Energy Justice in low-TRL Research

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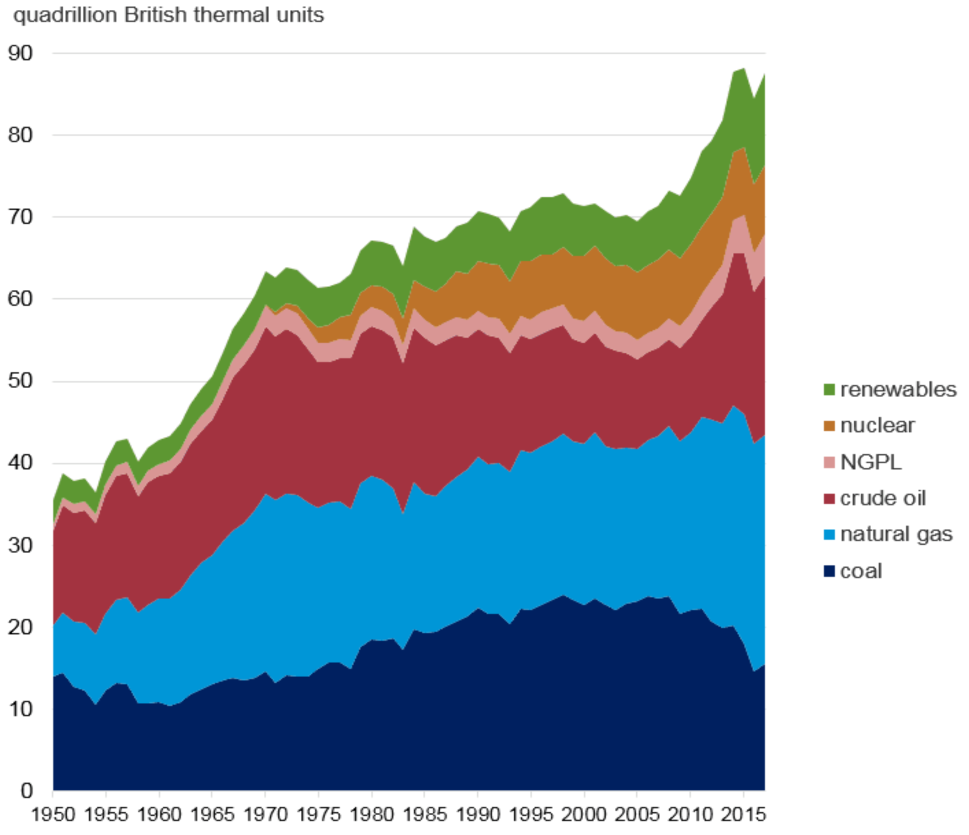
Clean energy is growing

U.S. primary energy production by major sources, 1950-2017



Note: NGPL is natural gas plant liquids.
Source: U.S. Energy Information Administration, *Monthly Energy Review*, Table 1.2, April 2018

conserving our natural resources and leveraging them to help drive our nation
toward a clean energy future, creating well-paying jobs with the opportunity
to join a union, and delivering justice for communities who have been
subjected to environmental harm.

