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Advancing Energy Equity Through Systems Engineering Approaches

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U.S. DEPARTMENT OF ENERGY BATTELLE

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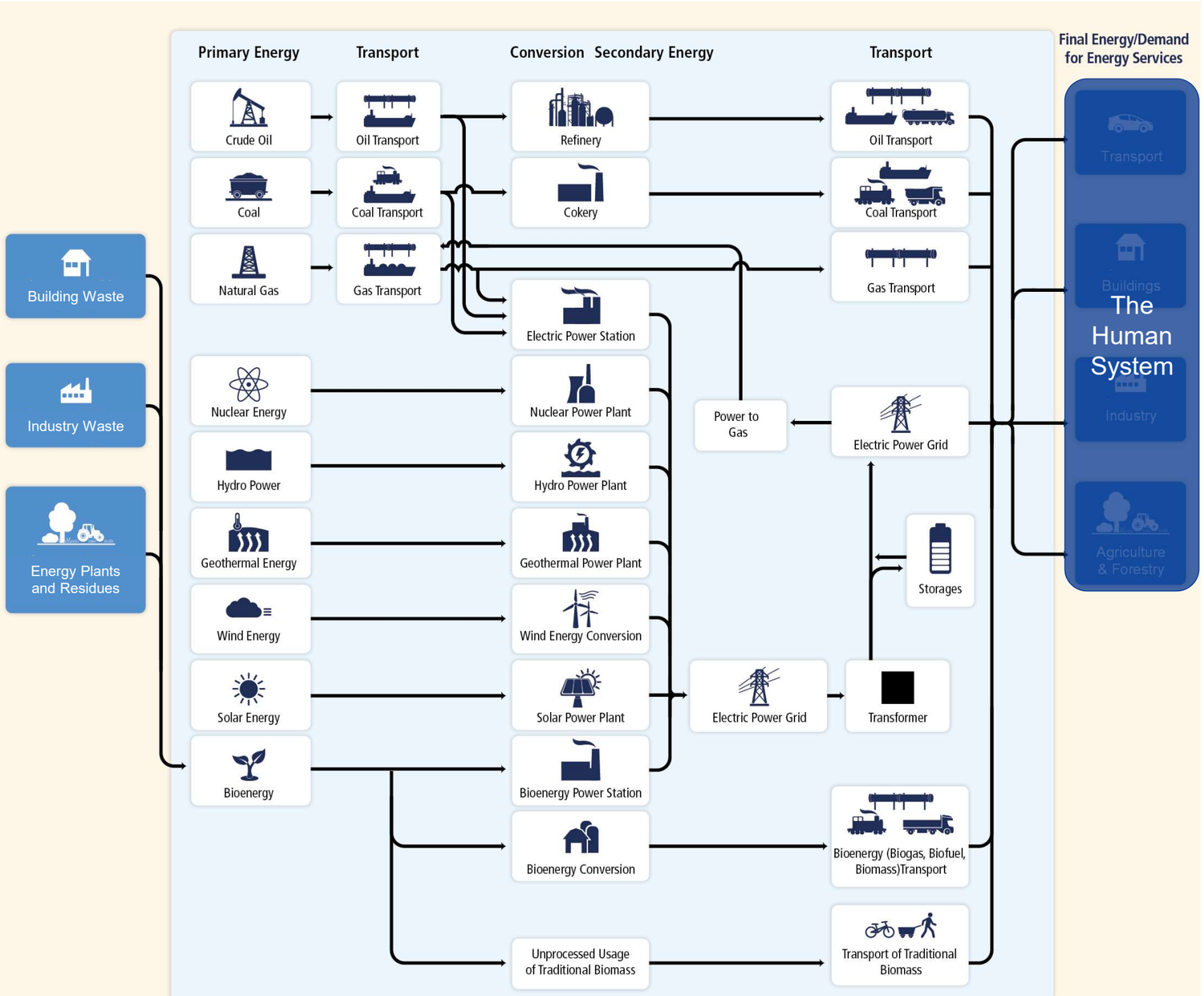
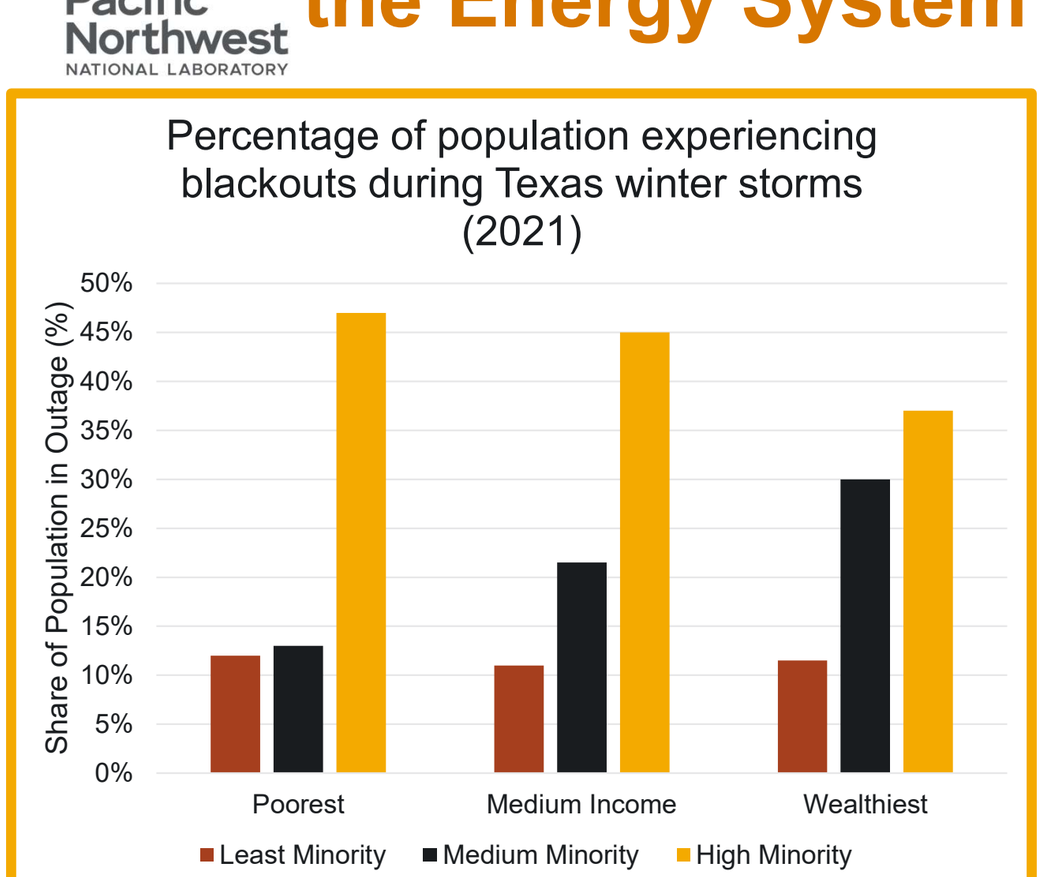
Our Energy System is a "System Of Systems"

