Developing Metrics to Assess Justice & Equity Implications of Early-Stage Research

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APS March Meeting

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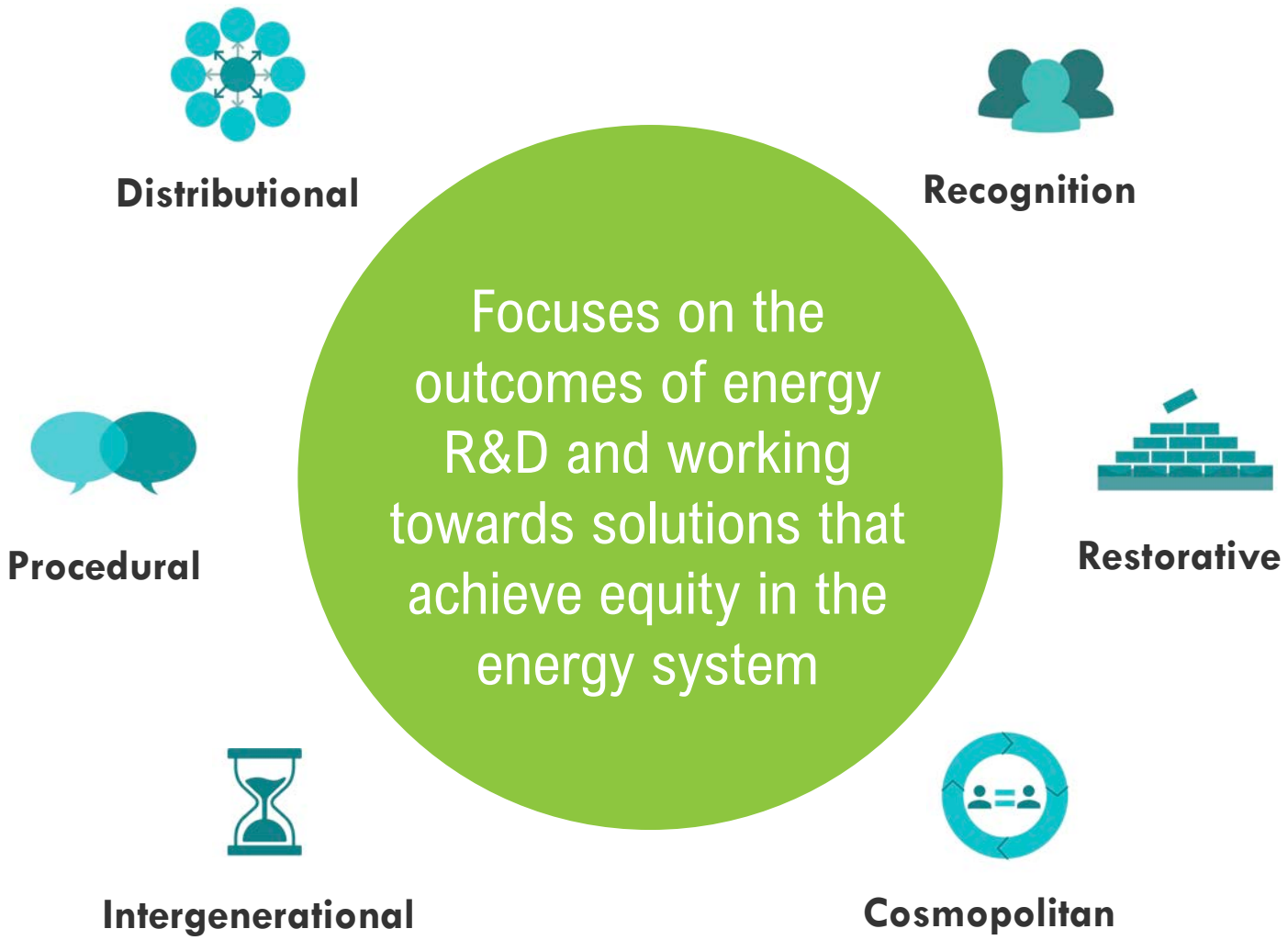
Outline

1. Intro to Energy Justice
2. Relevance to Early-Stage Research
3. JUST-R Metrics Framework
4. Case Study Evaluation
5. Future Developments

Energy justice places a focus on community impacts



Energy Justice aims to achieve equity in social & economic participation in the energy system, while remediating social, economic, & health burdens on those historically harmed by the energy system ("frontline communities").

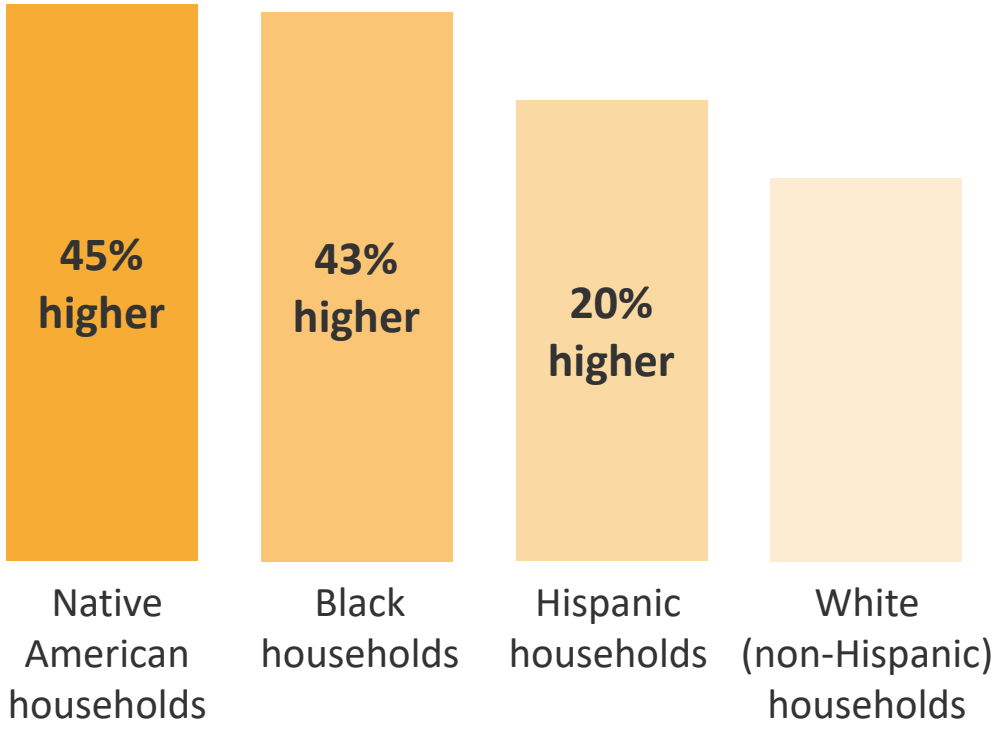
Equity recognizes individual's or group's circumstances & allocates resources/opportunities needed to reach a just outcome.

