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DISCUSSANT'S COMMENTS

Dealing With Global Warming: Carbon Neutrality and Beyond

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1 | Introduction

This Comment is a response to the contribution titled 'Analysis of policy measures and feedback effects on industry transformation towards carbon neutrality' by Ahlfs and Kieckhäfer (2024).

Global warming with the resultant climate change has been called by many the number one challenge facing mankind. The UN refers to it as 'the defining issue of our time' (United Nations 2024a). Accordingly, the number of publications on the topic of carbon neutrality is huge. The economic and political spheres are widely concerned with the achievements towards reaching the Paris climate targets and 'carbon neutrality'. In this vein, the authors of the paper, which we are discussing, plead for understanding feedback effects on industry transformation towards carbon neutrality and designing policy measures to shape it (Ahlfs and Kieckhäfer 2024).

For that purpose, a System Dynamics model is crafted with care and circumspection. All components and their interrelationships are explained clearly and following a coherent logic, from modules to variables and 'molecules' of stock-and-flow constructs. The model is fairly comprehensive, combining the following:

- quantitative variables representing aspects of energy and matter (e.g., CO_2 Emissions, Production Volume and Book Value Investment),
- qualitative variables standing for socio-psychological features (e.g., Willingness to Finance, Experience from Previous Environmental Investments, Willingness to Invest in Environmental Measures) and
- a set of parameters embodying constants (e.g., CO_2 Target, Delay Times and Investment Volume per Unit Electricity).

To summarise, the model is a consistent representation of the transformation of an industry sector that strives for minimising the dominant greenhouse gas: carbon dioxide. Technically, the model is a qualitative model, not yet ready for a quantitative simulation.

The following discussion of the paper by Ahlfs and Kieckhäfer (2024) aims to open a perspective leading from the stance of minimising carbon emissions, to a broader view: a holistic concept of society's or humanity's dealing with global warming.

2 | Strategies for Dealing With Global Warming

In discussing the options for dealing with global warming, we address three dimensions: two refer to the scope of strategy and one more to scale.

2.1 | The Two Dimensions of Scope

The dominant strategy of economic and political agents today, for coping with that challenge, is to combat carbon emissions. That is the dimension of Mitigation (EEA 2024; IPCC 2024). It relies strongly on technological measures, for example, the

substitution of fossil fuels by renewable energies, improve farming and protect forests.

A second strategy is often underrated: humans defending themselves against the consequences of climate change (UNDP 2024; Trittipo et al. 2023; Smit and Pilifosova 2024). From evolutionary history, we know about the fundamental capability of humans to cope with catastrophes and changes in general: developing new skills by means of learning, intuition, fantasy, intelligence and the will to survive. This is the dimension of Adaptation: Humanity takes measures to live with the effects of global warming and ultimately to survive.

Mitigation is aimed at prevention, assuming that the temperature of the atmosphere can be held constant, or its growth dampened, by a reduction of human-made carbon emissions. Adaptation is the other side of prevention. It aims at reducing vulnerability to the impacts of climate change and designing a system to avoid accidents and damage caused by climate-induced events. And it relies on the discovery of new paths, for example, the improvement and implementation of new legal frameworks, building better dams against floods and rising oceans, ecosystem restoration, practicing regenerative agriculture, planting crop varieties resistant to droughts, fostering biodiversity and redesigning protection services against natural catastrophes.

The two strategies manifest themselves in different expressions and intensities:

$$\begin{aligned}&\text{Scope: } (M,A), M=(m_1,\ \dots,m_p), A=(a_1,\ \dots,a_r),\\ &m_i, a_j\text{: Intensity of the expressions of the sub}-\text{dimensions.}\end{aligned} \tag{1}$$

The notation of m_i and a_j indicates that the intensities of the expressions can, if necessary, be quantified (e.g., on a scale of 1–10).

Figure 1 visualises the interplay of climate change and the strategies of Mitigation and Adaptation.

The loop in Figure 1 visualises the logic of climate change. Causes, mainly greenhouse gases, increase global warming. Global warming increases effects on nature and society. For example, forests are destroyed by wildfires, insect outbreaks, invasive species, and extreme weather events. These effects reinforce the causes, for example, deforestation increases CO_2 emissions because natural CO_2 absorption is reduced by the decline in trees.

The crossbars stand for time delays. The upper part of the diagram visualises these dynamics. In the lower part, the causes and effects are listed in more detail: greenhouse gases on the one hand and ecological, social and economic disasters on the other.

Strategies are labelled on both sides of the diagram: Mitigation *M* to reduce causes and Adaptation *A* to find ways of protecting the population and nature from effects. The diagram visualises the complementary nature of the two types of strategy.