- Requires a look at the whole and the parts simultaneously
- Human well-being and quality of life are critical system components



Adapted from Figure 7.1 [1]

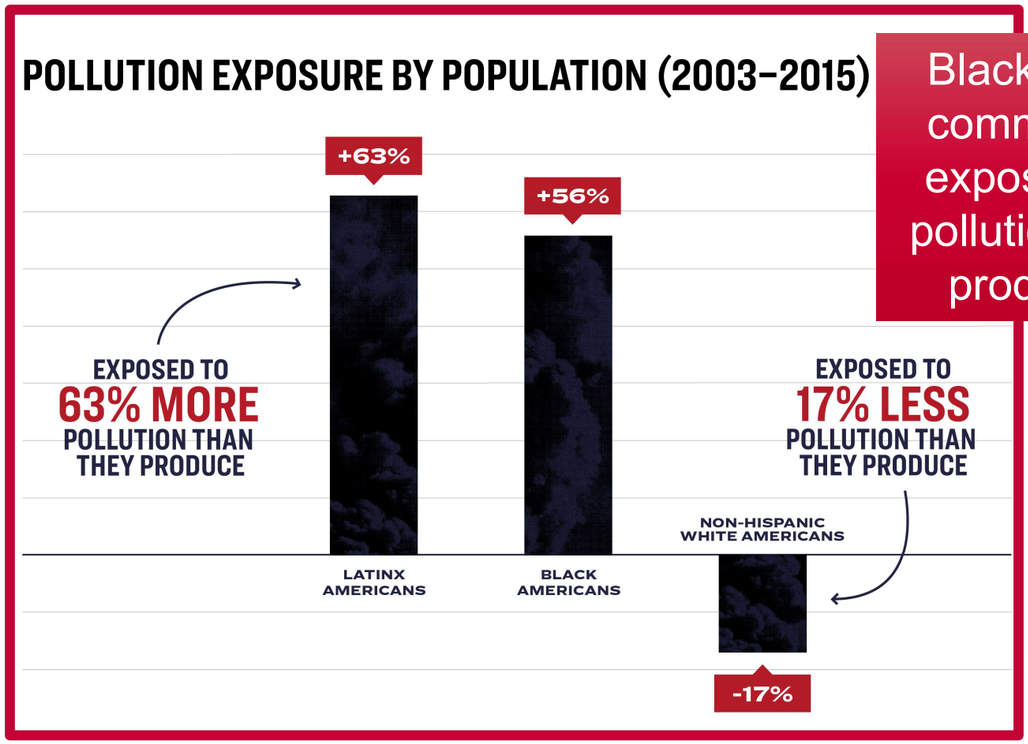
Inequities Exist in the Energy System



Low-income communities and communities of color have borne disproportionate burdens of long-duration and widespread outages. High minority areas were the most likely to suffer blackouts during Texas winter storms of February 14-18, 2021 [7].

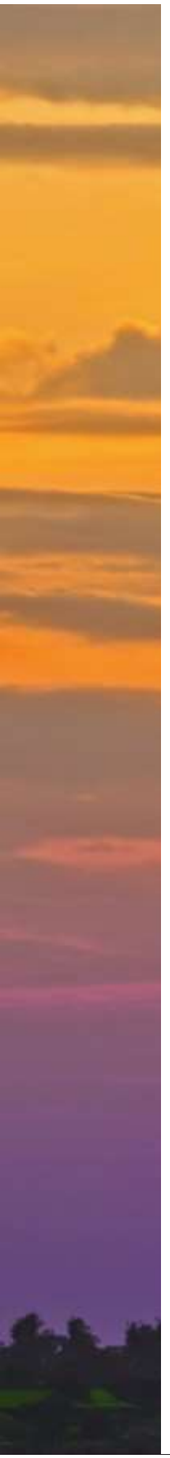
There is inequitable clean energy access across census tracts.

"Black- and Hispanic-majority census tracts with the same median household income and same home ownership as white-majority census tracts have installed less rooftop PV" [6].



Black and Latinx communities are exposed to more pollution than they produce [2, 3].

Energy insecurity and high energy costs affect nearly 1 in 4 American households [4] and are highly prevalent among low-income households [5].



Addressing Inequities in the Energy System

- Engineering is naturally a human-centric field
  - The goal of any engineering contribution is to improve the human condition through the development of technology and processes
  - Society demands rigor in engineered systems to maintain people's safety and well-being
  - **Making equity an energy system objective is a natural addition**
- A systems engineering approach is appropriate for energy equity integration because
  - We are balancing multiple, and sometimes competing, objectives
  - We need multiple disciplines to meet objectives
  - We must manage constraints from varying fields
  - Our efforts require evaluation to support critical and cost-significant infrastructure

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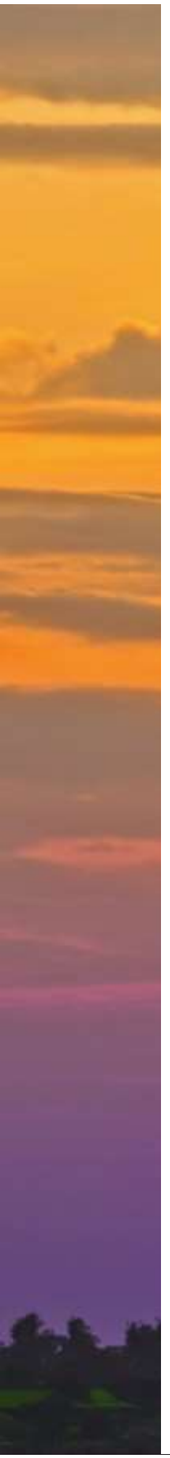
Background on Energy Equity



Energy Equity Builds on Energy Justice

Energy justice combines **social justice** and **energy systems concepts** to create a human-centered understanding of energy issues.