2020, "Equity vs. Equality: What's the Difference? | Online Public Health," GW-UMT; Cooper, 2019, "Section 1 - Defining Energy Justice: Connections to Environmental Justice, Climate Justice, and the Just Transition," Initiative for Energy Justice. (https://iejusa.org/section-1-defining-energy-justice/)

Example: Communities experience different benefits & burdens from the current energy system

Household energy burdens:

Median household energy burdens vary by demographics:



ACEEE 2022: https://www.aceee.org/energy-burden

Exposure to pollution from fossil fuel peaker plants:

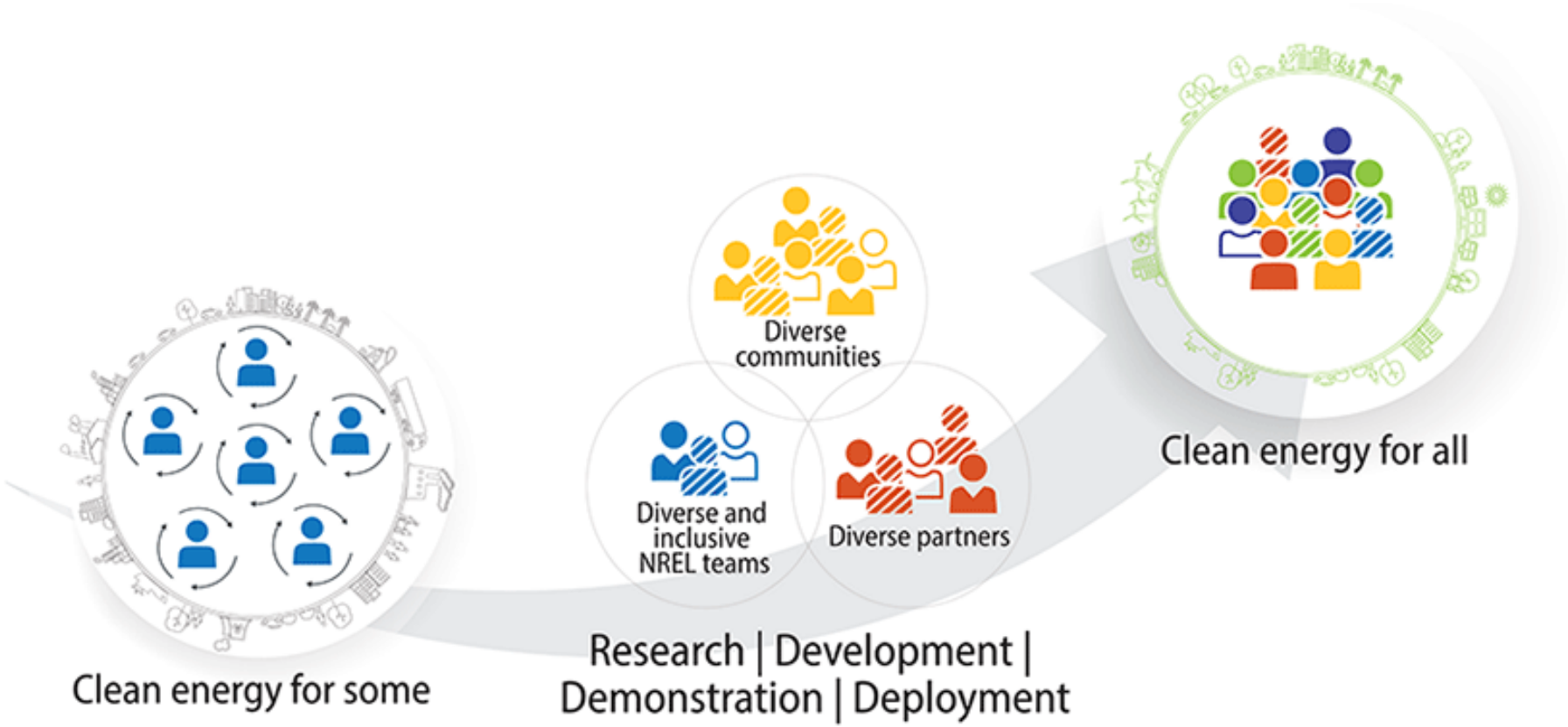
Highly polluting peaker plants neighbor areas with higher populations of people of color:

Number of Peakers	Average nitrogen oxide (NOx) emission rate	People of color percentage of population (within 3-mile radius)
346	14.6 lb/MWh	0 - 13%
304	16.4 lb/MWh	13 - 31%
348	14.2 lb/MWh	31 - 65%
150	**23.8 lb/MWh**	**65 - 100%**

Clean Energy Group, "Mapping the Inequities of Fossil Fuel Peaker Power Plants": https://www.cleanegroup.org/mapping-the-inequities-of-fossil-peaker-power-plants/

