INL/EXT-21-65347

Emerging Energy Market Analysis Initiative

November 2021

Methodological Framework

The EMA Team

INL is a U.S. Department of Energy National Laboratory operated by Battelle Energy Alliance, LLC

INL/EXT-21-65347

Emerging Energy Market Analysis Initiative

Methodological Framework

Steven Aumeier and David Shropshire
Idaho National Laboratory
Todd Allen
University of Michigan
Kathleen Araújo
Energy Policy Institute and Boise State University
Christi Bell
University of Alaska Anchorage
Michael Craig
University of Michigan
John Parsons
MIT Sloan School of Management
Tara Righetti
University of Wyoming

November 2021

Idaho National Laboratory
Idaho Falls, Idaho 83415

http://www.inl.gov

Prepared for the
U.S. Department of Energy
Office of Nuclear Energy
Under DOE Idaho Operations Office
Contract DE-AC07-05ID14517

Page intentionally left blank

SUMMARY

Planning and operations of the electric power sector are undergoing radical changes. Climate change mitigation efforts have forced rapid changes to the technology mix. Technologies like wind and solar have experienced rapid growth, while investment in fossil sources has peaked or is declining. These foundational changes are forcing changes to energy systems. Demand-side adoption of electrified technologies, including electric vehicles, is changing load profiles and opening up new avenues for consumer participation in the power systems. The implications of an evolving power system pertain to more than environmental and technical dimensions. Changes to the generation mix and its consequent upstream and downstream impacts such as fuel production have significant and highly concentrated consequences on economies and employment. Shifts towards distributed (or decentralized) generating assets offer the potential to reshape economic and employment opportunities associated with the energy sector across space and socioeconomic groups.

The Emerging Energy Market Analysis (EMA) initiative aims to identify sustainable, regionally acceptable, and high-value energy solutions that are secure and equitable. Unlike short-term, least-cost choices that can narrowly account for traditional options, EMA's focus on emerging energy markets recognizes that new or adapted practices and technologies can alter the frontier of solutions and advance a community's social, economic, and natural pathways. Such change requires a more comprehensive analysis of societal input, resources, capabilities, and infrastructure. These considerations lay the foundation for community decision-making models that are responsive to community values as well as the history and drivers. The result is a community-based decision and engagement model that will be valuable to decisionmakers and developers of advanced and emerging energy solutions, seeking a social license to operate prior to project development.

Page intentionally left blank

ACKNOWLEDGEMENTS

Steven Aumeier and David Shropshire from Idaho National Laboratory, recognize the important contributions from the EMA initiative team members including Christi Bell (University of Alaska Anchorage Business Enterprise Institute); Todd Allen (Nuclear Engineering and Radiological Sciences at the University of Michigan); Michael Craig (School for Environment and Sustainability at the University of Michigan); Tara Righetti (School of Law at the University of Wyoming); John Parsons (MIT Sloan School of Management); and Kathleen Araújo (Energy Policy Institute – Center for Advanced Energy Studies and Boise State University).

Additional contributors include: Temple Stoellinger, Steve Smutko, and Rachael Budowle (all with the University of Wyoming Haub School of Environment and Natural Resources); Javaun Garcia (University of Wyoming student); Steve Colt (University of Alaska Fairbanks, Alaska Center for Energy and Power); Nolan Klouda, Richelle Johnson and Ian Mills (all with the University of Alaska Center for Economic Development); Ruaraidh MacDonald (MIT Nuclear Science and Engineering Department post doctorate), Anna Wrobel (University of Alaska Anchorage student), and Haydn Bryan (INL Nuclear Science and Technology).

All authors and contributors have been collectively referred to as the EMA team.

Page intentionally left blank

CONTENTS

FIGURES

TABLES

Page intentionally left blank

ACRONYMS

BSU	Boise State University
CAES	Center for Advanced Energy Studies
DOE	Department of Energy
EASIUR	Estimating Air pollution Social Impact Using Regression
EIS	Environmental Impact Statement
EMA	Emerging Energy Market Analysis
EPA	Environmental Protection Agency
EPI	Energy Policy Institute at Boise State University
HIFLD	Homeland Infrastructure Foundation-Level Data
IEA	International Energy Agency
INL	Idaho National Laboratory
JEDI	Jobs and Economic Development Impact (model)
MCDA	Multi-criteria decision analysis
MIT	Massachusetts Institute of Technology
NEPA	National Environmental Policy Act
NREL	National Renewable Energy Laboratory
O&M	Operations and Maintenance
OR-SAGE	Oak Ridge Siting Analysis for power Generation Expansion
PAD-US	Protected Areas Database – United States
SMR	Small modular reactor
UA	University of Alaska
UM	University of Michigan
UWy	University of Wyoming
WTA	willingness to accept

Page intentionally left blank

Emerging Energy Market Analysis Initiative

1. INTRODUCTION

The objective of the Emerging Energy Market Analysis (EMA) initiative aims to identify sustainable, regionally acceptable, and high-value energy solutions that are secure and equitable. Unlike short-term, least-cost choices that can narrowly account for traditional options, EMA's focus on emerging energy markets recognizes that new or adapted practices and technologies can alter the frontier of solutions and advance a community's social, economic, and natural pathways. Such change requires more comprehensive analysis that accounts for societal input, resources, capabilities, and infrastructure.

The underlying logic of EMA is that energy choices are locationally based and defined by community values and capabilities, as well as place-based resources and conditions. For example, options for clean and affordable energy in a location with inexpensive hydropower may differ considerably from a remote Arctic community with water limitations. Not only could the natural resources be distinct, but the infrastructure and capabilities to manage them as well. Importantly, distinctions can also exist in how clean or affordable energy is defined by communities.

EMA recognizes that more enduring energy strategies account for local values, input, and opportunity. EMA does so by engaging with communities and other stakeholders to qualitatively develop a value profile, locationally specific/cultural priorities and sensitivities that inform the range of technically and economically feasible choices and related assumptions. Quantitative analysis is informed by these difficult to quantify values. In turn, quantitative analysis can then inform more comprehensive decision-making.

Understanding that energy choices involve complex and multidimensional aspects, EMA brings together qualitative, quantitative, and mixed method experts to analyze value for communities and markets. It does so in a way which recognizes that value may be defined differently by communities and not all priorities may be quantified.

EMA's differentiated capabilities and approach are distinct from technoeconomic ones that are employed by many current lab and university energy centers. The EMA team is composed of a multidisciplinary group of experts who collaborate to help stakeholders and decisionmakers understand the trade-offs and underlying values associated with future energy choices, and to make informed decisions. With a focus on emerging energy markets, including transitions from fossil to zero net-carbon systems by 2050, the EMA team includes sociotechnical, legal, economic, environmental science, policy, business, and engineering experts that work to identify robust energy strategies to support policies that optimize at the intersection of social, environmental, economic and technical dimensions.

1.1 Value-Informed Decision Framework

The EMA team evaluates the societal, resource, and infrastructural dimensions of energy system choices, with a framework for community engagement in the associated decision processes. Such considerations include, without limitation: (1) community preference, capabilities, and socioeconomic profiles; (2) community cohesion factors; (3) historic analysis of energy decision processes and outcomes; (4) understanding the physical and sociotechnical playing fields in which a project may be developed; (5) social/anthropological analysis of energy preferences; and (6) analysis of local, state, federal, and/or international regulatory/policy frameworks. Analysis of these aspects is done to reveal underlying, community energy preferences and to identify current needs that are either unmet or met with difficulty, systems deployment needs, and technological as well as systems attributes that are preferable or necessary based on social considerations (e.g., local form of management). These considerations lay the foundation for community decision-making models that are responsive to community values and aims as well as the history and drivers. The result is a community-based decision and engagement model that will be valuable to decisionmakers and developers of advanced and emerging energy solutions, seeking a social license to operate prior to project development.

Specific to markets, the EMA team performs multivariate, multidisciplinary value analyses to create a basis for deployment considerations and to evaluate the potential value for varied markets. Attributes of "value" are analyzed and compared qualitatively and quantitatively to the baseline conditions. The value of a market application is a complex intersection of system attributes that may address a given community or market's needs. Examples of system attributes that might influence value differently in distinct profile market contexts include, but are not limited to, the items listed in Table 1.

Table 1. Example system attributes.

Availability (timeline for development)	Simplicity, adaptability, and scalability
Affordability (capital finance, operations costs) and maintainability	Safety and security
System predictability and reliability	Resilience to disruption
Environmental sustainability and impact (used fuel management and transport)	Community appropriateness
Economic development potential	Self-determination/local governance

The EMA team evaluates several energy solutions for each profile market, creating a basis for understanding how the elements of value "stack-up" in creating value-informed solutions that consider social, environmental, economic, and technical dimensions. Outputs from the study may be used as the basis to inform policy and support government and industry in consensus building and community-driven future facility siting processes. The EMA framework for value-informed decision-making is illustrated in Figure 1.

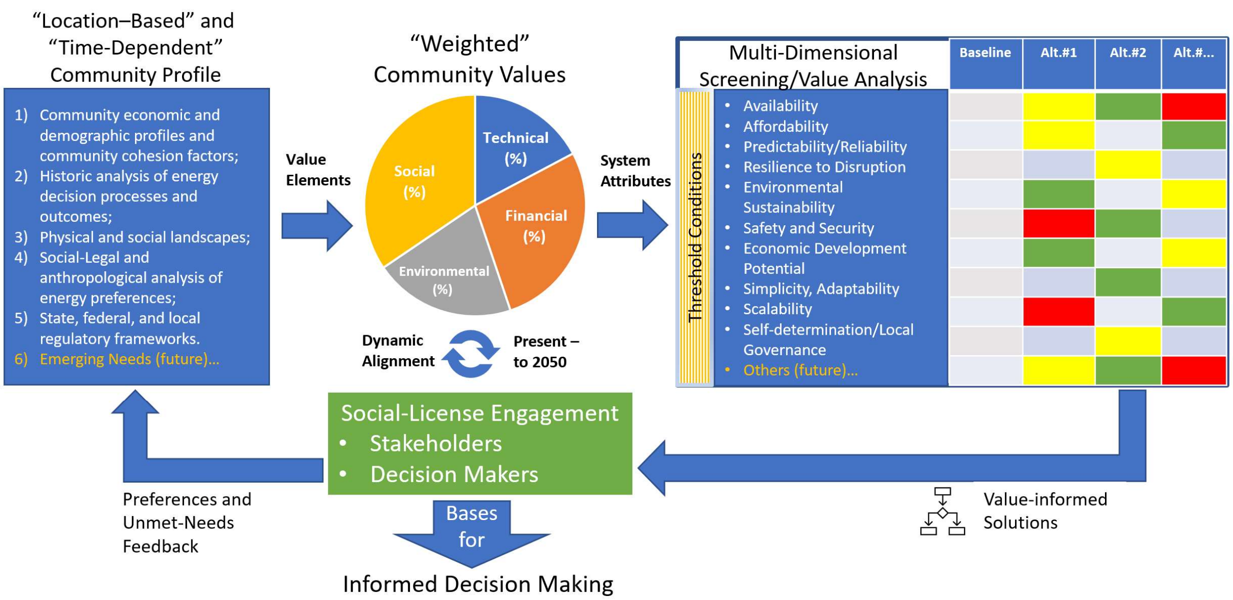


Figure 1. Framework for value-informed decision-making.

