Transdisciplinary science is harder, more expensive, and more prone to failure. We still need to try.

Session 5: “The Role of the National Science Foundation”

June 22, 2023

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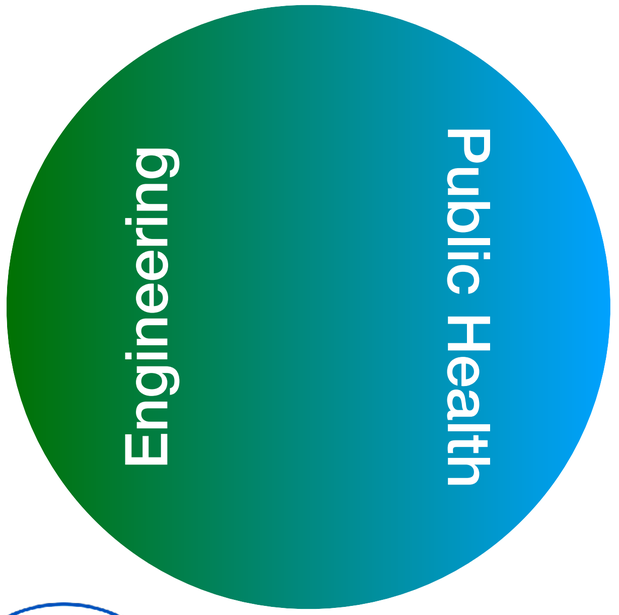
My 10-yr transdisciplinary journey



The UNIVERSITY of VERMONT

BS Civil Engineering
(Math + Applied Physics)

Colorado State University

Environmental Health

NIH National Institutes of Health

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

NIH K25 Career Award
(Physiology, Molec Bio, Lung Tox)

MS Industrial Hygiene
(Aerosols+ Exposure Sci)

PhD Environ Engineering
(Phys Chem + Fluids)

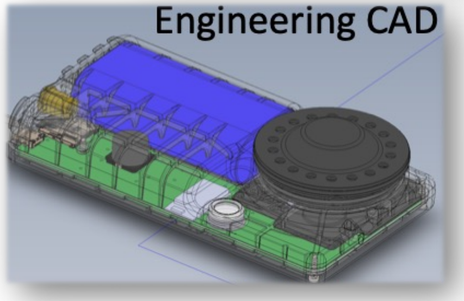
GILLINGS SCHOOL OF GLOBAL PUBLIC HEALTH
FROM THE WELL TO THE WORLD

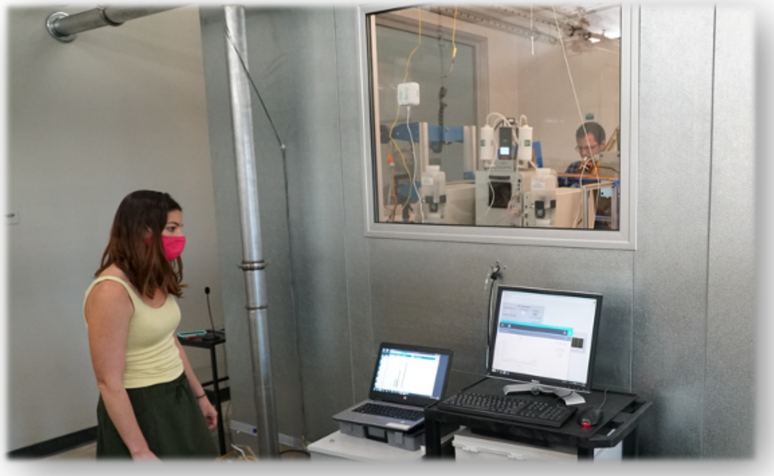
Colorado State University

Prof. of Mechanical Engineering
(Imposter Syndrome)

Mission: Engineering for Public Health

Vision: A world where everyone has access to clean air for each and every breath





My Transdisciplinary Journey: 17 years in the making

Disciplines

- History and Philosophy of Science & Technology (Science and Technology Studies)
- Environmental and Energy Humanities
- Cultural Studies

UNIVERSITY OF CAMBRIDGE

CRASSH

Visiting Scholar, University of Cambridge
Center for Research in the Arts, Social Sciences, & Humanities
"Climate Histories" Research Group

