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Energy Equity Opportunities in Distributed Wind Hybrid Systems for Rural Loads

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Kendall M Parker
Anneliese Fensch
Kamila Kazimierczuk
Sarah Barrows
Bethel Tarekegne

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Acronyms and Abbreviations

CEJST	The Climate and Economic Justice Screening Tool
DER	Distributed Energy Resources
DOE	Department of Energy
DW	Distributed Wind
EIA	Environmental Impact Assessment
MIRACL	Microgrids, Infrastructure, Resilience, Advanced Control Launchpad
NEPA	National Environmental Policy Act
PNNL	Pacific Northwest National Laboratory
RADWIND	Rural Area Distributed Wind Integration Network Development

Executive Summary

Energy equity is the ability of the energy system to fairly distribute the benefits and burdens of the clean energy transition, while also guaranteeing that decision-making processes are fair, and stakeholders have access to information and can participate in the process. Distributed wind (DW) hybrid systems, or combinations of distributed energy resources with wind energy technologies, have potential to provide energy equity benefits for rural loads. However, project developers and end-users do not understand these benefits well. This report outlines energy equity opportunities that result directly from DW-hybrid projects and proposes a framework that demonstrates how to advance equity in DW-hybrid systems, which can enhance existing resilience and valuation tools by incorporating a way to include equity considerations.

The report draws from ongoing equity work, such as the Energy Storage for Social Equity Initiative[1] and the Department of Energy (DOE) Justice40 Initiative.[2] It leverages the Idaho National Laboratory Resilience Framework and Pacific Northwest National Laboratory Valuation Framework developed under the Microgrids, Infrastructure Resilience, and Advanced Controls Launchpad research initiative, and it aligns with the case study reports developed by the Rural Area Distributed Wind Integration Network Development project.[3]

Equity Metrics & Frameworks Review.x

This report defines energy equity opportunities achievable with DW-hybrid systems for rural loads by the core principles of energy justice. As well, this work proposes an equity framework and includes a catalog of equity resources, metrics, technology-agnostic frameworks, and best practices linked in the adjacent Excel file.[4]

Electric cooperatives, technical assistance providers (including national laboratory and DOE staff), DW project developers, and technology providers can use this work to understand, evaluate, and define equitable outcomes for potential DW-hybrid projects. Key takeaways are below.

Consumers with rural energy loads are more likely to have a higher energy burden, experience greater grid reliability challenges, and be exposed to more aging and inefficient grid infrastructure than their metropolitan counterparts. DW-hybrid systems can improve energy affordability through reduced transmission costs due to the system being on the distribution side of a substation and the demand for energy being fulfilled by the on-site system. DW generation can enhance power supply reliability by improving energy quality and reducing transmission and distribution losses (e.g., line losses). DW-hybrid systems also improve access to modern, renewable energy technologies.

Energy equity opportunities require consideration of the social, economic, and health factors that may influence deployment. Many of the equity benefits of a potential DW-hybrid

[1] https://www.pnnl.gov/projects/energy-storage-social-equity-initiative
[2] https://www.energy.gov/diversity/justice40-initiative
[3] The Microgrids, Infrastructure Resilience, and Advanced Controls Launchpad research initiative and Rural Area Distributed Wind Integration Network Development project are funded by the DOE Wind Energy Technologies Office.
[4] The embedded Excel file requires a desktop version of Adobe Acrobat to open. An additional copy of the catalog is available on the DW website https://www.pnnl.gov/distributed-wind#:~:text=Wind%20turbines%20in%20microgrids%2C%20distribution%20networks%2C%20and%20hybrid%20systems.

system relate to grid services and electricity affordability. Strategic engagement processes with rural energy consumers can enable accessible and fair electric system decision-making. Aligning project potential benefits to social, economic, and health factors will increase the impact of equity efforts.

The equity assessment framework first baselines community conditions, pairing potential equity activities with community needs and desires and using metrics to track impacts. Energy equity assessments for rural loads should characterize existing inequities, challenges, and factors specific to the communities surrounding the site. Pairing needs to address inequities with potential project outcomes helps align actions with the principles of energy justice. Tracking equity impacts through metrics can help advance equity implementation by converting more abstract goals into objective observations through measurements.

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1.0 Introduction

Distributed wind (DW) refers to wind energy used as a distributed energy resource (DER) and connected at the distribution level of the electric grid or used in off-grid applications [1]. When coupled with other DER technologies such as solar or batteries, DW projects are known as DW-hybrid systems. Many co-ops, developers, and energy service providers with rural loads could benefit from DW-hybrid systems, but may lack information, training, or are simply overwhelmed by project development efforts [2]. In addition, DW and DW-hybrid systems may provide energy equity benefits that are not yet well-defined. Previous work under Microgrids, Infrastructure, Resilience, Advance Control Launchpad (MIRACL) project[5] leveraged the Idaho National Laboratory Resilience Framework, Pacific Northwest National Laboratory (PNNL) Valuation Framework, and the Use Case, Value Case, and Business Case Studies developed by Rural Area Distributed Wind Integration Network Development (RADWIND) [1, 3, 4] to define benefits of DW-hybrid systems. This report is part of the On-Site Wind for Rural Load Centers project which focuses on evaluating rural energy needs and providing tools and resources for communities considering DW-hybrid systems. Findings in this report will expand previous work to aid stakeholder understanding of the equity benefits DW offers.