This recognizes that the decision process should cycle iteratively between alternatives and explore the values (i.e., social, technical, financial, and environmental) represented by the stakeholders and decisionmakers. In the conceptual EMA framework, the "weighted" community values are not preset values but instead may vary over a range, dependent upon the community values. When the analysis of alternatives is conducted, the "costs" and "trade-offs' needed to support the defined value set becomes better defined. This provides grounds in the decision analysis for negotiation between stakeholders, value revision, and compromise toward finding common ground. While any segment of the framework can be used for analysis, the importance of the value identification process to decision-making is recognized.

Value identification, if done with collaborative decision-making, engages stakeholders in collectively making a choice from the alternatives before them (Smutko 2021). The process is formal, typically consensus-oriented, and deliberative in which participants define the decision opportunity or problem to be resolved; identify the interests and fundamental objectives of each party; generate alternatives that can more or less satisfy the interests of each party; evaluate each alternative based on objective criteria; negotiate the trade-offs among each alternative; and reach agreement (Smutko 2021). A key to successful group decision-making is cycling iteratively with a facilitator resolving differences and finding common ground (Smutko 2021).

This draws on negotiation, mutual gains concepts, and consensus building that is highlighted in Figures 2 and 3. Iterative engagement in decision-making with multiple methods that mutually inform is how a more locationally relevant and value-driven decision-making may be completed (Araújo and Shropshire 2021).

INCREASING IMPACT ON THE DECISION

	INFORM	CONSULT	INVOLVE	COLLABORATE	EMPOWER
PUBLIC PARTICIPATION GOAL	To provide the public with balanced and objective information to assist them in understanding the problem, alternatives, opportunities and/or solutions.	To obtain public feedback on analysis, alternatives and/or decisions.	To work directly with the public throughout the process to ensure that public concerns and aspirations are consistently understood and considered.	To partner with the public in each aspect of the decision including the development of alternatives and the identification of the preferred solution.	To place final decision making in the hands of the public.
PROMISE TO THE PUBLIC	We will keep you informed.	We will keep you informed, listen to and acknowledge concerns and aspirations, and provide feedback on how public input influenced the decision.	We will work with you to ensure that your concerns and aspirations are directly reflected in the alternatives developed and provide feedback on how public input influenced the decision.	We will look to you for advice and innovation in formulating solutions and incorporate your advice and recommendations into the decisions to the maximum extent possible.	We will implement what you decide.

Figure 2. Public participation (iap2 n.d.).

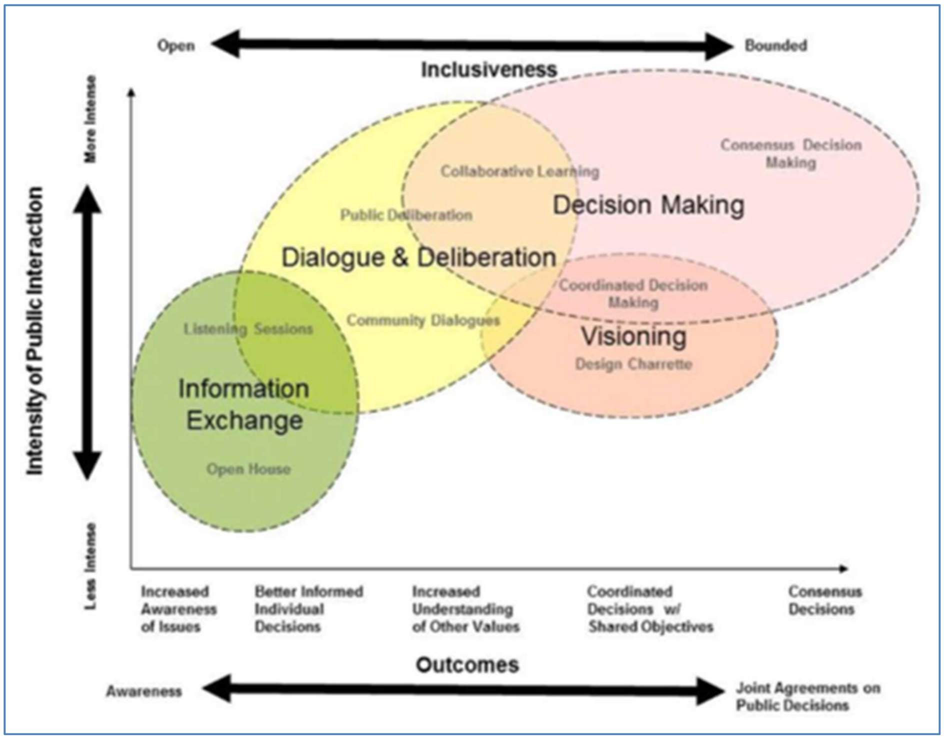


Figure 3. Public involvement (Smutko 2021).

1.2 Timeliness of the EMA Initiative

The sophistication of the analysis provided by EMA is needed now more than ever. Valuing and understanding social preferences upfront mutually informs broader assessment more efficiently.

- Societal demands for energy are shifting. Energy market transitions are driven by conflicting demands for clean, reliable, or affordable energy, local and regional economic development (jobs), mitigation and adaption to climate change, innovations in energy resource extraction and generation, competition, shifting populations and demography, and equitable distribution of the benefits of energy production, delivery, and use.
- Traditional energy strategies are being rapidly replaced by options that are seen as more competitive or favorable. Evolving energy technologies, such as natural gas with fracking and low-cost renewables, are altering the economic choice, viability, and social appropriateness of existing resources.
- Regional, national, and global economies are beginning to experience profound changes in their energy playing fields, structures, economies, and approaches to energy utilization that affect and are affected by energy policies, economics, and infrastructures for decades to come.
- Regional asymmetric markets are increasingly complex and differentiated from energy market transitions experienced in the past. For example, states like Wyoming and Alaska that have been heavy exporters of fossil fuels are experiencing the economic impacts of shifting demand with stranded assets that could result in premature write-downs and operating losses. In such cases, new energy and economic development strategies are urgently needed.

The EMA analytical framework changes the paradigm for advanced energy systems by providing the means to identify, understand, and deploy new technologies in emerging energy markets.

- Internationally, emerging markets will be critical to economic, social, and environmental stability. Global population increases, particularly in new and emerging economies such as in South America, Southeast Asia, and Africa, will require adapted energy paradigms to serve their rapidly increasing populations. These markets are key to U.S. interests. Access by these regions to clean energy is vital for the future health and well-being of their citizens.
- Energy systems choice and decisions should transcend technical assessment. Energy source choices, based solely on technocratic considerations, are increasingly risky. Including multidisciplinary understanding of sociotechnical and economic assessments, with perspectives from sociotechnical, geographical, cultural, and regulatory domains, creates a more inclusive and lower-risk approach to energy choice, which, in turn, may increase social acceptance or license.
- The need to define clear strategic adoption paths that may include renewables, nuclear, carbon capture, and energy storage as part of low-carbon energy systems is more widely apparent. The EMA initiative focuses on emerging markets, yet the insights gained can provide a window to broader trends in U.S. and global markets. This knowledge is important to the adoption of new technology paths in future power markets and non-electric applications. For example, international competition for designs and economic shifts in northern latitudes (e.g., Arctic and northern Canada) could influence national and regional security and influence. Strategic planning, informed by EMA, can position advanced energy solutions in the transition to a clean energy portfolio.

1.3 Significance Across Scales

> *"For the clean energy transition to succeed it has to be just – or there will be no transition. Individuals and communities that are dependent on fossil industries today must not be left behind tomorrow. Our recommendations and the many great cases from all around the world clearly demonstrate that people-centered clean energy transition is not only possible – it is already happening. I hope this will serve as inspiration to others."*
>
> *Minister Jørgensen, Denmark's Minister of Climate, Energy and Utilities (IEA, 2021)*

A paradigm shift is underway, driven by a confluence of changes to the energy landscape from security threats to highly interconnected energy systems, a changing climate, global population growth and energy poverty, mass migrations creating new megacities, and socioeconomic asymmetry. These pressures are shaping energy system transitions in developing economies as well as in industrialized economies. Today's approaches for energy are shaped by decision-making and infrastructure from decades ago, largely driven by post World War II growth and available technology at the time. Looking forward, emerging markets have the opportunity to create new system architectures and deploy technologies that are more resilient, environmentally friendly, and adaptable with higher value over the long-term (e.g., co-benefits), not simply the lowest cost option. Additionally, a people-centered approach is critical to the clean energy transition (see textbox), according to Minister Jørgensen in recommendations to the International Energy Agency (IEA) Global Commission on People-Centered Clean Energy Transitions. IEA's findings prioritize design transitions that maximize the creation of decent jobs, ensure that the policies enhance social and economic development, incorporate gender equity and social inclusion, and involve the public through participation and communication, along with other recommendations (IEA 2021).

Global emerging markets and domestic market transitions can shape energy investment and partnerships for decades to come. By establishing frameworks to understand the complex sociotechnical and economic attributes of a particular locational choice, the capacity is developed to better inform stakeholders on energy decision-making that is suited for their needs and priorities.

The EMA initiative meets this challenge by representing the forward thinking needed by regions, communities, and their markets. EMA researchers consider long-standing fossil programs now facing uncertain energy futures. They also work with utilities that must define future low-carbon energy portfolios and how they will achieve zero carbon by mid-century. Technology considerations may include renewable sources (wind, solar, hydro, geothermal, and others), advanced nuclear technology including small modular reactors (SMRs) and microreactors, energy storage, and carbon capture, utilization, and storage. EMA researchers may also work through the Department of Energy and Department of State to collaborate with developed countries interested in evaluating new energy pathways and seeking a holistic understanding of options and also with developing economies grappling with options to eliminate energy poverty and raise their standard of living.

The elements of the EMA framework are described in this report along with illustrations of the methodology based on specific analysis conducted on profile markets described in Section 2.

2. COMMUNITY PROFILES AND VALUES

In conjunction with EMA's value-based and locationally defined focus, analysis is provided by developing a library of prospective emerging markets and energy systems-in-transition through profiles markets or test cases. The purpose is to understand the distinguishing characteristics that should be considered in developing/evaluating the community value proposition (costs and benefits) and the system attributes within the framework for value-informed decision-making. The EMA team identified profile markets or test cases for study as described in the following sections.