…but not for everyone

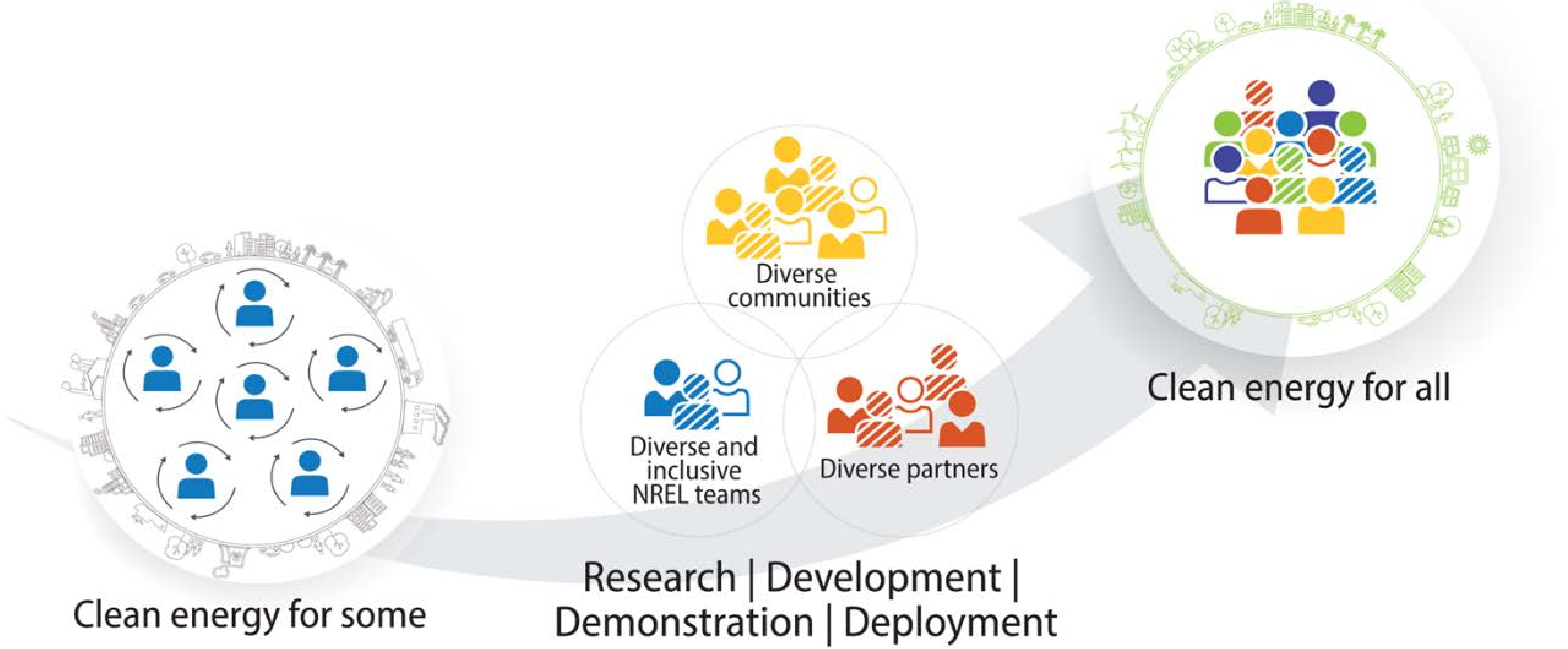
- **Black-majority census tracts installed 69% less rooftop PV** than no-majority tracts of same household income
- **Less than half of U.S. community solar projects include low-income households**
- Nearly 60% of all new solar capacity in 2018 was utility-scale PV, expanding access. However, **benefits such as lower costs are rarely transferred directly to customers**

- Since 2006, **90% of electric vehicle income credits were received by the top income** quintile.
- **Renters and those living in multi-family housing often lack access to home charging locations**, where 80% of electric vehicle charging occurs.
- **37% of rental housing units have a garage or carport** compared to 78% of owner-occupied housing.

- The **least affluent 20% of households spend a 3x greater share of income on transportation** than the most affluent 20%
- **70% of American households** live in neighborhoods where **combined housing and transportation costs are not affordable**
- **30%-45% of urban populations** exposed to **poor air quality near busy roads**
- **≈10% of people with multiple disabilities have no access to paratransit** because they live in paratransit deserts

The success of a traditional technology-centric approach is limited by socioeconomic factors.

NREL's vision is a clean energy future for the world



NREL's Energy Justice Vision

Drive equitable access to the benefits of sustainable energy to accelerate a clean energy future for the world while also remediating economic and environmental burdens of those historically harmed by the energy system.

Build capacity

Build NREL's capacity for integrating energy equity and energy justice principles in its internal planning and processes and its external activities and collaborations

Partner with Communities

Partner with frontline and historically underserved communities in pursuit of an equitable and just transition to clean energy

Center equity early and throughout RDD&D

Center energy equity throughout technology research, development, demonstration, and deployment in a sustainable way for present and future generations

Communicate

Communicate and amplify the role of energy equity in NREL's mission, the clean energy industry, and the clean energy transition, both domestically and internationally

Prioritizing equity at every stage

Centering energy justice starts with metrics

- Develop appropriate energy justice metrics for technology research and innovation cycle
- Integrate metrics and human-centered characteristics into analysis resources and technology innovation