To this end, PNNL evaluated energy equity opportunities specific to DW-hybrid systems for rural loads. PNNL considered the established energy justice tenets [5] to characterize the overlapping aspects of energy equity, including questions of identifying:

- where there is an unequal distribution of benefits and burdens associated with the rural electric system (or distributive justice)
- how accessible and fair electric system decision-making processes are (or procedural justice)
- who is underserved or disproportionately burdened by the electric system (or recognition justice)
- what can be done to mitigate past burdens and enhance more just outcomes (or restorative justice).


Equity Metrics & Frameworks Review.x

Section 2.0 lays a foundation by defining equity and its relevance, along with an overview of equity for consumers with rural loads. The tenets are a useful frame of reference for outlining equity benefits and are discussed in Section 3.0. Section 4.0 proposes an equity evaluation framework for co-ops, developers, and technology providers to use when considering DW- hybrid systems. Findings in this report contribute to the overall project goal of streamlining processes for DW to serve rural loads. The Excel file linked to the left catalogues the literature sources and metrics used to identify best practices and define an equity framework .[6] The cataloging was developed in a way that is compatible with the MIRACL Distributed Wind Valuation Framework. Future work can investigate the addition of equity as a value element category in the framework.

[5] DOE's MIRACL project contains a valuation framework for DW that demonstrates the net benefits of an existing or proposed DW project and can help stakeholders better understand DW's value in a particular scenario and use case. https://www.osti.gov/servlets/purl/1777484

[6] The embedded Excel file requires a desktop version of Adobe Acrobat to open. An additional copy of the catalog is available on the DW website https://www.pnnl.gov/distributed-wind#:~:text=Wind%20turbines%20in%20microgrids%2C%20distribution%20networks%2C%20and%20hybrid%20systems.

2.0 Background

This section provides a brief overview of energy equity, including its definition for this work and examples of inequities. It also reviews what rural loads are and why they have unique equity considerations.

2.1 Working Definition of Equity

The term *energy equity* stems from the concept of *energy justice.* Energy justice combines social justice and energy systems concepts to create a human-centered understanding of energy issues [6]. This forms the foundation for the energy equity goal of ensuring the fair distribution of benefits and burdens associated with the energy system during production, distribution, and consumption [7]. Energy equity in this context operates as a tool used to recognize and address the unique characteristics of consumers with rural loads and the systemic imbalances that prevent them from participating in DW-hybrid systems. Energy justice differs in its focus on the energy system more wholistically, encompassing the laws, policies, procedures, and individuals responsible for implementation and enforcement.

Energy equity is defined as the ability of the energy system to fairly distribute the burdens and benefits of the clean energy transition, while also guaranteeing that decision-making procedures are fair and stakeholders have access to information and can participate in the process [6, 8]. Implicit in this definition is the recognition that disadvantaged and frontline communities have been historically harmed by disproportionately high and adverse human health or environmental effects in the energy system [9]. These communities include, for example, low-income, marginalized, and/or vulnerable groups, such as communities of color, tribal communities, and rural communities, as well as those who are vulnerable to electric costs and outages to ensure comfort, well-being, and opportunity. Implementation of equity should encompass both social and economic participation and mitigate social, economic, and health burdens imposed on those disproportionately affected by the negative externalities of energy infrastructure [8]. Table 1 provides the definitions of different types of energy system inequities.

Table 1. Energy equity definitions

Type of Inequity	Definition
Energy burden	The percent of a household’s income spent to cover energy costs
Energy access	The proximity to modern energy services (i.e., electricity and clean, modern cooking solutions, telecommunications, etc.)
Energy insecurity	The inability of a household to meet their basic energy needs
Energy poverty	The lack of access to basic, life-sustaining energy
Energy vulnerability	The propensity of a household to suffer from a lack of adequate energy services in the home
Energy democracy	The notion that communities should have a say and agency in shaping and participating in their energy future

Equity is important to DW-hybrid systems because there are germane equity factors that will influence project outcomes. Resilience, land-use conflicts, safety, and property value are examples of factors that will have implications on project beneficiaries. Moreover, economic indicators like poverty and income status can compound inequities in the electricity system [10, 11]. Policy attention on electricity system inequities, energy transitions, and broader environmental and economic issues highlight the importance of tailoring new DW projects to local needs [12, 13, 14, 15]. Considering equity for consumers with rural loads is important because rural communities are more likely to have a higher energy burden, experience greater grid reliability challenges, and be exposed to more aging and inefficient grid infrastructure than their metropolitan counterparts [16, 17]. DW-hybrid systems can help mitigate challenges related to energy affordability and quality by delivering lower cost power and enhancing grid reliability [18].

2.2 Rural Loads

Rural locations make up many of the areas in the United States with high wind resource qualities and population densities acceptable for DW development [1]. Rural areas have features and challenges that can be addressed by DERs alongside specialized energy management and control approaches to provide electricity autonomy, more reliable electricity, and support for economic goals.

The term “rural” has multiple definitions since many researchers and policy officials use different distinguishing criteria and because rural is a multidimensional concept. The defining criteria can be both population density and geographic isolation (“remote”) [19]. Population thresholds used to differentiate rural and urban communities range from 2,500 up to 50,000, depending on the definition [19]. Geographic isolation is often defined by proximity to metropolitan areas.