2.1 Profile Markets

Profile market analysis serves as a guide for more in depth studies at a particular location. Profile markets are studied to gain insights into the markets' structural elements, their future energy needs, and other “market attributes” that describe the behavior characteristics. Studies of the profile markets offer lessons and provide a guide for energy system deployment in various markets—both domestic and foreign. Selected profile markets generally share the following characteristics:

- Heavy dependence on fossil energy sources for electricity, heat, and transport
- Local and regional economies heavily linked to fossil energy sources
- Acutely vulnerable to emerging global trends (e.g., climate change, migration)
- Underrepresented markets that are economically and/or socially marginalized
- Potential early adopters of emerging clean energy technologies (i.e., renewable sources, energy storage, nuclear microreactors, and SMRs).

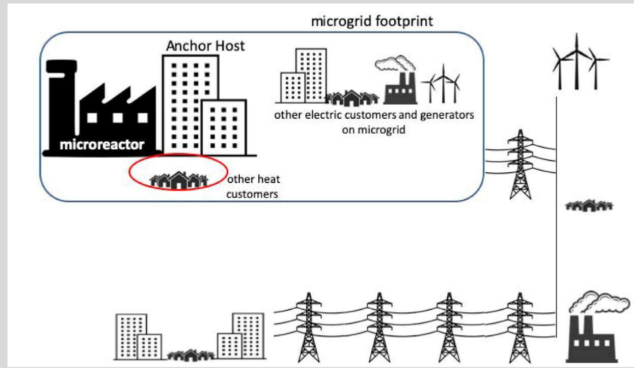
To date, potential emerging markets have been studied in Alaska and Wyoming, using current baseline energy landscapes (e.g., market supply/demand and infrastructure) and associated structural, social, and economic systems. These markets are assessed for their existing energy security and opportunities for improvement and generally reflect specific trends or conditions. The following illustrates existing work that compares a range of energy technology options with microreactor technology in a number of profile markets.

Profile markets are used to describe how regions with differing overall economic development approaches can achieve energy and economic resiliency. Initial, illustrative profile markets include:

- **Profile Market #1:** Government/Commercial Shared Energy Center. Includes an anchor host (e.g., a military base) connected into the regional electric grid;
- **Profile Market #2:** Mineral Extraction and Processing Energy Center. Includes an off-grid mining center in a rural-remote location (e.g., Mining districts within the Northwest Arctic region of Alaska);

Example: Profile Market #1, Grid Connected

A microreactor is one potential generator among natural gas, diesel, wind, solar, pumped hydro, and batteries. Peak Load: 483 MWe, 1.59 GW$_{th}$



- **Profile Market #3:** Native Lands. Consists of an area of land tenure governed by a federally recognized Native American tribal nation (e.g., Tribal Lands in Wyoming and Native Alaskans) seeking increased sovereignty, independence, and self-sufficiency.

The study of profile markets is illustrative, as there is no specific project under consideration.

2.2 Profile Market Analysis

Profile market or test case analysis captures the broad benefits of an energy technology on a surrounding community. Notwithstanding the importance of economic solutions, as governments and industry increasingly focus on non-monetary value and public goods, such broad benefits can play a significant part in driving the value proposition of different technologies. Analysis is used to define boundary conditions in deployment and differentiate the importance of energy system attributes. Locational profiles for profile markets are characterized with baseline data, including the population, industry, geography, income, energy use (hourly), energy subsidies, source, etc., that describe the current conditions and future energy planning that may include:

- Assessment of feasible pathways for decarbonization including technology advancements, changes in practices, and economic development options in a global context
- Economic development preferences from the local community and/or regional development plan(s)—identifying additional projects requiring access to affordable energy.

Research on profile markets was conducted through a review of secondary data, including U.S. Census data; tribal economic and lands data; Department of Labor data sets (the U.S. and state); energy cost data from federal, state, and utility data; and historical cultural, climatic, and geological data from web searches, reviewing of community comprehensive planning documents, reliance on past work conducted in the representative regions, and local community interviews.

In the analysis of profile markets, data from existing communities that reflect prospective adopters is used to inform the evaluation and guide the development of the frameworks. These cases provide researchers an opportunity to evaluate and compare decision processes for communities with various attributes, including historically marginalized communities, energy transition communities, and those who lack access to an energy grid system.

In the University of Alaska Anchorage study for the U.S. DOE Microreactor Program, a summary of the community or regional profile was completed for representative communities. The community profiles included the following elements: Background and Economic Drivers; Islanded Community Description and Drivers; Cultural, Climatic and Geological Attributes; Community Cohesion Attributes; and a review of Energy Preference and Utility Providers. The community profile development team also worked closely with EMA team researchers to obtain necessary access to energy use databases. (UAA 2020a; 2020b).

3. SOCIAL AND CULTURAL SUITABILITY AND VALUE INDICATORS

In addition to economic assessments, the physical, sociotechnical, cultural, and legal context guides emerging energy technology market analyses. These factors are critical to understanding multiple value

Who are Stakeholders?

Generally speaking, participants in a community-informed decision process are those who:

1. are affected or potentially affected by the decision
2. can affect a decision or its implementation
3. have the authority and resources to carry out the decision.

Such a broad definition of stakeholders will incorporate people and organizations who are located both within and outside the emerging market boundary.

Stakeholders who will be affected or potentially affected by a decision about energy production are those who directly benefit from the decision as well as those who shoulder any of its costs or externalities. Most of the people and organizations in this category are those located in the project area and may include:

- residential, municipal, regional, and corporate customers
- individuals and organizations, whether utility customers or not, who may be positively or negatively affected by the decision such as those whose livelihoods are altered by a change in the means of production and distribution of electricity, including NGOs, interest groups, etc.
- energy utilities or other entities that produce or distribute electrical power to customers such as retail electric service providers and electric distribution utilities.

The interests of stakeholders in this category may be represented by a variety of organizations, firms, or corporations. Utility customers may be represented by a utility commission or a public service commission, as well as grassroots organizations such as neighborhood associations. Non-customers may also be represented by formal organizations and interest groups, or they may have no formal association and represent only their own interests.

Stakeholders who have the potential to affect a decision or its implementation include people and organizations who have sufficient power and influence in the decision-making process to alter or even block a decision. Power and influence can come from those with positional power such as elected bodies (i.e., state legislatures, municipal councils, tribal councils, and appointed bodies such as industrial siting boards, game and fish commissions, and so forth). Other organizations that can affect the outcome of the decision are those who can influence people with positional power and include nonprofits and lobbying organizations such as local, regional, and national environmental NGOs, taxpayer associations, and economic development organizations, among others. In indigenous communities, stakeholders, such as elders, may also serve as decision gatekeepers.

elements and the relative weight that communities, stakeholders, and regulators may place on each. Further, information gathered through the assessment of these community attributes will be critical to understanding the decision processes of host communities and designing an appropriate strategy for community engagement. These indicators are important to assessing the suitability of an emergent energy technology to a given community and shaping and determining opportunities for other value attributes. As such, cultural, sociotechnical assessments are critical to both threshold determinations of appropriateness as well as place-based and value-oriented assessments.

3.1 Community Interest and Appropriateness

Communities make choices about their energy futures based on factors that transcend the technical merits of each option. Communities include people with both shared and heterogenous—or even competing—values and interests (Agrawal and Gibson 1999; Berkes and Ross, 2013; Cohen 1985; Dove 2006). When considering appropriateness here, EMA draws on place-based community concepts that include people grounded in locations, social connections, norms, interests, and natural resource bases (Amit and Rapport 2002; Berkes and Ross, 2013; Cohen 1985), as well as non-local stakeholders in specific social-ecological and energy contexts. The anthropological "community of practice" concept, which reflects people forming a community through shared engagement in activity over time, can account for non-local stakeholders (Eckert and McConnell-Giner 1992; Lave and Wenger 1991). Both place and practice concepts of community inform appropriateness of energy options in specific social-ecological contexts with a range of local and non-local stakeholders.

Determining *community interest and appropriateness* involves community members assessing the consequences of their choices with respect to such factors as the impacts to the physical and human environment, the compatibility of existing legal and regulatory frameworks, and the congruity with social and cultural norms and values. In addition, the integration of and interactions across social and technical choices should be taken into account. Importantly, community appropriateness and public energy or sentiment is interrelated with and a function of other value elements in the emerging market analysis model, including:

- Availability and affordability
- System predictability and reliability
- Environmental sustainability
- Economic development potential
- Simplicity, adaptability, and scalability
- Safety and security
- Resilience to disruption.

Moreover, the process for making these energy choices should be inclusive, open, and transparent, not least because a non-transparent process could challenge the ability to implement adoption of energy technologies due to public or community backlash. The process of information gathering and community engagement, either voluntary or as part of formal legal processes requiring public participation, may be an important mechanism for a project's potential to develop a social license (Stoellinger, Smutko, and Western 2018).

Social license is an evolving concept that is gaining acceptability by nongovernmental organizations and some private corporations, particularly the mining sector (Owen and Kemp 2013). Social license is voluntary and often informal and is granted by a community based on the opinions and views of stakeholders. It is often tied to a place or a community.

The term "social license," or "social license to operate," generally refers to society's or a local community's acceptance or approval of a firm's activities or operations. (Yates and Horvath 2013).

In the world of globalization and increasing scrutiny and mobilization of local voices, companies have come to understand that negative community impacts can damage their reputation, or result in loss of operation time and profits, and can put future investment opportunities at risk. Companies and their investors are increasingly recognizing the need to secure a social license to operate is a precondition to development (Morrison 2014) and are extrapolating the concepts of social license to more complex social structures with a diverse array of constituents, a web of relationships and networks, and varying political jurisdictions and decision authority.

Social and cultural indicators will inform community perceptions and relative importance across the spectrum of the elements of value. Project developers should research past and current energy choices and work with host communities to learn about the cultural appropriateness of new technologies. Appropriateness may be based on cultural values or defined by past engagement with energy development, either positive or negative. In addition to being a value element in and of itself, social and cultural perceptions of energy technologies may be core to development and ultimately, community acceptance.

Approaches to achieving social license include direct, one-on-one consultation and engagement as well as information sessions, open houses, workshops, and other forms of engagement (Yates and Horvath 2013). At its core, social license to operate involves a significant degree of meaningful dialogue between a project proponent and the community in the planning and operation of the industrial activity. Dialogue in this context is face-to-face interaction with multiple parties (i.e., collaboration) that encourages long-term relationships between industry and affected communities, and where the firm and affected stakeholders resolve their opposing interests in order to achieve their respective goals.

Collaboration, collaborative decision-making, and collaborative governance define the process and structures of public policy decision-making and management that engage people constructively across the public, private, and nonprofit sectors to carry out a public purpose that could not otherwise be accomplished (Emerson, et al. 2011). A collaborative process involves partnering with communities and affected constituents, engaging in face-to-face discussions to share interests, mutually investigating the issues, and developing consensus-based solutions. Cormick et al. (1996) indicate that in such processes, while participants may not agree with all aspects of the outcome, consensus is reached when they can all "live with" the total package. Yosie and Herbst (1998) note that the increased use of environmental stakeholder processes is reflective of a societal interest in more interactive forms of decision-making. The application of collaborative decision-making processes to energy and environmental issues is well documented (Doern 2005; Keiter and Lindstrom 2011; Nolon 2011; Keir and Ali 2014; Consensus Building Institute 2015).

