapse risks. Among other things, this clarifies the difference between societal collapse and state failure. The central government is one system within society among others, so its collapse is not necessarily tantamount to the collapse of the society as a whole.

This article is organized as follows. We begin by critically assessing previously proposed definitions of collapse. Next, we present our concept of collapse, explain how it

improves on prior concepts, and explore some of its consequences. Following this, we use our concept to examine the risk of collapse in (i) small island developing states (SIDS) and (ii) the property insurance market in the US state of Florida.

## Prior Collapse Concepts

In this section, we critically assess prior collapse concepts. We located definitions of "collapse" by consulting well-known works on the subject (e.g., Tainter, 1988), conducting literature searches using Google Scholar and PhilPapers with "collapse" as a keyword, and examining the reference lists of publications that discuss collapse. Only definitions that pertain to the collapse of human societies are considered. While we do not examine every definition of societal collapse, we do claim to have represented the major types. These types can be distinguished by whether they define "collapse" as (1) a socioeconomic transformation, (2) sociopolitical simplification, or (3) political decentralization. We arrived at these categories by considering the content of definitions, the types of objections they are susceptible to, and by minimizing the number of categories for expositional parsimony. In the remainder of this section, we argue that none of the definitions we consider adequately addresses challenges posed by climate change.

### *Collapse as Transformation*

Several authors conceive of collapse as a large-scale socioeconomic transformation. Butzer and Endfield (2012: 3628), for instance, define "collapse" as a "transformation at a large social or spatial scale, with long-term impact on combinations of interdependent variables: (i) environmental change and resilience; (ii) demography of settlement; (iii) socioeconomic patterns; (iv) political or societal structures; (v) ideology or cultural memory." Similarly, through an examination of archaeological and historical cases, Weiss and Bradley (2001: 609) define "collapse" as events that "occurred quite suddenly and [that] frequently involved regional abandonment, replacement of one subsistence base by another… or conversion to a lower energy sociopolitical organization."

The difficulty with defining "collapse" in such a manner is that, while all collapses may be transformations, not all transformations are collapses (Middleton, 2017: 16). This observation is especially pertinent with respect to climate change. Transitioning from fossil fuels to renewable energy would have long-term impacts on all five of Butzer and Endfield's (2012) aforementioned criteria. Specifically, a worldwide renewable energy transition would impact (i) the environment and resilience by reducing greenhouse gas emissions. It would affect (ii) demography and settlement in many ways, including the likely loss of population in present-day oil towns. Given the centrality of fossil fuels in the world economy throughout the 20th century to the present, a renewable transition would also (iii) reshape socioeconomic patterns and (iv) politics. The size of cars would be less sensitive to trends in gasoline prices. Cheap fossil fuels would cease to be a major economic and political concern capable of swaying elections and motivating wars. Such changes would undoubtedly affect (v) culture and ideology. For instance, financial support for think tanks that churn out ideological justifications of fossil fuels would dry up. And consigning fossil fuels to the dustbin of history would

impact how future generations remember their collective past. One can imagine school children in 2100 being taught that the fossil fuel age was a polluted and unjust time. In short, a renewable energy transition would fundamentally transform the world. But far from constituting a societal collapse, such a transformation is urgently needed to *prevent* collapse.

Related objections apply to Weiss and Bradley's (2001) definition, in which collapse involves abandoning settlements, a change in subsistence base, or conversion to a lower-energy socioeconomic system. Work on transformative adaptation emphasizes that managed retreat—and hence abandonment of some settlements—can be a more effective long-term adaptation strategy than retaining current settlements (Mach and Siders, 2021). A renewable energy transition would transform the world's subsistence base by removing fossil fuels as a significant source of energy. Climate change mitigation also requires reducing emissions from agriculture, which may require transitioning to primarily plant-based diets (Xu et al., 2021; Scarborough et al., 2023). Finally, effective mitigation is likely to involve transitioning to less energy-intensive socioeconomic systems in sectors such as transportation. Electric vehicles are far more energy efficient than their internal combustion counterparts, and active transport in the form of walking, cycling, and public transit is more efficient still (Brand et al., 2021). Taken together, successful mitigation and adaptation to climate change may involve abandonment of settlements, significant changes in the subsistence base, and conversion to lower energy input socio-economic systems. But these would all be done to *prevent* collapse. Again, the key point is that in the context of climate change, collapse cannot be equated with transformation.