UNIVERSITY OF ALBERTA

Two Postdoctoral Fellowships in "Energy Humanities"
- Canada Research Chair in Cultural Studies Postdoc
- Banting Postdoc

universität wien

University of Vienna, Center for Interdisciplinary Research &
Institute of the Vienna Circle, History and Philosophy of Science

Duke

Graduate Certificate in History and Philosophy of Science

THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL

Ph.D. English, Literary Studies

Graduate Certificate in Cultural Studies

Pomona College

B.A. English Major, Philosophy Minor

Associate Professor, English

COLORADO STATE UNIVERSITY

COLLEGE OF LIBERAL ARTS

ENERGY INSTITUTE

CENTER FOR ENVIRONMENTAL JUSTICE

A team can learn to become interdisciplinary; it will take hundreds of hours of effort.

How does a team become “Transdisciplinary”?
It’s an individual journey that takes years.

Earth's Future

COMMENTARY

10.1029/2021EF002115

Envisioning ARPA-C: A Transdisciplinary Institution for Radical Climate Research and Intervention

Lynn Badia[1], Josette M. Plaut[2], Joseph C. von Fischer[3], John Volckens[4], and Jeff Muhs[5]

[1]Department of English, Colorado State University, Fort Collins, CO, USA, [2]Institute for the Built Environment, Colorado State University, Fort Collins, CO, USA, [3]Department of Biology, Colorado State University, Fort Collins, CO, USA, [4]Department of Mechanical Engineering, Colorado State University, Fort Collins, CO, USA, [5]CSU Energy Institute, Colorado State University, Fort Collins, CO, USA

Key Points:

- Advanced Research Projects Agency–Climate (ARPA-C) must be a new transdisciplinary platform designed to contend with the wicked problems of climate change
- No US institution has an operational model, requisite funding, and primary mandate to convene global action in response to climate change

Citation:

Badia, L., Plaut, J. M., von Fischer, J. C., Volckens, J., & Muhs, J. (2021). Envisioning ARPA-C: A transdisciplinary institution for radical climate research and intervention. *Earth's Future*, *9*, e2021EF002115. https://doi.org/10.1029/2021EF002115

Received 26 MAR 2021
Accepted 13 MAY 2021

Abstract President Joe Biden's administration is poised to make a significant investment in climate research, including the creation of ARPA-C (Advanced Research Projects Agency–Climate). This commentary serves to promote discourse on ARPA-C and the future of government-led climate research. Here, we propose a revolutionary leap to the ARPA model that incorporates a focus on culture and equity in a unique institutional structure anchored by transdisciplinarity. With ARPA-C, we argue for a radical rethinking of climate interventions that reconciles and evolves the relationship between social, technical,

English / History of Science

Sociology / Built Environment

Biology / Environmental Science

Engineering / Public Health

Business / Policy

We started a weekly conversation in 2019

… and we published our findings in 2021

It took 2 years of effort to become a functioning interdisciplinary team

Our work aligns with the 2022 NASEM ESS Report

Table 1
Comparing Past ARPA Organizations and the Proposed ARPA-C

Parameter	Classic ARPA Model	Vision for ARPA-C
Scope of Activities	STEM-dominated R&D leading to sector-specific technology demonstration	Transdisciplinary research leading to holistic climate interventions
Evaluative Metrics	Focus on development of technology and pathways for adoption	Convergence of social, cultural, technological, and environmental metrics
Program Leadership	Single autonomous and term-limited STEM expert with support network	Autonomous and term-limited leadership teams combining diverse disciplines
Ownership & Funding	Existing U.S. federal funding agency with modest industry cost-share	A public-private partnership, funded by a blend of domestic and international sources
Geopolitical Motive	Domestic self-interests in distinct, sector-specific industries	Global imperative across all industries and social systems impacting climate

Badia et al. *Earth's Future* (2021)

ARPA-C: Advanced Research Projects Agency - Climate

AGU ADVANCING EARTH AND SPACE SCIENCE

Earth's Future

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1. Introduction

Climate change is an evolving and distributed problem that threatens the welfare of life on Earth. Humans have caused climate change through actions within a complex social-ecological web. Yet, despite the fundamental role of social forces in climate change, there is a pervasive tendency to seek technological solutions that will "solve" the climate change problem. We argue that a transformative response to climate change must, instead, be as radical as the problem itself: The creation of a new transdisciplinary institution with an ARPA-like spirit to research and implement impactful and equitable climate interventions.