Historic and contemporary analyses of social and cultural attributes of communities are a critical component of evaluating energy preferences, choices, and suitability related to advanced and emerging energy technologies. Moreover, these analyses provide a baseline from which to further evaluate cultural, economic, and social factors underpinning energy choices and preferences including first adopter fears and quality of life factors.

Despite numerous other value indicators, a culturally inappropriate energy use may fail as a threshold matter based on community opposition. Moreover, cultural and social analyses should evaluate a host community's cultural practices and existing energy development decision processes, including identifying stakeholders and influencers within the anchor community.

Cultural and social data is highly location specific. Project developers can obtain cultural or social background information through the following sources:

- Surveys
- Literature and media review relative to past energy siting
- Case analysis which may include evaluation of historical and archival data, ethnographies, interviews, and field-based participant observation and industrial histories that consist of assessments of historical data and local knowledge of an industry's evolution
- Community meetings and workshops.

3.2 Location Suitability: The Natural, Social, and Built Environment

The location of energy development can significantly impact the regulatory framework, risks, and community acceptance, among considerations. Preliminary analysis of natural, social, and built indicators is necessary to determine variables related to the location of the proposed development or community under study. These variables may inform choices and analyses across the numerous value attributes. For instance, land indicators related to physical geographic features may drive decisions about technology choice, engineering parameters, and suitability. Other indicators, such as the availability of necessary infrastructure, may determine the availability of technology choices. Still other indicators may be interconnected with legal and regulatory analyses, analyses of cultural and anthropological indicators, and may be valuable when identifying key stakeholders and decision makers. Given this, analysis of land indicators should be an aspect of value-attribute analyses of profile markets. The following section provides a brief overview of sample indicators: land ownership, natural attributes, human geographic features, and industrial siting history.

3.2.1 Land Ownership

Assessment of land ownership of the proposed site and surrounding area is necessary to evaluate stakeholder engagement processes, legal and regulatory siting frameworks, and economic value. In this context, land ownership analysis refers to an examination of the current and historic title, use, and ownership of the land on which the proposed project will be built. Preliminary analysis of ownership should identify private, state owned, and federal surface and subsurface interests within the proposed project area in addition to easements, leases, mining claims, and security interests. Examinations should also evaluate the interests, if any, of current and historic users of the land—including identifying potential parties or groups with ancestral ownership interests, cultural ties to the land, or who are currently occupying the land in informal settlements. Many land ownership analyses will include a mix of sovereign/federal, state, tribal, and private ownership.

The results of this analysis may significantly impact the decision processes and the regulatory framework. For instance, a project in the United States involving federal land will almost certainly require NEPA (National Environmental Policy Act) review, including associated public outreach and public comment but may benefit from NEPA coordination and efficiency. Projects involving or near properties of traditional historic or cultural significance may require consultation pursuant to National Historic Preservation Act. Requirements associated with public consultation and environmental analysis may relatedly increase time to development and potential legal challenges, but if done well can facilitate greater community acceptance or local governance. Conversely, a project with a significant amount of private land could face coordination issues among numerous landowners. The results may also impact aspects of other value attributes. Projects near public access and recreation areas may benefit from potential economic development opportunities related to outdoor recreation and suffer from potential public opposition to new project development. As a result, ownership of land is directly linked to other value attributes and siting indicators including:

- Availability and time to development
- Regulatory and legal framework
- Stakeholder identification
- Community appropriateness
- Economic development potential
- Self-determination and local governance.

In most areas of the United States, a preliminary review of land ownership can often be conducted by accessing county assessor records online and using the U.S. Protected Areas Database (PAD-US) database (USGS n.d.). For projects involving both surface and subsurface attributes, it may also be necessary to review the county real property records, district court orders and decisions such as degrees of distribution and probates, and records within the offices of state land and federal land and regulatory agencies. For project including land managed by the Bureau of Land Management (BLM), the BLM Land and Mineral System Report (LR2000) database provides access to information including mineral use authorizations, mining claim recordation, status on land classifications and withdrawals, and legal land descriptions. Project proponents should consider the appropriate buffer zone for analyses based on project specifications and current and historic uses of the surrounding lands. Land registration systems internally differ based on the country. These may be locally or centrally maintained. In all systems, incomplete or inaccurate data may be an issue and surveys may be necessary.

3.2.2 Natural Attributes

Natural attributes, such as land indicators, should include an assessment of the physical geographic and environmental characteristics of a proposed location and surrounding area. Features may include identifications of wetlands and navigable rivers, coastal areas, slope, soil quality, and geologic hazards. Other natural attributes could include biological assessments to identify vulnerable species and sensitive or protected wildlife habitat areas.

These natural attributes may be significantly interrelated with other value attributes such as the regulatory and legal framework and community appropriateness and be important to assessments of site suitability. These factors may relate to the cost or difficulty or construction or necessitate additional conservation, preservation, or permitting. Issues related to endangered species, historic preservation or other environmental factors should be considered within the context of the legal and regulatory frameworks. For example, a project near navigable waters or within wetlands may require additional permitting pursuant to the Clean Water Act; a project within or near a valued view scape or recreational area may face significant public opposition; and communities dependent on subsistence or industries related to wildlife such as salmon fisheries may be less likely to accept a project with adverse wildlife impacts. Additionally, a review of the historic and traditional land uses and land ownership within an area may add to understanding regarding potential community concerns associated with the risks and impacts of development. Natural attributes may be vital to threshold determinations of interest, appropriateness and value-attribute assessment including:

- Economic development potential
- Resilience
- Availability/time to development
- Environmental sustainability and impact

- Regulatory and legal compatibility.

In addition to site visits and mapping software, natural attributes may be determined through environmental assessment processes, which can, in some cases, include biological, archeological, geologic, and cultural assessments. These assessments may be part of required regulatory processes, such as the preparation of an environmental impact statement or environmental assessment pursuant to NEPA, similar procedural environmental statutes under state law, or their international equivalents. Additionally, information on natural attributes may be generated through the Phase I and Phase II environmental site assessment processes. The Oak Ridge Siting Analysis for power Generation Expansion (OR-SAGE) from Oak Ridge National Laboratory and a siting tool developed by the University of Michigan, compile a number of these attributes.

Identification of these natural attributes alone, however, may not fully inform planning, valuation, or decision processes. Emerging market evaluations should also endeavor to understand the value that communities, stakeholders, and regulators attribute to natural features. Through well designed and implemented consultation and engagement with community members and stakeholders (discussed in more detail below) project developers can utilize local knowledge to help identify the natural attributes relevant to the project and also understand how the community views and values these attributes.

3.2.3 The Social and Built Environment

The social and built environment is reflected in human geographic and sociotechnical features that inform value attributes. Analysis of the social and built environment includes infrastructural features, such as power transmission lines, pipelines, mines, oil and gas operations, roads, ports, and electric substations, along with community rules and practices, and potential system dependencies and interactions with societal aims, like resilience or security. Analysis may include industrial history and projected trends. It should also include current and historic uses of land, water, air or infrastructure in the region and zoning that may restrict or facilitate use. These indicators may overlap with indicators in the community economic profiles.

A detailed analysis should include a study of how physical and societal conditions intersect in economic development, resilience, and residential and recreational purposes. It should identify important legal designations, including cross-jurisdictional complexities, identification of sub-state delegations, such as counties and cities, and areas of protected land including public access, recreational, and wildlife areas.

The availability of existing infrastructure will directly impact the potential and suitability of new energy development as well as the economic development potential of the area. Land use designations and sociotechnical factors will not only impact regulatory and permitting processes but will also stakeholder identification. These indicators may impact the following value attributes:

- Economic development potential
- Technology sentiment
- Availability/time to development
- Environmental sustainability and impact
- Community appropriateness
- Self-determination/local governance.

Depending on the regulatory framework and structure of the community of study, data of interest for human geographic and sociotechnical indicators may be located or generated in the following ways:

- PAD-US

- Homeland infrastructure foundation-level data (HIFLD)
- On-site surveys and evaluation
- Case, ethnographic, field-based data (e.g., interviews)
- City or county websites
- Industrial siting and development history.

3.3 Regulatory, Policy, and Legal Compatibility

An understanding of the regulatory, policy, and legal framework is critical to any well-thought energy development assessment, including facility siting and pre-project planning process. Such understanding is even more pertinent to an advanced or emerging energy project. The regulatory, policy and legal framework provides information necessary for the deployment of a specific type of energy technology and for the development of a community/stakeholder engagement process. The regulatory, policy, and legal framework ensures the process complies with all applicable rules and laws and operates within correct processes and under correct assumptions about formal adjudication and approval processes. An evaluation of regulatory, policy and legal indicators will also help project developers and others identify opportunities and challenges to facilitate an advanced or emerging energy project development.

Development of regulatory, policy, and legal analysis requires a detailed review of applicable rules, policies, and case law that a proposed project may implicate. Such analysis will most likely include rules and policies that are applicable to specific types of energy (i.e., net zero targets), environmental statutes implicated by the projects' location and/or projected impacts, property laws including zoning and planning laws, procedural laws requiring review and approval by governmental entities, and decommissioning requirements. It may also include corporate policy. These analyses are specific to both the proposed energy type and a proposed location. For instance, industrial siting and environmental laws and regulations may be unique to specific types of energy whereas the location of the project would determine jurisdiction for purposes of tribal and local government zoning and siting laws. Additionally, newly built projects may have different requirements compared to retrofit projects.

Requirements may also significantly affect affordability through regulatory and permitting costs as well as through defending legal challenges. Additionally, state specific energy policies such as renewable portfolio standards may impact regional energy markets. For example, many states now have renewable energy portfolio standards that require 80% of the electricity sold in the state be from specifically described renewable energy sources. Additionally, low-carbon or zero-carbon requirements or the application of carbon taxes may impact the affordability of other energy alternatives such as coal or natural gas. State public utility regulators may further require an additional planning process, including cost recovery for investments in replacement generation.

Legal requirements may also differ based on the identity of the project developer. For instance, in the United States, many state eminent domain statutes and constitutional provisions limit the right of condemnation to projects directed by the state or by public utilities—private entities or electric cooperatives might not have the same authority.

Regulatory, policy, and legal analysis would inform numerous value elements, including:

- Local governance/self-determination
- Environmental sustainability
- Community appropriateness
- Availability
- Affordability.