To facilitate the understanding of the global warming archetype, the example of deforestation given above is inserted into the general structure of the climate change-global warming problem, in Figure 2.

2.2 | The Dimension of Scale

The third dimension is scale, as a measure of structure. It has a set of subdimensions, which range from the smallest unit to the largest unit of reference, individual, organisation, municipality, region and so on, to world. The reference units of a given level are embedded in units of the next higher level, and they are composed of units of the lower level:

$$\text{Scale: } R_1 \subset R_2 \subset \ \cdots\ \subset R_n, \tag{2}$$

with R_i denoting the reference systems on levels *i (i = 1, ..., n)*. Normally, the reference system consists of >1 units.

$$R_i : R_{i,1},\ \dots\ , R_{i,k}.$$

It is often argued—by prominent institutions, politicians and scientists—that global warming is a problem to be coped with on the global level (e.g., Hansen et al. 2023). Other voices demand

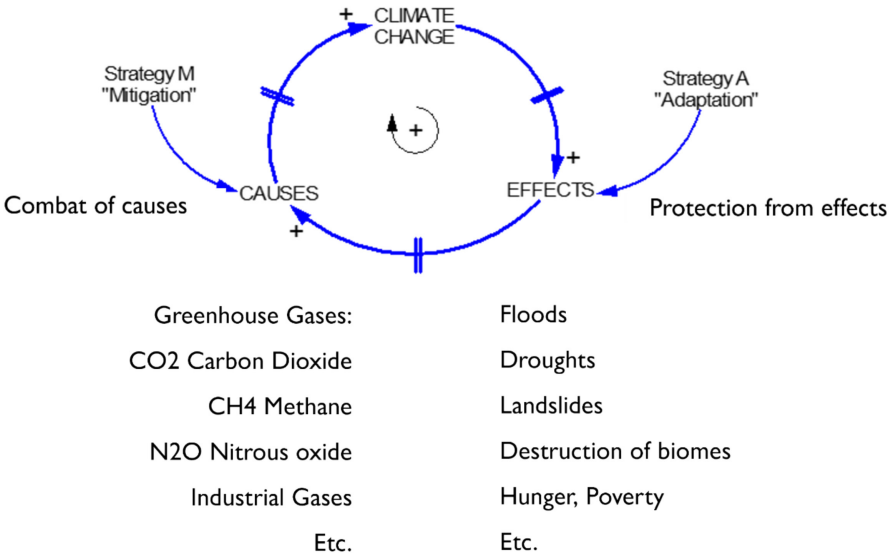

FIGURE 1 | Global warming archetype–causes, effects and strategies for coping. [Colour figure can be viewed at wileyonlinelibrary.com]

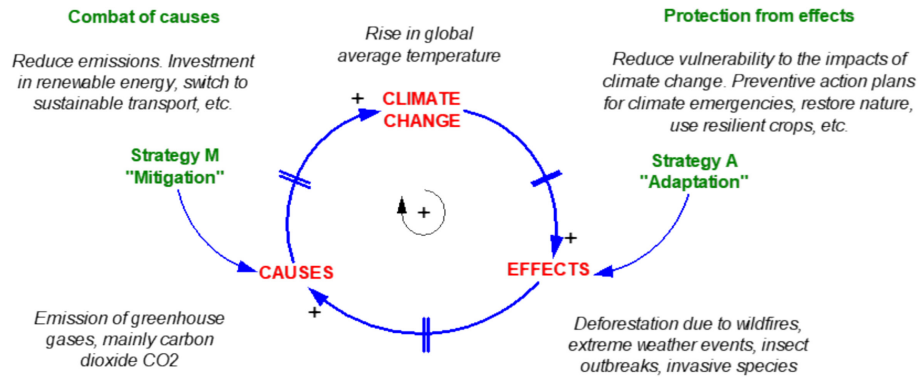

FIGURE 2 | Global warming archetype with the example of deforestation. [Colour figure can be viewed at wileyonlinelibrary.com]