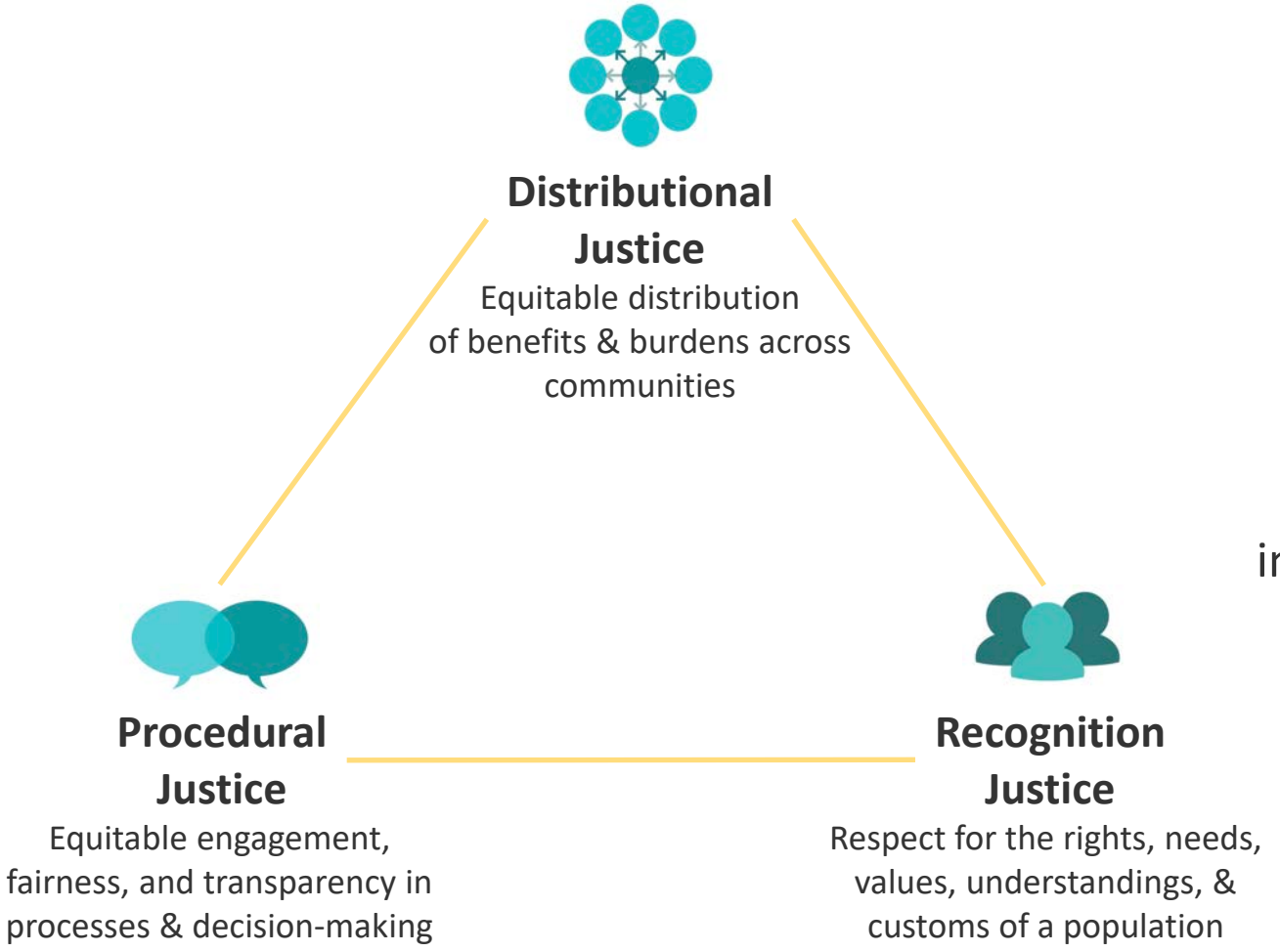
A just transition seeks to address these inequities in a transition to clean energy

Energy justice overlaps climate & environmental justice, which are all relevant to a just transition, but energy justice places a specific focus on development & deployment of energy technologies/systems.



Graphic by Anthony Castellano.

Key principles of energy justice



These ask us to consider:

How did we get here?

Who is **included** and who is not? Who experiences burdens or benefits?

What is the **context** of our work, and what impacts do we expect it to have in the **future**?

What **trade-offs** are we making?

McCauley, D. A., Heffron, R. J., Stephan, H., and Jenkins, K., 2013, "Advancing Energy Justice: The Triumvirate of Tenets," International Energy Law Review, **32**(3), pp. 107–110.; Jenkins, K., McCauley, D., Heffron, R., Stephan, H., and Rehner, R., 2016, "Energy Justice: A Conceptual Review," Energy Research & Social Science, **11**, pp. 174–182.

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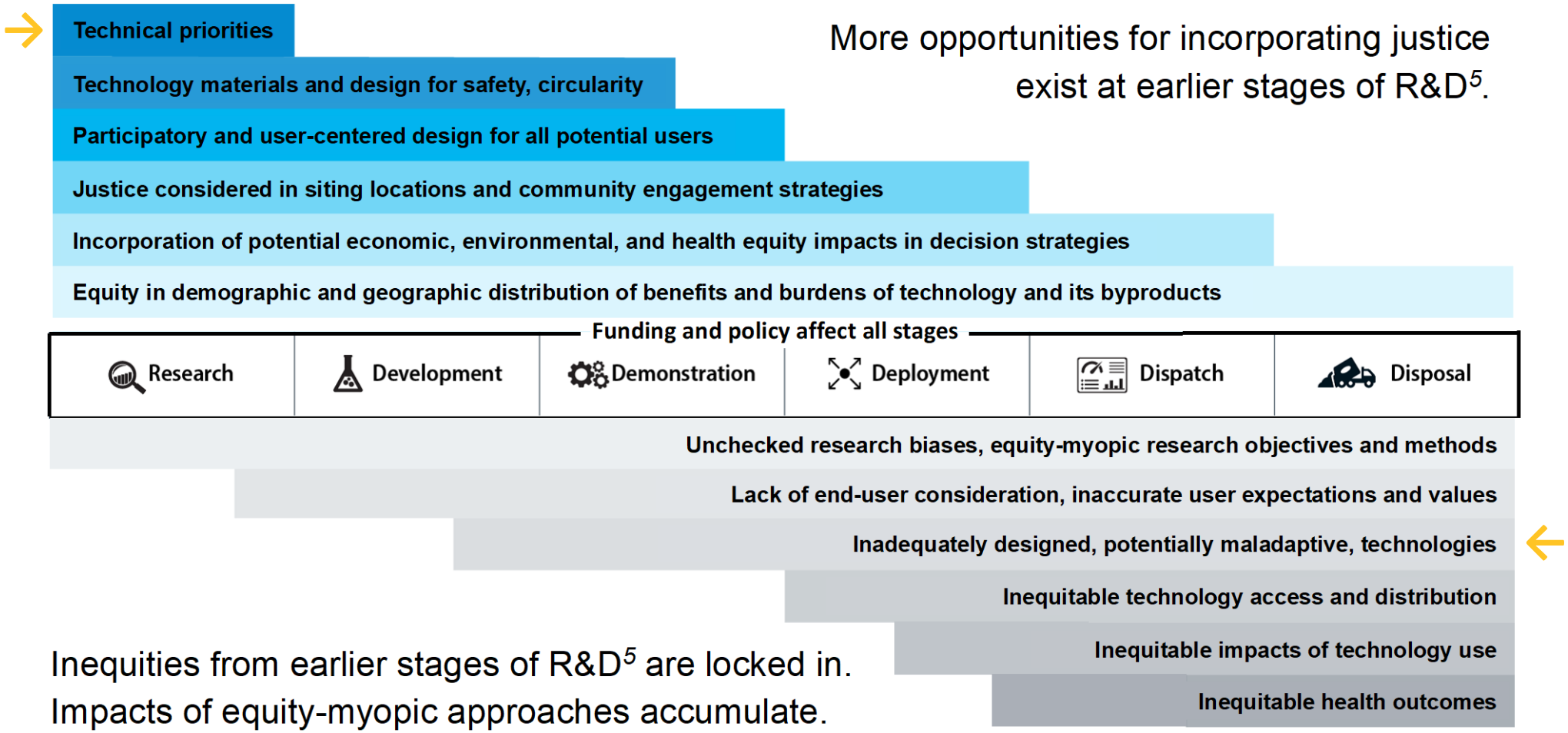
Why consider energy justice in early-stage work?