In completing regulatory, policy, and legal analysis, an understanding is needed and can be done by drawing from local regulatory, policy, and legal knowledge as well as research software platforms such as the DSire database and Lexis and WestLaw. Researchers should examine the project through the lens of the authorities' hierarchy at every jurisdictional level. This hierarchical approach requires starting at the highest level of authority (i.e., federal and state constitutions, then federal and state statutes, and then the state and federal agency regulations, etc.). Finally, researchers should examine prior local, state, regional, and federal case law to understand how judges have interpreted the law when addressing prior conflicts associated with similar types of projects.

The analysis must be done at every jurisdictional level that is implicated by the project in order to gain a full understanding of the complete regulatory, policy, and legal scope. Although it is impossible to develop a generic framework that would apply nationally and internationally, the various jurisdictional levels that may be implicated by a proposed project are identified in the sections that follow.

3.3.1 International

Depending on the proposed project's location and energy fuel type, international treaties or agreements may be implicated, particularly in the subarctic region. For instance, the UN Declaration of the Rights of Indigenous Peoples requires sovereigns to obtain the free, prior, and informed consent of indigenous persons prior to development on indigenous land or territory. This obligation is core to principles of self-determination and non-discrimination. The law of the sea, as well as the Convention on the Physical Protection of Nuclear Material and its 2005 Amendment are examples of other sources of international law that govern energy projects.

3.3.2 Federal

Development of a regulatory, policy, and legal framework at the federal level includes considerations of applicable federal energy and environmental statutes that may be triggered based on the type of project proposed and the project's location. For example, if the project involves nuclear technology, federal permitting is required from the Nuclear Regulatory Commission. Additionally, suppose the proposed project is to be developed on federal land, it will most likely trigger the requirement to comply with NEPA requiring the drafting of an environmental impact statement (EIS). This multi-year process involves consideration of the environmental impacts of the problem, analysis of alternatives, and public engagement, comment, and appeal process. Potential impacts on the natural environment and wildlife species must also be projected as they may trigger federal environmental statutes such as the Clean Air Act, the Clean Water Act, or the Endangered Species Act.

3.3.3 State

State regulation, policy, and laws must also be thoroughly analyzed as well. States commonly enact unique energy and environmental statutes concerning the development of natural and economic resources within their jurisdiction. Projects on private land may be subject to state regulation. States also implement federal statutes such as the Clean Water Act and Clean Air Act under cooperative federalism arrangements with the federal government and understanding the scope of their permitting authority is important.

3.3.4 Tribal

If a project is proposed on sovereign tribal land, the regulatory, policy, and legal framework must consider applicable Federal Indian law and tribal law. Federal Indian law is the body of law addressing the relationship of tribes with the federal government, including any treaty rights that might be implicated with a proposed energy development project. Tribal law is the body of law that each tribe develops and implements, governing their land, affairs, and members. Tribal governments, like states, also often implement federal statutes like the Clean Water Act and the Clean Air Act so an understanding of their permitting authority is important. Beyond formal law, tribal customs and norms can also have a pivotal bearing on decision-making processes. These might not be documented.

3.3.5 Local Government

Depending upon the state in which they are located, local governments are granted varying levels of authority applicable to energy development that should be documented in a regulatory, policy and legal framework. Generally, local governments have authority over the zoning and planning of development within the boundary of their jurisdiction. This authority is often divided at the county and municipal level and may be subject to preemption by conflicting state or federal laws.

3.4 Industrial Histories: Understanding Local Development

Related to the analysis of the social and built environment, an industrial history identifies areas of current and previous industrial development, progress, and violations. This can be specific to a proposed site or for the broader region, and account for stakeholder communities. Specific to siting, this will include identifying potential brownfield and greenfield locations, environmental enforcement actions, and polluted locations. More broadly for the region, this also reflects the evolution of an industrial cluster in terms of jobs, the supply chain and interdependencies.

Understanding the industrial, environmental, and energy siting history of a community can help project developers identify areas of both potential challenge and opportunity for the introduction of new energy source implementation.

Information on past and current industrial uses may impact permitting or

Example: Uranium Milling in Fremont County, Wyoming

The history of uranium milling in Wyoming is important for understanding current perspective on the front and back-end of the nuclear fuel cycle.

A former uranium mill owned by Susquehanna–Western operated on the eastern-end of the Wind River Reservation near the communities of Riverton and the Arapahoe and St. Stephens Mission from 1958 to 1963 in support of U.S. Cold War efforts. The mill produced uranium oxide (U_3O_8) using both acid and alkaline mill circuits. Sulfuric acid was also produced at an on-site facility and continues to operate today under the direction of the privately-held Chemtrade Logistics, Inc. Throughout the life of the mill, approximately 1 million cubic yards of radioactive tailings were produced and subsequently stockpiled for more than 25 years on 70 acres southeast of the site. Remedial action was conducted on the Riverton tailing site pursuant to the Uranium Mill Tailings Radiation Control Act (UMTRCA) beginning in 1987. There were three additional uranium mills in the Gas Hills area and one in Jeffrey City, also all within Fremont County. Over time, other areas surrounding the mill have become contaminated as a result of mill processing activities, stockpiling, and wind dispersal of tailings. In addition, groundwater in two of three aquifers underlying the site are also contaminated as a result of uranium processing operations at the mill.

The region also includes the Gas Hills Uranium Mining District of Wyoming. According to the Wyoming State Geologic Survey, the district produced more than 111 million pounds of uranium concentrate (U3 O8) between 1954 and 1988. Production derived from five different mills, three in the Gas Hills, and one each in Riverton and Jeffrey City.

Understanding the history of the Chemtrade facility as well as the history of uranium mining and milling in the region may be important to project developers evaluating the potential of emerging markets in Fremont County, Riverton, on the Wind River Reservation, or in Wyoming. Potential sources of data for this information would include the Wyoming Department of Environmental Quality, the United States Environmental Protection Agency, and the Nuclear Regulatory Commission, as well as participant surveys and interviews.

potentially give rise to future liability for reclamation activities, thus affecting the cost and availability of a project. Additionally, understanding the environmental baseline is critical to assessing the environmental sustainability value of a project, and whether the project will have positive, negative, or neutral impacts on current environmental issues.

Industrial history can also reveal important social and cultural information that may not otherwise apparent in geographic-type data. This may provide important insights into how communities have experienced energy development including jobs, mining, and waste disposal activities. Understanding this history and how it has shaped community and cultural values around energy choice are important to unpacking how the community reached its current status quo and drivers important to energy siting decisions.

An industrial history may inform the following attributes:

- Permitting and regulatory requirements
- Technology sentiment
- Self-determination/local governance
- Community appropriateness
- Economic development potential.

Depending on the regulatory framework and structure of the community of study, data of interest for industrial and energy project histories may include:

- Case and/or ethnographic analyses, synthesizing historical and archival data, semi- and unstructured interviews, and field-based participant observation focused on community member experiences of place-specific energy and industrial histories (i.e., an anthropological perspective combines “formal” historical data with “informal” local understandings of those histories and contemporary social group-level experiences)
- Identification of the historical electric producers within the microgrid and/or the history of grid connectivity or reasoning for non-grid connectivity
- Documentation of industrial applications in the region, including the mix of customers inside the microgrid, employment patterns, and any pertinent public health outcomes
- Consideration of historical studies or popular media analyses of community sentiment relative to industry/energy generally
- Oil and hazardous substance spill history
- Search of permits and violations with industrial siting and environmental regulatory agencies
- Review and analysis of mining claims
- Surveys and on-site assessment
- Current and historic analysis of non-attainment areas for criteria pollutants
- Economic and job impact analysis.

The sources of this data will vary substantially depending on the location of a project. In the United States, some data will be available through the U.S. Environmental Protection Agency (EPA) or through state or tribal environmental quality agencies. Community surveys and interviews may also provide information on past industrial land uses.

4. SYSTEM ATTRIBUTES

Value elements are identified for each representative profile market based on the factors described in Section 3. The elements help describe how “representative communities” internalize values and costs. Value elements may differ broadly from one market to another, and the importance of the specific values will reflect the specific location-based and time-dependent conditions of the community. They may include: product/path cost and benefit, predictability of operational costs and benefits, and containment of costs; operations and maintenance (O&M)—driving workforce and overall operating cost factors; regulatory compliance; economic development factors including energy security, environmental quality, self-sufficiency, resiliency, etc.; and social factors—first adopter considerations and quality of life factors. Within the EMA framework, the values are converted into system attributes that can be used to compare alternatives to the baseline. The specific value elements and their relative importance (weighting) is important to how future strategies may be assessed as illustrated in Figure 4. Further details on the modeling of the system attributes are provided in Section 6 and remarks on monetizing value elements are provided in Appendix A.

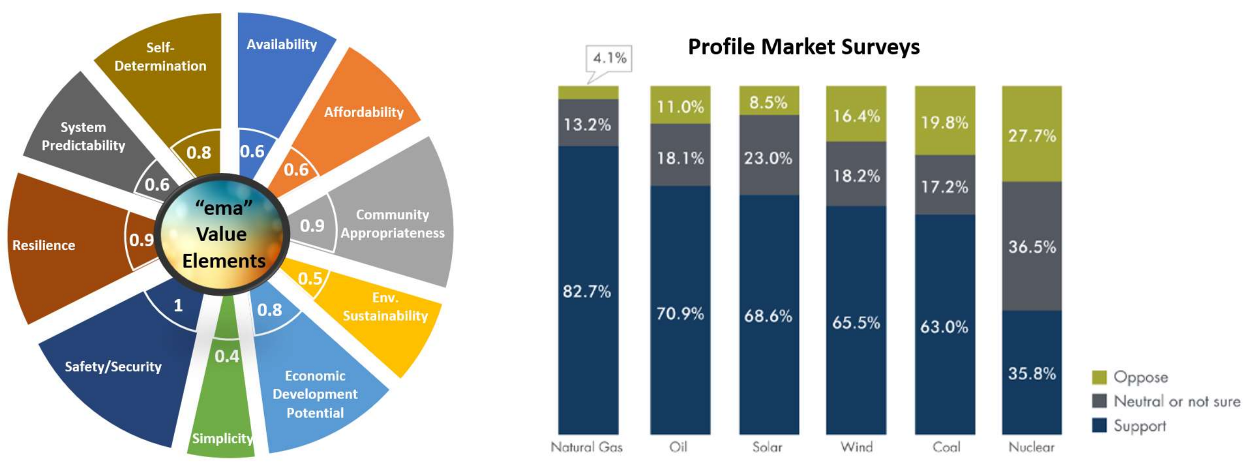


Figure 4. Sample of covariance of attributes in the EMA framework (Western and Gerace 2020).

4.1 Quantitative System Attributes

The following sample sources of value are considered and put into a quantitative framework. That is, they are deemed amenable to monetization given sufficient specific data:

1. Avoided monetary cost of fossil fuel (electricity, space heat)
2. Avoided price volatility of fossil fuel (energy price stability)
3. Benefits of increased energy availability (capacity factor) and decreased costs (resiliency)
4. Human health benefits (avoided health costs)
5. Avoided carbon emissions (avoided environmental costs)
6. Environmental benefits from reduced spills and reduced supply chain activity
7. Lowered capital and operating costs (supporting increased resiliency)
8. Modularity in initial deployment and ongoing adaptability
9. Operating flexibility (ramping, regulations, and heat/power split)
10. Increased efficiency from combined heat and power.