Tenets of Energy Justice

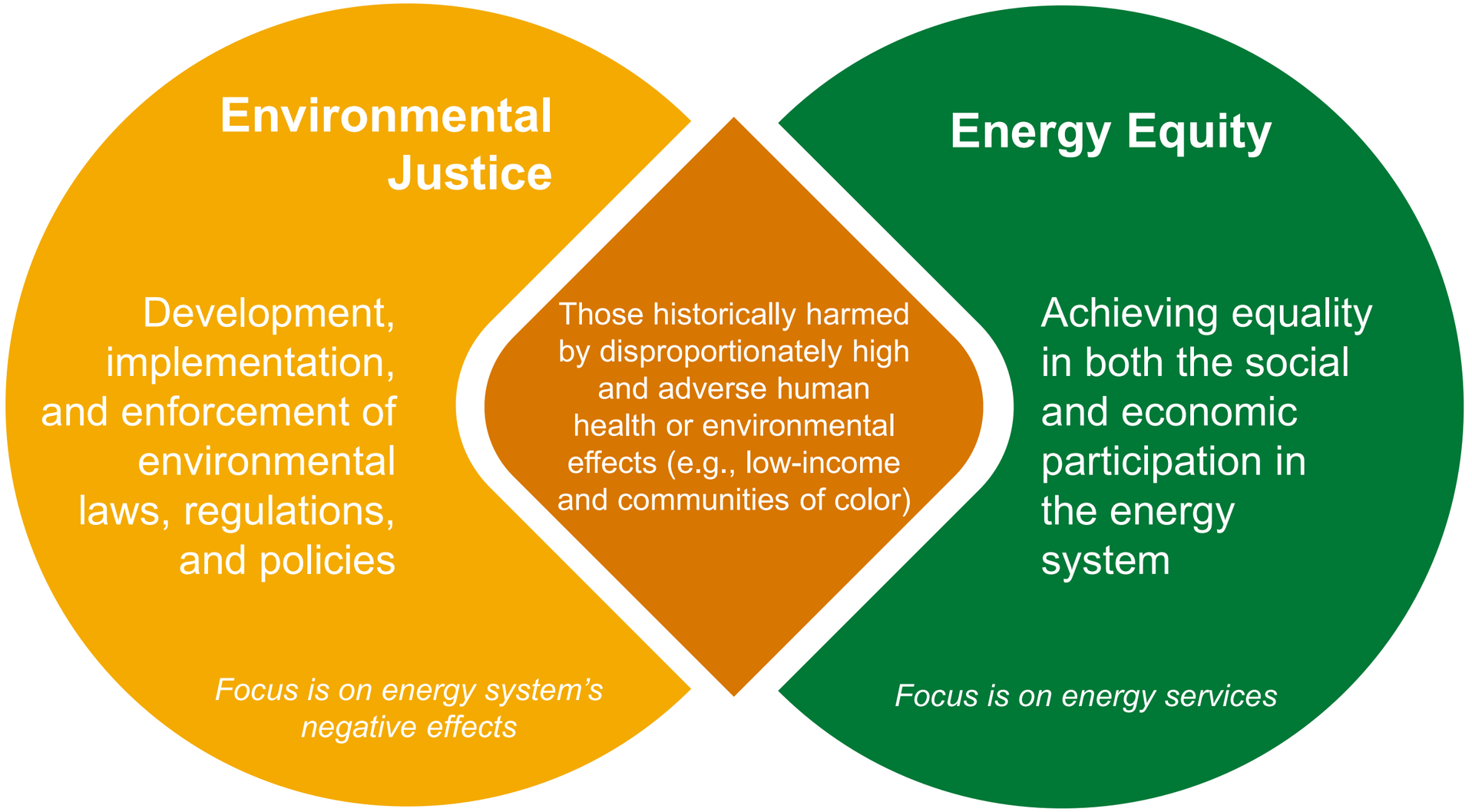
1. Distributive Justice
   - Addresses the allocation of benefits and burdens in society and their associated responsibilities
2. Recognition Justice
   - Emphasizes the need to understand different types of vulnerability and specific needs associated with energy services among social groups (especially marginalized communities)
3. Procedural Justice
   - Evaluates decision-making processes to assess whether all stakeholders have been included in a nondiscriminatory way
4. Restorative Justice
   - Focuses on repairing harm and relationships with those impacted by the burdens of energy projects

Energy Justice Borrows from Environmental Justice Advocacy

- Environmental justice emerged in the early 1980's as both an activist practice and field of scholarship
- By 1994, Executive Order 12898 directed federal agencies to

  "…the greatest extent practicable and permitted by law . . . make achieving environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations in the United States…"
- A key work in 2008 by Dr. Robert Bullard (The Father of Environmental Justice) reported communities of color often faced disproportionate environmental burdens, and the suite of recently passed environmental laws did little to protect such communities from environmental harm [8]
- Today, Executive Order 14008 (2021) builds upon these foundational environmental justice efforts and establishes the **Justice40 Initiative**