Negative impacts can be "locked in" by early-stage R&D decisions. More opportunities exist to address these impacts the earlier they are considered:



Arkhurst, B.K., et al., Incorporating energy justice throughout clean-energy R&D5 in the United States: A review of outcomes and opportunities, Cell Reports Sustainability (2024).

Example: Critical material dependence can be locked in by early-stage research

Cobalt in lithium-ion batteries poses both energy justice (e.g., resource depletion, unethical mining) & economic (e.g., expensive, unstable supply chain) challenges.

ARTICLE

https://doi.org/10.1038/s41467-022-29022-z OPEN

Check for updates

Battery technology and recycling alone will not save the electric mobility transition from future cobalt shortages

Anqi Zeng[1,2,3,8], Wu Chen[2,8], Kasper Dalgas Rasmussen[2], Xuehong Zhu[1,3✉], Maren Lundhaug[4], Daniel B. Müller[4], Juan Tan[5], Jakob K. Keiding[5], Litao Liu[6], Tao Dai[7✉], Anjian Wang[7] & Gang Liu[2✉]

Nature Communications (2022).

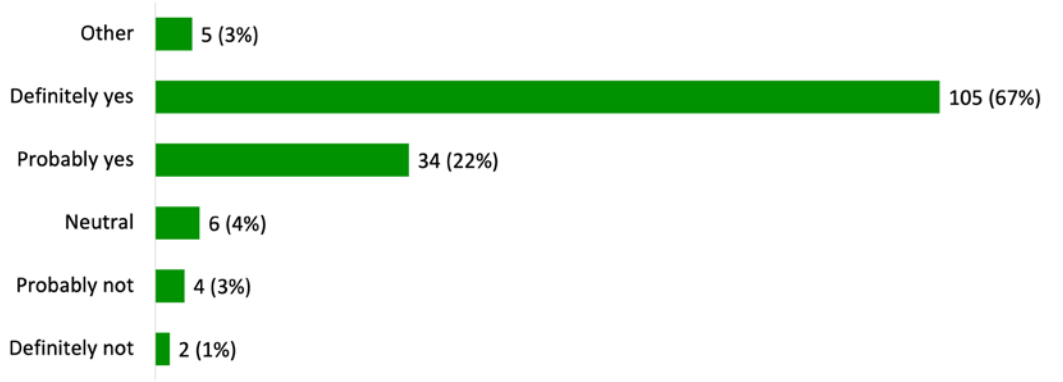
"Low-cobalt battery cathode technology development could alleviate, but not prevent, the supply crisis. The demand-supply gap would still occur around 2028-2033, even though cobalt-free LFP technology already penetrated the market in 2020 and it is predicted that the next-generation cobalt-free battery technologies will become commercialized by 2030."

Challenge: Lack of resources for considering energy justice in early-stage R&D

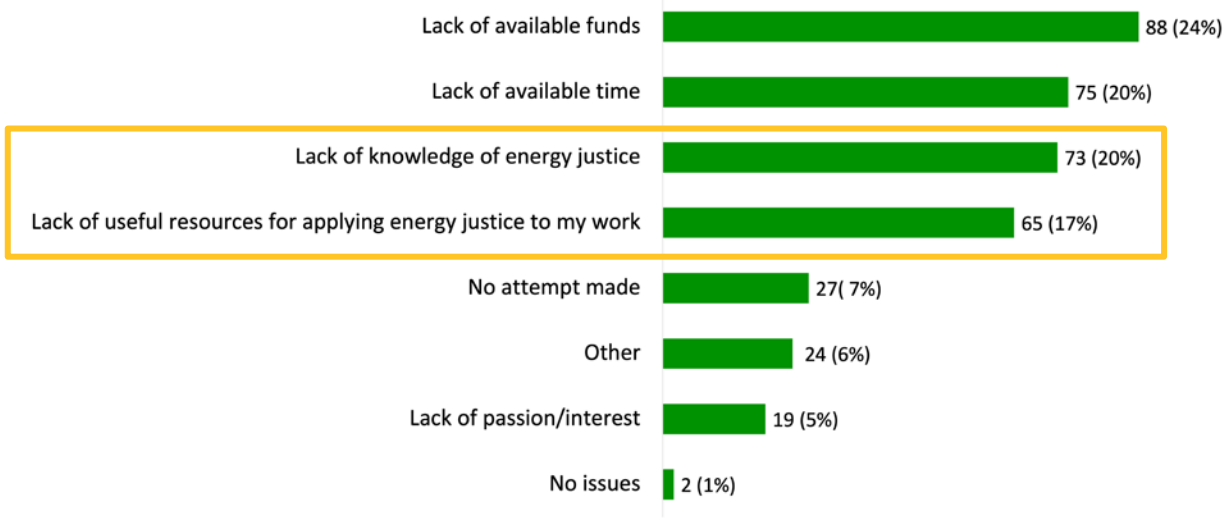
Literature reviews, surveys, and interviews showed a substantial gap in knowledge on how to incorporate energy justice into early-stage research.