The U.S. Census Bureau defines rural as “open country and settlements with fewer than 2,500 residents” [19]. Programs like DOE’s Office of Clean Energy Demonstrations Energy Improvements in Rural or Remote Areas define rural as having 10,000 or fewer people [20]. The Department of Agriculture Economic Research Service most often uses data on nonmetropolitan counties outside the boundaries of metro areas to depict rural location trends [19]. The Rural-Urban Continuum Codes, first created in 1974 by the Department of Agriculture’s Office of Management and Budget, are updated every ten years to distinguish rural and urban counties based on population, degree of urbanization, and adjacency to a metropolitan area [21].

Rural areas distinguished by geographic location, sometimes referred to as “fringe” or “micropolitan” areas, are urban-influenced parcels beyond urban areas. Land use in the fringe is both nonresidential and residential [22] and may reflect uses that have either purposely moved away from the urban area or which require large tracts of land unavailable in the urban space [23]. Open land areas often exist in the fringe and can reflect agricultural land, rangeland for cattle, or woodland. Due to this, the primary planning concern in the fringe is change of land use. For areas where land may be expensive, otherwise valuable, or a source of revenue, DW-hybrids can be co-located with existing land use. This is important because equitable projects should preserve the community’s ability to thrive through human development initiatives, and this involves deriving project value in the form of more than just energy services, but the ability to maintain subsistence activities, too. For example, in three rural midwestern counties, a mixed-methods study found that communities were concerned about the impact of utility-scale wind energy on rural lifestyles and other development [24]. In comparison to utility-scale projects, DW-hybrids can accommodate rural land use because the projects have a smaller footprint compared to other DERs [3].

Rural areas may experience poor quality, unreliable electricity due to badly maintained or lack of electrical infrastructure. This creates increased vulnerability to extreme weather conditions due to more frequent power outages. DW generation can enhance power supply reliability by improving energy quality and reducing transmission and distribution losses (e.g., line losses) [3]. Moreover, DW-hybrid systems can provide power reliability support, which can address inequities related to the propensity of a household to suffer from a lack of adequate energy services.

Energy access and energy burden are additional inequities seen in rural areas. Being further away from urban areas can impact the ability to obtain modern energy services (e.g., DERs, telecommunications). Higher energy costs in rural areas often come from the older housing infrastructure and its lack of energy efficiency [25]. Some remote communities are particularly burdened by fuel prices, as they rely on diesel but can only get it at certain times of the year [26]. Areas with rural distinction due to depopulation face additional, nonenergy inequities that impact well-being. Shrinking populations can lead to closure of local critical facilities like healthcare centers and hospitals which, when compounded lack of insurance coverage for residents, creates health risks and more expensive health care needs [27]. That being said, increased health risks can be exacerbated by a lack of accessible and affordable electricity. With a DW-hybrid system, rural residents can experience modern, renewable energy sources, with possible opportunity for ownership depending on the structure [1], thereby advancing energy access. DW-hybrids can also reduce energy burden because projects are on the distribution side of a substation, thus reducing transmission costs.

Rural areas have often relied on single industries, such as agriculture, resource extraction, or manufacturing, often linked to energy resources. If these industries decline, populations can decline, leaving rural areas needing an economic boost [28]. Studies comparing rural versus urban areas reveal rural areas have consistently higher poverty rates and stagnant economic development relative to urban areas [29, 30, 31]. According to DOE research, DW capacity additions to rural distribution grids have significant economic potential for project owners [32]. Depending on the size of the load served and economic conditions, such as access to finance and policy, DW projects can provide a positive net present value to support the economy in rural areas with significant economic potential in disadvantaged communities [33].

3.0 Energy Equity Opportunities

DW can be deployed in many sectors and locations within the energy system, allowing for the prioritization and targeted support of underserved and historically disadvantaged communities. New tax incentives, such as the energy community tax credit bonus in the Inflation Reduction Act, enable both wind deployment and equity advancement for eligible projects.[7] The Energy Improvements in Rural or Remote Areas program, part of the DOE's Office of Clean Energy Demonstrations, also seeks to help rural areas by funding renewable energy projects to improve energy resiliency, reliability, and affordability.[8] Assessing the equity aspects of a potential DW system in a rural location needs to consider the social, economic, and health factors that may influence deployment. These factors extend to DW-hybrid systems as well and will help outline where to focus potential benefits and mitigate harm.

Because of energy equity's justice foundation, we outline equity opportunities by the established tenets of energy justice. Recognition justice understands who is most burdened by modern energy systems; distributive justice identifies where those burdens and future benefits are dispersed; procedural justice focuses on how to procedurally engage the most vulnerable social groups in decision-making; and restorative justice looks at what to do to repair and mitigate those burdens [5]. Within the broader tenets, current scholarship uses justice principles to identify energy system inequities [34].

Justice principles can be linked to the tenets, as follows: distributive justice is assessed through the affordability and availability principles; recognition and procedural justices are assessed through transparency, accountability, and due process principles; and restorative justice is assessed through the sustainability, responsibility, inter- and intragenerational principles. The tenet–principle correspondence provides a foundational mnemonic to apply the tenets of energy justice to projects. This association does not prevent cross-application of the principles to other tenets (e.g., affordability to advance recognition justice). A summary of the correspondence is in Figure 1.