Transformation is closely related to loss of system identity, where old actors and components decline, new ones emerge, and connections are rearranged. As a result, collapse definitions that emphasize loss of system identity face difficulties similar to those discussed above. Consider Cumming and Peterson's (2017) definition of "collapse" as a rapid and long-lasting loss of system identity and socio-ecological capital. Loss of system identity means that "key actors, system components, and interactions must disappear" (Cumming and Peterson 2017: 699). Losses of social-ecological capital must be "substantial" and are illustrated by examples such as reductions in population, food sources, and economic output (Cumming and Peterson, 2017: 699). A successful worldwide renewable transition by 2050 would apparently count as collapse of the energy system by Cumming and Peterson's definition. Key actors (e.g., Saudi Aramco, Exxon Mobil, the Organization of Petroleum Exporting Countries, etc.), system components (e.g., pipelines, oil refineries, fleets of oil tankers, etc.), and interactions among them *would disappear. Substantial socio-economic capital in the form of fossil fuel* company profits, stock values, and assets would be lost. The change would also be fast according to Cumming and Peterson's (2017: 699) approximate 25-year threshold. And a transition to renewable energy would be extremely difficult to reverse once completed. Like those that focus on transformation, then, definitions that emphasize loss of system identity have difficulty distinguishing collapse from other types of major societal change.

One response to the difficulties discussed above is to define "collapse" as an extremely harmful transformation. For example, Young and Leemans define "collapse" as a "rate of change to a system that has negative, intolerable consequences on human welfare, results

in a substantial restructuring of the system, and cannot be stopped nor controlled" (2007: 450). However, not all harmful societal transformations are collapses. For example, some have considered global dictatorship as a possible solution to collective inaction on climate change (Wainwright and Mann, 2018). In such a scenario, an authoritarian world government would enforce a rapid transition away from fossil fuels. Climate authoritarianism, then, would be a societal transformation that might prevent collapse while negatively impacting welfare, for instance, through human rights violations (cf. Beeson, 2010; Shahar, 2015; Von Stein, 2022).

## *Collapse as Loss of Complexity*

Tainter (1988) argues that sociopolitical complexity is the central explanatory variable behind collapse. According to Tainter, increased sociopolitical complexity is a means for solving societal problems; yet, as societies age, they often need to devote an increasing share of resources to maintaining their accumulated complexity, with declining marginal returns. In other words, early increases of complexity bring large benefits at low cost, while later complexification brings small benefits at high cost. This dynamic can ultimately result in collapse due to inadequate reserves or to social disintegration as the benefits of complexity no longer justify its expense (1988: 119–121).

Tainter, then, defines "societal collapse" as "a rapid, significant loss of an established level of sociopolitical complexity" (1988: 4). This definition is influential and several authors adopt it in full or propose variations of it (cf. Diamond, 2005; Lenton et al., 2023). Tainter states that sociopolitical complexity varies with inequality in access to resources and the heterogeneity of social roles; inequality is said to be the "vertical" dimension of complexity, while heterogeneity is the "horizontal" dimension (Tainter, 1988: 23). Thus, a society in which wealth and political power are concentrated in the hands of a few, and where a vast multitude of professions, social niches, and cultural groups coexist, would be highly complex. Conversely, a society that became more equal while maintaining the same level of heterogeneity would experience a drop in complexity. Collapse, for Tainter, involves a qualitative step down in the level of complexity. Although he does not explain what constitutes a level of complexity, he does give some examples. A transition from a nation-state to a collection of chiefdoms would be a reduced level of complexity, as would the fragmentation of a chiefdom into feuding villages (1988: 5).

One objection to Tainter's collapse concept is that sociopolitical complexity can be dysfunctional and thus simplification can sometimes be essential for preventing collapse (Cumming and Peterson, 2017: 697). Streamlining an overly complex and inefficient bureaucratic structure, for instance, might be necessary for the survival of an organization. Indeed, Tainter himself discusses an example that illustrates this point. He suggests that the Byzantine Empire avoided collapse and was "rejuvenated" in the 7th century due to a strategic simplification in which the size of the government was slashed and "the economy developed into its medieval form, organized around self-sufficient manors" (2006: 97–98). However, the claim that Byzantium was rejuvenated through simplification appears incompatible with defining collapse as a rapid loss of an established level of sociopolitical complexity. That definition seems to entail that the

Byzantine Empire *collapsed* in the 7th century. Tainter might seek to avoid this unwanted conclusion by arguing that 7th century Byzantium's loss of complexity did not amount to a qualitative drop in level.[2] However, such a response would not address the underlying difficulty. The fact that simplification can be a strategy for avoiding collapse suggests that collapse should not be defined as loss of complexity.

This objection is also relevant to climate change. The ultra-rich have outsized carbon footprints, while the most impoverished are at greatest risk of adverse climate impacts despite their negligible emissions (Otto et al., 2019). Moreover, economic inequality within nations has significantly increased since the 1980s (Heimberger, 2020). Such observations lead many to argue that a successful green transition cannot be limited to pricing carbon or substituting fossil fuel technologies with renewable alternatives (Mintz-Woo, 2024). From this perspective, transitioning to a more sustainable global society also requires the world to become substantially more economically equal and politically fair. Since inequality is Tainter's vertical dimension of sociopolitical complexity, a just transition would represent a substantial drop in complexity as he defines it. This strikes us as a problem for defining collapse as loss of sociopolitical complexity.