Energy Equity's Connection to Environmental Justice

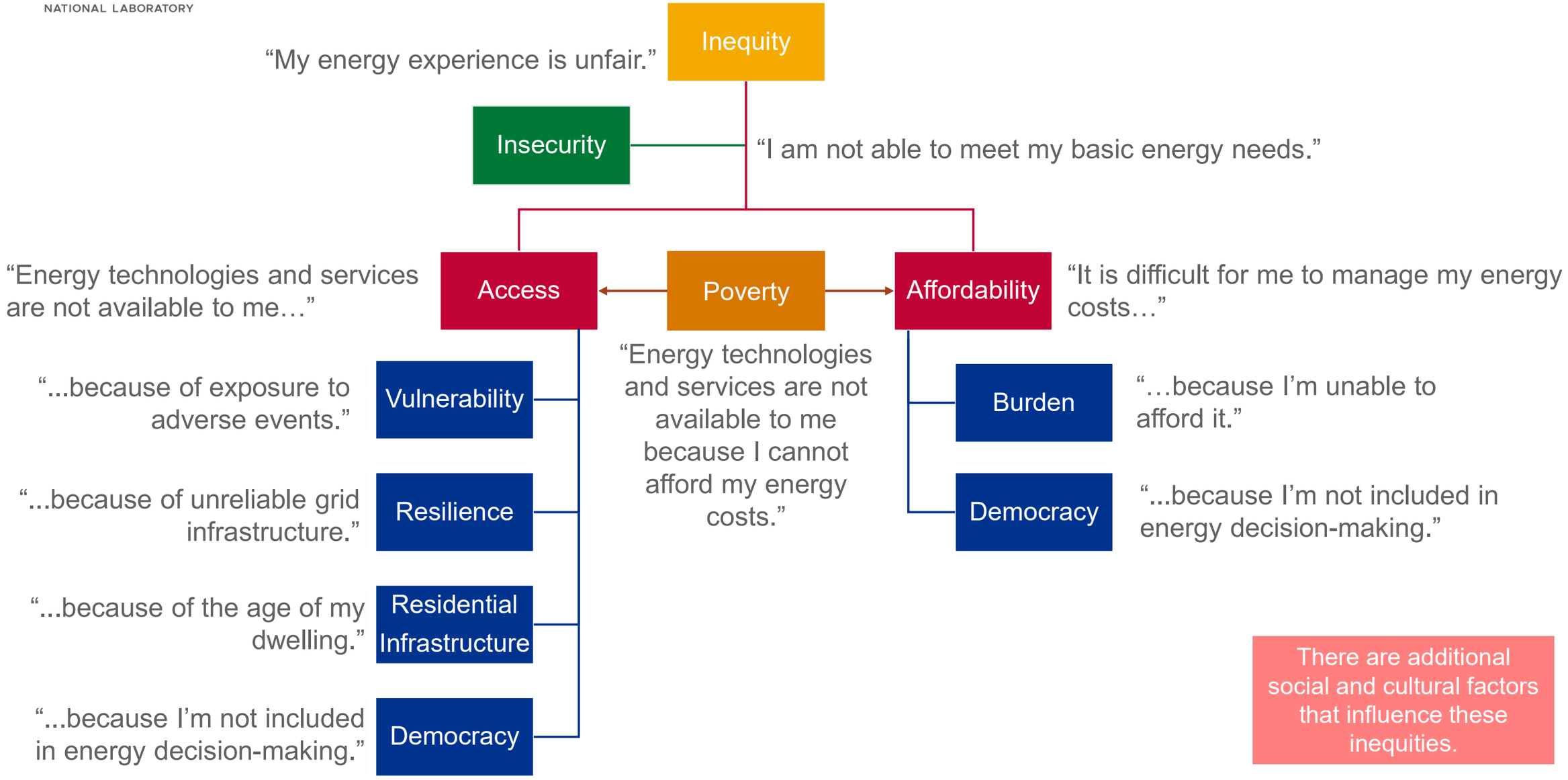


Working Definition of Energy Equity

https://www.pnnl.gov/projects/energy-equity

- Energy equity is defined as the ability of the energy system to
  - **Fairly distribute the benefits and burdens** of the clean energy transition
  - Guarantee that energy **decision-making procedures are fair**
  - Guarantee stakeholders have **access to information and participation in energy decision-making**
- This definition implies we **recognize there are communities that have been historically harmed** by disproportionately high and adverse human health or environmental effects in the energy system

Types of Energy Inequities



There are additional social and cultural factors that influence these inequities.

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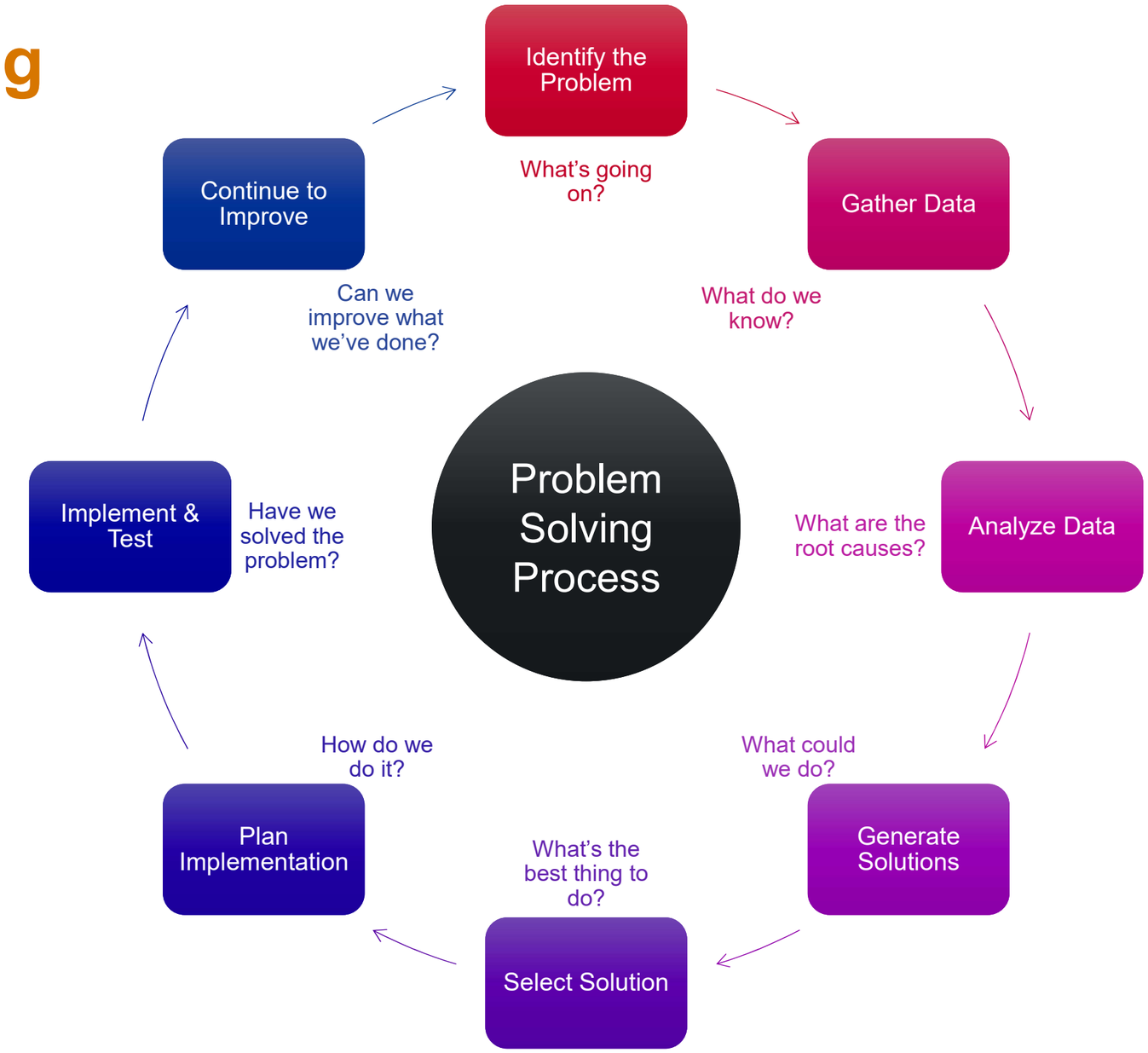
Background on Systems Engineering Approaches