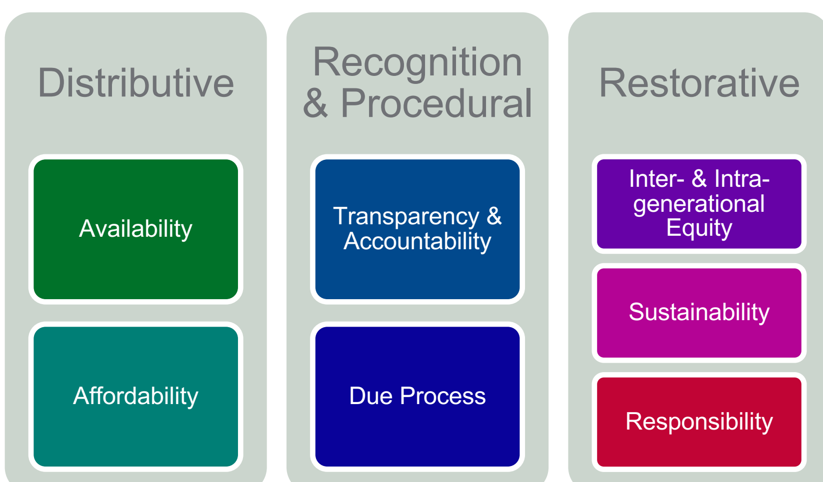

Figure 1. Prominent principles corresponding to each justice tenet

[7] The Inflation Reduction Act, which became law in August 2022, includes both the Production Tax Credit and Investment Tax Credit for Wind Energy. https://windexchange.energy.gov/projects/tax-credits
[8] https://www.energy.gov/oced/energy-improvements-rural-or-remote-areas-0

Tracking equity impacts through metrics can help advance equity implementation by converting more abstract goals into objective observations through measurements [35]. There are three categories of metrics used in this report following previous work: target population identification, investment decision-making, and project impact assessment [13]. Target population identification metrics capture descriptive analytics on the population considered for DW-hybrid systems. Investment decision-making metrics are often developed by contrasting target population metrics between groups to describe how populations compare. Project impact assessment metrics evaluate how well a project has helped a target community. For a more exhaustive list of metrics under each metric type, see the Excel file in Section 1.0.

It is important not to rely solely on measurements to advance equity. Metrics should be used to aid accountability and determine whether an equity target has been achieved but should not solely define how to proceed with equity action. Metrics do not fully address concerns of procedural and restorative justice or the fundamental need to ensure that those most impacted by energy system and climate have prominent seats at the decision-making table [36]. Guiding principles and qualitative best practices should be uplifted over metrics where appropriate.

3.1 Distributive Justice

Increasing availability and affordability of energy are the primary principles involved in distributive justice to allocate benefits and harms. Availability means providing access to energy technologies for everyone across the socioeconomic spectrum. Tax credit-based incentives are not favorable for communities and consumers with low or no tax liability. Production incentives are not compatible with low-income communities and consumers because of high upfront costs or extended payback periods. However, through tailored incentives and business models, DW-hybrids could be owned by more types of consumers. Benefits could take many forms including group-oriented tax revenues for municipalities, community funds included with individualized lease payments to landowners ‘hosting’ turbines, and partial or outright ownership of a project by local citizens or community groups who share in the profits [37]. Varying DW-hybrid ownership models can also influence project value; an example of varying use cases for DW can be found in [3].

Affordability ensures consumers have low energy burden and low energy insecurity. Rural and low-income households spend a high percentage of their income on energy cost [16, 38]. This lack of affordability is exacerbated by systemic inequities across demographic indicators, and equity factors such as resource access, health impacts, and air pollution. An additional challenge, particularly for low-income customers, is the potential for increased financial burdens imposed by shifting technologies, tariffs, and regulations [10].

For behind-the-meter systems, where turbines connect to the customer side of the meter to serve a local load, wind project owners could generate part, if not all, of their energy consumption needs. This can offset their utility’s energy and demand charges, resulting in significant economic savings over the lifetime of a project [3]. Moreover, owners could form independent power producer groups to sell their energy, thereby lowering their energy bills.

Grid services are an additional benefit of DW-hybrid systems that fall under both availability and affordability. For those historically harmed by the energy system, lack of reliable electricity can impact personal safety and comfort as well as electricity cost and economic development in the area (e.g., a business may be hesitant to build a factory where the electricity has large voltage swings or cuts out regularly). Regulation, primary frequency response, load following, voltage support, and flexible ramping are examples of grid services that are possible for DW-hybrid systems through smart inverters and other distributed generation technology [3]. For a front-of-the-meter project where turbines are connected directly to the distribution grid, if generation is coincident with peak demand, the project could reduce demand on a distribution system, lowering congestion and saving on capacity and transmission costs [3].

Measuring distributive justice requires metrics that quantify reduction in harms and improvement of lives, as well as the distribution of energy system benefits and investments [36]. The distribution of benefits and harms can be evaluated through investment decision-making (pre-development) and project impact (post-operation) metrics. Examples include quality of new jobs created by project operation and maintenance for underrepresented demographics and climate resilience benefits and reductions in disparities.