→ **Goal:** Develop metrics to **integrate energy justice in all phases of technology development**, from early research through deployment.

Do you believe aspects of energy justice should be incorporated into the energy technology design process?



Which of the following have been issues you have faced when attempting to apply energy justice to your work?



Arkhurst, B.,K., A. Schauer, K. Fu, & K. Anderson. 2023. "An Investigation of the Energy Justice Landscape in Renewable Energy Technology Research and Design" (*In Preparation*).

JUST-R Metrics for Early-Stage Energy Research

Justice Underpinning Science & Technology Research

Dutta, Nikita S., Elizabeth Gill, Bettina K. Arkhurst, Mary Hallisey, Katherine Fu, and Kate Anderson. 2023. "JUST-R Metrics for Considering Energy Justice in Early-Stage Energy Research." *Joule* **7** (3), 431-437.

JUST-R Objective

JUST-R: Justice Underpinning Science and Technology Research

Goal: Develop energy justice metrics that...

- Highlight opportunities to **incorporate justice throughout the process** of early-stage research.
- Prepare an emerging technology to **meet later-stage energy justice metrics**
- Applicable at the level of an **individual researcher or project** on a relatively **immediate timescale**

New metrics seek to…

Consider the whole research life cycle

Distribution of hazard exposure during research life cycle + Hidden process costs

Broaden the knowledge guiding our research

Breadth of pre-existing knowledge review + Distribution of research results

Expanding our solution parameter space

Identification of set vs. flexible parameters

Example 1: Consider the whole research life cycle

Distribution of hazard exposure during research life cycle:

- ↓ Hazard level of extracting or synthesizing material inputs
- ↓ Hazard level of lab processes
- ↓ Hazard level of managing waste
- ↓ Extent to which hazards would increase at industrial scale

Hidden process costs:

- ↓ Estimated cost of managing waste generated by research
- ↓ Estimated cost of energy consumed during research
- ↑ Projected cost savings from operating new tech vs. competing tech

Asks of the researcher: Consider the whole research life cycle, beyond what occurs in lab.

EJ impacts: Evaluating parts of life cycle individually gives insight into how costs, savings, & hazards may be distributed among communities on scale-up.

Example thought process: Cobalt-containing lithium-ion batteries

- Hazard level of laboratory processes
  → *Sufficiently **low** due to small scale & engineering controls at NREL.*

- Hazard level of extracting or synthesizing material inputs
  → ***High** health hazards associated with artisanal & small-scale cobalt mining – **hazards distributed among individuals & communities who are not necessarily technology end users**, an example of cosmopolitan justice.*

Example 2: Broadening use of knowledge

Breadth of pre-existing knowledge review:

- ↑ Number of social science papers reviewed
- ↑ Number of non-academic sources reviewed
- ↑ Diversity of authors of scientific papers reviewed

Distribution of research results:

- ↑ Proportion of results published open access
- ↑ Number of non-academic reports of results
- ↑ Number of non-academic oral presentations of results
- ↑ Diversity of audience reached
- ↑ Diversity of team members credited for & publicly presenting work

Asks of the researcher: Reflect on knowledge that goes into or out of a research project – who is represented or benefits?

EJ impacts: Promotes public engagement, cultural compatibility, & earlier identification of social impacts.

Example thought process: Heterogenous catalysis for fuel production

- Number of social science papers reviewed
  → *Learn about **social impacts of precious metal extraction** for catalysts.*

- Number of non-academic sources reviewed
- Diversity of authors of scientific papers reviewed
  → *Learn about **feedstocks appropriate for different communities or geographies** & social perception or impacts of their use.*

Example 3: Expanding parameter spaces

Identification of set vs. flexible parameters:

- ↑ Number of alternatives explored to waste-intensive processes
- ↑ Number of alternatives explored to energy-intensive processes
- ↑ Number of alternatives explored to hazardous or unethically sourced materials
- ↑ Number of environmental parameters tested
- ↑ Number of non-tech solutions explored to solve key problems

Asks of the researcher: Combat the inertia of following what is normally done in the field, ask questions, & think creatively.

EJ impacts: Early insight into whether technology is likely to be deployable at scale in diverse environments without significant negative impacts.

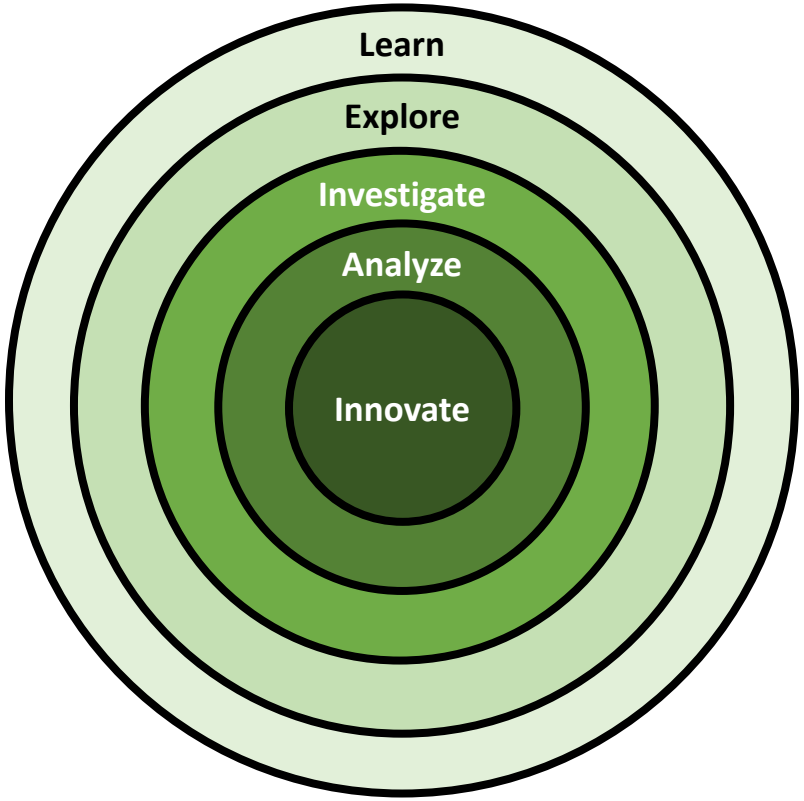
Example thought process: Wind resource modeling