Traditional Systems Thinking

- Systems thinking transforms a system need into a set of detailed specifications which will ‘best’ satisfy the need
- The problem-solving process looks below the surface, like an iceberg, to break down problems and develop solutions
  - On the surface is the problem, but below are the patterns and underlying structures



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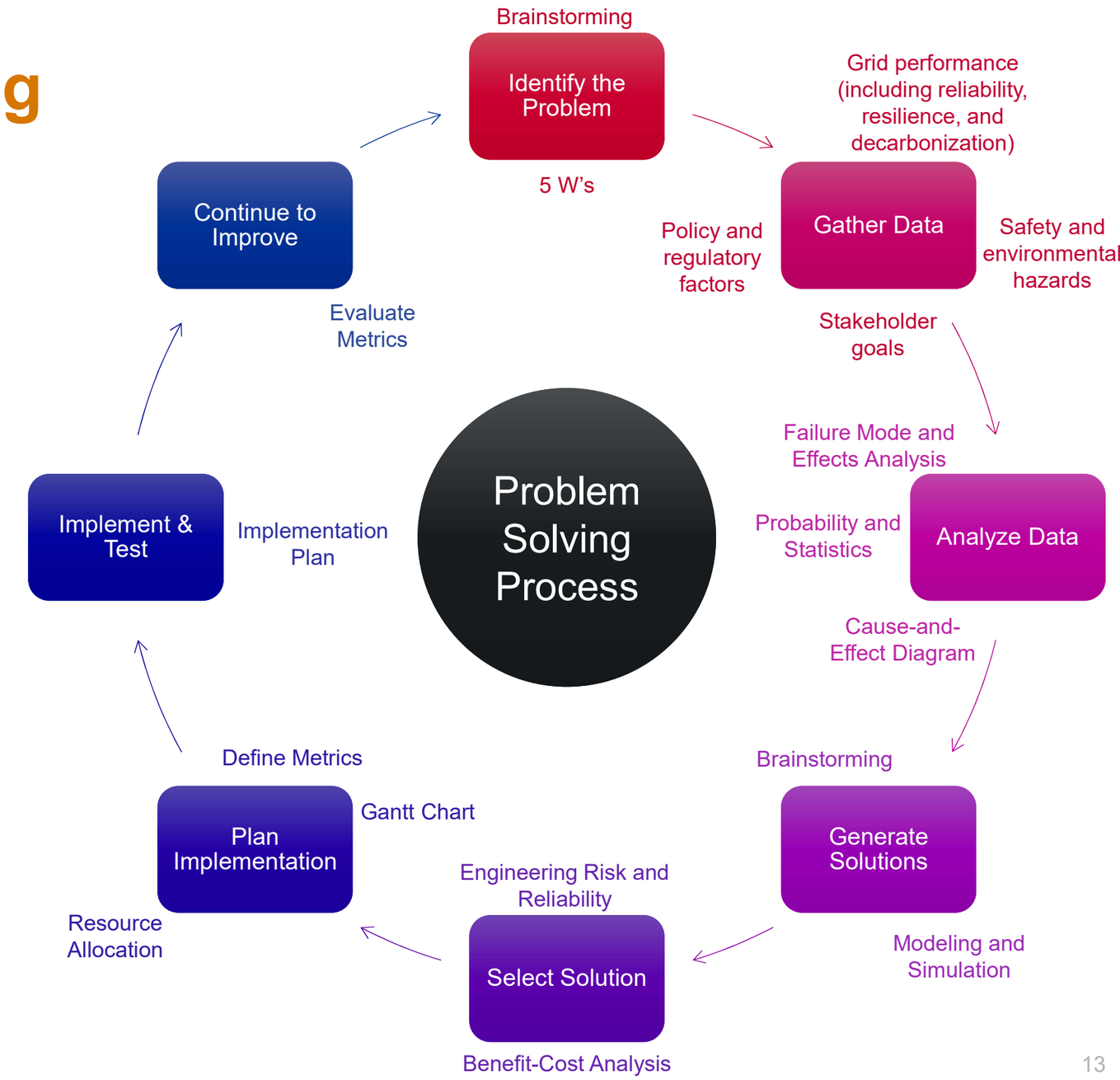
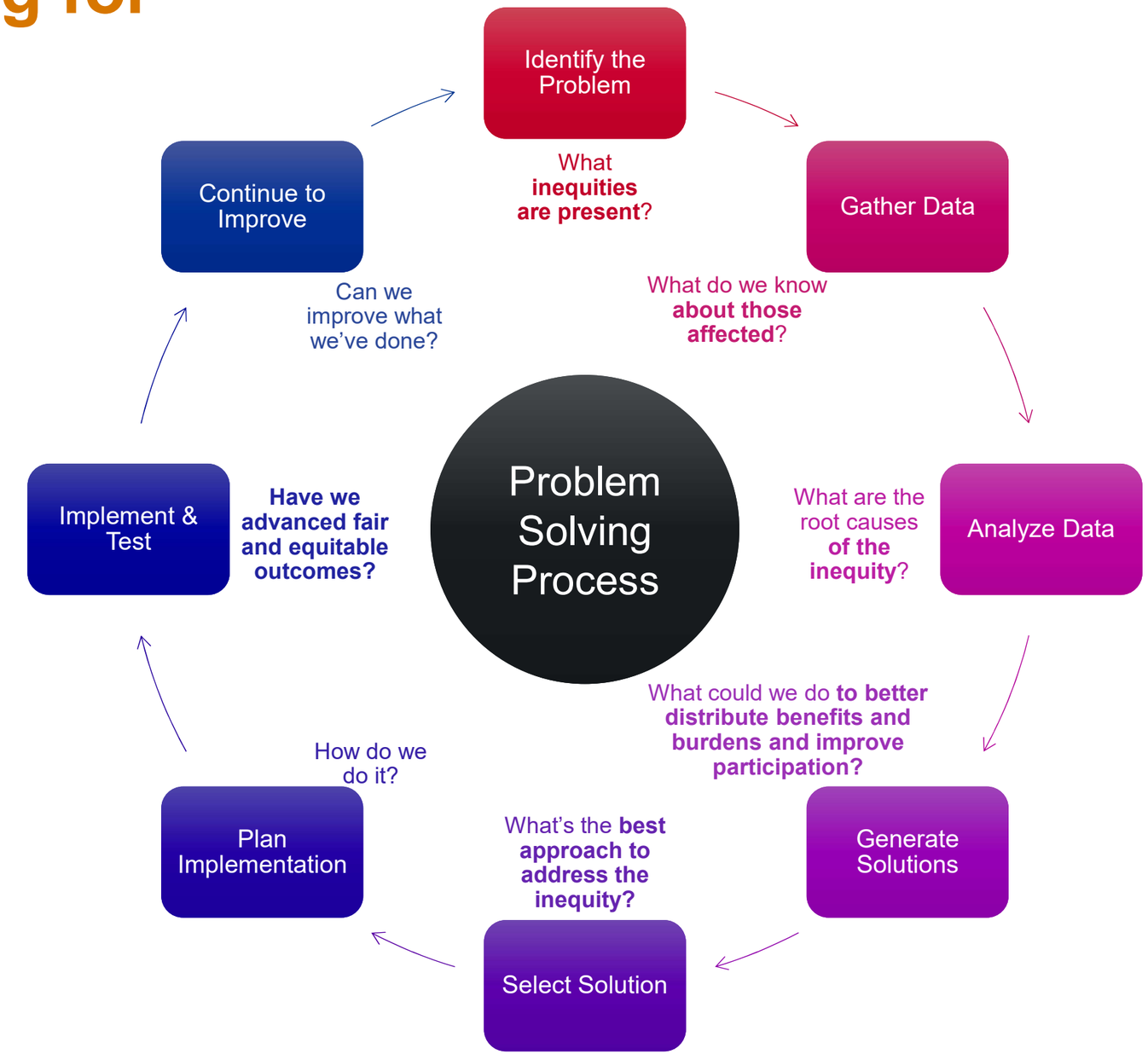