Currently no U.S. institution has an operational model, requisite funding, primary mandate, and authority to convene global action in response to the threat of climate change. Extending the successful model of the ARPA programs (see Table 1), we have called for the formation of an ARPA-C (Advanced Research Projects Agency–Climate), a concept later adapted by the Joe Biden presidential campaign (In an April 2019 collaboration, we worked with former Colorado Governor Bill Ritter to propose the creation of ARPA-C to President Joe Biden's presidential campaign. In June 2019, the Biden Campaign unveiled a climate platform including the creation of ARPA-C, however, the stated focus was limited to decarbonizing domestic energy systems through well-established technology-based pathways. In January 2021, the office of the White House National Climate Advisor, Gina McCarthy, requested our white paper on ARPA-C before officially announcing the creation of ARPA-C on February 11, 2021 (The White House Briefing Room, 2021). In April 2021, President Biden released a proposed budget that included a combined allocation of $1 billion to fund ARPA-C and ARPA-E (Mervis, 2021)). In our vision, ARPA-C must be a new platform specifically designed to contend with the wicked problems of climate change and to harness the methods of complexity science in the Anthropocene. Namely, it requires that transdisciplinary teams work together—from program inception through project implementation—to incorporate methods appropriate to evolving, dynamic systems that are simultaneously environmental, social, and technical in nature.

ARPA institutions—past and current—have developed revolutionary innovations by focusing on science and technology. Here, we envision an ARPA-C that is revolutionary in its integration of social and cultural disciplines with STEM approaches. A growing body of evidence indicates that such transdisciplinary collaboration is essential (rather than additive) to transformative scientific research: Scientific studies of natural systems must recognize their imbrication with human systems, including our deeply rooted history of exploitation and inequity (Chevallier et al., 2020; Inkpen & DesRoches, 2019; Keys et al., 2019). Models

THE WHITE HOUSE

BRIEFING ROOM

Biden-Harris Administration Launches American Innovation Effort to Create Jobs and Tackle the Climate Crisis

FEBRUARY 11, 2021 • STATEMENTS AND RELEASES

White House Forms Climate Innovation Working Group, Outlines Innovation Agenda

U.S. Department of Energy Announces $100 Million Climate Innovation Research Opportunity

Today, the Biden-Harris Administration is initiating an ambitious innovation effort to create American jobs while tackling the climate crisis, which includes the launch of a new research working group, an outline of the Administration's innovation agenda, and a new $100 million funding opportunity from the U.S. Department of Energy to support transformational low-carbon energy technologies. The announcements kickstart the Administration's undertaking to spur the creation of new jobs, technology, and tools that empower the United States to innovate and lead the world in addressing the climate crisis.

President Biden is fulfilling his promise to accelerate R&D investments, creating a new Climate Innovation Working Group as part of the National Climate Task Force to advance his commitment to launching an Advanced Research Projects Agency-Climate (ARPA-C). The working group will help coordinate and strengthen federal government-wide efforts to foster affordable, game-changing technologies that can help America achieve the President's goal of net zero economy-wide emissions by 2050 and can protect the American people from the impacts of droughts and flooding, bigger wildfires, and stronger hurricanes. The working group will be co-chaired by the White House Office of Domestic Climate Policy, Office of Science of Technology and Policy, and Office of Management and Budget.

"We are tapping into the imagination, talent, and grit of America's innovators, scientists, and workers to spearhead a national effort that empowers the United States to lead the world in

tackling the climate crisis," **said Gina McCarthy, President Biden's National Climate Advisor**. "At the same time, we are positioning America to create good-paying, union jobs in a

Earth's Future

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Key Points:

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- No US institution has an operational

Lynn Badia[1], Josette M. Plaut[2], Joseph C. von Fischer[3], John Volckens[4], and Jeff Muhs[5]