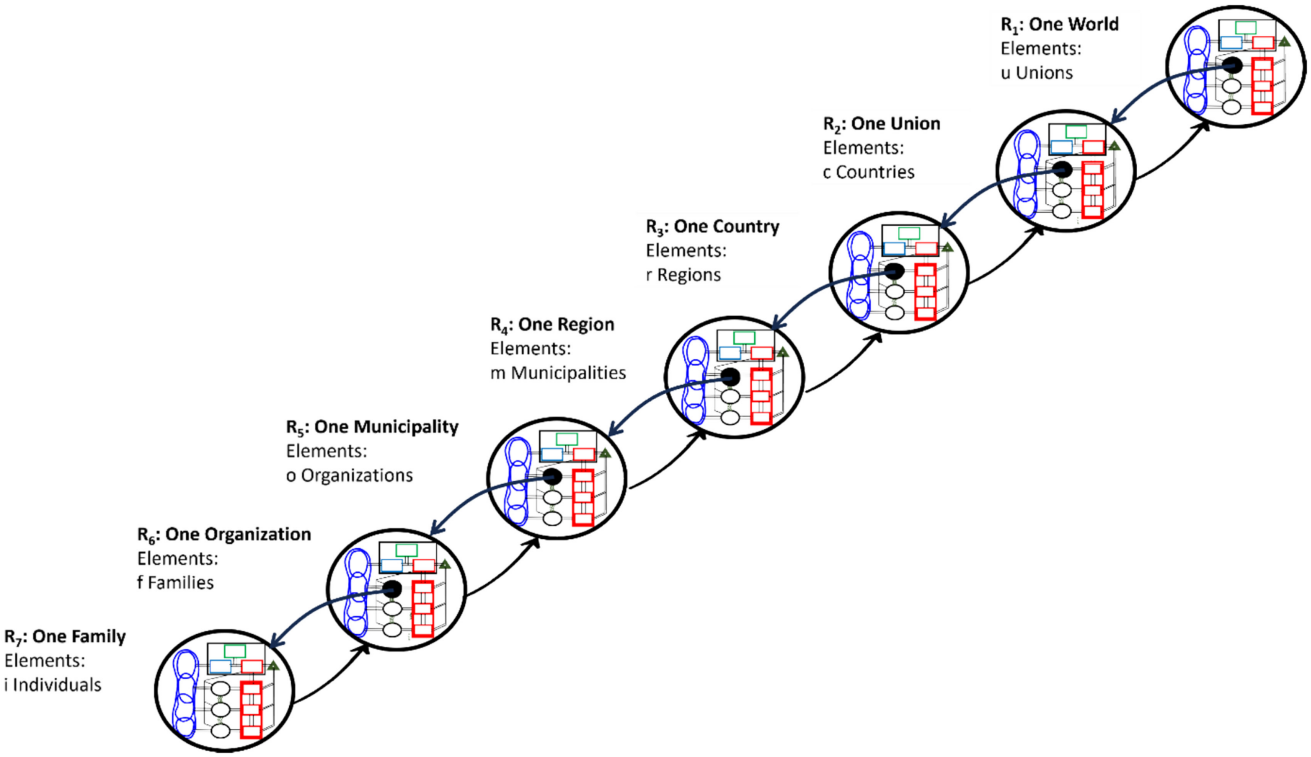

FIGURE 3 | Recursive structure for enabling sustainability at multiple levels (adapted from Schwaninger 2018). [Colour figure can be viewed at wileyonlinelibrary.com]

exactly the contrary: Weathering climate change is considered to be an issue at the individual level (Levermann 2019). We contend that global warming cannot be coped with on the level of small agents alone, say individuals or families. On the other hand, it cannot be solved on a global level either, even though that is often believed. In fact, activities and measures at any one given level alone cannot solve the problem. An effective strategy to weather global warming can in principle be achieved only if all recursive levels from individual to global, for example, local, regional and national, are mobilised to contribute their respective efforts.[1]

The attribute of recursiveness denotes the property of the different levels of observation of being isomorphic in one sense: They face and have to deal with the same problem, global warming.

The climate issues emerge at each one of these levels and can also be different from level to level. If we take the 17 Sustainable Development Goals established by the United Nations (2024b), they all are of great importance at the global level but do not have the same relative importance at each of the recursive levels. For example, with respect to goals such as 'no poverty' or 'no hunger' and the associated problems, policies and actions may not be as urgent at the level of a particular family. But that very family might have contributions to these goals on its agenda and be successful in achieving them.

This rationale has been elaborated in an earlier publication: As shown in Figure 3, the quest for sustainability must encompass all the aforementioned levels (Schwaninger 2018). Their organisation must ensure the sustainability of the units at each one of these levels. The pertinent theory of organisational viability