Systems Thinking for Energy Equity

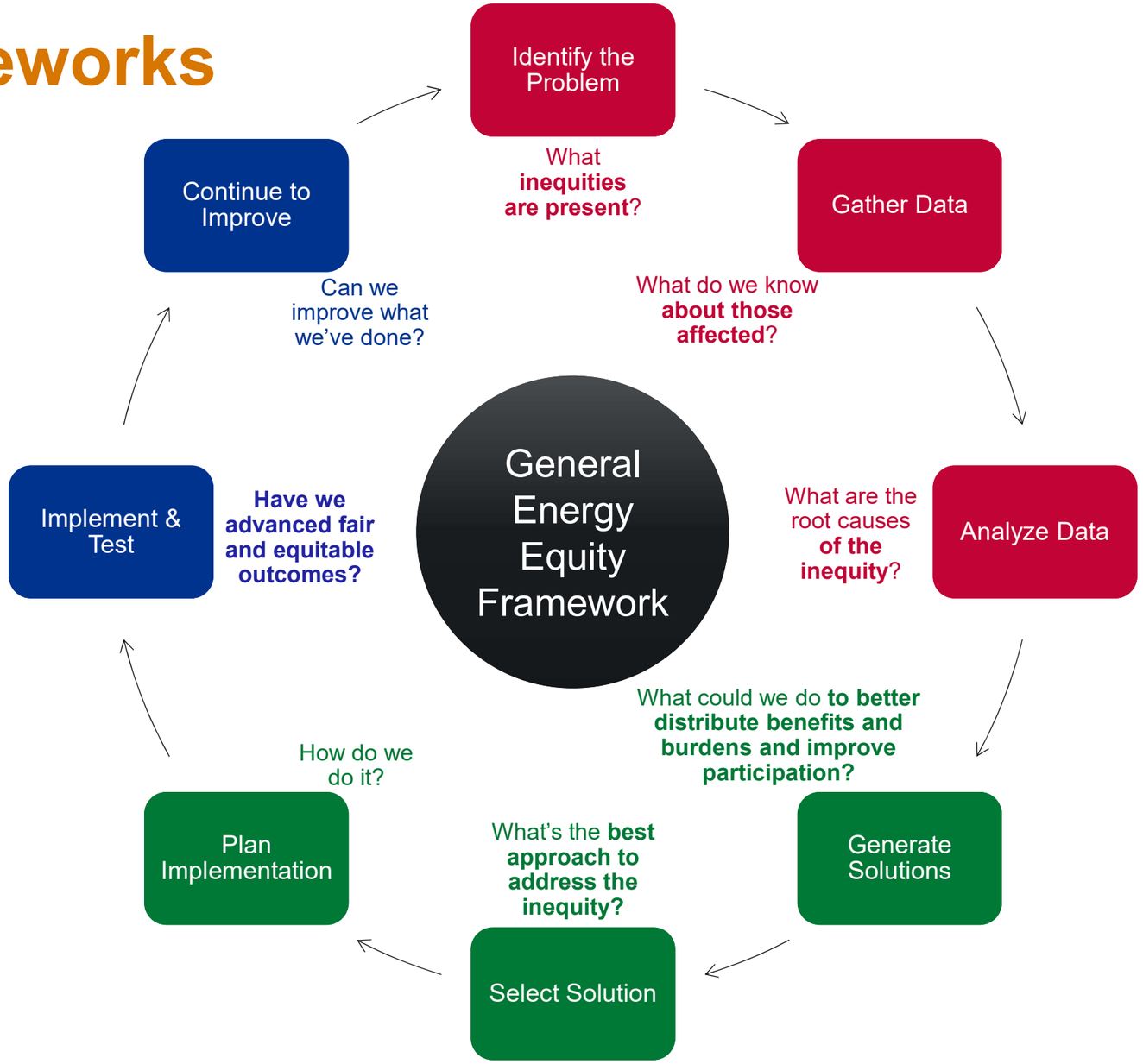
- Pivoting from traditional systems thinking requires consideration of inequities as the "problem" by which we create "solutions"
- The results are still system-level
  - Qualities
  - Properties
  - Characteristics
  - Functions
  - Behaviors
  - Performance