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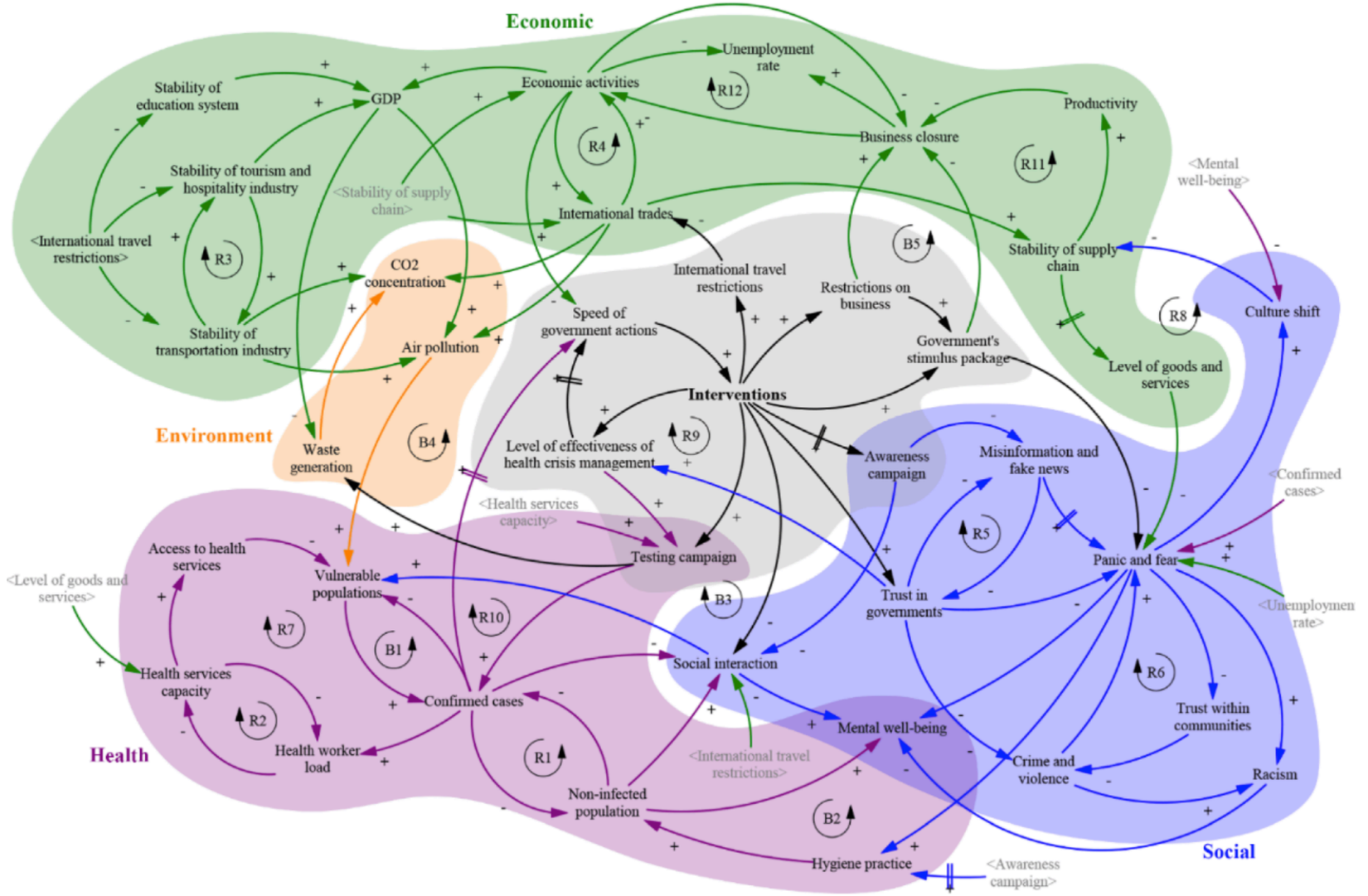
Why Transdisciplinary Research:

1	**The science is different.** The Earth system is inexorably coupled to human-made systems (e.g., fossil-fuel infrastructure and industrial agriculture).
2	**Transdisciplinarity enables assessment of complex externalities.** Externalities manifest outside disciplinary boundaries.
3	**Mandate equity and justice.** Inequity is a self-sustaining phenomenon. Climate interventions will require new forms of deliberation and democratic process.
4	**Prioritize human wellbeing.** Focusing solely on technology is a red flag for implementation.
5	**Leverage human-centered pathways.** Current patterns in greenhouse gas emissions are entrenched in society. Climate interventions need to focus on culture and human behavior at scale to create the capacity to work within social systems.