JUST-R Metrics for Early TRLs

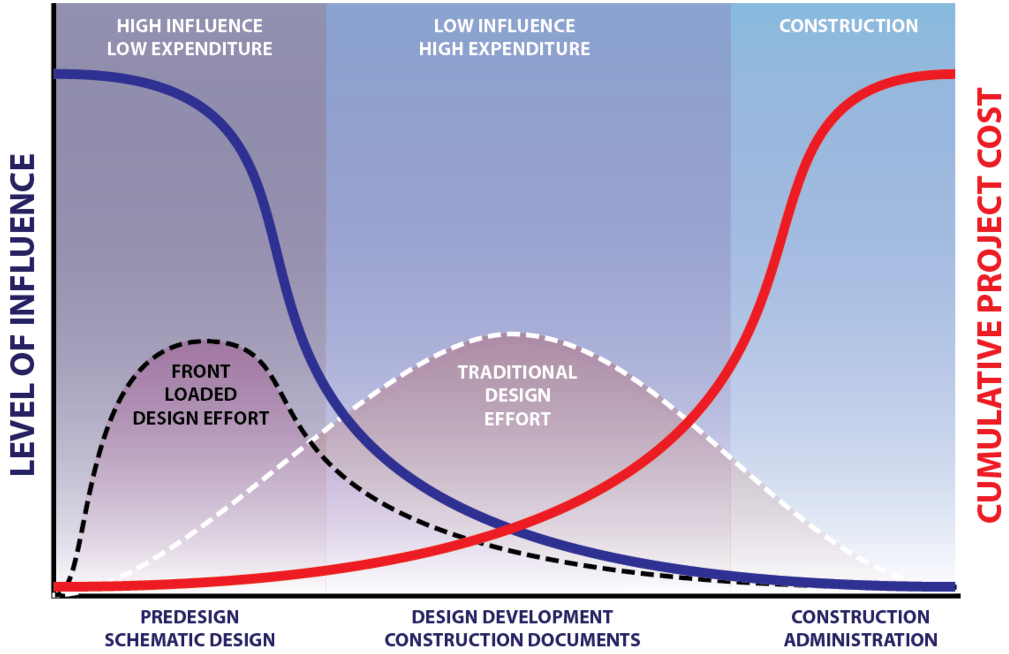
Justice Underpinning Science & Technology Research

Nikita Dutta, Bettina Arkhurst, Elizabeth Gill, Clara Houghteling, & Kate Anderson

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.

Energy justice seed-LDRD to address lack of early-TRL energy justice resources

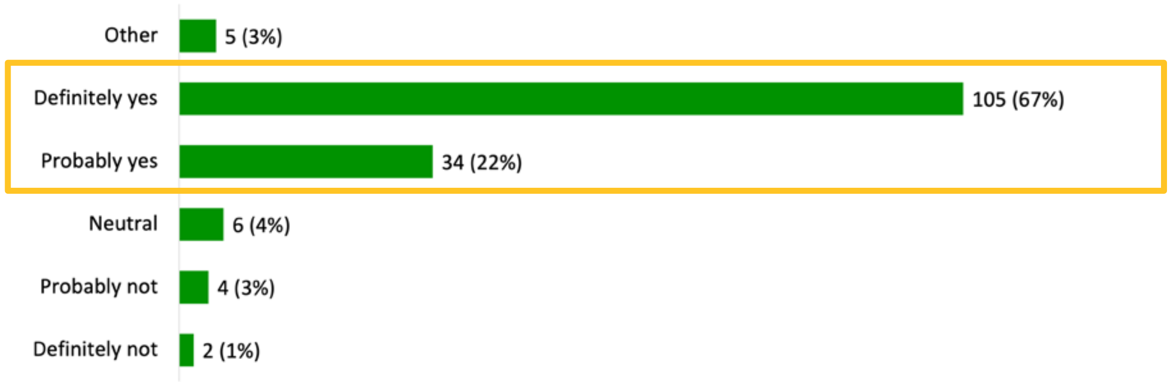
Can be costly & difficult to address energy justice issues late in tech development:



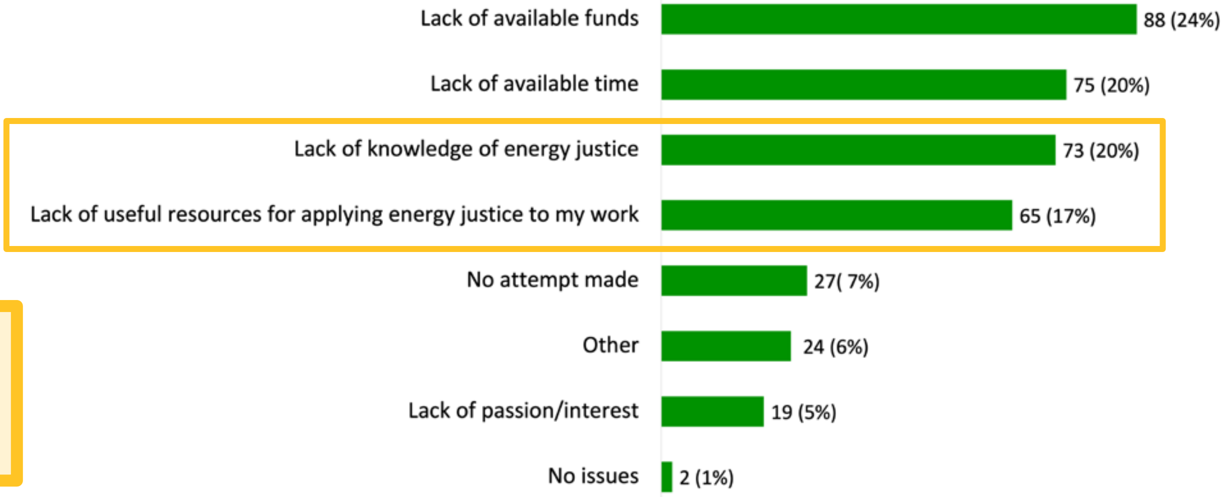
Source(s): Wheeler Kearns Architects; Paulson, 1976