- Number of alternatives explored to energy-intensive processes
  → *Incorporate **energy consumed by turbine/material transport** into analyses.*

- Number of environmental parameters tested
  → *Ensure models take into account **diverse boundary conditions/features relevant to different communities**, e.g. cultural differences in architecture, geographic differences in terrain.*

Applying JUST-R to a research project

1. **Learn:** Courses, workshops, readings on energy justice. For example, Initiative for Energy Justice introduces basic concepts.
2. **Explore:** JUST-R metrics paper provides a starting point for early-stage research discussion, with conceptual background & further resources in SI: https://doi.org/10.1016/j.joule.2023.01.007
3. **Investigate:** Fill out blank JUST-R Metrics Worksheet in SI, or upcoming offline JUST-R Tool for the project.
4. **Analyze:** What are 1-2 potential impacts one could aim to improve as a first step? What new research questions can be asked to address these?
5. **Innovate:** Apply the new research ideas and build a foundation for incorporating equity and justice principles into the technical area.



Case Study Evaluation

Arkhurst, Bettina K., Clara Houghteling, Nikita S. Dutta, Katherine Fu, Ardelia Clarke, Kate Anderson, and Elizabeth Gill. 2023. “Evaluating energy justice metrics in early-stage research using the JUST-R metrics framework.” *Frontiers in Environmental Science* 11:1206013.

JUST-R Framework Evaluation

Case studies with 12 research teams used to assess effectiveness of framework

Effectiveness

Appeal

Accessibility/Usability

- Do researchers **understand** the framework and associated concepts well enough to apply them?
- Can researchers put the framework into **practice**?
- How **applicable** are these methods to researchers' projects?

Impact

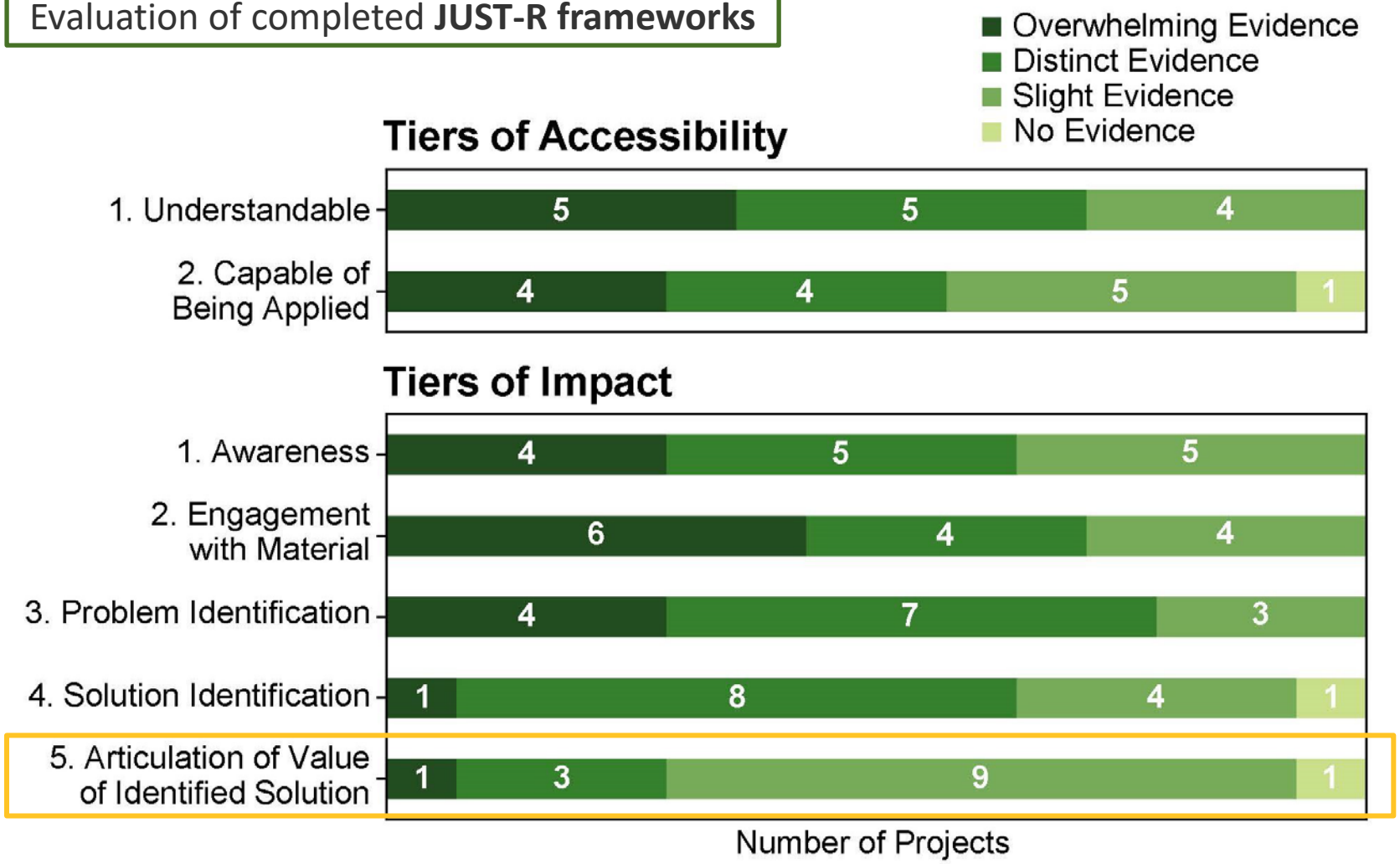
- Are the researchers using the methods as **intended**?
- Do we see **changes** in thought processes, actions, and/or decision making?
- Are researchers able to identify **problems** and potential **solutions**?

Appeal

- Do researchers see **value** in using the framework?
- Would they **continue** using the framework or recommend it to others?

Results: Evidence of accessibility, engagement, & problem/solution identification

Evaluation of completed **JUST-R frameworks**



Evidence of accessibility, engagement, & problem/solution identification observed across most cases.

Cases were less able to articulate the value of applying identified solutions to their research.

Arkhurst & Houghteling et al., *Front. Env. Sci.* (2023).