Many attributes of "value" may be monetized to provide a cost-benefit basis for comparison. The value of a market application is a complex intersection of system attributes that can meet or otherwise consider or address the various market needs. Where quantitative assessments are not feasible, qualitative analyses will ensure more comprehensive understanding. Certain benefits, for example with greater safety or security, may not be monetized.

4.2 Qualitative System Attributes

To more fully account for community and market resonance, certain attributes are best reflected qualitatively and not monetized. Moreover, qualitative and quantitative attributes must mutually inform.

Qualitative attributes may be identified and refined through a review of community-client priorities, stakeholder and expert consultations, review of current literature, etc. The following are sources of value in qualitative assessments:

1. Clean and/or locally-sourced forms of energy
2. Alignment with existing capabilities/expertise
3. Utilization contributes to technology/regional leadership
4. The safety and security of the community
5. Ease of use/complexity
6. Sustainability and system resilience
7. Allows independence/self-sufficiency
8. Procedural and scaling flexibility
9. Allows for novel institutional oversight/trust
10. Coherence with/impacts to other social priorities.

5. BASELINE AND ALTERNATIVE SELECTION

In development of future alternative scenarios, threshold determinations are based on cultural and social appropriateness as well as place-based, value-oriented, and sociotechnical assessments. As described in Section 3, despite numerous other positive value indicators, a culturally inappropriate energy use may fail as a threshold matter based on community opposition.

The EMA team analyzes energy futures for profile markets or test cases. Such markets and energy futures have features that reflect emerging global trends. First, such futures capture several emerging technologies that will shape operations of power markets in the near future: decarbonized transportation and industrial heat. Second, they capture the broad benefits of a technology on a surrounding community. As governments and industry increasingly focus on non-monetary value and public goods, such broad benefits can significantly enhance the value of different technologies. For illustration purposes, here, alternative energy futures consider nuclear microreactors and small modular reactors, collectively referred to as SMRs.

An example of the baseline and future strategies are provided in the insert.

Example: Alternative Use Selection

Profile Market #1: Government/Commercial Shared Energy Center.

This analysis considers use of a SMR with supporting infrastructure at a government or commercial shared energy center located nearby large population centers.

Baseline: Continued use of fossil fuels, particularly diesel generators for electricity and fuel oil for space heating.

Alternative #1: SMR provides all electricity production. A utility sites an SMR and supporting infrastructure near (or on) a government facility (laboratory, secured facility) to be used as the primary energy source for electricity (possibly microgrid) and/or heat (heat-only) to support critical operations. The SMR is scaled for the application, with a typical size of 5–40 MWe, and will include any required infrastructure upgrades to integrate the SMR.

Alternative #2: SMR provides electricity plus energy storage. The SMR provides electricity and/or thermal storage of varying technologies and designs.

Alternative #3: SMR provides electricity plus direct heat for communities and industry. SMR deployed as part of a broader energy center to provide broad benefits to nearby communities and industry. Specifically, the energy center will provide heat to adjacent industrial or community applications during low periods of consumption by the host facility. Heat can be used for containerized hydroponics or community district heating.

Alternative #4: SMR provides electricity plus hydrogen production for communities and industry. The energy center will use excess electricity and/or heat production from the SMR to produce hydrogen.

6. MULTIDIMENSIONAL VALUE ANALYSIS

Decision criteria (e.g., environmental, economic, and social) cannot be analyzed in isolation. However, different alternative energy futures will likely introduce trade-offs between these criteria. Such trade-offs are contrasted using multi-criteria decision analysis (MCDA) (Figure 5). MCDA, unlike optimization, does not produce a single “optimal” solution, but rather emphasizes the trade-offs between different options. The MCDA framework can also incorporate other value streams not discussed above but captured in other tasks, including resilience. While MCDA can combine criteria using individuals’ preferences (e.g., derived from a utility function) MCDA is applied to highlight the decision space available to communities. The decision space, in turn, can function as a tool to help inform communities about the value of different futures.

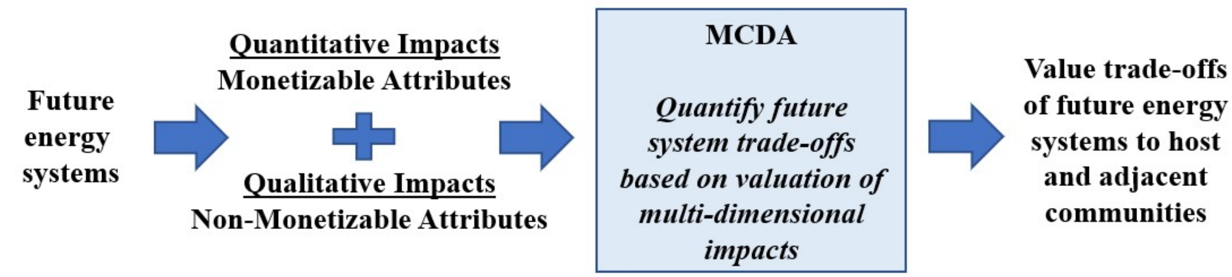


Figure 5. MCDA used to compare multiple criteria to value trade-offs of different energy systems.

The methods used to evaluate the baseline and alternative strategies consist of qualitative and quantitative analysis techniques. As discussed previously, some system attributes (e.g., self-determination and security) are difficult to measure; therefore, methods are used that provide relative preference rankings. For other attributes, particularly market demand and economic measures, models can be used to quantify differences. A description of the different tools and methodologies needed to provide a multidimensional value analysis are presented in this section.

6.1 Qualitative Analysis

Stakeholder input is fundamental to locationally informed, value-driven decision-making. Processes may include consensus building and/or master planning for value identification and deliberation. Related to, but also distinct from, stakeholder input is qualitative analysis. System attributes, such as those described in Section 4.2, are evaluated using techniques, including expert elicitation, pairwise comparisons, Delphi ranking, case analysis, historical record review, etc. Processes that include consensus building, simulations, master planning, and other forms of stakeholder engagement may be combined with qualitative analysis to elucidate underlying logic and areas for mutual gain. Special consideration should account for regulatory, policy, and legal needs and constraints; qualitative impacts on the human-natural-built conditions; regional development, job and industry impacts; plus community needs, preferences, and related impacts.

It is important to note that qualitative and quantitative analysis, if done strategically, can mutually inform. Qualitative inputs and analysis inform assumptions and sharpen scoping for quantitative analysis. Similarly, quantitative inputs inform or sharpen qualitative assessments.

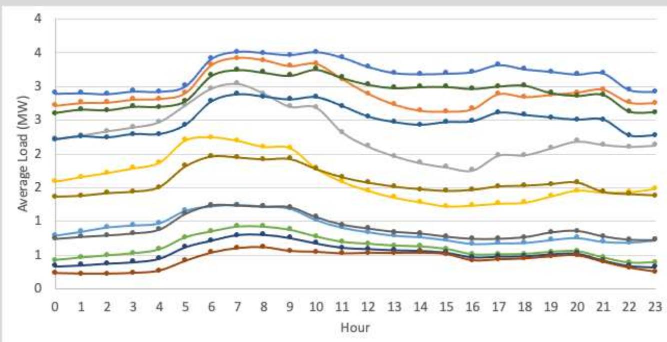
6.2 Quantitative Analysis

The depth of understanding of the market value attributes can be increased through quantitative analysis. Studies may consider energy demand profiles for electricity and heat; and integrated studies including environmental impacts on land, air, and water; economic and social impacts including employment, investment and operational costs; impacts from disruptions to energy users through added system resilience; and potentially other areas. These areas of analysis are described in the following sections.

6.2.1 Bottom-up Demand Model

Example: Profile Market Energy Demand

Community-wide monthly demand profiles for heat and electricity are input into the GenX model (Jenkins 2017). Combined average heat and electricity demands are evaluated by time of day for each month. Communities can vary significantly in their total demand and exhibit different load profiles. Also demand varies by season with peak demand occurring in the winter for profile markets in Alaska. A typical demand profile is shown below.



Bottom-up demand profiles are generated using long-term hourly forecasts for heat and electricity demand given differing assumptions of technology adoption. Data inputs include residential and commercial electricity and heating demand. Future model capability includes demand from industrial heat, mining operations, and electrified or fuel cell transportation. To quantify residential and commercial demand for a given community, the model takes in community building information. By matching input building data to "typical meteorological year" (TMY2) demand datasets (NREL 2021), it produces a community-level demand profile.

The GenX model[a] captures energy technologies included in profile markets and alternative energy futures, including decarbonized transportation and industrial heat demand. Model outputs may be used to estimate environmental, economic, and social impacts of different alternative energy futures, then analyze the trade-offs across these criteria between futures via MCDA.

6.2.2 Integrated Studies

The following three areas of study reflect quantitative assessments that are informed by locationally informed qualitative analysis to better understand the trade-offs between environmental protection, economics, social acceptance, and energy security.

6.2.2.1 Environmental Analysis

A sample area of environmental interest is local and global air pollution. For a profile study, emissions arise from three parts of an energy center: electric power, heat, and displaced end uses. To quantify emissions consequences of an SMR-based energy center, we will apply emissions factors to output from GenX. Emissions factors differ significantly during steady-state versus startup operations, which can be captured in the analysis. With respect to end uses, the most relevant to the analysis is transportation, specifically offset emissions from internal combustion engines. Displaced transportation activity may be estimated, then emissions factors of that activity may be quantified with conventional versus hydrogen fuels. Emission factors for vehicles may be parameterized using literature values. Modeling air-quality impacts of avoided emissions is outside the scope of this analysis, but quantification of health benefits is discussed next.

---

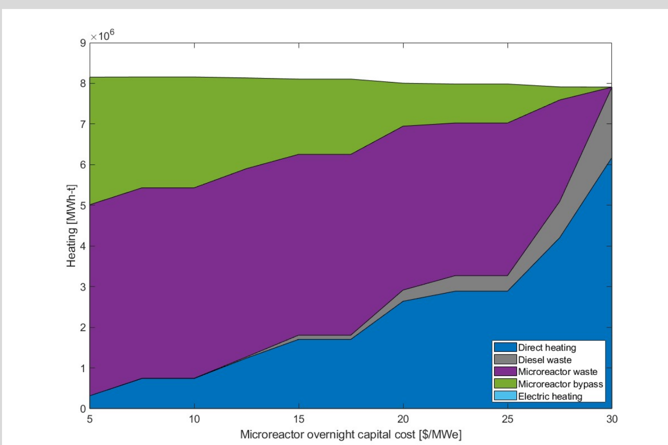
[a] GenX is an open-source capacity expansion and dispatch model: energy.mit.edu/genx. It determines the cost-optimal generation portfolio, energy storage, and transmission investments needed to meet a pre-defined system demand, while adhering to various technological and physical grid operation constraints, resource availability limits, and other imposed environmental, market design, and policy constraints.