Complex Natural-Social Systems

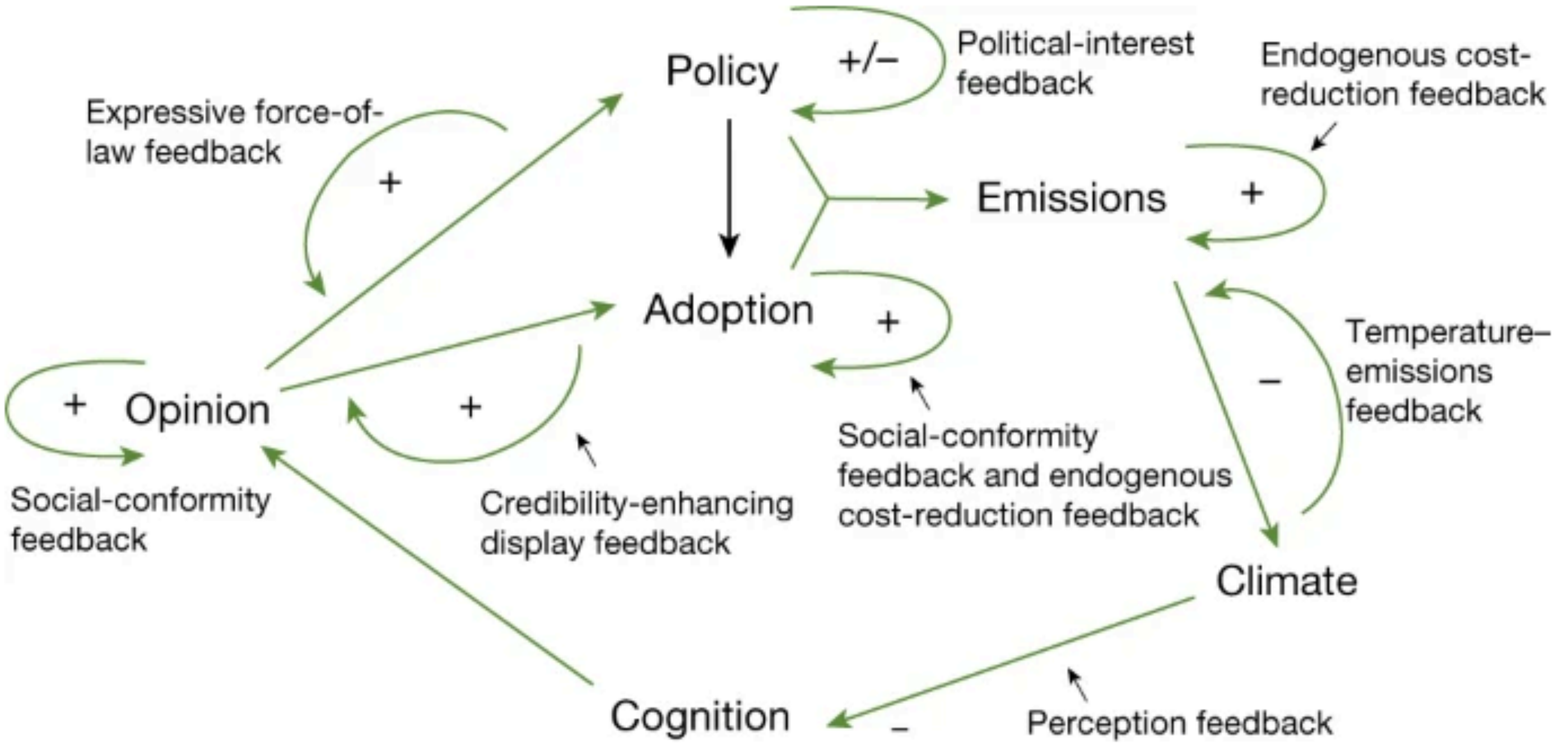
Sahin, Salim, H., Suprun, E., Richards, R., MacAskill, S., Heilgeist, S., Rutherford, S., Stewart, R. A., & Beal, C. D. (2020). **Developing a Preliminary Causal Loop Diagram for Understanding the Wicked Complexity of the COVID-19 Pandemic**. *Systems (Basel)*, 8(2), 20.



Complex Natural-Social Systems

Moore, Lacasse, K., Mach, K. J., Shin, Y. A., Gross, L. J., & Beckage, B. (2022). **Determinants of emissions pathways in the coupled climate-social system**. *Nature (London)*, 603(7899), 103–111.