Evaluation results highlight change in researchers' perspectives & areas for improvement

Theme 1: New Perspectives
Broadened perspective & expanded scope

- JUST-R broadened researchers' perspectives on other work, but also lead to concerns about scope creep
- Rese
thinki

Theme 2: Institutional Support
Need for improved incentives, resources, & supportive institutional policies

- Researchers highlighted a need for more time, funding, & incentives, as well as assistance
ise

*"It kind of forced me to think **outside of my usual box**… I don't normally think that way every day; I feel happy with that."*

Theme 3: EJ Understanding
Need for more explicit connection to broader energy justice concepts

- Researchers expressed uncertainty over whose responsibility it is to address justice
- Researchers felt they didn't fully understand energy justice or have solutions for concerns

Theme 4: Method Design
Suggested improvements to JUST-R

- Researchers desired for a more specialized tool with a conclusive ending, such as a "score"
- Researchers valued examples, but these could also limit their perspectives & creativity

Structural barriers continue to pose a challenge

Challenges around scope creep or lack of incentives were commonly cited:

"The further we cast our net, the more discussions we would need, ***the more people we would need to involve****…"*

"I think even the most energy justice-oriented people… have a hard time with that [applying energy justice to their work] unless they know that that's ***part of the incentive structure that they're supposed to be reporting to****, because otherwise their priorities need to be somewhere else."*

Connects back to barriers cited in surveys, **emphasizing the importance of institution & scientific community support.**

Arkhurst & Houghteling et al., *Front. Env. Sci.* (2023); Arkhurst et al. *(In Preparation)*.

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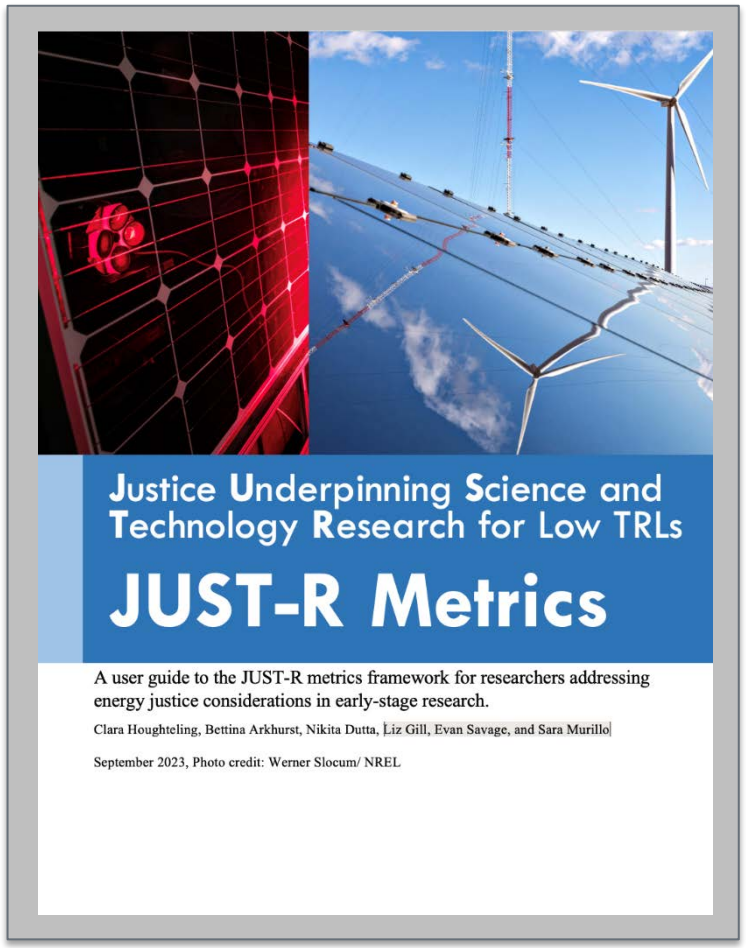
5. **Future Development**

Offline tool supports selecting relevant metrics & assessing throughout a project