Energy Equity Integration Frameworks

- There are a couple of frameworks created for equity integration into energy infrastructure projects
- At their core, each framework consists of **three steps** which can be paralleled to the problem-solving process:

Step	Associated Tenets
1. Characterize conditions and needs	Restorative, Recognition, and Procedural Justice
2. Develop solutions	Restorative, Distributive, and Procedural Justice
3. Set and implement equity targets	Restorative, Procedural, and Distributive Justice



Example Approach to Energy Equity Integration

Consider an **Alaskan electric co-op** that wants to provide **additional local generation** with an **isolated**, front-of-the-meter **distributed wind** hybrid system

Community Conditions	Community Needs	Project Capabilities
Isolated and remote, outside of transmission system	Improved resilience to disaster events	Provide ancillary services Enhance the ability to respond, withstand and recover from outages
Heavy diesel use for heating, electricity, and water treatment	Reduced dependency on fuel supply Improved air quality	Reduce dependency on diesel
Fishing and subsistence lifestyle and economy	Consideration of sensitive ecosystems	Flexible siting, with turbines placed near loads
Average earnings per year and median household income are significantly below national average	(Additional needs learned from residents)	Provide O&M jobs
Poverty rate is well-above national average	Reduced energy cost	Provide fuel cost savings
Aging infrastructure	Access to modern energy technologies	Generate electric power from a renewable source

Example Approach to Energy Equity Integration

Consider an **Alaskan electric co-op** that wants to provide **additional local generation** with an isolated, front-of-the-meter **distributed wind** hybrid system

Step 1: Characterize Conditions and Needs

- Inequities present:
  - Energy burden due to high energy costs
  - Energy vulnerability due to heavy impact of climate change
  - Energy access due to limited proximity to modern energy services
- Resources
  - Direct engagement with residents
  - US Census American Community Survey Data
  - Local and State Government Resources
  - Environmental Justice Screening and Mapping (EJSCREEN) Tool
  - Climate and Economic Justice Screening Tool (CEJST)
  - CDC/AGTSDR Social Vulnerability Index

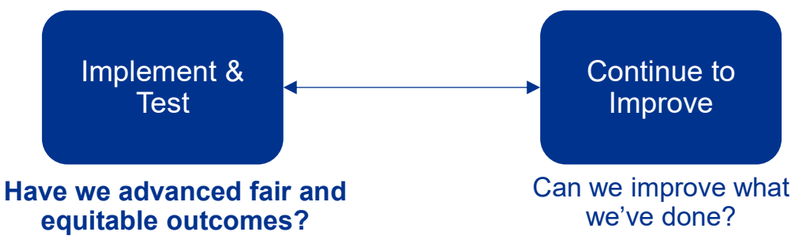
Example Approach to Energy Equity Integration

Consider an **Alaskan electric co-op** that wants to provide **additional local generation** with an isolated, front-of-the-meter **distributed wind** hybrid system

Step 2: Develop solutions

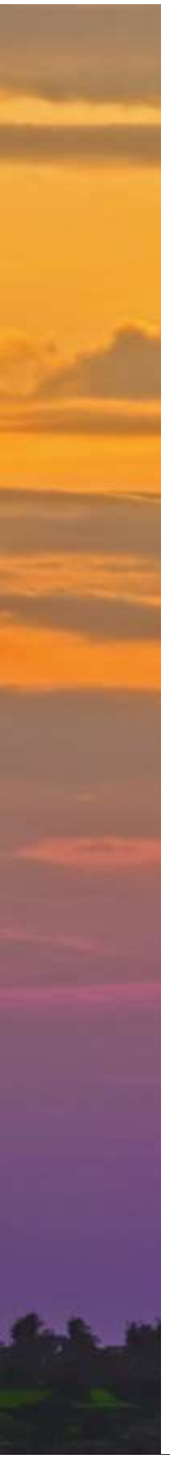
- Solutions must be co-developed with community members
- Energy services should foster community capabilities and be within the project's technical capabilities and scope
- Solutions are not intended to solve inequities, but instead should result in fair and equitable outcomes that meet community needs

Step 3: Set and implement equity targets



Sample of Works with Energy Equity Integration

Authors	Title	Highlights
University of Michigan	Energy Equity Project Report	Provides guidance for measuring the recognition, procedural, distributional, and restorative dimensions of energy equity, as well as case studies and best practices for implementation of these metrics to address local energy equity needs.
Department of Energy	DOE Justice40 General Guidance	Helps DOE offices and potential funding applicants incorporate Justice40 goals into projects. Policy priorities frame benefits for energy equity. Includes suggested metrics.
Bharati et al.	Advancing Energy Equity Considerations in Distribution Systems Planning (DSP)	Proposes an iterative framework for advancing energy equity as a DSP objective. Shows how metrics can be applied to benchmark equity performance at various stages.
E4TheFuture, Lawrence Berkley National Laboratory	Energy Equity and Benefit Cost Analysis (BCA)	Develops a conceptual framework where distributional equity analyses (DEA) are conducted alongside BCAs when evaluating distributional impacts of DER programs
Kennedy et al.	Understanding Energy Justice Needs Among Alaska Native Communities in the Transition to Clean Energy: A framework for conducting energy justice assessments	Develops an energy justice methodology and framework using the example of Alaska Native communities. Includes results from informational meetings and interviews with energy experts in Alaska regarding energy justice