Fig. 1: The climate–social model components and feedback processes.



Complex Natural-Social Systems

Beckage, Gross, L. J., Lacasse, K., Carr, E., Metcalf, S. S., Winter, J. M., Howe, P. D., Fefferman, N., Franck, T., Zia, A., Kinzig, A., & Hoffman, F. M. (2018). **Linking models of human behaviour and climate alters projected climate change**. *Nature Climate Change*, 8(1), 79–84.

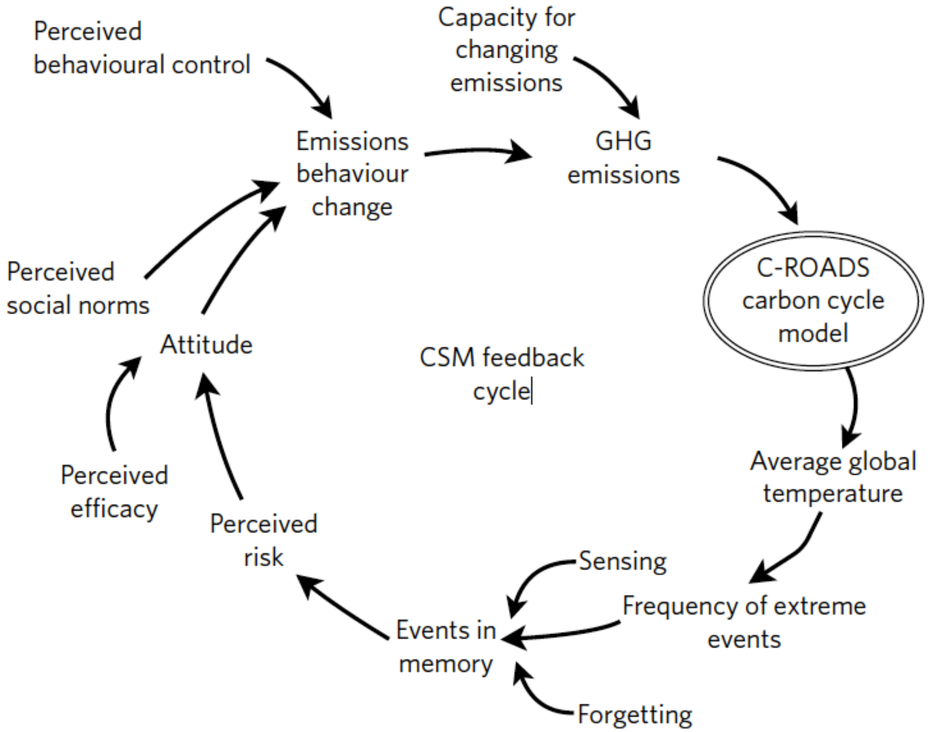


Fig. 1 | Conceptual model. Linkages between temperature, extreme events, perceived risk, social components and GHG emissions in the CSM. Average global temperature is calculated from the GHG concentration using the carbon cycle model of C-ROADS[7].