Environmental analysis is an important component of analysis for the EMA team. This should include local environmental impacts, such as land, air and water footprints. These local environmental impacts often drive local opposition to projects. Alleviating them can provide significant community value.

6.2.2.2 Economic and Social Analysis

> *Advanced energy systems can have a positive influence on local and regional economic development, particularly when new business applications are enabled by the technologies.*

Select economic and social impacts may be included in quantitative analysis because they are intertwined. (This would be informed by related, location-specific treatment in qualitative analysis.) In an EMA analysis of profile markets, a range of economic and social impacts may be evaluated including: employment (number of jobs and wages),[b] investment and operational costs, select community benefits,[c] health impacts of emissions, and fuel savings. Social and economic impacts will differ across space, time, and groups; impacts on the host facility will differ from those on adjacent communities, workers in low-carbon sectors, and workers in fossil sectors. For each impact, a quantitative assessment may be done to highlight differences across dimensions.

> *Example: Profile Market Economic Analysis*
>
> The GenX system cost model is used to evaluate the costs tradeoffs in generating heat and electricity.
>
> 
>
>
> Competitive conditions when:
> - Natural gas is not available
> - Microreactor capital cost is <$29,000/kWe
> - A cap on carbon, heat is a major value.

Employment impacts of an SMR deployment or establishment of a broader energy center, for example, are economic and social factors to evaluate. Anticipated employment gains can shape public acceptance and stimulate local economies; similarly, anticipated employment losses can shape social opposition. Employment occurs during construction and installation and during operations and maintenance; employment in each category should be examined separately. To capture the uncertainty surrounding employment factors, data may be derived from sources: existing literature, industry surveys, NREL's Jobs and Economic Development Impact (JEDI) models, and qualitative assessments of industry. The JEDI models are input-output economic model used to determine the direct and indirect jobs associated with different technology investment. Use of JEDI would be supplemented, as it lacks employment factors for SMRs and has outdated factors for other technologies like solar, with published literature values and industry surveys. Numerous studies have estimated total employment in energy sectors or employment factors associated with energy technologies using input-output and survey-based methods. BW Research Partnership annually surveys energy employment

---

[b] The quality of jobs would be reflected under qualitative assessments or combined analysis.

[c] This is also covered in qualitative assessments.

by county, 6-digit North American Industry Classification System (NAICS) code that is augmented by surveys and technology. Further discussion on macroeconomic analysis is provided in Appendix B.

Key economic impacts include investment and operational costs and avoided costs, and direct benefits (e.g., jobs, technology leadership, and greater resilience) with an SMR-based energy center and the counterfactual energy mix. GenX optimizes for investment and operational costs of energy provided by the energy center. By running GenX under different inputs established above, GenX will quantify different futures' investment and operational costs. Some of these costs will apply to the host facility, while others (e.g., hydrogen for vehicles) will apply to nearby communities.

The willingness to pay is a key social indicator of the quantitative analysis. Social acceptability will partly be driven by community-level benefits of the alternative futures; some of which may also be quantified.

As an oil exporter, Alaska—the state for the first case assessment—may use deferred oil consumption for exports. This analysis quantifies the value of the oil exports across a range of possible future oil prices as part of our economic analysis.

Finally, by using reduced-form health impacts models like Estimating Air pollution Social Impact Using Regression (EASIUR), analysis may link emissions changes from prior analysis to health benefits. This is particularly relevant to the Fairbank area, for example, which has suffered from poor air quality for part of the year. EASIUR provides a reduced-form regression model that links emission reductions to health benefits. By quantifying emissions across potential futures with SMR versus alternative energy sources, the analysis quantifies emission benefits of an SMR energy center.

6.2.2.3 Energy Security: Resilience Analysis

Advanced energy systems have potential to reduce the impacts from disruptions to energy users through added system resilience. The monetizable and qualitative value of resiliency is often not accounted for in energy systems studies. Resilience analysis may be used to define targets to compare baseline energy security-resilience for advanced system designs, either alone or as part of a zero-carbon system for a profiles/markets. These assessments can help to place a value on resilience, define risks and potential disrupters, and provide further value-based inputs for comparison of future energy strategies.

Advanced energy systems have potential to reduce the impacts from disruptions to remote energy users through added system resilience.

The EMA initiative developed a meta-level framework for evaluating resilience (Araújo and Shropshire 2021). The framework is used to evaluate future energy systems resilience by drawing from what is known about a system's resilience and the remaining gaps of understanding. It allows for additional practices and tools to be incorporated and provides the process necessary for evaluation. The framework is based on design principles of built systems including: resilience transcends scale; diverse and redundant systems are inherently more resilient; resilience anticipates interruption and a dynamic future; community contributes to resilience; and resilience is not absolute (Pimblott 2018). For power systems, coverage includes the baseload versus non-dispatchable balance, supply security of fuel, system agility, weatherization, cyber-attack surface, etc. and will formally characterize the types and tiers of specialized and integrated knowledge from diverse perspectives.

Resilience studies should include the technical resilience of the energy system, as well as the economic, social/institutional, ecological, and infrastructural dimensions and interdependencies. Such a study can include a potential pathway, as with demand response, that involves coordinated change in practices at specific times, which requires advanced management techniques. For low-carbon energy systems-in-transition (present to 2050), resilience is characterized as a function of the rigor of the analysis from qualitative, quantitative and integrated analysis (including geospatial aspects), that includes more advanced assessments of a specific location.

Stakeholders and decisionmakers seek tools and alternatives to weigh the trade-offs between alternatives to meet their decarbonization goals. Costs (and benefits) alone do not capture the full value of these complex trade-offs, particularly when evaluating specific choices for place-based decisions. One of the biggest challenges in decision analysis is to fully comprehend the complex trade-offs in achieving resilience. This assessment would be relatively simple if only technical considerations are of concern, but the full implications are only understood when the resilience of other critical systems, such as water, agriculture, and transport are more fully factored.

7. PLANNING WITH VALUE-INFORMED STRATEGIES

Planning and operations of the electric power sector are undergoing radical changes. Climate change mitigation efforts have forced rapid changes to the technology mix. Technologies like wind and solar have experienced rapid growth, while investment in other low-carbon technologies is also on the rise. As these new technologies have come onto the grid, they bring changes in how planning and operations should be approached. Variable technologies, like wind and solar, require additional operating and planning reserves or different types of grid management. Greater operational reserves incentivize more flexibility in other generating and storage assets, while larger planning reserves may translate to resilient or under-utilized elements of the systems.

It is not only the supply and delivery-side that is changing. Demand-side adoption of electrified technologies, including electric vehicles, is changing load profiles and opening up new avenues for consumer participation in the power systems. Decarbonization of thermal inputs (e.g., for industrial or residential and commercial heating) are also introducing industry-electric power connections, as various generation technologies can directly output heat. Some thermal demand, especially for heating, can also be met via electric heating, changing load profiles.

The implications of an evolving power system pertain to more than environmental and technical dimensions. Changes to the generation mix and its consequent upstream and downstream impacts have large and highly concentrated consequences on economies and employment. Shifts towards distributed (or decentralized) generating assets offer the potential to reshape opportunities associated with the energy sector across space and socioeconomic groups. Furthermore, adoption of new technologies is contingent on social and community acceptance and buy-in, which largely depends on the actual and perceived value new technologies and related practices and impacts provide to individuals and the community. Historically, communities have often been neglected in the siting process. Coal plants, for instance, often are based near minority and or low-income communities. More fair energy transitions acknowledge disparities in energy adoption (including electric power systems) and account for such differences in planning for a decarbonized future. Disparities in energy sector development can occur at the micro, meso, and macro scales. Most relevant to this project, micro-scale disparities pertain to how power plant investment, retirement, and operational decisions affect the local community.

From these changes arise new value opportunities. In performing an EMA analysis, value propositions of different energy futures are evaluated for a set of profile markets. Energy pathways are discussed along with operational, economic, environmental, and social implications and/or requirements for those futures. The analysis should balance multidimensional consequences (i.e., environmental, economic, and social consequences) across different portfolios of future energy systems.

As described in Section 6, MCDA brings together quantitative and qualitative factors and evaluate trade-offs across the various criteria. An illustration of the analysis of alternatives based on a sampling of system attributes is provided in Figure 6. The attributes may be evaluated by qualitative or quantitative measures and compared relative to the MCDA assessment of alternative energy futures. Targeted consideration is given to the preferences toward specific values/attributes resulting from the social engagement.

Community Values	System Attributes (examples)	Change in 2040	Difference from Baseline in 2040		
		Baseline	Alt #1.	Alt #2	Alt. #3
Economic - Affordability	Fuel costs Price volatility	- -	+	0	+ +
Social - Human Health	Health costs Carbon emissions	- - -	+ + +	+ +	+ +
Financial - Cost outlay	Capital costs Operating costs	-	+	-	0
Technical - Resiliency	Energy availability Seasonal Outages	- -	+ + +	?	- -

Legend

+++ Very clearly positive	- - - Very clearly negative
++ Clearly positive	- - Clearly negative
+ Slightly positive	- Slightly negative
0 Neutral	? Not enough information

Figure 6. Example of MCDA assessment of alternatives.

8. SOCIAL ENGAGEMENT

Determination of an alternative energy future may be more fully guided by the value and risks that are evaluated by stakeholders and decision makers.

Social engagement with stakeholders and decision makers is critical to successful project implementation. The process of engagement is used to identify key stakeholders and decision makers, assess needs and concerns, and formulate effective future energy strategies. If done well, this can strengthen knowledge and inform decisions, build legitimacy, and enable more enduring solutions (Araújo and Shropshire, 2021; Araújo 2017).

EMA team members aim to inform policy and support government, industry, and business leaders in community-driven energy decisions. These interactions can shed light on stakeholder preferences, value formulation, and realignment on preferences as conditions change over time. The engagement also supports multi-level decision-making processes, selection of system attributes that will influence the acceptance of change, understanding the perspectives from state, local, tribal, and federal regulators, that will ultimately govern the project, and also revealing views from key constituencies and stakeholders.

9. SUMMARY AND CONCLUSION

Planning and operations of the electric power sector are undergoing radical changes. Climate change mitigation efforts have forced rapid changes to the technology mix. Technologies like wind and solar have experienced rapid growth, and investment in fossil sources has peaked or is declining. These foundational changes are forcing changes to energy systems. Demand-side adoption of electrified technologies, including electric vehicles, is changing load profiles and opening up new avenues for consumer participation in the power systems. The implications of an evolving power system pertain to more than environmental and technical dimensions. Changes to the generation mix and its consequent upstream and downstream impacts have large and highly concentrated consequences on economies and employment. Shifts towards distributed (or decentralized) generating assets offer the potential to reshape economic and employment opportunities associated with the energy sector across space and socioeconomic groups.