FY22 seed-LDRD goal: Develop resources to apply energy justice to early-stage research.

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?



JUST-R metrics for TRLs 1-3 span tenets of justice

Distributive

- Life cycle greenhouse gas emisisons[2]
- Life cycle water consumption[2]
- Life cycle air pollution[2]
- Land use[2]
- Job opportunities[1]
- Potentialities of the research to impact positively/negatively on some social groups[1]
- Concentrations of pollutants or toxins[3]
- **Hidden process costs (3)**

Procedural

- Efficiency of resource use[1]
- Levels of safety[1]
- Transparency[1]
- Data availability[1]
- Information disclosure[4]
- Accountability level[1]
- Capability to communicate to stakeholders[1]
- Percentage of researchers who believe it is important to consider/address issues related to social justice in their research methodology[1]
- Flexibility[1]
- **Distribution of research results (5)**
- **Identification of set vs. flexible parameters (5)**

Recognitional

- Education[1]
- Institutional representation[4]
- Level of ability of the research problem to address an access problem of a disadvantaged social group[1]
- Compatibility with culture[1]
- **Breadth of pre-existing knowledge review (3)**

Cosmopolitan

- **Distribution of hazard exposure during research life cycle (4)**

[1]Carbajo & Cabeza, "Sustainability & Social Justice Dimension Indicators for Applied Renewable Energy Research: A Responsible Approach Proposal," *Applied Energy* (2019).

[2]Nock & Baker, "Holistic Multi-Criteria Decision Analysis Evaluation of Sustainable Electric Generation Portfolios: New England Case Study," *Applied Energy* (2019).

[3]Balal & Cheu, "A Metric-Concept Map for Scoping Impact Studies of a Transportation Project on Environment & Community Health," *International Journal of Transportation Science & Technology* (2019).

[4]Mundaca, Busch, & Schwer, "'Successful' Low-Carbon Energy Transitions at the Community Level? An Energy Justice Perspective," *Applied Energy* (2018).

Intergenerational justice overlaps with these categories.

New themes in bold (# of specific metrics).

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

JUST-R Metrics for Early-TRL

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

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

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 material
- ↑ Number of environmental parameters tested
- ↑ Number of non-tech solutions explored to solve key problems

Distribution of hazard exposure during research life cycle:

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

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

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
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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

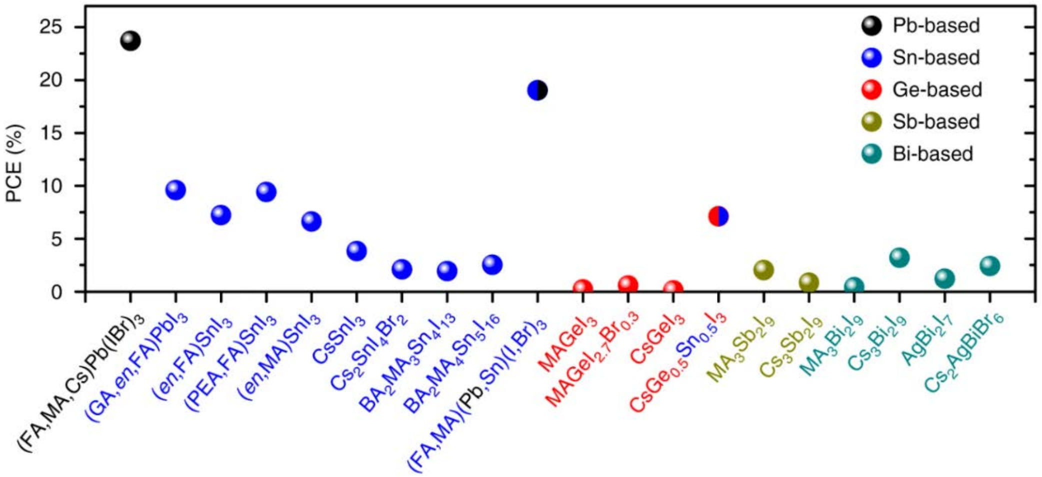
- Number of alternatives explored to energy-intensive processes
  → *Consider how **energy consumed by computing** can be mitigated through model design.*