Complex Natural-Social Systems

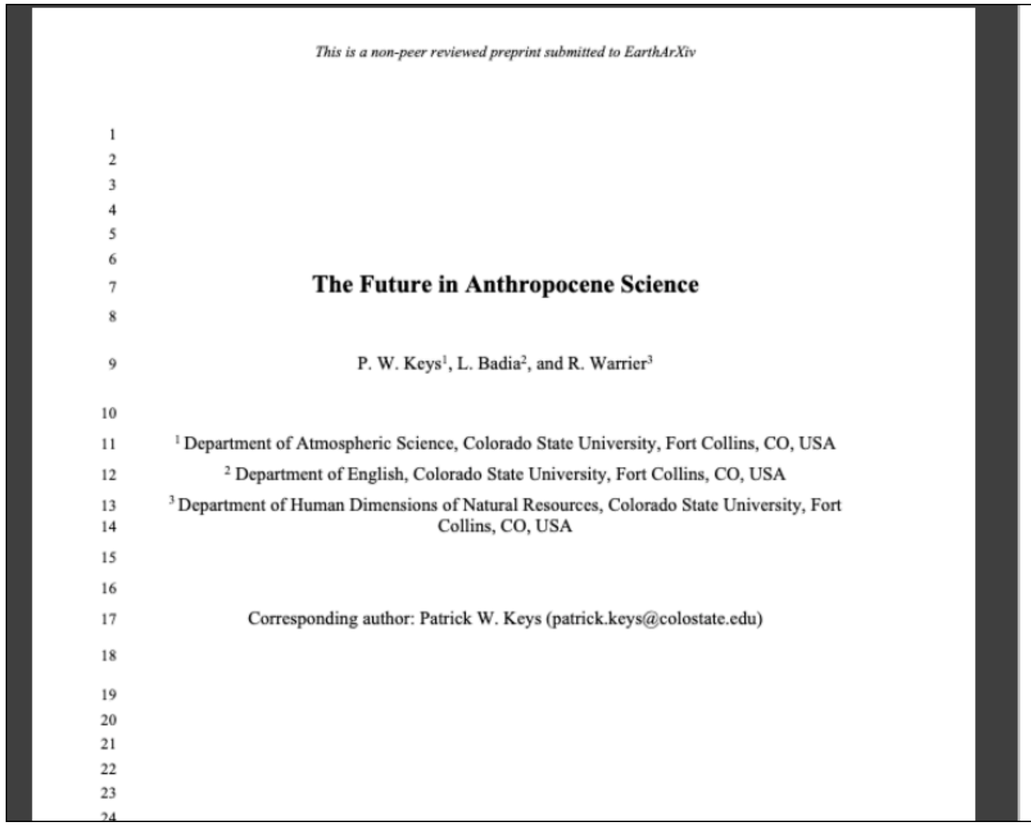
Lynn Badia, "**Climate Scenarios: Worlding an Uncertain Future**."

Patrick Keys, Lynn Badia, Rekha Warrier. "**The Future in Anthropocene Science**."
Preprint available at EarthArXiv: https://doi.org/10.31223/X5Z385

Dr. Pat Keys
Atmospheric Science

Dr. Rekha Warrier
Human Dimensions
of Natural Resources

Dr. Lynn Badia
Science and Technology Studies



This is a non-peer reviewed preprint submitted to EarthArXiv

The Future in Anthropocene Science

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[2] Department of English, Colorado State University, Fort Collins, CO, USA
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Authors

Patrick W Keys, Rekha Warrier, Lynn Badia

Abstract

The Anthropocene is the present time of human-caused accelerating global change, and new forms of Anthropocene risk are emerging that society has hitherto never experienced. Science and policy are grappling with the temporal and spatial magnitude of these changes, as well as the diminishing margin between science and policy itself. However, there is a gap in the transparency — and perhaps even in the awareness — of the profound role that Anthropocene science plays in shaping the structure and possibility of our future world. In this work, we explore three broad categories of Anthropocene science, including international energy scenarios, clim... more

DOI

https://doi.org/10.31223/X5Z385

Subjects

Climate, Environmental Studies, Nature and Society Relations, Sustainability

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Research Requirements Tied to *Progressive Funding (demonstration, down-selection, increasing $):*

1	Diverse Team Structure (e.g., Social, Physical, Humanities)	A "nascent" interdisciplinary team will take hundreds of hours of effort (of paid, protected time) to become functional. Many academic institutions are in conflict with this reality.
3	Rigorous (peer) review in addition to stakeholder input all along the research timeline.	Climate interventions are ethically knotted with costs and benefits. Teams must strive to understand stakeholder biases and blind spots.
2	Concrete plan for epistemic and disciplinary growth	Interdisciplinarity does not happen naturally or quickly; it must be actively cultivated and guided. Proposals must articulate specific trajectories of each individual's transdisciplinary growth, akin to a "career development plan".
4	Holistic metrics for success that incorporate social and ethical considerations	Utilization of holistic metrics for project success, such as the merger of: • technology readiness levels (TRL) • community readiness levels (CRL) • society readiness levels (SRL) • impact readiness levels (IRL)

What evidence suggests that transdisciplinary research works?

(NSF should fund the NASEM to formulate a model for transdisciplinary research on climate)

1: Determine a structure for epistemic/disciplinary growth within convergence research. These skills are likely unique to a given climate intervention.

2: Find and document evidence of success in transdisciplinary research. Use this information to create an effective/efficient model for new NSF convergence centers.

3: The peer review process for transdisciplinary research is flawed. How can we develop an interdisciplinary peer-review process that challenges the science ALL along the way (not just at funding and publication)?