3.2 Recognition and Procedural Justice

Recognition is necessary to define procedural equity efforts; hence, the combined consideration of both tenets and the overlapping use of the principles of transparency and accountability. Both tenets include a historical dimension to understand cumulative disparities and how they came to be.

Transparency and accountability do not have a single definition. Transparency brings about accountability by empowering communities with information to hold institutions accountable and shed light on decision-making processes [36]. Accountability can be improved by broadening the actors involved in a project, particularly by including affected communities as consultants with control over project outcomes. Fair involvement of underrepresented demographics can aid transparency because it prevents institutions from performing inequitable practices and pursuing initiatives without involving communities. Moreover, more inclusive planning processes can improve information sharing. Clearer permitting processes with defined approval paths for projects with opportunities for both communities and stakeholders to participate in decision-making will also advance procedural justice. Transparency in front-of-the-meter DW-hybrid systems can look like regular data reporting from utilities and contractors, stakeholder groups that allow community-led project design and evaluation, and regular town halls for information sharing and community feedback. The role of public support and acceptance in projects is a popular procedural equity mechanism because of the ability for residents to affect project outcomes [39]. Giving communities control over decision-making and using bottom-up approaches from project conception will promote procedural equity.

Furthermore, energy power plant siting processes have historically focused on sites of production versus sites of consumption, resulting in low-income and indigenous populations bearing a disproportionate burden of the energy production and power plant siting. When project developers only consider renewable energy project efficiency (e.g., resource availability) and cost effectiveness measures (e.g., levelized cost of energy) in siting considerations, it narrows decision-making, reinforcing social imbalances. Including community or social impact assessments can reduce siting inequities seen in traditional energy planning since they evaluate changes to way of life (how people live, work, play), culture (beliefs, customs, values, language), community (stability, character, services, and facilities), and wellbeing [36]. DW-hybrids can address recognition and procedural justice for marginalized groups by identifying and deploying DW-hybrids in underserved communities to reduce siting harm. The goal is to promote energy independence and community wealth by using renewable resources, such as local or virtual ownership and participation business models.

DW-hybrids can also be an educational asset to the community [3]. Experience with DW-hybrids can prepare a community for future distributed generation development opportunities to invest in long-term community resilience.

Target population identification metrics can outline existing inequities and population disparities. Community characteristics can then be associated with disproportionate outcomes (benefits and burdens) through metrics. Example metrics are energy affordability through energy burden among households, Social Vulnerability Index, presence of toxic facilities, severe storm exposure, percentage of eligible customers served by financial assistance programs, percent of population in mobile homes, or number of power outages over a certain timeframe. Metrics under recognition and procedural equity should also evaluate how accessible projects are to communities, especially those most heavily impacted by climate change [6, 36]. Project impact metrics can assess ease of access to participate meaningfully (e.g., thoroughness of public-facing communication; recurrence of community meetings; ease of submitting public comments; or quality of public data), information transparency measures, participatory budgeting and program design, utility penalties for missing equity targets, and staff and decision-maker representation.

3.3 Restorative Justice

Restorative justice, like the principles of transparency and accountability, does not have a unified definition but instead captures different practices centered around repairing harm and relationships arising from energy decision-making outcomes [36]. It involves addressing inter- and intragenerational inequities, creating long-term sustainability, and establishing responsibility as principles. Due to the nature of restorative justice, it is really the duty of those who have inflicted the harm (e.g., decision-makers, project developers, and energy system practitioners) to lead implementation of this tenet to embody the corresponding principles.

DW-hybrids have the potential to address inter- and intragenerational inequities by rejuvenating rural areas that may have been affected by economic marginalization and population decline. Job creation can help repopulate areas with large out-migration rates, and with DW-hybrid project lifetimes upward of 20–25 years, it necessitates a long-term workforce capable of maintaining the technology (e.g., good, long-term jobs encourage people to stay in rural areas). The willingness of communities to agree to projects is influenced by how their local history is embedded in wider social, economic, and policy contexts.

Creating sustainability can involve using preventive measures to avoid injustices that may arise in the future and outlining how they can be repaired. Environmental impact assessments (EIAs), often used in compliance with the National Environmental Policy Act (NEPA), follow a similar model to the restorative justice process, and a well-executed EIA can be used as a preventive tool in the restorative equity process.[9] The NEPA process overall encourages responsible stewardship of the environment. EIAs evaluate the environmental consequences of a project prior to the decision to move forward and require mitigation plans to be in place before harm is done. This process involves a form of public participation and documentation of decision-making by allowing comments from people within and outside the project area and requiring those

[9] EIAs are required under NEPA if a project creates an action that may significantly affect the quality of the human environment. Proposing any federal action triggers NEPA, including federal jurisdiction and associated permits, federal funding (in whole or in part), projects on federal land or affecting federal facilities, continuing federal actions with effects on land or facilities, and new or revised federal rules, regulations, plans, or procedures [43].

comments to be addressed by those administering the project. As a restorative justice tool, EIAs recognize land and treaty rights, add local power to the decision-making process, and emphasize bringing lasting positive gains to the environment and community near a project [36]. Best practices on EIAs vary by federal agency, but general guidance can be found from various universities and training groups., such as Shipley Group and Rutgers University. EIAs may add to project time and cost; however, the mitigation of harm and the involvement of other entities would make for better long-term success of projects.