- 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.*

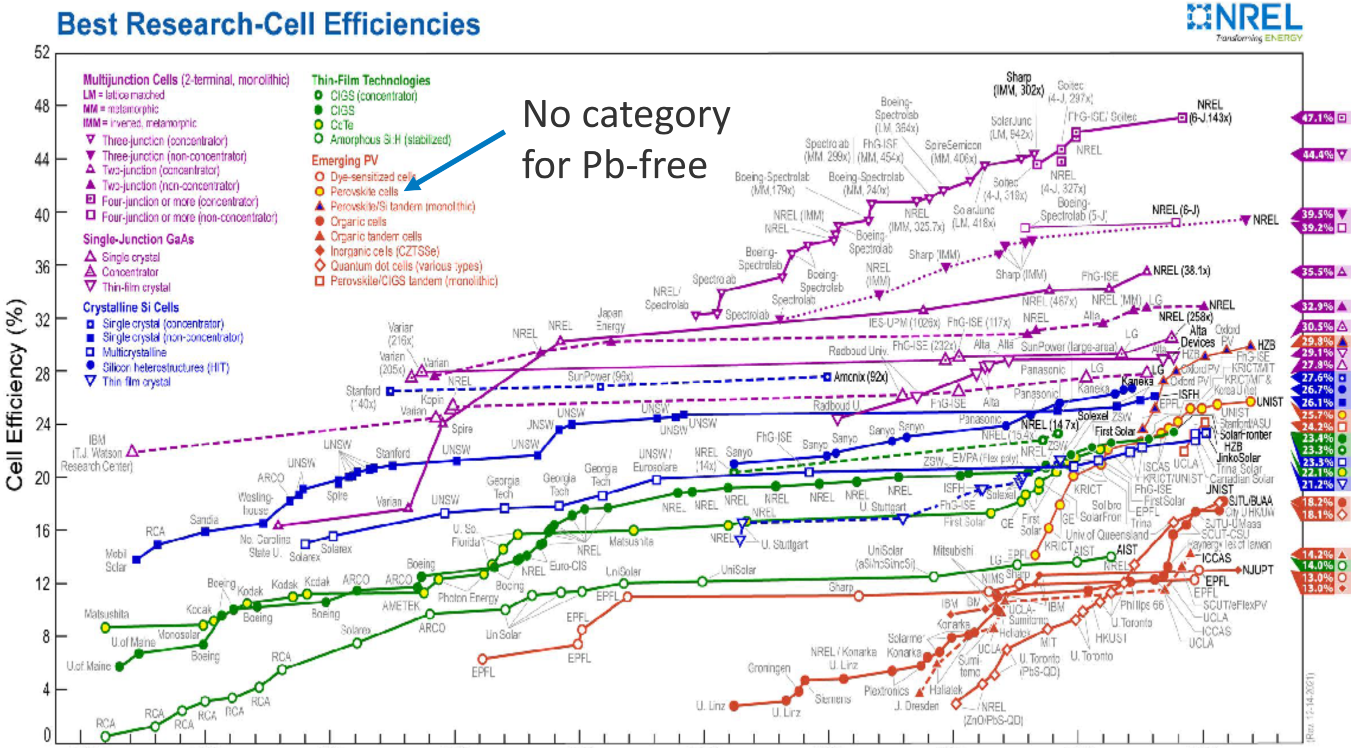
Challenges: Potential for tradeoffs between EJ & technical or economic metrics

Example: Perovskite photovoltaics

>25% of metrics improve with a Pb-free perovskite, at the expense of lower efficiency:



Ke & Kanatzidis, “Prospects for low-toxicity lead-free perovskite solar cells,” *Nature Communications* (2019).



At early-TRL, EJ is a very long-term incentive; unrealistic to expect it to compete with tangible, short-term incentives (e.g. publishing, grants, career progression) without institutional support.

Energy justice considerations for carbon-negative hydrogen

- Siting
- Workforce development
- Engagement with local communities on business model design
- Financing approaches that support underserved communities
- Managing environmental justice considerations on health and community acceptance

Thank you!

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