## *Collapse as Decentralization*

Another approach is to define "collapse" in terms of political decentralization or fragmentation. Renfrew observes that many archeologists take loss "of central administrative organization of the early state; disappearance of the traditional elite class; collapse of centralized economy; settlement shift and population decline" to be evidence of societal collapse (1979: 482). Similarly, Schwartz (2006: 5) characterizes collapse as possessing "some or all of the following features: the fragmentation of states into smaller political entities; the partial abandonment or complete destruction of urban centers, along with the loss or depletion of their centralizing functions; the breakdown of regional economic systems; and the failure of civilization ideologies." More recently, Kemp et al. (2022: 5) define "societal collapse" as a "significant socio-political fragmentation and/or state failure along with the relatively rapid, enduring, and significant loss of capital, and systems identity, [which] can lead to large-scale increases in mortality and morbidity."

However, definitions of "societal collapse" focused on decentralization/fragmentation face similar challenge as those that emphasize complexity. Like complexity, political centralization can be dysfunctional. When that happens, decentralization and fragmentation of political authority might result in a more sustainable societies that are better able to meet the needs of their populations over the long term. Energy decentralization illustrates the relevance of this point for climate change. Traditionally, electricity generation was a matter of industrial scale power plants owned by utility companies distributing electricity to customers. In contrast, the growth of renewable energy in the power sector is creating a system of interacting utility and smaller scale electricity producers (Brinker & Satchwell, 2020). The ability of photovoltaic solar combined with battery storage to be installed at individual and community levels is already reshaping electricity infrastructure in many parts of the world. For example, the European Union changed energy regulations in 2018 to recognize the rights of individuals and "renewable energy communities" to generate and sell electricity (Lowitzsch et al., 2020). And the benefits of decentralized

electricity infrastructure for lower-income countries is increasingly recognized (Khan, 2020). Brinker and Satchwell (2020) distinguish four aspects of energy decentralization: (1) the geographic dispersal of power sector technologies, (2) policies that promote or inhibit decentralization, (3) ownership of energy resources, like rooftop solar, at individual or community levels, and (4) decentralized decision-making authority. The last of these components is a form of political decentralization. Thus, political decentralization may be part of transitioning to a more sustainable society, reducing the risk of collapse.

One who defines "collapse" in terms of political decentralization could argue that energy decentralization does not check all the boxes of their definition. For example, it does not involve population loss, abandonment of urban centers, or state failure. But as with our discussion of Tainter's definition, such responses fail to address the central challenge. If decentralization can promote sustainability, then it is an unpromising basis for understanding the difference between collapse and societal transformations needed to address climate change. Thus, we propose a different approach.

## Collapse and Collective Capacity

The paradigm image associated with "collapse" is a building falling down into a pile of rubble. Extending the word "collapse" to economies, ecosystems, or societies, then, amounts to an analogy. A collapsed society bears some important similarity to a collapsed building. But what is that similarity? We suggest the following answer: both cases exhibit a pervasive and difficult-to-reverse loss of capacity to carry out basic functions. Suppose the building was a house. Then its basic functions included providing shelter, storage for belongings, and a site for interactions among household members. After the collapse, the house can no longer perform these functions, and reversing that situation would require reconstruction. This loss of capacity is also pervasive. The entire structure, not just one room or wing, was affected. For a society, basic functions include provision of food, security, and shelter to the population. A societal collapse, therefore, would entail a pervasive and difficult-to-reverse loss of collective capacity to carry out these functions. Pervasive in this context means that impacts were felt throughout the society, even if distributed unequally.

The example of a falling house also suggests a dynamic understanding of collapse. Perhaps one wall fell first, thereby destabilizing the beams holding up the roof, which subsequently fell and brought the remaining structure down. Our approach to collapse likewise views societies as containing mutually supporting sectors or systems, such as governments, industries, trade networks, transportation, education, agriculture, healthcare, and so on, where the collapse of one may destabilize others. Societal collapse, then, happens when the collapse of various subsystems leads to a loss of collective capacity to such an extent that the basic needs of the population can no longer be met. This dynamic collapse concept is useful for climate change, which can create broader societal risks by threatening key systems, such as agriculture or property insurance.