Establishing responsibility aligns with the principle of accountability. The subtle difference is that responsibility is task-oriented, and accountability is how one takes ownership over results. Decision-makers should acknowledge equitable and democratic governance failures and create mechanisms to prevent them. Obtaining social license to operate throughout the operational lifespan of the project is an example of establishing responsibility and can ensure ongoing approval of the project by affected communities.

Metrics under restorative equity are difficult to define because it is hard to quantify restorative activities intended to restore balance, heal relationships, and shift power. The primary measurement approach is qualitative best practices, such as shifting away from traditional views of power, ownership, and growth; not placing profit over people; and healing our relationship to the land, water, and air [36].

4.0 A Suggested Equity Framework

Though there are not any comprehensive templates for analyzing equity impacts specifically for DW-hybrid systems in rural areas, there are technology-agnostic equity resources that provide guidance on measuring and implementing the equity tenets [36, 40, 41]. This section presents a framework built on these technology-agnostic resources to evaluate and define equitable outcomes for potential DW-hybrid projects. The Energy Equity Project Report is a framework from the University of Michigan with 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 [36]. It includes a succinct numerated process for integrating equity into energy projects. The Justice in 100 Metrics toolkit offers a framework composed of equity indicators (quantitative measures of equity) and utility actions (steps utilities can take to advance equity) [40]. Heffron and McCauley, two scholars whose work is foundational to energy justice literature, created a phased approach to apply energy justice to decision-making in the project lifecycle [41]. To design a framework for this report, we recognized the approaches in all these resources have three core steps that can be adapted into a framework for DW-hybrid systems.

The framework for DW-hybrids focuses on a bottom-up approach of matching project solutions to needs by first identifying community equity factors and baseline conditions, then using the tenets to identify equity opportunities relevant to the community's needs. The hope is that the framework will help project developers conduct energy equity assessments for DW-hybrid systems that are informed by technical, community, environmental, and cultural needs.

To meaningfully evaluate needs around a potential project site, energy equity assessments should characterize existing inequities, challenges, and factors specific to the communities surrounding the site. The term "energy equity factor" in this work is used to define a feature that helps characterize a rural load and impacts the accessibility, affordability, and quality of energy in the potential project area. Equity factor is not a term from literature, but instead our term to define elements that contribute to energy inequities. Examples of equity factors for rural loads include:

- Regional characteristics
- Load characteristics
- Infrastructure quality
- Population density
- Geographic landscape
- Wind resource potential
- Land use
- Air pollution
- Climate change risk
- Poverty statistics
- Workforce availability
- Economic sectors
- Resilience needs
- Livelihood characteristics
- Ownership models
- Energy cost
- Energy quality
- Energy supply
- Reliability and resilience
- Access to resources
- Sound and visual pollution
- Safety
- Incentives and mandates
- Health impacts
- Property value
- Market structure
- Tariffs
- Community structures
- Political structures
- Ethnic and racial composition
- Age and sex distribution
- Education composition
- Population size and growth
- Disadvantaged status

4.1 Framework Steps

Step 1 of the framework is to characterize the community. Here, the goal is to establish baseline conditions using equity factors to understand equity issues the community may be facing. In addition, any community desires for project impact should be documented in this step. Target identification metrics will be useful to capture descriptive analytics on impacted populations. Both historical and present issues should be considered. There are economic drivers and natural hazards that influence inequities. Local resistance factors such as land-use changes, inadequate economic incentives, non-inclusive planning processes, lack of local ownership, and health impacts are also unique to each community. This step utilizes principles from recognition and procedural justice to understand what has shaped marginalization and prevented meaningful and fair participation in energy projects in the past.

The next step develops solutions to the inequities and challenges identified in Step 1. Assuming the project scope and technical capabilities are known, the focus of Step 2 is to pair the potential equity activities from a DW-hybrid system to community needs and desires. Activities can span energy services, economics, capacity building, human health, environmental, social, cultural, and community well-being Technical and social science experts can help point out potential project-specific equity activities, but communities should lead optimal solution identification. Achieving energy equity should focus on providing energy services that foster community capabilities. Within this step, it is useful to align the pairings of equity actions to community needs with the principles of energy justice. Through application of the principles, this step identifies opportunities to alleviate inequities. Equity prompts in the Energy Equity Project Report by the University of Michigan can help foster a mindset for how each group of actors can advance equity [36, p. 17]. Distributive and procedural justice are the primary tenets used in this step since project benefits are being defined.

Following the identification of activities to advance equity, Step 3 should set equity targets, considering whether the approaches in Step 2 can be measured quantitatively or qualitatively, and select metrics as appropriate. The spreadsheet in Section 1.0 includes example metrics for project impact assessment and investment decision-making.

Community and energy end-user ownership models can use this framework to match their needs to system capabilities. For DW-hybrid systems with utility or third-party owners, this framework should include community-led decision-making along with a transdisciplinary approach. Multiple disciplines can participate to assess issues and compare solutions, but the characterization of energy justice needs, and solution development should be co-designed with the communities impacted by the system. For instance, participatory, historical, ethnographic research, and other social science methods can enhance Step 1 (community characterization), and technical expertise can aid Step 2 in evaluating project feasibility. Figure 2 summarizes the three steps in the equity assessment framework. Step 3 reflects the distributive justice tenet because measurement is used to evaluate the distribution of benefits and burdens.