Final Thoughts

- The way we analyze the energy system is becoming sociotechnical [9]
  - Traditional systems engineering has been focused on analysis of the technical system
  - The energy transition calls for an approach that unpacks socioeconomic factors
- Mapping outcomes to justice tenets can be challenging
  - Interdisciplinary project teams make this easier
  - We can never know all the factors unless we engage with project recipients/end-users
- Future exploration:
  - Can systems thinking guidance on places to intervene in a system help us better identify opportunities to advance equity?
  - Is it possible to create a balanced, self-reinforcing feedback loop so that equity efforts are self-correcting and close equity gaps?

References

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Thank you

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Education

PhD – Mechanical Engineering University of Florida, 2021 Dissertation: Advancements towards Enhanced Meter Privacy and Grid Reliability	M.S. – Mechanical Engineering University of Florida, 2019 Graduate Certificate in Control Systems	B.S. – Mechanical Engineering Florida A&M University, 2017 Internships in nuclear power, materials science, cyber-physical security

What I do at PNNL

- Assess energy infrastructure projects for equitable impacts
  - National Environmental Policy Act (NEPA)
  - Future hydrogen hubs (H2Hubs)
  - Grid planning
  - Distributed wind
- Support community energy goals by providing technical assistance

Interests

- Developing and analyzing outcomes to advance energy equity and justice
- Smart meter data privacy
- Grid planning for resilience and reliability

Energy Justice Core Principles

- Created to help operationalize the lofty moral elements of energy justice

- Part of a three-step framework to help apply energy justice to real world problems
  - The framework was created by R. Heffron and D. McCauley in “The Concept of Energy Justice Across the Disciplines“

Availability
- People deserve high quality, sufficient resources

Affordability
- Energy services should not be a financial burden for consumers

Due process
- Countries should respect due process and human rights in their production and use of energy

Transparency and accountability
- All people should have access to high quality information about energy and the environment and fair, transparent, and accountable forms of energy decision-making

Sustainability
- Energy resources should not be depleted too quickly

Intra-generational equity
- All people have a right to fairly access energy services

Inter-generational equity
- Future generations have a right to enjoy a good life undisturbed by the damage our energy systems inflict on the world today

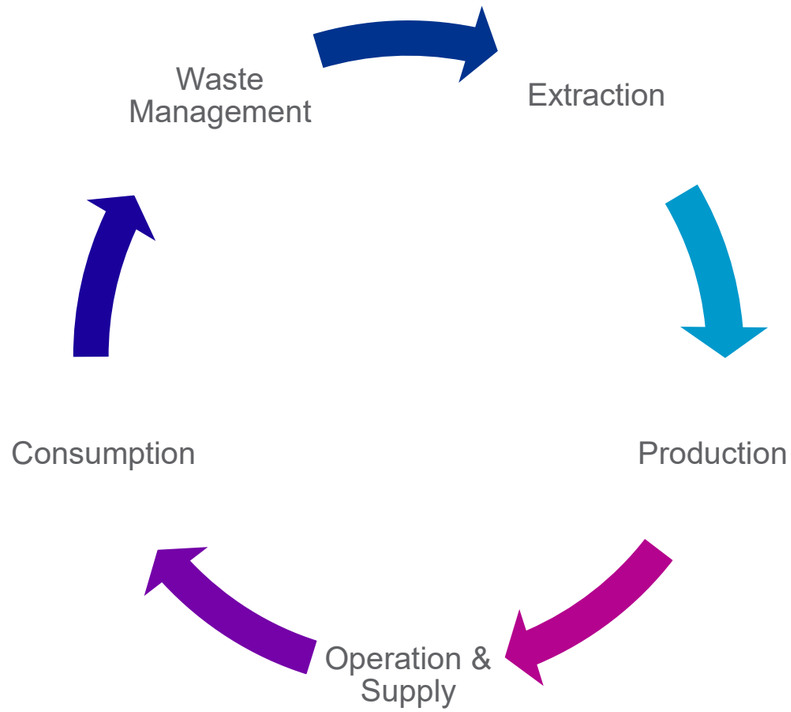
Responsibility
- Everyone must work to protect the natural environment and reduce energy-related environmental threats

*R. Heffron and D. McCauley, “The concept of energy justice across the disciplines“, *Energy Policy*, vol. 105, pp. 658-667, 2017.

Phases of Decision Making for Applying Energy Justice*

1. Three Core Tenets of Energy Justice

- Distributional
- Procedural
- Recognition



2. Cosmopolitan Justice Across the Energy Life-Cycle (system)

3. Applied Principles for Practice of Energy Justice

- Availability
- Affordability
- Due Process
- Transparency & Accountability
- Sustainability
- Intra and Inter-generational Equity
- Responsibility

Restorative Justice

*R. Heffron and D. McCauley, "The concept of energy justice across the disciplines", *Energy Policy*, vol. 105, pp. 658-667, 2017.

The DOE Justice40 Policy Priorities address Energy Inequity

1. Decrease **energy burden** in **disadvantaged communities (DACs)**
2. Decrease environmental exposure and **burdens** for DACs
3. Increase parity in clean energy technology (e.g., solar, storage) **access** and adoption in DACs
4. Increase **access** to low-cost capital in DACs
5. Increase clean energy enterprise creation (MBE/DBE) in DACs
6. Increase the clean energy job pipeline and job training for individuals from DACs
7. Increase **energy resiliency** in DACs
8. Increase **energy democracy** in DACs

Systems Thinking

- Systems thinking centers our awareness on the “whole” and looks at how the parts within the whole interrelate
  - For a system of systems, we must consider interrelation of the systems and the elements
- Each system may have a different objective
  - Systems thinking evaluates how those objectives can be addressed simultaneously through a structured process
  - Must meet objectives within constraints