Elaborating our conception of collapse requires unpacking the terms *collective capacity* and *basic functionality*. We expand on these terms in the course of considering three questions that can be asked about collapse concepts: (1) *What is the unit of analysis?* (2) *What declines?* and (3) *What is distinctive about collapse?*

## What is the Unit of Analysis?

A collapse concept should be clear about the sort of things to which it applies. What, in other words, is the unit of analysis. This question could be answered in several ways. Renfrew (1979) is concerned with early states from historical and archeological records. Kemp et al. (2022) focus on failed states and apparently take collapse to be something that happens to nation-states. For his part, Tainter (1988) insists that collapse can occur to societies of any level of sociopolitical complexity. Many other definitions are simply unclear on this matter. Our concept resembles Tainter's insofar as it does not restrict collapse to a particular type of sociopolitical organization.

Collapse as we understand it is a phenomenon that can affect systems of social coordination that provide collective services or goods, like commerce, agricultural production, preserving social order, developing and maintaining civic infrastructure, and so on. This includes most states, interconnected groups of states, local governments, corporations, universities, and a variety of other types of social institutions, sectors, and systems. These units may be inequitable and impose severe harms, but our concept applies to them so long as they are capable of functioning to provide benefits to some of their participants.

Flexibility in the units of analysis prompts consideration of interacting societal subsystems, which are central to our dynamic conception. Some systems directly address key population needs, like food, water, shelter, income, and so on. Other systems play more indirect roles, supporting sectors of society that meet basic needs. Climate risks to property insurance in the US state of Florida, discussed below, is a good example of this type of situation. Moreover, our dynamic conception emphasizes that societies implement various adaptations when important systems are threatened with collapse. Whether the risk of collapse to an important system leads to a societal collapse can depend on which adaptive strategies are pursued.

## What Declines?

Most definitions of "collapse" emphasize the decline of some key variable, such as sociopolitical complexity, political centralization, or system identity. The declining variable in our collapse concept is collective capacity, understood as a system's material and organizational ability to provide services or support collective goods, such as engaging in trade, providing food, housing, and security. This explains why not every societal transformation is a collapse. For example, a successful renewable energy transition would be a profound transformation, but not a collapse because it would not undermine collective capacities to meet societal needs. On the contrary, it would enable those needs to be met in a more sustainable manner.

Collective capacity is closely related to the political science concept of "state capacity." Berwick and Christia (2018) propose a unifying framework that identifies three types of state capacity: extraction, coordination, and compliance. Extraction capacity refers to the ability of a state to collect resources (e.g., natural resources, taxes) and it is often considered the foundation of other types of state capacity. Coordination capacity refers to the capacity of a state to organize collective action and it thus has to do with the

way various institutions are designed to guarantee that resources extracted are effectively used. Lastly, compliance capacity is related to the ability of the state to ensure compliance with its objectives. This can be achieved through various means, from ideology and economic incentives to coercion. The three dimensions of state capacity often intersect. For instance, without tax revenues, it is difficult for the state to redistribute wealth and thus ensure compliance with its goals. Similarly, without coordination capacity, effective extraction of resources can be difficult.

Collective capacity, then, is a generalization of the concept of state capacity. Other forms of social organization, including local governments, corporations, non-profit organizations, and international networks of trade or mutual assistance, can also possess collective capacity. Grasping this point is important for appreciating the difference between societal collapse and state failure. According to Bøås and Jennings (2007: 477), state failure is characterized by the "inability to control territory, borders, and internal legal order and security, and lack of capacity or will to provide services to the citizenry (typically due to some kind of large-scale institutional collapse)." This definition suggests that loss of state capacity is an important element of state failure which in turn can be linked to collapse. However, state failure does not entail societal collapse if other forms of organization retain sufficient collective capacity to meet population needs.

Some authors who emphasize loss of complexity, political centralization, or system identity as indicators of collapse seem to presume that these entail a corresponding loss of collective capacity. For example, Tainter writes:

> In a complex society that has collapsed … the overarching structure that provides support services to the population *loses capability* or disappears entirely. No longer can the populace rely upon external defense and internal order, maintenance of public works, or delivery of food and material goods. (1988: 20, italics added)

Yet when sociopolitical complexity is dysfunctional, simplification may be essential for maintaining collective capacity. We suggest, therefore, that the focus on collective capacity in our proposal is an important advantage over alternatives.

## *What is Distinctive about Collapse?*

Definitions of "collapse" often focus on a declining variable, such as complexity or decentralization, but then say little about what distinguishes ordinary fluctuations in this variable from collapse. One common way to address this issue is to require that the decline be rapid. However, rapidity is insufficient for this purpose, since minor fluctuations often happen quickly while collapse may take a century or more to play out (Butzer, 2012).