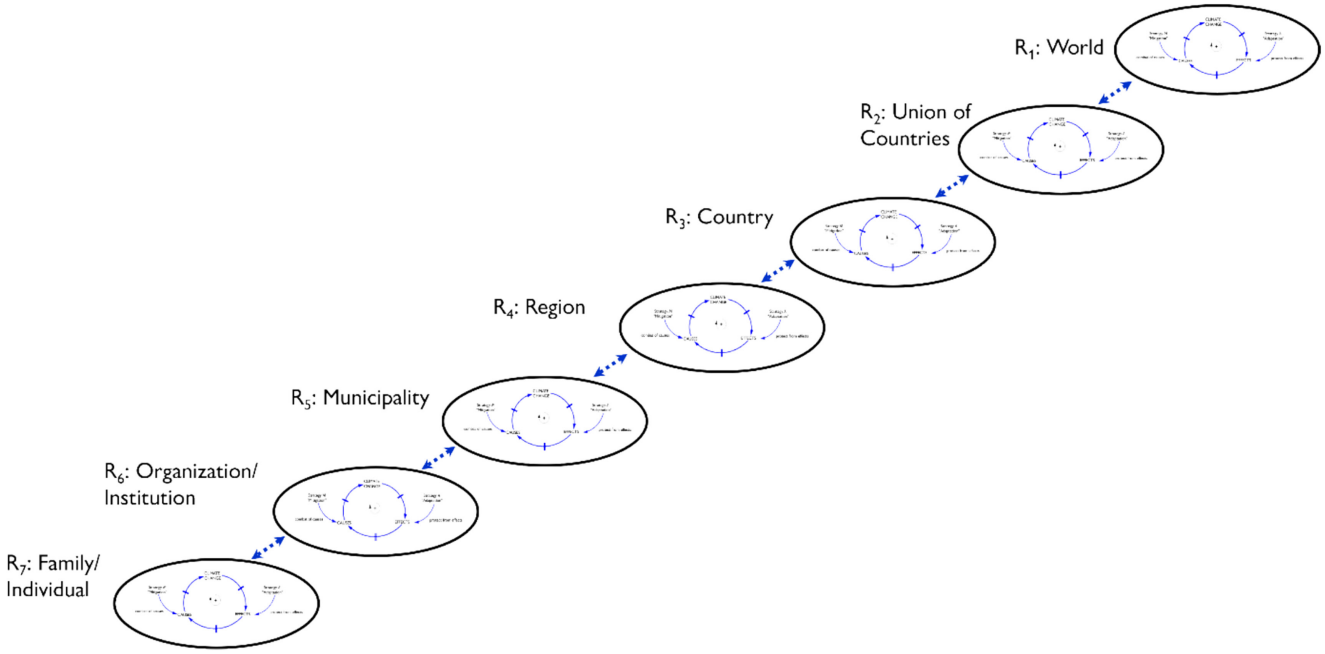

FIGURE 4 | Recursive framework for strategies dealing with global warming. [Colour figure can be viewed at wileyonlinelibrary.com]

comes from Stafford Beer (1979, 1985), the father of management cybernetics. That theory proposes the Viable System Model, a model that defines the necessary and sufficient conditions for a system to be viable and sustainable (Espinosa 2023). If coping with climate change is a contribution to viability and sustainability, then the recursive logic is as well applicable to dealing with global warming.

The structure of this model is recursive. In other words, one and the same organisational principle can be found in the units of all levels: a structure to enable the viability of the system-in-focus. To emphasise this basic aspect, an icon of a viable system has been drawn into each one of the recursive levels.

3 | Conclusion

Our discussion of Ahlfs and Kieckhäfer (2024) is more of a complement than a critique. That paper is dedicated to the question of how the emissions of greenhouse gases can be minimised to halt climate change. We have placed that endeavour in context: An approach to coping with global warming has been outlined, from a perspective that aspires to both the avoidance of hazard and the strengthening of system resilience. The two strategies of Mitigation *M* and Adaptation *A* open a spectrum of responses that is wider than the recipes for 'fighting' and 'defeating' climate change, as they are often given. They are the components of an ambidexterity that embraces both combat and protection: combat as mitigation and protection as adaptation. Mitigation strategy is usually in the spotlight. Adaptation has received less attention and should be reinforced.

Finally, recursive organisation enables a system to cope with huge complexities. As shown, the issues emanating from global warming manifest themselves at each recursive level, from individual to world. At each level of recursion, the nature of the issues can be distinct. They must be dealt with by the agents of that level. This way, the unmanageable complexity of the overall situation is broken down. It is mastered on the distributed fronts where the decentral complexities arise (Figure 4). At the same time, local autonomy and competence are promoted.

Recursive organisation, in combination with the strategies outlined, is key to understanding the management of complexity, here in a crucial domain of ecological management.

The dimensions of our framework are distinct, not in the sense of a difference of degree but a difference of kind. Herein lies their aptitude for complementarity and their potential for synergy. The framework presented here opens new perspectives for humanity's coping with global warming/climate change.

Endnotes

[1] Utilitarian ethicists have stipulated that in certain cases, the efforts and responsibility for achieving sustainability goals should be shifted from the individual level to the institutional level (Rieder 2024).

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