The EMA initiative aims to identify sustainable, regionally acceptable, and high-value energy solutions that are secure and fair. Unlike short-term, least-cost choices that can narrowly account for traditional options, EMA's focus on emerging energy markets recognizes that new or adapted practices and technologies can alter the frontier of solutions and advance a community's social, economic, and natural pathways. Such change requires more comprehensive analysis that accounts for societal input, resources, capabilities, and infrastructure. These considerations lay the foundation for community decision-making models that are responsive to community values as well as the history and drivers. The result is a community-based decision and engagement model that will be valuable to decisionmakers and developers of advanced and emerging energy solutions, seeking a more socially informed and inclusive path to development.

10. REFERENCES

Agrawal, A. and C. C. Gibson. 1999. “Enchantment and disenchantment: The role of community in natural resource conservation.” World Development 27(4): 629–649. https://doi.org/10.1016/S0305-750X(98)00161-2.

Amit, V. and N. Rapport. 2002. *The Trouble with Community: Anthropological Reflections on Movement, Identity and Collectivity*. London: Pluto Press.

Araújo, K. and D. Shropshire. 2021. “A Meta-Level Framework for Evaluating Resilience in Net-Zero Carbon Power Systems with Extreme Weather Events in the United States.” Energies 14(14): 4243. https://doi.org/10.3390/en14144243.

Araújo, K. 2017. *Low Carbon Energy Transitions: Turning Points in National Policy and Innovation.* New York, NY: Oxford University Press. ISBN: 9780199362554.

Berkes, F. and H. Ross. 2013. “Community resilience: Toward an integrated approach.” Society and Natural Resources 26(1): 5–20. https://doi.org/10.1080/08941920.2012.736605.

Cohen, A. P. 1985. *The Symbolic Construction of Community*. London: Tavistock Publications.

Consensus Building Institute. n.d. “Collaborative Approaches to Environmental Decision-Making: A State Agency’s Guide to Effective Dialogue and Stakeholder Engagement.” Assessed on November 22, 2021. https://www.cbi.org/report/collaborative-approaches-to-environmental-decision-making-state-agency-s-guide-to-effective-dialogue-and-stakeholder-engagement/.

Cormick, G. W., N. Dale, P. Emond, S. G. Sigurdson, and B. D. Stuart. 1996. *Building consensus for a sustainable future: Putting principles into practice*. Ottawa: National Round Table on the Environment and the Economy.

Doern, G. B. 2005. *Canadian Energy Policy and the Struggle for Sustainable Development*. Toronto: University of Toronto Press.

Dove, M. R. 2006. “Indigenous people and environmental politics.” Annual Review of Anthropology 35: 191–208. https://doi.org/10.1146/annurev.anthro.35.081705.123235.

Eckert, P. and S. McConnell-Giner. 1992. “Think practically and look locally: Language and gender as community-based practice.” Annual Review of Anthropology 21: 461–90. https://doi.org/10.1146/annurev.an.21.100192.002333.

Emerson, K., T. Nabatchi, and S. Balogh. 2011. “An Integrative Framework for Collaborative Governance. Journal of Public Administration Research and Theory.” Journal of Public Administration Research and Theory 22(1): 1–29, https://doi.org/10.1093/jopart/mur011.

iap2. n.d. “Core Values, Ethics, Spectrum – The 3 Pillars of Public Participation.” Accessed October 4, 2021. https://www.iap2.org/page/pillars.

IEA. 2021. “Recommendations of the Global Commission on People-Centered Clean Energy Transitions”. Accessed on November 24, 2021. https://iea.blob.core.windows.net/assets/a01c5f4a-e833-42da-9387-830fcb024046/Recommendationsoftheglobalcommissiononpeople-centredcleanenergytransitions.pdf

Jenkins, J. and N. Sepulveda. 2017. “Enhanced decision support for a changing electricity landscape: The GenX configurable electricity resource capacity expansion model.” MITEI-WP-2017-10, MIT Energy Initiative. https://energy.mit.edu/wp-content/uploads/2017/10/Enhanced-Decision-Support-for-a-Changing-Electricity-Landscape.pdf.

Keir, L. S. and S. H. Ali. 2014. “Conflict Assessment in Energy Infrastructure Siting: Prospects for Consensus Building in the Northern Pass Transmission Line Project.” Negotiation Journal 30(2): 169–189. https://doi.org/10.1111/nejo.12054.

Keiter, R. B. and K. Lindstrom. 2011. “Lessons from Nine Mile Canyon: Achieving Consensus over Energy Development on the Public Lands.” Paper No. ID 2336227, Social Science Research Network.

Lave, J. and E. Wenger, E. 1991. *Situated learning: legitimate peripheral participation*. Cambridge: Cambridge University Press.

Morrison, J. 2014. *The Social License: How to Keep Your Organization Legitimate*. London: Palgrave Macmillan.

Nolon, S. F. 2011. “Negotiating the Wind: A Framework to Engage Citizens in Siting Wind Turbines.” Paper No. ID 1898814, Social Science Research Network.

NREL. n.d. "Typical Meteorological Year (TMY)." NSRDB: National Solar Radiation Database. Accessed on November 4, 2021. https://nsrdb.nrel.gov/about/tmy.html.

Pimblott, S. and J. A. Kennedy. “Scale for Measuring Materials Development for Nuclear Energy Systems.” INL/LTD 18-45283, Idaho National Laboratory.

Smutko, S. 2021. “Public Participation and Participatory Decision Process Protocol for Siting Small Modular Nuclear Reactor Technology in Alaska and on the Wind River Reservation in Wyoming.” White Paper, University of Wyoming.

Stoellinger, T., L. S. Smutko, and J. M. Western. 2018. “Collaboration Through NEPA to Achieve a Social License to Operate on Federal Public Lands.” Public Land and Resources Law Review 39(1): 203–252.

UAA. 2020a. “Microreactors in Alaska Customer Discovery and Perception” University of Alaska, Center for Economic Development. https://static1.squarespace.com/static/59f6b60bcf81e02892fd0261/t/60189afcbc397811525aca24/1612225286635/Customer+Discover+and+Perception+Analysis.pdf.

UAA. 2020b. "Microreactors in Alaska Use Case Analysis: Executive Summary." University of Alaska, Center for Economic Development. https://static1.squarespace.com/static/59f6b60bcf81e02892fd0261/t/60189a8fc18e871112eff45b/1612225177349/Use+Case+Analysis_Executive+Summary.pdf.

USGS. n.d. Gap Analysis Project. PAD-US Data Download. Accessed October 4, 2021. https://www.usgs.gov/core-science-systems/science-analytics-and-synthesis/gap/science/pad-us-data-download?qt-science_center_objects=0#qt-science_center_objects.

Western, J. and S. Gerace. 2020. *Social License for Wyoming's Energy Future: What Do Residents Want?* Laramie: University of Wyoming School of Energy Resources and Ruckelshaus Institute of Environment and Natural Resources.

Yates, B. F. and C. L. Horvath. 2013. "Social license to operate: How to get it, and how to keep it." Paper from the 2013 Pacific Energy Summit. The National Bureau of Asian Research. https://www.nbr.org/publication/social-license-to-operate-how-to-get-it-and-how-to-keep-it.

Yosie, T. F. and T. D. Herbst. 1998. "Managing and communicating stakeholder-based decision making." Human and Ecological Risk Assessment: An International Journal 4(3), 643–646. https://doi.org/10.1080/10807039891284505.

Page intentionally left blank

Appendix A
Select Monetizing of Value Elements

Value Element	Remarks on Monetizing this Value
Avoided monetary cost of fossil electricity	Monetize if costs are reported; must consider which costs are avoidable
Avoided monetary cost of fossil space heat	Monetize if costs are reported; must consider which costs are avoidable
Select benefit of increased energy use due to lower prices (elasticity benefits)	Monetize based on estimated price elasticity and/or knowledge of specific options that are enabled
Select human health benefits from reduced fossil fuel and wood combustion	Avoided cost of premature mortality from air pollution; other costs can be assessed for specific circumstances
Avoided carbon emissions	Social cost of carbon
Environmental benefits from reduced spills and other fossil fuel supply chain activity	Little data currently available
Low initial capital cost of installation	Straightforward
Low operating cost	Straightforward
Modularity in the initial deployment	Monetize using real options framework
Modularity/adaptability in ongoing deployment (plug and play, reconfigurable)	Difficult to monetize due to changing operational requirements
Operating flexibility (load-following, ramping, regulation, and heat/power split)	May be monetized using the avoided cost of alternatives
Increased efficiency from combined heat and power provision (economies of scope)	Cost savings compared to alternatives
Resilience and reduced supply chain disruptions	Difficult to monetize; contingent valuation surveys might be done;
Energy price stability	Difficult to monetize; hedging contracts would provide data but are hard to observe
Local economic activity benefits—local jobs, local materials, spending, or tax revenues	May monetize economic impact; more difficult to monetize the net economic value
Locally identified benefits	Difficult to monetize; qualitative inputs will be key
Materials requirements—avoid using critical/imported materials for which market prices do not reflect scarcity value	Could apply a social cost of cobalt similar to a social cost of carbon
Develop new industry for exports or import displacement	“Local economic activity” may become “national economic activity”

Page intentionally left blank

Appendix B
Macroeconomic Analysis

Macroeconomic analysis is used to define certain aspects of (non-qualitative) economic development potential—direct, indirect, and induced benefit of representative profiles/markets energy futures. The analysis provides comparisons (e.g., microreactors versus existing fossil systems and renewables) between scenarios and examines whether the energy transition could result in net economic benefit for example with jobs and tax revenue to the local area and region as compared to existing operations.

The first step in the analysis is to determine if the strategy is expected to be competitive (see Section 6.2.2.2) against the "business as usual" case. Establishing the baseline requires gathering information on the current energy production system including system capacity, usage requirements, and estimated total fuel and non-fuel diesel costs. If the strategy is expected to be economic, the analysis continues by assessing the economic development potential for the communities through input-output modeling and analysis. This macroeconomic methodology enables estimating the economic impacts of the energy transition on the economy of interest. Additionally, this methodology allows researchers to analyze how these direct impacts ripple throughout the economy. Using the results, interested parties will better understand potential business and economic development outcomes resulting from the energy transition and ultimately help drive business decisions.

Secondary data may be collected to understand sample communities' energy systems and hypothetical energy centers in transition. Economic impact analysis is performed on the transition from the current operating system to new energy scenarios, including microreactors. In the analysis of alternatives, fuel and non-fuel costs are considered as they relate to operating the current system. When data is not readily available, proxy data is substituted from similar systems with similar external cost drivers (e.g., transportation needs and seasonal considerations). Data on other economic variables, including but not limited to employment, construction materials, economic sectors, taxes, and royalties, is also gathered. These data will be used to approximate a region's current economy and the magnitude of the impacts post-transition.