Our definition of "collapse," therefore, includes a threshold: a pervasive and difficult-to-reverse loss of basic functionality. Basic functionality refers to the core goods or services provided by the type of social system in question. For a system of flood insurance, this would mean the capacity to provide affordable insurance policies to those whose properties are exposed to non-negligible risk of flooding. For a society, it minimally involves provision of the population's basic needs (Pölzler, 2021). For

example, Cochet (2011) suggests that societal collapse be understood to mean that "basic needs (water, food, housing, clothing, energy, transportation, security) are no longer provided to a majority of the population."[3]

Basic functionality refers to the capacity of the system, not to its actual behaviors. This point can be important in connection with governments, which sometimes deliberately deprive segments of the population. Whether a social system can maintain basic functionality may depend on the crises confronting it. A level of collective capacity that suffices for basic functionality in good times may be insufficient when a shock, such as a drought, strikes. Basic functionality is also tied to the existing size of a society or system. Thus, an agricultural system that loses its capacity to feed an existing population of one million might still be sufficient to provide for one hundred thousand. According to our proposal, this would be a collapse of the agricultural system because it would no longer be able to meet the needs of the majority of the population.

In our definition of "collapse," the loss of basic functionality must be pervasive and difficult to reverse. We understand a pervasive loss of basic functionality to be one that impacts the majority of the participants in a given system, such as the population of a state. Collapses may be difficult to reverse for several interconnected reasons, including a lack of incentive among the relevant agents to shoulder costs of reconstruction, the loss of an economic basis for rebuilding, dispersion of the affected population, or the creation of entrenched conflicts. Short-term losses of basic functionality, such as a three-day electrical outage following a storm, are not collapses according to our definition.

Our proposal neatly captures the intuitive idea that unsustainable societies are more prone to collapse, while societies less susceptible to collapse are more sustainable. Salas-Zapata and Ortiz-Muños (2019) suggest that, when applied to an object like an ecosystem or society, sustainability refers to "the capacity of such systems to maintain certain characteristics, resources, processes or functions over the long term in spite of disturbances" (2019: 157). Thus, a sustainable society maintains capacities to carry out essential functions across a lengthy period of time, which is to say it avoids crossing the threshold of collapse in our definition. Conversely, a society that suffers collapse as we define it undergoes a loss of capacities needed to sustain itself. Nevertheless, a society's capacity to sustain core functions over the long term is never absolute. Even the most sustainable society could not survive a giant asteroid impact that destroyed life on Earth, for example. Both collapse and sustainability are also tied to population size. A food and energy system based on hunting, gathering, and burning organic materials might be sustainable for a population of several thousand but not for the approximately 8 billion currently alive (Ritchie, 2024).

The connection between collapse and sustainability can be further clarified by considering the relationship of both to resilience. Although there is no universally accepted definition of resilience (Nüchter et al., 2021; Roostaie et al., 2019) nor agreement about how resilience is related to sustainability (Marchese et al., 2018), a distinction between two important interpretations of resilience due to Thorén (2014) is useful here. According to Thorén (2014), resilience can be understood in a local or global sense. Local resilience "refers to the ability to return to some reference state after a disturbance," whereas global resilience is "maintenance of some property during a disturbance" (Thorén, 2014, 303). Rebuilding a damaged electricity grid after a storm would be an example of local

resilience, while maintaining the capacity to meet energy needs throughout a transition to renewable energy could be a case of global resilience. Sustainability, as we use the term, resembles global resilience, differing only in its explicit emphasis on societal capacities and the long-term. However, sustainability's relationship to local resilience is more complex.

Local resilience, we suggest, is a necessary but not sufficient condition for sustainability. Since major socioeconomic reconfigurations normally take an extended period of time, short-term responses to disruptions often involve quickly returning to a prior state, as when an electrical grid is put back online after a storm. A society without local resilience, then, would be unlikely to maintain its core capacities in the long run and would face risks of collapse. But robust local resilience can also coincide with unsustainability. Thus, while fossil fuels provide capacity to rebuild after disruptions, the climatic effects of a fossil-fuel-driven global economy make it unsustainable in the long run. Unlike local resilience, then, sustainability may require transition to a new state rather than reverting to a prior one.

Finally, our proposal provides a nuanced perspective on whether collapse is catastrophic. On the one hand, societal collapse has severely harmful impacts since it involves the inability of the majority of its population to meet their basic needs. But our concept also applies to units of analysis besides entire societies. Clearly, not every collapse of a societal system is a catastrophe: a collapsed system may be unimportant, dysfunctional, or harmful to all but a few. And even if it performs some essential function, its collapse may occur as part of a transition to a superior alternative. For example, the collapse of the fossil-fuel industry in the face of the growth of renewable energy stands to produce many benefits, including reduced climate change risks, less air pollution, cheaper electricity, and greater energy security.

## Examples

In this section, we present two examples that illustrate how our proposal applies to climate change-related collapse risks. The first example concerns Small Island Developing States (SIDS), while the second looks at property insurance markets in the US state of Florida. The first example demonstrates the advantages of conceptualizing collapse in terms of collective capacity, while the second illustrates our dynamic approach.