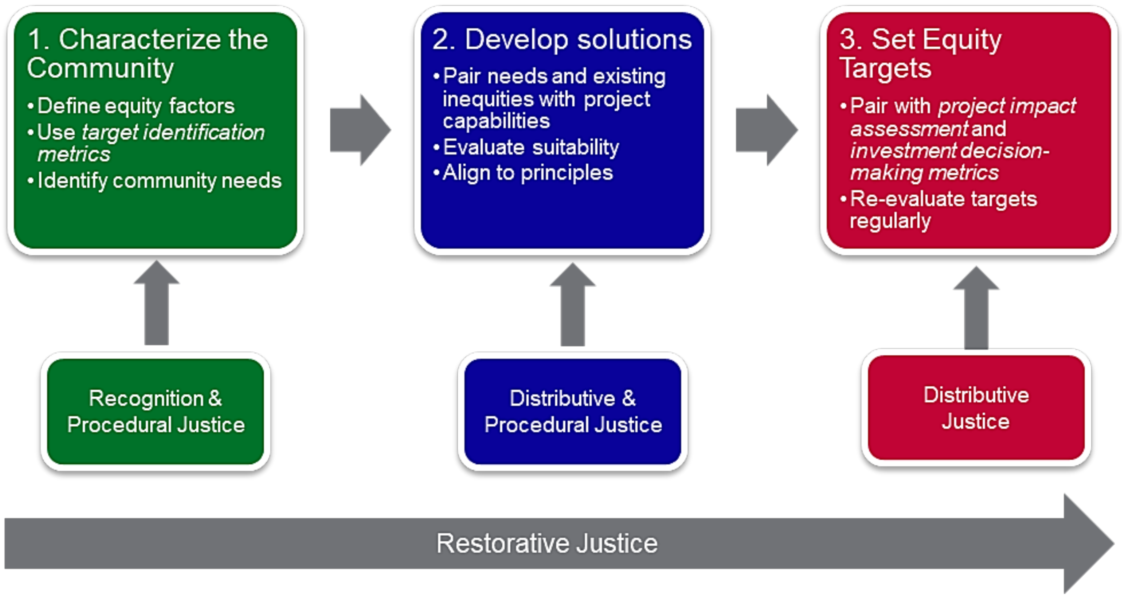

Figure 2. Summary of the equity assessment framework. Restorative justice aims to repair the harm done and is enabled throughout the assessment process.

4.2 Example Framework Application

To demonstrate application of the framework, the PNNL team considered a hypothetical case: a member-owned Alaskan electric cooperative that seeks to provide additional local energy generation via a front-of-the-meter DW-hybrid system in a remote Alaskan city on an isolated grid. The details and analysis below are arbitrary, used illustrate the framework's application, and not intended to represent any current or past DW projects.

Step 1: Characterize the Community

The following information can be gathered from the U.S. Census 2020 American Community Survey [42], information from local government and state websites, the Environmental Protection Agency's Environmental Justice Screening and Mapping Tool, the Climate and Economic Justice Screening Tool (CEJST), and the Social Vulnerability Index from the Center for Disease Control and Agency for Toxic Substances and Disease Registry. For an actual framework application, additional characteristics should be gathered from the community members, such as interest in other DERs and critical service gaps. Applying the target identification metrics to the cooperative's service territory can help further evaluate how equity factors, like homeownership and health, may be intertwined with energy needs.

Regional Characteristics: The rural city is in the western part of Alaska, along a river. It is a first-class city, meaning it must have at least 400 permanent residents and operate under general law. Under first-class status, state law defines powers, duties, and functions of the legislature.

Livelihood and Economic Sectors: There are Native villages in the area that maintain a fishing and subsistence economy and lifestyle. Additional economic sectors in the area include government, business services, and healthcare.

Population Size and Growth: There are under 1,000 residents, and the population is expected to stay steady for the next ten years.

Demography: Racial makeup is over 90% Native American, with the remainder being two or more races, white, or Native Hawaiian and Pacific Islander. Median age is under 25 years.

Poverty Statistics: Average earnings per year is well below the national average, across all demographics and genders. The overall poverty rate is over four times the national average. Unemployment is five times the national average. Rate of home ownership is consistent with the national level.

Air Pollution, Climate Change Risk, Disadvantaged Status: Lead paint exposure is at the 65th percentile; air toxics are in the 33rd percentile; diesel particulate matter is in the 70th percentile; wildfire and flood risk is in the 80th percentile. The Social Vulnerability Index, which measures a community's ability to prevent human suffering and financial loss in a disaster, is 0.56 which is considered medium to high. CEJST classifies the city as disadvantaged due to high energy cost (90th percentile), low-income population (91st percentile), multiple health indicators, low median income, high unemployment, and particulate matter in the air.

Energy Supply: The grid is isolated from any outside transmission system. It includes a diesel power plant. A nearby reservoir provides water and is treated by waste heat from the power plant.

Infrastructure Quality: The community has a few miles of seasonal-use road. There is a single grid interconnection point to the community's airport. Most homes in the city have complete plumbing and are connected to the piped water and sewer system. Emergency services have access to the river, but limited highway and air access. The nearby river is impassable during the winter.