Offline Tool



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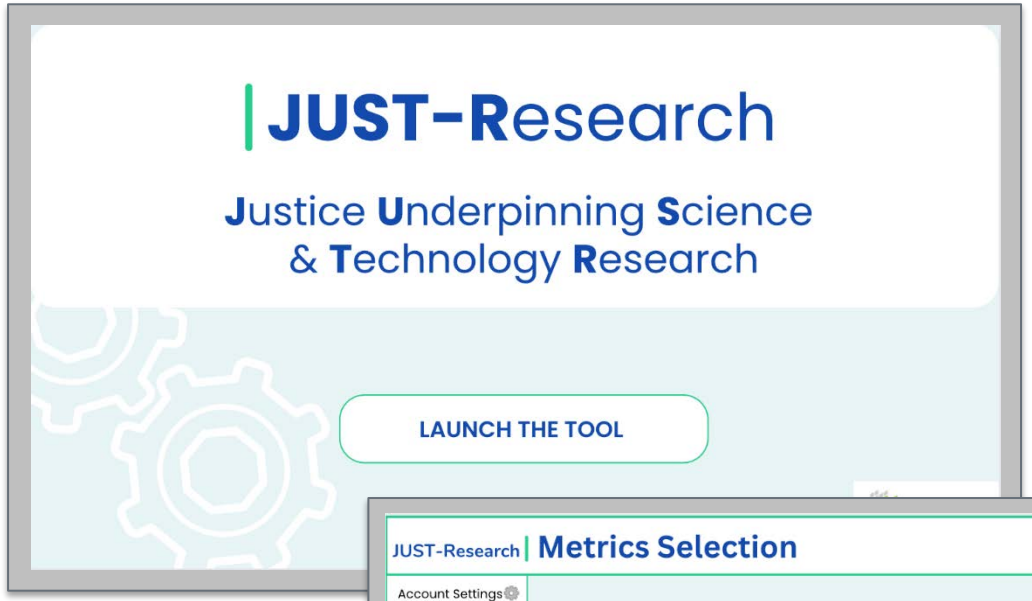
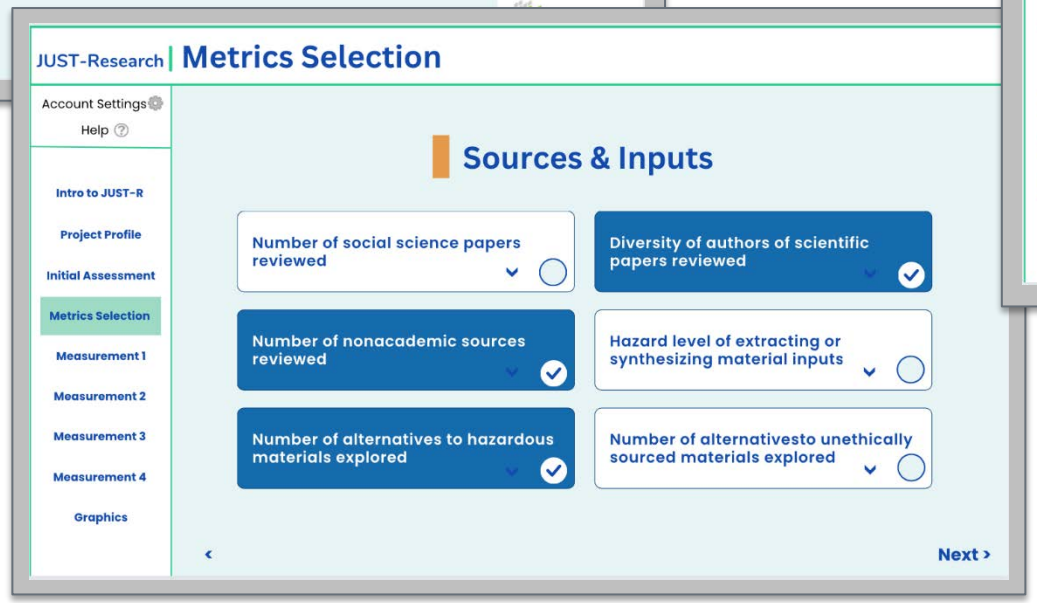
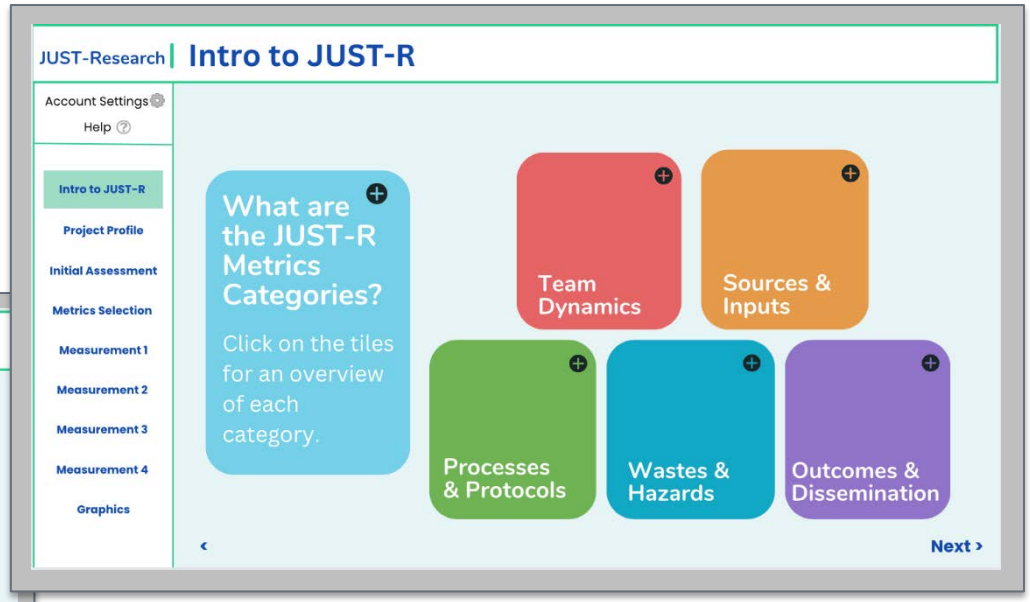
	Metric Selection	Metric	Units		Planning: Pre-assessment	Target	Action Plan	Potential Barriers	Notes	Measure 1
										Complete By:
5	Selected	Accountability level	Varies	↑						
6	Selected	Capability to communicate with stakeholders	Varies	↑						
7	Selected	Percentage of team members who believe it is important to consider/address issues related to social justice/inclusion in their work and/or methodologies	Percentage (%)	↑						
8	Selected	Number of social science papers reviewed	Number of Papers	↑						
9	Selected	Diversity of authors of scientific papers reviewed	Varies	↑						
10	Selected	Number of nonacademic sources reviewed	Number of Sources	↑						
11	Selected	Hazard level of extracting or synthesizing material inputs	Varies	↓						
12	Selected	Number of alternatives explored to hazardous materials	Number of Alternatives	↑						
13	Selected	Number of alternatives explored to unethically sourced materials	Number of Alternatives	↑						
14	Selected	Estimated energy consumed during project activities	Consumption/Time (e.g., kWh/year)	↓						
15	Selected	Number of alternatives explored to energy-intensive processes	Number of Alternatives	↑						
16	Selected	Number of environmental parameters tested	Number of Tested Parameters	↑						
17	Selected	Number of nontechnological solutions explored to solve key problems in project	Number of Nontechnological Solutions	↑						
18	Selected	Estimated financial cost of managing waste generated by project	Currency/Time (e.g., $/year)	↓						
19	Selected	Hazard level of project processes	Varies	↓						
20	Selected	Hazard level of managing waste	Varies	↓						
21	Selected	Extent to which hazards would increase at industrial scale	Varies	↓						
22	Selected	Number of alternatives explored to waste-intensive processes	Number of Alternatives	↑						

Online tool planned for development in 2025

Online Tool

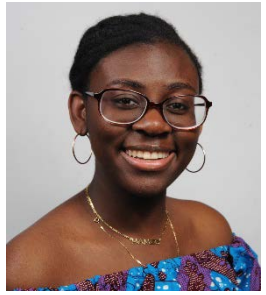






Conclusion & Acknowledgements

- The JUST-R Framework provides metrics to **assess energy justice considerations of early-stage research**.
- In case studies, the framework **broadened researcher perspectives**, but they were still **limited by structural barriers**.
- Stay tuned for **future offline & online tools**!



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Further Information:

JUST-R Tool Homepage

JUST-R Framework:
DOI: 10.1016/j.joule.2023.01.007

JUST-R Case Study Evaluations:
DOI: 10.3389/fenvs.2023.1206013

Thank you!

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