### *Small Island Developing States*

Climate change presents a multifaceted threat to Small Island Developing States (SIDS), amplifying the frequency and intensity of climate-related hazards. SIDS are disproportionately affected by climate change-driven occurrences due to their close reliance on the environmental conditions of coastal and ocean ecosystems for sustenance (Thomas et al. 2020). Notably, sea-level rise, resulting from ocean warming and subsequent ice-shelf melting, is anticipated to persist across all future climate scenarios, including those where ambitious climate mitigation measures are adopted (Naughten et al., 2023). When coupled with wave-induced overwash, triggered by extreme weather events like tropical storms and cyclones, these phenomena can engender recurrent flooding, causing severe damage to freshwater aquifers and other essential infrastructure

(Storlazzi et al., 2018). Adaptation efforts of SIDS are hindered by a combination of physical and economic constraints, threatening their ability to adapt in situ to climate change (Thomas et al., 2020). For this discussion, then, we assume that the populations of some small island states will be compelled to relocate. This assumption prompts the inquiry: does the resettlement of the population inevitably imply societal collapse?

The answer to this inquiry hinges, in part, on one's interpretation of societal collapse. Given our definition, the pivotal consideration centers on whether the society under examination—such as the Maldives, Marshall Islands, Bahamas, Tuvalu, etc.—can maintain its collective capacity to carry out basic functions and fulfill the essential needs of its population. To avoid the appearance of making predictions, we refer generically to a given relocated small island state as "the Island." Whether the Island's relocation is a collapse can also depend on how it occurs. Thus, we apply our notion of societal collapse to two scenarios, which we label *diaspora* and *ex-situ statehood*.

In the diaspora scenario, the Island's population becomes a refugee diaspora and its government is dissolved. In this case, the Island's collective capacity for self-determination and meeting the needs of its population would be significantly diminished. At this point, we can consider two diaspora sub-possibilities: one in which other states are *not* willing to resettle the Island's population and another in which they are. If other states were unwilling to accommodate refugees from the Island, that could result in basic needs not being met for the majority of its population. Given our conception, this worst-case scenario would be a societal collapse of the Island. More optimistically, agreements might be made with neighboring states to allow legal entry of the Island's citizens as refugees who are afforded essential services. In this case, the Island's government would still collapse, but societal collapse of the Island more broadly could be avoided. The basic needs of the Island's population would be met, but at the cost of transforming the Island from an autonomous political entity into a marginalized ethnic minority.

Consider how other collapse concepts apply to the diaspora scenario. Abandonment of the Island and relocation of its population would be a transformation with long-term environmental, demographic, economic, social, and cultural impacts. So, it would count as a collapse by any definition focused on transformation or related concepts like loss of system identity. Collapse concepts that focus on loss of complexity and decentralization are somewhat unclear in the diaspora scenario. Disappearance of the Island's government is plausibly a loss of sociopolitical complexity and thus collapse according to Tainter's definition. However, the refugee diaspora would make host societies more complex by increasing their ethnic diversity and prompting expansion of bureaucracy for managing refugee populations. Similar points apply to definitions that focus on decentralization. There is an obvious sense in which the Island undergoes decentralization when its government is dissolved and its population scattered. But viewed more broadly, the diaspora scenario involves a political consolidation in which the Island's population is absorbed into larger, already existing states. From this perspective, the diaspora scenario is an example of centralization, akin to the Roman Empire acquiring new territory through conquest. Finally, the crucial difference between the two sub-possibilities—other states permitting or not permitting entry of the Island's population—does not seem to be significant for prior collapse concepts. Either case would be a transformation and have ambiguous effects on complexity and centralization.

In the ex-situ statehood scenario, the Island maintains its statehood even after the relocation of its population (Burkett, 2011). In this situation, the risk of both societal collapse and the collapse of the Island's governing system can be averted, according to our view, provided that collective capacities are sustained. Burkett (2011) proposes a "trustee" framework under the auspices of the UN, in which elected representatives of the Island negotiate with members of other states to secure legal resettlement of its population, continued recognition of the Island's government, and its ability to act on behalf of its citizens even after they no longer reside on the Island. The ex-situ state's capacity to act in its citizen's interests would depend on an economic foundation, among other factors. For instance, continued international recognition of economic rights linked to the exclusive economic zone of the Island could be leveraged to generate revenue through the sale of licenses to commercial fishing fleets. The key factor for robust ex-situ statehood, then, is the preservation of collective capacities for effective self-governance. If this is achieved, then the Island would avoid both societal collapse and collapse of its government. That contrasts with a scenario in which the ex-situ state is officially recognized but has no significant capacity to advance its citizens' interests. We refer to this situation as ex-situ statehood in name only. Merely maintaining a symbolic presence, such as a website, social media representation, a flag, and a seat at the UN, would not be enough for robust ex-situ statehood. Ex-situ statehood in name only would be a de facto collapse of the Island's government according to our proposal even if it was not a societal collapse.