Reliability and Resilience: The community has experienced several federally declared disasters in the past 15 years. In addition, there have been winter storms, floods, fires, and a sinkhole in the same period.

Geographic Landscape: Tundra interspersed with boreal forests and weather patterns of long, cold winters and shorter, warmer summers place the community in a transitional climate zone.

Energy Cost: Energy prices for electric power, gasoline, and diesel (heating fuel) are among the highest in the nation. Barge and aircraft supply fuel and food resources.

Incentives: The city is eligible for significant government assistance considering the rural and remote location, predominantly Alaskan native population, and heavy dependence on diesel and gasoline.

From these baseline conditions, there are at least three energy inequities present: high energy burden due to energy costs, poor energy access due to limited passageway to modern energy services, and high energy vulnerability due to increased exposure to disaster events. Poor energy resilience is also a byproduct of energy vulnerability. These inequities impact community resources, finances, livelihood, and safety. Disaster events have cut off road access, burned thousands of acres of wilderness, contributed to poor air quality, deterred access to electricity, and threatened residential safety.

Step 2: Develop Solutions

A DW-hybrid system in the city could generate electric power from a renewable resource to reduce the local dependency on fuel oil. Because of the size of the local grid and consequent demand from the city's prime power plant, there could be a bulk energy service benefit in the form of fuel cost savings that would otherwise operate on-site diesel generators. There is also the potential to provide renewable energy certificates, ancillary services, and distribution upgrade deferrals.

Energy storage would provide load following and ramping support by controlling the dispatch strategy of the diesel generators and turbines. This would allow less reliance on the diesel generators. The technical project benefits that may accrue to the Alaskan electric cooperative would align with the principles of affordability and availability because they will reduce electricity cost, improve energy quality, and increase energy access for customers.

Step 1 highlighted additional needs in resiliency. A DW-hybrid system could enhance the ability of the city to respond to, withstand, and recover from adverse situations that lead to outage events. Without the DW-hybrid system, an outage could occur from a disruption in the diesel fuel supply, through equipment failure, or an adverse event like a winter storm. If the annual fuel supply to the city were unable to be delivered, outages would occur until the point that additional fuel could be delivered. With the DW-hybrid system, there can be more adaptation after disaster strikes, leading to improved resiliency.

The DW-hybrid system could also create jobs in operations and maintenance of the turbines. Expansion to a sector outside of the traditional fishing and subsistence economy could spur economic growth for the city. Clean, reliable electricity will improve quality of life, avoid harmful emissions, and provide more electricity for heating and water treatment, leading to improved health outcomes. This has the possibility to spur an increase in life expectancy and median age. Collectively, addressing these needs aligns with the principles of sustainability, responsibility, and availability.

Selecting the location of the turbine should consider human-environment interaction, specifically the viewshed, noise, and impacts to wildlife. These impacts may be considered burdens by residents and must be equally distributed based on preferences. Disruption to scenic resources may impact tourism and should be considered. Consultation with local Indigenous groups, especially those with subsistence lifestyles, along with experts on the geography, accompanied by formal environmental assessments, should guide turbine siting as well to prevent installation in sensitive ecosystems.

The city may be eligible for the DOE Office of Clean Energy Demonstrations Energy Improvements in Rural or Remote Areas grant, funding from the DOE Office of Indian Energy, and the DOE's state energy programs assistance. These programs further the principles of sustainability and inter- and intragenerational equity by investing in under resourced communities. These target funding mechanisms also advance procedural justice by addressing the systems that create disparities and improving resource access for rural and remote communities.

Step 3: Set Equity Targets

For the solutions mentioned in Step 2, equity targets should be set on all the co-op benefits and elements of value (e.g., ancillary services like load generation and voltage support, improved resilience and outage mitigation, job creation, and reduced NOx emissions from diesel fuel). Impact assessment metrics can track progress toward these targets by telling how well the project has helped the community through avoided energy burden, improved energy quality, outage duration, and workforce impact. The spreadsheet in Section 1.0 lists additional metrics.

Overall, Step 3 should assess whether the implemented solutions are resolving the historical and current energy inequities identified in Step 2 and addressing the needs identified in Step 1. Assessment should be an ongoing process that considers changes and alternative solutions, along with feedback from community members. Metrics will aid monitoring and evaluation of project success. Future equity action should be informed wholistically by assessment results and not metrics alone.

5.0 Conclusion

DW-hybrid system planning should consider the social, economic, and health factors experienced by the consumers of the system. Consumers with rural energy loads are more likely to have a higher energy burden, experience greater grid reliability challenges, and be exposed to more aging and inefficient grid infrastructure than their metropolitan counterparts. Electric cooperatives, technical assistance providers, DW project developers, and technology providers can incorporate the four tenets of energy justice into DW-hybrid system planning using a bottom-up framework. The framework helps determine how a DW-hybrid system can unlock potential for improved energy affordability, power supply reliability, and access to modern, renewable energy technologies. Using the framework will enable the different parties to evaluate and define equity impacts by matching project solutions to community needs. Future work can use the equity content of this report as guidance for a toolkit intended to streamline the adoption of DW-hybrid systems.

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Pacific Northwest National Laboratory

902 Battelle Boulevard
P.O. Box 999
Richland, WA 99354
1-888-375-PNNL (7665)

www.pnnl.gov