Compare how competing collapse concepts apply in the ex-situ statehood scenario. Whether robust or not, this scenario involves a major transformation of the Island, illustrating again the need to distinguish collapse from non-collapse transformations in climate change contexts. Concepts focused on decentralization are again ambiguous. The Island's central government is maintained in a robust ex-situ scenario, but ex-situ statehood in name only would be a political consolidation of the Island's population into a larger state. Finally, collapse concepts focused on complexity seem unable to clearly distinguish between robust and in-name-only ex-situ statehood. Whether robust or merely symbolic, the newly created category of ex-situ states would likely create new bureaucracy in multilateral fora and in host states. This again illustrates the importance for collapse of distinguishing functional from superfluous sociopolitical complexity.

The arguments in this section reinforce the advantages of a collapse concept in which collective capacity is the central criterion. Losing the collective capacity for autonomous self-government, along with the effects that may have on the ability of people to meet their needs, is what is at stake when it comes to collapse risks of SIDS. Unlike collapse concepts focused on transformation, sociopolitical simplification, or political decentralization, our proposal captures this fundamental point. Our approach also suggests conditions in which societal collapse and collapse of self-governance could be avoided for SIDS whose populations are forced to relocate.

## *Property Insurance and Climate Change in Florida*

Our collapse concept can be applied to interacting subsystems within a society and suggests that risks of collapse to one system often prompt adaptive responses in others.

Avoiding societal collapse in such circumstances requires finding sustainable adaptive pathways in the face of threats to key systems. The example of property insurance in Florida provides a good example of our dynamic conception of collapse risks and illustrates how powerful incentives may steer adaptation in unsustainable directions.

Extreme weather has threatened the solvency of property insurers in Florida at least as far back as 1992, when South Florida was struck by Hurricane Andrew (Carrillo et al., 2022). Since then, the population of Florida has increased by nearly 60% (from approximately 13.5 to almost 22 million residents), and about 98% of that population growth has occurred in coastal counties (Carrillo et al., 2022: 241). Climate change-induced extreme weather poses significant challenges for insurers in this context (Born and Viscusi, 2006). For example, the 2004–2005 hurricane seasons resulted in significant losses for insurance companies in the US, leading to bankruptcy for some and withdrawal from high-risk coastal states for others (Benali and Feki, 2017). The withdrawal of private companies from the property insurance market has been especially acute in the state of Florida (Craig, 2019). Following the hurricane season of 2004, some insurance companies in Florida went bankrupt (Born and Viscusi, 2006), while other major insurers decided to no longer provide property insurance in Florida, and departures or bankruptcies of private insurers in Florida have been frequent since then (Leefeldt, 2023).

The precarity of the property insurance market in Florida is a risk for the broader economy and government revenues in the state. Property insurance is typically required to obtain a bank loan for a residential property in the US. Thus, inaccessibility of property insurance would be a significant threat to Florida's real estate market. Florida does not have an individual income tax, and 22% of its GDP came from real estate and about 30% of local government tax revenue came from property taxes in 2018 (Woetzel et al., 2020). Consequently, a significant real estate devaluation would threaten the fiscal solvency of many local governments in Florida and would likely have knock-on effects to the economy.

In the face of these risks, the state government has repeatedly stepped in to support the property insurance market (Silvis, 2018). In 2002, the State of Florida established the Citizens Property Insurance Corporation (CPIC), a non-profit company aimed at providing property insurance to residents who are unable to do so through the private market (Citizens Property Insurance Corporation, 2023). However, claims paid to policyholders following extreme weather events have at times threatened the financial stability of CPIC, and the program barely survived the 2017 hurricane season (Craig, 2019). In addition to CPIC, Florida has implemented measures to prop up private insurers. In December 2022, the state government of Florida approved a $1 billion bailout package for private insurance companies in the wake of Hurricane Ian, after having just approved a $2 billion reinsurance fund to support the industry in May of that same year (Brown, 2022).

Property insurance in Florida should be viewed within a wider household insurance arena that significantly involves the US Federal Government. Homeowner insurance policies in the US usually do not provide coverage for flood damage. Flood coverage is almost exclusively provided by the National Flood Insurance Program (NFIP), established by Congress in 1968 due to private companies' inability to provide coverage in high-risk areas (Silvis, 2018). Similar to CPIC, NFIP aims to keep its premiums at a reasonable price, focusing on increasing the uptake of flood insurance with the aim to ensure

that a majority of households is indemnified for flood losses. Property and flood insurance markets are linked because they often pay claims originating from the same events and consequently face similar challenges to their financial sustainability due to climate change.

The long-term sustainability of property and flood insurance markets in Florida is unclear. Both NPIF and CPIC are intended to cover claims with revenues generated from premiums paid by policyholders. However, despite attempts at reform, the NFIP has been running a deficit since Hurricane Katrina in 2005 and currently has a $20.5 billion cumulative debt with the US Treasury (Congressional Research Service, 2022). The underlying difficulty is that premiums paid by NPIF policyholders are insufficient to cover claims generated by increasingly extreme weather (Silvis, 2018; Congressional Research Service, 2022). This situation is likely to worsen in the coming decades. According to a recent study by Wing et al. (2022), flood risk in the United States is poised to increase by 26% by 2050 due to climate change. This situation has prompted a number of scholars to raise concerns that the federal government may eventually cease to use taxpayers' money to subsidize insurance for households located in flood-prone areas (American Academy of Actuaries, 2020: 31; Craig, 2019; Elliott, 2021; Knowles & Kunreuther, 2014; Silvis, 2018).

The predicament of Florida's property insurance market illustrates our dynamic conception of collapse. Collapse or the imminent risk of collapse to one system (e.g., a property insurance market) can threaten other systems (e.g., real estate markets, the economy, municipal governments, etc.). That in turn may prompt other systems (e.g., the state government) to pursue various adaptations (e.g., creating a public property insurance program, bailing out private insurers). The example also illustrates how economic and political incentives can drive decision-makers to pursue policies whose sustainability is widely questioned. Given the importance of the real estate market to the economy and government budgets in Florida, it is unsurprising that significant public monies would be dedicated to propping up the current system. Finally, the difficulties besetting Florida's property insurance market show how collapse risks are relevant to well-resourced places.

## Conclusions

Climate change presents special challenges for understanding societal collapse. In this context, avoiding collapse cannot be equated with maintaining the status quo, because climate change mitigation and adaptation entail major societal transformations. And changes that enhance societal sustainability and reduce collapse risks may involve sociopolitical simplification and decentralization—two commonly proposed definitional criteria for collapse. Consequently, prior collapse concepts struggle to distinguish collapse from non-collapse trajectories in connection with climate change.

We propose a novel collapse concept that addresses these challenges more effectively. A system collapses, according to our proposal, when it undergoes a pervasive and difficult-to-reverse loss of collective capacity, resulting in an inability to sustain basic functionality. Our concept is dynamic, in that it highlights the interplay of constituent systems within societies. From this perspective, societal collapse is an emergent property

ensuing from the collapse of multiple systems that, taken together, make it impossible to meet basic needs of the population. This proposal explains, for instance, why a renewable energy transition would not be a societal collapse, while a climatic catastrophe likely would be.

Climate risks facing SIDS and Florida's property insurance market bring out the advantages of our proposal in greater depth. While relocation would likely be traumatic for the population of a small island state, it need not involve societal collapse or collapse of the island's government. Unlike prior collapse concepts, our proposal provides a simple explanation of how this is so that connects with discussions of ex-situ statehood. In addition, by emphasizing that threats of collapse to important societal systems typically prompt adaptations in others, our dynamic concept is useful for studying collapse risks in well-resourced settings, like Florida.

Climate change-induced risks of societal collapse are too significant to ignore. But to study them, we need a collapse concept that is fit to purpose. That is what we have endeavored to provide here.

## Author contributions

Daniel Steel, Giulia Belotti, Ross Mittiga and Kian Mintz-Woo contributed to the conception, drafting, and editing of the manuscript. Daniel Steel, Giulia Belotti, Ross Mittiga and Kian Mintz-Woo read and approved the final manuscript. Kian Mintz-Woo compiled the manuscript as a corresponding final author.

## Availability of data and materials

No data were used in this article.

## Declaration of conflicting interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

## Ethical approval

This article does not contain any studies with human or animal participants performed by any of the authors.

## Funding

The authors disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This research was supported by the Social Sciences and Humanities Research Council of Canada Insight (Grant number 435-2022-0189).

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## Notes

1. A brief clarification of our usage of the terms "concept" and "definition" may be helpful. We take a concept to be a general understanding of how to apply a term, and a definition to be a concise verbal statement of a concept. In many cases, grasping a concept involves more than memorizing a definition. It may also require, for instance, knowledge of a theoretical background in which that definition is situated.
2. An anonymous reviewer suggests that the loss of complexity in 7th century Byzantium could not be collapse because it was the result of a deliberate policy. However, Tainter's definition does not specify that collapse must be unintentional, and Tainter sometimes speaks of collapse as a rational, deliberate response to diminishing returns on complexity (1988: 196).
3. Translated from the French, "besoins de base (eau, alimentation, logement, habillement, énergie, mobilité, sécurité) ne sont plus fournis à une majorité de la population."

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